Climate Change Management

Walter Leal Filho
Leonardo Esteves de Freitas *Editors*

Climate Change Adaptation in Latin America

Managing Vulnerability, Fostering Resilience

Springer

Climate Change Management

Series editor

Walter Leal Filho, Hamburg, Germany

More information about this series at http://www.springer.com/series/8740

Walter Leal Filho · Leonardo Esteves de Freitas
Editors

Climate Change Adaptation in Latin America

Managing Vulnerability, Fostering Resilience

Springer

Editors
Walter Leal Filho
FTZ-NK
Hamburg University of Applied Sciences
Hamburg
Germany

Leonardo Esteves de Freitas
OTSS and Geography Department
Fiocruz and UFRJ
Rio de Janeiro
Brazil

ISSN 1610-2010 ISSN 1610-2002 (electronic)
Climate Change Management
ISBN 978-3-319-56945-1 ISBN 978-3-319-56946-8 (eBook)
https://doi.org/10.1007/978-3-319-56946-8

Library of Congress Control Number: 2017943123

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

Similar to what is seen in other parts of the world, there are clear signs of the impacts of climate change to Latin American countries. The region, where a substantial portion of the world's biological diversity can be found, hosts a wide range of ecosystems including rainforests (especially, but not only in the Amazon region) and semi-arid zones. The disruption of natural ecosystems is one of the main causes of biodiversity and ecosystem losses in Latin America, a proportion of which is due to human-induced climate change.

According to the Fifth Assessment Report (AR5) produced by the Intergovernmental Panel on Climate Change (IPCC), climate change in Latin America is likely to contribute towards altering coastal and marine ecosystems, with mangrove degradation being observed on the north coast of South America, for instance.

In addition, AR5 mentions the fact that significant trends in precipitation and temperature have been observed in Central America (CA) and South America (SA) and that changes in climate variability and in extreme events have severely affected the region.

The above state of affairs illustrates the need for a better understanding of how climate change affects the Latin American region, and for the identification of processes, methods and tools which may help the countries in the region to adapt. There is also a perceived need to showcase successful examples of how to cope with the social, economic and political problems posed by climate change in Latin America.

This book, which contains a set of papers presented at the Symposium on Climate Change Adaptation in Latin America, held in Rio der Janeiro, Brazil, in November 2016, plus some additional ones, serves the purpose of showcasing experiences from research, field projects and best practice in climate change adaptation in Latin American countries—with examples from Bolivia, Brazil, Colombia, Guatemala, Mexico and Uruguay—which may be useful or implemented in other countries and regions. A further aim of this book is to document and disseminate the wealth of experiences available today.

This book is structured in two main parts. Part I addresses the connections and impacts of climate change to ecosystems. It entails a set of papers which describe current and future impacts of climate change to fauna, flora and landscapes.

Part II is concerned with the socio-economic aspects of climate change adaptation. As one of the most vulnerable regions in the world, Latin America is especially affected by a variety of social problems, as a result of climate change. Part II describes some of these issues and examines some ways they may be overcome.

A short, final chapter presents some perspectives on climate change in Latin America and outlines some of the research needs seen in the region.

We thank the authors for their willingness to share their knowledge, know-how and experiences, as well as the many peer reviewers, which have helped us to ensure the quality of the manuscripts.

Enjoy your reading!

Hamburg, Germany
Rio de Janeiro, Brazil
Winter 2017–2018

Walter Leal Filho
Leonardo Esteves de Freitas

Contents

Part II Socio-economic Aspects of Climate Change Adaptation

Part I
Climate Change and Ecosystems

Chapter 1
Pasture Degradation in South East Brazil: Status, Drivers and Options for Sustainable Land Use Under Climate Change

Dietmar Sattler, Roman Seliger, Udo Nehren, Friederike Naegeli de Torres, Antonio Soares da Silva, Claudia Raedig, Helga Restum Hissa and Jürgen Heinrich

Introduction

Land degradation is a global phenomenon, which is defined by the FAO as "··· the persistent decline or reduction in the capacity of the land to provide ecosystem goods and services and assure its functions over a period of time for the beneficiaries of these". Mostly addressed with regard to soil degradation in drylands, several estimates of the global extend of land degradation, based on varying approaches, indicate that 20–25% (Clausing 2011) up to 35% (Bai et al. 2008; Nachtergale et al. 2011) of all used land can be considered as degraded, at least to some extent. Bai et al. (2008) assessed land degradation using long-term (1981–2003), remotely sensed Normalized Difference Vegetation Index (NDVI) data at country level. Following this analysis, 1.882 million km^2 or 22.11% of Brazil's

D. Sattler (✉) · R. Seliger · F.N. de Torres · J. Heinrich
Institute of Geography, Physical Geography and Environmental Research, University of Leipzig, Johannisalle 19, 04109 Leipzig, Germany
e-mail: sattler@uni-leipzig.de

A.S. da Silva
Laboratory of Physical Geography, Institute of Geography, State University of Rio de Janeiro - UERJ, Rua São Francisco Xavier, 524 Bloco D, Sala 4015, Rio de Janeiro, RJ CEP 20550-900, Brazil

H.R. Hissa
Secretariat of Agriculture and Livestock of the State of Rio de Janeiro - SEAPEC, Rio Rural Programme, Alameda São Boaventura, 770 – Fonseca, Niterói, RJ CEP 24120-191, Brazil

U. Nehren · C. Raedig
Institute for Technology and Resources Management in the Tropics and Subtropics (ITT), Technische Hochschule Köln, University of Applied Sciences, Betzdorfer Straße 2, 50679 Cologne, Germany

W. Leal Filho and L. Esteves de Freitas (eds.), *Climate Change Adaptation in Latin America*, Climate Change Management,
https://doi.org/10.1007/978-3-319-56946-8_1

territory are subject to degradation. Before the background of Brazil's outstanding natural heritage, the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA) established a more focused definition, where land degradation "…occurs when native vegetation and fauna has been destroyed, removed or displaced, the fertile soil is lost, removed or eroded and the hydric system has been altered. Land degradation takes place when the capacity for natural physical, biological and chemical adaption is lost and makes socio-economic development unfeasible" (IBAMA 1990). Pasture farming is among the most habitat consuming land uses in Brazil, making up almost half of all agricultural activities (Dias Filho 2014). Being a human-modified landscape, pastures exhibit degradation as a combination of unsuitable land use (use of land for purposes for which it is environmentally unsuited) and inappropriate land management practices (use of land in ways which could be sustainable if properly managed, but necessary practices are not adopted). Additionally, pasture farming systems in SE Brazil are exposed to some natural degradation hazards which limit the inherent capacity of the ecosystems for the provision of adequate geo-ecological services, such as water retention, nutrient availability and recycling and habitat for biodiversity. In this paper, we briefly analyse the drivers and status of pasture degradation in SE Brazil and assess the possibilities for bringing together both sustainable pasture rehabilitation and management and transformation potentials of this widespread land use towards climate change mitigation.

Land Use Development and Transformations in the State of Rio de Janeiro

The Southeast Region of Brazil with the states of São Paulo (SP), Minas Gerais (MG), Rio de Janeiro (RJ), and Espirito Santo (ES) is the economic backbone of the country where about 50% of the national GDP is generated (IBGE 2013). About 85 million people live in an area of 924,620 km^2 (IBGE 2014), which corresponds to about 40% of the total Brazilian population, but only to 11% of the country's territory. Such an enormous concentration of both economic power and population results in high pressure on the land and water resources and makes the region particularly vulnerable to extreme climate events and natural hazards such as floods, landslides, mudslides, droughts, and heat waves as well as to long-term effects of land degradation.

RJ is the smallest of the four Southeastern states with an area of 43,910 km^2 and a population of 16.5 million (IBGE 2014). Biogeographically, the state is located within the Atlantic Forest (Mata Atlântica) biome. The Mata Atlântica has been suffering from high historical deforestation rates (Dean 1995). Hence, the formerly forested region turned successively into a highly fragmented landscape which today is widely dominated by livestock farming, agricultural systems, and forest monocultures (mainly *Eucalyptus* species). The coastal zone around the metropolitan area of Rio de Janeiro is densely populated and urbanized, while the mountainous hinterland of the state has a primarily rural character. Due to overexploitation, the rural landscapes show serious soil degradation, such as rill and gully erosion and soil compaction (Nehren et al. 2013). Despite the high degree of fragmentation and land degradation in large parts of the state, the remaining forest patches in the central corridor of the Serra do Mar are highly diverse and are home to numerous endemic species of which many are endangered (Eisenlohr et al. 2015; Raedig and Lautenbach 2009; Galindo-Leal and Gusmão Câmara 2003).

The process of large scale deforestation and land use intensification started already with the arrival of the European colonizers about 450 years ago. Exploitation cycles with the selective extraction of Brazilwood (*Paubrasilia echinata* (Lam.) Gagnon, H.C. Lima & G.P. Lewis), followed by sugar cane plantations, gold mining in Minas Gerais and transportation to the harbors of RJ, as well as coffee plantations are well known and described in the literature (Dantas and Coelho Netto 1995). Several authors also point out the increasingly rapid destruction of the Atlantic Forest that is associated with these exploitation cycles (Dean 1995; Cabral and Fiszon 2004; Nehren et al. 2013). However, while the coastal zone and lower ranges of the Serra do Mar have already been widely deforested and severely degraded in the 17th–18th century (Nehren et al. 2016) the development of the mountainous hinterland of RJ started later and reached a high dynamic within the last 100–150 years. This rapid process of land use intensification was triggered by an active immigration policy in the early 20th century and infrastructural development with railway and road construction. Wide parts of the hilly and mountainous land were used for cattle ranching, while intensive agricultural production was limited to the fertile floodplains and intra montane basins. Moreover, already after the first collapse of the coffee market in RJ in the late 19th century, large former coffee plantations were converted into pasture land. The remaining coffee market in RJ was then affected by the Great Depression of 1929, so that most of the remaining plantations were also transformed into grazing land. Therefore we could consider cattle ranging as the fifth large exploitation cycle.

Status of Pasture Management and Drivers of Pasture Degradation in Rio de Janeiro

Following the last agricultural census of Brazil in 2006, Brazil has 172.3 million ha of pasture land (Dias Filho 2014), making up 48% of all registered agricultural production units. While the pasture area increased on average only by 4% within the period from 1975 to 2006, the herd size increased by 100.8%. Hence, the stocking densities per unit pasture area increased remarkably. Looking at the grand sub-regions of Brazil, this ratio becomes even more pronounced. In the same period of time, the Northern and Central-eastern part of the country showed an increase of stocking density to more than 200%, whereas a respective increase of 62% in SE

Brazil can still be considered as very high (Dias Filho 2014). Taking into account that around half of the pastures in SE Brazil are natural, non-planted and mainly unmanaged (SEA 2011), the grazing pressure on these pastures strongly increased. When compared to the Brazilian federal states of Mato Grosso, Minas Gerais and Goias, which are leading in cattle stock and herd size (IBGE 2013), cattle farming in RJ is mainly made by many small family farmers. Nevertheless, 55% of RJ's area is used as pasture land, especially in the Northern and North-western parts of the state (SEA 2011). Only 3% of these pastures are situated in alluvial plains, which are mainly used for crop production, due to the fertile soils, suitable relief and stable water supply. Hence, the vast majority of the state's pastures are on more or less steeply sloped hills. Pasture farming sloping hills carries a high risk for degradation, mainly due to the predominance of weathered tropical soils (Acrisols according FAO-WRB, or Ultisols according to USDA soil classification, respectively). Even though not taking into account possible inadequate or lacking management, natural forces of water erosion combined with soil compaction due to cattle stock activity and the related formation of initial erosion forms (e.g. slope parallel cattle tracks and trails along vertical fences) are exacerbating degradation risk (Galdino et al. 2015; Silva and Botelho 2014). When combined with excessive cattle stock density, lacking pasture grass management and lacking vegetation recovery periods, these drivers lead to rapid and severe pasture degradation (Fig. 1.1).

The attempt to intensify cattle ranging productivity in smallholder farming systems is mainly made by enhancing cattle stock density. Taking into account the geo-ecological conditions in rural RJ and lacking adequate and sustainable pasture management, the opposite effect occurs. Mainly due to soil compaction and subsequent erosion the overgrazed pastures become increasingly degraded, resulting in production losses (Junior et al. 2013). Due to the pressure of an increased number of trampling cattle per unit area, the bulk density of the mainly fine textured, clay rich Acrisols increases, while soil porosity and water infiltration decreases. Such

Fig. 1.1 Sloped pasture showing multiple erosion forms such as gullies, rills, cattle tracks and bare soils. Municipality of Porciuncula, RJ © D. Sattler 2014

compacted top soils impede plant root penetration and hinder soil aeration and drainage (Araujo et al. 2004). Hence, a vicious cycle of soil and vegetation impoverishment and laminar erosion is initiated. Soil bulk density data from RJ (Sattler et al. 2014, own unpubl. data) reveal significant differences for soils under forest (0.6–1.2 g cm^{-3}) when compared with pasture soils (up to 1.6 g cm^{-3}). Soil erosion especially starts in areas that combine soil compaction and the steepness of slopes, ranging between 8 and 20%. As shown in Fig. 1.1, soil compaction and the loss of a well-drained humus-rich topsoil may lead to scattered vegetation cover and progressive erosion forms (e.g. deep gullies). Additionally, the surface runoff caused by heavy rains that occur during the austral summer aggravate the erosion of initial forms (e.g. cattle tracks and small gullies). The thus exposed subsoil with clay contents often exceeding 40 g kg^{-1} and apparent soil bulk density above 1.6 g cm^{-3}, generate even higher surface runoff that accelerates further erosion (Silva and Botelho 2014).

Another driver of soil erosion at pastures is the widespread practice of tillage for seedbed preparation for pasture renewal. While the adoption of no-tillage management in annual crops production, in Brazil mainly soybean and corn, has gained raising attention, the tillage of pastures is still a common management practice. Sparovek et al. (2007) estimate an area of 10 million ha $year^{-1}$ of pasture renewal by tilling at a large spatial dispersion over Brazil, especially in the Central-Western and South-eastern parts of the country. This area can easily compete with the magnitude of non-protective annual crop production. The mainly sloped pastures in RJ are particularly prone to soil erosion caused by top-down hill tillage, as mechanized tillage following slope parallel contours is mostly not possible due to steep slope angles. On the other hand, the traditional, low impact and slope parallel ox-ploughing is a fading out management practice due to understaffed rural labour. Even though the local effects of top soil erosion by pasture tillage are often compensated with soil liming and fertilizing, the off-site effects of such management are tremendous. In SE Brazil, pasture tilling is applied at the beginning of the rainy austral summer to ensure the growth of the sawn, mainly African *Brachiaria* pasture grasses. The soil washed away by strong summer rains causes a multitude of negative environmental effects such as silting and sedimentation of rivers and water reservoirs, contribution to river floods, degradation of riparian areas and decrease of water quality due to sediment load and related decline of dissolved oxygen (Niyogi et al. 2007; Sparovek et al. 2007).

Besides the strong degradation hazards caused by overgrazing, soil compaction and lacking or inadequate pasture management, projected environmental conditions driven by climate change will exacerbate land degradation. Regional climate models suggest that in the future droughts might affect SE Brazil in higher frequency and intensity, while at the same time heavy rainfall events will also increase (Dereczynski et al. 2013; Salazar et al. 2015). Especially when combined with unsustainable or inappropriate land use, both will trigger further degradation of rural areas, and in the worst case lead to badlands, which cannot be used for pasture farming and agriculture anymore in an economically feasible way. This will have implications not only on the geo-ecological stability and resilience of the natural landscape, but can lead to the loss of a family agriculture-dominated rural cultural landscape in RJ, and in the long run to accelerated rural exodus.

Options for Sustainable Pasture Farming and Mitigation of Degradation

Since 2013, the Brazilian–German research and development Project INTECRAL ("Integrated eco technologies and services for a sustainable rural Rio de Janeiro") has been developed as a cooperation of the German research institutions TH Köln University of Applied Sciences, the University of Leipzig, the Friedrich-Schiller-University of Jena and several small and medium sized German enterprises, all funded by the German Federal Ministry of Education and Research (BMBF), and the Rio de Janeiro State Secretariat of Agriculture and Livestock (SEAPEC). SEAPEC coordinates a large scale development project for rural areas of RJ, the "Rio de Janeiro sustainable rural development project" (Projeto Rio Rural, PRR), funded by the World Bank and supported by the United Nations Food and Agriculture Organization (FAO). Following a pilot phase, the actual phase of PRR project from 2011 to 2018 invests about USD 233 million in the family farming and environmental sector. In this phase, the programme strengthens organization and community mobilization in 366 watersheds of 71 municipalities in all regions of RJ, developing skills and encouraging the adoption of best practices. By 2018, the program will benefit 48,000 farmers, rural women and young people, encouraging them to become key players in developing their watersheds. More than food producer, the farmer is considered the main ally in the sustainable management of natural resources indispensable to the survival and well-being of the entire population. The PRR farm level activities are mainly implemented as community-based investments in water and sanitation infrastructure, sustainable agricultural management, land restoration and preservation activities, and in related capacity building. Most of those activities are supported by the INTECRAL project by providing scientific, technical and operational assistance necessary for the development and adaptation of technologies. Together with the Rio de Janeiro state Enterprise of Technical Assistance and Rural Extension (EMATER-RIO) and the Agricultural Research Corporation of Rio de Janeiro State (PESAGRO-RIO), the INTECRAL project develops and implements several research based pilot measures, e.g. for water quality monitoring, sustainable small scale sugarcane farming, silvo-pastural farming and pasture rehabilitation for degradation mitigation.

Pilot Pasture Rehabilitation Measure

In the light of frequent and severe pasture degradation in RJ, the INTECRAL research group of the University of Leipzig is developing a pasture degradation assessment system, using remote sensing data, field based indicators and participative monitoring of the awareness of pasture degradation within the farmer communities. Rehabilitation measures to prevent and counteract land degradation in rural RJ will only succeed if based on a wide farmer's acceptance and applicable and pragmatic best practice approaches at low cost. Based on respective assessment data a pilot pasture rehabilitation measure has been planned and implemented on a degraded pasture in the municipality of Itaocara, RJ. The pilot measure was implemented from June to December 2015 by the INTECRAL project with the aim to break the erosive power of surface runoff and interflow at the pasture hill by hedge terraces and subdivide the pasture slope into lots allowing for extensive rotational grazing.

The pilot area is located 6 km southeast of Itaocara city (S21° 41′ 44.10; W42° 02″ 02.51). The pasture has been used for extensive cattle ranching for decades as most of the pastures which cover 70% of the territory within the municipality of Itaocara. Slope degrees of the pilot area mainly range from 8.5° to 24° that represents the two dominant slope classes 'moderately steep' and 'steep' characterizing 50% of municipality territory. Compared to this, plain areas (nearly level and very gently sloping up to 1.1°) with only 3% coverage are strongly underrepresented in this municipality. Sheet erosion, rills and cattle tracks are the major erosion types showing a moderate erosion degree and extent. Moderately degraded areas are preferably recommendable for rehabilitation measures due to an expected high rehabilitation effect at rather low cost. The property size of 22.5 ha corresponds to small to medium farm-size, typically for this region. A good visibility and accessibility of the study area is given due to proximity to the state road RJ 116. This facilitates training activities with farmers and local stakeholders and makes transport and storage of measure-related materials and goods easy. Moreover, the land-owner kindly agreed to cooperate with the project and to hand-over part of his land for temporary research purposes.

The pilot area (3.3 ha) occupies 15% of the whole property area (see Fig. 1.2) This area has been taken off from cattle ranching since end of May 2015 for enabling the measure's implementation. Using a micro-tractor and rotating tiller, three terraces (1 m wide, slightly tilted against the slope) positioned at approximately 20 m altitude difference each have been installed slope-parallel considering the horizontal slope form. Terrace sections crossing erosion areas such as rills and bare soils have been stabilized by 16 palisade constructions using local material such as eucalyptus and bamboo. The terraces subdivide the slope into four parcels (bottom, middle, upper slope and hilltop) and act as breaklines for erosive surface runoff. Each parcel can be accessed through five gates located in different positions of the terraces to better control and vary future cattle movement applying a rotational pasture management concept. Five species of native tree seedlings

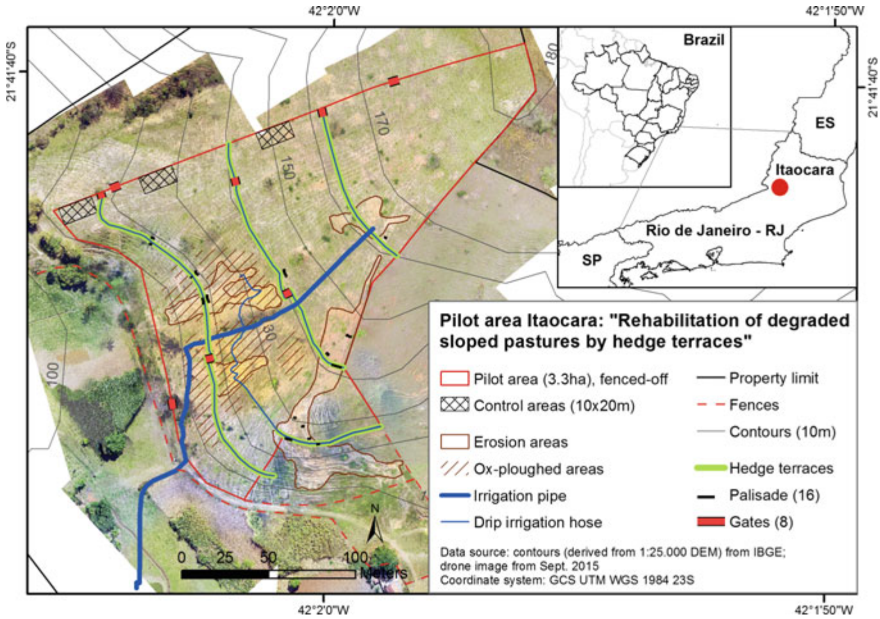


Fig. 1.2 Schematic map of the pilot measure area based on a high resolution DJI Phantom II Drone image © R. Seliger 2016

(*Chloroleucon tortum* (Mart.)Pitt., *Machaerium nyctitans* (Vell.)Benth, *Schinus terebinthifolia* Raddi, *Anadenanthera colubrina* (Vell.)Brenan *var. cebil* (Griseb.) Altschul and *Enterolobium contortisiliquum* (Vell.)Morong were horizontally planted each 20 cm along all three terraces (total length: 515 m, n = 2.433). To make the seedlings more resistant against long-lasting dry periods, a hydrogel has been applied on seedling roots during planting process. An installed drip-irrigation system supports the initial growth phase of the tree-seedlings. Bare soil areas were ox-ploughed and seeded with *Brachiaria* grass afterwards. Moreover, areas strongly compacted and/or suffering from rill erosion, have been planted with grass sods. Areas with extreme erosion forms were excluded from the pilot area; here afforestation should be undertaken as most promising and cost-efficient measure. Finally, both a soil (pH) correction with lime and a NPK fertilization have been applied on the pasture, complemented by a novel stonepowder-dung mixture (Silva 2010). During the whole planning and implementation process the land-owner’s expertise and advice have always been considered in order to reach maximum acceptance and prospect of success. Continuous scientific monitoring of the pilot measure includes the evaluation of tree-species performance and it’s root development along the terraces, impact of pest species, biomass production, effects of erosion control and effects on physical soil features. A more detailed description of the bio-engineered techniques applied by Hebner et al. (2016) is available in this volume.

Potential Carbon Storage Capacity of Afforested Pastures

The rehabilitation and reformation of degraded pastures on slopes for subsequent pasture farming under appropriate and sustainable management is just one option for dealing with degradation phenomena. Taking into account the persisting risk of degradation due to the given combination of unsuitable geo-factors on the one hand (e.g. erodibility and low productivity of predominant Acrisols, steeply sloping relief), and on the other hand the demand for areas to be afforested within the framework of REDD + (Reducing Emissions from Deforestation and Forest Degradation), PES (Payment for Ecosystem Services) and other carbon storage and nature conservation projects, degraded pastures on steep slopes can be perceived as excellent opportunity areas for the enhancement of the landscapes carbon storage capacity by afforestation. Establishing planted or spontaneous vegetation at such areas with marginal agricultural yields which are unsuitable or barely suitable for food or stock production provides multiple positive effects for the re-establishment of ecosystem services and the landscapes resilience to projected climate changes (Dereczynski et al. 2013).

As such action is urgently needed while financial resources for interventions are limited, the prioritization of areas to start with is a crucial issue. Two simple indicators can be used to approach prioritization of areas to be re-vegetated with remote sensing data: a land use land cover (LULC) map for the delineation of pastures and a digital elevation model for the definition of respective slope angle classes. In an exemplary case study we assessed these indicators for two regions, one situated in the mountain foreland of the Serra dos Órgãos Mountain range (Guapi-Macacu Watershed, GMW) and one in the North-western region of RJ (Itaocara municipality, IM). The digital elevation model (DEM) was derived from 10 m equidistant isolines (source: Brazilian Institute of Geography and Statistics, IBGE) as a raster with 20 m resolution. Based on this we calculated the slope angles and subsequently classified them in nine slope classes (0–2°, >2–5°, >5–10°, >10–15°, >15–20°, >20–25°, >25–30°, >30–45° and >45°). As LULC data provided by IBGE are only available from 2007 and at a comparably rough resolution, we produced this information for both municipalities. The land use map for the GMW was derived from a newly developed multisensorial product with 5 m resolution from 2011 (Landsat 5, RapidEye and SPOT 5; unpublished data) and the land use map for IM was developed based on a multi temporal Landsat 8 data product with 15 m resolution. Both land use classifications were then calculated using the Random Forest Classifier (Breimann 2001) with the open-source software R 3.2.2 (R Core Team 2015) and the R Package ‘randomForest’ (Liaw and Wiener 2015) and obtained excellent overall accuracies of >95%. From both land use maps we extracted the pasture area and calculated the proportions per slope class using the software ArcGIS 10.3. on the 20 $\times$ 20 m pixel basis of the slope angle raster (see Table 1.2).

About 40% of the Guapi-Macacu Watershed and 60% of the Itaocara municipality are pastures. In GMW, 24% of them are situated at slopes steeper than 15°, in IM 43%, respectively. This fraction of pastures represents priority areas to be suggested for abandonment of pasture farming an for the implementation of planted or spontanuously regenerating forest. Taking into account the potential carbon storage capacity of afforestation and varying successional stages of Atlantic forest, based on above- and below ground biomass estimates (Table 1.1), approximately 80,000 MgC could be stored at these steeply sloped pastures of the two example areas just by anbandonment and spontaneous growth of shrubby vegetation. A (potentially supported) forest succession could even sequester up to 3.4 million MgC (Table 1.2) at steeply sloped pastures of the two example areas. The critical point of this calculation is the uncertainty regarding the time needed to reach the respective successional stages.

The time scale of Atlantic Forest succession within human-modified landscapes is difficult to predict because initial site conditions, proximity to other forest fragments and local climate may result in alternative regeneration pathways, most of them resulting in more or less species poor, edge affected secondary forests (Joly et al. 2014). Hence, this time scale uncertainty is a major constraint and limits the validity of the calculation presented above. Nevertheless, secondary Atlantic Forest can reach structural convergence to the canopy structure of an old-growth forest in as little as 12 years (Nascimento et al. 2014), which is important in terms of carbon storage capacity and landscape resilience. Supporting natural regeneration by enrichment planting or protecting spontaneously grown tree seedlings from remaining pasture grass are easy and cheap alternatives to comparably expensive forest plantations (De Moraes et al. 2013; Parotta et al. 1997). However, the carbon storage capacity of marginal, low yield and high environmental risk pastures is enormous and should be taken into account first when designing incentive payment for ecosystem services strategies.

Potential Contribution of Degraded Pastures to Biodiversity Conservation

One option for the use of degraded pastures in the state of regeneration is the integration into conservation activities. The awareness for the need of biodiversity conservation in Brazil is increasing. An indicator for this development is the growing number of established private protected areas, the so-called Natural Heritage Private Reserves (Reservas Particulares do Patrimônio Natural, RPPNs). However, the conversion of regenerating pastures into an RPPN is only possible, if 70% of the entire area planned as an RPPN consists of natural forest, and only 30% of the area is degraded (INEA 2015). Nonetheless, such areas could be included into corridor strategies: in order to re-establish linkages between forest remnants, they can serve as connectors between isolated forest stands in the long run. Corridor

Table 1.1 Biomass and carbon content of varying vegetation formations of Southeastern Atlantic Forests and afforestations

Source	Location	Vegetation type	DBH range (cm)	AGB (Mg/ha)	BGB (Mg/ha)	MgC/ha (0.47 × AGB + BGB)
Robinson et al. (2015)	Itatiaia, RJ	Seasonally dry semi-deciduous AF fragment	>3	158.90 (±42.10)	39.72 (±10.52)	93.35 (±24.73) C
		Trees (initial succession) at abandoned pasture (30 year ago)		10.90 (±6.30)	2.72 (±1.57)	6.40 (±3.70)
		Trees + shrubs (Capoeira) at abandoned pasture (30 year ago)		5.90 (±3.50)	1.47 (±0.87)	3.46 (±2.06)
Alves et al. (2010)	Serra do Mar State Park, SP	Submontane tropical moist evergreen forest	5–156	247.70 (±14.70)	61.92 (±3.67)	145.52 (±8.64)
Barbosa et al. (2014)	Vale do Ribeira, SP	Ombrophilous tropical forests, initial succession	1.6–47.8	54.00 (±68.00)	13.5 (±17.00)	31.72 (±39.95)
		Ombrophilous tropical forests, advanced succession		128.00 (±190.00)	32 (±47.50)	75.20 (±111.62)
Sattler et al. (2014)	REGUA, Guapiaçu, RJ	4 year old afforestation, plane	4–116	81.00 (±15.00)	20.25 (±3.75)	47.59 (±8.81)
		4 year old afforestation, slope		37.20 (±12.60)	9.3 (±3.15)	21.85 (±7.40)
Lindner and Sattler (2012)		Submontane dense ombrophilous secondary forest	10–70	250.40 (±77.90)	62.6 (±19.47)	147.11 (±45.77)
Tiepolo et al. (2002)	Serra do Itaqui, Guaraqueçaba, PR	tropical moist forest, young secondary	4–116	45.10	11.275	26.50
		Tropical moist forest, medium secondary		150.60	37.65	88.48
Diniz et al. (2015)	Pinheiral, Vale do Paraiba do Sul, RJ	Seasonally dry semi-deciduous AF, 25 year medium succession	N/A	34.30	8.575	20.15
		Seasonally dry semi-deciduous AF, 65 year advanced succession		115.60	28.9	67.91

AGB Above ground biomass, *BGB* below ground biomass (root/shoot ratio 0.25 according to Nogueira Junior et al. 2014), *DBH* diameter at breast hight (1.30 m), *RJ* Rio de Janeiro state, *SP* São Paulo state strategies support biodiversity conservation, since they facilitate the exchange of propagules (including individuals, seeds and genes of species) between isolated forest stands.

Conclusions

Pasture based livestock farming in SE Brazil is a widespread rural land use, mainly situated at marginal land of sloping hills. As economic pressure is becoming stronger, overgrazing and no or minimal investments in sustainable pasture management lead to severe degradation of these areas. Without consolidated intervention towards sustainable management, alternative land use and incentives for abandonment of steeply sloped pastures, an accelerated degradation process will continue. In combination with projected climate change, a system tipping point can be reached where former pastures remain badlands for decades. Our findings indicate that the adoption of bio-engineered pasture rehabilitation measures for erosion control combined with intensification of cattle farming at non-hazardous prime locations (e.g. rotational grazing) can stop or at least considerably reduce pasture degradation. Even though there are many low budget options for pasture rehabilitation, it seems unlikely that these measures are applicable at a large scale, taking into account the economic situation of many developing countries. Furthermore, the acceptance of such measures by a majority of involved farmers and stakeholders needs to be improved. This can only be achieved by better and more widespread education of all actors in the agricultural sector. The respective societal structures and training activities established by the Rio Rural Programme are exemplary in this regard.

Brazil's pasture based livestock production will still grow within the next decades, and ongoing pasture degradation will lead to shortages of suitable pasture land. Nevertheless, extensive expansion of pastureland at the expense of natural habitats is no reasonable option, and intensified pasture farming combined with economic incentives for farmers for the abandonment of hazardous (sloped) pasture areas can lead to sustainable pasture farming (Lataviec et al. 2014). Adopting intelligent and sustainable pasture management, Brazil's productivity of pasture based products can be increased up to more than 50% by 2040 without further conversion of natural habitats (Strassburg et al. 2014). Intensified pasture farming at prime locations and abandonment of critical ones can liberate rural areas for alternative, diversified production with agro-silvopastoral systems that both increase yields and provide a higher productive flexibility (Balbino et al. 2011) when facing future weather extremes. Furthermore, abandoned degraded pastures are excellent opportunity areas for carbon sequestration by afforestation and spontaneous forest re-growth. The implementation of such measures will encompass multiple positive effects (water retention, water quality, erosion control, diminished flood risk, habitat for biodiversity etc.) for both the ecological and economic resilience of RJ's rural landscapes. To meet such complex challenges

Table 1.2 Carbon storage capacity of steep pasture slope classes potentially afforested or spontaneously re-vegetated

Pasture slope class	G-M Watershed (ha)	Itaocara municip. (ha)	Capoeira (30 year) (Robinson et al. 2015) (MgC)	Afforestation 4 year, slope (Sattler et al. 2014) (MgC)	Young sec. forest (Tiepolo et al. 2002) (MgC)	Dense ombroph. forest (Lindner and Sattler 2012) (MgC)
>15°–20°	4125.6	5609.6	33,683.9	212,714.9	257,983.9	1,432,151.2
>20°–25°	3502.4	3695.5	24,904.8	157,274.5	190,744.9	1,058,886.0
>25–30°	2390.2	1475.4	13,375.1	84,464.2	102,439.5	568,674.3
>30°–45°	1447.2	485.04	6685.4	42,218.6	51,203.3	284,245.9
>45°	152.6	0.88	531.0	3353.5	4067.2	22,578.4
Total	11,618.0	11,266.44	79,180.3	500,025.9	606,438.7	3,366,535.9

G-M Watershed = Guapi-Macacu Watershed

evoked by climate change and social transformation in Brazil's and other developing countries rural landscapes, the continuous support of state, federal and international rural development programs such as the Rio Rural Program of the Secretariat of Agriculture and Livestock of the State of Rio de Janeiro will be indispensable.

Acknowledgements We like to thank the German Federal Ministry of Education and Research (BMBF) for funding the research and development Projects "DINARIO" (FKZ 01LB0801B) and "INTECRAL" (033L162F) and the Rio de Janeiro State Secretariat of Agriculture and Livestock (SEAPEC), hosting the Rio de Janeiro sustainable rural development project (Rio Rural) for facilitating a fruitful cooperation. Furthermore, we are grateful to the staff of EMATER-Rio, PESAGRO-Rio and EMBRAPA Solos for providing excellent logistic backup. Special thanks to Juliana Marisa Santos (Institute of Geography, University of Jena, Germany) and Giuseppe Latorraca for their outstanding support of pilot measure implementation and field research.

References

Alves LF, Vieira SA, Scaranello MA, Camargo PB, Santos FAM, Joly CA, Martinelli LA (2010) Forest structure and live aboveground biomass variation along an elevational gradient of tropical Atlantic moist forest (Brazil). For Ecol Manag 260(5):679–691

Araujo EA, Lani JL, Amaral EF, Guerra A (2004) Land use and physical and chemical properties of a distrophic Yellow Argisol in the western Amazon region. Revista Brasileira De Ciencia Do Solo 28(2):307–315

Bai ZG, Dent DL, Olsson L, Schaepman ME (2008) Proxy global assessment of land degradation. Soil Use Manag 24:223–234

Balbino LC, Barcellos ADO, Stone LF (Eds) (2011) Marco referencial: integração lavoura-pecuária-floresta. EMBRAPA, Brasilia, 130 pp

Barbosa JM, Melendez-Pastor I, Navarro-Pedreno J, Bitencourt MD (2014) Remotely sensed biomass over steep slopes: an evaluation among successional stands of the Atlantic Forest, Brazil. Isprs J Photogramm Remote Sens 88:91–100

Breiman L (2001) Random forests. Mach Learn 45(1):5–32
Cabral DC, Fiszon JT (2004) Padrões sócio-espaciais de desflorestamento e suas implicações para a fragmentação florestal: estudo de caso na Bacia do Rio Macacu, RJ. Scientia Forestalis 66:13–24
Clausing P (2011) Peak soil: soil destruction and the food crisis—the loss of fertile land and how to avoid it. Local land and soil news no.38/39 II. Bull Eur Land Soil Alliance (ELSA) e.V
Dantas ME, Coelho Netto AL (1995) Impacto do ciclo cafeeiro na evolução da paisagem geomorphológica no medio vale do Rio Paraiba do Sul. Cad. Geociências, S. 15–22
De Moraes LFD, Assumpção JM, Pereira TS, Luciari C (2013) Manual Técnico para a Restauração de Áreas Degradadas no Estado do Rio de Janeiro. Instituto de Pesquisas Jardim Botanico de Rio de Janeiro, Rio de Janeiro, 108 pp
Dean W (1995) A Ferro e Fogo – a história e a devastação da Mata Atlântica Brasileira. Ed. Schwarcz Ltda., 483 S., São Paulo
Dereczynski C, Silva WL, Marengo J (2013) Detection and Projections of Climate Change in Rio de Janeiro, Brazil. Am J Clim Change 2:25–33
Dias-Filho MB (2014) Diagnóstico das Pastagens no Brasil. Embrapa Amazônia Oriental, Belém, 36 pp
Diniz AR, Machado DL, Pereira MG, Balieiro FDC, Menezes CEG (2015) Biomassa, estoques de carbono e de nutrientes em estádios sucessionais da Floresta Atlântica, RJ. Rev Bras de Ciências Agrárias 10(3):443–451
Eisenlohr P, de Oliveira-Filho A, Prado J (2015) The Brazilian Atlantic Forest: new findings, challenges and prospects in a shrinking hotspot. Biodivers Conserv 24:2129–2133
Galdino S, Sano EE, Andrade RG, Grego CR, Nogueira SF, Bragantini C, Flosi AHG (2015) Large-scale modeling of soil Erosion with RUSLE for conservationist planning of degraded cultivated Brazilian pastures. Land Degrad Dev 27:773–784
Galindo Leal C, de Gusmão Câmara (Eds) (2003) The Atlantic Forest of South America: biodiversity status, threats, and outlook (state of the hotspots, 1). Center for Applied Biodiversity Science at Conservation International. Island Press, Washington D.C., 488 S
Hebner A, Kopielski K, Dulleck A, Gerth A, Sattler D, Seliger R, Hissa HR (2016) Bioengineered measures for prevention of proceeding soil degradation as a result of climate change in South East Brazil. In: Leal Filho W, Gallo E, Coelho Netto AL (eds) Climate Change Adaptation in Latin America: managing vulnerability, fostering resilience. Climate Change Management, Springer Int, Pub. Switzerland
IBAMA (1990) Manual de recuperação de áreas degradadas pela mineração: técnicas de revegetação. Brasília, 96 pp
IBGE—Instituo Brasileiro de Geografía e Estatistica (2013) Produção da pecuaria municipal. Vol. 41, Rio de Janeiro, 108 pp
IBGE—Instituo Brasileiro de Geografía e Estatistica (2014) Estimativas da população residente no brasil e unidades da federação com data de referência em 1º de julho de 2014. Diário Oficial da União, em 28 de agosto de 2014, Brasilia
INEA—Instituto Estadual do Ambiente (2015) Protocol for the technical study of RPPNs, Rio de Janeiro
Joly CA, Metzger JP, Tabarelli M (2014) Experiences from the Brazilian Atlantic Forest: ecological findings and conservation initiatives. New Phytol 204(3):459–473
Junior PRR, Silva VM, Guimarães GP (2013) Degradação de pastagens brasileiras e práticas de recuperação. Enciclopédia Biosfera, Centro Científico Conhecer - Goiânia 9(17):952–968
Liaw A, Wiener M (2015) randomForest: Breiman and Cutler's random forests for classification and regression. R package version 4. 6–10. Online available: https://cran.r-project.org/web/packages/randomForest/ randomForest.pdf
Latawiec AE, Strassburg BBN, Valentim JF, Ramos F, Alves-Pinto HN (2014) Intensification of cattle ranching production systems: socioeconomic and environmental synergies and risks in Brazil. Animal 8(8):1255–1263
Lindner A, Sattler D (2012) Biomass estimations in forests of different disturbance history in the Atlantic Forest of Rio de Janeiro, Brazil. New Forests 43(3):287–301

Nachtergaele R, Biancalani R, Petri M (2011) Land degradation. SOLAW Background Thematic Report 3
Nehren U, Kirchner A, Sattler D, Turetta A, Heinrich J (2013) Impact of natural climate change and historical land use on landscape development in the Atlantic Forest of Rio de Janeiro. Brazil. Anais Academia Brasileira de Ciências 85(2):311–332
Nehren U, Kirchner A, Heinrich J (2016) What do yellowish-brown soils and stone layers tell us about Late Quaternary landscape evolution and soil development in the humid tropics? A field study in the Serra dos Órgãos, Southeast Brazil. CATENA 137:173–190
Nascimento LM, Sampaio E, Rodal MJN, Lins-e-Silva ACB (2014) Secondary succession in a fragmented Atlantic Forest landscape: evidence of structural and diversity convergence along a chronosequence. J For Res 19(6):501–513
Nogueira Junior LR, Engel VL, Parrotta JA, Galvao de Melo AC, Re DS (2014) Allometric equations for estimating tree biomass in restored mixed-species Atlantic Forest stands. Biota Neotrop 14(2):1–9
Niyogi DK, Koren M, Arbuckle CJ, Townsend CR (2007) Stream communities along a catchment land-use gradient: Subsidy-stress responses to pastoral development. Environ Manage 39 (2):213–225
Parrotta JA, Turnbull JW, Jones N (1997) Catalyzing native forest regeneration on degraded tropical lands. For Ecol Manage 99(1–2):1–7
Team RC (2015) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org. Accessed 9 May 2016
Raedig C, Lautenbach S (2009) Broad-scale angiosperm diversity in Brazil's Mata Atlântica: using monographic data to assess prospects for conservation. In: Gaese H, Torrico JC, Wesenberg J, Schlüter S (eds) Biodiversity and land use systems in the fragmented Mata Atlântica of Rio de Janeiro, Cuvillier Verlag Göttingen pp 217–243
Robinson SJB, van den Berg E, Meirelles GS, Ostle N (2015) Factors influencing early secondary succession and ecosystem carbon stocks in Brazilian Atlantic Forest. Biodivers Conserv 24:2273–2291
Salazar A, Baldi G, Hirota M, Syktus J, McAlpine C (2015) Land use and land cover change impacts on the regional climate of non-Amazonian South America: a review. Global Planet Change 128:103–119
Sattler D, Murray LT, Kirchner A, Lindner A (2014) Influence of soil and topography on aboveground biomass accumulation and carbon stocks of afforested pastures in South Eastern Brazil. Ecol Eng 73:126–131
Secretaria de Estado do Ambiente do Estado do Rio de Janeiro (SEA) (2011) O estado do ambiente: indicadores ambientais do Rio de Janeiro. Rio de Janeiro/INEA.160 pp
Silva AS (2010) Recuperação e reabilitação de áreas degradadas por mineração na zona rural de Santo Antonio de Pádua (RJ). Relatório técnico Edital MCT/CNPq/CT-Agronegócio n° 26/2010
Silva AS, Botelho RGM (2014) Degradação dos solos no estado do Rio de Janeiro. In: Guerra AJT, Jorge MCO (eds) Degradação dos Solos no Brasil. 1ed.Rio de Janeiro: Bertrand Brasil, 2014, v., pp 261–292
Sparovek G, Correchel V, Barretto A (2007) The risk of erosion in Brazilian cultivated pastures. Sci Agri 64(1):77–82
Strassburg BBN, Latawiec AE, Barioni LG, Nobre CA, da Silva VP, Valentin JF, Vianna M, Assad ED (2014) When enough should be enough: Improving the use of current agricultural lands could meet production demands and spare natural habitats in Brazil. Glob Environ Change-Hum Policy Dimens 28:84–97
Tiepolo G, Calmon M, Feretti AR (2002) Measuring and Monitoring Carbon stocks at the Guaraquecaba climate action project, Parana, Brazil. Taiwan For Res Inst Ext Ser 153:98–115

Chapter 2
Impacts of Climate Change: A Case in Watersheds in South of Brazil

Amanda Lange Salvia, Vanessa Tibola da Rocha, Luciana Londero Brandli and Sabrina Antunes Vieira

Introduction

The 21st century is the century of cities, as people are increasingly living in urban areas and there has been greater impact in the natural resources. However, with increased pressure on the environment, the risks are inevitable, with extreme events causing severe consequences including damage to infrastructure, properties and even loss of life. In this sense, identify risks and vulnerability before the disaster to occur is essential to effective risk reduction in long-term periods (Birkmann 2007). It seems that enhancing the resilience of the urban environment is indispensable for the sustainability of cities.

The increase in population density, traffic, waterproofing of roads and various other needs of modern cities greatly contribute to the risk of natural disasters. These anthropological actions on the environment tend to lead to climate change and stimulate global warming. Despite the availability of water resources being also affected by intense urbanization, land use, occupation and deforestation, climate events certainly emphasize all these problems, causing floods that bring great economic damage and loss of life, and also droughts that damage agriculture, human consumption and the generation of hydroelectric power (Marengo 2006).

In this context, water is an important factor for the development of any community and there is no doubt that climate change threatens the security of this resource. Thus, growth and development resilient to climate change is essential. Strategies, plans and investments that promote good water management are alternatives to promote climate resilience and better management of water resources benefits many sectors (health, energy and agriculture) and also contributes to the goals of sustainable development (AMCOW 2012).

A.L. Salvia (✉) · V.T. da Rocha · L.L. Brandli · S.A. Vieira
School of Engineering and Architecture, University of Passo Fundo, Passo Fundo, Brazil
e-mail: amandasalvia@gmail.com

W. Leal Filho and L. Esteves de Freitas (eds.), *Climate Change Adaptation in Latin America*, Climate Change Management,
https://doi.org/10.1007/978-3-319-56946-8_2

According to the Intergovernmental Panel on Climate Change (IPCC 2007a), the impacts of climate change on water resources will be through changes in the hydrologic cycle, increased extreme events, change in the average flow of the watercourse, longer drought events, rise in sea levels and increased frequency of floods. The increase in the intensity of precipitation will also result in increased erosion and new watershed models. Trenberth (2011) also states that precipitation varies from year to year and over decades, and changes in amount, intensity and frequency affect the environment and society, especially when it potentiates extreme events.

Additionally, limitations on measurements and records of rainfall are difficulties that concern researchers, because the frequency and reliability of the records of regional and global rainfall do not have scales to secure regard to control and record the data. This is because in situ measurements in areas of steep and complex topography does not occur due to numerous limitations (Adam et al. 2006).

The impact scenario on water resources will vary according to the region in Brazil. For example, the tendency is that the precipitation increase in the South and decrease in the North and Northeast (Marengo 2006). This will result in a change in river flows in these regions. The occurrence of floods is due to changes in the watershed and precipitation patterns, and this problem is often seen in urban areas. Therefore, it is necessary to develop new concepts and practices in management and public governance processes to improve coexistence with this phenomenon and minimize the impacts to the affected communities (Kobiyama et al. 2006).

Considering all the impacts to be caused in a watershed, it is impossible to guarantee 100% security and the risk culture is needed. Taking into account, it is particularly important that communities develop the ability to deal with the uncertainties in three main aspects: preparation, response and recovery (Federal Office for Civil Protection 2013). Thus, they are connected to the concept of resilience, that can be understood as "the ability of a country or city to respond to and evade the consequences brought about by global warming and to adapt to them." The construction of a society based on the principles of resilience requires new commitments and cooperation of all (Mateus 2004).

According to Randhir (2014), it is important to renew the understanding of resiliency, adaptability, and transformability of watersheds through social and ecological research. Its management to climate change requires a thorough understanding of state and dynamics and the result must be information dissemination and decision support systems related to a watershed to enhance resilience to handle adverse impacts of climate change. Urban planning needs to incorporate knowledge of the vulnerability and risk, to propose measures to mitigate potential impacts and to aim the adaptation to increase urban resilience; for that, it is required multidisciplinary approach and integration of researchers from different areas of knowledge (IPCC 2007b; Frank and Sevegnani 2009).

Farwell et al. (2012) point out that quantifying the anticipated changes allows water managers to match adaptive strategies with expected impacts to improve watershed resiliency to potential impacts. Some of the potential impacts include changes in precipitation patterns and temperature changes. In this context, the present study addresses the potential impacts of climate change on patterns of maximum monthly precipitation in Passo Fundo River and Várzea River Watersheds, located in south of Brazil, relating to temperature data. The results can enforce the need of operational management and urban resilience.

Method

Study Area

This research focus on two watersheds and they are show in the Fig. 2.1. The Passo Fundo River and Várzea River Watersheds are located in north region in Rio Grande do Sul State, and belong to the Hydrographic Region of Uruguay.

The climate in the region researched is characteristic of southern of Brazil, the humid Subtropical type. The seasons are well defined, with hot and humid summer and cool winters. The winds affect the climate, and in summer the trade winds blowing, coming from the southeast, causing high temperatures and heavy rains.

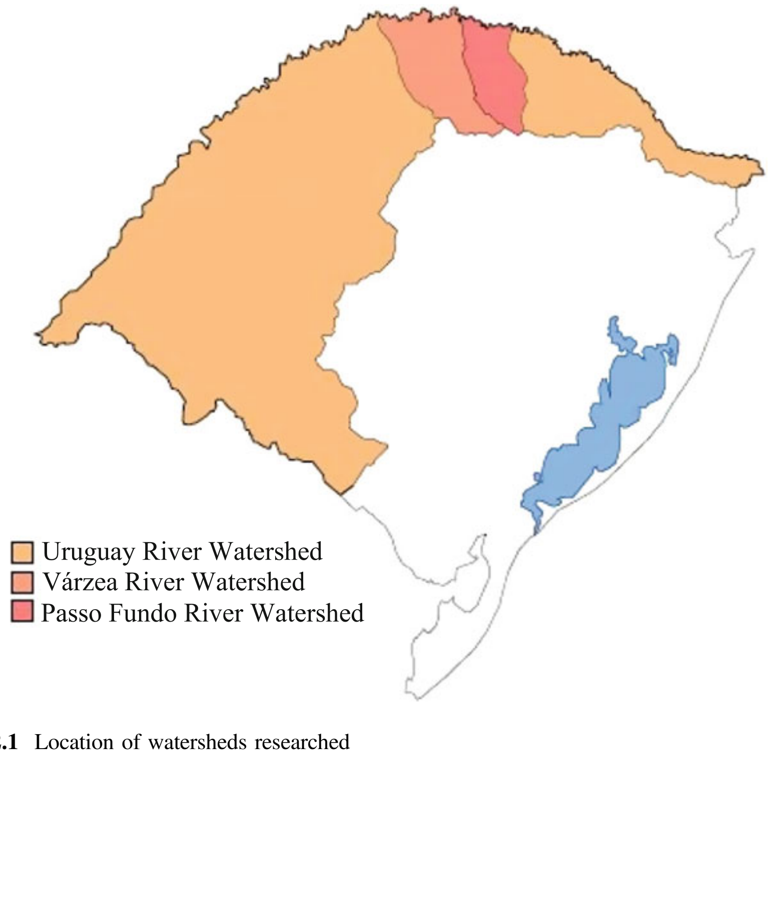


Fig. 2.1 Location of watersheds researched

In the winter, there is occurrence of cold front followed generally of air masses from the South Pole (Rossato 2011).

The Table 2.1 shows the characteristics of watersheds researched (SEMA 2010; FEPAM 2016a, b).

Data Collection

The precipitation data were obtained from the software Hidro 1.2, in website Hidroweb (ANA 2014), with a database from pluviometric stations (Table 2.2). In the study area, there are 26 pluviometric stations with precipitation data, but only 9 contain representative historical series with data for the analysis period. According

Table 2.1 Watershed's characteristics

	Passo Fundo River Watershed	Várzea River Watershed
Latitude and longitude	27° 04′–28° 19′ S 52° 13′–52° 51′ W	27° 00′–28° 20′ S 52° 30′–53° 50′ W
Main waterways	Passo Fundo River and Timbó Stream	Várzea, Porã, Guarita, Ogaratim Rivers and the Sarandi and Goizinho Streams
Main uses	Animal watering, irrigation, industrial use and human consumption	Animal watering, irrigation and human consumption
Drainage area	4785.7 km^2	9.324 km^2
Municipalities covered by watershed	30 municipalities	55 municipalities
Watershed population	168.370 inhabitants	328.057 inhabitants

Table 2.2 Pluviometric stations

Watershed	Codigo	Location/City	Latitude	Longitude	Altitude (m)
Várzea River Watershed	2753004	Sarandi	27:48:42	53:01:40	350
	2753014	Liberato Salzano	27:35:57	53:04:17	378
	2852006	Carazinho	28:17:36	52:43:27	570
	2753015	Palmeira das Missões	27:54:48	53:18:39	610
	2852007	Distrito Xadrez	28:11:21	52:44:45	593
	2753002	Frederico Westphalen	27:21:40	53:23:51	530
	2853026	Chapada	28:03:31	53:03:58	450
Passo Fundo River Watershed	2752017	Itatiba do Sul	27:23:20	52:27:16	350
	2752006	Erebango	27:51:15	52:18:17	763

to Tucci (2002), for analysis of historical precipitation series, they shall contain data for at least 30 years. For this reason, only this 9 were included in the analyses.

The temperature data were obtained from National Institute of Meteorology (INMET), which have a database with maximum monthly temperatures for each station (http://www.inmet.gov.br/portal/index.php?r=home2/index). Since there was no availability of temperature data for the exact locations of pluviometric stations studied, the temperature was estimated based on concepts of meteorology, and for every 180 m higher in altitude has been a decrease in temperature of the order of 1 °C (Dury 1972).

Analysis

To show the potential impacts of climate change on patterns of maximum monthly precipitation in the area studied, the analysis looked evidence about extreme events like of drought, floods and windstorms. For this, thermo-pluviometric diagrams are presented for each pluviometric station, using the maximum monthly precipitation and temperatures. The thermo-pluviometric diagram represents the precipitation data in blocks and temperature data in lines. Besides that, the average maximum precipitation is also presented, in order to support the analysis. Thus, is possible to verify the interference of temperature on precipitation, qualitatively, since the statistic was not used in this study.

Results and Discussion

Figures 2.2 and 2.3 show the average maximum temperatures of two pluviometric stations: Sarandi, in the Várzea River Wathershed and Erebango, in the Passo

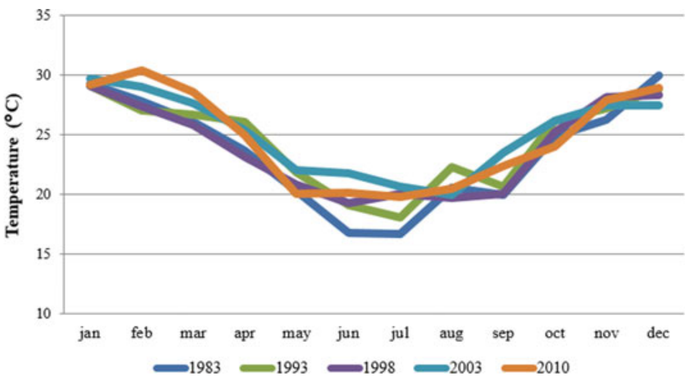


Fig. 2.2 Average maximum temperatures in Sarandi pluviometric station

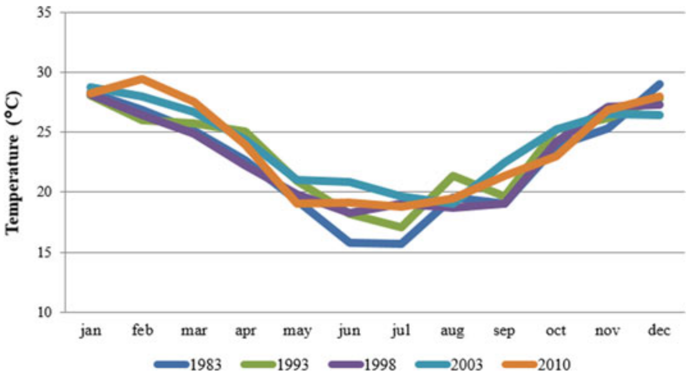


Fig. 2.3 Average maximum temperatures in Erebango pluviometric station

Fundo River Wathershed, respectively. After analysis of all periods, it is possible to notice a tendency of increase in maximum temperatures in recent years.

Increase in Earth's average temperature has been mainly evidenced by studies conducted by the Intergovernmental Panel on Climate Change, which, in a more optimistic scenario, forecasts an increase of about 2 °C (IPCC 2007b). However, observing the figures above, it can be seen that the temperature in June and July, which are the months with lower temperatures, already showed an increase of about 4 °C between 1983 and 2010.

Várzea River Watershed

Seven stations were studied in Watershed Várzea River. In 1983, the initial year of the study, there is no evidence of droughts or floods, as shown in Fig. 2.4, which illustrates the situation using the Sarandi pluviometric station, but the same is observed in Xadrez District and Chapada.

Between 1983 and 1994 most stations did not have evidences of extreme events, except for a few. One example is Frederico Westphalen pluviometric station, as shown in Fig. 2.5, which in February of 1991 had maximum precipitation of less than 10 mm, well below the average maximum. In 1991 and in a similar situation, Xadrez District station's maximum precipitation was less than 5 mm in March. These results are combined with the observation of high temperatures in these months in comparison with the temperature observed in previous years (equal or above 30 °C).

In 1995, Chapada pluviometric station had an average maximum precipitation of about 40 mm, below the average observed in the previous periods, which were between 50 and 60 mm. Furthermore, there was extreme precipitation in October, as shown in Fig. 2.6.

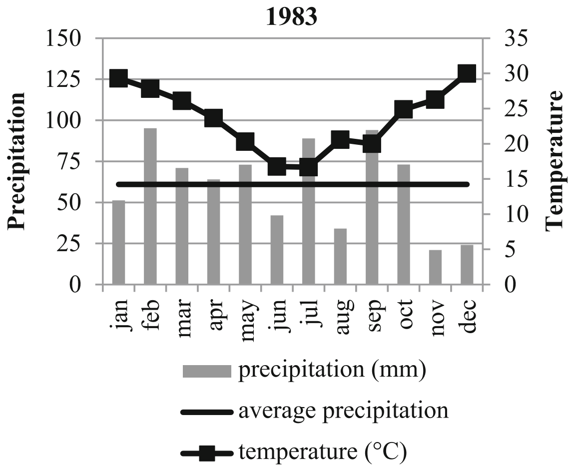


Fig. 2.4 Termopluviometric diagram of Sarandi (1983)

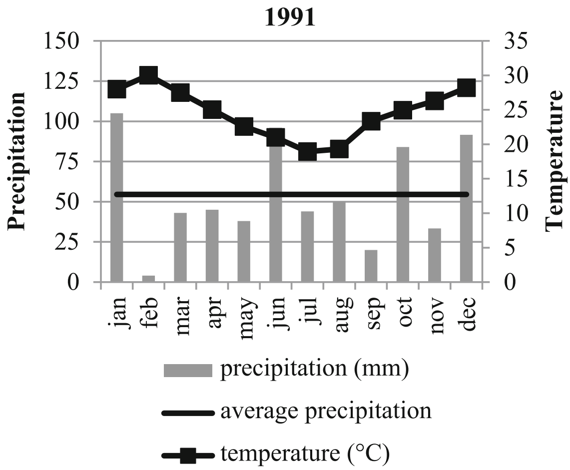


Fig. 2.5 Termopluviometric diagram of Frederico Westphalen (1991)

In the following years there were some extreme events in Chapada, such as the low maximum precipitation in February of 2005 and the high ones in September and October 2012. Such situations can be seen in Fig. 2.7.

From these diagrams obtained, it is observed that for the Várzea River Watershed, the temperature rise may be influencing the hydrological series, causing extreme events of drought and floods with greater frequency and magnitude than in the past. It can also be noted that the periods between January and May and November and December are more prone to droughts, while the months from June to October are more prone to floods.

Regarding the maximum monthly temperature data, it is observed that in the months of June and July, in the earlier years of study, the value was close to 15 °C, and in recent years the result is closer to 20 °C or even above it.

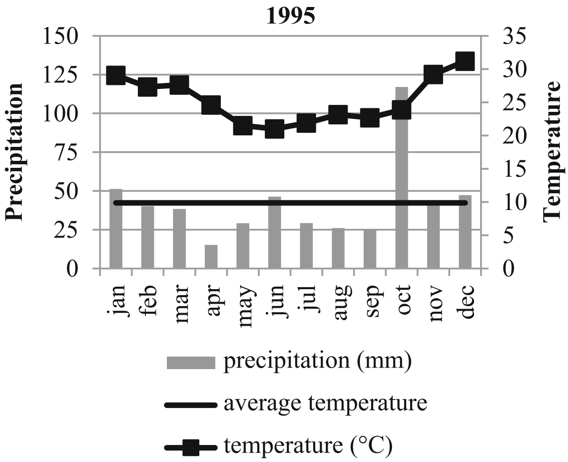


Fig. 2.6 Termopluviometric diagram of Chapada (1995)

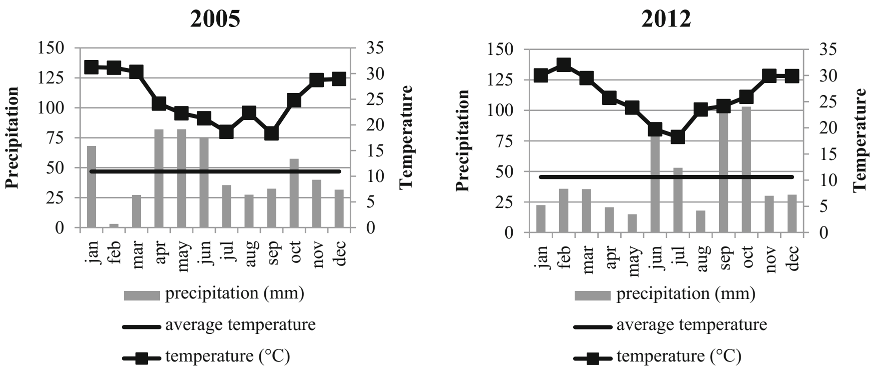


Fig. 2.7 Termopluviometric diagram of Chapada (2005–2012)

It is known that natural disasters such as droughts, floods and windstorms are occurring more frequently and with greater intensity in recent years in Rio Grande do Sul (Reis et al. 2012; Junior et al. 2012; Albuquerque and Mendes 2009). According to the Civil Defense of Rio Grande do Sul, approximately 400 drought events were recorded during the years 2002, 2005, 2009 and 2012. Also, flash floods were recorded in the years 2009, 2010 and 2011 with higher frequency than the annual average (CEPED UFSC 2013). However, not only climate change affects the increase in occurrence of extreme events, but it also affect the use and occupation of land, deforestation and population growth.

Passo Fundo River Watershed

Two pluviometric stations were studied in Passo Fundo River Watershed. The identified behavior is similar to the observed in Várzea River Watershed, with a greater tendency to extreme events. Additionally, this watershed also has higher precipitations in some months and intensified droughts in others.

In 1983 both stations showed a different behavior, as observed in Fig. 2.8. In terms of maximum monthly temperature, they are similar, but when it comes to precipitation, Itatiba do Sul has values higher than 40 mm in each month (except for December) and maximum of over 140 mm in July and September. Erebango has several months with precipitation around 30 mm, and maximum of around 90 mm in May and July. This can be explained by the difference in altitude between these stations, since Itatiba do Sul station is located 350 m above the sea and Erebango station is 763 m above the sea.

Figure 2.9 shows extreme precipitation in 1985 in Itatiba do Sul, in the same month that there was higher maximum temperature if compared to 1983. In 1991, the same city had extreme low precipitations, especially during southern hemisphere's summer. This episode may be related to the increase of 1–2 °C in temperature during these months, in comparasion to previous years.

Erebango, as shown in Fig. 2.10 for 1991, when compared to the beginning of the study data, presented an increase in the maximum monthly temperature and precipitation higher than expected in January and lower in February and March, which are also characterized as extremes events because of the variation in relation to the average of the year.

In 2002, both stations showed low levels of maximum precipitation, coinciding with the increase in the maximum monthly temperature in relation to the early years of the study and in relation to its annual average. This situation is shown in Fig. 2.11. Qi et al. (2016) in their study of watershed systems, also observed there is a decline in precipitation in recent years in relation to the past ones, along with continuous increases in temperatures, from 1980 to 2005.

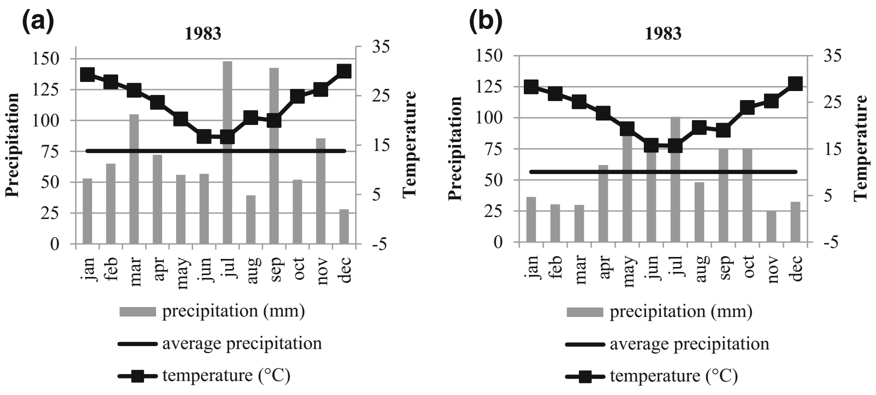


Fig. 2.8 Termopluviometric diagram of Itatiba do Sul (**a**) and Erebango (**b**) (1983)

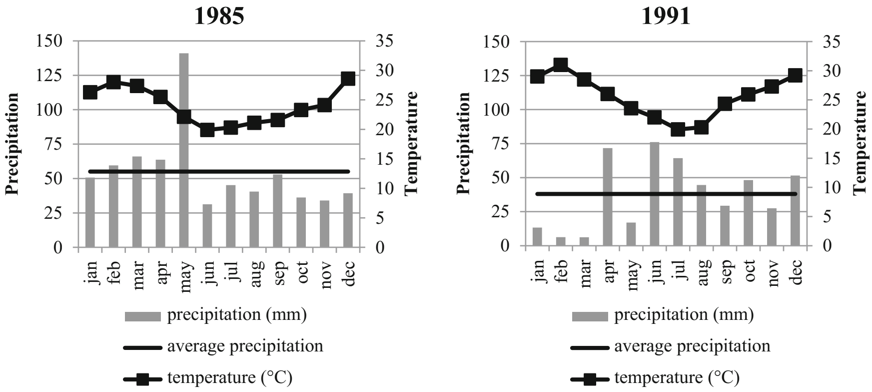


Fig. 2.9 Termopluviometric diagram of Itatiba do Sul (1985–1991)

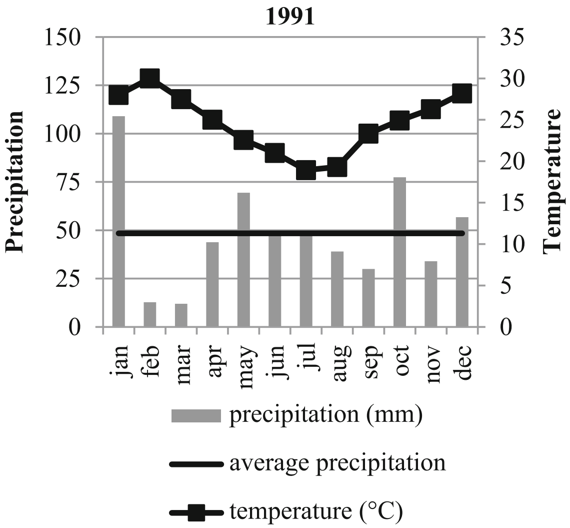


Fig. 2.10 Termopluviometric diagram of Erebango (1991)

It is noticed that Itatiba do Sul station shows a more intense drought than Erebango's, with maximum monthly precipitation around 15 mm in the first three months of the year. According to the Civil Defense of Rio Grande do Sul, 413 cases of droughts were registered in this watershed in 2002, the third year most affected by this phenomenon, in a study of the years 1991–2012 (CEPED UFSC 2013).

In the years 2009 and 2012 both stations showed similar behavior, with a reduction of the maximum average precipitation in relation to initial years of study and precipitation below the average. Then, Erebango presents the most critical values, with maximum precipitation lower than 5 mm in April and May. Figures 2.12 and 2.13 show the behavior of the stations for these years.

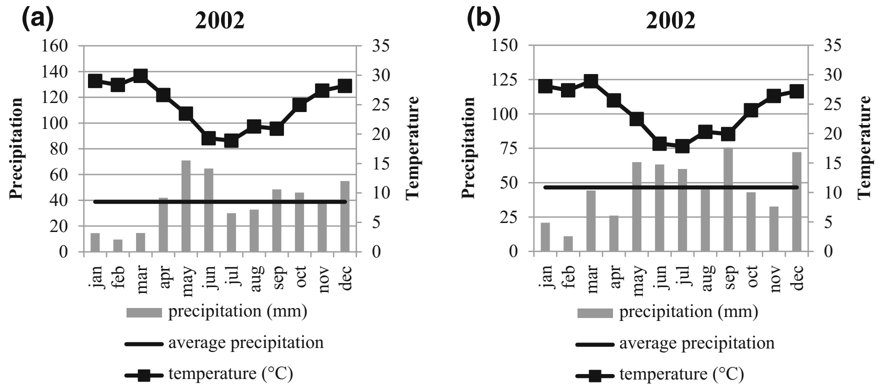


Fig. 2.11 Termopluviometric diagram of Itatiba do Sul (**a**) and Erebango (**b**) (2002)

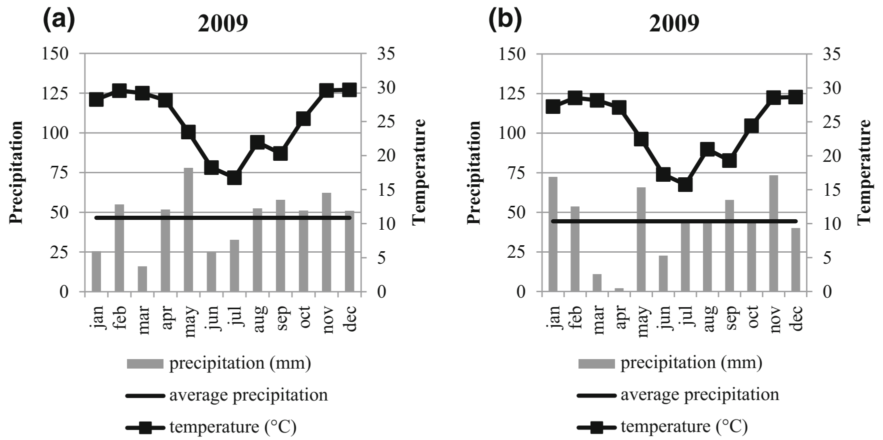


Fig. 2.12 Termopluviometric diagram of Itatiba do Sul (**a**) and Erebango (**b**) (2009)

In 2012, Erebango also presented an extreme event characterized by high precipitation in October, well above the annual average. Itatiba do Sul, on the other hand, draws more attention to the reduction of the maximum precipitation over the years under study and presents maximum precipitation below the annual average.

For this watershed, it can be seen that the results are similar to the previous one, just showing some extreme events in the previous years. This can be explained by the difference in altitude and also land use and occupation.

So, it is possible to highlight some extreme events in both watersheds, related to droughts or floods, as well as an increase in temperature, which may be related to climate changes. The results show the same as Alexander et al. (2006) and indicates the precipitation indices have tendencies toward different conditions but not all show statistically significant changes.

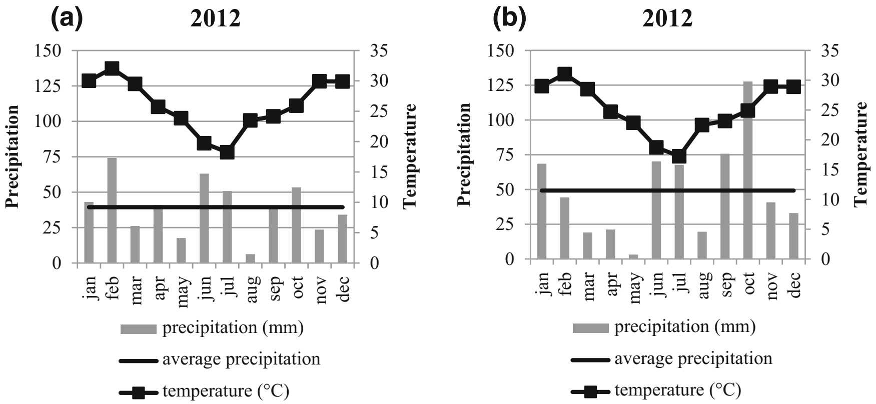


Fig. 2.13 Termopluviometric diagram of Itatiba do Sul (**a**) and Erebango (**b**) (2012)

Even though, studies regarding changing in patterns and potential impacts of climate change must be encouraged to verify the tendency through the years and to provide subsidies for implementation of control measures (see Solomon et al. 2007). Mainly because measuring the watershed impacts becomes more complex as its interventions consider how hydrogeological aspects affect livelihoods. In this context, integrated assessments of watersheds must have resilience as an important attribute, especially in the context of climate change impacts (Reddy and Syme 2014).

The Resource Innovation Group (2012) reinforce that changes in precipitation and the increase in frequency of extreme weather events are related to climate change, leading to negative consequences as drying of wetland areas, shifts in vegetation conditions, higher concentrations of pollutants. Considering that, studies on watershed's conditions and its effective planning to resilience can reduce long term costs, identify opportunities for immediate local benefits, increase in local economic and community security by reducing the risks of damage from major floods or droughts, and identification of new economic, social, and ecological opportunities that may arise with changing climate conditions.

Conclusions

In this study we sought to evaluate the consequences in precipitation series caused by the increase of temperature, which is one of the main impacts of climate change. The evaluations were made between the years 1983 and 2013, however presents some flaws due to lack of data, especially temperature, then an analysis of 25 years was made.

It is noticed that there was an increase in the frequency and intensity of extreme events such as droughts and floods, and that the maximum temperature has increased over the years, especially in the winter (June and July), showing the occurrence of milder winters than before.

Thus, it is observed that climate changes tend to be interfering in the hydrologic series of precipitation for the Passo Fundo River and Várzea River Watersheds, mainly in the form of increasingly frequent extreme events. Some stations have suffered more severe effects than others, but all are being affected. Therefore, the two watersheds have been presenting consequences probably due to the increase in the average temperature on Earth.

Climate change is placing cities at the risk of being increasingly hit by extreme weather phenomena and there is a need to review the current patterns of consumption of natural resources, in order to continue enjoying the benefits of community life and minimize the impact of urban agglomerations. The preparation for the occurrence of disasters is also essential, both for civil society and for the government, and resilience is essential for communities.

These results point to the need for greater planning regarding watersheds, incorporating resilience fundaments. According to The Resource Innovation Group (2012), some entities such as watershed councils and formal and informal governance agreements have vital importance to this subject.

Urban resilience also depends on the awareness of individuals about the possibilities of occurrence of environmental disasters, and coping ability when necessary, with adaptation measures; and, if possible, to minimize them by mitigation methods. The form of planning and management of cities, their infrastructure, services and institutions should be planned and managed in the best possible performance before, during and after the occurrence of extreme weather events.

References

Adam JC et al (2006) Correction of global precipitation products for orographic effects. J Clim 19 (1):15–38

Albuquerque TMA, Mendes CAB (2009) Avaliação do processo de gestão da seca: estudo de caso no Rio Grande do Sul. J Rega 6(1):17–29

Alexander LV et al (2006) Global observed changes in daily climate extremes of temperature and precipitation. J Geophys Res 111(5):23

AMCOW (2012) Water safety development and resilience to climate change: strategic framework, the African Union Commission

ANA (2014) Hidroweb: hydrological information. http://hidroweb.ana.gov.br. Accessed 10 March 2014

Birkmann J (2007) Risk and vulnerability indicators at diferente scales: applicability, usefulness and policy implications. Environ Hazards 7(1):20–31

CEPED UFSC (2013) Atlas Brasileiro de Desastres Naturais: 1991-2012, 2 edn. Centro Universitário de Estudos e Pesquisas sobre Desastres, Federal University of Santa Catarina, Florianópolis, 184 pp

Dury GH (1972) High temperature extremes in Austrália. Ann Assoc Am Geogr 62(3):388–400

Farwell J et al (2012) Making watersheds more resilient to climate change a response in the Grand River Watershed, Ontario, Canada. http://archive.riversymposium.com/index.php?element=FARWELL. Accessed 1 April 2016

Federal Office for Civil Protection (2013) The cycle of integrated risk management. http://www.planat.ch/en/specialists/risk-management/. Accessed 10 June 2016
FEPAM (2016a) Passo Fundo River Watershed. http://www.fepam.rs.gov.br/qualidade/bacia_uru_passofundo.asp. Accessed 28 March 2016
FEPAM (2016b) Várzea River Watershed. http://www.fepam.rs.gov.br/qualidade/bacia_uru_varzea.asp. Accessed 28 March 2016
Frank B, Sevegnani L (2009) Desastre de 2008 no Vale do Itajaí: Água, Gente e Política. http://srv2.lemig.umontreal.ca/donnees/Projet%20Bresil/dados/4%20blu/cap03-livroDesastre2008noVI_med.pdf. Accessed 5 April 2016
IPCC (2007a) Climate change 2007: impacts, adaptation and vulnerability. Cambridge University Press, Cambridge
IPCC (2007b) WGI AR4: climate change 2007: the physical science basis: summary for policymakers, Paris, France
Junior MAS et al (2012) Estiagem na região sul do Brasil: caracterização por meio de imagens EVI/MODIS. http://mtc-m16d.sid.inpe.br/col/sid.inpe.br/mtc-m19/2012.pdf. Accessed 29 March 2016
Kobiyama M et al (2006) Prevenção de Desatres Naturais: Conceitos Básicos, 1st edn. Organic Trading, Curitiba
Marengo JA (2006) Mudanças Climáticas Globais e seus Efeitos sobre a Biodiversidade: Caracterização do Clima Atual e Definição das Alterações Climáticas para o Território Brasileiro ao Longo do Século XXI. http://www.mma.gov.br/estruturas/imprensa/_arquivos/livro%20completo.pdf. Accessed 20 March 2016
Mateus R (2004) Novas Tecnologias Construtivas com vista à Sustentabilidade da Construção. http://repositorium.sdum.uminho.pt/handle/1822/817?mode=full. Accessed 10 June 2016
Qi M et al (2016) Resilience changes in watershed systems: a new perspective to quantify long-term hydrological shifts under perturbations. J Hydrol 539:281–289
Reddy VR, Syme GJ (2014) Integrated assessment of scale impacts of watershed intervention: assessing hydrogeological and bio-physical influences on livelihoods. Elsevier, New York, 454 pp
Reis JT et al (2012) valiação dos desastres naturais ocorridos no Rio Grande do Sul de 2007 a 2011. Brazilian Congress on Natural Disasters, São Paulo
Rhandir TO (2014) Resilience of Watershed systems to climate change. J Earth Sci Clim Change 5(6):34
Rossato MS (2011) Os climas do Rio Grande do Sul: Variabilidade, tendências e tipologia. http://www.lume.ufrgs.br/bitstream/handle/. Accessed 25 April 2016
SEMA (2010) Rio Grande do Sul Watersheds. http://www.sema.rs.gov.br/. Accessed 28 March 2016
Solomon SD et al (eds) (2007) Contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge. http://www.ipcc.ch/publications_and_data/ar4/wg1/en/contents.html. Accessed 29 June 2016
The Resource Innovation Group (2012) Toward a resilient Watershed. http://static1.1.sqspcdn.com/static/f/Watershed±Guidebook±final±LR.pdf. Accessed 15 April 2016
Trenberth KE (2011) Changes in precipitation with climate change. Climate Res 47:123–138
Tucci CEM (2002) Hidrologia: ciência e aplicação, 3rd edn. UFRGS/ABRH, Porto Alegre

Chapter 3
Modelling Potential Biophysical Impacts of Climate Change in the Atlantic Forest: Closing the Gap to Identify Vulnerabilities in Brazil

Marco Follador, Jennifer Viezzer, Mariana Egler, Martin Becher, Lukas Hach, Virgílio Pereira, Andre Rocha, Ciro Vaz, Thiago Vieira, Melina Amoni and Samantha Hartzell

Introduction

Climate change adaptation is becoming a pressing issue in Brazil. The National Adaptation Plan (NAP) was launched through a Ministerial Order (Portaria MMA no. 150/16) on May 2016, encompassing 11 sectors: agriculture, biodiversity and ecosystems, coastal zones, cities, disaster risk and management, freshwater resources, food security, health, infrastructure, industry and mining, and vulnerable

M. Follador (✉)
ALSO, Rua Mondovi 879, Belo Horizonte, MG CEP 31340-590, Brazil
e-mail: follador@alsocabra.com

J. Viezzer
Brazilian Ministry of Environment (MMA)/Secretariat of Biodiversity and Forests, SEPN 505 Norte, Bloco “B”, Edifício Marie Prendi Cruz, Sala 402, Brasília, DF CEP 70730-542, Brazil

M. Egler
Brazilian Ministry of Environment (MMA)/Secretariat of Climate Change and Air Quality, SEPN 505 Norte, Bloco “B”, Edifício Marie Prendi Cruz, Sala 301, Brasília, DF CEP 70730-542, Brazil

M. Becher · L. Hach
Gesellschaft für Internationale Zusammenarbeit GmbH, c/o Brazilian Ministry of Environment (MMA), SEPN 505 Norte, Bloco “B”, Edifício Marie Prendi Cruz, Sala 402, Brasília, DF CEP 70730-542, Brazil

M. Follador · V. Pereira · A. Rocha · C. Vaz · T. Vieira · M. Amoni
Waycarbon, BH-TEC Parque Tecnologico, R. Prof. José Vieira de Mendoça, Belo Horizonte, MG 31310-260, Brazil

S. Hartzell
Department of Civil and Environmental Engineering, Duke University, Box 90287, 121 Hudson Hall, Durham, NC 27708-0287, USA

W. Leal Filho and L. Esteves de Freitas (eds.), *Climate Change Adaptation in Latin America*, Climate Change Management,
https://doi.org/10.1007/978-3-319-56946-8_3

populations. PNA represents a federal and sectorial approach intended to guide long-term investments in climate change risk reduction. Moreover, it constituted a political framework that has raised adaptation to a prominent position in the political agenda on the country. NAP is the backbone for implementing the Nationally Determined Contributions (NDC) adaptation component that focuses on disaster risk reduction in urban contexts, pro-poor growth, water security and biodiversity preservation.

PNA defines adaptation needs for country's key-sectors, introducing a mismatch between the federal approach and the demand of local decision makers for a vulnerability assessment based on regional peculiarities. The main outcomes of the study will help improving the regional adaptation frameworks by providing new datasets and evidences for climate change impacts in the Atlantic Forest region through a spatially explicit modeling. Most of the projected impacts will directly affect several key-sectors of NAP and NDC, including agriculture, biodiversity, health and disaster risk management, and this calls for proactive measures aimed at reducing future risks of losses and damages in site-specific contexts.

The study has been developed in the context of the "Biodiversity and Climate Change in the Atlantic Forest" project (here referred to as Mata Atlântica Project, MAP), which takes place in the context of the International Climate Initiative (ICI) of the German Federal Ministry of Environment, Nature Protection, Construction and Nuclear Safety (BMUB), implemented by the Brazilian Ministry of Environment (MMA). With technical assistance by the German technical cooperation agency Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, the project aims to help local decision makers define effective climate change adaptation strategies through ecosystem-based adaptation (EbA) measures. The next steps of the MAP will include mainstreaming impacts and vulnerability assessments into land-use planning tools, such as river basin management and urban territorial planning, thus overcoming the limits

Case Study Region

Brief Overview of Brazilian Atlantic Forest

The Atlantic Forest, one of the world's five hotspot areas, is home to more than 120 million Brazilians and the heart of the Brazilian economy—more than 70% of the national GDP is generated here. While only 22% of the originally 1.3 million km^2 still are preserved, the remaining forest fragments play a major role as a carbon sink and deliver key ecosystem services for Brazilian society. Unfortunately, the progressive destruction and fragmentation of this environment poses a threat to the preservation of biodiversity, social systems and local economies. Climate change represents an additional challenge for the region. Extreme weather events have caused tangible socioeconomic losses in past years. Even so, neither climate change

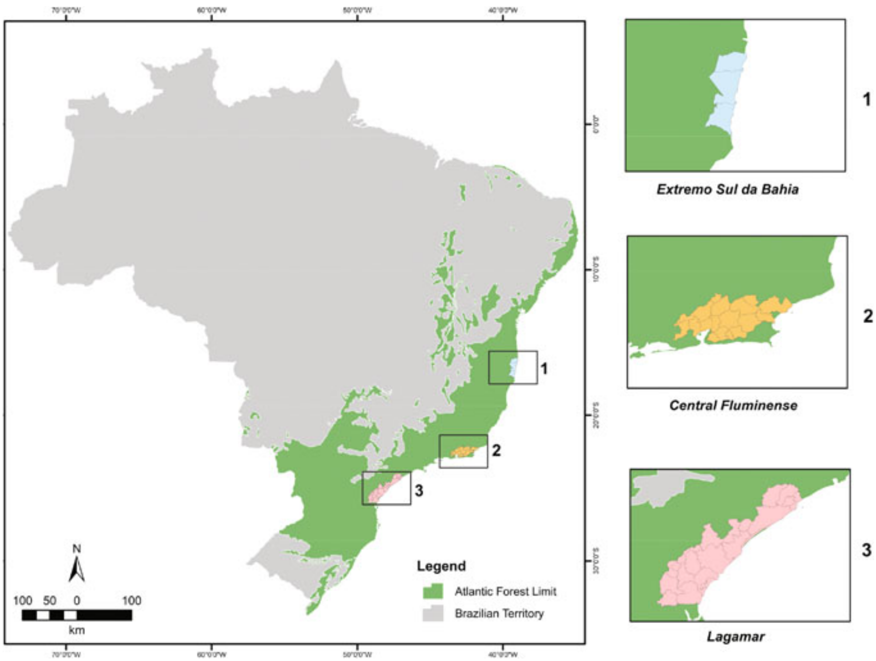


Fig. 3.1 Brazil, Atlantic forest domain and municipality of the mosaics areas (Mosaico de Áreas Protegidas do Extremo Sul da Bahia (MAPES), do Mosaico Mata Atlântica Central Fluminense (MCF) e do Mosaico Litoral Sul do Estado de São Paulo e Litoral do Estado do Paraná (Lagamar))

nor the value of biodiversity in reducing vulnerability have been seriously taken into account for regional and local land use and political planning.

The MAP embraces the whole Atlantic Forest biome. It focuses its activities on three protected regions, specifically the Mosaic of the Extreme South of Bahia (*Mosaico de Áreas Protegidas do Extremo Sul da Bahia*—MAPES), the Mosaic of Central Fluminense (*Mosaico Central Fluminense*—MCF) in Rio de Janeiro, and the Mosaic of Lagamar, in southern São Paulo and coastal Paraná States (Fig. 3.1).

Biophysical Data

Thanks to federal investments in remote sensing, the volume of data on biophysical and environmental attributes has notably increased during the last several years, yet Brazil is still faced with insufficient and unreliable local observation networks, and a very limited capacity for sharing existing datasets (Follador 2015). Rural and forested areas are glaring examples which show the lack of high quality data in the country, and they contain large regions characterized only by coarse, and often outdated, macro-information. Even though the Atlantic Forest region hosts the largest share of the country's population and economic activities, detailed information about its territory cannot be relied upon, as there is a heterogeneous distribution of datasets within its borders. A very few limited studies have been developed in site specific contexts by local universities, NGOs and private sector initiatives, but they cover only a modest portion of the Atlantic Forest and were not useful for modeling impacts on the scale of interest.

That said, a number of judgments and approximations were necessary to translate the conceptual modeling framework into a pragmatic selection of sound explicative factors with an adequate resolution to assess climate change impacts. The final list of input variables was dictated by a trade-off between (i) the relevance to phenomena at stake; (ii) the ability to capture important regional aspects; (iii) the spatial and temporal coverage of available datasets; and (iv) data accessibility and quality. Proxy indicators were used to model impacts when desired data were unavailable (OECD and JRC 2008); proxies introduced an additional uncertainty to the analysis but represented a valid tool to overcome the chronic lack of reliable or accessible information.

Climate Data

Climate projections used in this study were derived from the regionalization of two global climate models, HadGEM2-ES and MIROC5, by the Weather Forecasting and Climate Studies Center of the National Institute for Space Research (CPTEC/INPE). The models' outputs cover the entirety of Brazil with a resolution of 20×20 km^2, while a finer resolution of 5×5 km^2 is available only for the Southeastern region (Chou et al. 2014). The huge raw datasets were processed to obtain basic statistics for the periods 1961–2005, 2011–2040, 2041–2070 and 2071–2099, aggregated by trimesters DJF (December, January and February), MAM (March, April and May), JJA (June, July and August) and SON (September, October and November). Two Representative Concentration Pathway scenarios (Moss et al. 2008), RCP 4.5 (optimistic) and RCP 8.5 (pessimistic), were considered for climate forecasting until 2100. Climate extremes are calculated on an annual basis.

The climate parameters used to feed the models are: precipitation (mm)—average and absolute values; temperature (°C)—average, maximum and minimum values; relative humidity (%)—average and absolute values; consecutive dry days (CDD), the largest number of consecutive days where precipitation is less than 1 mm/day; number of heavy precipitation days (R10mm), the annual count of days when precipitation ≥ 10 mm; warm night frequency (TN90p), the percentage of days when minimum temperature >90th percentile; and warm spell duration index (WSDI), the annual count of days in intervals where at least 6 consecutive days had a maximum temperature >90th percentile.

Relative variations of future temperature and precipitation versus historical baseline are displayed in Fig. 3.2 (RCP 4.5) and Fig. 3.3 (RCP 8.5).

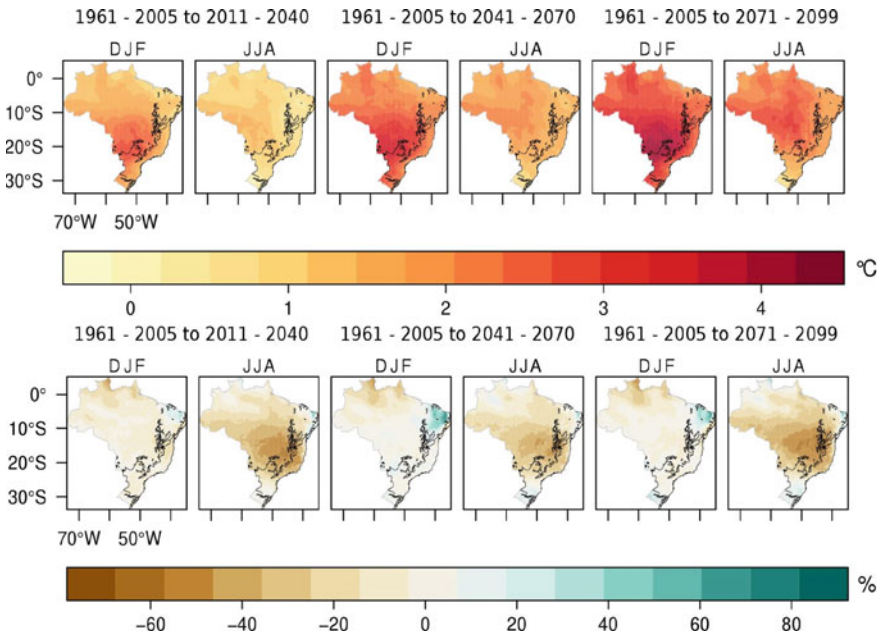


Fig. 3.2 Relative variation of the temperature (°C) and precipitation *RCP 4.5* (*optimistic scenario*)

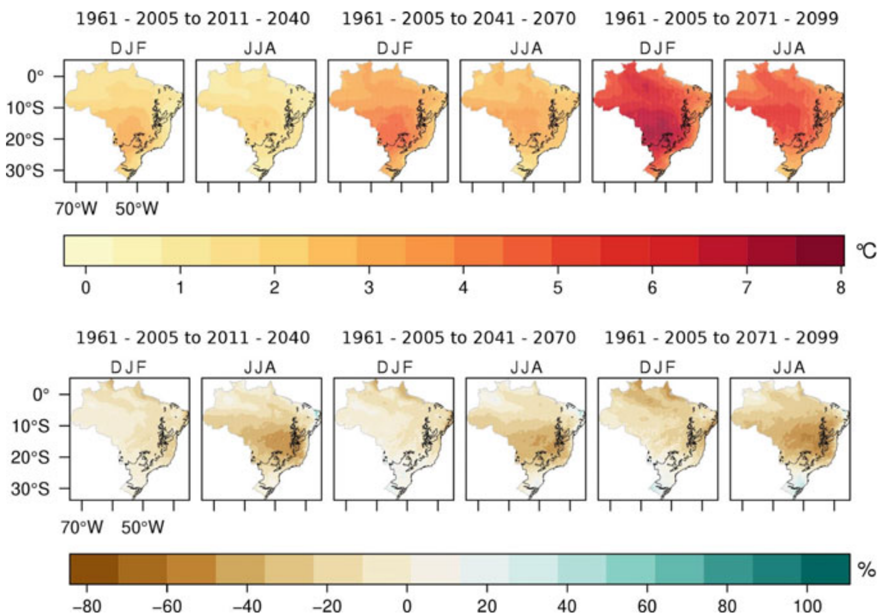


Fig. 3.3 Relative variation of the temperature (°C) and precipitation (%) RCP 8.5 (pessimistic scenario)

Methodology

Theoretical Framework of Impact Assessment

In the literature, there are very different ways to assess impacts and vulnerability to climate change. Scholars from different disciplines apply various approaches, often generating misunderstanding in interdisciplinary research on climate change (Füssel 2007).

According to IPCC (2007, 2014) the potential impacts of climate change are defined by combining a system's biophysical, socioeconomic and environmental characteristics with its exposure to climate variability and extremes (Fig. 3.4). The process of identifying climate-related impacts and their cause-effect relationships with existing system weaknesses starts with a deep literature review and brainstorming processes with experts in order to arrive at sound indicators and robust modeling approaches.

This study assessed the effects of climate change on: (i) floods; (ii) rainfall erosivity; (iii) landslides; (iv) dengue vector distribution; (v) soil moisture; (vi) agro-climatic zoning; and (vii) fitophisionomy. Only potential direct impacts have been considered. Nevertheless, they offer an approximate picture of possible

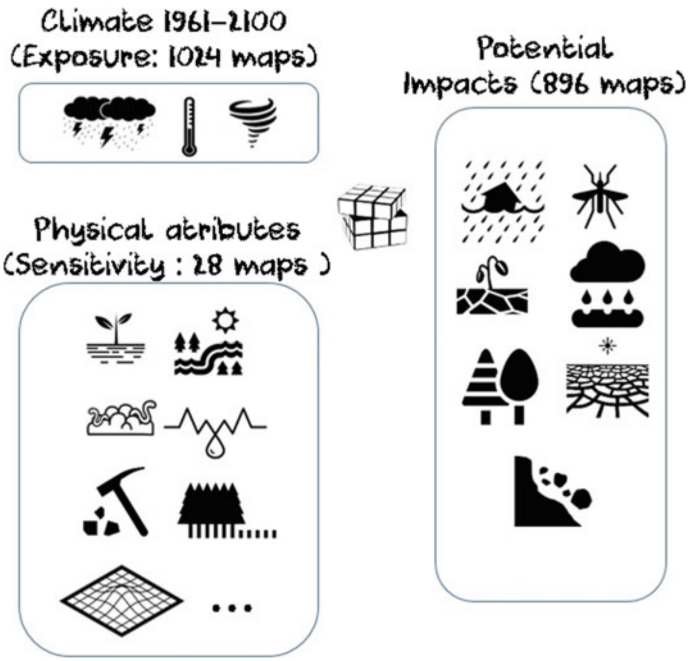


Fig. 3.4 The potential impacts of climate change are defined by combining the biophysical attributes of the system and its exposure to climate extremes and variability (IPCC 2007)

losses and damages, along with their repercussions for regional economic growth and societal well-being (indirect impacts).

Modelling Framework

The modeling framework was shaped considering the following characteristics:

- Time extent: 2100;
- Time windows: 1961–2005 (historical); 2011–2040; 2041–2070; 2071–2100;
- Time frame: Quarterly (DJF; MAM; JJA; SON);
- Emission scenarios: RCP 4.5 (optimistic) and RCP 8.5 (pessimistic);
- Climate forecasting: average values from HadGEM2-ES and MIROC5 models;
- Spatial extent: Atlantic Forest, with a zoom on the 3 Mosaic areas;
- Spatial resolution: defined by available data resolution and relevance to phenomena;
- 7 impact-models; stand-alone approach;
- Target audience: policy makers.

1024 climate change maps (exposure) and 28 biophysical parameters (sensitivity) have been used to feed the impact-models, resulting in 826 impact maps (Fig. 3.4).

The impact maps have been generated through the Model for Vulnerability Evaluation (MOVE[1]) platform. MOVE is an integrative assessment tool that enables users to run climate-impact models and manage indicators to assess the vulnerability of a system or sector in specific climate scenarios. A spatially explicit approach is used to capture context-contingent processes varying across different scales, pointing out areas where climate change impacts and regional characteristics are compounded resulting in hotspots of vulnerability (Oppenheimer et al. 2014). The modeling frameworks and their input/output links are displayed in Fig. 3.5.

Seven impact-models have been run in order to estimate the potential impacts of climate change on (i) floods; (ii) rainfall erosivity; (iii) landslides; (iv) dengue vector distribution; (v) soil moisture; (vi) agro-climatic zoning; and (vii) fitophisionomy.

The modeling approach did not rely on detailed impact-models as such models need large, high quality input databases, not available for this case study. This proxy modeling—whose development was based on robust literature review and expert opinions—represented a pragmatic solution to overcome data constraints and produce useful results to inform adaptation policies in the Atlantic Forest region.

Technical details and references about models development are summarize in Annex 1.

[1]For further information please refer to: www.moveonadaptation.com.

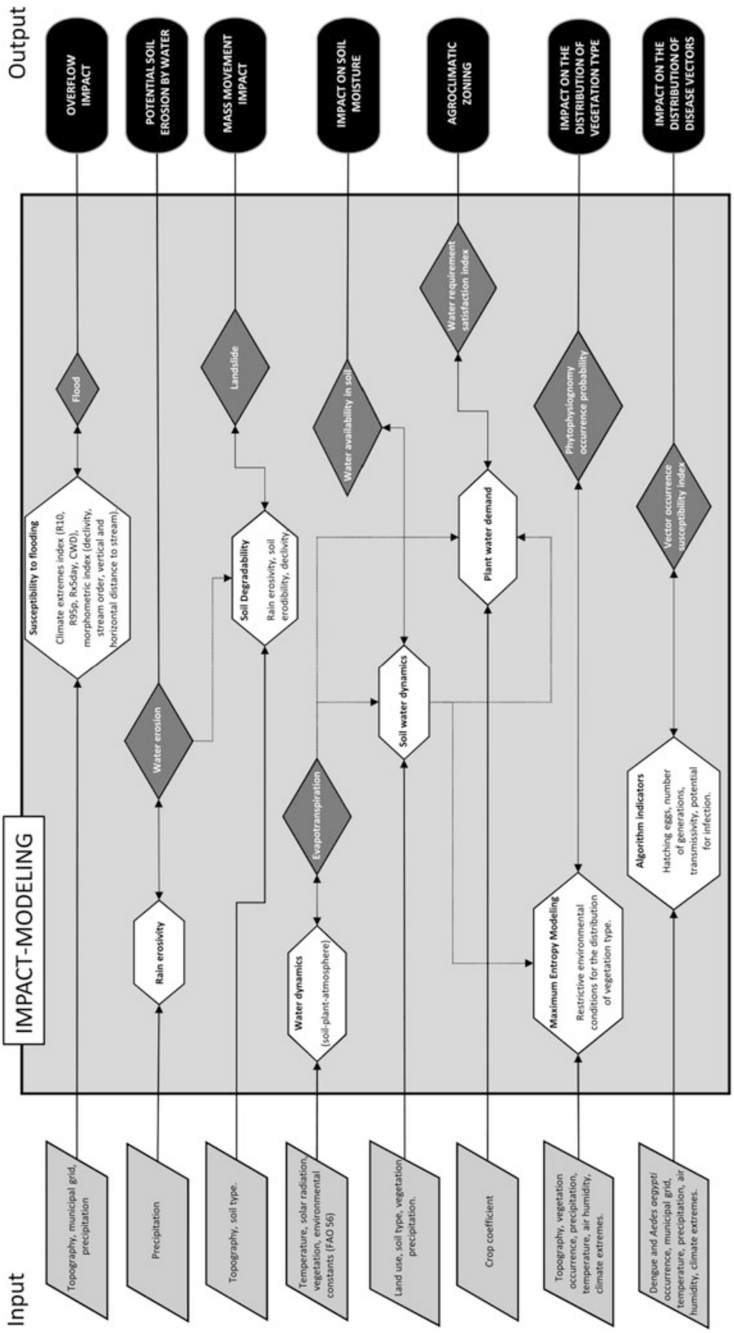


Fig. 3.5 The modeling framework of MOVE for the analysis of potential biophysical impacts of climate change in the Atlantic Forest

Results and Discussion

For the sake of simplicity, we presented only the results for the dry (JJA) and rainy (DJF) seasons, considered as extreme situations of the possible range of the model outputs, and for the whole Atlantic Forest biome.

Floods

The results indicate that most areas along the Brazilian coast are susceptible to flooding. These environments are physically sensitive, consisting of well-developed river floodplains and high flow.

The highest values of the flood indicator in the Southern region is associated with predictions of increased extreme precipitation events in that area that cause tangible changes in hydrological cycle (Trenberth 1999; Roy and Balling Jr. 2004; Shaw et al. 2011). Indeed, among the regions of Brazil, the South has the greatest values of extreme precipitation indicators, as measured by R95p. The results corroborated with preliminary studies made by CEPED (2012), in the Atlas Brasileiro de Desastres Naturais, that showing that the South is one of those regions that have more areas with flooding risk.

The analysis of the relative change (%) of the potential impact indicator to flooding shows that for both scenarios, all regions of Brazil are expected to have a decreased occurrence of flooding, except the South and Southeast, and, to a lesser extent, a few coastal zones in the Northeast (Fig. 3.6). The South shows an increase under both scenarios, reaching values of 19.72% for the period between 2071 and 2099. By using the climate data with the highest resolution ($5 \times 5\ \text{km}^2$), available only for this region and RCP 8.5, these numbers rose to 28%, with an average value of 12.77% in the Mosaic Lagamar region (Fig. 3.7). These results are explained by an increase in the values of extreme precipitation indices produced for different time windows, which showed a concentrated upward trend in this portion of the Brazilian territory, while in the other regions the trend is decreasing.

Rainfall Erosivity

Rainfall erosivity is the potential of rainfall to cause soil loss (Wischmeier and Smith 1978). The highest variations in rainfall erosivity (%) are expected in the Southern regions—specifically in the south coast of São Paulo and North of Santa Catarina—due to an increase in the values of average (PBMC 2014) and extreme precipitation indices in this part of Brazil (Fig. 3.8).

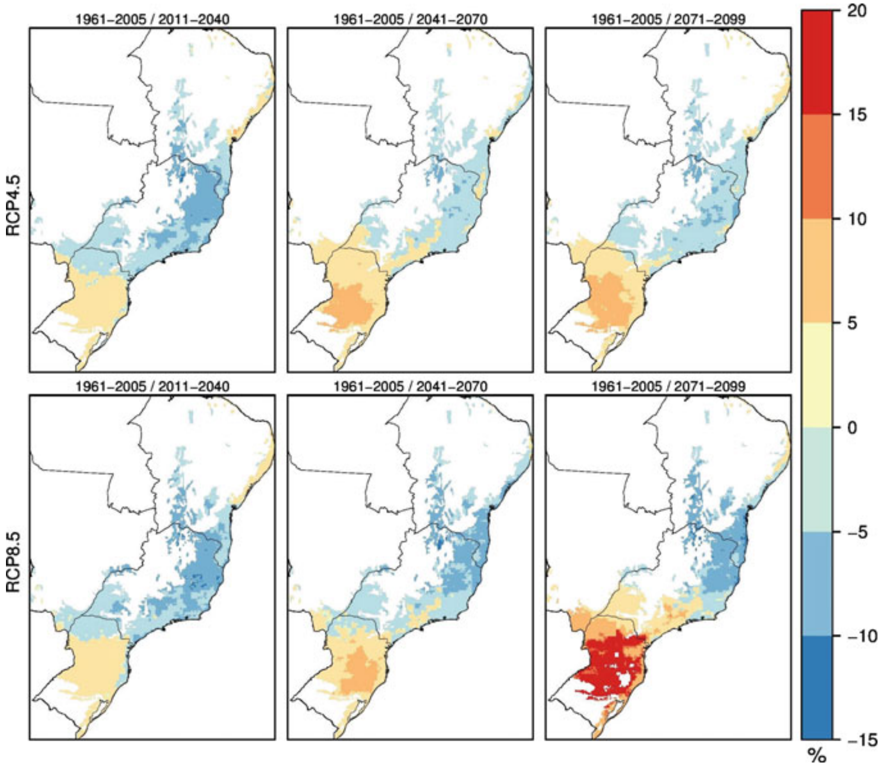


Fig. 3.6 Variation (%) of potential floods (annual average) versus historical baseline. Floods are expected to increase in the southern areas of Atlantic Forest regions following the soaring trend of heavy rainfall events

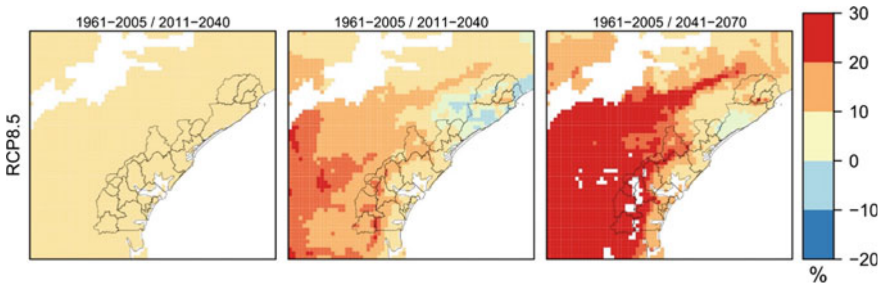


Fig. 3.7 Variation (%) of potential floods (annual average) versus historical baseline in the Mosaic Lagamar. The 5 × 5 km^2 resolution of climate projections (RCP 8.5) allows a more accurate assessment

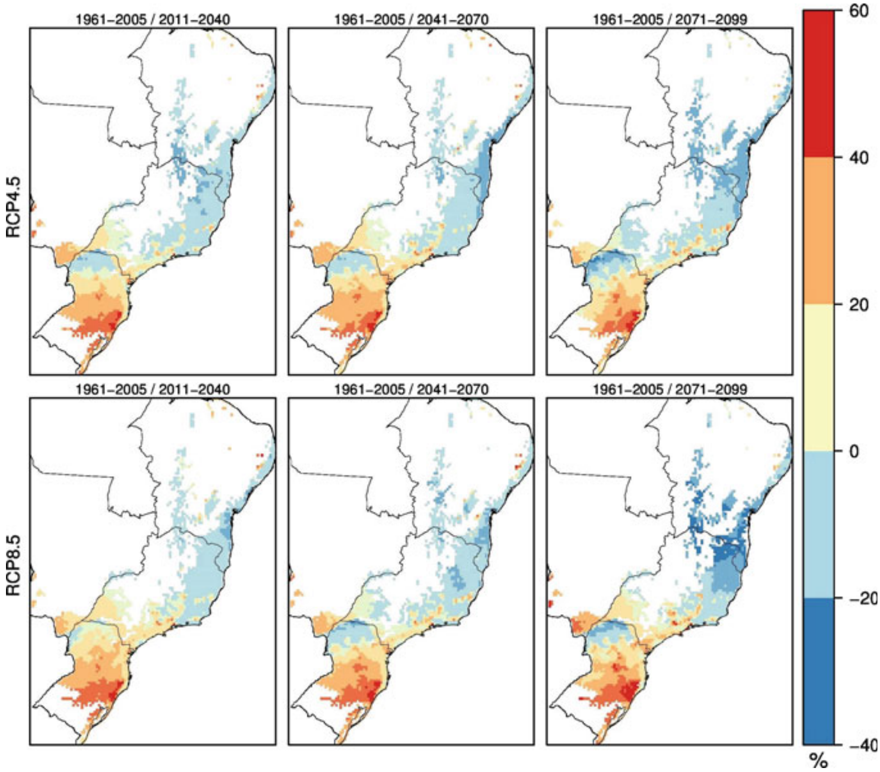


Fig. 3.8 Variation (%) of potential rainfall erosivity (annual average) versus historical baseline

Landslides

Even though the expected variation in the landslide risk in the Central-West region showed the greatest averages in the rainy season, these do not necessarily have the greatest potential to cause damages, since these variations occurred in low risk areas for both historical and projected scenarios (absolute value of potential impacts). To avoid this confusion we removed from this assessment all the flatlands at low risk and we focused on the expected variations in mid-to-high risk areas (Figs. 3.9 and 3.10).

In the JJA quarter, the largest variation in landslide risk is expected in the Southern region. The expected increase in landslides in this region is linked to a projected upward trend in average and extreme precipitation events. This region has historically had well-distributed rainfall throughout the year (Oliveira 1986), which keeps the soil saturated, increasing susceptibility to erosivity and mass movements. The biophysical characteristics of the region also contribute to this result. The friable cambisol soil, highly eroded (Crepani et al. 2001) and the vegetation cover, less dense with shallow roots, favor landsliding when subjected to heavy

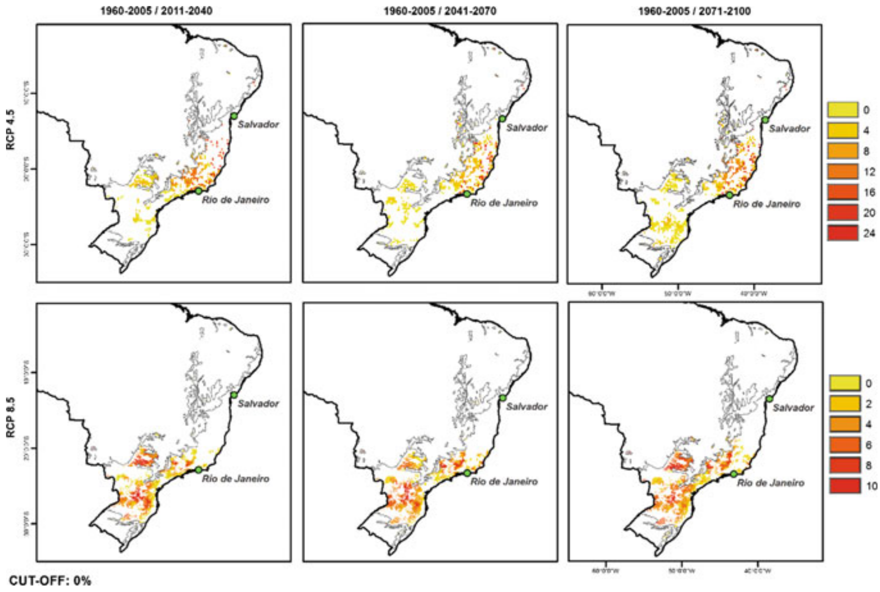


Fig. 3.9 Variation (%) of potential landslide occurrences versus historical baseline. Quarter (DJF). Only positive variations have been displayed

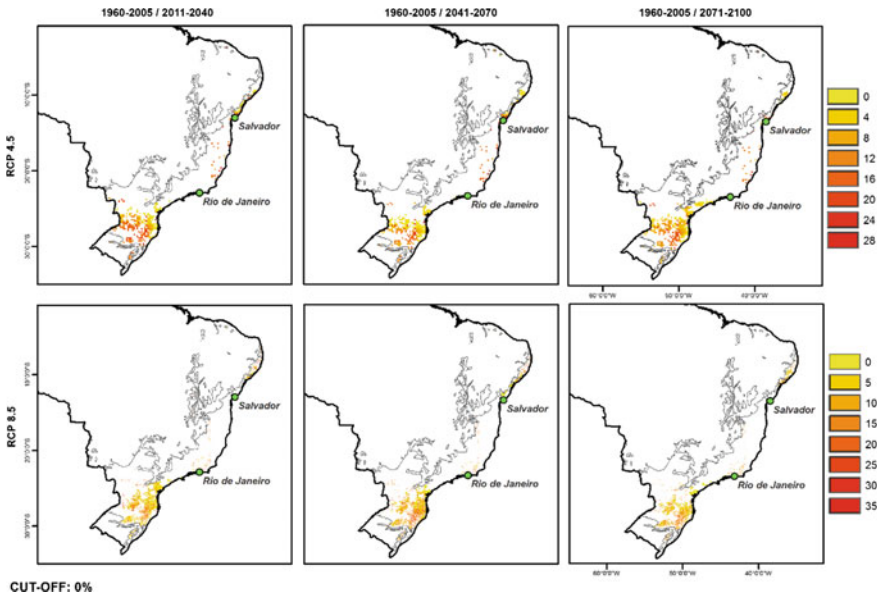


Fig. 3.10 Variation (%) of potential landslide occurrences versus historical baseline. Quarter (JJA). Only positive variations have been displayed

precipitation (Moro et al. 2011). In DJF a relevant increase in landslides risk is expected in the mountain regions between Rio de Janeiro, Minas Gerais, Sao Paolo and Espirito Santo, hotspots characterized by friable cambisol soil and steep slopes. The Northeast presented a few areas with increasing landslide occurrences during its rainy season (JJA).

Dengue Vector Distribution

The expected changes in the distribution of disease vectors are mixed. In general, the dengue fever vector *Aedes aegypti* is expected to affect the South and Southeast regions most over time (Lowe et al. 2013). On the other hand, the potential for disease vectors in the Northeast and Midwest regions is predicted to decrease by an average of 5% due to the decrease in rainfall.

One of the main determining factors of *Aedes aegypti* survival is temperature, which has been associated with seasonal changes in mosquito populations and limits their geographical distribution. The amount and frequency of rainfall is also correlated with the distribution of the mosquito vector, but less strongly. Excessive rains wash mosquitoes breeding spots, thus reducing the probability of mosquito's reproduction (Beebe et al. 2009). For example, light rain can increase the air humidity, an important factor that enhances the hatching of eggs (Fullerton et al. 2014; Naish et al. 2014; Russel et al. 2009).

In the Southeast, the potential impact may increase 9% on average in the DJF quarter, a considerable value, since this region is already greatly affected by mosquito transmitted viruses (Fig. 3.11). The South, currently little affected, is expected to be notably impacted, with a potential increase of 20% on average, and outliers of 200% in a few areas (Campbell et al. 2002; Colón-González et al. 2013). Since this study did not consider how other factors which determine disease transmission will relate to population increase in the mosquito, caution must be emphasized. In regions where weather becomes milder, people may become more exposed to the environment, and contact between vector and host may be favored (Goto et al. 2013).

The decrease in rainfall rates may reduce this impact in the Midwest and Northeast. At the same time, the lack of rain implies a lack of water supply. This encourages the often inappropriate development of water reserves, favoring the emergence of breeding spots (Campbell et al. 2015).

Dengue impacts in the Northeast are expected to increase by 20% in the JJA quarter (Fig. 3.12). Higher temperatures coincident with the rainy period in this region will yield an environment that enables vector population growth. All other regions have a small positive potential impact (0–5%) compared to the Northeast. The increase in average and minimum temperatures favors mosquito establishment even in the winter in the Southeast, Midwest and Southern regions. Therefore, investment in controlling breeding locations and mosquito development will need to take place throughout the year, and not only during rainy seasons (WHO 2015).

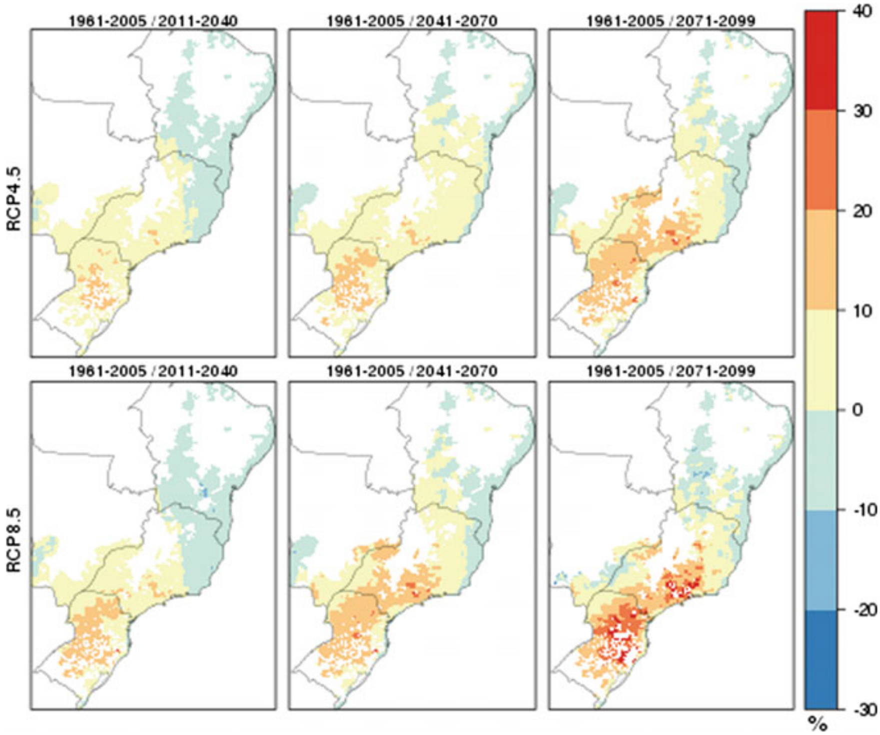


Fig. 3.11 Variation (%) of potential dengue distribution versus historical baseline. Quarter (DJF)

Soil Moisture

The results show a significant loss of soil moisture in the Brazilian Atlantic forest in all scenarios and time windows. This loss reflects water scarcity, poorly distributed rainfall, and a temperature increase which promotes high rates of evapotranspiration (Senevirante et al. 2010; Melillo et al. 1993).

The areas with the largest expected decrease in soil moisture are the Central-West and Southeast regions (Figs. 3.13 and 3.14). Generally, the most extreme predictions regard the Central-West in the DJF quarter and the Southeast in the JJA quarter. The DJF quarter shows a variation, between 4 and 7% in RCP 4.5, and between 9 and 15% in RCP 8.5. The JJA quarter shows a decrease of the soil moisture three times greater than in the DJF quarter, with the worst variation ranging between 12 and 17% in RCP 4.5, and between 14 and 16% RCP 8.5.

Even though the Northeast shows milder decreases, it must be considered a priority hotspot, as it is the region most affected by water scarcity and high levels of drought (Gevaerd and Freitas 2006). In semi-arid areas, shallow soils are predominant, and these tend to saturate quickly with rainfall and dry out easily during the dry season. Furthermore, the combination of water scarcity, high temperature,

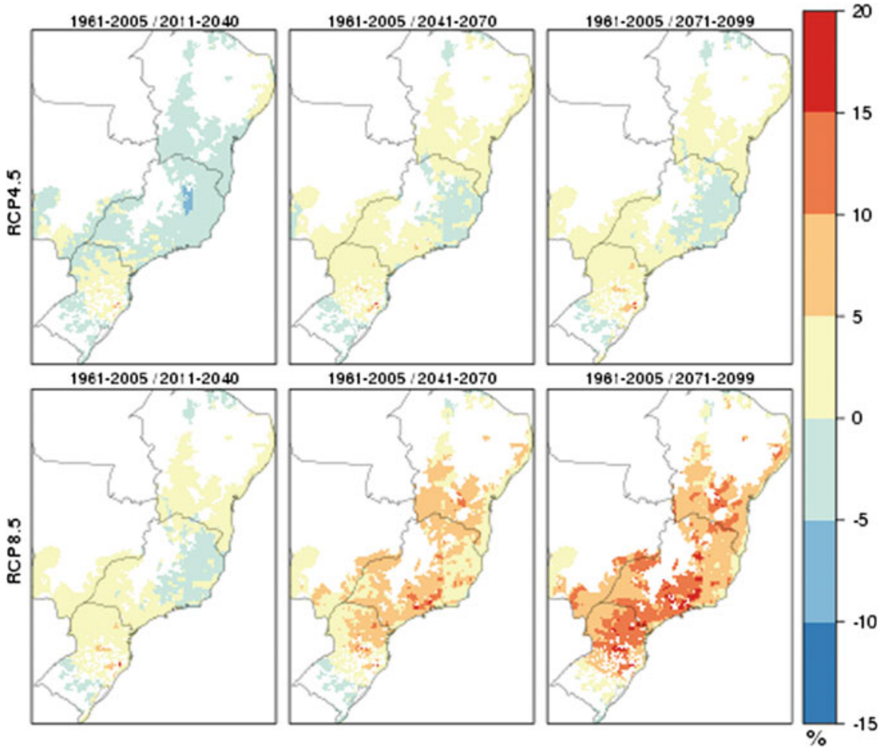


Fig. 3.12 Variation (%) of potential dengue distribution versus historical baseline. Quarter (JJA)

and high evapotranspiration rates can lead to a severe crisis, affecting subsistence crops in these areas. In the JJA quarter, a soil moisture increase of 10% is predicted in some locations in the Northeast (Douville et al. 2016). These percentage gains are not significant, however: since the region already had very low soil moisture, the modest increase shows little relevance to real environmental benefits (Roux et al. 2013).

In general, the Southern region presents the largest decrease. However, an excess of rain leading to waterlogged soils is a problem given the local soil type, and this area currently suffers from crop losses due to excessive rains and atypical flood events.

In the Southeast, Central-West and Northeastern regions, which show low water availability in soils, suggested water saving and conservation techniques include the redesign of agroecosystems with crop rotation, planting direct over straw, increasing soil organic matter by green manuring, and implementing recovery areas related to evolution and root synchronization (Ruml et al. 2012). For the Southern region, which has waterlogged soils, interventions should be directed to improve drainage of soils as green technical recovery of natural ecosystems, and implement recovery areas of water recharge by planting species that benefit the biology and

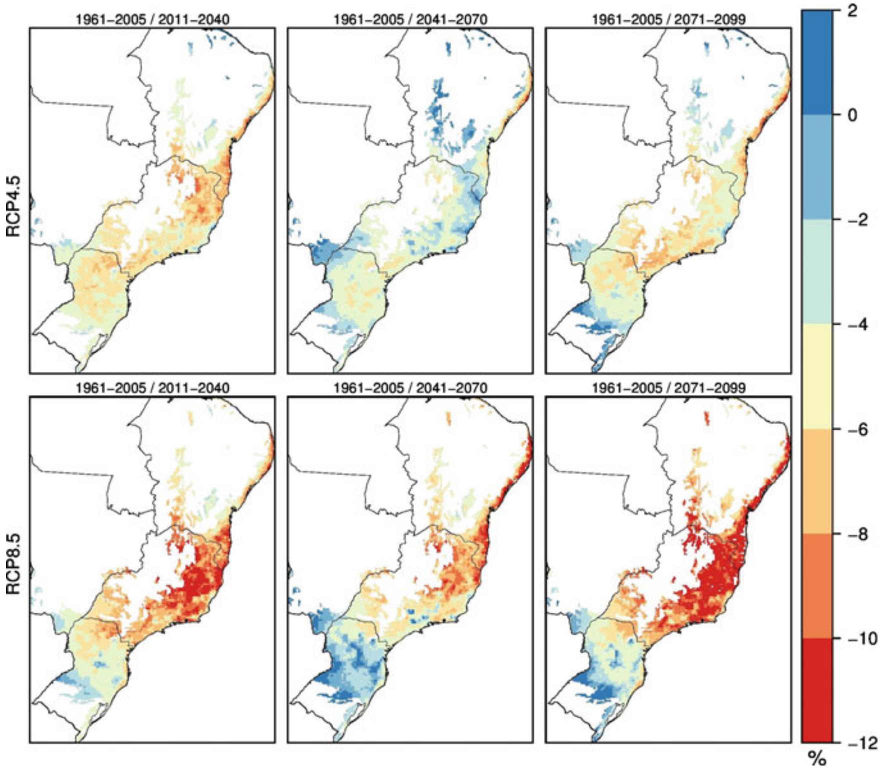


Fig. 3.13 Variation (%) of potential soil humidity versus historical baseline. Quarter (DJF)

soil aeration. Moreover, physical interventions for drainage and erosion containment, and terracing by alleys of trees, may improve outcomes (Destouni and Verrot 2014).

Agro-climatic Zoning

The results represent the values of the Water Requirement Satisfaction Index (WRSI). Climate change impacts on agricultural susceptibility tend to follow the trends in the distribution of water availability in the soil. Therefore, a general loss of areas suitable for agriculture is expected due to increased evapotranspiration rates (Assad et al. 2013).

The Midwest is the area expected to be least affected in the DJF quarter, with a negative impact of approximately 10%, which is considerable given the current extent of agricultural activities in the area. The South, despite predicted soil moisture increases, is expected to lose 13% of farmland on average, mainly due to

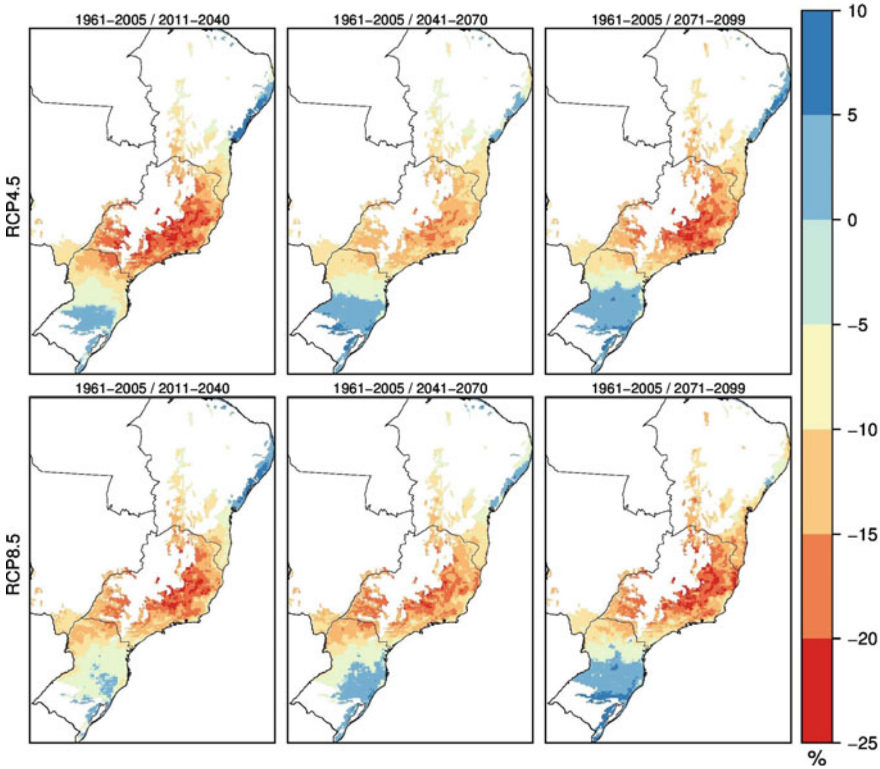


Fig. 3.14 Variation (%) of potential soil humidity versus historical baseline. Quarter (JJA)

excessive rainfall, which negatively affects crops. In RCP 8.5 the Southeast is expected to have more significant impacts, with extreme losses of 60% of agricultural potential in few locations. The Northeast shows average gains up to about 5% in RCP 4.5 (2011–2041) but considerable losses (approximately by 10%) in RCP 8.5 in the last time period studied (2071–2099) (Muller et al. 2011; Connor et al. 2012).

The impacts follow a similar trend in the JJA quarter. The Southeast and Midwest are in a historically dry region this time of year, and feature less pronounced relative changes. Knowing that this stressful situation will be exacerbated, however, this change is of great importance, especially for winter cropping and perennial crops (Piao et al. 2010). During this quarter the Southeast region remains the most affected. Slight farmland gains, not exceeding 3% on average, are expected in the South and Northeast.

In the Atlantic Forest, a negative impact is expected on rice, beans and maize crops. Rice has high climate sensitivity in the Southeast and Northeast. Although these states may cease to produce rice, the impact on total production would not be

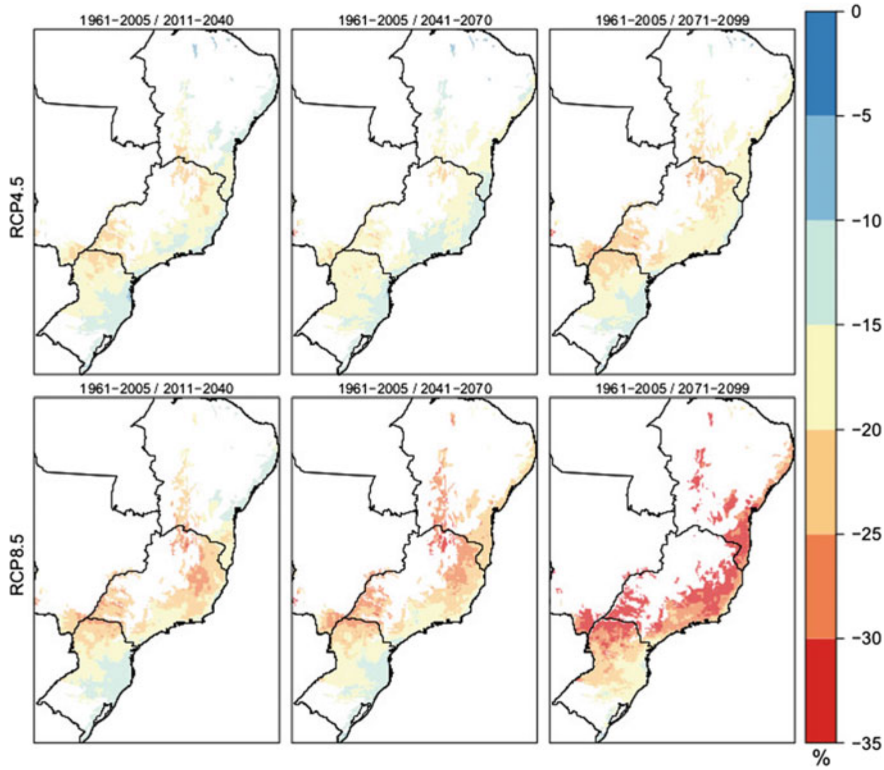


Fig. 3.15 Variation (%) of potential agro-zoning versus historical baseline. Quarter (DJF)

significant, since, in 2014, they accounted for just over 1.3% of the total produced in Brazil (Assad et al. 2013; Calzadilla et al. 2013).

Beans and maize, very important products for food security in Brazil, are expected to be impacted strongly. Among the largest producers of maize, Mato Grosso do Sul and Rio Grande do Sul will be the most affected (Streck 2006). The largest area of change in land viable for maize production is expected to occur in the Northeast. Even though the region accounts for less than 10% of national yield, production of maize in this region occurs mainly in smallholdings, and as such, a decrease in production here may potentially affect the food security of vulnerable social groups (Follador et al. 2015; Burney et al. 2014; Anwar et al. 2013). This region also shows negative climate effects on bean cultivation. Among the largest bean producers, Minas Gerais shows the most significant variations of suitable area for this crop. By the way of example, Figs. 3.15 and 3.16 were built by considering crops most sensitive to climate change, thus representing a conservative assessment of potential losses of agriculture lands.

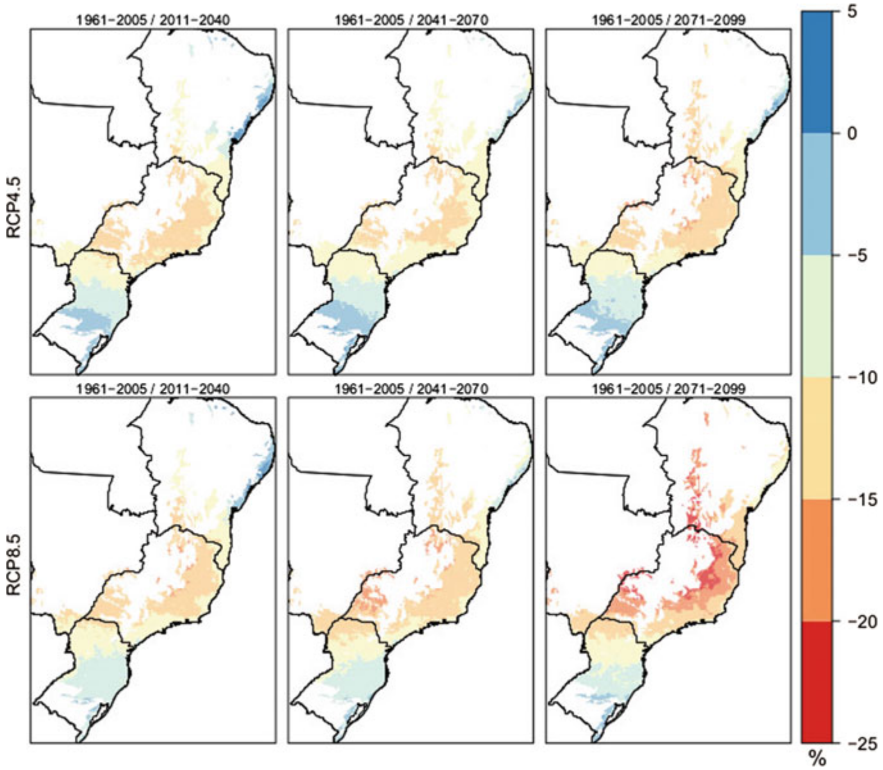


Fig. 3.16 Variation (%) of potential agro-zoning versus historical baseline. Quarter (JJA)

Vegetation Types

We evaluated the impacts of climate change on the seven main classes of vegetation type, namely Dense Ombrophilous Forest, Mixed Ombrophilous Forest, Open Ombrophilous Forest, Semi-deciduous Seasonal Forest, Deciduous Seasonal Forest, Pioneer Formations, and Ecotones.

The main outcomes expected for each vegetation type are presented in Table 3.1.

The results represent the probability of occurrence for each vegetation type studied in the Atlantic Forest area. The combination of increased temperature and changes in precipitation indicates less water availability. In simple terms, the increase in temperature induces a higher evaporation, reducing the amount of water in the soil, even if the rainfall does not decrease significantly. This factor alone can trigger changes in plant communities, with current communities being substituted by others more suited to climates with less water availability (Marengo 2007; Raghunathan et al. 2015).

Table 3.1 Relative variation (%) of the potential impact of vegetation type on the Brazilian Atlantic Forest

Vegetation types	Loss of the climatic aptitude (%)	Gains of the climatic aptitude (%)
Dense ombrophilous forest	47.00	32.00
Mixed ombrophilous forest	37.00	33.00
Open ombrophilous forest	45.00	*167.00*
Semideciduous seasonal forest	53.00	37.00
Deciduous seasonal forest	*60.00*	50.00
Pioneer formations	31.00	55.00
Ecotones	39.00	*364.00*[a]

[a]The ecotones zones corresponds to the frontiers of the other vegetation type, this gains of the climatic aptitude represents the gains of the transitions areas

The Seasonal Deciduous and Semi Deciduous Forests present the most critical scenario, with more than 50% of potential loss of suitable area. Since these two classes are spatially distributed across the whole biome, from north to south, they are exposed to different impacts throughout the entire year, when subjected to regional climate change (Garcia-Romero et al. 2010; Colombo 2007).

Ecological hotspots and fields did not show significant variations in area, demonstrating that their establishments are better explained by biophysical factors, such as elevation, geomorphology and soil type, than by climatic factors. For this reason, these statistics have not been included in Table 3.1.

We pointed out for pioneer formations a potential loss of up to 30% of the current climate fitness area. In contrast, a potential gain of more than 50% of suitable area is projected into other significant coastal regions (Nehren et al. 2013). As a strategy for protecting the coastal region, the conservation and preservation of currently existing areas and the possible expansion for future suitable areas is advised in order to conserve biodiversity and areas of estuaries (Althoff et al. 2016; Lezine et al. 2013).

The spatial variability of dense and open rainforests is directly related to limited periods of high humidity. Due to the scarcity of well-distributed rainfall, a potential loss of up to 45% is expected in these areas. Open rain forest, more tolerant to water stress, can make areas suitable for up to 167% of the current domain (Zhao and Wu 2014). Due to its high resilience and ability to adapt, this type of vegetation can colonize different soil types. The situation of dense tropical forests appears to be more critical. This vegetation type is noted for its high water demand, and its future domain becomes quite limited with the reduction of well-distributed rainfall. In the case of mixed rain forest only a small net change is expected, with a 37% loss and 33% gain of potential area.

For the transition regions between vegetation types, the potential for climate change related gain in area up to 364% demonstrates how the weather will be acting to possibly displace and rearrange plant classes in the Atlantic Forest in Brazil. This high rate suggests how new climatic conditions may favor or disfavor the current occurrence of vegetation types (Knapp et al. 2002).

It is important to clarify that it is not only the weather that determines the distribution of vegetation on a regional scale, but also other factors such as soil type, topography, land use, the occurrence of fires, and many other factors (Politti et al. 2014; Rashid et al. 2015).

Conclusions

The results presented in this study are an important step towards planning actions to reduce vulnerability across the entire Atlantic Forest biome. The existence of information regarding potential biophysical impacts of climate change is a large step forward in assessing potential socioeconomic impacts and risks, thus allowing the optimal allocation of finances to the most critical areas in order to reduce future losses and damages. These new insights will act as a major contribution in developing concrete and cost-effective adaptation measures within the context of the National Adaptation Plan, particularly for the sectors of agriculture and food security, health, biodiversity and disaster management.

Moreover, this study will help to identify and rate the magnitude of climate change impacts in the Atlantic Forest regions, refining the list of indicators of the National System for Monitoring and Observation of Climate Change Impacts[2] (SISMOI) in Brazil.

It is not possible to give an overall conclusion of this study; the huge extension of the Atlantic Forest demands a clustering of the main outcomes according to regional peculiarities. In Southern regions, landslides and floods will show soaring trends caused by an increase of extremes of precipitation. A few instances of floods are expected in the Northeast during its rainy season on well-developed floodplains. Longer droughts and falling soil moisture will contribute to reducing viable agricultural lands in the Midwest, Southeast and Northeast regions, with implications for smallholders' wellbeing (mainly in the Northeast) and production of commodities (mainly in the Midwest and Southeast). The distribution of dengue-vector will increase in most of the Southern regions due to increasing temperatures and rains; the Midwest does not show relevant variations and will continue to be a critical region, whilst in the Northeast the observed decrease in the distribution of dengue-vector is caused by falling rains during the dry season. The combination of increased temperature, changes in precipitation and soil moisture decline will trigger displacements and rearrangements in plant communities, with the likely expansion of more resilient ones to new climate conditions.

---

[2]SISMOI is a project under responsibility of the Brazilian Ministry of Science, Technology and Innovation.

This study altered only climate parameters to assess future potential impacts; other important explicative factors, such as land use and management, were maintained constant across time, due to the lack of reliable socioeconomic and environmental forecasting. Given the importance of the Atlantic Forest region in the country's economy and societal wellbeing, further modelling and monitoring researches will be needed in order to quantify, with a smaller degree of uncertainty, the projected impacts of climate change, and their relationships with human activities and planned economic growth.

Annex 1

Flood Model

Results describing physical susceptibility to flood occurrence were produced by crossing data about major relief characteristics such as: Declivity; Stream Order; And Vertical and Horizontal Distance to Stream (Strahler 1964; Rennó et al. 2008), as displayed in Fig. 3.17.

Extreme precipitation events are closely linked to flood occurrence (Parr et al. 2015; Alfieri et al. 2015; Apurv et al. 2015; Yoon et al. 2015). The indicators of climate extremes selected as model inputs are: Annual count of days with precipitation greater than 10 mm (R10); Annual rainfall during days when precipitation is greater than or equal to the 95th percentile of all humid days of the year, with rainfall values higher than or equal to 1 mm (R95p); Maximum number of

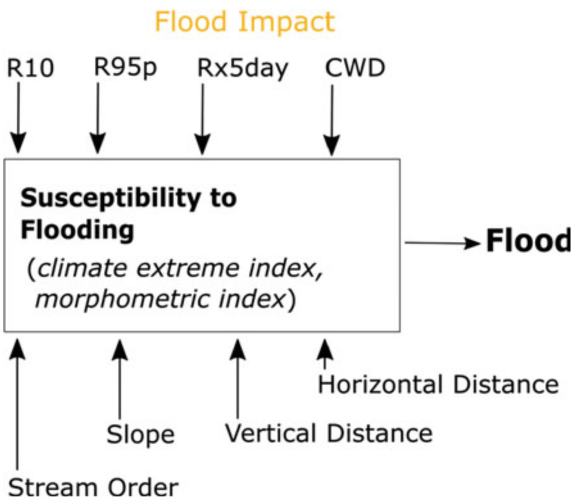


Fig. 3.17 Floods submodel flowchart

consecutive wet days a year (CWD); And Maximum annual rainfall on 5 consecutive days (Rx5 day).

The model results were calibrated and validated by using data from the Sistema Integrado de Informações sobre Desastres (SEDEC) and Atlas Brasileiro de Desastres Naturais (CEPED 2012).

Rainfall Erosivity Model

Figure 3.18 displays the model of rainfall erosivity (i.e., erosive force of rain), based on the equations suggested by Silva (2004); Silva (2001); Rufino et al. (1993); Neto and Moldenhauer (1992); and Val et al. (1986). Rainfall data include monthly and annual precipitation averages.

Landslides Model

Soil slope and erodibility, together with rainfall erosivity, were used to generate an indicator of the physical sensitivity of the system to landslides. The slope was calculated using the Digital Elevation Model (DEM) for the Topodata-INPE project. The erodibility was classified according to Silva and Alvares (2005) and Lino (2010). The rainfall erosivity characterizes the exposure as described in section "Rainfall Erosivity Model" (Fig. 3.19).

All the information was normalized and crossed using a weighted average: erosivity and erodibility were given a weight 0.3 and slope was given a weight of 0.4, since gravity plays an important role in landslides.

The calibration and validation of the model's output used records provided by the Civil Defence, CEMADEN and newspaper.

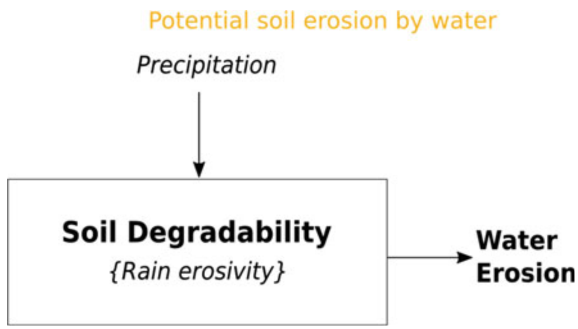


Fig. 3.18 Potential soil erosion by water submodel flowchart

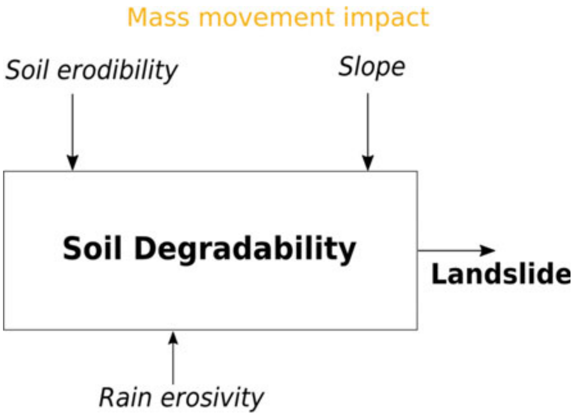


Fig. 3.19 Landslide submodel flowchart

Dengue Vector Distribution Model

In general, the model projection of tropical disease vector distribution was constituted from the geostatistical relationships between the distribution of exposure and climatic extremes observed in periods of high infestation, and the data indicating the presence of the vector in the territory. Thus, it is possible to draw up a spatial representation of potential distribution of the tropical disease vector in the face of climate change, including future exposure data. The result is shown by a composed index pointing the susceptibility of the region to this vector (*Aedes aegypti*). The first indicator presents the probability of occurrence generated by the MAXENT algorithm (Phillips et al. 2004). The second reports on the likely number of vector generations according to temperature limits (Fernandes et al. 2006). The third indicator sets the transmission potential, also related to temperature data (Lambrechts et al. 2011). The fourth indicator designs positivity for hatching eggs, associated with rainfall, temperature and relative humidity (Vianello et al. 2006). In addition, the fifth indicator is known as General Susceptibility Index, a methodology for quantitative assessment of susceptibility (Brasil 2005). The indicators were crossed as the same weight by map algebra and thus it was possible to draw up a spatial representation through a normalized ratio vector distribution of the potential impact of tropical diseases according to climate change as shown in the following Fig. 3.20.

The results of this model were calibrated using data from the international repository DRYAD and validated by comparison to a study from the University of Oxford (Kraemer et al. 2015).

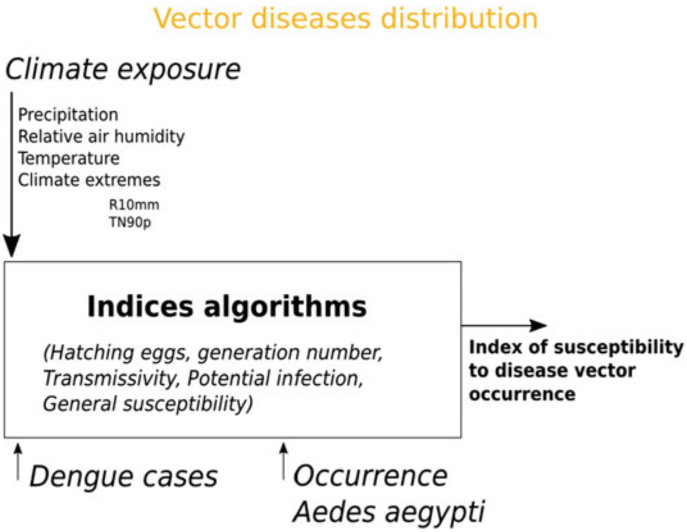


Fig. 3.20 Vector diseases submodel flowchart

Soil Moisture Model

Soil moisture is typically incremented through rainfall events and lost through runoff, infiltration to deeper soil layers and groundwater, and evapotranspiration. In turn, the evapotranspiration is controlled by vegetation and atmospheric conditions. The dynamics of water in the soil depends mainly on these processes. Based on this logic, we apply soil equations describing these dynamics (Porporato et al. 2004) to understand how changes in climate conditions may affect soil moisture. Soil moisture estimations are made using a numerical model which implements these equations (Fig. 3.21).

This modeling seeks to simplify the large number of processes that make up the dynamics of water in the soil. These hydrological phenomena are accompanied by a high degree of spatiotemporal nonlinearity. The potential evapotranspiration (amount of transpiration which would occur if sufficient water were available), one of the input variables, is obtained from an algorithm described by FAO (Food and Agriculture Organization of the United Nations) (Allen et al. 1998) that uses minimum, average and maximum temperature related to the extraterrestrial solar radiation latitude.

The result generated by the model is the average predicted soil moisture taking into account climatic, pedological and vegetation conditions. The final product is a prediction of volumetric soil moisture (mm^3 of water/mm^3 of soil).

The soil moisture maps consistently reproduced the standards expected for tropical regions, with satisfactory agreement in the temporal variability on climate

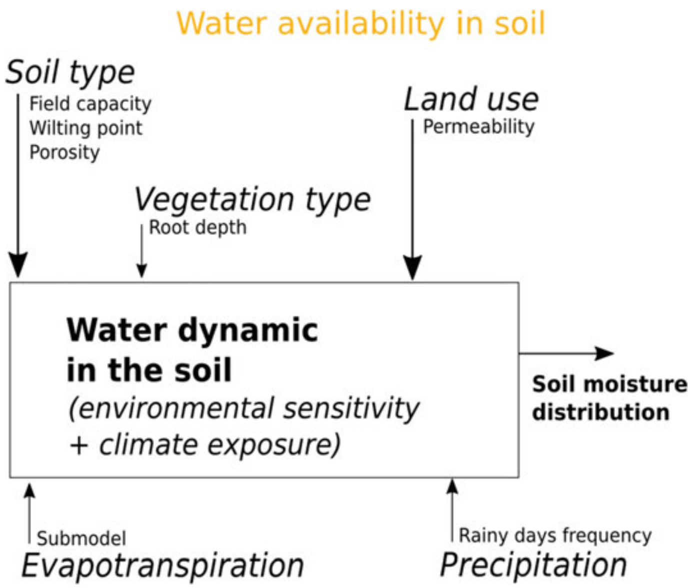


Fig. 3.21 Water availability in soil submodel flowchart

change validated from INPE (National Institute for Space Research) expert judgement (Gevaerd and Freitas 2006) and results design by MODIS project.

Vegetation Type Model

The projections were made by Maximum Entropy model approach—MAXENT (Phillips et al. 2004). The entropy concept refers to the uncertainty of a probability distribution. The MAXENT is an algorithm that seeks to calculate and minimize this uncertainty, finding the nearest future distribution of real uniform distribution, based on the constraints of environmental variables available. The algorithm seeks this new distribution by minimizing a measure of divergence between actual and simulated results, given the same set of constraints. The actual phytophysiognomy data, together with historical environmental variables, are used as model inputs to calibrate and set the constraints. Subsequently, the restrictions set by the MAXENT algorithm are used to reference the likelihood occurrence of vegetation type in relation to the constraints identified in the spatial distribution of future climate variables. Therefore, input data for the model were: occurrences of phytophysiognomies; soil moisture; topography information; historical climatic exposure and weather extremes for calibration and future data for the generation of projections of potential distributions. The data resulting from this analysis indicates the potential

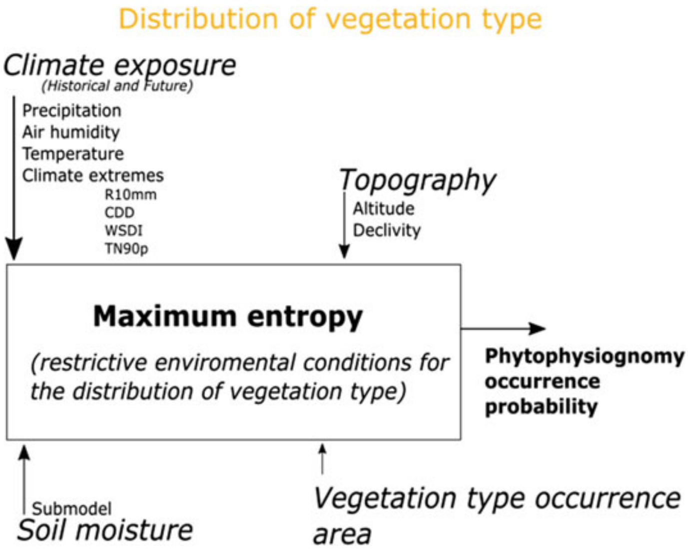


Fig. 3.22 Vegetation type submodel flowchart

distribution of vegetation type according to future climate conditions, as shown in Fig. 3.22.

Because of the low availability of supporting data, the results of changes in the distribution of vegetation types were validated by Report No. 6: Climate Change and possible changes in South America Biomes (Marengo 2007).

Agro-climatic Zoning Model

This impact was modeled from the variation of climatic characteristics, which mainly influence the phases of germination and grain filling, crucial to a good crop yield. The form and extent of climate change, related to the physical aspects of the environment, affect the optimal conditions of agricultural productivity of a region can be analyzed from these results. The site is considered to have low susceptibility to climate impacts if the chance of successful harvest is at least 80%.

The Water Requirement Satisfaction Index (WRSI), the ratio between the actual and the maximum level of agricultural evapotranspiration, was used as a measure of the crop water stress. The modeling was performed by using the data of the soil moisture submodel as an input to the Eagleman (1971) equation to define the real coefficient of culture. To the maximum coefficient, tabulated data are listed per culture. The air temperature rasters and extraterrestrial solar radiation are used as inputs in the evapotranspiration sub-model. These data reported above are the input components in the FAO methodology notebook 56 (Allen et al. 1998) to define the

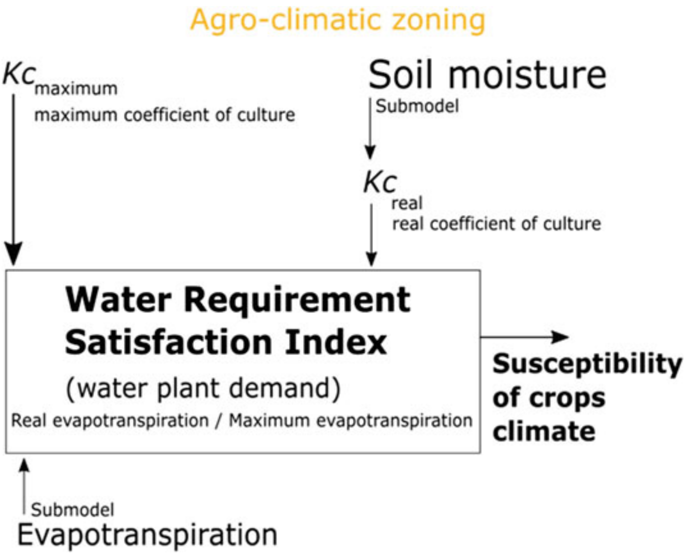


Fig. 3.23 Agro-climatic zoning submodel flowchart

actual and maximum evapotranspiration, which is used to calculate the WRSI as shown in Fig. 3.23.

The crops considered in the preparation of this study (maize, soybean, beans, cotton, sugarcane and rice) were those viewed as strategic for the economy and food security of Brazil. The results are shown sorted by a WRSI ranging from 0 to 1, with higher values suggesting lower degrees of water stress. The information generated by the model was validated using experimental results of the study by Embrapa (Assad et al. 2013), for maps of the Ministry of Agriculture, Livestock and Supply (MAPA) and results of the project (MODIS).

References

Alfieri L, Feyen L, Dottori F, Bianchi A (2015) Ensemble flood risk assessment in Europe under high end climate scenarios. Glob Environ Change 35:199–212

Allen RG, Pereira LS, Raes D, Smith M (1998) Crop evapotranspiration—Guidelines for computing crop water requirements—FAO Irrigation and drainage paper 56, vol 300(9). FAO, Rome, p D05109

Althoff TD, Menezes RSC, de Carvalho AL, de Siqueira Pinto A, Santiago GACF, Ometto JPHB et al (2016) Climate change impacts on the sustainability of the firewood harvest and vegetation and soil carbon stocks in a tropical dry forest in Santa Teresinha Municipality, Northeast Brazil. For Ecol Manag 360:367–375

Anwar MR, Li Liu D, Macadam I, Kelly G (2013) Adapting agriculture to climate change: a review. Theor Appl Climatol 113(1–2):225–245

Apurv T, Mehrotra R, Sharma A, Goyal MK, Dutta S (2015) Impact of climate change on floods in the Brahmaputra basin using CMIP5 decadal predictions. J Hydrol 527:281–291
Assad E, Pinto HS, Nassar A, Harfuch L, Freitas S, Farinelli B et al (2013) Impacts of climate change on Brazilian agriculture (no. 18740). The World Bank, Washington
Beebe NW, Cooper RD, Mottram P, Sweeney AW (2009) Australia's dengue risk driven by human adaptation to climate change. PLoS Negl Trop Dis 3(5):e429
Brasil (2005) Análise da população brasileira aos impactos sanitários das mudanças climáticas. Ministério de Ciência e Tecnologia. Fiocruz. Brasília, p 201
Burney J, Cesano D, Russell J, La Rovere EL, Corral T, Coelho NS, Santos L (2014) Climate change adaptation strategies for smallholder farmers in the Brazilian Sertão. Clim Change 126 (1–2):45–59
Calzadilla A, Rehdanz K, Betts R, Falloon P, Wiltshire A, Tol RS (2013) Climate change impacts on global agriculture. Clim Change 120(1–2):357–374
Campbell LP, Luther C, Moo-Llanes D, Ramsey JM, Danis-Lozano R, Peterson AT (2015) Climate change influences on global distributions of dengue and chikungunya virus vectors. Philos Trans R Soc B 370(1665):20140135
Campbell-Lendrum D, Reithinger R (2002) Dengue and climate change. Trends Parasitol 18(12):524
Centro Universitário de Estudos e Pesquisas sobre Desastres (CEPED) (2012) Atlas brasileiro de desastres naturais 1991 a 2010: volume Brasil. Florianópolis, CEPED, UFSC
Chou SC, Lyra A, Mourão C, Dereczynski C, Pilotto I, Gomes J, Campos D (2014) Assessment of climate change over South America under RCP 4.5 and 8.5 downscaling scenarios. Am J Clim Change 3(05):512
Colombo AF (2007) Conseqüências das mudanças climáticas globais para as espécies arbóreas da Mata Atlântica. Doctoral dissertation, Dissertação de Mestrado), Instituto de Biologia/ UNICAMP, Campinas, Brazil
Colón-González FJ, Fezzi C, Lake IR, Hunter PR (2013) The effects of weather and climate change on dengue. PLoS Negl Trop Dis 7(11):e2503
Connor JD, Schwabe K, King D, Knapp K (2012) Irrigated agriculture and climate change: the influence of water supply variability and salinity on adaptation. Ecol Econ 77:149–157
Crepani E, Medeiros JD, Hernandez Filho P, Florenzano TG, Duarte V, Barbosa CCF (2001) Sensoriamento remoto e geoprocessamento aplicados ao zoneamento ecológico-econômico e ao ordenamento territorial. INPE, São José dos Campos, Brazil
da Silva AM (2004) Rainfall erosivity map for Brazil. Catena 57(3):251–259
Destouni G, Verrot L (2014) Screening long-term variability and change of soil moisture in a changing climate. J Hydrol 516:131–139
Douville H, Colin J, Krug E, Cattiaux J, Thao S (2016) Midlatitude daily summer temperatures reshaped by soil moisture under climate change. Geophys Res Lett 43(2):812–818
Eagleman JR (1971) An experimentally derived model for actual evapotranspiration. Agric Meteorol 8:385–394
Fernandes C, Beserra EB, Castro FP Jr, Santos JW, Santos TS (2006) Biologia e exigências térmicas de aedes aegypti (l.)(diptera: Culicidae) provenientes de quatro regioes bioclimáticas da paraıba. Neotrop Entomol 35:853–860
Follador M (2015) Sistematização de informações e critérios para definição do Sistema de Monitoramento e Observação dos impactos das mudanças climáticas (SISMOI) – Proposta Final. UNESCO e Ministério de Ciência, tecnologia e informação, Brasília, Brazil
Follador M et al (2015) Avaliação de impactos econômicos de riscos climáticos e proposta preliminar de medidas de adaptação a nível nacional – setor Segurança Alimentar. Produto 2: Impactos Macroeconômicos. CEPAL e Ministério de Meio Ambiente, Brasília, Brazil
Fullerton LM, Dickin SK, Schuster-Wallace CJ (2014) Mapping global vulnerability to dengue using the water associated disease index. United Nations University, Hamilton
Füssel HM (2007) Adaptation planning for climate change: concepts, assessment approaches, and key lessons. Sustain Sci 2(2):265–275

García-Romero A, Muñoz J, Andrés N, Palacios D (2010) Relationship between climate change and vegetation distribution in the Mediterranean mountains: Manzanares Head valley, Sierra De Guadarrama (Central Spain). Clim Change 100(3–4):645–666
Gevaerd R, Freitas S (2006) Estimativa operacional da umidade do solo para iniciação de modelos de previsão numérica da atmosfera parte I: descrição da metodologia e validação. Revista Brasileira de Meteorologia 21(3):1–15
Goto K et al (2013) Analysis of effects of meteorological factors on dengue incidence in Sri Lanka using time series data. PLoS ONE 8(5):e63717
IPCC (2007) Summary for policymakers. In: Contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, London
IPCC (2014) Climate change 2014: impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects. In: Contribution of working group ii to the fifth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge
Knapp AK, Fay PA, Blair JM, Collins SL, Smith MD, Carlisle JD et al (2002) Rainfall variability, carbon cycling, and plant species diversity in a mesic grassland. Science 298(5601):2202–2205
Kraemer MU, Sinka ME, Duda KA, Mylne A, Shearer FM, Barker CM, Moore CG, Carvalho RG, Coelho GE, Van Bortel W, Hendrickx G, Schaffner F, Elyazar IR, Teng H-J, Brady OJ, Messina JP, Pigott DM, Scott TW, Smith DL, Wint GW, Golding N, Hay SI (2015) The global distribution of the arbovirus vectors Aedes aegypti and A. albopictus. Elife 4:e08347. doi:10.7554/eLife.08347
Lambrechts L, Paaijmans KP, Fansiri T, Carrington LB, Kramer LD, Thomas MB, Scott TW (2011) Impact of daily temperature fluctuations on dengue virus transmission by Aedes aegypti. Proc Natl Acad Sci 108(18):7460–7465
Lézine AM, Assi-Kaudjhis C, Roche E, Vincens A, Achoundong G (2013) Towards an understanding of West African montane forest response to climate change. J Biogeogr 40(1): 183–196
Lino JS (2010) Evolução do sistema plantio direto e produção de sedimentos no Rio Grande do Sul. Doctoral dissertation, Escola Superior de Agricultura Luiz de Queiroz) Piracicaba, São Paulo, Brazil
Lowe R, Bailey TC, Stephenson DB, Jupp TE, Graham RJ, Barcellos C, Carvalho MS (2013) The development of an early warning system for climate-sensitive disease risk with a focus on dengue epidemics in Southeast Brazil. Stat Med 32(5):864–883
Marengo JA (2007) Mudanças climáticas globais e seus efeitos sobre a biodiversidade: caracterização do clima atual e definição das alterações climáticas para o território brasileiro ao longo do século XXI. Brasília: MMA nº26, Brazil
Melillo JM, McGuire AD, Kicklighter DW, Moore B, Vorosmarty CJ, Schloss AL (1993) Global climate change and terrestrial net primary production. Nature 363(6426):234–240
Moro GT, de Souza LVMP, Almeida ES (2011) Levantamento de susceptibilidade a deslizamento e erosão em encostas–estudo de caso: Morro da Cruz–Itajaí–SC. XV SIMPÓSIO BRASILEIRO DE SENSORIAMENTO REMOTO (SBSR). Anais… Editor INPE, Curitiba, pp 4162–4169
Moss R, Babiker M, Brinkman S, Calvo E, Carter T, Edmonds J, Elgizouli I, Emori S, Erda L, Hibbard KA et al (2008) Towards new scenarios for analysis of emissions, climate change, impacts, and response strategies. IPCC expert meeting report on new scenarios. intergovernmental panel on climate change, Geneva
Müller C, Cramer W, Hare WL, Lotze-Campen H (2011) Climate change risks for African agriculture. Proc Natl Acad Sci 108(11):4313–4315
Naish S, Dale P, Mackenzie JS, McBride J, Mengersen K, Tong S (2014) Climate change and dengue: a critical and systematic review of quantitative modelling approaches. BMC Infect Dis 14(1):1
Nehren UDO, Kirchner A, Sattler D, Turetta AP, Heinrich J (2013) Impact of natural climate change and historical land use on landscape development in the Atlantic Forest of Rio de Janeiro, Brazil. Anais da Academia Brasileira de Ciências 85(2):497–518

Neto FL, Moldenhauer WC (1992) Erosividade da chuva: sua distribuição e relação com perdas de solo em Campinas, SP. Bragantia 51(2):189–196

OECD and JRC (2008) Nardo M, Saisana M, Saltelli A, Tarantola S, Hoffman A, Giovannini E (2005) Handbook on constructing composite indicators: methodology and user guide (no. 2005/3). OECD Publishing, Paris

Oliveira AS (1986) Interações entre sistemas frontais na América do Sul e convecção na Amazônia. São José dos Campos. INPE-4008-TDL/239). Dissertation. Instituto Nacional de Pesquisas Espaciais, São José dos Campos, São Paulo, Brazil

Oppenheimer M, Campos M, Warren R, Birkmann J, Luber G, O'Neill B, Takahashi K (2014) Emergent risks and key vulnerabilities. In: Climate change 2014: impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects. contribution of working group ii to the fifth assessment report of the intergovernmental panel on climate. Cambridge University Press, Cambridge, pp 1039–1099

Parr D, Wang G, Ahmed KF (2015) Hydrological changes in the U.S. Northeast using the Connecticut River Basin as a case study: Part 2. Projections of the future. Glob Planet Change 133:167–175

PBMC—Painel Brasileiro de Mudanças Climáticas (2014) Base científica das mudanças climáticas. Contribuição do Grupo de Trabalho 1 do Painel Brasileiro de Mudanças Climáticas ao Primeiro Relatório da Avaliação Nacional sobre Mudanças Climáticas. In: Ambrizzi T, Araujo M (eds) COPPE. Universidade Federal do Rio de Janeiro, Rio de Janeiro, RJ, Brazil

Phillips SJ, Dudík M, Schapire RE (2004) A maximum entropy approach to species distribution modeling. In: Proceedings of the 21st international conference on machine learning (ICML-04). ACM, Princeton, p 83

Piao S, Ciais P, Huang Y, Shen Z, Peng S, Li J, Friedlingstein P (2010) The impacts of climate change on water resources and agriculture in China. Nature 467(7311):43–51

Politti E, Egger G, Angermann K, Rivaes R, Blamauer B, Klösch M et al (2014) Evaluating climate change impacts on Alpine floodplain vegetation. Hydrobiologia 737(1):225–243

Porporato A, Daly E, Rodriguez-Iturbe I (2004) Soil water balance and ecosystem response to climate change. Am Nat 164(5):625–632

Raghunathan N, François L, Huynen MC, Oliveira LC, Hambuckers A (2015) Modelling the distribution of key tree species used by lion tamarins in the Brazilian Atlantic forest under a scenario of future climate change. Reg Environ Change 15(4):683–693

Rashid I, Romshoo SA, Chaturvedi RK, Ravindranath NH, Sukumar R, Jayaraman M et al (2015) Projected climate change impacts on vegetation distribution over Kashmir Himalayas. Clim Change 132(4):601–613

Rennó CD, Nobre AD, Cuartas LA, Soares JV, Hodnett MG, Tomasella J, Waterloo MJ (2008) HAND, a new terrain descriptor using SRTM-DEM: Mapping terra-firme rainforest environments in Amazonia. Remote Sens Environ 112(9):3469–3481

Roux PC, Aalto J, Luoto M (2013) Soil moisture's underestimated role in climate change impact modelling in low-energy systems. Glob Change Biol 19(10):2965–2975

Roy SS, Balling RC Jr (2004) Trends in extreme daily precipitation indices in India. Int J Climatol 24:457–466

Rufino RL, Biscaia RCM, Merten GH (1993) Determinação do potencial erosivo da chuva do estado do Paraná, através de pluviometria: Terceira aproximação. Revista brasileira de Ciência do Solo 17(3):439–444

Ruml M, Vuković A, Vujadinović M, Djurdjević V, Ranković-Vasić Z, Atanacković Z et al (2012) On the use of regional climate models: implications of climate change for viticulture in Serbia. Agric For Meteorol 158:53–62

Russell RC, Currie BJ, Lindsay MD, Mackenzie JS, Ritchie SA, Whelan PI (2009) Dengue and climate change in Australia: predictions for the future should incorporate knowledge from the past. Med J Aust 190(5):265–268

Seneviratne SI, Corti T, Davin EL, Hirschi M, Jaeger EB, Lehner I et al (2010) Investigating soil moisture–climate interactions in a changing climate: a review. Earth Sci Rev 99(3):125–161

Shaw SB, Royem AA, Riha SJ (2011) The relationship between extreme hourly precipitation and surface temperature in different hydroclimatic regions of the United States. J Hydrometeorol 12:319–325

Silva AM (2001) Índice de erosividade e sua relação com a pluviometria e coeficiente de chuva em Juazeiro (BA). ESALQ, Piracicaba, São Paulo

Silva AMD, Alvares CA (2005) Levantamento de informações e estruturação de um banco de dados sobre a erodibilidade de classes de solos no Estado de São Paulo. Geociências 24(1): 33–42

Strahler A (1964) Quantitative geomorphology of drainage basins and channel networks. In: Chow VT (ed) Handbook of applied hydrology. McGraw-Hill, New York

Streck NACM (2006) Simulação do impacto da mudança climática sobre a água disponível do solo em agroecossistemas de trigo, soja e milho em Santa Maria, RS. Ciência Rural 36(2): 424–433

Trenberth KE (1999). Conceptual framework for changes of extremes of the hydrological cycle with climate change. In: Weather and climate extremes. Springer, Dordrecht

Val LA, Bahia VG, Freire JC, Dias Júnior MS (1986) Erosividade das chuvas em Lavras, MG. Ciência e prática 10(2):199–209

Vianello RL, Pessanha JEM, Sediyama GC (2006). Previsão de ocorrência dos mosquitos da dengue em Belo Horizonte, com base em dados meteorológicos. In: Proceedings of the 14th Congresso Brasileiro de Meteorologia, Florianópolis, Brazil

World Health Organization (WHO) (2015) Dengue and severe dengue. WHO fact sheet No117 (updated September 2014). http://www.who.int/mediacentre/factsheets/fs117/en

Wischmeier WH, Smith DD (1978) Predicting rainfall erosion losses. Agriculture Handbook. U.S. Deparment of Agriculture, Washington

Wischmeier WH (1959) A rainfall erosion index for a universal soil-loss equation. Soil Sci Soc Am J 23(3):246–249

Yoon SK, Kim JS, Moon YI (2015) Urban stream overflow probability in a changing climate: Case study of the Seoul Uicheon Basin, Korea. J Hydro Environ Res 13:52–65

Zhao D, Wu S (2014) Responses of vegetation distribution to climate change in China. Theor Appl Climatol 117(1–2):15–28

Chapter 4
Adaptation Strategies to Face the Effects of Extreme Hydrometeorological Events on Agricultural Systems

Joyce Maria Guimarães Monteiro and José Luis Santos

Introduction

In many Latin American countries most rural low-income population live in exposed and marginal areas (e.g., flood areas, hillsides, arid or semi-arid zones), which puts them in risk of facing the negative impacts of climate change and especially to extreme hydrometeorological events (EHEs; UNISDR 2013). There is clear evidence of ongoing changes in rainfall patterns in South America (Haylock et al. 2006).

For these people, even minor changes in the climate can have a disastrous impact on their livelihoods. The impacts can be intense for subsistence farmers located in fragile environments, where major changes in productivity are expected. These farmers are greatly affected by changes in the normal climate pattern.

The processes of environmental degradation of the agricultural sector contribute to the vulnerability in the face of the effects produced by EHE (CATIE 2010). Such vulnerability is caused by the lack of environmental awareness among farmers, the poor access to land and funds, the scarce investments in infrastructure and the irregular occupation of the soil (CEPAL 2009).

There have been few studies documenting farmers' reactions in the presence of EHE in South America (Torres et al. 2009). Local perceptions on climate risk and impact, as well as the profile of the lifestyles at local scale, can contribute to assess vulnerability and resilience in the context of climate change (Di Falco et al. 2011).

J.M.G. Monteiro (✉)
Brazilian Agricultural Research Corporation – Embrapa Rua Jardim Botânico, 1024, Rio de Janeiro, RJ 22460-000, Brazil
e-mail: joyce.monteiro@embrapa.br

J.L. Santos
Escuela Superior Politécnica del Litoral, Km 30.5 Via Perimetral, Campus Gustavo Galindo, Guayaquil, Ecuador
e-mail: jlsantos@espol.edu.ec

W. Leal Filho and L. Esteves de Freitas (eds.), *Climate Change Adaptation in Latin America*, Climate Change Management,
https://doi.org/10.1007/978-3-319-56946-8_4

The emblematic cases may be chosen based on the recurrence, the effect on agricultural production and population, and the response (positive or negative) of the authorities and/or the community, which may be an extreme flood or drought. The central point is to gather information and assess how effective the measures have been taken by the authorities and the farmers to generate further information for decision makers who must face similar phenomena.

Thus, an analysis based on aspects of social and natural capital is necessary to propose effective adaptation measures. Identifying how farmers face EHE, what the main impacts of the event on farming systems are, and, especially what the strategies adopted by farmers are, can help to extract lessons learned that may contribute to the proposition of effective adaptation measures.

Within this context, the purpose of the study was to identify how decision makers deal with situations of extreme weather and what are the aspects that reduce or increase the vulnerability of local farmers in the face of such impacts. This research was conducted in five Latin American countries: Argentina, Brazil, Colombia, Chile and Ecuador. This paper presents the results of Brazil's case study.

Brazil has recently registered EHE, such as droughts and intense floods. These events resulted in heavy losses in the agricultural sector, the supply of water and food, health care and the economy in general (Rittl 2012). Historically natural disasters related to heavy rains in the summer period have been recorded in southeastern Brazil. In this region, the main phenomena related to natural disasters are related to heavy rains, causing floods, landslides, deaths and economic losses. In the southeastern region heavy rains led to floods and landslides in 2008, 2009 and 2011. There is an increasing trend of disasters caused by floods in recent decades, mainly due to the use and disorderly occupation of lands (Tominaga et al. 2009).

The State of Rio de Janeiro is located in southeastern Brazil. Rio de Janeiro state contains several patches of the Atlantic Forest biome, which has its native forest cover highly fragmented or restricted to small portions of land due to successive land use cycles and the pressure exerted by population growth (Rodrigues and Gandolfi 2004). The mountain region of the State of Rio de Janeiro is the most important site of agricultural production, mainly of vegetables, due to the proximity to the City of Rio de Janeiro, a large market. On the other hand, the mountain region of Rio de Janeiro is also one of the most vulnerable in the state. The pressure of rapid population growth in the region, the hilly terrain, the use and occupation of disordered soil associated with the predominance of low-productivity agriculture, mainly horticulture, makes it highly vulnerable.

This study presents lessons learned that contribute to propose effective measures to forward adaptation. Therefore, we analyzed the main impacts on agricultural systems, the strategies adopted by farmers, their achievements, difficulties and the changes adopted to deal with the EHE by the rural community of Barracão dos Mendes, situated in the City of Nova Friburgo, in the mountain region of Rio de Janeiro State. This paper also presents a brief analysis of the aspects of governance, the special laws and regulations to deal with the impacts of extreme weather events on local, regional and national levels.

Methodology

This work is part of a regional research project funded by the Inter-American Institute for Global Change Research through the Seed Program Projects (TISG-II). This Institute promoted two colloquia on knowledge integration in the interface between science and politics, during which it was possible to form a network of experts in the field of environment and rural development. These colloquia resulted in a project called "Lessons learned in dealing with the effects of extreme weather events in ecosystem services and agricultural systems in Latin America" (Argentina, Brazil, Colombia, Chile and Ecuador).

For the development of this project five case studies were chosen. Each case study was selected according to two criteria: the work of the researchers involved in the project and the occurrence of extreme weather events of major proportions that affected the agricultural sector in each Latin American country participating in the project. The case studies are: in Argentina, 'Floods and droughts in agro-ecosystems of wetlands in the Lower Paraná Delta'; in Brazil, 'Floods in the mountain region of Rio de Janeiro state'; in Chile, 'A country of contrasts experiences dry times'; in Colombia, 'Floods and Droughts, a challenge for Colombian agriculture'; and in Ecuador, 'The Ecuadorian coastal farmer reaction to floods and droughts'.

In this chapter, the results of the Brazilian case study will be presented, specifically in the rural community of Barracão dos Mendes, located in Nova Friburgo municipality, in the State of Rio de Janeiro. This region is one of the most important sites of agricultural production, mainly of vegetables, and also one of the most vulnerable in the state.

The technique to map actors (Gutiérrez 2007; Gondim 2002) was used to identify the key players and understand the plot of social relationships in the study site. The analysis was based on the case study that characterizes and describes the experiences of different actors and social groups in the occurrence of EHE in the agricultural sector. Thus, the events were described, initially based on primary sources (interviews with farmers and technical and policy-making agencies) and secondary sources (databases, scientific articles, official reports, press releases, etc.).

To develop the study case, we carried out a general characterization of the study area (Barracão dos Mendes) and of the EHE that occurred in the mountain region (in January 2011). Interviews with previously selected family farmers took place in the rural communities of Barracão dos Mendes on 18 and 19 November 2013. The interviews took place in a free format; however, property and production system data, the main impacts of the EHE, the aid measures received by the farmers and the lessons learned from their point of view were registered.

The lessons learned drawn from this study are indications collected on the characterization of local vulnerability, interviews with farmers, field observations, information collected from the decision makers to the agricultural sector and the characterization of adaptation and governance measures.

Study Area

The Barracão dos Mendes rural community is located in the Rio Grande Watershed in the municipality of Nova Friburgo, Rio de Janeiro (22° 16′ 55″ S and 42° 31′ 52″ W), at an average height of 985 m, in the Atlantic Forest biome, some 200 km from Rio de Janeiro City. The landscape is mountainous in a very hilly area and the topography ranges from steep slopes to large lowland extensions (CPRN 2002).

The climate is tropical altitude. Average temperatures are around 18 °C, the average temperature in summer is 24 °C and in winter 13 °C, with frost in floodplains and hailstorms in the summer. The average rainfall is 1650 mm/year. Rainfall distribution is very unequal, with 60% of the total annual rainfall occurring from December to March (summer), with accumulated deficits in winter, from May to July (INMET 2013).

There are some 256 properties belonging to family farmers in Barracão dos Mendes communities. Most of the properties have less than 10 ha. The agricultural system in Barracão dos Mendes is intensive, characterized by commercial polyculture (horticulture), whose seasonality of crops allows the intensive use of land throughout the year (SEAPEC 2011).

Common tillage is widely used, mainly plowing using tractors downhill, contributing to soil loss, silting of streams and sediment transport. These facts largely contribute to local erosion. Continued land use for crops and pastures impoverished and compacted soils, and these areas are still productive due to the intensive use of fertilizers and agrochemicals. In Barracão dos Mendes the appropriate techniques recommended for hillside conditions (for example, minimal tillage) are not usually adopted.

The remaining forests are located only in the higher areas, and they are often secondary forest covers of the Atlantic Forest. Human activities significantly affected all local waterways, due to the techniques used in production, such as low hill plowing (without contour).

Results

Aspects of Local Vulnerability and Impacts

The mountain region of Rio de Janeiro is highly vulnerable to the impacts caused by EHE. The factors that contribute to the risk of disasters are mainly local environmental characteristics of this mountain region, with steep slopes and formed by rocks covered by a thin layer of soil. These features generate quite unstable soils and liable to landslides (Busch and Amorim 2011).

Combined with the natural vulnerability, the risks are even worse due to the historical occupation of the riverbanks and streams, the removal of vegetation strips that protect the waterways; irregular construction in the hillside areas; accumulation of garbage on the slopes and deforestation. In this context, the strong summer rains often cause erosion, flooding and landslides.

In the last 25 years flooding with landslides occurred in 1987, 1988, 1999, 2000, 2003, 2007, 2008 and 2011, which led to hundreds of dead, missing, homeless or displaced residents. However, none of these events can be compared to what happened in January 2011, considered the largest natural disaster ever seen in the country. Between the evening of 11 January 2011 and the morning of the 12th, a strong storm occurred in the mountain region of Rio de Janeiro State, especially in the Cities of Petropolis, Teresópolis and Nova Friburgo.

In the mountain region, the large volume of rain combined with soil saturation and the natural vulnerability of the region caused overflowing of rivers and streams and landslides, destroying bridges, roads, rural buildings, houses and crops, leading to over 900 deaths, hundreds of missing and more than 30,000 homeless people. The entire region was covered by mud, hundreds of houses were swept away by land and dozens of people were buried. The tragedy also caused geographical changes in the area: rivers, streams and canals had their courses changed (Canedo et al. 2011).

Barracão dos Mendes was one of the most affected places by landslides and flooding. Losses were registered in agricultural areas by overflow of mud from the flood, erosion and landslides, as well as suppression of crop areas. Several agricultural areas became unproductive due to leaching of fertilizers and laminar and deep soil erosion. According to information of the Department of Agriculture and Rural Development of Nova Friburgo, the loss of areas exploited in this activity exceeds 1500 ha, of which the majority of the affected areas were planted with horticulture. About 1400 ha suffered superficial laminar erosion and 153 crops were partially or totally wasted (SEAPEC 2011). Most crops were damaged, either by deposition of mud and stones, or sand. What was left could not be sold due to the depreciation of production. The devaluation of agricultural products was due to the widespread information that the vegetables were being irrigated with water that contained human remains. The price of agricultural production fell sharply.

Governance Aspects

In Brazil, government institutions directly related to the use of planning and land use (environment), land development (agriculture) and risk management (civil defense) in the three levels of government (national, regional and municipal) are well structured, in the same way as the entire legal framework referring to the question.

The Ministry of National Integration organizes the actions and programs related to risk management and disasters and it has capillarity in all levels of the Brazilian government. The Brazilian Civil Defense is the agency chosen by the ministry to deal with these phenomena and is organized in the form of a system: the National Protection and Civil Defense System. The National Secretariat of Protection and

Civil Defense—SEDEC is the central body of the system, responsible for coordinating the actions of protection and civil defense throughout the country. SEDEC provides, in addition to preventive actions, assistance to those affected by disasters and response actions. All these services are made possible through a transfer of resources to states and municipalities under states of emergency.

Although the theme of disaster risk reduction (RRD) has advanced in Brazil, few preventive actions have been implemented, according to Brazil's plan risk reduction, presented to the United Nation in 2009. It generates higher expenditures to attend to the affected population (emergency action) in comparison with the total spent on prevention (Busch and Amorim 2011).

Therefore, in the case of the mountain region, the natural vulnerability of the region is widely recognized and documented. The Agenda 21 of Nova Friburgo developed from 2006 to 2008 contains the identification of risk areas, steep and irregular occupation of slopes by illegal settlements. The council also prepared the Action Plan for Sustainable Development and requested resources to implement the National Fund for the Environment in 2010. This document presents the negative aspects to local rural development, among others: the poor education and health services in the field, insufficient environmental monitoring due to lack of infrastructure and labor.

However, in this case study we have found that the risk prevention actions and disasters had not been implemented with the necessary effectiveness to deal with the EHE. There was no effective contingency plan or proper risk planning with defined responsibilities to deal with emergencies and carry out streamlines as necessary responses to abnormal events. On the other hand, in terms of emergency actions the role of the Rio de Janeiro State's Department of Agriculture and Livestock (SEAPEC) was crucial. Soon after the tragedy, SEAPEC carried out emergency actions and currently collaborates to restructure agricultural areas affected by the rains in January 2011. Technical performers of SEAPEC developed along with rural households projects to start the recovery of productive activities and provided the necessary guidelines for access to federal government emergency loans to the farmers.

Lessons Learned

In this case study, we could observe that the occurrence of EHE helped to raise awareness regarding environmental problems in rural areas. In the region, the lack of planning to use natural resources results in problems such as soil erosion and pollution of rivers. Some farmers began to question their agricultural practices and their consequent environmental impacts, which could result in increased local vulnerability. There was an increase in the dissemination and awareness of the importance of adopting soil conservation practices and water and agro-ecological production practices. Some local farmers point out, for example, the importance of plantations for ground cover with leguminosae spp, the benefits of crop rotation and tillage, among others.

These results converge to the notion of sustainable adaptation as defined by O'Brien and Leichenko (2003), as they indicate measures that reduce vulnerability and promote long-term resilience in an environment of climate change. This sustainable adaptation can be a useful and widely applicable approach to adapt to prevention because it can increase nature's capacity to cushion the adverse effects through the sustainable provision of ecosystem services.

Regarding governance aspects, government institutions that deal with reduction risk are well structured in all three-government levels. Nevertheless, the integration of local plans and government programs related to risk prevention and disaster plans and local development programs is important to generate efficient adaptation measures. In this case, that includes the local farmers and seeking feasible solutions to be deployed, considering the importance of the local diagnosis and the proposition of actions that consider the environmental, economic and cultural site. The Agenda 21 set an example of local initiatives. It includes boards and committees of river basins involving the diagnosis of problems and the preposition of solutions with broad involvement of society.

Regarding adaptation measures, as mentioned above the lessons learned refer to the need to strengthen and implement risk prevention strategies to disasters, i.e., adaptation measures related to the prevention of losses, both human and economic. Although the institutional framework is well structured, adaptation measures related to risk prevention do not seem to be sufficient. In this issue, the question of planning and land use plays a major role, regarding both the occupation of the slopes in mountain regions and subject to landslides and the illegal occupation and pollution of rivers. Therefore, the need to strengthen local government institutions and community associations to deal with risk prevention becomes a central point. Thus, it was found that in addition to the natural and socio-economic vulnerabilities on site, there is also an institutional and organizational vulnerability to deal with risk prevention in the region.

Conclusion

Floods and landslides are recurrent situations in the mountain region of the State of Rio de Janeiro; however, adaptation measures related to prevention were insufficient in the face of the severe impacts reported in the case study. Greater emphasis on prevention strategies is necessary, such as planning, strengthening of rural communities, containment of work slopes, improvement of warning systems, among other adaptation measures that may increase the resilience of the agricultural production of rural communities. The results of the case study suggest that the integrated management of the community level landscapes allows the agricultural producers to adopt adaptation measures in due course and prepare rural communities to face the EHE.

The environmental degradation processes in the agricultural sector greatly contribute to the vulnerability to EHE. Its causes involve the lack of environmental awareness among farmers, lack of access to land and capital, the few investments in infrastructure and the illegal occupation of land. It shows the importance of institutional mobilization to strengthen the actions that benefit or increase the organization and participation of rural communities in the discussion of local environmental solutions, participation in environmental education, the dissemination of sustainable agricultural practices, and other actions that contribute to spread measures related to the protection of natural resources and socio-economic empowerment of the people. Thus, it is clear that it is important to invest in the dissemination of measures related to the protection of natural resources and the provision of ecosystem services that can enhance the resilience of agriculture systems in the face of EHE.

On the farmers' lack of knowledge and preparation, this limit could be overcome by empowering communication between the government, researchers, agricultural extension agents and farmers. We suggest that community strategies support the integration of these levels and allow the search for new alternatives—some of them, connected to the performance of regulatory environmental services that may reduce environmental impacts. Either way, we must stress the importance of the government´s role, guiding the development of policies to ensure the continuation of prevention actions and action plans to reduce risks rather than just emergency actions.

References

Busch A, Amorim S (2011) A tragédia da região serrana do Rio de Janeiro em 2011: procurando respostas. ENAP: Casoteca de Gestão Pública. http://casoteca.enap.gov.br/index.phptragédia-da-região-serrana. Accessed 3 Dec 2013

Canedo P, Ehrlich M, Lacerda WA (2011) Chuvas na região serrana do Rio de Janeiro: Sugestões para ações de engenharia e planejamento. Programa de Engenharia civil, COPPE/UFRJ, Rio de Janeiro. http://www.coppe.ufrj.br/pdf_revista/relatoriochuvas.pdf. Accessed 3 March 2013

Centro Agronómico Tropical de Investigación y Enseñanza (CATIE) (2010) Adaptación al cambio climático y servicios ecosistémicos en América Latina: libro de actas del seminario internacional SIASSE 2008. In: Martínez Alonso C et al (eds) Serie técnica. Manual técnico/CATIE, no. 99, 2010, 1st edn. CATIE, Turrialba, 144 pp

Comisión Económica para América Latina y el Caribe (CEPAL) (2009) La economía del cambio climático para América Latina y el Caribe, Santiago de Chile. http://repositorio.cepal.org/bitstream/…/S1420656_es.pdf. Accessed 20 Jan 2016

Centro de Pesquisa de Recursos Naturais (CPRN) (2002) Projeto Rio de Janeiro. Rio de Janeiro, RJ. CD Room

Di Falco S, Veronesi M, Yesuf M (2011) Does adaptation to climate change provide food security? A micro-perspective from Ethiopia. Am J Agric Econ 93(3):829–846

Gondim SM (2002) Grupos focais como técnica de investigação qualitativa: Desafios metodológicos. Paid Cad Psicol Educ 12(24):149–161

Gutiérrez PM (2007) Mapas sociales: método y ejemplos prácticos. www.preval.org. Accessed 21 May 2012

Haylock MR, Peterson T, Abreu de Sousa JR, Alves LM, Ambrizzi T, Anunciação YMT, Baez J, Barbosa de Brito JI, Barros VR, Berlato MA, Bidegain M, Coronel G, Corradi V, Garcia VJ, Grimm AMI, Jaildo dos Anjos R, Karoly D, Marengo JA, Marino MB, Meira PR, Miranda GC, Molion L, Moncunill DF, Nechet D, Quintana J, Ramirez E, Rebello E, Rusticucci M, Santos JL, Trebejo I, Vincent L (2006) Trends in total and extreme South American rainfall 1960–2000 and links with sea surface temperature. J Clim 19:1490–1512

Instituto Nacional de Meteorologia (INMET) (2013). http://www.inmet.gov.br/portal. Accessed 3 Dec 2013

O'Brien K, Leichenko R (2003) Winners and losers in the context of global change. Ann Assoc Am Geogr 93:99–113

Rittl C (2012) Eventos Climáticos Extremos no Brasil Impactos, Ciência e Políticas Públicas. WWF. Brasil São Paulo, Agosto de 2012. www.fapesp.br/eventos/2012/08/IPCC/Rittl.pdf. Accessed 13 Jan 2014

Rodrigues RR, Gandolfi S (2004) Conceitos, tendências e ações para recuperação de florestas ciliares. In: Rodrigues RR, de Leitão-Filho HF (eds) Matas ciliares: conservação e recuperação. EDUSP, São Paulo, pp 235–247

Secretaria de Estado de Agricultura e Pecuária (SEAPEC) (2011) Projeto Desenvolvimento Rural Sustentável em Microbacias Hidrográficas do Estado do Rio de Janeiro - Rio Rural/ BIRD - Plano Executivo da Microbacia de Barracão dos Mendes. Rio de Janeiro, RJ, 5 pp

Tominaga LK, Santoro J, Amaral R (2009) Desastres naturais: conhecer para prevenir. Instituto Geológico, São Paulo, 12 pp

Torres P, Rodríguez L, Ramírez C (2009) Sustentabilidad y cambio climático. Lineamientos de políticas de adaptación para la agricultura y el desarrollo rural, Veredas. Revista del pensamiento sociológico, n.18, México, UAM-Xochimilco, pp 39–62

United Nations Office for Disaster Risk Reduction (UNISDR) (2013) Global assessment report on disaster risk reduction. http://www.preventionweb.net/english/hyogo/gar/2013/en/home/download.html. Accessed 13 Jan 2014

Chapter 5
Bioengineered Measures for Prevention of Proceeding Soil Degradation as a Result of Climate Change in South East Brazil

Anja Hebner, Kathrin Kopielski, Sven Dulleck, André Gerth, Dietmar Sattler, Roman Seliger and Helga Restum Hissa

Introduction

Brazil belongs to one of all worldwide countries abounding in fresh water. Beside deforestation, unsuitable water and soil management, waste of water and disturbance of environment are chief drivers of fresh water shortage (de Araújo et al. 2004). An extreme drought at least in January 2016 gathered Brazil. Just followed about 4 weeks later partial areas of lower altitude near Rio Paraíba do Sul also around Itaocara were affected by floods. Flooding was promoted by extraordinary strong precipitation (01/2016: 205 mm, 01/2015: 0 mm, 01/2014: 58.6 mm; source: Pesagro) leading to increased runoff in higher altitudes. As a consequence dams reached maximum capacity and opening of gates promoted flooding event.

As a result of climate change, occurrence of long dry periods followed by heavy rainfalls increased which leads in advancing of the intensity of soil erosion and the emerge of mudslides significantly (Sparovek et al. 2007). About 60% of eroded soil

A. Hebner · K. Kopielski · S. Dulleck · A. Gerth (✉)
Vita 34 AG, Business Unit BioPlanta, Deutscher Platz 5a, 04103 Leipzig, Germany
e-mail: andre.gerth@vita34.de

A. Hebner
e-mail: anja.hebner@vita34.de

D. Sattler · R. Seliger
Institute of Geography, Physical Geography and Environmental Research, University of Leipzig, Johannisallee 19a, 04103 Leipzig, Germany
e-mail: sattler@uni-leipzig.de

R. Seliger
e-mail: roman.seliger@uni-leipzig.de

H.R. Hissa
Secretariat of Agriculture and Livestock of the State of Rio de Janeiro - SEAPEC, Rio Rural Programme, Alameda São Boaventura 770, Fonseca, Niteroi, RJ, Brazil
e-mail: helga.hissa@globo.com

W. Leal Filho and L. Esteves de Freitas (eds.), *Climate Change Adaptation in Latin America*, Climate Change Management,
https://doi.org/10.1007/978-3-319-56946-8_5

Fig. 5.1 Cattle tracks (*left*) and gully erosion (*right*), © Roman Seliger

reach streams which leads to an impairment of water quality (Pimentel and Kounang 1998). Widespread loss of vegetation cover is often connected to inappropriate agricultural activities strengthen fluvial soil degradation. In case of sloped pastures unsuitable tillage (vertical to slope) and overgrazing are main reasons which effect increased runoff leading to intensified soil erosion like cattle tracks, rills, sheet and gully erosion (Lammeranner et al. 2005; Pimentel and Burgess 2013; van Oudenhoven et al. 2015), as shown in Fig. 5.1. Especially vertical tillage, most common practice for management of sloping agricultural land in Brazil, is one of the most driving factors for degradation of soil (Sparovek et al. 2007). Especially, overgrazing increases this effect by compacting soil by cattle tracks and reducing vegetal cover, leading to impaired succession. As a consequence, soil structure is modified by reduced infiltration capacity, especially in slope toe areas where this effect is increased by blocking of fine pores by colluvial sediments (Pimentel et al. 2004).

Crop yields on eroded areas are 15–30% lower than on none degraded soils whereas main reasons are decreased water availability and reduced soil fertility (Pimentel and Kounang 1998). Loss of arable soil is one of the main causes for food shortages and economic looses in agricultural sector (Blaschke et al. 2000). In Brazil this sector is characterized by predominant share in pasture land that is often managed unsuitably leading to soil degradation and to consequent economical losses (Martinelli et al. 2010).

Against this background a German-Brazilian consortium developing a joint project entitled INTECRAL, which is promoted by Rio Rural Program ("Executive Subprojects"). INTECRAL is a scientific cooperation project that is supported by the German Federal Ministry of Education and Research (BMBF) and the State Secretariat of Agriculture and Livestock Project Rio Rural (SEAPEC-PRR). The project tends to foster the competitive position of the rural economy sector of Rio de Janeiro state focusing on sustainable watershed management by implementation of environmental sound technologies and services. In this regard the partners of the subproject created a concept comprising bioengineered measures for reducing soil degradation on sloped pastures as a tool for implementation of ecological and economical methods for land rehabilitation. The concept was realized by pilot measures.

Bioengineered measures against soil degradation comprise application of living plants, organic construction materials and extensive technical measures. Plants can be implemented single or in combination with additives, e.g. hydrogel, wood, sand, stones, wire or geotextile (Howell 2001; Lammeranner et al. 2005; Burri et al. 2009; Dass et al. 2010) to (1) stabilize soil structure by roots, (2) protect soil from water erosion, (3) increase water absorption by plants, (4) act as barrier for decreasing runoff and interflow and (5) act as trap for soil material moving down slope (Donat 1995; Preti and Giadrossich 2009; Thomaz and Luiz 2010; Stokes et al. 2013). Several studies showed the successful implementation of bioengineered measures against soil degradation (Schiechtl 1985; Donat 1995; Petrone and Preti 2008; Evette et al. 2009), also for pastures (Lammeranner et al. 2005; Zuazo et al. 2007; Thomaz and Luiz 2010; Bhandari 2014). Main advantage of bioengineered measured is given by their persistence as plants are adapting to existing vegetation and forming new vegetation cover. Contemporaneously they assume ecological functions compared e.g. to mechanical measures against soil erosion. Measures for care are reduced to short initial start up phase and costs for implementation and maintenance are low (Schiechtl 1985; Evette et al. 2009; Petrone and Preti 2009). For this reasons bio-engineered measures for reducing soil erosion on sloped pastures were developed at a pilot area 6 km southeast of Itaocara city and adjusted into an action plan. Itaocara is a small municipality with about 23,000 inhabitants, about 270 km in north-eastern direction to the capital Rio de Janeiro. The pilot area is illustrated within Fig. 5.2, showing a slope with proceeded soil erosion.

Fig. 5.2 Illustration of slope of pilot area at Itaocara, Rio de Janeiro from 06/2015 (*above*) and 06/2016 (*below*), © Roman Seliger

Slope of pilot area (about 3.3 ha) range from 8.5° to 24° It is used as pasture land for dairy cattle farming. To avoid spreading of bushes they were cut off. In addition, farmer practice top-down hill tillage for cultivation of pastures to assure yield. As a consequence, ecosystem services are impaired significantly. Due to long lasting loss of native vegetation (deforestation) and unsuitable agricultural practices pastures are affected by soil erosion.

Soil erosion processes as a major reason of land degradation needs to be more analysed, controlled and decelerated in order to guarantee future land productivity and conservation before irreversible tipping points of land resilience are reached. Main erosion drivers in the project area are a changing climate towards higher frequency and intensity of rainfall events on the one hand and shortened rainy seasons on the other hand (Dereczynski et al. 2013), rapid mineralisation of organic matter due to tropical Aw-climate, hilly mountainous landscape with majority of moderately-steep to steep slopes (70% of province area) and minority of plain areas (3% of province area nearly level or very gently sloping). Moreover land degradation is driven by erosion susceptible clay-rich soils (Acrisols) on top of structural saprolite, past and present high loss or degradation of vegetation as well as vast cattle farming on differently cultivated pastures.

Basic Natural Conditions in the Municipality of Itaocara

The municipality of Itaocara belongs to the hydrographic region VII Rios dois Rios and drains into the Paraibo do Sul River. The hilly-mountainous landscape with altitudes ranging from 40 to 620 m is dominated by moderately to steep slopes (8.5°–24°). Pre-cambric gneisses of the Rio Negro Complex (ortho-gneiss and migmatite) and of the Serra dos Orgãos Batholiths (ortho-gneiss) are interrupted by two northeast-southwest trending thin ridgelines out of marble and quartzite. The river and creek valleys consist of clayey-sandy sediments from recent fluvial accumulation as well as older alluvial and colluvial formations from the Holocene. The deeply weathered crystalline bedrock forms massive saprolites on which mainly red-yellow Acrisols (Argissolo Vermelho-Amarelo) and sporadic red Acrisols (Argissolo Vermelho) have developed (DRZ 2012). The acid and strongly weathered Acrisols show high clay and aluminium content in the subsoil (argic-horizon) that requires liming and fertilizing in order to enable worthwhile land-use (IUSS Working Group WRB 2015). The saprolite is highly vulnerable to water erosion, obviously visible in the landscape. This erosion takes mainly place on rather steep pastures with low vegetation cover and a distinct loss and/or compaction of the top-soil due to permanent cattle farming. A tropical Aw-climate (according to Köppen and Geiger) accelerates the erosion process.

Selection Criteria for Pilot Area

The pilot area 6 km southeast of Itaocara city represents regional-typical site conditions and pasture management practices. Located right next to the state road RJ 116, the pasture has been used for cattle farming since the beginning of the twentieth century. Sheet erosion, rills, gullies and cattle tracks are the main erosion types showing a moderate to severe erosion degree and extent. Moderately degraded areas are preferably recommended for rehabilitation measures due to an expected high impact of the measure at rather low costs. The property size of 22.5 ha corresponds to small to medium farm-size, typical for this region. Apart from a great visibility and accessibility of the study area, the proximity to RJ 116 also raises awareness for the measure, supports training activities with farmers and local stakeholders and facilitates transport and storage of measure-related materials. On the pilot area access to water for irrigation (pond) and electricity are available.

Methodology

Ongoing research within the INTECRAL project on soil erosion and land degradation in the province of Itaocara focus on scientific and participatory assessment and monitoring of pasture degradation indicators, analysis of legal and environmental pre-conditions for appropriated, pragmatic and cost-effective rehabilitation measures. Besides implementation and monitoring of a pilot measure against soil erosion in Itaocara, soil characteristics, vegetation, climate conditions, intensity and forms of erosion were analysed in the region to explain better status and causes for increasing soil erosion.

Areas of higher slope degrees, decreased or low vegetation cover and high precipitation maxima are considered as vulnerable to water erosion. Slope degrees and surface runoff paths are derived using a 20 m DEM (digital elevation model, source: IBGE). Vegetation cover was derived from NDVI (Normalized Difference Vegetation Index) statistical regression analysis over a period from 2000 to 2014 using Landsat TM/ETM imagery (thematic mapper/enhanced thematic mapper), done at the Institute of Geography at Friedrich Schiller University of Jena (Germany). The increase respective decrease of the NDVI value corresponds to the positive or negative change trend of vegetation cover. The statistical correlation between the annual values and the calculated regression rises if larger areas show the same tendency. Areas with both, a continuous decrease of the NDVI value or a permanent low NDVI-value over time were considered as areas with decreased resp. low vegetation cover. The year-to-year NDVI-value analysis also enables to distinguish pasture land from arable land, since on latter, frequently alternating annual NDVI values are expected compared to rather stable NDVI-values of pasture areas. Precipitation data recorded by the Brazilian National Institute for

Meteorology (INMET) was analysed for weather stations near Itaocara, combined with locally available data recorded at the Pesagro Itaocara station for the last 36 years (Fig. 5.3).

Current land-use and land-cover (LULC) is derived from a pre-processed Landsat8 image (30 m resolution) composite with images representing both, dry and rainy seasons from 2014 to 2016 with no or low cloud coverage. The stand-alone Remote Sensing Module *ILMSimage 2.4* (Selsam and Schwartze 2016) was used for object based image analysis such as segmentation, feature retrieval and LULC classification. On selected pastures with low, medium and high erosion vulnerability, present erosion forms (sheet, rills, cattle tracks and gullies) are identified on aerial imagery from 1970 and 2006. Their number, slope-position and geometry are measured on-site supplemented by high resolution (less than 10 cm) drone image analysis. Additionally, information on past and present land use types, pasture management practices and farmers' perception of land degradation and visions for future land management was gained from interviews with local cattle farmers.

Physico-chemical soil properties relevant to erosion were analysed on several pastures of different age, management, slope position and erosion degree. In addition, soils under crop farming, forest fragments, forest succession or eucalyptus plantation are also analysed for obtaining reference values to pastures. Four soil sampling spots have been placed in and near the study area combined with vegetation analysis carried out within. Plots from 10 × 10 m located on flanks, sinks and knowes of pastures and tree-covered areas of different age and cultivation status were investigated. Information on vegetation quality and coverage on pasture was derived from analysis on diversity and density of indicator species (University of Leipzig, Institute for Geography). Locations of sampling places for pilot area near Itaocara are illustrated in Fig. 5.4.

Based on results of inventory established by participating project partners a concept for technical implementation of bioengineered measures adapted to the pilot area was developed. In regard to reduction of erosion hedge terraces were applied on the slope to decrease surface runoff and interflow. Areas with extended gullies were stabilized by palisades and bare soil re-vegetated by seeding and sod

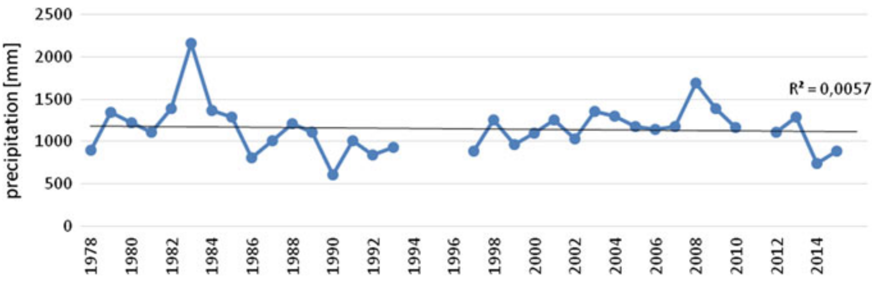


Fig. 5.3 Total annual precipitations (mm) near Itaocara city, rain gauge 6 km far from the pilot area (S 21° 38′ 23.40, W 42° 2′ 30.08), © Pesagro-Rio

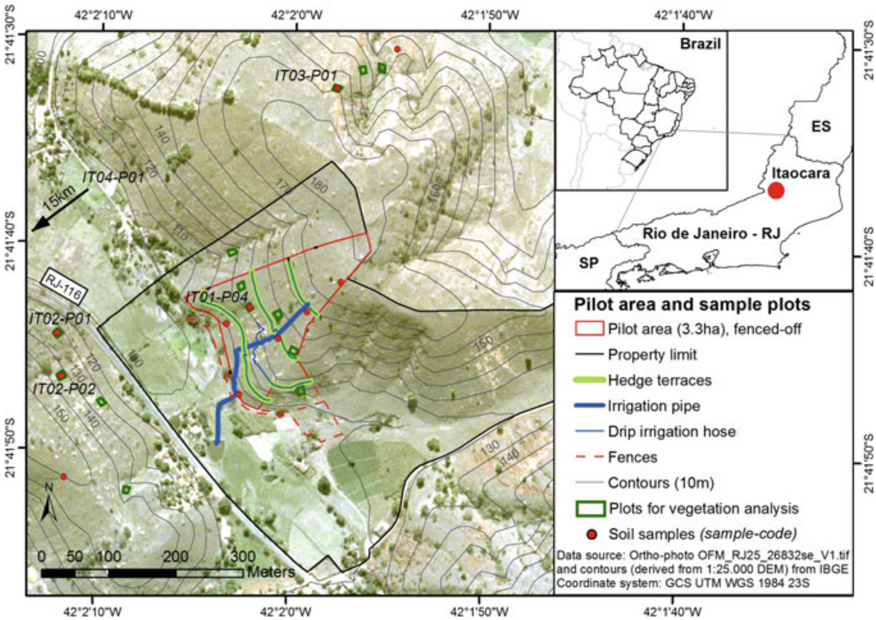


Fig. 5.4 Basic design for bioengineered measured to be realized at pilot area, © Roman Seliger

Table 5.1 Developed bioengineered in situ measures in chronological order

Measure	Time/time period
Construction of bush layer/hedge terraces	06–10/2015
Installation of palisades	06–10/2015
Ox-ploughing/seeding of *Brachiaria spec*.	11/2015
Transplantation of grass sods	04/2016
Monitoring	11/2015, 04/2016, 09/2016 (scheduled)

planting. Three fenced-off control areas (each 20 × 10 m in size) placed on all three parcels each along the northwest border of the pilot area served as reference areas where no direct human/cattle impact was taking place anymore.

Effectiveness of measures was supervised by a subsequent monitoring. To ensure a further sustainable management a concept was developed. This management concept includes practices on soil cultivation including tilling and fertilization, maintenance of hedge terraces and prevention of unintentional growth of bushes and trees as well as extensive cattle farming. All main bioengineered measures developed on pilot area are summarized in Table 5.1. Major implementation work was carried out during the dry season lasting from June to August 2015 in order to avoid intense and long rain events.

In preparation of installation of hedge terraces three terraces had to be constructed at the slope. The construction was realized using a rotary hoe. In Fig. 5.4 the location and course of the terraces in the pilot area is illustrated. The terraces course followed roughly the contour lines of 160, 140 and 120 m a.s.l respectively. The profile depth of each terrace was set to approximately 80 cm, which results in an upslope directed flank of about 20–30 cm, depending on gradient of slope. Upper terrace had a total length of 93 m, middle terrace of 149 m and lower terrace of 273 m.

The terraces were set to cross areas with progressive erosion forms such as rills. Greatest dimensions of gullies amounted up to 75 cm depth and 5–6 m wide. Terraces itself pose as element for decrease of surface runoff and interflow. This effect was enhanced by planting of each terrace. Roots of plants contribute to stabilization of soil. Moreover, vegetation cover adsorbs water, increases infiltration and prevents soil from wind and water erosion (Montgomery 2007). Therefore 5 tree species were planted: *Chloroleucon tortum*, *Machaerium nyctitans*, *Schinus terebinthifolius*, *Anadenanthera colubrina var. cebil* and *Enterolobium contortisiliquum*. In total 2433 pre-cultivated plants with a total height of 1.10–1.20 m (one shoot, pre-cultivated in bags) with a distance of 20 cm in between were planted on all three terraces. All species were planted horizontally to base of terrace. For improving growth conditions each plant was supplied with about 0.5 L of Hydrogel (Forth©, Gel para plantio). Precautionary a device for drip-irrigation was installed following the course of terraces for guarantee of water supply during prolonged dry and hot periods. To protect newly planted hedges from potential damage by cattle a mobile electric fence was temporary established.

Within the range of subset erosion structures such as rills palisades were constructed against proceeding erosion. In total 16 palisades were installed on the pilot area. They consist of vertical pillars from eucalyptus (2 m height) with a distance of 1–1.7 m in between and horizontally installed cut bamboo stems. Pillars are installed in soil by approximately $^1/_3$ of their total length. Depending on wide of gully structure 3 respective 5 pillars were set. In hillside direction cut bamboo stems were fixed up to a height of approximately 80–120 cm above ground. The base of bamboo stems was set about 10–20 cm below ground level.

Chosen material and machines were local available and cost-efficient. This makes them economic feasible for reducing degradation of soil. Moreover it was intended to install eco-friendly material renouncing slowly rotting materials like plastics. The structure of palisades horizontal to slope warrants an accumulation of colluvium at the backside of construction. This decreases the intensity of relocation of soil particles by sedimentation and succession.

Areas of compacted and unvegetated soil were ox-ploughed parallel to the slope for loosening of soil in preparation of seeding with grass (*Brachiaria spec.*). Within areas of missing germination or inaccessibility for ox-ploughing grass sods were re-planted. Therefore, a donator area was chosen in direct vicinity of pilot area. Using a sample ring of 10 cm diameter (15 cm height) grass sods were cut out until a depth of about 10 cm. Grass sods were transported to target area where planting holes were dug using sample ring. Before re-planting of grass sods about 100 mL of

Hydrogel was added to each planting holes. About 40 sods were transplanted resulting in a total planted area of 10–15 m^2. Overall objective was to set basis for spread of vegetation on former unvegetated areas.

The hedges subdivide the pilot area into three parcels, an intended strategy for implementation of improved pasture management. The underlying intention of concept was the realization of selective pasturing of the three parcels. The access to each parcel is warranted by 2 wide apart gates, ensuring no permanent one-sided usage of paths between parcels. Moreover, recommendations on pre-pasturing (short time pasturing of selected areas on start of vegetation season) or rotating usage of parcels are included within management concept.

Implemented measures are still monitored twice since beginning of project. University of Leipzig documented inter alia growth of vegetation (hedges, grass). Additionally, selected erosion structures were surveyed. Integral supervision of all measures was conducted by remote sensing.

Monitoring of bioengineered methods comprised recording of sediment loss and gain at palisades both-sided (up-slope and down-slope) by measuring distance between top of eucalyptus pillars and between pillars to ground level using laser measuring. Monitoring was conducted in November 2015 (t1) and April 2016 (t2). The deviation of measured values at one point from t1 to t2 provides information on sediment dislocation on punctual scale.

Preliminary Results

Soil samples taken near the pilot area (IT01-IT03, Fig. 5.4) represent strongly weathered dystrophic red-yellow Acrisols at upper and middle slopes under various LULC and erosion types. Sample IT04 was taken in a region characterized by eutrophic red Acrisols, 15 km southwest of the pilot area. Samples were taken at 0–10 cm and 30–40 cm depth representing A- and transition zone AB/BA or beginning Bt-horizon showing sandy clay loam to sandy clay texture with a remarkable decrease of Corg up to 40 cm soil depth. Shallow soil layers are strongly compacted due to cattle ranching showing bulk-density above 1.19 g/cm^3 (Table 5.2) with weak microstructures and massive macrostructures. Low CEC (cation exchange capacity), base saturation and nutrient availability as well as high Al-toxicity further complicate a profitable and sustainable pasture management.

Overall objective for implemented bioengineered measures was the reduction of soil erosion on slope of pilot area. A feasible tool for monitoring of developed measures is rating of vegetation and determination of sediment accumulation respective degradation at palisades. Growth of planted hedges was monitored using vitality of plants, pest infestation and plant height. Results from vegetation analysis are under preparation by Sattler et al. (University of Leipzig).

In Fig. 5.5 results from monitoring of sediment accumulation and degradation is illustrated for palisade 15, as an example. Results are presented as deviations between first monitoring in November 2015 (t1) and second in April 2016 (t2).

Table 5.2 Physico-chemical soil properties of soil samples taken within/near pilot area (I: 0–10 cm, II: 30–40 cm) under different LULC-types (1-pasture, 2-former pasture, 3-forest succession, f-flank, k-knowe) and presence of erosion types (c-cattle track, g-gully, r-rill, s-sheet erosion)

Sample	LULC-(position)	Erosion type	Bulk density (g/cm^3)	Corg (g/kg)	pH (1:2.5) H_2O	CEC at pH 7, ($mmol_c/kg$)	Grain fraction (g/kg)		
							Total sand	Silt	Clay
IT01P04-(I)	1-(f)	c, r, s	1.29	17.5	5.4	53.5	580	210	210
IT01P04-(II)	1-(f)	c, r, s	1.34	9.3	5.2	44.1	500	220	280
IT02P01-(I)	3-(k)	No	1.26	21.1	5.3	66.2	560	130	310
IT02P01-(II)	3-(k)	No	1.27	8.4	4.7	33.9	390	170	440
IT02P02-(I)	1-(k)	c, s	1.18	15.4	4.8	39.3	590	120	290
IT02P02-(II)	1-(k)	c, s	1.19	7.6	4.6	39.0	330	130	540
IT03P01-(I)	1-(k)	c, g	1.22	14.4	4.9	40.3	510	190	300
IT03P01-(II)	1-(k)	c, g	1.20	8.4	4.9	28.5	430	170	400
IT04P01-(I)	2-(k)	No	1.19	19.3	5.9	70.2	470	320	210
IT04P01-(II)	2-(k)	No	1.19	13.4	5.8	68.7	380	320	300

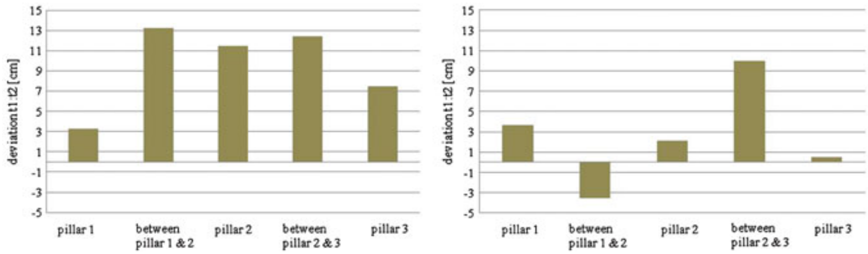


Fig. 5.5 Monitoring results for palisade 15, delta of measurements between t1 and t2 up-slope (*left*) and down-slope (*right*)

For analyzing dislocation of sediment and assessment of efficiency up to now insufficient data are available. A monitoring which is scheduled for September 2016 is needed for final assessment.

Preliminary results up-slope of palisade 15 indicates an effective performance as a trap for sediments. Measurements down slope of palisade 15 show varying deviations. Metering point between pillar 1 and 2 was further investigated visually by reason of assumption of undercutting, although measurement error was set to 3 cm. A slight undercut was observed. In future this circumstance will be monitored in detail. If applicable the construction will be enhanced to avoid undercutting.

As illustrated in Fig. 5.6 the accumulated sediments uphill the palisade 15 built the base for succession which leads to stabilization and protection of soil. Further, the interruption of grazing contributes to establishment of vegetation cover. It is apparent that the rinsed structure downhill palisade 15 has not enlarged in depth and wide which points out the fact that palisade and vegetation cover hold back erosion drivers like unobstructed runoff and interflow.

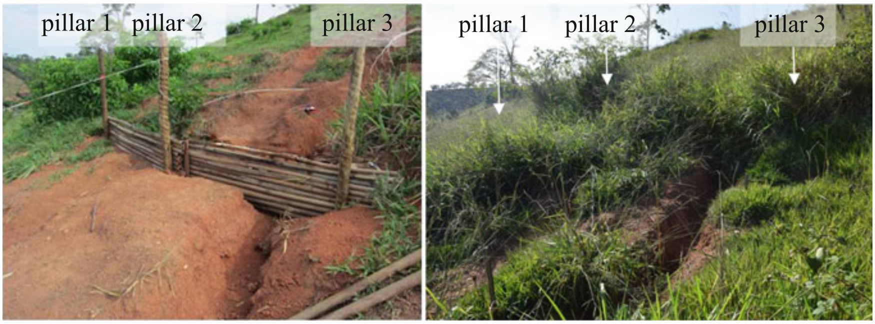


Fig. 5.6 Palisade 15 in November 2015 (*left*) and July 2016 (*right*), © Anja Hebner, Roman Seliger

Conclusion

The example shows that diminishing soil erosion on the pilot area was observable and measureable already 8 months after implementation. Developed bioengineered measurements in single and in combination offer low cost and efficient tools which can easily adapted to any other (pasture) locations affected by soil erosion. Not only *on site* effects of erosion can be diminished but also *off site* effects like input of soil particles into surface water, increase of flood events and impairment of water quality (Van Oost et al. 2007). Resulting this does not only contribute to ensure agro business of local farmers but also to national economic welfare (Pimentel et al. 1998; Martinelli et al. 2010). Within context of climate change implemented measures proved as an effective tool for reducing progressive climate change which leads also to reduction in national investments for deletion of consequences of climatic change (Boardman et al. 2003).

Main challenges were existed in planning because of changes in the nature and availability of materials and labor. This extended the schedule for the realization of pilot measures partially. As development of measures was limited to end of dry season there were restraints by water scarcity during initial growth and germination to be expected. They were counteracted by irrigation during initial start-up-phase. Results from vegetation monitoring will be evaluated and published by University of Leipzig.

Final results will be available after finishing the monitoring scheduled in September 2016. Subsequent, data from vegetation monitoring, survey of erosion structures and from recording sediment accumulation and degradation at the palisades will be obtainable. This data pool will set the basis for the comprehensive evaluation of bioengineered measures. Moreover this should enable the determination of variables to be adjusted for potential transfer of measures to other pasture sites. However, preliminary results indicate that chosen measures are suitable for diminishing erosion on slope of pilot area as vegetation has adapted wide spread (see Fig. 5.6). Warranting persistence of the success of implemented measures it is required to keep the regulations of the management concept.

Further activities focus, beside on scheduled monitoring in September 2016, on training of government representatives and farmers whereas bioengineered measures will be taught, which contributes to more sustainable use of land and improvement of agricultural practices. The overall objective of these trainings comprises the transfer of knowledge for transferring bioengineered measures conducted on pilot area to further pastures affected by soil erosion. Stakeholders and local farmers will be made aware of the advantages of cost efficient and ecological sound bioengineered measurements against soil degradation.

Acknowledgements Described pilot investigations were undertaken by Vita 34 (business Unit BioPlanta) in close collaboration with University of Leipzig. The project was co-financed by Federal Ministry for Education and Science of Germany (BMBF, support code: 033L162G). We like to thank BMBF and the Rio de Janeiro State Secretariat of Agriculture and Livestock (SEAPEC) which hosted the Rio Rural project for assistance. Further thanks belong to teams of EMATER-Rio, PESAGRO-Rio and EMBRAPA Solos for their support.

References

Boardman J, Poesen J, Evans R (2003) Socio-economic factors in soil erosion and conservation. Environ Sci Policy 6(1):1–6

Bhandari G (2014) A review on soil erosion conservation measures in Nepal. Peak J Phys Environ Sci Res 2(3):41–47

Blaschke PM, Trustrum NA, Hicks DL (2000) Impacts of mass movement erosion on land productivity: a review. Prog Phys Geogr 24(1):21–52

Burri K, Grfa F, Böll A (2009) Revegetation measures improve soil aggregate stability: a case study of a landslide area in Central Switzerland. For Snow Landsc Res 82(1):45–60

Dass A, Sudhishri S, Lenka NK, Patnaik US (2010) Runoff capture through vegetative barriers and planting methodologies to reduce erosion, and improve soil moisture, fertility and crop productivity in southern Orissa, India. Nutr Cycl Agroecosyst 89:45–57

de Araújo JC, Döll P, Güntner A, Krol M, Abreu CBR, Hauschild M, Mendiondo EM (2004) Water scarcity under scenarios for global climate change and regional development in semiarid Northeastern Brazil. Water Int 29(2):209–220

Dereczynski C, Silva WL, Marengo J (2013) Detection and projections of climate change in Rio de Janeiro, Brazil. Am J Clim Chang 2(1):25–33

Donat M (1995) Bioengineering techniques for streambank restoration: a review of central European practices. Watershed Restoration Project Report No 2, Province of British Columbia, Ministry of Environment, Lands and Parks, and Ministry of Forests

DRZ Geotecnologia e Consultoria (2012) Plano Municipal de Saneamento Básico. Plano regional de saneamento com base municipalizada nas modalidades água, esgoto e drenagem urbana. Produto 4 – Diagnóstico setorial. – Itaocara, Rio de Janeiro

Evette A, Labonne S, Rey F, Liebault F, Jancke O, Girel J (2009) History of bioengineering techniques for erosion control in rivers in Western Europe. Environ Manag 43(6):972–984

Howell J (2001) Application of bio-engineering in slope stabilization: experience from Nepal. In: Tianchi L, Chalise SR, Upreti BN (eds) Landslide hazard mitigation in the Hindu Kush-Himalayas, pp 147–161

IBGE. http://mapas.ibge.gov.br/bases-e-referenciais/arquivos-raster. Accessed 10 May 2016

INMET. http://www.inmet.gov.br/portal/index.php?r=estacoes/estacoesAutomaticas. Accessed 19 Jan 2016

IUSS Working Group WRB (2015) World reference base for soil resources 2014, updated 2015. International soil classification system for naming soils and creating legends for soil maps. World Soil Resources Reports No 106. Food & Agriculture Organization, Rome

Lammeranner W, Rauch HP, Laaha G (2005) Implementation and monitoring of soil bioengineering measures at a landslide in the Middle Mountains of Nepal. Plant Soil 278:159–170

Martinelli LA, Naylor R, Vitousek PM, Moutinho P (2010) Agriculture in Brazil: impacts, costs, and opportunities for a sustainable future. Curr Opin Environ Sustain 2:431–438

Montgomery DR (2007) Soil erosion and agricultural sustainability. Proc Natl Acad Sci 104(33): 13268–13272

Petrone A, Preti F (2008) Suitability of soil bioengineering techniques in Central America: a case study in Nicaragua. Hydrol Earth Syst Sci Discuss Eur Geosci Union 5(1):379–403

Petrone A, Preti F (2009) Soil bioengineering for risk mitigation and environmental restoration in a humid tropical area. Hydrol Earth Syst Sci 14:239–250

Pimentel D, Burgess M (2013) Soil erosion threatens food production. Agriculture 3:443–463

Pimentel D, Harvey C, Resosudarmo P, Sinclair K, Kurz D, MacNair M, Crist S, Shpritz L, Fitton L, Saffouri R, Blair R (2004) Environmental and economic cost of soil erosion and conservation benefits. Science 267:1117–1123

Pimentel D, Kounang N (1998) Ecology of soil erosion in ecosystems. Ecosystems 1:416–426

Preti F, Giadrossich F (2009) Root reinforcement and slope bioengineering stabilization by Spanish Broom (*Spartium junceum L.*). Hydrol Earth Syst Sci 13:1713–1726

Schiechtl HM (1985) FAO Watershed Management Field Manual/F2888—vegetative and soil treatment measures. Food & Agriculture Organization, Rome

Selsam P, Schwartze C (2016) Remote sensing image analysis without expert knowledge—a web-based classification tool on top of Taverna workflow management system. World Multidisciplinary Earth Sciences Symposium, WMESS 2016, Prague (in press)

Sparovek G, Correchel V, Barretto AG (2007) The risk of erosion in Brazilian cultivated pastures. Sci Agricola 64(1):77–82

Stokes A, Grant BD, Fourcaud T, Giadrossich F, Gillies C, Hubble T, Kim JH, Loades KW, Mao Z, McIvor IR, Mickovski SB, Mitchell S, Osman N, Phillips C, Poesen J, Polster D, Preti F, Raymond P, Rey F, Schwarz M, Walker LR (2013) Ecological mitigation of hillslope instability: ten key issues facing researchers and practitioners. Agriculture 3:443–463

Thomaz EL, Luiz JC (2010) Soil loss, soil degradation and rehabilitation in a degraded land area in Guarapuava (Brazil). Land Degrad Dev 23:72–81

Van Oost K, Quine TA, Govers G, De Gryze S, Six J, Harden JW, Giraldez JV (2007) The impact of agricultural soil erosion on the global carbon cycle. Science 318(5850):626–629

van Oudenhoven APE, Veerkamp CJ, Alkemade R, Leemanns R (2015) Effects on different managements regimes on soil ersosion and surface runoff in semi-arid to sub-humid rangelands. J Arid Environ 121:100–111

Zuazo VHD, Pleguezuelo CRR (2007) Soil-erosion and runoff prevention by plant covers. A review. Agron Sustain Dev 28:65–86

Chapter 6
Eco-social Observatory of Climate Change Effects for High Altitude Wetlands of Tarapacá Region, Northern Chile

David E. Uribe-Rivera, Carolina Vera-Burgos, Maritza Paicho and Guillermo Espinoza

Introduction

Climate change is a global problem with regional and local consequences that may impact on different and complex ways, not only the physical environments but also biodiversity; therefore it is unavoidably that affect human population as well. Most of the evidences of such effects came from studies carried out on temperate areas (Root et al. 2003), however, because of the restricted climate conditions that tropical species are adapted to, it have been suggested that tropical species are more vulnerable than those from temperate environments (Deutsch et al. 2008; Feeley and Silman 2010). In addition to this, and since it is expected that the climate change effects will be stronger at higher altitudes, species inhabiting on mountain environments from tropical areas should be even more sensible than those on lowlands (Bradley et al. 2006; Vuille et al. 2008; McCain 2009; Larsen et al. 2011).

The huge lack of knowledge prevents to distinguish the climate change effects (understood as a long term phenomena) from those that are part of the natural climatic variability of this region. This uncertainty lead to stakeholders on natural resources management of this region do not consider climate change as a threat on the decision making processes, ignoring the possibility of planning under dynamic but uncertain climate scenarios (Castillo 2015).

In spite of the high vulnerability of this region, there is a poor understanding about which ecosystems processes control their own functionality, and even less on how those processes are interacting with climate processes on a regional scale, forcing changes in biodiversity or affecting life quality of local communities (Anderson et al. 2011). The most appropriate way to study and describe the mechanisms that control the climate change effects on the ecological and social systems, is to carry out a continuous and high quality monitoring on social, bio-

D.E. Uribe-Rivera · C. Vera-Burgos (✉) · M. Paicho · G. Espinoza
Centro de Estudios del Desarrollo (CED), 551 San Crescente, 7550347 Santiago, Chile
e-mail: cverabu@gmail.com

W. Leal Filho and L. Esteves de Freitas (eds.), *Climate Change Adaptation in Latin America*, Climate Change Management,
https://doi.org/10.1007/978-3-319-56946-8_6

logical and physical variables, being this essential to detect long term patterns (Conly and Van der Kamp 2001).

Northern Chile is characterized by extreme aridity of the Atacama Desert, mainly due to the subtropical anticyclone of the southeast Pacific, which produces atmospheric stability; and due to the double and pronounced rain shadow by the Coastal Range (>1000 m) and the central Andes (>4000 m), which impede the advance of humid air masses from the Pacific Ocean and from the Amazon Basin, respectively (Houston and Hartley 2003). Climates of the region are also characterized by strong altitudinal gradients which define the geographic patterns of climates: the coast and Coastal Range have a Coastal Desert climate (0–1000 m), with high humidity but scares or null precipitations (means of less than 2 mm per year); between 1000 and 2000 m, the climates are classified as Inland Deserts, with high thermal oscillation, solar radiation and evaporation, and null precipitations; the Andean foothills (i.e., 2000–3300 m) has a mild desert climate, with high temperature oscillation due to the scarce humidity, and a marked altitudinal gradient in precipitations, which starts on 0 mm in its lower altitudinal limit, and 100 mm of precipitations in its upper altitudinal limit. The Andean highlands (i.e., >3300 m) has a cold desert climate, specifically the Andean steppe, with mean annual temperatures below 5 °C, high solar radiation, and wet summers (Garreaud et al. 2003).

These hard climatic conditions restrict the life to the surroundings areas of limited wetlands, making them the most productive ecosystems in the region, therefore providing the most of the ecosystem goods and services to the human population. This gives to the wetlands of northern Chile a greater ecological, social and cultural relevance, becoming noticeable that during the last thousands of years local communities develop their life in or around those ecosystems and their natural cycles (Núñez et al. 2002).

High altitudes wetlands cover only about 3% of the Earth surface (Maltby and Immirzi 1993), however it is estimated that their soils storage about 30% of the total carbon storage from terrestrial ecosystems, being considered carbon sinks of global relevance (Blodau 2002). Unlike forests, wetlands have not trickled down on the anthropogenic climate change management with the relevance that they should reach, given their high capacity of carbon sequestration from the atmosphere, representing an underexplored management opportunity. This is more evident in regions where such ecosystems have not been studied, since there is no empirical basis on which to support management actions. In this context, Chile is not an exception: most of the legal instruments related with this ecosystems protection do not even mention climate change (Castillo 2015), meanwhile legal instruments concerning climate change do not mention wetlands as a potential regulators on climate change on a regional scale (CED–CEH 2012).

Despite the high environmental, social and economic costs predicted as a climate change consequence, these have been rarely evaluated from a social perspective. The Observatory proposed to use the community knowledge to ask socio-environmental questions about climate change. An advantage of local knowledge is that this can be rapid and efficiently evaluated (Sutherland et al. 2014), unlike what happens with the observational study of climate change effects. Such knowledge can generate new research hypotheses, and provide tools to design management actions in face of climate change scenarios (Reidlinger and Berkes 2001; Alexander et al. 2011; Chaudhary and Bawa 2011; Turnhout et al. 2012). The need of a multidisciplinary approach that integrates different knowledge systems (including indigenous and local knowledge) in the climate change effects assessment arise as imperative, as the Intergovernmental Platform on Biodiversity and Ecosystem Services recommend (Díaz et al. 2015).

In Northern Chile in general and in the Central Andean Puna ecoregions (*sensu* Olson et al. 2001) in particular, changes on seasonality and intensity of precipitations—becoming less frequent but more intense—and also an increase on temperatures are expected during the 21st century (Marengo et al. 2011; Steinhoff et al. 2015; López-Franca et al. 2016). Predict how wetlands will respond to these changes and the potential consequences that they will have on human welfare is the main objective of this Observatory. The specific objectives are (i) monitoring climatic behavior in selected high altitude wetlands of the Tarapacá Region, (ii) monitoring selected biotic indicators of climate change effects on high altitude wetlands of the Tarapacá Region, (iii) describe and monitor the perceptions of key stakeholders of the Tarapacá Region about climate change and their incidence on their welfare.

With the implementation of the Observatory we expect to (i) generate the information needed to improve decision-making on management of high altitude wetlands in the Chilean Puna in a climatic change context, (ii) promote the transfer of such information to policy and management instruments, and (iii) promote the implementation of management measures that take into account the dynamics of such ecosystems to future climate change scenarios.

Methods

Wetlands Selection

For the selection of the study sites, we considered the following a priori established criteria: (i) the availability of meteorological data or climate proxies in the latest three decades, preferably in the vicinity of the wetlands or in the basins where they are located, (ii) to provide and arrange all the documentation and permits that facilitate the biotic studies (e.g., permits from local communities and authorities), (iii) that they present different levels of dependence to water sources, and (iv) that they can share similarities in their nature but contrasts in the degree of anthropogenic disturbance, giving the chance to attribute causality to observed changes.

In order to collect the information needed to assess the selection criteria before the implementation of a long term research project for monitoring the effects of global changes on high altitude wetlands in Chile, the Centro de Estudios de Humedales (CEH) performed an inventory of wetlands (CONADI/CED–CEH 2012) and the creation of an integrated geographic information system which considered a multi-temporal analysis on focal wetlands (CED–CEH 2010), an inventory and characterization of weather stations (hydro/climatic stations), and the selection of priority watersheds for monitoring the effects of climate change (CED–CEH 2011). In addition, a number of studies oriented to generate knowledge regarding the relationships between climate change and anthropogenic disturbances on the functioning of these wetlands were performed (CED–CEH 2012; MMA/CED–CEH 2013). In those studies, and due to the marked altitudinal gradient of climates, two types of main wetlands were defined: high altitude (>3500 m) and Andean foothill wetlands (2500–3500 m).

Monitoring Variables Selection

We searched ISI Web of Knowledge database (1989–2012) and Scholar Google, in order to identify the variables to monitor: physical environment variables, components of biodiversity and climate change perceptual indicators for local communities. The combinations of the keywords used were: (i) Wetland* + * + monitor climate change; (ii) climate change Wetland* + * + indicat; (iii) Wetland* + integrity + indicat*; and (iv) Wetland + integrity + monitor*. The search was complemented with non-conventional literature mainly technical reports of public services with competence in the environmental area. The information was classified by component (i.e., physical, biological, and social environment). From this information and expert consultation, a small number of variables and the frequency in which each of them would be monitored were selected.

Physical Environment

From the hydro-climatic data network for the Tarapacá Region (CED–CEH 2011), big spatial and temporal gaps were identified on the measurements of the current operative stations network. Taking that into account, and with the previous selection of the wetlands to be monitored, meteorological stations were installed to give observational autonomy to the monitoring, incorporating variables and improving the frequency of the meteorological measurements. Besides that, and considering that most of the watersheds from the Puna biogeographic region are closed systems that end in evaporation water bodies conforming salt lakes (Risacher et al. 2003), an evaporimeter was installed near the salt lake of Salar del Huasco, and one will soon be installed near the Saline Lagoon of Lagunillas.

Biodiversity

A compilation of all the biological indicators of climate change was generated, selecting those that meet a set of a priori established criteria modified from Everard (2008), and adapted to the focus of this Observatory, the effects of climate change. The selection criteria were:

(i) Indicators must be relevant to policy and management practice;
(ii) Population data must be robust and cost-effective to collect;
(iii) Taxa selected should depend to some extent upon habitats of conservation concern, or at the very least a representative sample of them;
(iv) Taxa must be widespread so that sample size is sufficient and assessments of spatial and/or temporal changes and trends can be made with confidence;
(v) Taxa must also be sufficiently common for adequate representation in an unbiased sampling strategy. Ideally, random stratified or other random site selection is needed to avoid auto-correlation but, if an unbiased sampling method is unattainable, the bias needs to be consistent and known for reliable trend analyses to be achieved;
(vi) Taxa must respond in a predictable way to pressures, ideally reacting quickly to reflect changes in ecosystem health;
(vii) Data must be robust enough for statistical analysis to enable accurate assessment of error, support determination of trends over time, measure rate of change and changes in the rate, and (ideally) also sustain analysis at finer spatial scales.

Given the scarce knowledge regarding biodiversity of the Puna ecoregions, and after the selection of the wetlands, all the biodiversity assessments available from public databases (e.g., Chilean National System of Environmental Information SINIA, http://www.sinia.cl/; National Digital Library, http://www.bibliotecanacionaldigital.cl/) were identified, particularly those carried out under the environmental regulations framework for approval of investment projects (Chilean environmental impact assessment system, http://www.seia.gob.cl/) in selected wetlands and its vicinity (sub-basin spatial scale). These initiatives were used as background information to assess the compliance of the previously described criteria for selecting taxa as potential indicators of climate change for the Puna of Tarapacá Region.

Social Component

In order to complement the monitoring of physic and biotic variables, we are currently designing an instrument to describe and monitor local perceptions about climate change and its implications on both, biodiversity and productive processes that affect their welfare. This instrument will be a semi-structured survey, and is being developed according to the local reality. It is being designed to answer the following questions: (1) How do local the communities perceive the climate variability and changes across time? (2) Do the local communities perceive any response of biodiversity to climate changes, and (3) Do the local community perceives any effect of climate variability on their welfare?

The design of the instrument addressed the following steps: (i) a review of the state of the art, including the most commonly used approaches to assess local perceptions, (ii) focal interviews with key stakeholders of the region, (iii) expert consulting to generate a first draft of the instrument, and (iv) validation through massive application, and adjustment if its necessary.

Results

Wetlands Selection

CED–CEH (2011) study identified the Salar del Huasco Sub-basin as the most suitable to carry on climate change effects studies because of his low anthropogenic disturbances (i.e., no mega-mining projects, no industrial water extraction, nor other common high impact disturbances on the region). From this Salar del Huasco was selected as the first high altitude wetland. Salar de Lagunillas was selected because of his common origin and nature to Salar del Huasco, both being located between 3800 and 4100 m.a.s.l., in contiguous sub-basins, both endorheic, but with contrasting anthropogenic disturbances (by industrial water extraction in Lagunillas Sub-basin; Carrasco et al. 2005). In the case of Andean foothills wetlands, the selection would ideally include wetlands from foothills sub-basins contiguous to Salar del Huasco and Lagunillas ones, however, this was not possible since no agreements was reach with local communities. In their replacement the high altitude Fertile Plaine of Copaquire, which display low disturbances, and is located on the Salar de Llamara Sub-basin; and the Iquiuca-Parca Ravine Wetland, with historical and current disturbances from subsistence agriculture from local communities (Luebert 2004; CONADI/CED–CEH 2012) were selected. Both Andean foothill wetlands are located on the western slope of the central Andes (Fig. 6.1).

Monitored Variables

Since 2013, weather stations and fix monitoring stations for biodiversity were established in each of the four study sites. Table 6.1 summarizes the variables monitored by each component (i.e., physical, biotic and social components), the methods used for each monitored variable, wetlands where each of them is being monitored, and their frequency.

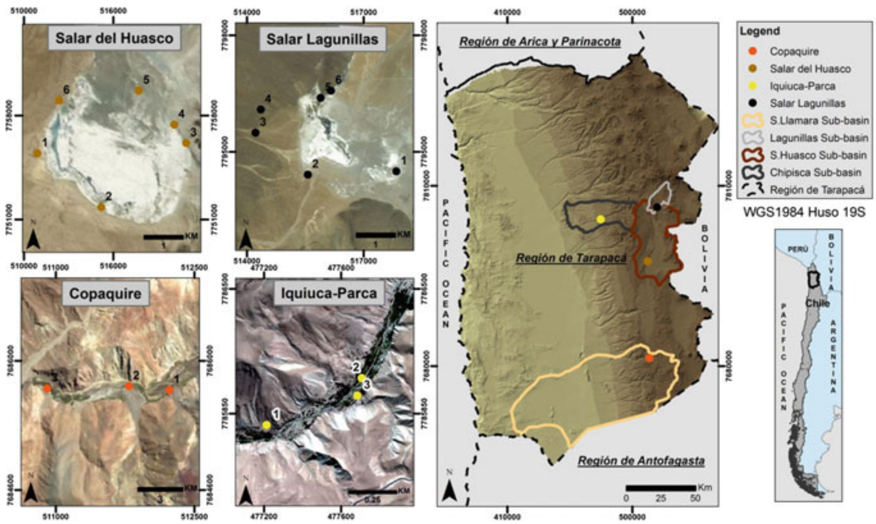


Fig. 6.1 Map of the selected wetlands for the ecological–social observatory of climate change effects

Physical Environment

In addition to the installation and administration of meteorological stations, the review of variables to monitor identified to water physicochemical parameters as a group of relevant variables. These variables are highly variable both in time and space (Labaugh et al. 1987) and have large implications for wetland ecology (e.g., Donald et al. 1999) allowing to follow changes in habitat quality for aquatic species, either as a result of effects of climate change, or as a result of other anthropogenic disturbances.

Biodiversity

According to the literature review, a compilation of climate change indicators was made. Due to the lack of previous research that allows to demonstrate the compliance of all selection criteria by a taxa as a potential biological indicator of the climate change effects, they were prioritized in the selection to those that evidence from other similar initiatives in other parts of globe demonstrate a clear relationship between the indicator and variability of climate (i.e., satisfying the sixth selection criterion). Micromammals, plankton, aquatic birds and vascular plants were selected this way.

With the aim of clarify the mechanism behind the observed changes in the selected taxa (e.g.. direct and indirect effects of climate transmitted through trophic webs; Gilman et al. 2010; Frau et al. 2015), we designed monitoring at different

Table 6.1 Variables monitored by each component (i.e., physical, biotic and social components), methods used for each monitored variable, wetlands where each of them is being monitored, and their frequency

Component	Indicators	Variables	Methods	Locality	Frequency	Starting
Physical environment	Physicochemical parameters of water	pH, oxide-reduction potential, conductivity, total dissolved solids, salinity, resistivity, dissolved oxygen, temperature	In situ measuring	Streams (S. del Huasco, S. de Lagunillas, Iquiuca-Parca and Copaquire) and salt lakes (S. del Huasco and S. de Lagunillas)	Austral spring and autumn (April–May and November–December, respectively)	Autumn 2013
	Meteorology	Temperature, relative humidity, wind speed, wind direction, solar radiation, precipitations, evaporation	Weather stations	S. del Huasco, S. de Lagunillas, Iquiuca-Parca and Copaquire	Every 15 min	June 2013
Biodiversity	Small mammals	Population densities	Mark-capture–recapture	S. del Huasco, S. de Lagunillas, Iquiuca-Parca and Copaquire	Austral spring and autumn (April–May and November–December, respectively)	Autumn 2013
	Aquatic birds	Total abundance	Bird census	S. del Huasco and S. de Lagunillas	Austral spring and autumn (April–May and November–December, respectively)	Autumn 2013
	Zooplankton	Population densities	Sieving at fixed stations	Streams (S. del Huasco, S. de Lagunillas, Iquiuca-Parca and Copaquire) and salt	Austral spring and autumn (April–May and November–	Autumn 2013

(continued)

Table 6.1 (continued)

Component	Indicators	Variables	Methods	Locality	Frequency	Starting
				lakes (S. del Huasco and S. de Lagunillas)	December, respectively)	
	Phytoplankton	Population densities	Counting in Utermöhl settling chambers	Streams (S. del Huasco, S. de Lagunillas, Iquiuca-Parca and Copaquire) and salt lakes (S. del Huasco and S. de Lagunillas)	Austral spring and autumn (April–May and November–December, respectively)	Autumn 2013
	Seed banks	Seed densities in superficial soil	Counting of seeds in fixed volume samples	S. del Huasco, S. de Lagunillas, Iquiuca-Parca and Copaquire	Austral spring and autumn (April–May and November–December, respectively)	Autumn 2013
	Flowering phenology	Flowering phases	Direct observation of marked individuals	S. del Huasco, S. de Lagunillas, Iquiuca-Parca and Copaquire	Every 15 days (October–April)	October 2014
	Carbon cycling related ecosystem functions	Annual net ecosystem carbon and water exchange of bofedales (H_2O, CO_2, CH_4); annual ecosystem respiration; annual gross ecosystem production of bofedales	Eddy covariance system	Salar del Huasco	Every 15 min	Proposed
Social component	Local perceptions of climate change	Local perceptions of climate change per se; local perceptions of the effects of climate change on biodiversity; local perceptions of the effects of climate change on their own welfare	Household interviews, focused group discussions and quantitative surveys	Inland territory of Región de Tarapacá	Once a year	2017

levels in two focus trophic webs: phytoplankton-zooplankton-aquatic birds (especially flamingos, main predators on salt lakes in the central Andes Puna; Hurlbert and Chang 1983; Mascitti and Kravetz 2002); seeds–micromammals.

Finally, flowering phenology of vascular plants was implemented on the monitoring (i.e., monitoring the inter-annual seasonality of focus species flowering), which has been reported as one of the most closely linked biological indicator with environmental seasonality, so they provide one of the most convincing evidence that species and ecosystems have been influenced by climate change (Cleland et al. 2007).

Besides the indicators already being monitored, the Observatory propose to implement in the future at least one eddy covariance system to estimate the exchange of greenhouse gases (i.e., H_2O, CO_2 and CH_4) between ecosystems and the atmosphere as a product of the ecosystem functions (e.g., primary productivity and ecosystem respiration) in endemic peatlands of the central Andes Puna called bofedales, which play an important role as carbon sinks, but nevertheless its functionality and the influence that the climate would have on them have not been studied (Squeo et al. 2006; Hribljan et al. 2015). Greenhouse gases exchange between wetlands and the atmosphere has been identified as one of the most relevant climate change indicators for high altitude wetlands for the Tarapacá Region, but the high costs have prevented its monitoring at the moment. Raising funds for the monitoring establishment of this variable is one of the current priorities for the Observatory.

Social Component

Monitoring local perceptions of climate change will recognize the perspective of local communities and include their perception on an active, dynamic and contextual way, providing to the Observatory an integral understanding of the consequences of climate change and how to deal with its consequences.

The current progress in the instrument is not enough to be validated through its massive application. However, it should be validated on 2017. The sample to be considered will segregate the stakeholders by socio-cultural and geographical origin, allowing to assess differences in the perception of climate change between ethnic groups with different cultural practices and meanings (Chaudhary and Bawa 2011) and between groups from different geographical areas, given the current climate variability and projected changes are expected to be different between the high and lowlands (Bennett et al. 2016).

The validated (and eventually adjusted) instrument will be applied once a year to a selection of relevant stakeholders, allowing to contrast the evidence collected through monitoring of physical and biological components against the interpretation of patterns in the perception of local communities on the climate variability and its effects. The development of the instrument will take place in the following stages:

(a) Identification of essential concepts and potential perceptual indicators of climate change. Potential indicators will be classified within a conceptual matrix of questions related to local perceptions of climate change. Preliminary hypotheses for its contrast will be generated through this instrument.
(b) Expert consultation, through focused workshops for concepts, indicators, questions and hypotheses validation.
(c) In-depth interviews in the territorial contexts of stakeholders, in order to take account of the different geographical and social realities.
(d) Testing of the instrument, from its application to a limited number of stakeholders.
(e) Statistical analysis and hypothesis testing using factorial analysis, using sociocultural and geographical context as factors.

Conclusions

To our knowledge, the Eco-social Observatory of Climate Change Effects is the first attempt to carry on systematic monitoring focused on climate change effects in the central Andes Puna. This pioneering initiative has the advantage of integrating different sources of knowledge from disciplines of natural and social sciences, to respond to the imperative need to understand the factors/forcings of change in both biodiversity and local communities' performance driven by climatic change, on one of the least studied and most vulnerable regions of the world.

The implementation of the different components of the Observatory has been a gradual process that is still ongoing. In spite of being in the early stages of its operation, the Observatory has already generated significant observations of these natural systems. However, implementation has not been exempt from problems. It is therefore important to emphasize that a major challenge accepted by the CEH is to manage the Observatory in an adaptive management scheme, in which continually meeting the objectives is reevaluated, readjusting protocols if necessary.

The understanding of climate change effects on natural and social systems through the knowledge created by the Observatory will help to generate better predictions of future climate change scenarios and their effects. This knowledge will provide new tools to design more efficient management measures, such as mitigation or adaptation of social and natural systems to climate change effects.

Acknowledgements Research funded by Centro de Estudios de Humedales, and the projects FONDECYT 1150701 "Participatory research through eco-social observatories changes and climate Uncertainty of the Andean highlands of northern Chile" and FONDECYT 1120204 "Multi-scale analysis of climate change and its consideration in the strategic environmental assessment of sustainable regional development Altiplano of northern Chile".

References

Alexander C et al (2011) Linking indigenous and scientific knowledge of climate change. BioScience 61(6):477–484. http://bioscience.oxfordjournals.org/content/61/6/477.short. Accessed 13 July 2016

Anderson EP et al (2011) Consequences of climate change for ecosystems and ecosystem services in the tropical Andes. In: Herzog SK, Martinez R, Jørgensen PM, Tiessen H (eds) Climate change and biodiversity in the tropical Andes. Inter-American Institute for Global Change (IAI) and Scientific Committee on Problems of the Environment (SCOPE), Saint Louis, pp 1–18. http://www.iai.int/?p=5922. Accessed 12 July 2016

Bennett M et al (2016) Climate complexity in the Central Andes: a study case on empirically-based local variations in the Dry Puna. J Arid Environ 128:40–49. http://www.sciencedirect.com/science/article/pii/S0140196316300040. Accessed 11 July 2016

Blodau C (2002) Carbon cycling in peatlands: a review of processes and controls. Environ Rev 10:111–134. http://www.nrcresearchpress.com/doi/pdf/10.1139/a02-004. Accessed 11 July 2016

Bradley RS et al (2006) Threats to water supplies in the tropical Andes. Science 312:1755–1756. http://science.sciencemag.org/content/312/5781/1755. Accessed 10 July 2016

Carrasco C et al (2005) Estado ambiental del bofedal de Lagunilla 1992–2005. Technical report prepared by CENIMA (Universidad Arturo Pratt) for Minera Cerro Colorado. Iquique

Castillo MP (2015) Análisis estratégico de las implicancias del cambio climático en el proceso de desarrollo regional de Tarapacá-chile. Master Thesis, Universidad de Chile, Santiago

Centro de Estudios del Desarrollo–Centro de Estudios de Humedales (CED–CEH) (2010) Análisis multitemporal de cuencas de los humedales altoandinos prioritarios de chile: Informe final. Centro de Estudio de Humedales, Pica

Centro de Estudios del Desarrollo–Centro de Estudios de Humedales (CED–CEH) (2011) Diseño e implementación de un sistema de información hidro-climática para el seguimiento de los efectos de los cambios globales en los humedales altoandinos de Chile: Informe final. Centro de Estudio de Humedales, Pica

Centro de Estudios del Desarrollo–Centro de Estudios de Humedales (CED–CEH) (2012) Humedales del altiplano Andino y su rol en el cambio climático: Informe final. Centro de Estudio de Humedales, Pica

Chaudhary P, Bawa KS (2011) Local perceptions of climate change validated by scientific evidence in the Himalayas. Biol Lett rsbl20110269. http://rsbl.royalsocietypublishing.org/content/roybiolett/early/2011/04/16/rsbl.2011.0269.full.pdf. Accessed 10 July 2016

Cleland EE et al (2007) Shifting plant phenology in response to global change. Trends Ecol Evol 22(7):357–365. http://labs.biology.ucsd.edu/cleland/cleland/Publications_files/Cleland_etal_TREE_2007.pdf. Accessed 10 July 2016

Conly FM, Van Der Kamp G (2001) Monitoring the hydrology of Canadian prairie wetlands to detect the effects of climate change and land use changes. Environ Monit Assess 67(1–2):195–215. http://link.springer.com/article/10.1023/A:1006486607040. Accessed 13 July 2016

Corporación Nacional de Desarrollo Indígena CONADI, Centro de Estudios del Desarrollo–Centro de Estudios de Humedales (CED–CEH) (2012) Catastro de Humedales y Usos Indígenas de la Provincia del Tamarugal Etapa 1 y 2. Corporación Nacional de Desarrollo Indígena CONADI, Iquique

Deutsch CA et al (2008) Impacts of climate warming on terrestrial ectotherms across latitude. Proc Natl Acad Sci USA 105:6668–6672. http://www.pnas.org/content/105/18/6668.full.pdf. Accessed 30 June 2016

Díaz S et al (2015) A Rosetta Stone for nature's benefits to people. PLoS Biol 13(1):e1002040. http://journals.plos.org/plosbiology/article?id=10.1371/journal.pbio.1002040. Accessed 10 July 2016

Donald DB et al (1999) Agricultural pesticides threaten the ecological integrity of northern prairie wetlands. Sci Total Environ 231(2):173–181. http://www.sciencedirect.com/science/article/pii/S0048969799000911. Accessed 10 July 2016
Everard M (2008) Selection of taxa as indicators of river and freshwater wetland quality in the UK. Aquat Conserv 18(6):1052–1061. http://onlinelibrary.wiley.com/doi/10.1002/aqc.896/full. Accessed 30 June 2016
Feeley KJ, Silman MR (2010) Biotic attrition from tropical forests correcting for truncated temperature niches. Glob Change Biol 16:1830–1836. http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2486.2009.02085.x/full. Accessed 13 July 2016
Frau D et al (2015) Controlling factors in planktonic communities over a salinity gradient in high-altitude lakes. Ann Limnol Int J Limnol 51:261–272. http://www.limnology-journal.org/articles/limn/abs/2015/03/limn140066/limn140066.html. Accessed 30 June 2016
Garreaud R et al (2003) The climate of the Altiplano: observed current conditions and mechanisms of past changes. Palaeogeogr Palaeoclimatol Palaeoecol 194(1–3):5–22. http://www.sciencedirect.com/science/article/pii/S0031018203002694. Accessed 30 June 2016
Gilman SE et al (2010) A framework for community interactions under climate change. Trends Ecol Evol 25(6):325–331. http://www.cell.com/trends/ecology-evolution/pdf/S0169-5347(10)00061-3.pdf. Accessed 10 July 2016
Houston J, Hartley AJ (2003) The Central Andean West-slope rain shadow and its potential contribution to the origin of hyper-aridity in the Atacama Desert. Int J Climatol 23:1453–1464. http://onlinelibrary.wiley.com/doi/10.1002/joc.938/pdf. Accessed 16 July 2016
Hribljan JA et al (2015) Carbon storage and long-term rate of accumulation in high-altitude Andean peatlands of Bolivia. Mires Peat 15(12):1–14. http://mires-and-peat.net/media/map15/map_15_12.pdf. Accessed 13 July 2016
Hurlbert SH, Chang CC (1983) Ornitholimnology: effects of grazing by the Andean flamingo (*Phoenicoparrus andinus*). Proc Natl Acad Sci USA 80(15):4766–4769. http://www.pnas.org/content/80/15/4766.full.pdf. Accessed 10 July 2016
LaBaugh JW et al (1987) Hydrology and chemistry of selected prairie wetlands in the Cottonwood Lake area, Stutsman County, North Dakota, 1979–82. U.S. Geological Service: professional paper 1431. http://pubs.usgs.gov/pp/1431/report.pdf. Accessed 9 July 2016
Larsen TH et al (2011) Range shifts and extinctions driven by climate change in the tropical Andes: synthesis and directions. In: Herzog SK, Martinez R, Jørgensen PM, Tiessen H (eds) Climate change and biodiversity in the tropical Andes. Inter-American Institute for Global Change (IAI) and Scientific Committee on Problems of the Environment (SCOPE), Saint Louis, pp 47–67. http://www.iai.int/?p=5922. Accessed 12 July 2016
López-Franca N et al (2016) Changes in temperature extremes for 21st century scenarios over South America derived from a multi-model ensemble of regional climate models. Clim Res 68(2–3):151–167. http://www.int-res.com/abstracts/cr/v68/n2-3/p151-167/. Accessed 29 June 2016
Luebert F (2004) Apuntes sobre la vegetación de bosque y matorral del desierto precordillerano de Tarapacá (Chile). Chloris Chil 7(1). http://www.chlorischile.cl/luebertmyrica/imagua.htm. Accessed 10 July 2016
Maltby E, Immirzi P (1993) Carbon dynamics in peatlands and other wetland soils, regional and global perspectives. Chemosphere 27(6):999–1023. http://www.sciencedirect.com/science/article/pii/004565359390065D. Accessed 8 July 2016
Marengo JA et al (2011) Climate change: evidence and future scenarios for the Andean region. In: Herzog SK, Martinez R, Jørgensen PM, Tiessen H (eds) Climate change and biodiversity in the tropical Andes. Inter-American Institute for Global Change (IAI) and Scientific Committee on Problems of the Environment (SCOPE), Saint Louis, pp 110–127. http://www.iai.int/?p=5922. Accessed 11 July 2016
Mascitti V, Kravetz F (2002) Bill morphology of South American flamingos. Condor 104(1):73–83. http://www.aoucospubs.org/doi/abs/10.1650/0010-5422(2002)104%5B0073%3ABMOSAF%5D2.0.CO%3B2. Accessed 11 July 2016

McCain CM (2009) Vertebrate range sizes indicate that mountains may be 'higher' in the tropics. Ecol Lett 12(6):550–560. http://onlinelibrary.wiley.com/doi/10.1111/j.1461-0248.2009.01308.x/full. Accessed 13 July 2016

Ministerio del Medio Ambiente MMA, Centro de Estudios del Desarrollo–Centro de Estudios de Humedales, CED–CEH (2013) Humedales y cambio climático en la Región de Tarapacá, Informe final. Public tender ID: 609102-4-LE12. Ministerio del Medio Ambiente, Iquique

Núñez L et al (2002) Human occupations and climate change in the Puna de Atacama, Chile. Science 298(5594):821–824. http://science.sciencemag.org/content/sci/298/5594/821.full.pdf. Accessed 10 July 2016

Olson DM et al (2001) Terrestrial ecoregions of the world: a new map of life on earth, a new global map of terrestrial ecoregions provides an innovative tool for conserving biodiversity. BioScience 51(11):933–938. http://bioscience.oxfordjournals.org/content/51/11/933.full.pdf+html. Accessed 13 July 2016

Riedlinger D, Berkes F (2001) Contributions of traditional knowledge to understanding climate change in the Canadian Arctic. Polar Rec 37(203):315–328. https://www.cambridge.org/core/journals/polar-record/article/contributions-of-traditional-knowledge-to-understanding-climate-change-in-the-canadian-arctic/3071259EEF4A71F160BB0BD2B73CA7BD. Accessed 9 July 2016

Risacher F et al (2003) The origin of brines and salts in Chilean salars: a hydrochemical review. Earth Sci Rev 63(3):249–293. http://www.sciencedirect.com/science/article/pii/S0012825203000370. Accessed 25 June 2016

Root TL et al (2003) Fingerprints of global warming on wild animals and plants. Nature 421:57–60. http://www.nature.com/nature/journal/v421/n6918/abs/nature01333.html. Accessed 29 June 2016

Squeo FA et al (2006) Bofedales: high altitude peatlands of the central Andes. Rev Chil Hist Nat 79(2): 245–255. http://rchn.biologiachile.cl/pdfs/2006/2/Squeo_et_al_2006.pdf. Accessed 28 June 2016

Steinhoff DF et al (2015) Projected impact of twenty-first century ENSO changes on rainfall over Central America and northwest South America from CMIP5 AOGCMs. Clim Dyn 44(5–6):1329–1349. http://link.springer.com/article/10.1007/s00382-014-2196-3. Accessed 24 June 2016

Sutherland et al (2014) How can local and traditional knowledge be effectively incorporated into international assessments? Oryx 48:1–2. https://www.cambridge.org/core/journals/oryx/article/how-can-local-and-traditional-knowledge-be-effectively-incorporated-into-international-assessments/38F60914684AC933F6BC71BFAD6E3A11. Accessed 27 June 2016

Turnhout E et al (2012) Listen to the voices of experience. Nature 488:454–455. http://www.nature.com/nature/journal/v488/n7412/full/488454a.html. Accessed 27 June 2016

Vuille M et al (2008) Climate change and tropical Andean glaciers: past, present and future. Earth Sci Rev 89(3–4):79–96. http://www.sciencedirect.com/science/article/pii/S0012825208000408. Accessed 22 June 2016

Chapter 7
Ecological Sanitation: A Territorialized Agenda for Strengthening Traditional Communities Facing Climate Change

Gustavo Carvalhaes Xavier Martins Pontual Machado, Cristina Jasbinschek Haguenauer, Tiago Ruprecht, Francisco Xavier Sobrinho and Edmundo Gallo

Introduction

The worsening of climate change and the increase in the number of environmental disasters (with its ensuing increase in social inequality) expresses how unsustainable the current hegemonic model of production and consumption is (Gallo and Setti 2014). Because of this model of production, in the next decade, climate change will affect the majority of populations and increasingly impact the most vulnerable groups in the planet (Bowen and Friel 2012). Climate change is one of the most important scientific and political challenges of this century (Neves et al. 2015).

In Brazil, intense climate events impact populations and economies of big cities, small towns and rural communities, generating high risk situations (Bonatti et al. 2016). Moreover, according to the report of the Intergovernmental Panel on Climate Change (IPCC)—"Climate Change (2014): Impact, Adaptation and Vulnerability"—the most vulnerable groups, such as coastal populations, traditional and poor communities are under greater risk of socioenvironmental impacts.

Since vulnerability is socially constructed, human action can change it (Bonatti et al. 2016). This perspective resulted in the dissemination of social technologies (STs) to assure the adaptation of these populations through the adequate use of water resources (Paes 2014). These initiatives have been playing an important role, not only regarding socioenvironmental problems, but also in the minimization of climate change. Recently, STs have been recognized as important tools in the fight against climate change in Brazil (Fonseca 2008). To organize this fight, promoting an evaluation of the country's vulnerabilities and developing actions that vary depending on the local reality and microclimate is crucial (Ventura et al. 2014).

G.C.X.M.P. Machado (✉) · C.J. Haguenauer · T. Ruprecht · F.X. Sobrinho · E. Gallo
Oswaldo Cruz Foundation (Fiocruz) and Federal University of Rio de Janeiro (UFRJ), Paraty, Rio de Janeiro, Brazil
e-mail: gustavoxmartins@gmail.com

W. Leal Filho and L. Esteves de Freitas (eds.), *Climate Change Adaptation in Latin America*, Climate Change Management,
https://doi.org/10.1007/978-3-319-56946-8_7

In this perspective, it is the lifestyles of these traditional communities—their rational use of resources and their permanence in their territories—that assure the preservation of natural resources throughout the world as explained in a recent study carried out in more than 80 areas in the world (Stevens et al. 2016).

This report on community forest rights and climate change provides much-needed evidence at the global scale, demonstrating the tremendous potential of strengthening communities' forest rights for reducing emissions. According to this study, community forests in the Brazilian Amazon tend to be relatively carbon-rich, containing 36 % more carbon per hectare than areas of the Brazilian Amazon outside Indigenous Lands (Stevens et al. 2016). In this context, assuring the right of these communities to remain in their territories and assuring their well-being must be one of the priorities in fighting climate change.

In Brazil, Decree 6.040/2007, which creates the National Policy for the Sustainable Development of Traditional Peoples and Communities (PNPCT) includes, among its goals: promoting the sustainable development of traditional peoples and communities, focusing on recognizing, strengthening and assuring their territorial, social, environmental, economic and cultural rights, while respecting and valuing their identity (BRASIL 2007a).

It should be mentioned that the National Policy for the Integral Health of Rural, Forest and Water Populations (NPIHRFWP)—as well as the National Policy for the Integral Health of the Black Population (NPIHBP)—are part of a set of equity-promoting policies dedicated to reducing the vulnerabilities of these groups, which are driven by social determinants of health, such as the level of participation in local politics, intercultural conflicts, housing conditions and the access to the four components of basic sanitation (potable water, sewage system, solid waste collection and stormwater drainage), among others (Brasil 2007b).

With the impacts of climate change and environmental disasters, which produce deep changes in the planet's hydrologic cycles, making the access to high-quality water more difficult, which profoundly affects the health of these people, it becomes harder to maintain these groups and communities in their territories.

In this context, environmental sanitation and the access to potable water have already been considered universal rights by the UN, and the importance of assuring the access to them has been proven by numerous studies on sanitation, which showed that interventions on water provision and sewage systems positively impact various health indicators (Heller 1997). Moreover, the implementation of the 2030 Agenda and its Sustainable Development Goals (SDGs) includes sanitation as a critical dimension for health promotion (UN 2012), especially regarding SDG #6, which seeks to assure the availability and the sustainable management of water and sanitation for all, highlighting the link between health and sanitation. This Goal includes the debate on water into a much broader context, as part of a strategy to increase global equity (UNU-INWEH 2010), in alignment with NPIHRFWP and NPIHBP.

In Brazil, given its inadequate wastewater treatment infrastructure, as well as its structure to drain and reuse stormwater, many areas have water shortages, while others are flooded, although most regions have water available. With such effects amplified by climate change and deforestation, the reality was intensified, which was observed in 2014, when the Central-West and Southeast regions suffered from a severe draught, which made it necessary to ration water in at least 142 cities in 11 states of the country (Hackley 2014).

The situation is worst for Traditional Communities and rural settlements given the dispersion of their populations and the difficult access, which makes it complex for the rights of a considerable part of the population to be fulfilled by the State. In the history of Public Health, there have been reports of difficulties sanitation and health technicians had in rural zones or peripheral urban neighborhoods in the twentieth century to get people to adhere to various health actions, including sanitary systems (Philippi Jr. 2005).

This happens due to the numerous territorial and cultural differences of Rural, Forest and Water Populations, and the distance between technicians and the realities and forms of knowledge of each community, as well as the lack of an inclusive perspective focused on the perspectives of each territory. Therefore, it has been observed that health interventions unlinked from educational interventions are unsustainable (FUNASA 2014).

However, to strengthen these peoples and territories—which are very important for the preservation of forests and the global fight against climate change (Stevens et al. 2016)—it is crucial to develop participatory modes of governance based on an ecology of knowledge, focusing on empowering communities, as well as communicating and listening to the needs of these communities through a transpersonal perspective of individuals and groups. Therefore, it is important that sanitation interventions in Traditional Communities are territorialized, transdisciplinary, include the many stakeholders involved and promote sustainability, equity and autonomy.

This paper describes the development of a pilot ecological sanitation project implemented by the Observatory of Sustainable and Health Territories of Bocaina (OSHT) using action research and ecology of knowledge methods in the traditional Caiçara community of Praia do Sono, in the municipality of Paraty, in Rio de Janeiro, a counter-hegemonic model of fighting climate change by strengthening territories.

Based on the integration of structural and structuring actions as a form of social mobilization, this paper evaluates how the experience of developing a social technology for ecological sanitation contributed to the strengthening of the lifestyles of traditional communities and their permanence in their territories, resisting the advance of real-estate speculation and the conservation movement, while assuring the preservation of the natural, social and cultural resources of each people and, therefore, of the land.

Rural Sanitation in Brazil

To understand the reality of Traditional Communities, it should be mentioned that they usually inhabit Environmental Protection Areas (APAs), ecological reserves and/or rural zones. According to the Demographic Census carried out by the Brazilian Institute of Geography and Statistics (BIGS) in 2010, in Brazil, approximately 29.9 million people lived in rural areas, in a total of approximately 8.1 million homes (Salati et al. 2015).

The coverage of the sanitation services provided to this part of the population is very low. It is greatly recognized that, if they have any form of sewage system, the majority of homes in traditional communities and rural settlements have only cesspits or septic tanks.

According to data collected by the 2012 National Household Sample Survey (NHSS), only 33.2% of homes in rural areas are connected to water supply systems, with or without piping inside. For the rest of rural homes (66.8%), the population collects water from fountains or wells (protected or not), directly from rivers (without treatment) or from other alternative sources (often inadequate for human consumption), which directly affects the health of these populations. The situation is even direr in regards to wastewater. Only 5.2% of homes have their sewage collected, and 28.8% use cesspits as a solution for the treatment of their wastewater. The other homes (66.5%) use “rudimentary” cesspit system or simply dump the sewage in rivers or openly over the ground (NHSS 2012). This directly contributes to the dissemination of waterborne diseases (Salati et al. 2015).

The relevance of a sanitation plan for rural, forest and water populations is highlighted by the percentage of the rural population covered without access to basic sanitation and with negligible health conditions. According to studies of Brazilian rural areas today carried out by the Inter-American Institute for Cooperation on Agriculture (IICA), the Brazilian population is 36.2% rural.

Rural, Forest and Water Populations normally live in low-population-density regions that are difficult to access. Therefore, in order for them to have sewage collection and treatment, decentralized systems are crucial.

According to the Brazilian National Basic Sanitation Law (11,445/2007), regulated by Decree 7217/2010, in the absence of a public basic sanitation system, individual solutions are allowed. However, if such individual systems are poorly sized or installed in areas where the groundwater is high, they may pollute the groundwater through infiltration of pollutants and pathogens (Bernardes 2014).

The goal of the rural sanitation program in the 2013 National Basic Sanitation Plan (PLANSAB) was to serve rural populations and traditional communities—such as indigenous and maroon populations, as well as populations living in extractive reserves—highlighting the specificities of these territories, which require approaches that are different from the conventionally employed in urban areas, both technologically speaking and concerning their management and the relations established with the communities (PLANSAB 2013).

> In the Program, interventions dedicated to filling the physical infrastructure gap will necessarily come accompanied by structuring measures in the fields of community participation, environmental education for sanitation, as well as of management and training mechanisms, among others (PLANSAB 2013).

In this context, the ideas of decentralization and participation empower and strengthen the citizenry of the population served, which drives the universalization of sanitation further.

However, PLANSAB itself states not only that conceptual advances are necessary for sanitation interventions, but also that the discussions of authors on the issue and on aspects of the territory and the communities in question should be considered. This shows the importance both of a global understanding of the situation and, simultaneously, of local action.

Therefore, the implementation of territorialized, collectively-developed agendas are necessary. In order to fulfill all its demands and be effective, the agenda must include the many actors involved in the territory in a process of participatory governance that is able to establish priorities based on needs identified by the community. Moreover, a participatory form of planning dedicated to the development of technological, social and political solutions using a strategic/situational form of management and communication processes is necessary (Gallo and Setti 2012a, b, 2014). The importance of the convergence of agents is pointed out in "Sanitation as a Key to Global Health: Voices from the Field" (2010):

> access to sanitation does not automatically equate to use and change in behavior. Therefore, education, empowerment and community-participation are equally critical, as evidenced by the success of community-led total sanitation. When coupled with national government support and programming, this can make significant inroads (UNU-INWEH 2010).

Therefore, more than pointing toward a specific result, it is fundamental to educate people and produce empowerment, equity and sustainability, especially for vulnerable populations. In this process, the development of sustainable and healthy territories is the consequence of the implementation of different points of view on the social development of space. Such points of view may, eventually, change the hegemonic mode of production and consumption, producing counter-hegemonic initiatives (Gallo and Setti 2014).

This new perspective coordinates the academia and traditional communities in a effective partnership which can be understood in light of the ecology of knowledge, promoting new perspectives and the development of simple and broadly-replicable social technologies (Williams and Hardison 2013; Ford 2012; Dagnino 2009).

This paper seeks to show the importance of a transdisciplinary perspective, based on ecosophy—an ethical-political articulation among three ecological spheres: nature, human relationships and human subjectivity (Guatarri 1990). Based on this perspective, as mentioned in PLANSAB, both structural and structuring actions, must be implemented and aligned with mechanisms of interaction and communication to stimulate sanitation projects in Traditional Communities and Rural Areas, promoting positive technological, ecological, social and individual impacts in the territory.

In this context, the ecological sanitation project (Gallo et al. 2016) of the Observatory of Sustainable and Healthy Territories of Bocaina (OSHT) could be considered a counter-hegemonic action to address climate change through a territorialized agenda with intersectoral actions that include the involvement of the community and all stakeholders. This paper addresses the implementation of an ecological sanitation scheme in a integral sanitation perspective based on Guatarri's (1990) three ecologies to promote a new awareness through action.

The Territory and the Project: Observatory of Sustainable and Health Territories of Bocaina (OSHT)

The Paraty region is a priority concerning cultural and natural conservation, containing relevant Atlantic Forest remnants and Traditional Communities coexisting with them. The level of socioenvironmental vulnerability of the region is high given climate change, real-estate speculation, predatory tourism and problems accessing public policies. In this context, Traditional Communities resist to maintain their lifestyles. It has been showed that their way of interacting with nature is a positive way of dealing with climate change and that there should be means to legitimize their actions (Stevens et al. 2016).

To assure that their rights would be fulfilled and recognizing their shared difficulties accessing public policies, maroon, indigenous and Caiçara communities gathered in the Forum of Traditional Communities of Angra dos Reis, Paraty and Ubatuba (FTC), created in 2007. The local community forum made the exercising of citizenry possible, in a partnership between the civil society and the public sphere (Lima et al. 2012).

Based on the demands pointed out by the FTC, a partnership with the Oswaldo Cruz Foundation (Fiocruz)—supported by the National Health Foundation (Funasa)—was established for the creation of the OSHT. Which is a technical-political space for the development of territorialized solutions based on the ecology of knowledge, solutions which have the potential of becoming regional and alternative strategies to assure the fulfillment of the rights of traditional communities, especially regarding the territory, culture, traditional activities and their quality of life. The OSHT also generates critical knowledge and develops technology for the implementation of structural and structuring actions regarding ecological sanitation, differentiated education, agroecology and community-based tourism aiming at health promotion, socioenvironmental sustainability and well-being.

Based on the demands of community members within the territory, the first step of the project was the integrated and participatory development of a territorialized, counter-hegemonic agenda (Gallo and Setti 2012a, b). Using action research, ecology of knowledge and participatory planning methodologies, as well as an ecosystemic approach (while listening to the needs of the territory through its representatives), a matrix of problems was jointly discussed. Therefore, the most important issues were identified and structural and structuring ecological sanitation actions were planned. During the collective agreement on the FTC, it was established that the starting point for the implementation of the ecological sanitation project would be the Caiçara communities (because the need is the greatest) and, more specifically, the community at Praia do Sono (Gallo et al. 2016).

The Ecological Sanitation Project

OSHT's Ecological Sanitation Project is being implemented in a transversal and integrated manner to promote the awareness of the community and other actors involved in the process. Priorities and territory-based interventions were jointly established with the targeted traditional populations, agents of their own transformation.

However, a new perspective on these communities—understanding them as active subjects—is necessary. Even today, these populations are considered targets, users or beneficiaries of compensations and adjustments, which makes the communities' empowerment and appropriation of technology harder (Lima et al. 2012).

Therefore, an integral sanitation strategy that includes structural and structuring ecological sanitation actions in line with the culture of the territory through the use of the ecology of knowledge is necessary. In this context, the implementation of an ecological sanitation system at the Martim de Sá School at the Caiçara community of Praia do Sono, as well as many other structuring actions in the field of environmental education—using the ecology of knowledge and including other actors as foundational parts of the process—was established as a pilot project (Gallo et al. 2016).

Methodology

An Integral Approach

As pointed out by Guatarri (1990), there is a large gap between the continuous development of new technologies dedicated to solving ecological problems and the low capacity of social organizations and subjective arrangements of communities to absorb these mechanisms to their territories with full awareness.

In order for environmental public policies to serve Rural, Forest and Water Populations, social participation and environmental education, aiming at the implementation of effective actions through the involvement of the community are necessary.

Therefore, discussing sanitation actions that include ethical-political articulations—Guatarri's (1990) "ecosophy"—is important. Therefore, actions that take care of nature—as well as promote awareness of social actors through an integral perspective of sanitation, understanding these actors not as mere receptors, but as integral parts of the social technology—are necessary.

Including individuals in all forms of action—stimulating the debate, as suggested by Paulo Freire in the field of Education—is fundamental. Through practice and aware action, individuals in a territory (a living territory) can take an active role and fight for their rights (Freire 1983, 2016).

Based on this, sanitation should be approached from a new and integral perspective, structured around mechanisms of interaction and dialogue aimed at the development of truly inclusive projects that produce positive technological, ecological, social and individual impacts on the territory.

As suggested above, through Guatarri's (1990) three ecologies, the use of transdisciplinary practices produces gains in sanitation. However, such approach includes ontological and epistemological challenges. The first challenge is the epistemological homogenization that promoted the separation between thinking subjects and objects in Western history. This way of addressing knowledge highlights the "symbolic capital" (Bourdieu 1998 and Vasconcelos 2004) of a specific group, producing exclusion and hegemony.

According to Toledo (2014), science is part of an epistemological imperialism that puts forth totalizing formulations, which act as "epistemological obstacles," limiting the perception of the scientific community and making concepts self-evident and unquestionable. Therefore, the knowledge that had been fragmented by positivist science now must be reintegrated into transversal actions.

For Morin (1991), a new scientific perspective on epistemology—one that values counter-hegemonic movements—is crucial. Therefore, both dialectic and non dialectic tools (implemented to produce a greater level of quality in the approach and the cooperation of the community on this problem) should be utilized (Toledo 2014). However, there is an ethical concern regarding the use of participatory studies, which can be manipulated, thus not considering the issues pointed out (Tripp 2005) and the wisdom of individuals approached, only collecting information.

Currently, because of interdisciplinarity and the use of the ecology of knowledge, the use of action research methodologies has been able to enhance and unify the knowledge produced (Toledo 2014; Weihs and Mertens 2013; Gallo and Setti 2014). However, researchers must maintain their scientific base as they include other languages, promoting the agreement between different disciplines, minimizing communication noise and increasing credibility through high-quality methodologies (Weihs and Mertens 2013).

The conclusion is that, despite such epistemological obstacles, given their participatory, reflective, dialogical, dynamic and interdisciplinary nature, action research and transdisciplinary practices were considered the most adequate for the area at hand. However, the potential for the collaborative generation of high-quality knowledge through the integrated use of dialectic and non dialectic methodological tools was also highlighted.

Methodology

Based on the assumption above, it could be stated that the territory is a central idea in all of OHST's projects. The "territory" is conceived as a strategic, living, dynamic, active place, a network of social, political, emotional, economic and symbolic relationships (Lima et al. 2012). This mode of governance is based on the collective development of the agenda and use of ecosystemic, communicational approaches in the strategic-situational planning as methods for analysis and action. Working like this requires actions that are capable of understanding, dialoguing and learning from the social practices of the territory (Santos 2003). To optimize the dialogue with the territory and its individuals, the OHST used action research in all its projects (Gallo and Setti 2012a, b, 2014; Gallo et al. 2016).

According to Thiollent (2011), action research is a type of social research associated to concrete actions dedicated to solving—in a cooperative and participatory manner—a collective problem in which researchers and representative participants are involved. It should be mentioned that actions must be established to serve the interests and the needs of the territory and that all stakeholders must be consulted (Giatti et al. 2007).

In this perspective, nature and culture cannot be separated, and one needs to conceive this interaction "transversally" (Moscovici 2007). It is clear that, in order to guide science and technique toward more human ends, collective management schemes and self-responsibility are crucial. Therefore, actions on nature should not be separated from society and the psyche of its members (Guattari 1990). When sanitation is visualized from the perspective of social ecology, it is about making an emotional and pragmatic investment in human groups of different sizes. In order for this type of exchange and symbolic social change to take place, projects must promote the exchange between all actors, with the horizontal inclusion of individuals in the territory through an "ecology of knowledge", thus generating individual and collective autonomy (Santos 2003; Gallo and Setti 2012a, b).

The challenge is developing practices that incentivize practice-based thinking and recreate collectivenesses in their different contexts. To do that, we need to focus on the modes through which subjectiveness is produced, that is, through the development of new collective symbols related to human care (Freire 1983).

Both the OHST and the ecological sanitation project are based on action research (Thiollent 2011; Morin 2004) to include the various actors of the territory, on the ecology of knowledge (Santos 2003, 2007) to provide a horizontal dialogue between all forms of knowledge, and critical thinking (Freire 1983) to provide a "praxis", to cause subjects to get into action and become aware of themselves and their territories. Beneficiaries thus become social actors together with the facilitators of the process.

Because of that need to act on the territory and based on an integral perspective of sanitation—one that includes the actions of all actors and the alignment of structural and structuring actions—it was established that an integral, holistic, systemic action research methodology (ISAR) (developed since 1970) would be used. In this approach, with the complexities of reality and its multiple mental constructs—mixing researchers and objects of research together—decisions are developed by consensus (Morin 2004).

ISAR is, essentially, a democratic methodology aimed at the promotion of strategic, successive changes based on the interaction between a living territory and a deep connection with the feedback received throughout the process. Because the goals of discourse, attitudes and social actions are emancipatory and transformative, the methodology demands researchers to be actors. Actors have a relationship (actors-researchers or participant researchers), and a cycle of thinking and action in modeling phenomena and developing strategies to solve problems as they emerge and with the participation of all (Morin 2004).

Therefore, in OHST, academic and community researchers—as well as the community itself—work together, exchanging knowledge and information to find collective solutions. The research project is mostly based on ISAR, from the implementation to the oral and written discourse, including a multidisciplinary team—composed of 2 academic researchers, 2 specialists in ecological sanitation and 3 community members—that cooperates proportionally and horizontally, making decisions by consensus.

To implement the ecological sanitation at Praia do Sono, a bibliographic survey was carried out in the area, secondary data of the actions already developed in the territory were collected and a qualitative research was carried out during the activities. Data were always triangulated under a integral and systemic perspective.

Triangulation keeps researchers from avoiding attempting ultimate objectivity, recognizing that reality can never be fully apprehended (Morin 2004). Based on a systemic view, data were collected during actions through participant observation and the use of a field diary, actively understanding the process, and the complexity of the interaction between all actors could be observed.

To collect qualitative data, the following techniques were used: (1) participant observation in the field during the entire period of action research, between March 2015 and March 2016; (2) educational seminars to introduce the issue to various local actors; (3) semestral participatory planning workshops with the community; (4) monthly follow-up meetings between academic and local researchers, with the participation of various actors involved throughout the process, especially the community in which the action in question is being implemented, and (5) a semestral meeting with the multidisciplinary team dedicated to the developing ideas collectively and making decisions by consensus, collecting information and performing constant evaluations (Thiollent 1986; Morin 2004; Gallo et al. 2016).

Participant observation is a major ethnographic research strategy designed to provide the researcher with an intimate approach with a given subject through involvement with people in their natural territory. It usually involves a range of methods (Bonatti et al. 2016). In this project, it involved: direct observation in the field, participation in the life of the group and in collective discussions/dialogue during the period from March/2015 until March/2016.

All the process was systematized based on the collection of data and the evaluation of results in weekly meetings with the multidisciplinary team through interpretational analyses and based on three dimensions (autonomy, sustainability and equity), evaluating evidences on the efficacy of strategies dedicated to promoting sustainable and healthy territories (Gallo and Setti 2012a, b, 2014).

After the end of the first module and the presentation of the data to the community in a general meeting, a strategic, participatory evaluation was carried out by the internal team of the project, using an effectiveness matrix (Gallo and Setti 2014).

The Development of the Action Research in the Territory

After the agreement on the target territory, the region was initially characterized through the triangulation of secondary sources (INEA 2011) and field visits with dwellers, not only to understand the territory, but also to create inclusive action strategies. After this initial characterization, in order to develop an ecological sanitation project, the literature was reviewed and many other related Brazilian experiences were explored through technical visits of a multidisciplinary team composed of community members and researchers. The whole project was developed through meetings with many actors: the community, the Municipal Government of Paraty (MGP) and environmental institutions of the region—the Juatinga State Ecological Reserve of the State Environmental Institute (JSER/SEI) and the Cairuçu Environment Protection Area (EPA Cairuçu) (Gallo et al. 2016).

The proposal was based on the ecology of knowledge and was developed by a multidisciplinary team of Caiçara community members, educators, permaculture specialists, academics and technicians of various institutions. A prototype was developed through a profound and constant dialogue between the sciences of sanitation engineering and permaculture, a positive and horizontal association between technique and popular wisdom. There was consensus that the suggested alternatives should emphasize the autonomy of the local population, promoting the training of its members and the dissemination of an easily-replicable social technology (Gallo et al. 2016).

Instead of a linear system, a closed-cycle system for the water and nutrients was chosen, based on the idea of ecological sanitation. The so-called Evapotranspiration Tank (a sealed tank) uses sewage as feedstock, that is, nutrients and water for the soil, generating products (bananas) and returning the water to the atmosphere via evapotranspiration. The Martim de Sá Municipal School at the Caiçara community of Praia do Sono was chosen for the first phase because of its central location in the community and its symbolic power, also being suitable regarding environmental education (Gallo et al. 2016).

Based on that, the structural and structuring actions regarding the implementation of the first ecological sanitation module at the Martim de Sá School in the municipality of Paraty, Rio de Janeiro, took place in a way that stimulates a new form of action, including stakeholders for each different action, so a new collective awareness could emerge.

Through the contact with the community and various other local actors, a need to focus on structuring actions that allowed the development of a new "culture of water"—since there were no local actors with sufficient theoretical knowledge to substantiate adequate and alternative local projects dedicated to the sanitation of traditional communities—was established.

To promote mobilization, dialogue and environmental education, monthly meetings dedicated to the planning and monitoring of the whole project, to the development of the module (with the participation of the entire multidisciplinary team) and to the dialogue between the various actors involved (the community, Funasa, MGP, JSER/SEI) were carried out with an intersectoral approach to produce a new form of knowledge, based on the subjective symbology of all stakeholders.

During the construction of the sanitation modules, local builders were hired to receive the social technology developed through an effective ecology of knowledge and to be trained as multipliers in future constructions, whether as part of the project of in future autonomous initiatives. Throughout the construction of the first prototype—which took 40 days—the multidisciplinary team remained at Praia do Sono, accompanying and participating hands-on in the construction, listening to the contractors and eventually changing aspects of the project. Besides their explanations to the builders, a great part of the social mobilization took place while members of the community passed by the construction site, in one-on-one conversations.

The structuring action of promoting a differentiated form of educommunication —especially regarding the link between sanitation, health and the improvement in the quality of life in the community and the relation between them and the ecological sanitation construction carried out—took place during the construction. As mentioned in the Environmental Education Program for Sanitation in Small Districts (EEPSSD), activities were developed in non-linear, participatory phases that included: diagnostic, planning, implementation (with problematization) and evaluation (Funasa 2014). The educommunication class plan was developed, in a participatory manner, by OSHT's Ecological Sanitation and Differentiated Education Teams together with representatives of the Caiçara community of Praia do Sono after discussing and validating aspects with the education and environmental teams of the MGP. Structured weekly activities were carried out cohesively with the daily activities organized by the school teacher.

To do that, the following actions were carried out: the link between Environmental Sanitation and the territory was discussed through integrated practical and theoretical activities, incentivizing a "practice" (Freire 1983); the planning and development of actions based on the idea and processes of "educommunication" and on the concept of differentiated education, with the participation of the children in the local community radio; the use of educational videos coupled with a critical discussion in the classroom and playful activities, like making posters and writing; the coordination of the network of existing actors in search for support during the classes, involving SEI's team at the Juatinga Ecological Reserve and the Water Surveillance team of the Paraty Municipal Government (MGP); a collective cleaning effort; the organization of ecological workshops on making soap with cooking oil; and the making of recycled toys. The activities were always carried out in dialogue with students, the teacher and MGP's Secretariat of Education. At the end of the classes, the texts, posters and audios created on the issues at hand were used to mobilize the community (the audios being broadcasted by the community radio). Besides mobilizing the community, the multidisciplinary team participated in meetings of the Committee of Drainage Basins in the Ilha Grande Basin (CDBIGB), which regulates that drainage basin, mentioning the project to many actors and community leaders in order to expand the discussion and promote the dissemination of ecological sanitation practices at other locations.

Other social mobilization actions promoted outside the community included the development of pedagogical materials such as essays, theses, booklets on construction, T-shirts and news pieces for magazines and the internet, communicating the project in many different forms, diversifying the reach and the dissemination of the technology and incentivizing a new perspective on sanitation and sewage as products.

After the first module was built, the whole intersectoral process was evaluated—including the licensing of the construction, the public hiring of services, the establishment of partnerships, the implementation of the first module and of social mobilization actions—in order for the team to collectively review its ideas and develop new ones, more adapted to nature and the community, thus meeting the inherent needs of the social technology chosen and of individuals. This evaluation was carried out with all actors involved through meetings and workshops with the goal of planning the second stage of the ecological sanitation project, in the homes of the community.

Since the study included people and was carried out inside a Conservation Unit, the research project was submitted for evaluation and approved by the Research Ethics Committee of the National School of Public Health (REC/NSPH) under number 1.527.081. The action research at the Caiçara community of Praia do Sono was duly authorized by SEI (number 044/14).

Results

The integral and systemic action research, the discussions and the activities carried out in the various meetings and visits offered relevant information on the sanitation problem for stakeholders, as well as for possible solutions. It should be mentioned that paying attention to the community adapted the project to the territory, bringing actors closer together. The statements presented refer to information obtained from participant observation and for ethical reasons, our informants are identified by pseudonyms. The voices of the stakeholders demonstrate the change in culture from a psychosocial gaze at evaluation meetings. Results were introduced in detail under the following topics of interaction with the community: (a) The territory; (b) Environmental Educommunication at the School; (c) Consequences of social mobilization and (d) effectiveness evaluation.

The Territory

The territory was initially characterized through georeferencing and technical visits, whose goal was the production of maps. However, since territories are living things, such characterization must be constantly updated, because there are subjective and cultural layers beyond the territory itself, which must be addressed through dialogue and the participant observation of individuals.

The Caiçara community of Praia do Sono is part of the Juatinga State Ecological Reserve (JSER), a 100-km^2 protected area in the extreme south of the state of Rio de Janeiro, in the municipality of Paraty. The reserve is part of the Cairuçu Environmental Protection Area (EPA Cairuçu), a 338-km^2 Federal Conservation Unit created in 1983. The last census—carried out in 2011—registered 314 native individuals (177 men and 137 women) in the community. People that were born and raised within JSER are considered "native" or "Caiçara." Therefore, their sense of belonging and their identity is deeply linked to the territory. Even though tourism —followed by maritime transportation and artisanal fishing—is currently the community's main economic activity, its culture is preserved by other activities that symbolically represent the territory (INEA 2011; Gallo et al. 2016).

The water supply and sewage treatment systems at Praia do Sono are precarious, which is also the reality for many of the various surrounding communities. To make matters worse, since it is a tourism region, significant increases in the floating population may cause problems such as: water shortage, surfacing sewage and waste accumulation. At the beginning of the project, the water supply at Praia do Sono was quite precarious. Water is collected at the Cachoeira river in an unprotected area. The water does not undergo any treatment. The raw water was distributed via improvised hoses assembled by the community, often close to sewage pipes, with leaks in both systems, which represented a great chance of cross-contamination between community members. After the beginning of the project and the dialogue between the FTC and the neighborhood association with the MGP, a few services were addressed by the municipal government. Simultaneously to the sanitation work carried out at the school, the MGP finished an adequate water distribution system, which improved conditions. However, there is no collective water treatment system.

Through participant observation and visits to the homes following a Health Agent, it was observed that the community is currently questioning the quality of the water available. Approximately 50% of the homes have ceramic water filters, which demonstrates their perception that the water has not been adequate for consumption. Plus, a few families consume bottled water. However, a large part of the community still consumes water with no treatment. This was also observed among children during the environmental educommunication classes. Many of the children said they did not drink water directly from the river anymore, only after it had been filtered.

The main river, the Barra river, receives domestic sewage daily. Through participant observation in field visits and participatory planning workshops, it was observed that homes separate their wastewater into kitchen and cleaning water (greywater) and residual water (sewage). Greywater is usually released on the soil or river untreated. Residual water (sewage), however, go to cesspits, called "fossas" ("pits") by the caiçara throughout JSER (Gallo et al. 2016).

It should be mentioned that calling it a "cesspit" gives them a false feeling that their sewage is being "treated." However, the culture is also present among other actors at JSER in the municipality of Paraty and at the Bocaina region. It not only represents a standard for the community, but mirrors the regional and national health dynamics. The National Basic Sanitation Plan (NBSP) confirms that most homes in rural areas in Brazil have only cesspits or septic tanks.

Through workshops in the neighborhood association, at JSER and at the MGP, the link between surface and underground water contamination and the release of sewage into cesspits or directly in the river without treatment was clarified. The constant dialogue (at the collective or individual levels) not only increased the awareness of the community and of many other local actors, but also stimulated the public to question their realities and suggest new paradigms.

In order to include the highest possible number of actors, intersectoral work was carried out during the implementation of the school's evapotranspiration tank. Three of the community's builders were hired to learn the technique with the multidisciplinary technical team and to act as disseminators of the technology. All the building material—as well as the maritime transportation of the material—was financed by the MGP. JSER/SEI offered land transportation at several moments, as well as the participation of their Rangers as builders, for a "praxis" action-thinking training. Such dialogue with all stakeholders throughout the process—in an atmosphere of curiosity and constant exchange—crystalized a perspective of new, alternative technologies that can care for nature.

A large part of the community was suspicious since the start of the construction. Other projects carried out there in the past only collected information and returned nothing or remained uncompleted, such as a previous sanitation construction in which holes were dug, but no material was brought to the homes. This feeling of neglect from the public sphere was observed right at the beginning: "the material never gets here" (Jorge, 36 years, male, community of Praia do Sono), "this construction will never happen" (Lucas, 29 years, male, community of Praia do Sono) "all they want is our money" (Jorge, 36 years, male, community of Praia do Sono) Several examples showed the community reacting to the project developed under a representative and open consultation to all.

Therefore, the field showed that one of the key issues with technology transfer in social and mental ecology is the absorption of repressive power by the oppressed. As mentioned by Guatarri (1990), the defenders of the oppressed reproduce, in their relationships, the pathogenic models that hinder freedom of speech and innovation. However, these voices cannot be opposed; they need to be embraced, dialogued, listened to, because cultivating dissent and the singularity of existence is crucial.

During the construction, there were at least two focal points in the community, working social mobilization, listening and explaining within the subjective symbolism of each individual. Throughout the whole process, community members passed by the school and looked at the construction, curious, but in disbelief: “is that going to work?” (Artur, 34 years, male, community of Praia do Sono), “it looks as if you are building a swimming pool” (Jaco, 52 years, male, community of Praia do Sono), “how is that again?” (Luana, 42 years, female, community of Praia do Sono), “If you close the bottom, how is the water going to escape it?” (Jaco, Luana, Artur, Jorge, mencioned above and others from the community of Praia do Sono). The team continuously provided explanations throughout the process, which caused the information to circulate the community through each individual, in this particular territory.

Collective meetings were organized and the community radio was used to communicate the project. However, the most effective action was the direct communication with individuals.

During the construction, there was a constant dialogue with the constructors, changing the project depending on the comments. Therefore, the tank—which was going to be buried on the ground—was only partially buried because of the rain and flooding in the area. The community required the location of the module to be changed so it wouldn’t be in their walkway. The internal lid of the prismatic tank, included in the original technical design, was altered by the builders, who did not think the previously planned system would work. Therefore, the “praxis” allowed everyone to learn and integrated the team with the technicians working in the construction as well.

Such exchange could be observed in various comments made after the work was finished, especially one from a community member/researcher that participated in the whole process: “I realized that no one knows everything, you know? I always thought that I knew a lot. Engineers always think they know it all. It is one of those moments that tell us that we know nothing, that we can learn from one another, with that exchange. This is very good. This way, we can always learn from others” (Carlos, 56 years, male, community and team of OSHT). To actually involve all actors produced an exchange of knowledge from all individuals, a greater awareness of the needs of others and of the importance of working together.

Environmental Educommunication at the School

Throughout the construction, environmental educommunication classes were carried out weekly at the school. One of the tools used was a mini diary of the construction, so students could visit the site every week and write down what they saw, which made students “active researchers of their own territory.”

Students were listened to throughout the process so that they themselves guided their actual interests. A spoken map was drawn in the blackboard with the participation of students to explain the importance of groundwater and of taking care of the territory. Students then spoke of the impact of tourism at Praia do Sono, especially during Carnaval. The students mentioned the following impacts: tourist throwing trash in inadequate places, feces, aluminum cans, cigarette butts, plastic bottles and bags found along the river and the low quality of the local water for consumption.

The quality of the water and the fact that it could not be drank directly from the river were broadly discussed. The students spoke of Poço do Jacaré, where “in the past, you could drink water from its waterfall, but, if you do it today, you’ll get sick” (spoken at the classroom). They also said that this is the best waterfall in the region, but that it is polluted. The current alternatives for water consumption—ceramic filters or bottled water—were also mentioned. The leaks in the community’s precarious water distribution system were also pointed out. During the drawing of the map and during the first classes, students already knew the critical factors for taking care of the territory mentioned by the technical team of the project. After such discussions, a number of joint actions to be carried out in the community were decided on: collectively cleaning the beach, creating posters and distributing them in the community to raise awareness, organizing a workshop on making soap with used cooking oil, and the children contributing audios that they recorded themselves to the community radio.

The participation of the students, communicating the project at their homes and to their families, should be highlighted. Another fact that should be called attention to was the increase in the proactivity of the students during class and in actions. Throughout classes, an apparent shyness gave way to a new will to participate and give an opinion. Their perspective on ecological sanitation—highlighting its importance for the school—was observed in the posters they made after the construction, as mentioned in the following account: “The New School, the new school at Praia do Sono has: fans, a new ceiling, a new fence, a new playground with a swing, a slider and a see-saw. There are new books and new desks. A new restroom for boys and girls. A TV room with DVD, chairs, popcorn and soda. But the best thing is the ecological sanitation, which made our school better”.

Another important point observed is that, based on the perceptions of the children on sanitation and their own way of explaining, using their own language, the technology that was implemented in the territory, a evapotranspiration tank, OSHT’s technical team changed the way they explained the theory of the project for the community: “so you remove the top lid from the hole and put it on the bottom, so the water comes out through the top, instead of through the bottom” (spoken at the classroom). This simple way of explaining how the water is absorbed by the banana trees and released to the atmosphere—instead of percolating through the soil and contaminating the groundwater—had the perfect symbology to reach the social ecology of that community.

Both the environmental educommunication program and the construction promoted a greater critical awareness of the community, including the active participation of the students throughout the process, which was a continuous learning experience, including the learning of researchers and technicians.

Consequences of the Implementation of the Module

Since the beginning and during the whole process, the team had problems with social mobilization, especially regarding the symbolic deconstruction of the destination of sewage. However, with the attention of each individual and with the construction finished, the attitude of the community changed. That was demonstrated by in their presence in the meetings. At one of the first meetings, there were only three community members, but in the meeting in which the construction was inaugurated there were 32.

The culture of the Caiçara concerning sanitation, health and the use of cesspits for the sewage changed, as observed in the following comments of community members in individual conversations recorded in the field diary: "Now that the school system is working, I can see that it can work for the homes as well, Barra (the main river in the community) is everyone's. It isn't clean. It looks clean, but it isn't" (Gustavo, 41 years, male, community of Praia do Sono), "most of us make cesspits with bricks, but no bottom, which pollutes the ground, now we are ashamed, because we learned the right way of releasing our sewage" (Aloisio, 31 years, male, community of Praia do Sono), "the existence of a project in which we are not mere targets, a project in which we are subjects of the process, especially in the decision-making" (Otavio, 43 years, male, Community and Team of OSHT).

Another important factor in the dissemination of the technology was the feeling of empowerment of the builders. One of them, between the first and the second phases of the project, was hired to build a module on one of the community's camping grounds, and did it all by himself only consulting the drawings of the initial design and following a few recommendations of the technicians of the project. It should be mentioned that the same builder already came up with changes for the project in its first replication, which is a form of awareness through "praxis" as mentioned by Freire (1983).

In the conversations with builders, other accounts that confirm their feeling of empowerment and belonging through their participation in the project were also collected: "now we can build it ourselves" (Guilherme, 28 years, male, constructor of Praia do Sono), "as far as I can see, because I worked in the school, nothing is going to the ground" (Carlos, 30 years, male, constructor of Praia do Sono), "we do it for the others, but we can do it for ourselves as well, right? we want to learn more and more" (Roberto, 32 years, male, constructor of Praia do Sono), "this thing doesn't pollute our waterfalls… this is awesome" (Guilherme, 28 years, male, constructor of Praia do Sono).

After the end of the construction, the community saw itself as the owner of the project and opened their homes for the technical team. After that phase, the community allowed the team to evaluate their homes and start a dialogue to consider new sanitation actions concerning their homes.

In May 2015, a workshop was organized with the community to discuss steps regarding the implementation of the ecological sanitation in homes. During the workshop, the financial information regarding the construction of the first module at the school was made available for the costs to be transparent. After the data was presented, the community replied and a debate on how the project should be changed for the future began. Researchers and the community validated the following steps together, by consensus.

The problems faced during the construction were highlighted, which stimulated the study of other construction technologies and methods. Building conventional masonry tanks involves costly materials that would have to be transported by sea. Another problem was the amount of time the construction of an internal masonry biodigester chamber would take.

After a discussion with the community, a project of an evapotranspiration tank (TEVAP) with superadobe walls, a permacultural technology, was chosen. This reduces the cost of construction for the walls of the tank and makes the technology more likely to be incorporated by the community. The bricks in the internal biodigester chamber were replaced by tires, which minimizes the cost of transportation, the workload, the time of construction and promotes the use of waste as building materials, while the quality of the system is maintained. The use of banana circles as a technology for the treatment of greywater was chosen.

Another important issue in the second phase was deciding which homes would come first. It was agreed by researchers and the community that the project would be extended to the homes at the upstream portion of the Barra river, in order for them to be able to monitor the river and observe changes in the quality of the water after the implementation of ten modules in the second phase. Listening to the territory helped the project change the first map, which had been drawn only through the georeferencing of the homes (Gallo et al. 2016). In face of the living territory, projects must adapt to the conditions and needs of communities. It was agreed that a new project that included visits to the homes and in which the community itself chose the homes to be first served would be developed. The account of one community member demonstrates that there was a greater level of commitment of individuals: "we wanted our homes to be first, but now I know that a certain order is demanded, so the river is cleaned right" (Gustavo, 41 years, male, community of Praia do Sono).

Effectiveness Evaluation

During the whole research process, in weekly meetings, the multidisciplinary team evaluated the feedback of the community to guide the project in a systemic manner and including all perspectives, making decisions by consensus, as mentioned by Morin (2004).

After the first module was finished and the information was presented to the community in a general meeting, the internal team of the project carried out a strategic, participatory evaluation meeting, using an effectiveness matrix (Gallo and Setti 2014) to check developments through participant observation, and focusing on three dimensions (sustainability, equity and autonomy). After the classification of

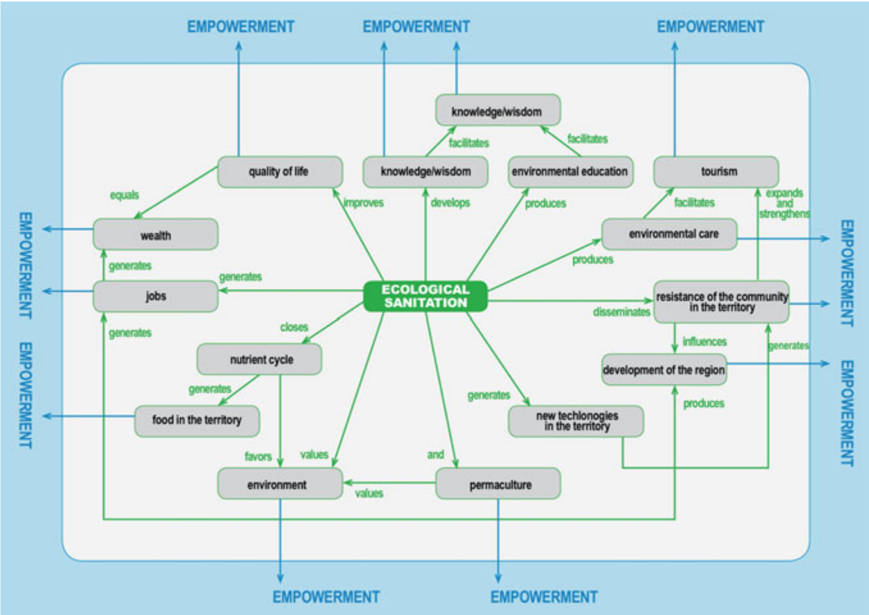


Fig. 7.1 Diagram with positive impacts of ecological sanitary on the community of Praia do Sono. OSHT, 2016

relevant elements through an interpretational analysis, a diagram with the positive impacts in the various spheres of the community—validated by the multidisciplinary team of researchers and community members—was created (Fig. 7.1).

The following elements were observed and validated by consensus by community members and researchers as positive impacts in the empowerment of the community:

- social incubation, for hiring the local workforce and generating wealth in the community; training builders as social multipliers;
- education, since after the construction, the school gained more support of the municipal government of Paraty (MGP) and expanded to cover the entire course of basic education;
- environmental education and cultural change, that is, a change in the perspective of children and adults regarding ecology; local tourism, given that the first ecological sanitation module at the school became a site in the tour provided by the community, which promotes social development, as observed in accounts of community members: "the sanitation is now part of our tour," and "we could never imagine that a cesspit could ever be part of a tour in a Caiçara community" (João, 41 years, male, Community of Praia do Sono);
- quality of life, stimulating a new awareness concerning water in the community, an awareness through which community members started feeling ashamed for

not having an adequate sanitation system and realized how relevant it was not to contaminate groundwater;

- in local food production, given that the sanitation technique produces bananas and other fruit, using sewage as raw material;
- and the promotion of the implementation of new social technologies in the territory, which could be observed in how community members accepted the change in technology (initially adapted), in the incorporation of a new technology such as a banana circle and the collective agreement to provide homes with it.

Elements observed throughout the process were classified as related to sustainability, equity or autonomy, based on the effectiveness matrix created and used by OSHT in its projects (Gallo and Setti 2012a, b).

Sustainability was observed in the ecology of knowledge, which guided the collective instances of management and the decision-making by consensus; in the intersectoriality of the mobilization and involvement of various relevant actors in the territory; in the territorialization (new technologies that were developed based on the territory, which strengthens the community, improves their quality of life and cares for the environment).

Equity was observed in the diversity (the involvement of community members as social multipliers and of both men and women in the interventional and social mobilization team), the vulnerability (the income distribution caused by the social incubation and the hiring of community members, whether for the construction of the ecological sanitation module or for social mobilization, transportation and catering, to stimulate the local economy and the development of the region) and the integrality (using light, health-promoting construction technologies that alter the nutrient cycle and produce food in the territory, as well as stimulating permaculture, a science based on traditional knowledge that incentivizes new ways of caring for people and the environment).

Autonomy was observed regarding social participation (the involvement of the community throughout the collective agreement of each step; the promotion of environmental education and structuring actions regarding dialogue, which promotes awareness) and empowerment (in the community members' ability to produce a new ecology of knowledge involving each stakeholder throughout the process).

The Fig. 7.1 links these impacts in the systemic and collective perspective of the multidisciplinary team in the field throughout the whole process. The empowerment of the community was pointed out as the most important aspect, in its direct and indirect links with all elements identified. One of the team members corroborated the perception with the following commentary: "a project in which we are not a mere target, which we promote, especially regarding the decision-making process, is important" (Otavio, 43 years, male, community and Team of OSHT).

The general strengthening of the community shows how territorialized and inclusive actions can produce direct and indirect impacts, making them more resilient as to assure their permanence in the territory and promote their role in the preservation of natural resources and habitats, in the face of climate change. One of the representatives of the neighborhood association demonstrated such link and the impact of the project in the sustainability of the community: "we used the opportunity of the sanitation debate to speak of other issues, issues that are especially important for us, that is, strengthening traditional territories. This strengthens our struggle, because we want to continue living in this land, but with more balance" (João, 41 years, male, Community of Praia do Sono).

Since the construction of the first module focused on structuring actions, it changed the culture not only of the community, but of the many local actors that were in touch with the project, as the account of a participant of the technical team demonstrated: "the interesting thing here at this ecological sanitation project and the observatory is to unify all stakeholders and make them talk among themselves… it's about making these local actors talk with one another and change this social technology for it to function locally… so the technology can expand" (Bernardo, 34 years, male, Team of OSHT).

After the presentation of the project in the many local networks, other communities showed interest in implementing it and changing their ways of sewage dispose, using an alternative form of ecological sanitation. After all the aspects raised through participant observation, a chart with the positive impacts on many levels of the community was created (Fig. 7.1).

Conclusion

OSHT's integral perspective on ecological sanitation includes structural and structuring actions aiming at the assimilation of the technology by the community through a gradual change in the culture and a constant level of knowledge exchange with the community and the many actors involved.

Currently, there has been a cultural change in the Caiçara community of Praia do Sono. The community is in transition, understanding not only the importance of properly disposing waste, but also the need to develop the right structural actions without excessive costs. The change in ecological intelligence—implemented through a qualitative field evaluation—and the various direct and indirect impacts of the structuring actions carried out in the community were observed in the many dialogue and intervention groups.

The focus on structuring actions is fundamental because, after a constant level of dialogue using the subjective symbology of individuals, the community is changing their perspective on and their sense of accountability toward sewage generation. It is expected that, therefore, builders participate, as social multipliers, in the construction of ecological sanitation systems in the region, where there has been a continuous proliferation of homes with inadequate systems. The goal is to disseminate the social technology regionally.

However, in order for projects that really include individuals in the territory to promote a sense of belonging and change the culture of the territory, it is important that the territory is understood in all its social, political, economic and environmental human subjectivities.

In this context, adapting the language and symbology of each actor and building knowledge through dialogue and exchange is fundamental. Based on the ecology of knowledge, facilitators can act as mediators and develop interfaces, being truly open to every actor involved and to learn together with them, having a horizontal perspective and valuing all forms of knowledge.

Therefore, when considering climate change, it is extremely important to think globally but act locally through technologies that are adapted to territories and to the culture of individuals in the territory. Therefore, focusing on ecological sanitation actions means promoting the resistance of these communities in their territories, preserving natural resources, causing a new culture, more aware of itself and the world, to emerge and strengthening individuals and wealth generation mechanisms through the promotion of new constructions and the consequences of the treatment process.

Moreover, in order to support the development of sanitation policies in traditional communities that are adequate to their territories—thus promoting effective and applicable actions that are truly incorporated by community members—, acting intersectorally is extremely synergic. In the case of the Caiçara community of Praia do Sono, working intersectorally allowed a greater level of convergence with the actions of the municipality, which is legally accountable for the service. Based on these strengthened bonds between the community, the MGP and the OSHT, new forms of shared accountability that effectively address community needs could be developed. The signing of a Technical Cooperation Agreement between Fiocruz and the MGP concerning ideas for technologies to universalize sanitation in Paraty (including rural areas) is one of the positive aspects that should be highlighted. Such dialogue includes the fact that—after the exchange of knowledge and practical experience—the municipal government has been considering the promotion of ecological sanitation actions in other communities of the municipality.

This experience shows that systematizing an integral sanitation methodology that listens to the territory (which is a living thing) and its individuals, that adapts to them, that carries out structuring actions to strengthen these vulnerable communities to fight climate change and socio-environmental unbalances is very important, ensuring its permanence and preservation of the territory.

Acknowledgements This chapter introduces partial results of research project “Sustainable and Healthy Territories: Sewage treatment system deployment in Caiçara’s Community Praia do Sono, located in Paraty, Rio de Janeiro, Brazil”. Funded by the Term of Cooperation No. 10/13, between the Oswaldo Cruz Foundation (FIOCRUZ) and the National Health Foundation (FUNASA) and also partial results of a thesis on ecological sanitation developed by a partnership between FIOCRUZ and the Federal University do Rio de Janeiro (UFRJ).

References

Bernardes FS (2014) Avaliação do Tratamento Domiciliar de Águas Negras por um Tanque de Evapotranspiração (TEvap), 7ª Edição nº 007, Vol 01. Revista Especialize On-line IPOG, Goiânia. ISSN 2179-5568. Accessed 15 May 2016

Bonatti M, Sieber S, Schlindwein SL, Lana MA, de Vasconcelos ACF, Gentile E, Boulanger J-P, Plencovich MC, Malheiros TF (2016) Climate vulnerability and contrasting climate perceptions as an element for the development of community adaptation strategies: case studies in Southern Brazil. Land Use Policy 58:114–122. http://dx.doi.org/10.1016/j.landusepol.2016.06.033. 0264-8377/© 2016 Elsevier Ltd. Accessed 29 July 2016

Bowen KJ, Friel S (2012) Climate change adaptation: where does global health fit in the agenda. Glob Health 8(1):10–17. doi:10.1186/1744-8603-8-10

Brasil, Presidência da República, Decreto nº 6.040 (2007) Institui a Política Nacional de Desenvolvimento Sustentável dos Povos e Comunidades Tradicionais. http://www.planalto.gov.br/ccivil_03/_ato2007-2010/2007/decreto/d6040.htm. Accessed 30 May 2016

Brasil, Ministério da Saúde, Secretaria de Gestão Estratégica e Participativa (2007) Política Nacional de Saúde Integral da População Negra. 1 edn. Brasília. http://bvsms.saude.gov.br/bvs/publicacoes/politica_nacional_saude_populacao_negra.pdf. Accessed 01 Jun 2016

Dagnino R (Org) (2009) Tecnologia social: ferramenta para construir outra sociedade. IG/UNICAMP, Campinas. http://www.actuar-acd.org/uploads/5/6/8/7/5687387/ts_ferramenta_sociedade.pdf. Accessed 30 May 2016

Fonseca AR (2008) Tecnologias sociais e ecológicas aplicadas ao tratamento de esgotos no Brasil. Rio de Janeiro (RJ) - Dissertação (mestrado), Escola Nacional de Saúde Pública Sérgio Arouca, Rio de Janeiro. http://bvssp.icict.fiocruz.br/pdf/Fonsecaarm.pdf. Accessed 17 July 2016

Ford JD (2012) Indigenous health and climate change. Am J Public Health 102(7):1260–1266

Gallo E, Setti AFF (2012a) Abordagem ecossistêmica e comunicativa na implantação de Agendas territorializadas de desenvolvimento sustentável e promoção da saúde. Cien Saude Colet 17 (06):1433–1446. doi:10.1590/1413-81232015216.07362016

Freire P (1983) Extensão ou Comunicação? Tradução de Rosisca Darcy de Oliveira, 8ª edição Paz e Terra Rio de Janeiro. http://www.emater.tche.br/site/arquivos_pdf/teses/Livro_P_Freire_Extensao_ou_Comunicacao.pdf. Accessed 20 July 2016

Freire P (2016) Conscientização. Editora Cortez, São Paulo. ISBN 9788524924279

FUNASA Fundação Nacional de Saúde (2014) Orientações Metodológicas para o programa de educação ambiental em saneamento para pequenos municípios: Caderno de Orientações: Caderno 1 / Fundação Nacional de Saúde; Universidade Estadual de Feira de Santana, Feira de Santana, UEFS, Brasilia. http://www.funasa.gov.br/site/wp-content/files_mf/orient_ed_sa_caderno1.pdf. Accessed 20 June 2016

Gallo E, Setti AFF (2012) Desenvolvimento Sustentável e Promoção da Saúde: implantação de agendas territorializadas e produção de autonomia. Saúde em Debate 36: 55–67. ISSN: 0103-1104. Accessed 26 July 2016

Gallo E, Setti AFF (2014) Território, Intersetorialidade e Escalas: Requisitos para a Efetividade dos Objetivos de Desenvolvimento Sustentável. Ciência e Saúde Coletiva 19(11): 4383–4396. ISSN: 1413-8123. Accessed 28 July 2016

Gallo E, Setti AFF, Ruprecht T, Sobrinho FX, Finamore P, Shubo T, Machado GCXMP (2016) Territorial solutions, governance and climate change: ecological sanitation at Praia do Sono, Paraty, Rio de Janeiro. Climate Change Management. 1st edn. Springer, Cham, pp 515–532. doi:10.1007/978-3-319-24660-4_28. Accessed 23 June 2016

Giatti LL et al (2007) Sanitary and Sócio-environmental Conditions in the Iauarete Indigenous Area, São Gabriel da Cachoeira, Amazonas State, Brazil. Revista Ciência e Saúde Coletiva, Vol 12, n 6, ISSN: 1711-1723. Accessed 13 July 2016

Guattari F (1990) As Três Ecologias, Tradução Maria Cristina F. Bittencourt, Campinas: Papirus. ISBN: 85-308-0106-7 Accessed 22 July 2016

Hackley R (2014) "Brazil cities rationing water as drought saps reservoir supplies," Bloomberg, February 17, 2014. http://www.bloomberg.com/news/2014-02-17/brazil-cities-rationing-water-as-drought-saps-reservoir-supplies.html. Accessed 22 June 2016
Heller L (1997) Saneamento e Saúde. OPAS/OMS—Representação do Brasil. http://www.bvsde.paho.org/bvsaia/fulltext/saneamento97.pdf. Accessed 12 July 2016
Lima DMA, Sá TS, Pinheiro AAA (2012) Communiy Fórums: a strategy for building Participatory Local Development. Psicologia Política, Vol 12, pp 59–70. http://pepsic.bvsalud.org/pdf/rpp/v12n23/v12n23a05.pdf. Accessed 30 July 2016
IPCC (2014) Climate change 2014: impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects. Contribution of working group II to the fifth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, New York. http://ipcc-wg2.gov/AR5/report/. Accessed 03 July 2016
INEA REJ (2011) Definição de categoria de unidade de conservação da natureza para o espaço territorial constituído pela reserva ecológica da Juatinga e área estadual de lazer de Paraty Mirim. Reserva Ecologica da Juatinga. http://arquivos.proderj.rj.gov.br/inea_imagens/reserva_ecologica_juatinga/caracterizacao_socioecu.pdf. Accessed 23 July 2016
Morin A (1991) Introdução ao pensamento complexo. Instituto Piaget, Lisboa. ISBN 978-85-205-0598-4
Morin A (2004) Pesquisa-ação integral e sistêmica: uma antropopedagogia renovada, DP&A, Rio de Janeiro. ISBN: 85-7490-312-4
Moscovici S (2007) Para pensar a ecologia. Mauad X: Instituto Gaia, Rio de Janeiro. ISBN: 857478220
Neves FM, Chang M, Pierri N (2015) As estratégias de enfrentamento das mudanças climáticas expressas nas políticas públicas federais do Brasil. Desenvolv Meio Ambient 34:5–23. doi:10.5380/dma.v34i0.37739
Paes WM (2014) Técnicas de Permacultura como Tecnologias Socioambientais para melhoria na qualidade da vida em comunidades da Paraíba, Dissertação (mestrado), Programa regional de Pós-graduação em Desenvolvimento e Meio Ambiente, Universidade Federal da Paraíba UFPB - PRODEMA, João Pessoa. http://tede.biblioteca.ufpb.br/handle/tede/4576?locale=pt_BR. Accessed 29 July 2016
Philippi A Jr (ed) (2005) Saneamento, Saúde e Ambiente: fundamentos para um desenvolvimento sustentável. Manole, Barueri, SP. ISNB 8520421881
PLANSAB, Ministério das Cidades (2013) Plano Nacional de Saneamento Básico, Secretaria Nacional de Saneamento Ambiental, Brasília. http://www.mma.gov.br/port/conama/processos/AECBF8E2/Plansab_Versao_Conselhos_Nacionais_020520131.pdf. Accessed 14 July 2016
Salati DS et al (2015) Sustentabilidade das ações de saneamento rural: proposições e possibilidades para um saneamento rural sustentável. In: Saúde e ambiente para as populações do campo, da floresta e das águas. Brasília. Ministério da Saúde. ISBN: 978-85-334-2280-3
Santos M (2003) Por uma outra globalização: do pensamento único à consciência universal. 10ª edn. Record, Rio de Janeiro. ISBN: 8501058785, 9788501058782
Santos BS (2007) Para além do pensamento abissal: das linhas globais a uma ecologia de saberes. Novos estudos - CEBRAP nº.79, São Paulo. http://www.scielo.br/scielo.php?pid=S0101-33002007000300004&script=sci_arttext. Accessed 21 July2016
Stevens C, Winterbottom R, Springer J, Reytar K (2016) Securing rights, combating climate change: how strengthening community forest rights mitigates climate change—World Resources Institute. https://www.wri.org/sites/default/files/securingrights-full-report-english.pdf. Accessed 20 June 2016
Thiollent M (1986) Metodologia da Pesquisa-ação – São Paulo – Ed. Cortez: Autores Associados. ISBN: 9788524917165
Thiollent M (2011) Metodologia da Pesquisa-ação, 18th edn. Cortez, São Paulo. ISBN 9788524911705
Toledo RF de, Giatti LL, Jacobi PR (2014) A pesquisa-ação em estudos interdisciplinares: análise de critérios que só a prática pode revelar. Interface - Comunicação, Saúde, Educação, 18

(51):633–646. http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1414-32832014000400633&lng=pt&tlng=pt. 10.1590/1807-57622014.0026. Accessed 28 June 2016

Tripp D (2005) Pesquisa-ação: uma introdução metodológica. Educação e Pesquisa 31(3):443–466. http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1517-97022005000300009&lng=pt&tlng=pt. 10.1590/S1517-97022005000300009. Accessed 22 July 2016

United Nations, UN (2012) El futuro que queremos. http://www.uncsd2012.org/content/documents/778futurewewant_spanish.pdf. Accessed 30 June 2016

UNU-INWEH (2010) Sanitation as a key to global health: voices from the field. United Nations University Institute for Water, Environment and Health. http://www.bvsde.paho.org/texcom/cd045364/sanitationkey.pdf. Accessed 08 June 2016

Vasconcelos EM (2004) Complexidade e pesquisa interdisciplinar – Epistemologia e metodologia operativa, 2ª edn. Editora Vozes, Petrópolis. ISBN 8532627919

Ventura AC, Andrade JCS, Garcia LF (2014) Social technologies for living in the semi-arid region as a mitigation—adaptation strategy to face climate change in brazil. Astrolabio, número 12, Nueva Época. ISSN: 1668-7515. Accessed 27 July 2016

Weihs M, Mertens F (2013) Os desafios da geração do conhecimento em saúde ambiental: uma perspectiva ecossistêmica. Cien Saude Colet 18(5):1501–1510

Williams T, Hardison P (2013) Culture, law, risk and governance: contexts of traditional knowledge in climate change adaptation. Clim Change 120(3):531–544. doi:10.1007/s10584-013-0850-0

Author Biographies

Gustavo Carvalhaes Xavier Martins Pontual Machado Chemical engineer (Federal University of Rio de Janeiro—UFRJ), graduate degree in sanitary engineering by the State University of Rio de Janeiro (UERJ), master’s in Environmental Engineer (UFRJ) and currently a Ph.D. student of Psycho-Sociology of Communities and Social Ecology at UFRJ. Gustavo has been working for 7 years at the Oswaldo Cruz Foundation (Fiocruz) in the environmental area, especially with the Management of Chemical Waste, Wastewater Treatment, Public Management and Sustainable Development. He is a researcher at Fiocruz, working at the Vice-Presidency of Environment, Healthcare and Health Promotion. He also currently coordinates the area of ecological sanitation in the Observatory of Sustainable and Healthy Territories of Bocaina, Brazil.

Cristina Jasbinschek Haguenauer Civil Engineer (State University of Rio de Janeiro—UERJ), master’s degree in engineering (PUC), Ph.D. (COPPE, Federal University of Rio de Janeiro—UFRJ). Cristina currently works as a researcher and professor in Communication School and Psycho-sociology of Communities and Social Ecology at UFRJ. She has experience in Communication and Education, with a focus in educomunication, education technologies, distance education, virtual environments and social medias.

Tiago Ruprecht Architect and Urbanist. Specialist in Permaculture, Ecological Sanitation and Bio-construction. He has extensive experience in working with communities in the search for a more permanent way of living, first in Mexico (2005–2012) and recently in Brazil. He worked as professor at schools and Universities in Mexico, moderated and participated in many conferences and certification courses in the areas of Permaculture, Ecosanitation and bioconstruction. As an architect, he has developed projects of his own, all of them following the principles of sustainable construction. He has worked with important design offices in Brazil and Mexico. Most recently, he worked as Technical Coordinator at the municipal government of Paraty, Rio de Janeiro/Brazil, and currently works as Ecological Sanitation Designer at OTSS/Fiocruz.

Francisco Xavier Ticote Permaculturist. He is from Pouso da Cajaíba, a traditional community, and worked with traditional knowledge his whole life. He is the founder of the Caiçara Permaculture Institute (IPECA). He is an associate researcher at the Oswaldo Cruz Foundation (Fiocruz). Francisco Currently works with ecological sanitation in the Observatory for Sustainable and Healthy Territories of Bocaina, Brazil.

Edmundo Gallo Physician, Doctor in Sciences by the Oswaldo Cruz Foundation (Fiocruz) (2009). He was the Municipal Secretary of Health in Belém-PA (1997–1999), Director of Investments at the Ministry of Health in Brazil (2002–2005) and General Secretary and President of the National Council of Health Departments in Brazil (1997–1999). He is an Associate Researcher at the Oswaldo Cruz Foundation, a Collaborative Member of the University of Coimbra, as well as a consultant for international organizations and government agencies. He has experience in the areas of Public Management, especially Strategic Planning, and Sustainable Development and Health Promotion. He currently coordinates the Observatory for Sustainable and Healthy Territories of Bocaina, Brazil.

Chapter 8
Improving Regional Landscapes Management to Support Climate Change Adaptation

Silvia Serrao-Neumann, Ana Paula Turetta and Darryl Low Choy

Introduction

There is growing recognition that climate change impacts are inevitable even if global carbon emissions are curbed and atmospheric concentration of $CO_{2\text{-}e}$ is stabilised (IPCC 2014; Monasterik 2009). Adaptation to climate change impacts is thus imperative on a number of fronts to ensure social-ecological systems continue to function (Blanco et al. 2009). Although a large percentage of human populations inhabit urban settlements (Birkmann et al. 2010), such settlements are directly dependent on the continuous supply of ecosystem services provided by the regional landscape in which they are located (Folke et al. 2005; Mix et al. 2014). Examples of this dependence include, inter alia, availability of water supply, local food production and tourism activities (Le Maitre et al. 2014). Hence, adaptation concerning urbanised areas must also consider strategies that deal with the regional landscapes to ensure their resilience.

Urban development and population growth pressures have created peri-urban settlements adjacent to metropolitan areas and led to significant land use cover changes (Antrop 2004). These include the replacement of native vegetation and formal agricultural land with suburban subdivisions therefore adding a new contingent of properties that are at risk of extreme weather events such as floods (Hall

S. Serrao-Neumann (✉) · D. Low Choy
Cities Research Institute, Griffith University, 170 Kessels Road, Nathan QLD 4111, Australia
e-mail: s.serrao-neumann@griffith.edu.au

D. Low Choy
e-mail: d.lowchoy@griffith.edu.au

A.P. Turetta
National Center of Soil Research - Embrapa Solos, Rua Jardim Botânico, 1024, Rio de Janeiro, RJ CEP 22460-000, Brazil
e-mail: ana.turetta@embrapa.br

W. Leal Filho and L. Esteves de Freitas (eds.), *Climate Change Adaptation in Latin America*, Climate Change Management,
https://doi.org/10.1007/978-3-319-56946-8_8

and Ashley 2008). In particular, urbanisation leads to environmental changes at the local and regional scale, including alterations to hydrological systems such as reduced baseflow and reduced lag-times leading to flash floods (Miller et al. 2014). The impacts caused by two extreme rainfall events in 2011 that affected the State of Queensland in Australia and the State of Rio de Janeiro in Brazil can be used as examples of the consequences of such environmental and land use cover changes. The events lead to human casualties and significant impact upon the regional landscapes of both countries, including direct damage to and loss of critical ecosystem services such as agricultural land/soil, biodiversity and waterways, and associated impact on people's livelihoods.

As climate change is likely to increase the intensity and frequency of extreme weather events such as the abovementioned ones, there is urgent need to improve the management of regional landscapes to minimise the vulnerability of social-ecological systems. This paper aims to contribute to informing such management by drawing on lessons from two extreme rainfall events, especially lessons related to the major impacts on social-ecological systems in the two most affected regions in both countries: the Lockyer Valley in Australia, and the Região Serrana of Rio de Janeiro in Brazil. To this end, the paper is structured in four parts. The first part provides an overview of the potential impacts of climate change on ecosystem services and implications for the management of regional landscapes and associated social-ecological systems. The second part describes the research approach, including the nature and impacts of the 2011 flood events in both case study areas. In the third part, current policies and initiatives for disaster risk reduction in both countries are discussed to investigate the extent to which they facilitate or hinder the protection, recovery and rehabilitation of social-ecological systems, including ecosystem services following flood events. The paper concludes with key lessons for improving regional landscapes management in light of future climate change impacts.

Impact of Climate Change on Social-Ecological Systems

At the centre of resilience thinking is the concept of social-ecological systems. There is increased understanding that ecological and social resilience are interdependent as people's livelihoods impact and are dependent on ecosystems and the services they provide (Adger 2000). It is also recognized that it is imperative to build resilience of social-ecological systems to address complexity and change, including climate change (Berkes et al. 2003). Building resilience of social-ecological systems calls for improved management of regional landscapes as they provide many ecosystem services that are critical for sustaining the viability of those systems.

The concept of ecosystem services emerged in the late 1990s to demonstrate and reinforce the interconnection between biodiversity, ecology, economics and human well-being (Plant and Ryan 2013). The concept strengthened with the release of the Millennium Ecosystem Assessment (MA) report in 2000 (MA 2003, 2005) and, over the last decade, has triggered a vast research and policy interest to develop the science of ecosystem and landscape functions and services (de Groot et al. 2010; Plant and Ryan 2013). The MA (2005) report broadly classified ecosystem services into four types: provisioning (e.g., food and water), regulating (e.g., air quality, erosion protection and water regulation), cultural (e.g., recreation, spiritual and religious inspiration) and supporting (e.g., nursery habitat and gene pool protection) services. This paper specifically focuses on one of the regulating services: water regulation associated with flood events. In terms of flood regulation, ecosystem services can act as moderators of weather events and regulators of hydrological cycle, including flood prevention and drainage and natural irrigation (Nedkov and Burkhard 2012). Regulating ecosystem services have preventive and mitigating functions (Nedkov and Burkhard 2012). Preventive functions include redirection or absorption of parts of incoming water from rainfall, reduction of surface runoff and associated amount of river discharge. Mitigating functions include flood compartment or retention space that can slow down and reduce destructive force of runoff.

Extreme weather events such as floods can trigger disturbances on ecosystems with subsequent impact upon their organisational and functional attributes (Depietri et al. 2012). For example, scholars (Croke et al. 2013) described three types of connectivity linking hydrology and geomorphology in relation to the passage of water and sediment across landscape compartments and drainage basin. These include landscape connectivity (e.g., physical coupling of landforms within a drainage basin), hydrological connectivity (e.g., passage of water from one part of the catchment to another—catchment runoff), and sedimentological connectivity (e.g., physical transfer of sediments and pollutants through drainage basin). These scholars argue that extreme flood events often lead to many thresholds of stability and connectivity in the hydrological connectivity to be crossed. Others (Le Maitre et al. 2014) noted that flow regulation can be controlled through water capture when land-cover is modified providing that sufficient vegetation canopy or basal cover is maintained, and cultivated lands have tillage patterns that capture and retain water along with suitable riparian buffers. Thus, regulating sediment dynamics, soil retention and water flow regulation through improved land use and land cover management is imperative to ensure impacts on human livelihoods and security, particularly downstream are minimised (Le Maitre et al. 2014).

Extreme weather events are likely to become more frequent and intense as a result of climate change (Parry et al. 2007), thereby influencing the supply and demand of ecosystem services related to flood regulation (Stürck et al. 2014). While there is great potential for ecosystem-based adaptation to support adaptation outcomes such as catchment management to protect against floods and droughts (Chong 2014), the extent of climate change impacts on ecosystem services related to flood regulation remains uncertain (Stürck et al. 2014). Authors (Leigh et al. 2013) highlight that managing and restoring ecosystem services delivery is challenging in regions where extreme rainfall and run-off events occur. Based on the context of the Australian landscape, which changed dramatically over the last century due to land clearing for pasture and agriculture as well as urbanisation processes, it was noted that during the dry season sediment and organic debris accumulate in the water channel which are then discharged during high-power run-off events leading to significant erosion and dislocation of sediments previously trapped in the channel (Leigh et al. 2013). Hence, natural resource management needs to integrate the impacts of current and past landscape changes as well as future climate change impacts, especially those impacts associated with extreme events.

However, the preventative and mitigating capacity provided by ecosystem services varies between land cover types. Additionally, mapping ecosystem services is not a straightforward process and, to date, mapping tools are still being developed and assessed (de Groot et al. 2010). Tools and methods are even more atypical in the context of flood regulation (Nedkov and Burkhard 2012). The viability of human systems is deeply connected to natural systems and needs to be considered from a social-ecological system perspective (Mix et al. 2014). In particular, ecosystems have the function of regulating essential ecological processes and life-supporting systems based on bio-geochemical cycles and other natural processes (Nedkov and Burkhard 2012). Additionally, social-ecological systems can only support economic development if ecosystems can continuously supply services such as the ones related to flood regulation (Mix et al. 2014).

Nevertheless, the potential of ecosystems in flood mitigation and absorption of flood impacts is largely neglected in decision-making (Nedkov and Burkhard 2012). Ecosystem ‘disservices’ such as impacts from floods are often created by human-induced landscape changes (Nedkov and Burkhard 2012). While the degree of land use intensity such as crop density, presence or absence of forest understory can influence the land cover capacity to regulate floods (Stürck et al. 2014), climate change impacts on ecosystems may lead to sudden and large crash of the services they provide and force stakeholders to adjust to a lower level and/or lack of ecosystems services (Breshears et al. 2011). Hence, current competing demands for ecosystem services including agriculture, tourism, and drinking water supply could be further exacerbated by climate change (Le Maitre et al. 2014).

Regional landscape management can play an important role in supporting the provision of ecosystem services as a tool for climate change adaptation. To this end, the main features of regional landscape management initiatives are fourfold. Firstly, ecosystem services provided by regional landscape of high social and ecological significance need to be identified and mapped, preferably with the input from local communities which impact and are dependent on such services. Secondly, an assessment of the level of quality of existing services (e.g., degree of degradation) need to be carried out to ensure they continue to support the viability of social-ecological systems. Thirdly, it is important to determine how climate change is likely to impact these services and further compromise their quality. Lastly, management options need to identify which critical services within the regional landscape are to be restored to both enhance their capacity of withstanding climate change impacts, and ensure their rehabilitation.

Research Approach

This paper adopts a case study approach (Flyvberg 2006) to draw lessons on regional landscape management based on major impacts caused by two extreme flood events which affected the State of Queensland in Australia and the State of Rio de Janeiro in Brazil in 2011. The two extreme weather events occurred concomitantly leaving traumatised affected communities, scarred landscapes and substantial economic losses. Although there was an element of surprise related to the scale and intensity of both events, it is important to understand that perhaps there were underlying clues in both landscapes that should have been given more thought and focus by government policies. The intensity of these two extreme flood events and related extent of social-ecological damages alone provide unique opportunity to explore how the management of regional landscapes, or lack of, may impact the quality and availability of ecosystem services that are important for the minimisation of future climate change effects, particularly floods. They also offer insights as to whether extreme weather events may in fact trigger more robust policy responses concerning regional landscape management to avoid the reoccurrence of impacts of similar magnitude on the two case study areas and elsewhere.

Lessons were drawn based on a document analysis reporting the major impacts the two flood events caused on the Lockyer Valley in Australia (see Fig. 8.1), and the Região Serrana of Rio de Janeiro in Brazil (see Fig. 8.2). Documents included

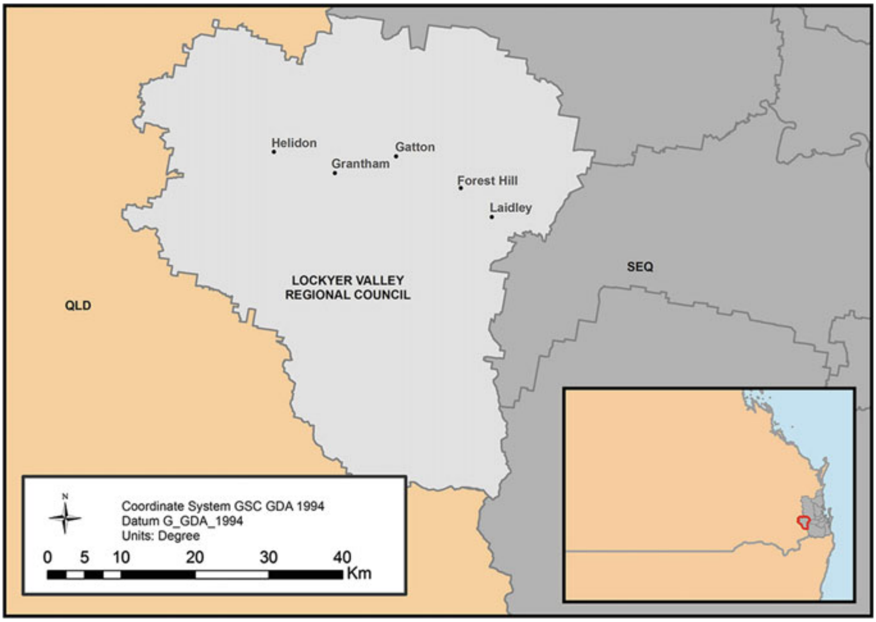


Fig. 8.1 Localization of the townships most affected by the 2011 floods in the Lockyer Valley, QLD—Australia

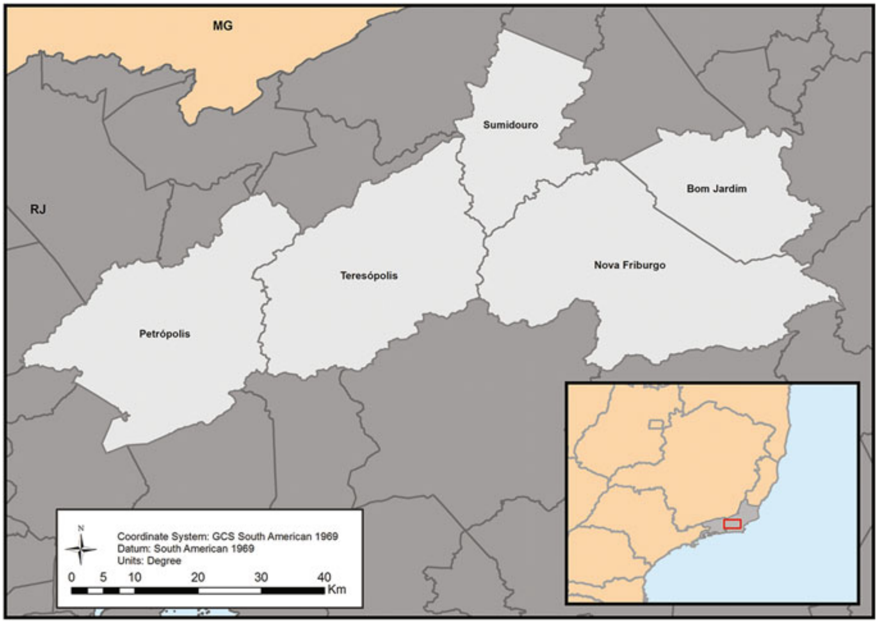


Fig. 8.2 Localization of the municipalities most affected by the 2011 landslides in the Região Serrana of Rio de Janeiro—Brazil

peer-reviewed publications identified using the Scopus database and technical reports specifically analysing the extreme weather events affecting the two case study areas. The findings outlined in the Discussion section are specific to the two case studies investigated by this paper and may not be transferable to other contexts. Additional comparative studies covering a larger number of cases would be suitable to provide more detailed information to guide the improvement of regional landscape management.

The Lockyer Valley—South East Queensland, Australia

The Lockyer catchment lies to the east of Toowoomba on the Great Dividing Range spanning an area of 3000 km^2 (see Fig. 8.1). The catchment has a typical bowl shape draining from the high elevation of the Ranges to the lower wide alluvial plains and lowlands. The Lockyer Creek comprises the main stream system in the catchment. Two major tributaries enter the catchment along the southern margins, including Murphy's Creek—a bedrock confined with a mean channel bed slope of 0.006 mm^{-1} on its upper reaches with isolated floodplain pockets and 0.008 mm^{-1} on the lower reaches (Leigh et al. 2013). The lower part of the catchment is characterised by a wide valley floor (2–13 km) where channel plan form alternates between low sinuosity reaches and tight meandering bends incised into bedrock (Leigh et al. 2013).

Two agricultural activities predominate in the area: grazing in the upper ridges and intensive agricultural production, especially horticultural activities on the domains of its fertile floodplain (Warner 2011). Clearing and settlement of the Valley began in the 1840s and by 1940 most waterways associated with the Lockyer Creek were cleared of vegetation (Warner 2011). As a result, erosion in the area is estimated to be 30 times higher than that of pre-European settlement (Olley et al. 2006). During large flood events, the main creek systems that form the catchment area do not have the capacity of absorbing water discharge from the upper area and it is estimated that more than 600 tones of sediment originated from the Lockyer Valley was discharged into Moreton Bay as a result of the 2011 floods (Warner 2011).

The 2011 flood event was the second highest on record for the past 100 years. It was a result of a strong La Niña event and elevated sea surface temperatures, following by the interaction of a low-pressure system situated of the mid and south Queensland coast and upper level monsoonal troughs (van den Honert and McAneney 2011). On January 10th massive storm cells converged and moved across the top of the Lockyer catchment covering an area of approximately 230 km^2. The most intense precipitation was observed in the upper catchment tributaries (i.e., 150 mm in 2 h). Recorded rapid and extreme rise in discharge in the upper catchment indicate a rise of 8 m in 30 min. Tributaries at the southern end of the catchment charged later leading to a 'double-peak' in the lower reaches of the catchment (Leigh et al. 2013).

The floods caused damage to road crossings, farmland and riparian vegetation (Alluvium Consulting Australia Pty Ltd. (Alluvium) 2012). The floods were an exemplar demonstration of how patterns of hydrological connectivity control patterns of sedimentological connectivity, and how threshold conditions for widespread sediment transport can be exceeded (Croke et al. 2013). Channel widened considerably as a result of the floods causing substantial damage to productive agricultural land due to floodwaters (Alluvium Consulting Australia Pty Ltd. (Alluvium) 2012). A decade earlier, authors (Apan et al. 2002) noted that the rate of clearing of riparian vegetation along first-order streams in the catchment had potential impact to contribute to water velocity and soil erosion. The legacy of such clearing already resulted in declined waterway quality and riparian condition and possibly contributed to significant bank erosion observed in the 2011 floods (SEQ Catchments Ltd. 2013). Additionally, post-floods reconstruction works in the area included the modification of channels and riparian zones further contributing to changes in flood hazard profiles in downstream reaches, including potential increased erosive forces on the channel (Alluvium Consulting Australia Pty Ltd. (Alluvium) 2012).

The Região Serrana—Rio de Janeiro, Brazil

Located approximately 70 km to the northeast of the city of Rio de Janeiro, the Região Serrana is characterized by rocky cliffs, thick soil and deforested areas of the Atlantic Forest, making it susceptible to landslides (Dantas et al. 2001). Historically, the region was continuously covered by the Atlantic rainforest which was significantly removed to give way to vegetable crops, pastures and urbanisation. Some parts of the original forest remain and in various locations re-colonization by secondary forests have occurred due to their unsuitability to agricultural activities. These regenerated forests permit the entry of water into the soil, however they do not have deep root anchoring systems that increase soil resistance on the slopes. During the expansion of urbanisation and rural activity, slopes were cut to enable the implementation of roads and residences (Avelar et al. 2011). This change in land use cover and associated urban development process increased the region's vulnerability to erosion and incidence of floods. Notably, in addition to geological and geomorphological conditions favorable to landslides and floods, the region also presents social issues associated with unplanned and unregulated urban development of slopes and hills. To date, political-administrative actions have proven to be insufficient to appropriatly adress both social and environmental issues confronting these hazardous areas (Oliveira 2014).

Four days of torrential rainfall attributed to a La Nina event affected the State of Rio de Janeiro in January 2011. In the Região Serrana, a month's worth of rain fell in just a few hours triggering numerous landslides and flash floods which caused more than 1500 deaths and severe damage to urban and rural infrastructure (Avelar et al. 2011). In particular, landslides destroyed neighbourhoods perched on steep hillslopes and low-lying areas were inundated by floods (Jefferson 2011).

Discussion

Despite the extensive damage to the regional landscape and loss of life caused by the 2011 floods in the Lockyer Valley, the Queensland Flood Commission of Enquiry (QFCI 2012)—especially established to investigate the extent of damage caused by the floods—did not directly discuss land management (Wenger et al. 2013). As noted by Wenger et al. (2013) the final report compiled by the QFCI identified the role and importance of vegetation management in reducing bank erosion and stabilising riverbanks but did not propose any recommendation associated with land management. Additionally, the current State legislation dealing with water resources (e.g., the *Water Act 2000*) reflects an Australian trend in water governance which neglects the provision of guidance and resources for authorities to deal with flood management (Godden and Kung 2011). Additionally, although a review of the National Disaster Relief and Recovery Arrangements (the main source of funds for reconstruction works following disasters) was undertaken after the 2011 floods, no means are provided for environmental recovery following disasters and further responsibilities were relocated upon state and local governments (Biggs 2012). Hence, at the state and federal levels flood management predominantly targets the protection of community infrastructure and private property from floods as opposed to landscape scale preventive measures (Godden and Kung 2011).

There is significant evidence that the poor conditions of the catchments in the Lockyer Valley have contributed to the intensity of the 2011 flood impacts (Warner 2011). However, there has been little coordinated effort to plan for and restore floodplains and their role in supporting productive rural industries. Floodplain and environmental management in SEQ has been generally poor resulting in many damaged and degraded watercourses that would benefit from remediation, therefore improving their capacity of flood regulation (Olley et al. 2006). Interestingly, management strategies to protect water's edge are also rarely implemented despite being supported by stakeholders. This is also the case in parts of the USA (Kenwick et al. 2009) and South Africa where the challenges are intrinsically related to policy implementation processes (Postel 2008). Additionally, past disasters such as the one caused by Hurricane Katrina left a powerful lesson that natural ecosystems can in fact mitigate the impacts of future natural hazards (Postel 2008).

In comparison, the recent incidence of multiple natural hazards leading to disasters in Brazil, including the extreme rainfall event that affected the Região Serrana in 2011, triggered some policy responses at the national level such as the launch of the Brazilian Atlas of Natural Disasters (UFSC 2011). Considered the major effort to organise information related to disasters in the country, the Atlas aimed to compile information about natural hazards-related disasters officially recorded by states and municipalities in the last 20 years (1991–2010). Additionally, in December 2011, the National Center for Monitoring and Natural Disasters Early Warning System (CEMADEN) was created to develop, test and implement a forecasting system for natural hazards in at risk areas throughout the country (Centro Nacional de Monitoramento e Alertas de Desastres Naturais (CEMADEN)). For municipalities to be monitored by CEMADEN they need to have mapped risk areas for mass movements such as landslides, debris flows, fallen land, fall/rolling boulders and erosion, as well as hydrological-related risks such as floods and landslides. The scheme also requires municipalities to estimate the extent of potential damage caused by natural hazards within their jurisdictions.

While authors (Alfieri et al. 2012) noted the value in investing in improved monitoring and information gathering to support early warning systems to deal with rainfall-induced landslides and avoid significant casualties, the above mentioned initiatives mostly focused on aspects of the physical enviroment. This narrow focus is problematic on a number of fronts. Firstly, the Brazilian society presents a high degree of social inequity and highly vulnerable settlements located on slopes/hillsides are often characterised by populations of low social-economic status (Marandola Jr. and Hogan 2009; Lapola et al. 2014). Secondly, the involvement of communities comprises a fundamental pre-requisite for successful ecosystem-based adaptation initiatives known to enhance the protection of ecosystem services as well as secure livelihoods of social-economic disadvantaged populations (Willemen et al. 2013). Thirdly, by not considering the social dimension involved in disaster risk reduction these initiatives also lack the communication component which must accompany effective risk reduction and preparedness of vulnerable communities (Di Giulio 2012; Dourado et al. 2012). Nevertheless, some locally based organizations are starting to emerge in response to the limitations of these initiatives and motivated by their dissatisfaction with the government's propositions. Such emergence gives hope that future discussions about real management solutions for those at-risk areas will involve all social actors and perhaps be conducive to a landscape scale governance approach.

Additionally, the Brazilian legislation does not clearly prescribe the role of local governments in developing and implementing policies related to water resources through strategic planning or land use planning and development control. Authors (Carneiro et al. 2010) emphasize the need to link water resources and urban and regional planning. In particular, uncontrolled/unplanned urban sprawl that may compromise the flood regulatory function of catchments leading to increased risk of flooding. Additionally, smaller, remote local governments, including the ones adjacent to large metropolitan areas such as Rio de Janeiro, have limited capacity to undertake and enforce urban development control further contributing to deficiencies in the management of regional landscapes (Carneiro et al. 2010).

Conclusion

This paper investigated the impact of two extreme rainfall events on social-ecological systems and inherent policy responses in Australia and Brazil; the Lockyer Valley and the Região Serrana, respectively. Findings indicated that despite of known vulnerability of both landscapes to extreme rainfall events associated with changes in their land use cover, policy responses to date have failed to support changes in landscape management that could minimize future impacts of natural hazards on their social-ecological systems. In both countries, government responses related to disaster risk reduction in the affected areas, and elsewhere, tended to predominantly focus on reconstruction of built structures (Australia) or improvement of early warning systems (Brazil). However, without a concerted effort to manage land use and development in those areas it is unlikely that disaster risks will diminish or ecosystem services will be enhanced and maintained, particularly in light of climate change. Based on findings, there are four key lessons that can be drawn regarding regional landscape management conducive to supporting climate change adaptation. These include:

(a) **Land use policies**

Policies associated with land use planning, development control and disaster risk reduction need to consider larger spatial and temporal scales to enable a whole-of-landscape management approach which understands the complexity of their social-ecological systems, including land ownership and tenure (Apan et al. 2002) to prioritise ecosystem rehabilitation efforts and support preventive measures (Alfieri et al. 2012). Larger temporal scales are particularly important to address future environmental and social changes that may eventuate in the regional landscape due to climate change impacts.

(b) **Informed decisions**

Land use planning and decision-making concerning areas at-risk should be informed by scientific information related to environmental management, including impacts of land use cover change on ecosystem services with potential mitigation functions to reduce effects of natural hazards or extreme weather events as a result of climate change.

(c) **Supporting monitoring systems**

Informed decisions require the allocation of resources to monitor how landscapes, including ecosystem services, are responding to natural and anthropogenic-induced changes as well as rehabilitation works. Such monitoring should inform policy implementation to enable the anticipation and adaptation to change over time possibly by adopting an adaptive management approach.

(d) **Public engagement**

Greater public engagement is needed in both plan-making and plan-implementation processes associated with land use planning and natural resource management to ensure there is better understanding of how local communities impact on and are impacted by changes in the availability and quality of ecosystem services within their regional landscapes.

It is important to highlight that the implementation of actions derived from these lessons requires a significant level of future and ongoing research concerning landscape management, especially in light of uncertainty of climate science. For that to occur, significant investment and commitment from both public and private sectors will need to be mobilised.

References

Adger WN (2000) Social and ecological resilience: are they related? Prog Hum Geogr 24(3):347–364. doi:10.1191/030913200701540465

Alfieri L, Salamon P, Pappenberger F, Wetterhall F, Thielen J (2012) Operational early warning systems for water-related hazards in Europe. Environ Sci Policy 21:35–49. doi:10.1016/j.envsci.2012.01.008

Alluvium Consulting Australia Pty Ltd. (Alluvium) (2012) Stream restoration strategy for Blackfellow Creek at Mount Sylvia: report to SEQ Catchments, Brisbane, Australia

Antrop M (2004) Rural-urban conflicts and opportunities. In: Jongman R (ed) The new dimensions of the European landscape. Springer, Dordrecht, pp 83–91

Apan A, Raine S, Paterson M (2002) Mapping and analysis of changes in the riparian landscape structure of the Lockyer Valley catchment, Queensland, Australia. Landsc Urban Plan 59:43–57

Avelar AS, Netto ALC, Lacerda W, Becker LB, Mendonça MB (2011) Mechanisms of the recent catastrophic landslides in the mountainous range of Rio de Janeiro, Brazil. Second World Landslide Forum, Rome, 3–7 Oct 2011

Berkes F, Colding J, Folke C (2003) Navigating social–ecological systems: building resilience for complexity and change. Cambridge University Press, Cambridge, UK

Biggs R (2012) Paying for disaster recovery: Australia's NDRRA and the United State's NFIP. Aust J Emerg Manag 27(2):26–30

Birkmann J, Garschagen M, Kraas F, Quang N (2010) Adaptive urban governance: new challenges for the second generation of urban adaptation strategies to climate change. Sustain Sci 5:185–206

Blanco H, Alberti M, Forsyth A, Krizek K, Rodriguez D, Talen E, Ellis C (2009) Hot, congested, crowded and diverse: emerging research agendas in planning. Prog Plan 71:153–205

Breshears DD, López-Hoffman L, Graumlich LJ (2011) When ecosystem services crash: preparing for big, fast, patchy climate change. AMBIO 40(3):256–263. doi:10.1007/s13280-010-0106-4

Carneiro PRF, Cardoso AL, Zampronio GB, de Carvalho Martingil M (2010) A gestão integrada de recursos hídricos e do uso do solo em bacias urbano-metropolitanas: o controle de inundações na bacia dos rios Iguaçu/Sarapuí, na Baixada Fluminense. Ambiente Soc 13:29–49

Centro Nacional de Monitoramento e Alertas de Desastres Naturais (CEMADEN). http://www.cemaden.gov.br/municipiosprio.php. Accessed 15 June

Chong J (2014) Ecosystem-based approaches to climate change adaptation: progress and challenges. Int Environ Agreem 1–15. doi:10.1007/s10784-014-9242-9

Croke J, Fryirs K, Thompson C (2013) Channel–floodplain connectivity during an extreme flood event: implications for sediment erosion, deposition, and delivery. Earth Surf Proc Land 38(12):1444–1456. doi:10.1002/esp.3430

Dantas ME, Shinzato E, Medina AIM, Silva CR, Pimentel J, Lumbreras JF, Calderano SB, Filho AC (2001) Diagnóstico Geoambiental do Estado do Rio de Janeiro, Brasília/CPRM. In: Estudo Geoambiental do Estado do Rio de Janeiro, Rio de Janeiro, Brazil

de Groot RS, Alkemade R, Braat L, Hein L, Willemen L (2010) Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. Ecol Complex 7(3):260–272. doi:10.1016/j.ecocom.2009.10.006

Depietri Y, Renaud FG, Kallis G (2012) Heat waves and floods in urban areas: a policy-oriented review of ecosystem services. Sustain Sci 7(1):95–107. doi:10.1007/s11625-011-0142-4

Di Giulio, Marques G (2012) Risco, ambiente e saúde: um debate sobre comunicação e governança do risco em áreas contaminadas. Annablume, São Paulo

Dourado F, Arraes TC, Silva MF (2012) O Megadesastre da Região Serrana do Rio de Janeiro – as Causas do Evento, os Mecanismos dos Movimentos de Massa e a Distribuição Espacial dos Investimentos de Reconstrução no Pós-Desastre. Anuário do Instituto de Geociências - UFRJ 35(2):43–54

Flyvberg B (2006) Five misunderstandings about case-study research. Qual Inquiry 12:219–245

Folke C, Hahn T, Olsson P, Norberg J (2005) Adaptive governance of social-ecological systems. Annu Rev Environ Resour 30:441–473

Godden L, Kung A (2011) Water law and planning frameworks under climate change variability: systemic and adaptive management of flood risk. Water Resour Manag 25(15):4051–4068. doi:10.1007/s11269-011-9887-x

Hall S, Ashley W (2008) Effects of urban sprawl on the vulnerability to a significant tornado impact in northeastern Illinois. Nat Hazards Rev 9(4):209–219. doi:10.1061/(ASCE)1527-6988(2008)9:4(209)

IPCC (2014) Climate change 2014: impacts, adaptation, and vulnerability—summary for policymakers. In: Working Group II Contribution to the IPCC 5th Assessment Report—Changes to the Underlying Scientific/Technical Assessment. International Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK

Jefferson A (2011) Landslides and flooding in Brazil. http://all-geo.org/highlyallochthonous/2011/01/landslides-and-flooding-in-brazil/. Accessed 10 June 2011.
Kenwick RA, Shammin Md R, Sullivan William C (2009) Preferences for riparian buffers. Landsc Urban Plan 91(2):88–96. doi:10.1016/j.landurbplan.2008.12.005
Lapola DM, Martinelli LA, Peres CA, Ometto JPHB, Ferreira ME, Nobre CA, Aguiar APD, Bustamante MMC, Cardoso MF, Costa MH, Joly CA, Leite CC, Moutinho P, Sampaio G, Strassburg BBN, Vieira ICG (2014) Pervasive transition of the Brazilian land-use system. Nat Clim. Change 4(1):27–35. doi:10.1038/nclimate2056. http://www.nature.com/nclimate/journal/v4/n1/abs/nclimate2056.html. Supplementary-information
Leigh C, Burford MA, Connolly RM, Olley JM, Saeck E, Sheldon F, Smart JCR, Bunn SE (2013) Science to support management of receiving waters in an event-driven ecosystem: from land to river to sea. Water (Switzerland) 5(2):780–797. doi:10.3390/w5020780
Maitre L, David C, Kotzee IM, O'Farrell PJ (2014) Impacts of land-cover change on the water flow regulation ecosystem service: invasive alien plants, fire and their policy implications. Land Use Policy 36:171–181. doi:10.1016/j.landusepol.2013.07.007
MA (2003) Ecosystems and human well-being: a framework for assessment. Island Press, Washington, DC
MA (2005) Ecosystems and human well-being: current state and trends. Island Press, Washington, DC
Marandola Jr EJ, Hogan DJ (2009) Vulnerabilidade do lugar vs. vulnerabilidade sociodemográfica: implicações metodológicas de uma velha questão. Revista Brasileira de Estudos da População 26(2):161–181
Miller JD, Kim H, Kjeldsen TR, Packman J, Grebby S, Dearden R (2014) Assessing the impact of urbanization on storm runoff in a peri-urban catchment using historical change in impervious cover. J Hydrol 515:59–70. doi:10.1016/j.jhydrol.2014.04.011
Mix K, Lopes VL, Rast W (2014) A systems approach to understanding the evolution of the agro-social-ecological system of the Upper Rio Grande-San Luis Valley, Colorado. Water Resour Manag 1–19. doi:10.1007/s11269-014-0735-7
Monasterik R (2009) A burden beyond bearing. Nature 458(30):1091–1094
Nedkov S, Burkhard B (2012) Flood regulating ecosystem services—mapping supply and demand, in the Etropole municipality, Bulgaria. Ecol Indic 21:67–79. doi:10.1016/j.ecolind.2011.06.022
Oliveira MS (2014) Relação entre chuva e deslizamento em Nova Friburgo/RJ. Masters Thesis, Programa de Pós-graduação em Engenharia Civil, COPPE, Universidade Federal do Rio de Janeiro – UFRJ, Rio de Janeiro, Brazil
Olley J, Wilkinson S, Caitcheon G, Read A (2006) Protecting Moreton Bay: reducing sediment and nutrient loads by 50%. In: River symposium, Brisbane
Parry M, Canziani O, Palutikof J, van der Linden P, Hanson C (eds) (2007) Climate change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the fourth assessment report of the intergovernmental panel on climate change. International Panel on Climate Change (IPCC). Cambridge University Press, Cambridge
Plant R, Ryan P (2013) Ecosystem services as a practicable concept for natural resource management: some lessons from Australia. Int J Biodivers Sci Ecosyst Serv Manag 9(1):44–53. doi:10.1080/21513732.2012.737372
Postel SL (2008) The forgotten infrastructure: safeguarding freshwater ecosystems. J Int Aff 61(2):75–90
QFCI (2012) Queensland floods commission of inquiry: final report. Brisbane, QLD, Australia
SEQ Catchments Ltd. (2013) Flood impacts report February 2013. Executive Summary
Stürck J, Poortinga A, Verburg PH (2014) Mapping ecosystem services: the supply and demand of flood regulation services in Europe. Ecol Ind 38:198–211. doi:10.1016/j.ecolind.2013.11.010
Universidade Federal de Santa Catarina (UFSC) (2011) Atlas brasileiro de desastres naturais 1991 a 2010: volume Rio de Janeiro. Florianópolis: Centro Universitário de Estudos e Pesquisas sobre Desastres (CEPED), Santa Catarina, Brazil

van den Honert RC, McAneney J (2011) The 2011 Brisbane floods: causes, impacts and implications. Water 3(4):1149–1173

Warner S (2011) Restoring ecological infrastructure for flood resilience: the 2011 southeast Queensland floods and beyond. Submission to the Queensland Floods Commission of Inquiry: SEQ Catchments, Brisbane, Australia

Wenger C, Hussey K, Pittock J (2013) Living with floods: key lessons from Australia and abroad. Gold Coast, NCCARF, Australia

Willemen L, Drakou EG, Dunbar MB, Mayaux P, Egoh BN (2013) Safeguarding ecosystem services and livelihoods: understanding the impact of conservation strategies on benefit flows to society. Ecosyst Serv 4:95–103. doi:10.1016/j.ecoser.2013.02.004

Author Biographies

Dr. Silvia Serrao-Neumann is a Senior Research Fellow for the Corporate Research Centre for Water Sensitive Cities at the Cities Research Centre, Griffith University, Australia. Her research interests are climate change adaptation, disaster resilience, urban and regional planning, environmental planning and water sensitive cities.

Dr. Ana Paula Turetta is a Researcher at Brazilian Agricultural Research Corporation—EMBRAPA. She has experience in natural resources management, with emphasis on environmental planning, working mainly with sustainability and environmental services in agricultural landscapes.

Professor Darryl Low Choy is Professor of Environmental and Landscape Planning and the former Head of Discipline (Planning) in the School of Environment, Griffith University, Australia. His current research is focused on growth management for developing regions; values led planning and indigenous landscape values; resilience and peri-urbanisation of the landscape; climate change adaptation for human settlements, planning for natural resource management and invasive species management; design of water sensitive cities, strategic post disaster recovery and the relationship between science and planning.

Chapter 9
Effects of Urban Occupation in Rivers Morphology: The Case Study of Upper Pedras River, in Jacarepaguá District, at the Tijuca Massif

Monica Bahia Schlee, Sonia Mena Jara, Maria Isabel Martinez and Ana Luiza Coelho Netto

Introduction

The impacts of urbanization and the consequent saturation of environmental carrying capacity in large Brazilian cities indicate the need to broaden the debate on the relationship between the conditions of local urban rivers, sanitation infrastructure, academic action and civic responsibility in Brazil and, especially in Rio de Janeiro (Rio).

Several rivers of Rio are channeled, buried underground the city or have their river beds strangled by landfills and buildings on its banks or even in their river beds. Household sewage discharge into rivers and streams of the city is among the main causes of pollution of its bays (Guanabara and Sepetiba Bays) and costal lagoons, with occurrence of eutrophication and sedimentation processes, with high levels of fecal coliform bacteria (Schlee 2002; Mena 2014). The degradation of these water bodies brings social and economic impacts, higher costs for public

M.B. Schlee (✉)
Prefeitura da Cidade do Rio de Janeiro, CMP/SMU/PCRJ e Universidade Federal do Rio de Janeiro, GEOHECO/IGEO/UFRJ, Rio de Janeiro, Brazil
e-mail: monbasch@gmail.com

S.M. Jara · M.I. Martinez
Universidade Federal do Rio de Janeiro, GEOHECO/IGEO/UFRJ, Rio de Janeiro Brazil
e-mail: soniamena@gmail.com

M.I. Martinez
e-mail: martinez.maisa@gmail.com

A.L. Coelho Netto
Universidade Federal do Rio de Janeiro, Coordenadora GEOHECO/IGEO/UFRJ, Rio de Janeiro, Brazil
e-mail: ananetto@acd.ufrj.br

W. Leal Filho and L. Esteves de Freitas (eds.), *Climate Change Adaptation in Latin America*, Climate Change Management,
https://doi.org/10.1007/978-3-319-56946-8_9

health and great damage to the conservation and protection of the environment, the landscape and the development of tourism in the city.

As stressed Dias and Rosso (2011), the fragmentation of sanitation systems solutions and the difficulties derived from the technological approaches adopted in Rio de Janeiro, as well as the lack of resources for its implementation, proper operation and maintenance, resulted in an enormous complexity and vulnerability in urban water management in Rio de Janeiro. The local sewage system approach still focuses the transportation of sewage without treatment to sites distant from the source, through two ocean interceptors. Sewage treatment existing solutions are punctual, insignificant in relation to the continuous demand and restricted to river outlets. The conflict of responsibilities between the state and municipal administration contributes to aggravate the situation.

Unruly urban expansion have caused numerous environmental problems in Rio de Janeiro, especially in the interface between the urban area and the forest (on the three Costal Massifs), causing changes in the natural hydrological dynamics of the region, with recurrent episodes of landslides, especially during rainy periods. In February 1996, heavy rains sparked hundreds of landslides in the western portion of Tijuca Massif (the most urbanized from the three massifs), especially in the slopes of Jacarepaguá, as well as numerous small landslides along the roads that cut through the massif (Coelho Netto 1996), causing loss of lifes and environmental damage, due to the waterways configuration change and the total or partial destruction of buildings along the path (Coelho Netto et al. 2012).

This article presents results of the research entitled “Applying Innovative Alternative Urban Infrastructure Technologies in River Revitalization Processes”. The project aims to integrate and develop an approach for promoting safe and sustainable water supply and improve water quality in a slum area of Rio de Janeiro, performing watershed management through urban planning, stakeholder engagement, natural hazard analysis and the implementation of low-cost infrastructure for sewage treatment. The ongoing phase seeks to expand the understanding of hillslope-river processes and non-conventional urban infrastructure technologies, in order to propose on-site innovative sewage treatment and sediment control solutions, using bioengineering techniques for morphological adaptation, stabilization, and water quality improvement on Rio de Janeiro urban favelas. The study area is located at Pedras River sub-basin, in Jacarepaguá District, Rio de Janeiro (Fig. 9.1).

Study Area

The area of analysis is located in the confluence of Pedras and Retiro River sub-basins (2.87 km^2), in Jacarepagua district, on the west slopes of Tijuca Massif, flowing into Barra da Tijuca Lagoon. Urban land is concentrated in middle and lower course of Pedras River. In addition to the intense urbanization in its lower course, the slopes of Pedras sub-basin, previously occupied by large fields and

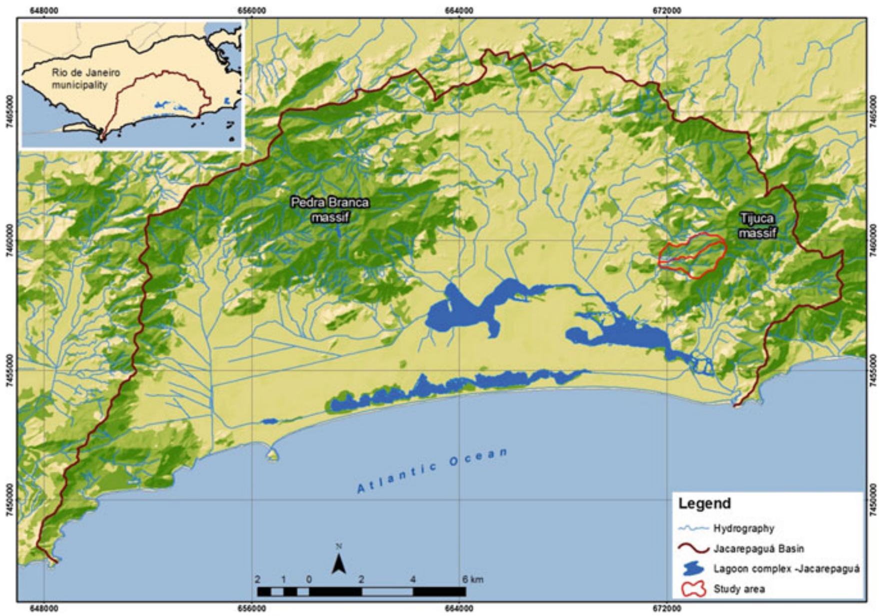


Fig. 9.1 Hydrographic system of Jacarepagua Basin, Rio de Janeiro (RJ), which includes Pedras/Retiro Rivers sub-basins. *Source* Authors

peri-urban sites and second residence, has been gradually occupied by *favelas* (slums) and closed condominiums (Fig. 9.2). The focus of the study and intervention is the *favela* Estrada do Sertão, located in the confluence of the upper portion of Pedras and Retiro River sub-basins, in-between the contour lines of 40 and 60 m above sea level. The population of the *favela* Estrada do Sertão was 1.127 people in 2010 (IBGE Census 2010).

The climate can be classified as Humid Tropical, encompassing: Köppen's Cf-type, in the upper mountain ranges, and Köppen's Am-type in the mid-lower portions. The average temperature is above 18 °C every month with precipitation exceeding the total evaporation. The upper Tijuca Massif, is the wettest area of the city of Rio de Janeiro recorded by Capela Mayrink raingauge station (470 m a.s.l.) located within the Tijuca Forest National Park. The total annual rainfall ranges from 1300 to above 3000 mm. Intense rains are mostly associated with the warmest month (February). Average monthly rainfall is around 100 mm. In high summer of regular years, mean monthly rainfall is on the order of 250 mm. Extreme monthly totals may reach above 900 mm, particularly due to an increasing frequency of intense rains above 100 mm/day (Coelho Netto et al. 2007). Landslides are usually induced by less frequent, intense and spatially nonuniform rainfall events, especially during summer rainy periods. Landslide magnitude may vary for similar rainfall inputs due to landscape component variables and related structure surface levels. Nowadays, the intensity of disasters is potentially increased by global

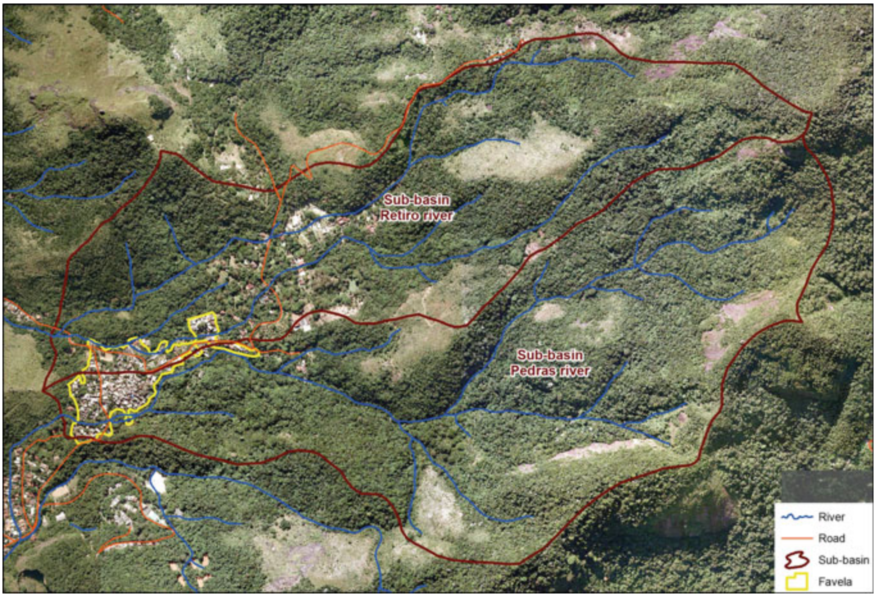


Fig. 9.2 Location of *Favela* Estrada do Sertão. *Source* Authors

climatic changes, linked to accelerated and disordered urban growth and the concentration of poorer populations in high-risk areas (Coelho Netto et al. 2009).

The *favela* Estrada do Sertão is an example of the complex situation of the slums located in the slopes of the city, which mix socio-environmental problems and precarious water infrastructure (water local catchment), with periods of water shortages, sewage disposal *in natura* in the two rivers that crossed the community and irregular urban occupation of their margins. Those multiple environmental problems have cumulative and synergistic impacts on local people lives. The extreme rainfall event of 1996 (380 mm/24 h) generated direct impacts on the morphology of Pedras River, destroying houses and loss of lives. Twenty years later, some risk factors still persist.

Conceptual Framework

The concept of resilience has been improved since the 1970s, incorporating the idea of heterogeneity and non-linearly interactions between temporal and spatial scales, incorporating the perception of a cycle that includes adaptation, reorganization and recovery, as pointed by Forman and Godron (1986), Pickett et al. (2004) and Folke (2006). Landscape resilience may be defined as the adaptive capacity of a landscape system to absorb impacts, reorganize and recover in face of transformations and changes, keeping its basic structure, functions and identity. This concept, based on input from Holling (1973), Folke (2006), Walker and Salt (2006), Ahern (2011) and Ehrlich et al. (2012), among others, was discussed in another publication (Schlee In: Batista et al. 2015). In the case of an urban landscape system, resilience is heavily influenced by urban morphology and land use patterns. The diversity, flow, permeability and connection between landscape components, both spatially and socially are, according to Pickett et al. (2004), Colding (2007) and Ahern (2011) aspects that directly contribute to ensure and strengthen landscape resilience.

With climate change forecasts indicating an increase in the intensity and frequency of rainfall events, the threat of new landslides and floods events in the study area is a latent danger. On the other hand, local inadequacies in urban occupation patterns, provision of infrastructure and services directly impact the quality of the environment, and consequently, may impair adaptive capacity to climate change.

As pointed out in SENDAI Framework (United Nations 2015), the improvement of land-use policy, including urban planning, land degradation and inadequate housing standards is essential for disaster risk prevention. Both, structural and non-structural measures may enhance economic, social, health and cultural resilience of communities, as well as of the environment.

This project seeks to gather and develop local solutions from a holistic perspective in order to increase landscape resilience and adaptative capacity in face of future extreme rainfall events due to climate change.

Methodology

The adopted methodology encompasses two phases, as shown in Fig. 9.3—Summary of Pedras River Watershed Management. Phase 1 comprised the formation of a collaborative network (including the local household association, researchers, local government and private initiative agents), in order to strengthen the knowledge about the study area, foster community involvement and ensure the sustainability of the project through time.

Network activities in the first phase involved collaborative working, discussions and information/knowledge transfer, through meetings with the local population (Estrada do Sertão Household Association and religious leaders), academic researchers (UFRJ), Federal government (FIOCRUZ), State government (INEA and ITERJ), and Municipal government agents (SMAC, CIVIL DEFENSE, COMLURB) and private experts.

This phase also encompassed the characterization of the study area (field surveys and GIS thematic mapping) and a holistic diagnosis of the local environmental problems through land assessment and interviews with local households. The analyses consider different layers: Land Use and Vegetation Cover, hidro-Geomorphology, geology Urban Land, River Morphology, Landslide Susceptibility and local Vulnerability.

The ongoing Phase 2 consists on water assessment and monitoring, encompassing hydrological, sediment and water quality parameters and the research,

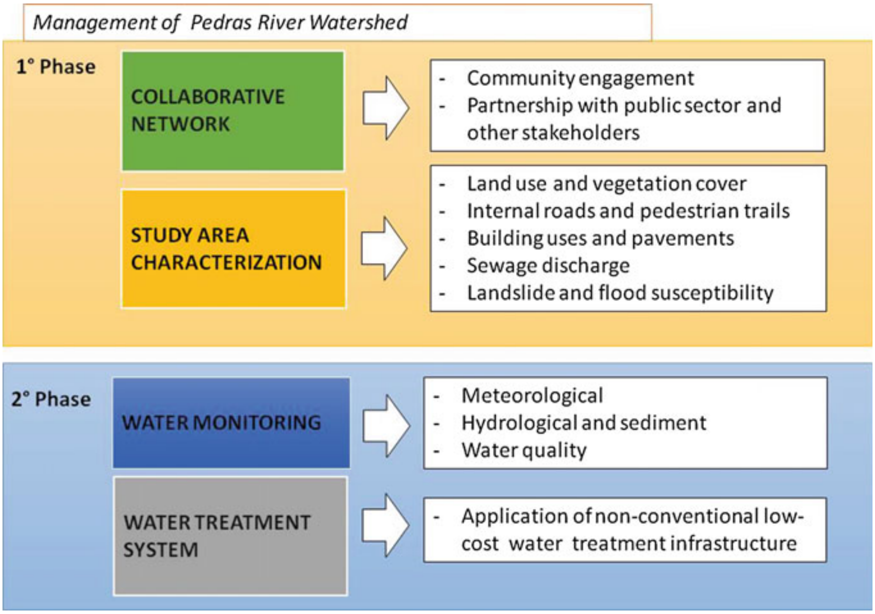


Fig. 9.3 Pedras River watershed management summary. *Source* Authors

discussion, selection and implementation of a locally adequate water quality treatment system.

The Land Use and Vegetation Cover mapping and analysis was elaborated based on the orthorectified aerial photographs of 2013 (Armazem de Dados/IPP/PCRJ 2013), considering the following classes: native forests in intermediate-advanced successional stage, native forests in early successional stage, non-native grassland, crops, urban trees (native and non-native), tree and shrub areas, bare soil, rock outcrops, recreational areas (football field), water bodies, urban occupation in accordance with local legislation and *favelas* (slums). Based on the field surveys, it was possible to update the network morphology of channels after the 1996 extreme rainfall event and delimitate sub-basins contribution zones within the study area. In order to identify the degree of conservation of local springs, the springs and their protection areas located in the upper sub-basins were identified and marked (50 m protection diameter, based on Brazilian Forest Code 2012).

The field survey and mapping of the urban occupation (Pedras and Retiro upper watersheds) was undertaken in order to have a better understanding of the urban infrastructure sustaining the community. The assessment comprised the identification of types of urban building use (residential, commercial, institutional, industrial, mixed use, in construction and vacant lot). Building uses indicated a priori the type of wastewaters potentially been discharged into the stream, suggesting industrial or domestic predominance. In the same way data registering the number of buildings provided the input to estimate sewage production volumes according to Sperling (1996). The height of built form (number of building floors), and the internal roads and pedestrian paths in the slum area were also mapped, based on Schlee (2002, 2011). The collected data may serve to complement the available information of local slum areas in the official municipal maps, which is current deficient.

From the perspective of urban and landscape planning, it is as important to provide a detailed characterization of the urban occupation and infrastructure, such as of geomorphology and vegetation. Parameters such as building uses and number of floors, as well as the number of buildings and the form of parcelling and implementation of the buildings on the ground have a direct influence on population and occupation density (and, consequently, on slope stability and on infrastructure availability and adequacy). Additionally, urban occupation also impacts soil permeability, stormwater runoff and landslide risks due to improper slope cuts and embankments, for example, thus impacting landscape adaptative capacity.

The landslide susceptibility analysis was based on the analytical-integrative method (Coelho Netto 1999; Coelho Netto et al. 2000) and consist of: (1) preparation and processing of database; (2) elaboration of thematic maps with reclassification and redefinition of classes (a. hidro-geomorphological analysis: drainage efficiency index, slope and topographic position index; b. land use and vegetation cover (2013); c. geology for similar behavior); (3) definition of weights according to the relative importance of each factor determined by experts; (4) calculation and preparation of synthesis map.

In order to identify additional risks (local vulnerable spots) in the study area, the susceptibility map was correlated with the maps of land use and vegetation cover, urban land, points of sewage discharge into the rivers and of constrictions due to occupation of the margins. Sewage discharge into the rivers increases risk to the population health and contributes to aggravate erosion processes and landslides on the river banks due to the continuous flow of water on an specific point. The mapping of the 1996 landslide scars (Cruz 2000; Negreiros 2011) was used as a reference for comparison, by measuring the overlap of these scars with the categories of Medium-High and High Susceptibility.

In addition, historical information such as the level of the river bed extravasations in 1996 and the change of river configuration in some places after this event were added. As spatial area analysis, we used the contribution of sub-basins that cross the community. These informations were helpful to understand the behavior of the basins after extreme rainfall events and may contribute to the prevention, awareness and empowerment of the community against risk situations. The conceptual diagram below summarizes the adopted methodology. Some of the factors influencing slope instability were described by Girão, Corrêa & Guerra (2007) (Fig. 9.4).

Results and Discussion

Collaborative Network

Outcomes of the first phase include the establishment of a knowledge transfer and information network with the community, which comprise local stakeholders, researchers and technicians from Municipal, State and Federal government, as shown in Fig. 9.5.

Since the beginning of the project, 16 meetings with the local community, specialists, researchers, religious leaders and government agents of Municipal, State and Federal level (Rio de Janeiro City Hall, INEA and FIOCRUZ) took place from July 2014 to May 2016. In addition, collaborative workshops on sanitation and environmental health with the community were set with FIOCRUZ and Civil Defense, which also informed on how to approach rainfall events during the summer season and handed out the early warning protocols.

Land Use and Vegetation Cover

In the analyzed reach in the upper Pedras and Retiro Rivers watersheds, around 92% of the territorial area is covered by vegetation, in contrast to approximately 8% of urban areas (formal settlements and *favelas*), as shown in Table 9.1. The urban area in the upper Pedras and Retiro Rivers watersheds is concentrated along the valley bottoms, between the contour lines of 40 and 60 m above sea level. Higher building density occurs in the areas occupied by the *Favela* (slum).

Products/Analysis	Analyzed parameter	Purpose of the analysis
MAP OF URBAN AREA	- Roads and pedestrian trails - Number of buildings - Building distribution - Building uses (residential, commercial, industrial, mixed uses) - Pavement types	Number of dwellings Population estimative (based on IBGE ratio) Sewage production estimative
LAND USE AND VEGETATION COVER	- Coverage percentage per class - Springs: local water source (Permanent Preservation Areas, APP)	Watershed land use/vegetation cover composition Input to landslide susceptibility analysis
LANDSLIDES SUSCEPTIBILITY	- Low/ Medium/High/ Very High Susceptibility	Level of susceptibility considering geological, hydro-geomorphological and land use and vegetation cover aspects
HISTORICAL RECORDS	- Landslide scars of 1996 (Cruz, 2000; Negreiros, 2011) - River overflow points of 1996 event - Fluvial morphological change	Assessment of past extreme events associated with current level of susceptibility (overlay with Medium/High and High Susceptibility)
ANTROPOGENIC FACTORS CAUSING SLOPE INSTABILITY AND ENVIRONMENTAL DEGRADATION	- Sewage and garbage discharge in slopes, river bed and banks - Leaks in water pipes and precarious connection to water supply - Slope cuts and ground movements - Urbanization of river banks - Siltation in drainage and river network	Analysis of anthropogenic factors that increase potential risk in areas previously categorized as susceptible, contributing to landslide events and flooding

Fig. 9.4 Methodology scheme. *Source* Authors

Fig. 9.5 Collaborative work, discussion meetings and workshops with Estrada do Sertão Household Association. *Source* Authors

Concerning vegetation cover, the most representative classes in the upper Pedras/Retiro Rivers watersheds are; Native forest in Intermediate-Advanced successional stage (35.9%), Native forest in early successional stage (28.8%), Urban trees and shrubs (16.8%) and Non-native grassland (10.3%). As shown in Fig. 9.6, most of the herbaceous plants and the early successional stage forest patches are

Table 9.1 Land use and vegetation cover

Class		Territorial area	
		km^2	%
Native forest (in intermediate-advanced successional stage)	Native forest (in intermediate-advanced successional stage)	1.037	35.99
Native forest in early successional stage	Forest (pioneer)	0.827	28.84
Urban trees and shrubs (native and non-native)		0.487	16.84
Non-native grassland	Pasture	0.297	10.38
Agriculture		0.017	0.40
Bare soil		0.007	0.28
Recreation area	Urban area	0.007	0.05
Formal occupation		0.087	3.06
Favela (slum) occupation		0.077	2.50
Rocky outcrop	Rocky outcrop	0.047	1.67
Total		2.867	100.0

Source Authors

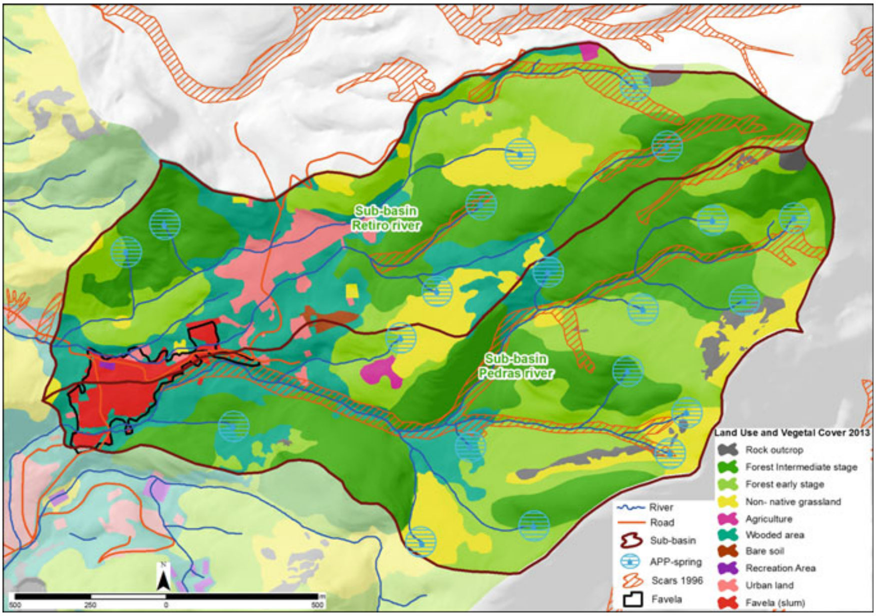


Fig. 9.6 Land use and vegetal cover (2013) and 1996 landslide scars. *Source* Authors, based on land use and vegetation cover map (IPP/PCRJ/Armazem de Dados 2013)

located in springs (local water source). It is important to mention that the spring areas are officially protected by the Forest Code (2012), under the figure of Permanent Protection Areas (APP). In the present case study, these steep areas, although protected by law, present sparse or degraded vegetation, contributing to feed sediment flow and help to impact water quality through the carrying of solid material into the rivers during extreme precipitation events. Moreover, the deforestation of springs, which directly supply the community Estrada do Sertão, compromises the water infiltration processes in the soil, reducing, in turn, the water availability in the basin.

Figure 9.6 also shows the scars of the 1996 landslide, along the natural drainage network. These scars register the level of threat that this particularly extreme rainfall event caused in these watersheds. Especially in Pedras River, considering its natural hazard history, the risk to the population is evident. Moreover, as claimed by Coelho Netto (2005), subsequent erosions in bare soils of landslide clearings-scars continue to add high sediment loads in the main channels of the Tijuca massif, contributing to the silting process in the drainage channels and surrounding lowlands.

This is an aggravating factor to the risk of flooding in extraordinary precipitation events. Findings related to the silting process of Tijuca Lagoon, to where the rivers that drain the study area flow, confirm the magnitude of the problem of transport and accumulation of sediment in Jacarepaguá and Barra da Tijuca lagoons, as a result of landslides registered in the Tijuca Massif, in the years 1966–1967 and 1996 (Mena 2014).

Urban Land

Table 9.2 shows the number of building in upper Pedras/Retiro Rivers watersheds and their uses, encompassing 452 buildings in the favela Estrada do Sertão and 77 buildings on the formal settlement (in accordance to local legislation). The analysis of building use types show that residential use predominate in both the upper Pedras/Retiro River watershed and the Favela Estrada do Sertão (Fig. 9.8). Mixed-use (residential and commercial) and institutional use occur in the main internal (vehicle) routes of the slum (Figs. 9.7 and 9.8). Although buildings of two floors prevail in the Favela Estrada do Sertão, buildings up to 5 floors also occur in the area (Fig. 9.9).

Based on the field surveys and the mapping analysis, it was possible to update the number of dwellings (favela and non-favela) and update the estimative of the population (in 2016) of the upper Pedras/Retiro Rivers watersheds and of *Favela* Estrada do Sertão. Current population of the upper Pedras/Retiro Rivers watersheds (2016) reaches 1.688 inhabitants in upper Pedras River watershed. From this amount, 1.451 inhabitants live in *Favela* Estrada do Sertão and 237 inhabitants in formal settlements (in accordance with local legislation) along Estrada do Sertão (Sertão Road). According to IBGE Census data (2010), the Favela Estrada do

Table 9.2 Building uses in upper Pedras/Retiro Rivers watersheds

Type	Number of buildings	Uses	Total
Favela (slum)	452	Residential	386
		Mixed	23
		Institutional	11
		Commercial	10
		In construction	4
		Industrial	2
		Empty lot	1
		No information	15
Formal settlement (in accordance to local legislation)	77	Residential	76
		Institutional	1

Source Authors

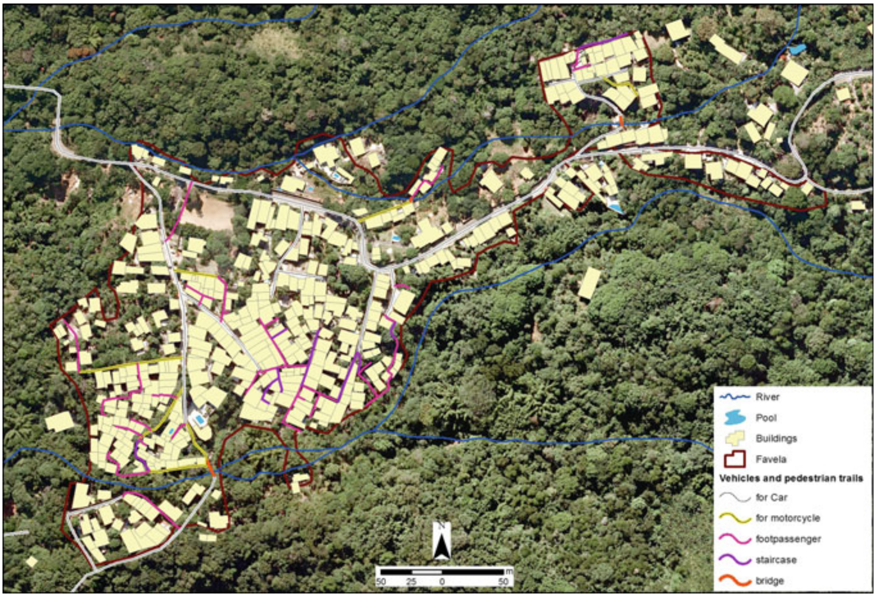


Fig. 9.7 Vehicles and pedestrian trails. *Source* Authors, after base PCRJ/IPP/Armazem de Dados

Sertão had 1.127 inhabitants in 2010. This result shows an increase in population of *the slum area* of 324 inhabitants between 2010 and 2016. Sewage volume production in the upper Pedras River watershed is 3.5 l/s, including formal and *favela (slum)* settlements.

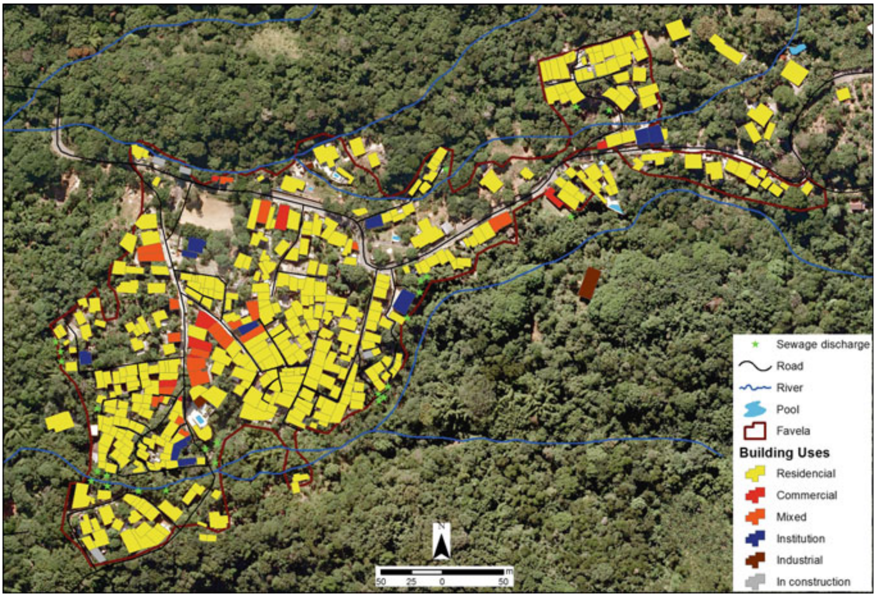


Fig. 9.8 Building uses. *Source* Authors, after base PCRJ/IPP/Armazem de Dados

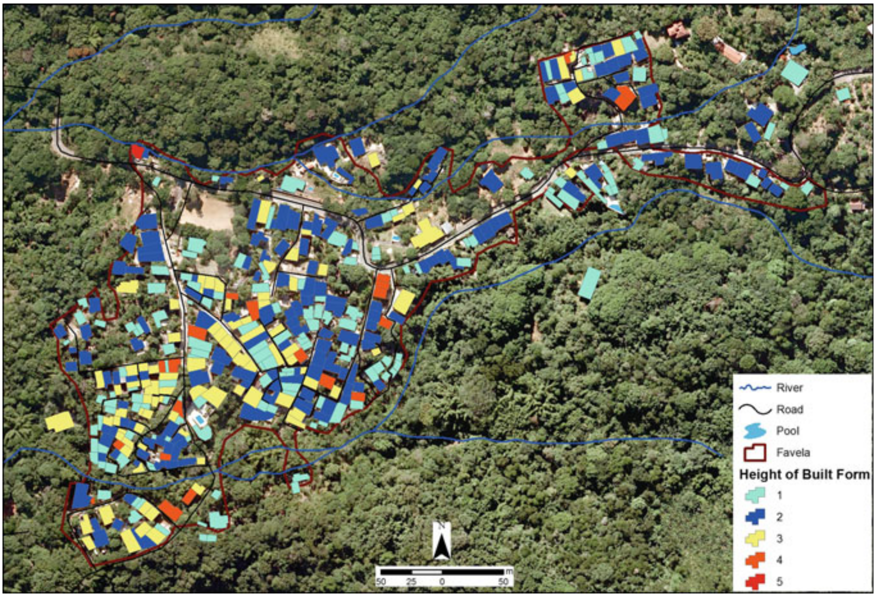


Fig. 9.9 Height of built form. *Source* Authors, after base PCRJ/IPP/Armazem de Dados

Fig. 9.10 Identification of environmental problems and precarious infrastructure. Fieldwork during the project. *Source* Authors

The research results demonstrate that a significant part of the urban population in the upper Pedras River live in illegal settlements formed outside any land-use plan, in hazard prone areas. Those high-risk areas lower the value of the land, on one hand, but decrease the inhabitants' chance of eviction, on the other. The field surveys carried out together with the community and the urban occupation analysis were fundamental to update slum population and housing data (providing a measure of the accuracy of the 2010 IBGE Census) and to make a more precise calculation of the sewage volume production on upper Pedras/Retiro Rivers watersheds, based on the literature (Sperling 1996; Vianna 2015).

The fieldwork also showed a large amount of domestic wastewater and garbage discharge into the rivers, the precariousness and deficiency of water pipes and water catchment infrastructure that supply the community (Fig. 9.10).

Landslide Susceptibility

As shown in Fig. 9.11 and Table 9.3, results of the landslide susceptibility analysis in the Pedras/Retiro Rivers watersheds, based on Martínez (2014), indicate a large

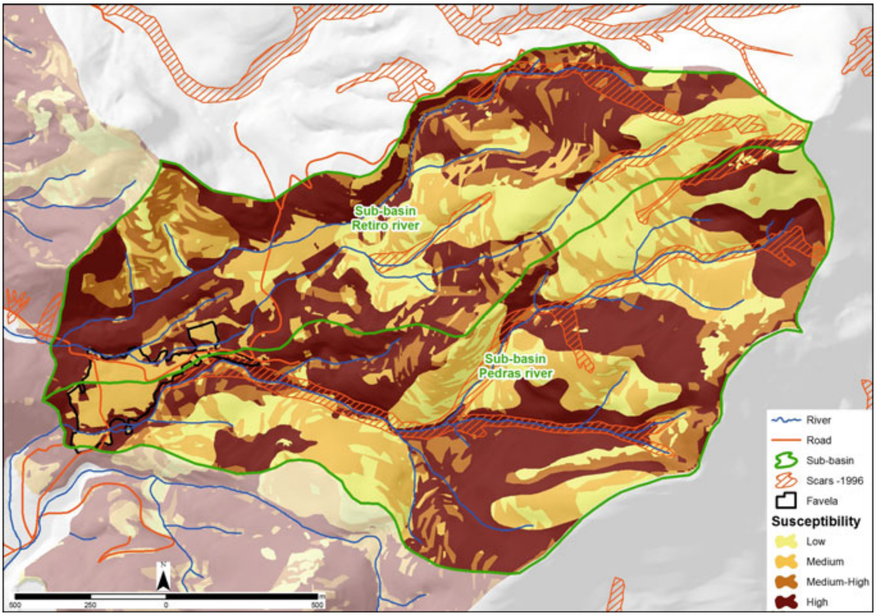


Fig. 9.11 Landslide susceptibility and 1996 landslide scars. *Source* Authors

Table 9.3 Percentage of landslide susceptible area for each class

Class	Percentage (%)		
	Sub-basin (2.86 km^2)	Favela (0.08 km^2)	Landslide scars area (0.27 km^2)
High	33.32	18.61	28.78
Medium–high	17.33	3.43	20.91
Medium	29.24	77.95	25.57
Low	20.1	0.02	24.74

Source Authors

percentage of areas with high susceptibility (33.32%) and medium-high susceptibility (17.33%) above the contour line of 40 m, indicating the level of hazard which the resident population in the basin is exposed. Likewise, in the *Favela* area, 77.95% of the territorial area corresponds to medium susceptibility, and 18.61% of high landslide susceptibility. Most areas classified as highly prone to landslide are positioned on the riparian area or near the watershed divisors. One of the largest medium-high susceptibility spots are located upstream of the Favela Estrada do Sertão, envolving it. The analysis of susceptibility to landslides in the study area and its correlation with the land use and vegetation cover and the local vulnerability points identified with the community are described in more details in another publication (Martinez et al. 2016 in press).

Similarly, there is an extensive overlap between the landslide scars occurred in 1996, documented in Coelho Netto (1996) and the areas classified in the present study as at risk. Around 49.6% of the scars area remains as medium-high or high landslide susceptibility. This confirms the vulnerability of the constructions (in both formal and *favela* settlements) placed on the margins of the two rivers (Fig. 9.11). It is important to highlight that mass movements can affect not only the areas circumscribed to the drainage channels (delimited by the scars), but also a larger area, due to the displacement of sediments and its consecutive deposition downhill.

Local Landslide and Health Hazard Vulnerability

Figure 9.12 emphasizes the usefulness of the data collected in the field together with the community, a valuable source of local information that provides an additional support for technical analysis of landslide risk susceptibility. Red ellipses and circles express the sum of current and historical factors that contribute to increase landslide susceptibility and health hazard risk in the area, which comprise: alteration in river morphology after landslide events; sewage and garbage discharge on slopes and river bed and banks; urban occupation in river margins and steep

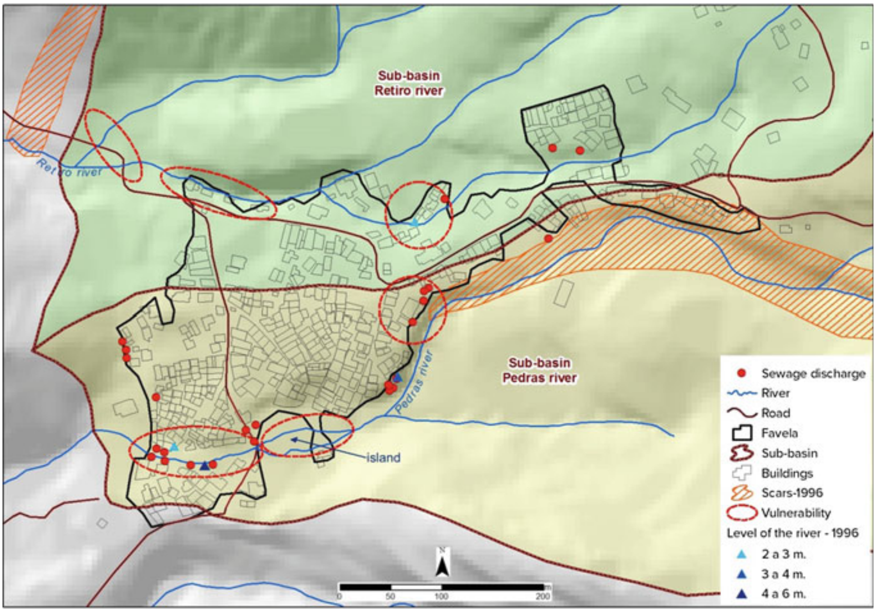


Fig. 9.12 Local vulnerable spots contribute to slope instability in the study area. *Source* Authors

slopes; river constriction due to urban occupation on river bed and banks; road crossing over the rivers; buildings located immediately downstream of the scars of past landslides; slope instability caused by household rainwater network and sewage pipes; and deterioration of vegetation cover. Those anthropogenic hazards together are leading to significantly increase the risk in the study area.

It worths to mention that, due to the steep slope conditions, the access to the upper areas of the watershed, where the springs are located, is limited. The water that supplies the community of Estrada do Sertão is capture uptaken in private properties and its residents need permission from the upstream property owners to capture it. According to the Estrada do Sertão community residents, in the dry season, access to water is limited (a few hours a day) while the upstream property owners give preference to fill the pools of their residences and small farms than pass the water to the community.

As shown in Fig. 9.12, according to local population reports, the Pedras River reached a height of 6 m in some spots during the extreme rainfall event of 1996. The streamflow increased dramatically during the event, generating alterations on channel morphology. After digging a step canyon upstream, the river was bifurcated due to erosion and sediment transportation, giving rise to a small island (approximately 1.321 m^2). Some isolated erosion spots on the river banks were still found on the Pedras River. There is also evidence of rockfall and boulder displacement from hillside to the riverbed, demonstrating the power of the mass movement on the occasion.

Sewage disposal are concentrate in four spots along Pedras River and two spots along Retiro river, as shown in Fig. 9.12. Sewage discharge severely impacts water quality and increase health hazard risk, develops a continuous runoff of polluted water on channel margins. This scenario tends to enhance the erosion processes and trigger mass movements in the already fragile slopes due to the occurrence of past landslides.

Final Considerations

This paper registered the application and articulation of transdisciplinary methods of analysis to gauge landscape change on the west slopes of Tijuca Massif in Rio de Janeiro and their impacts on slope stability and adaptative capacity. The analyses on the local level confirm that, once a significant part of the urban population in the upper Pedras River lives in illegal settlements formed outside any land-use plan (*favelas*), in hazard prone areas, it is pertinent to assess and characterize urban occupation patterns and discuss more adequate alternatives with the local community.

The correlation of complementary analyses demonstrated several effects of urban occupation on on catchment behaviour and morphology on the west slopes of the Tijuca Massif, which comprise: alteration in river morphology after landslide events; sewage and garbage discharge on slopes and river bed and banks; urban occupation in river margins and steep slopes; river constriction due to urban occupation on river bed and banks; road crossing over the rivers; buildings located immediately downstream of the scars of past landslides; slope instability caused by household rainwater network and sewage pipes; and deterioration of vegetation cover.

Those human processes of dealing with water and land together contribute to increase the risk of landslides in the study area. Once they are cultural processes grounded on collective behavior, changes on them will require the involvement of the whole community. For this reason, a collaborative network was set in order to expand the understanding of the local environmental problems and urban river processes and seek consensual solutions from a holistic perspective in order to increase the resilience of the local slope population in face of future extreme rainfall events. The analysis and joint work with communities vulnerable to landslide risk, opens a possible path to the inclusion of local stakeholders in decisions about their territory. The rescue of traditional knowledge and information on past experiences of extreme events, becomes essential in assessing current risks.

The analyses undertaken in the local level indicate that in hazard prone areas, pro-development landscape supportive initiatives must acknowledge a transdisciplinary approach, grounded on community involvement in search of a new restorative urban planning management model, as suggested by Schlee et al. (2012), that may enhance adaptive capacity to mitigate the effects of climate change, specially, the ones related to landslide disasters.

Concerning the methodology of analysis, although the present analysis of susceptibility has not applied a geotechnical base, as well as the shape of the slope and the type and thickness of the soil due to the lack of updated data bases, it is considered important to include these information on future studies to improve the classification of the different types of landslides and of the level of susceptibility.

Also, performing a detailed mapping of the rivers morphological changes throughout their courses, would be a useful prospect (a suggested continuity) for this research in regard to the issue of susceptibility. In addition, it would be desirable to assess some indicators that may evaluate to what extent the river morphological changes identified impact and influence the resilience of the local landscape. Furthermore, the comparison of aerial images before and after the event might provide useful information of vegetation cover and urban development processes, previous to the landslide occurrence in the study area.

Due to the complexity and coverage of the social environmental problems faced by the community of Estrada do Sertão, the time necessary to address and effectively deal with them is very long. On the other hand, maintaining and incentivizing high levels of participation and collective involvement in a research-action project is a real challenge, especially in an election year in a country facing a huge political crisis.

The beginning of the monitoring phase, for example, comes up against technical and operational difficulties concerning the installation of the assessment stations. This situation tends to increase the time required to accomplish the analyses related to water quality and river response to water level alteration and correlate them with the other analyses previously performed.

The problem of water quality and its environmental and social impacts, especially in poor communities, demand a transdisciplinary approach, collaborative thinking and working methods of analysis and intervention and, above all, the involvement and combining knowledge of various social actors.

By expanding the current state of local understanding on tropical rivers natural processes, this project may serve as a basis for a broader program for revitalization of rivers and watersheds, involving the university, the communities, the private and the public sectors, especially in densely populated *Favela* areas on the slopes of Rio de Janeiro.

The research on green infrastructure methods is in progress and a collective design planning with local residents and specialists will be the next step of the project. This initiative aims to encourage the involvement of the community in the discussion, selection and development of combined methods of environmental sanitation and river revitalization, implementing a socially inclusive and a landscape adequate approach in order to build a more resilient and sustainable city, complementing existing government sanitation programs.

Challenges arise in the sense of a better understanding of the complexity about how social structure within the community works, in order to provide local and realistic solutions for risk preparedness. This project has brought the opportunity of a constant learning-process about community bounds and the possibility to addresss internal conflicts during the process. In this sense, intervention models and methodologies should consider their inclusion to ensure the success of the project. Giving voice and visibility to neglected communities is probably the first step towards disaster risk reduction.

Acknowledgements We thank the Research Support of the State of Rio de Janeiro Foundation—FAPERJ the promotion of this research through—Notice 16/2014, “Programme Support Extension and Research Project—EXTPESQ—2014” and the Instituto Municipal de Urbanismo Pereira Passos (PCRJ/IPP/Armazem de Dados) for the access to municipal data bases. We also thank the residents of the Estrada do Sertão community, especially Claudio Jeronimo da Silva, Claudia Maria Helena da Silva, Paulo José de Almeida dos Santos, Reginaldo Silva, Jerry Nilson da Silva, Irineia Rodrigues, Beraldo of Santos, Conceição da Silva, Luiz Miguel Costa dos Santos, Lucia Santos Alcantara, Angelica Oliveira and Lindalva da Conceição Dias.

References

Ahern J (2011) From fail-safe to safe-to-fail: sustainability and resilience in the new urban world. Landsc Urban Plan 100:341–343

Batista MN, Schlee MB, Barra EE, Tangari VR (orgs) (2015) A Vegetação Nativa no Planejamento e no Projeto Paisagístico. FAU/UFRJ e Rio Books, Rio de Janeiro

BRASIL, Lei Federal 12.651, de 25 de maio de 2012 (2012) http://www.planalto.gov.br/ccivil_03/_ato2011-2014/2012/lei/l12651.htm. Accessed 8 Aug 2016
Coelho Netto AL (1996) Produção de sedimentos em bacias fluviais florestadas do maciço da Tijuca, RJ: respostas aos eventos extremos de fevereiro de 1996. In: Anais do II Encontro Nacional de Engenharia de Sedimentos, RJ, pp 199–209
Coelho Netto AL (1999) Catastrophic landscape evolution in a humid region (SE Brasil): inheritances from tectonic, climatic and land use induced changes. In: Supplementi Geografia Fisica e Dinamica Quaternaria Vol III, Fourth International Conference on Geomorphology: Bologna, pp 21–48
Coelho Netto AL, Machado LO, Castro MC, Oliveira RR, Lacerda WA, Avelar AS, Fernandes MC, Leão OMR (2000) Rio de Janeiro/Secretaria Municipal do Meio Ambiente (Processo14/000.831/99): Estudos de qualidade ambiental do geoecossistema do Maciço da Tijuca - subsídios à regulamentação da APARU do Alto da Boa Vista
Coelho Netto AL (2005) A interface florestal-urbana e os desastres naturais relacionados à água no Maciço da Tijuca: desafios ao planejamento urbano numa perspectiva sócio-ambiental. Revista do Departamento de Geografia, pp 46–60
Coelho Netto AL (2007) A Geoecologia e a Arquitetura da Paisagem do Rio de Janeiro no Século XXI: Da Degradação à Reabilitação Funcional da Cidade e da Floresta Atlântica Remanescente. In TÂNGARI, Vera Regina; SCHLEE, Mônica Bahia; ANDRADE, Rubens de e DIAS, Maria Angela. Águas Urbanas: A Regeneração Ambiental como Campo Disciplinar Integrado. PROARQ-FAU/UFRJ, Rio de Janeiro. ISBN: 9788588341104
Coelho Netto AL, Avelar A, Fernandes M, Lacerda W (2007) Landslide susceptibility in a mountainous geoecosystem, Tijuca Massif, Rio de Janeiro: the role of morphometric subdivision of the terrain. Geomorphology 7:120–131
Coelho Netto AL, Avelar AS, Lacerda WA (2009) Landslides and disasters in southeastern and southern Brazil. Latrubesse, E.M. natural hazards and human exacerbated disasters in Latin America. Dev Earth Surf Process 13:223–243
Coelho Netto AL, Avelar AS, Mululo Sato A, Accioly Dias M, Bahia Schlee M, Negreiros AB (2012) Vulnerabilidade em Geoecossistemas montanhosos e Desastres causados por deslizamentos na Interface Floresta-Urbana: Controles Geológicos Geomorfológicos e Geoecológicos. In Desastres Naturais – Suscetibilidade e Riscos – Mitigação e Prevenção – Gestão e Ações Emergenciais. COPPE/UFRJ – Rio de Janeiro, Lacerda WA et al (Org) Cap.5, pp 63–80
Colding J (2007) 'Ecological land-use complementation' for building resilience in urban ecosystems. Landsc Urban Plann 81:46–55
Cruz ES (2000) Reativação erosiva e revegetação em cicatrizes erosivas de movimentos de massa: estação experimental da cicatriz do pico do Papagaio/maciço da Tijuca – RJ. Dissertação de Mestrado. Rio de Janeiro: Programa de pós-graduação em Geografia, UFRJ
Dias APE, Rosso TC (2011) Análise dos Elementos Atípicos do Sistema de Esgoto – Separador Absoluto – na Cidade do Rio de Janeiro, Engevista. 13(3):177–192
Ehrlich PR, Kareiva PM, Daily GC (2012) Securing natural capital and expanding equity to rescale civilization. Nature 486:68–73
Folke C (2006) Resilience: the emergence of a perspective for social-ecological systems analyses. Glob Environ Change 16:253–267
Forman RT, Godron M (1986) Landscape ecology. Wiley, New York
Girão O, de Corrêa ACB, Guerra AJT (2007) Encostas Urbanas como Unidades de Gestão e Planejamento, a partir do Estudo de Áreas a sudoeste da cidade do Recife – PE. Re-vista de Geografia 24(3):239–267
Holling CS (1973) Resilience and stability of ecological systems. Annu Rev Ecol Syst 4:2–23
IBGE, Censo Demográfico (2010) http://www.ibge.gov.br/home/estatistica/populacao/censo2010/caracteristicas_da_populacao/default_caracteristicas_da_populacao.shtm. Accessed 25 Sept 2015
Instituto Trata Brasil/SNIS – Ministério das Cidades (2011) Benefícios Econômicos da Expansão do Saneamento Básico à Sociedade dos Municípios do Entorno da Baía da Guanabara. http://cebds.org.br/wp-content/uploads/2014/06/ITB-Ba%C3%ADa.pdf. Accessed 7 Oct 2014

Martínez GMI (2014) Avaliação da Suscetibilidade de Terreno para Deslizamentos Rasos: Maciço da Tijuca - Rio de Janeiro. Dissertação de Mestrado. Programa de pós-graduação em Geografia, UFRJ, Rio de Janeiro
Mena SD (2014) Análise das mudanças espaço-temporais na lagoa da Tijuca e o papel da Faixa Marginal de Proteção. Dissertação de Mestrado. Programa de pós-graduação em Geografia, UFRJ, Rio de Janeiro
Martinez M, Mena S, Schlee MB, da Silva O, Coelho Netto AL (2016) Uso do solo e vulnerabilidade socio-ambiental na sub-bacia do alto rio das Pedras (Rio de Janeiro/rj): subsídios para regeneração de rios neotropicais. Revista do Departamento de Geografia, Universidade de São Paulo
Negreiros, AB (2011) Recuperação de Floresta Atlântica e Resultante Hidro-Erosiva em Clareiras de Deslizamentos nas Encostas do Maciço da Tijuca. RJ. Tese de Doutorado em Geografia-Universidade Federal do Rio de Janeiro
Pickett ST, Cadenasso ML, Grove J (2004) Resilient cities: meaning, models, and metaphor for integrating the ecological, socio-economic, and planning realms. Landsc Urban Plann 69:369–384
Schlee MB (2002) Landscape change along the Carioca River, Rio de Janeiro, Brazil. Master thesis, The Pennsylvania State University, University Park, USA
Schlee MB (2011) A ocupação das encostas do Rio de Janeiro: morfologia, legislação e processos socioambientais. Tese de Doutorado em Arquitetura. Universidade Federal doRio de Janeiro, Rio de Janeiro, Rio de Janeiro
Schlee MB, Tamminga KR, Tângari VR (2012) A method for gauging landscape change as a prelude to urban watershed regeneration: the case of the Carioca river, Rio de Janeiro. Sustainability 4:2054–2098. doi:10.3390/su4092054
Sperling MV (1996) Introdução à qualidade das águas e ao tratamento de esgotos. Editora UFMG, Belo Horizonte. https://drive.google.com/folderview?id=0B16o-dcwGFHvfkhIVkxuVTBhcXNGQmJ3T0VGbUloZmJzaEt0dTRqNXViV2NrbkEyRjlFLUk&usp=sharing. Accessed 20 May 2016
United Nations (2015) Sendai framework for disaster risk reduction 2015–2030. UN World Conference Sendai, Japan, March 18. http://www.ifrc.org/docs/IDRL/Sendai_Framework_for_Disaster_Risk_Reduction_2015-2030.pdf. Accessed 8 Aug 2016
Vianna P (2015) Relatório do Macrodiagnóstico de Infraestrutura de Saneamento da Cidade do Rio de Janeiro. Prefeitura da Cidade do Rio de Janeiro/Secretaria Municipal de Urbanismo/Coordenadoria de Macro Planejamento, Rio de Janeiro
Walker B, Salt D (2006) Resilience thinking: sustaining ecosystems and people in a changing world. Island Press, Washington, DC

Author Biographies

Monica Bahia Schlee Ph.D. in Architecture, Federal University of Rio de Janeiro (2011). Master in Landscape Architecture, Pennsylvania State University (2002). Master in Urban Environmental Structures, University of São Paulo (1999). Landscape architect and urban planner of Rio de Janeiro City Hall since 1992, working at the Municipal Secretary of Urban Planning. Researcher of the GEOHECO Laboratory of the Federal University of Rio de Janeiro (since 2014).

Sonia Mena Jara M.Sc. in Geography (UFRJ, 2014, *Summa cum Laude*). B.Sc. in Landscape and Ecology (2004). Formerly a private and public sector employee in Chile as a Water resource manager, Landscape planner and Environmental Impact Assessment consultant, nowadays lives in the Netherlands and works as a consultant for Chile and as a researcher of the GEOHECO Laboratory of the Federal University of Rio de Janeiro (since 2014).

Maria Isabel Martinez M.Sc. in Geography from the Federal University of Rio de Janeiro, Brazil (2014). B.Sc. in Geography and Environment from the Pontifical Catholic University of Peru (2011). Researcher of the GEOHECO Laboratory of the Federal University of Rio de Janeiro (since 2012). From 2015, works as an environmental consultant for Conservation International—Brazil (Rio de Janeiro office).

Ana Luiza Coelho Netto Doctor of Science in Geomorphology/Geoecology (Catholic University of Leuven, Belgium, 1985, *Summa cum Laude*). Master of Science in Physical Geography/ Geomorphology (UFRJ 1979). B.Sc. in Geography (UFRJ 1973). Postdoctoral Fellow in Geomorphology (University of California/Berkeley—USA, 1987–1988). Full Professor (since 1998) and Head of GEOHECO/Laboratory of Geo-Hydroecology: integrated research on Geomorphology, Hydrology, Geoecology and Risk Management, Department of Geography, Institute of Geosciences, Federal University of Rio de Janeiro—UFRJ (since 1992). Researcher 1A-CNPq.

Chapter 10
Alluvions in Ravine Wetland Socio-ecosystems: Ecological Resilience and Social Vulnerability in Iquiuca-Parca, Tarapaca Region (Chile)

Maritza Paicho Hidalgo, Carolina Vera Burgos and Guillermo Espinoza González

Introduction

Wetlands are important due to their ecotonal characteristic and direct and indirect benefits that they provide to the society due to their intrinsic functions which are ecosystem services, such as water resources, carbon sink, habitats, soil fertilization and food, among others (Laterra et al. 2011).

Wetlands are dynamic ecosystems, changing constantly because of natural processes that occur at different spatial and temporal scales. Natural hydrologic disturbances take place constantly in the lotic systems which are part of the ecosystem. These may be classified as regular or random events according to the environmental conditions that produce the disturbance. Regular disturbances associated with periodic flooding regulate the fluctuating dynamics of the ecosystem. Random disturbances which are extreme, short and strong events like alluvions may also take place (Malvarez 1999). An alluvion is a natural phenomenon produced by local flash floods of high volume and short duration that overflow river streams, transporting large amounts of clay, gravel and rocks due to sporadic, short term and high intensity precipitation (Paez et al. 2013).

These unusual extreme events produce unexpected and drastic changes on wetland structure and landscape, especially on riparian vegetation, including decreases in habitats, shelters, food availability and nesting sites among others (Hauenstein et al. 2002). These disturbances involve profound modifications that remove the ecological memory of the ecosystem structure and functioning, returning the wetland to the first stage of ecological succession (Bendix and Hupp 2000). Although these disturbances have an initial negative effect, they are natural processes intrinsic to these ecosystems, which produce heterogeneity, dynamism,

M.P. Hidalgo (✉) · C.V. Burgos · G.E. González
Centro de Estudios de Humedales (CEH), Blanco Encalada 280, código postal, 1170077 Pica, Chile
e-mail: mpaicho@ceh.cl

W. Leal Filho and L. Esteves de Freitas (eds.), *Climate Change Adaptation in Latin America*, Climate Change Management,
https://doi.org/10.1007/978-3-319-56946-8_10

diversity, biological adaptation, high recovery capacity and resilience, allowing the ecosystem to reestablish (Manson et al. 2009).

Although alluvions are natural events, these events have negative consequences for the human inhabitants of the area and they may be a threat if they affect a marginal social system. Thus they are closely related to the vulnerability of the population living in the area around the wetland. This depends on the degree of exposure of the human population, its sensitivity to changes and capacity to adapt to the negative effects of the event (Aldunce et al. 2008).

Both the threats of natural disasters and the vulnerability of the society affect the risk of socio-natural disaster, which can be defined as the materialization of the risk that is produced by the interaction between a disturbance and the vulnerable society that suffers human, cultural and material losses (Carballo and Goldberg 2014). A resilient society has the capacity to face adversities and reorganize itself after a disturbance in ways that improve its function, structure and identity (Uriarte 2013). Socio-natural disasters associated with alluvial events may occur on fluvial wetlands with different degrees of anthropization and vulnerability, especially those that are used for social and economic purposes such as economical activities, waterworks, residential and recreational areas, among others.

Chilean geomorphology, climate and meteorological conditions produce areas susceptible to alluvions that have caused several socio-natural disasters in vulnerable populations (Aldunce and Gonzalez 2009; Figueroa and Silva 2010). Especially in the Tarapacá Region in northern Chile there have been occasional alluvions in the ravines and valleys throughout its history. These events have extended from the Andean foothills at 3000 m elevation to the Pampa del Tamagural at 1000 m or to the coast. The area has arid slopes and small areas covered by xerophytic vegetation and steep, high slopes which produce deep, narrow east-west canyons. Small continuous or sporadic streams flow in these ravines, which give rise to humid areas with riparian vegetation. These humid areas shelter several native, local endemic and threatened species such as *Telmatobius chusmisinsis*; and are important biological corridors for birds with altitudinal migration such as *Chroicocephalus serranus*.

Ancestral Andean populations settled near these humid areas; there is a close relationship between wetlands (streams, oases, springs, meadows and bogs) and the development of Andean peoples. These ecosystems provide the basis of social organization and traditional economic activities based on cattle and farming on terraces in the ravines of these communities (CONADI/CED-CEH 2012), which are based on the water resource and the use of native vegetation.

The precipitations that produce alluvions in this area derive from particular climatic situations due to regional atmospheric circulation, the high solar radiation in the Altiplano, daily temperature fluctuations, the movement and weakening of the jet stream during the austral summer, which produce changes in the predominance of surface air masses, the local orography, the south American monsoon (Garreud and Aceituno 2001) and La Niña episodes. The usual summer rains that occur on the Altiplano due to the south American monsoon among other factors increase during La Niña periods, since the alterations produced by the ocean–atmosphere strengthen the monsoon system, increasing precipitation in Brazil and the Altiplano area (Romero and Mendoca 2011). These conditions produce intense local downpours in specific areas of the Altiplano and the Chilean Andean foothills, which originate alluvions.

The last high magnitude flood in the ravines of the Tarapaca region occurred on 13 March 2012, after the event the zone was declared as a disaster area (supreme decree law N°289) and agricultural emergency area (exempt resolution N°98). There are no published studies on the effects of these flash floods on the riparian vegetation in the Tarapacá Region, and up to now government efforts have been limited to reconstruction of damages. The projections of climate change indicate that there will be an increase in the frequency and intensity of the precipitations that produce alluvions (Sarricolea and Romero 2015). Thus the objectives of this study were (i) to estimate the total area of riparian vegetation reduction in the Iquiuca-Parca wetland produced by the 2012 flash flood, and (ii) identify the material losses and disturbances in the life style of the affected population and the process of recovery of the Iquiuca-Parca community.

Study Area

The Iquiuca-Parca wetland is located administratively in the Tarapacá Region of Chile and physically in the middle section of the Chipisca subbasin in the Andean foothills (Fig. 10.1). At this altitude there is a high marginal desert climate; precipitation increases with altitude, thus in the west precipitation is close to 0 mm and in the east it may reach 100 mm per year. The settlements that use these wetlands and the resources and services that they provide are Iquiuca and Parca (Fig. 10.1).

Methodology

The methodological process was divided into two sections according to the objectives of the study, thus different techniques and methodology were applied in each section.

Geo-processing of Satellite Images

High spatial resolution satellite images were used to assess the changes produced by the alluvial phenomena. WorldView-2 satellite images with 2 m resolution were used in the multispectral mode, with data from before (18-08-2011) and after the flood (29-04-2012). Satellite images were pre-processed by geo-referencing,

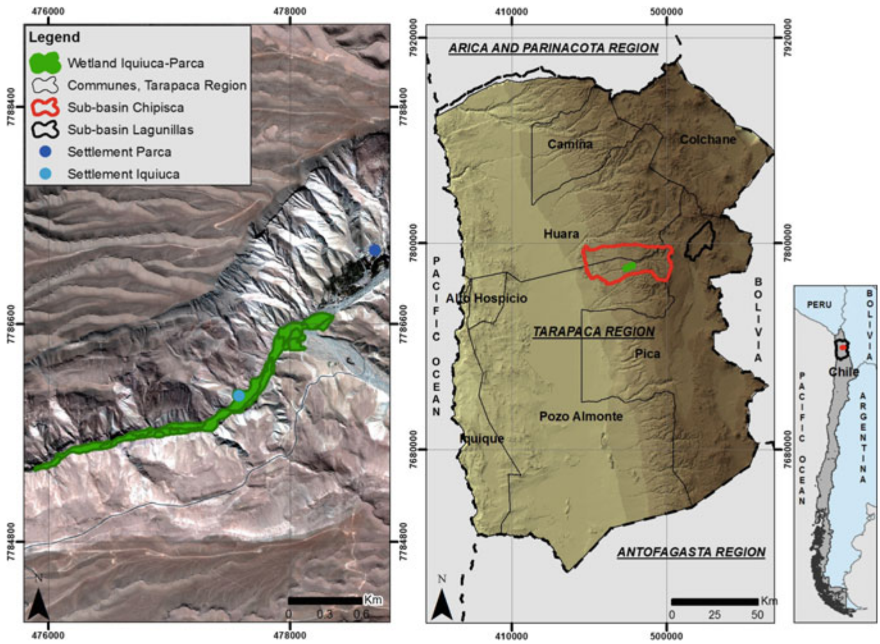


Fig. 10.1 Study area: Iquiuca-Parca wetland. *Source* Own elaboration

orthorectification and atmospheric correction. Then the semiautomatic tool Spear Delineation of ENVI was used to calculate the Normalized Difference Vegetation Index (NDVI). This index is based on the energy reflected and absorbed by the vegetation in the gamma range of the electromagnetic spectrum; the reflection in the near infrared band and the great absorption by chlorophyll a and be in the red band is expressed as a the difference between absorption in the near infrared and the red, normalized by their sum (Gilabert et al. 1997).

The Spear Delineation of ENVI classifies the values of NDVI, which range from −1 to 1, into 4 equidistant ranks, thus delimiting the vegetation surface. However, considering that the dominant apecies of the Iquiuca-Parca wetland are herbs and shrubs, with few trees, we reclassified the ranks according to the literature related to the vegetation types and their NDVI values, respectively. This produced one category *without vegetation* with rocks, naked soil, water or areas without vegetation classified between −1 and 0.18; a second category *scarce vegetation* for the areas with disperse bushes and herbaceous vegetation with values between 0.18 and 0.46; the category *moderate vegetation* for areas with values between 0.46 and 0.75 and finally areas with trees classified as *dense vegetation* with values between 0.75 and 1 (Marey 2013). We compared the results of the NDVI reclassification of the two satellite images to estimate the total reduction in the riparian vegetation and the reductions in the different types of vegetation.

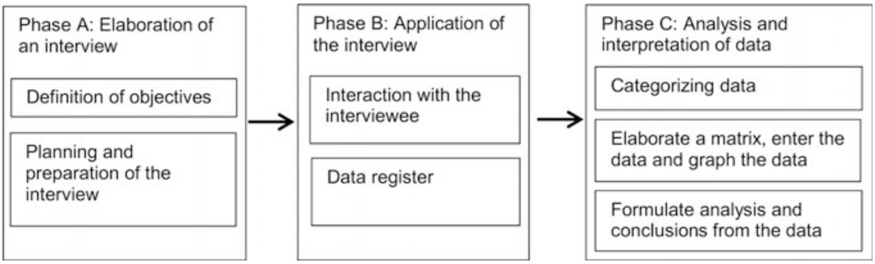


Fig. 10.2 Phases of the interview. *Source* Own elaboration based on the methodological procedures proposed by Kvale (2011)

Socio-cultural Analysis

In order to understand the socio-cultural effects of the alluvion on the Iquiuca-Parca community, first social and economic composition along with the historical background of the recovery process of the population was investigated. Then a semi-structured interview was applied to the main community stakeholders with the objective of: (i) complement the secondary information related to life style, (ii) identify damages in the local infrastructure produced by the flood, (iii) study the disturbances produced in everyday life of the community, and (iv) collect data on the recovery process (organization, initiatives, reconstruction, management) and resilient characteristics.

The semi-structured interview technique applied used the content and/or procedures for obtaining and analyzing information proposed by Kvale (2011, Fig. 10.2). Once the interview was planned, constructed and applied to the key actors, the data were transcribed and organized in two categories: information on land use a descriptive matrix organized by subject on the socio-cultural effects of the flood. This systematization allowed the data analyses.

Results

Changes in the Riparian Vegetation

Changes in the vegetation between 2011 and 2012 included a significant decrease in the scarce and moderate vegetation categories (Fig. 10.3) of more than 3 hectares. These vegetation categories were located in the central area of the river basin; according to the image from 2011 they were replaced by superficial soil runoff, soil without plants and alluvial material in the 2012 image (Fig. 10.3c, d).

Another singular difference is the increase in the dense area vegetation on 29-04-2012 (Table 10.1); the increase in this category is associated with positive changes on the productivity of the vegetation that survived during the rainy season

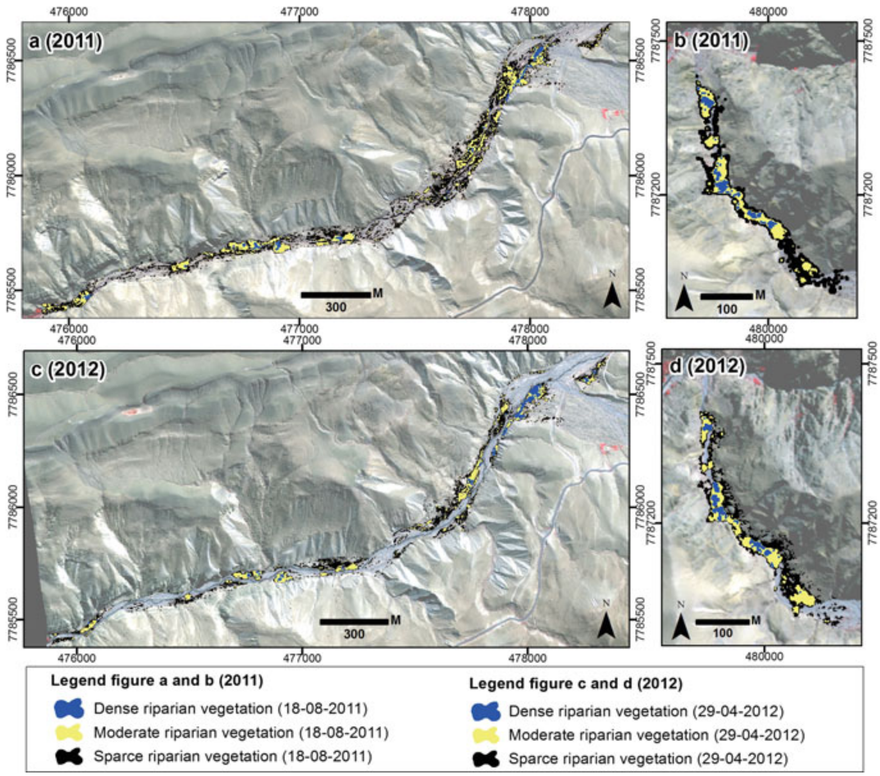


Fig. 10.3 Decrease of the vegetation surface in the Iquiuca-Parca wetland (2011–2012). *Source* Own elaboration

Table 10.1 Plant surface by categories and NDVI reclassification (2011–2012)

Wetland	Years	NDVI reclassifications			
		Surface (m^2) sparse veg.	Surface (m^2) moderate veg.	Surface (m^2) dense veg.	Surface (m^2) total vegetation
Iquiuca-Parca	2011	87.243,98	45.267,88	3.016,90	135.528,76
Iquiuca-Parca	2012	61.677,69	33.453,92	3.680,68	98.812,29
Difference between 2011–2012 (m^2)		−25.566,29	−11.813,96	+663.78	−36.716,47
Difference between 2011–2012 (%)		−29.30	−26.09	+22	−27.29

Source Own elaboration

and resisted the flood impact. Since vegetation has an immediate or delayed reaction to atmospheric changes, there is a direct relationship between the decrease or increase of NDVI values and intra and inter-annual precipitation (Iglesias et al. 2010); so excess precipitation allows an increase in plant vigor. The rain during the 2011–2012 austral summer in Iquiuca-Parca produced greater density of the vegetation that remained in the wetlands after the flood.

The areas where vegetation was reduced were grassland and shrubland, while forests and second-growth trees were practically unaltered. This is due in part to the trees being located out of the river bed where the alluvions flow, and thus escaping their effects, this explains the greater structure they have been able to achieve. Alluvions usually signify modifications of the habitat of the native fauna.

The alluvial event responsible for the reduction of the riparian vegetation was a non-periodic event that sometimes occurs in the lotic system analyzed. It was a strong perturbation that occurs at an irregular, inter-annual rate that immediately affects the structure of the wetland, modifying the habitat of the fauna of the system. However, these alluvions regulate the structure and functioning of these dynamic ecosystems, constantly re-establishing the first stages of ecological succession. This characteristic of fluctuating environments give them the capacity to resist the effects of natural perturbations by the duplication of their ecosystem functions and resistance thresholds, that is, resilience capacity (Manson et al. 2009). Especially the areas of riparian vegetation affected by the alluvion initiated processes of recolonization and re-vegetation that will re-establish the original vegetation or a similar structure, showing with these processes the immediate capacity for recovery and/or resilience they have.

Socio-cultural Impacts

The Iquiuca-Parca wetland has land use dynamics based on small-scale agriculture and subsistence cattle raising by the few inhabitants who resisted the migration process and remain in the area forming the community. The population has an old age range, vegetative growth and a negative birth rate.

The inundation of March 2012 produced material losses such as road destruction, reduction of and damage to cultivation areas (terraces), irrigation infrastructure and the infrastructure for cattle raising, as well as damage to agriculture and its byproducts.

In this territory agriculture is a fragile activity which depends on the ecosystem resources and the associated basic infrastructure. However, the life of the inhabitants is structured by agriculture, i.e., cultivation cycles determine the time dedicated to irrigation and farm care, along with fertilization, sowing, pruning and harvesting, and the travelling periods to take care of farms in remote areas. Due to the dependence on agriculture, any impact like those produced by a flood, involve interrupt by short or long periods of time resources use, everyday annual life structure and activities practice by the community.

The recovery process of damage to infrastructure, agriculture and cattle raising consisted of recording the material damages (INDAP 2012) and supplying funds for house reconstruction in the same vulnerable areas, rebuilding public places, irrigation system and terraces and some other basic infrastructure (supreme decree law N°289; exempt resolution N°3939). This program was designed by the central government and carried out bureaucratically by the regional government, that is management and external resources from outside the community that provided partial recovery.

The resilience practices still used for this community are the organization of the inhabitants in formal associations with elected representatives. There is also interest in the conservation of natural and cultural heritage (e.g. *Browningia candelaris* and some archeological places). There has also been a little development of community labors.

The resilience practices that have been abandoned or decreased include community crop sowing, community tasks related to agricultural, public and residential infrastructure, and the occasional organization for self-recovery infrastructure in emergencies. The qualities of the community that impede the maintenance of these practices and self-recovery include the reduced number of inhabitants and their ages, mistrust of the representatives of the associations and giving priority to the development of individual instead of community practices. These characteristics are the anti-pillars of community resilience (Uriarte 2013).

Conclusions

The atmospheric conditions that favor intense localized precipitation above the Andean foothills and the alluvions, such as the La Niña episodes and the increase of the south American monsoon and local phenomena of orographic forcing are not unusual in this area; these conditions are part of the extreme inter-annual and natural climate variability that characterizes the Altiplano and the northern Chilean Andean foothills (Romero et al. 2013).

Although the Iquiuca-Parca wetland had an important reduction riparian vegetation due to the alluvion of 13 March 2012, this event is part of the natural dynamics of this ecosystem, in which flooding perturbations are produced frequently and alternate with processes of re-establishment of the riparian vegetation and the structure of the wetland, that is, processes of ecological resilience.

The alluvion also produced material loss and destruction of the life style of the ancestral inhabitants living in this area as a result of the tight relationship between resources and services that the ecosystem provides. Thus in the socio-cultural area alluvions are not a regulation but rather a threat that may produce a natural-social disaster if they occur in a vulnerable social context (Aldunce et al. 2008). The area of study has a highly eroded socio-cultural community. Their subsistence activities are more and more reduced; some of the traditional community practices are no longer used, which produces greater vulnerability and reduces the adaptive capacity of the community to face unexpected situations. This social erosion is the result of several processes that have occurred in the Andean region of northern Chile that include migration, loss of reciprocity practices such as community tasks, the influence of modernization process and of policies related to developing this geographical area (Greve 1997; Gunderman and Vergara 2009).

The usual and extreme precipitations of the Altiplano and Andes foothills of northern Chile provide the water necessary for the maintenance of wetlands, but also originate alluvial phenomena. Precipitations in these areas are declining strongly, however in future climate change scenarios the distribution of the minimum and maximum precipitation will show greater irregularities. Thus there will probably be extreme events of precipitation greater than the current ones in spite of the generalized tendency to decrease in precipitation, alternating with periods of extreme drought (Sarricolea and Romero 2015). This scenario would have strong repercussions on the system of wetlands and salt flats, and obviously in the economic activities that depend on the resources that these systems provide (Sarricolea and Romero 2015). The reduction of water availability would have immediate effects in the composition of the wetland ecosystems and the native fauna. The possible increase in the intensity and frequency of extreme precipitations which originate the alluvions would imply even more extreme landslides, which would produce greater modifications in the structure and functioning of canyon wetlands and less time for recovery of the wetland ecosystem, which might exceed the threshold of ecological resilience.

It is evident that the communities which live around these ecosystems have great vulnerability, minimum resilience characteristics and non-existence of adaptive measures to confront alluvial phenomena, thus an increase in the intensity of alluvions may lead to greater material losses and the depopulation of these Andean zones.

In conclusion, the alluvion in March, 2012 in the Iquiuca-Parca area is non-periodic event typical in the area which could increase in the future scenario of climate change. Thus it is necessary to generate risk management instruments; technical-scientific studies directed to the prevention of and adaptation to this kind of threat, and to generate educational information for citizens on the local social-natural risks.

Acknowledgements Research financed and executed within the framework of the projects FONDECYT 1150701 “Participatory research through eco-social observatories changes and climate uncertainty of the Andean highlands of northern Chile” and 1120204 “Multi-scale analysis of climate change and its consideration in the strategic environmental assessment of sustainable regional development Altiplano of northern Chile”.

References

Aldunce P, Neri C, Szlafsztein C (eds) (2008) Hacia la Evaluación de Prácticas de Adaptación ante la Variabilidad y el Cambio Climático. Biblioteca do Núcleo de Meio Ambiente/UFPA, Brasil, p 105

Aldunce P, González M (2009) Desastres Asociados al Clima, en la Agricultura y Medio Rural en Chile. Universidad de Chile - Facultad de Ciencias Agronómicas, Santiago, Chile, p 118

Bendix J, Hupp C (2000) Hydrological and geomorphological impacts on riparian plant communities. Hydrol Process 14(16):2977–2990

Carballo, C. and S. Goldberg (2014) «Comunidad e información ambiental del riesgo». Editorial Dunken, Buenos Aires, Argentina, p 167

Corporación Nacional de Desarrollo Indígena/Centro de Estudios del Desarrollo-Centro de Estudios de Humedales (CONADI/CED-CEH) (2012) «Catastro de Humedales y Usos Indígenas de la Provincia del Tamarugal Etapa 1 y 2 (Licitaciones N°802-23-LE11 y N° 802-11-LE12)». [s.e.], Iquique, Chile, p 126

Decreto Supremo N°289 (2012) Diario Oficial de la República de Chile. Santiago, Chile

Figueroa, C. and B. Silva (2010) «Documentos para la Historia Regional. Luis Friedrich y su Acción Clerical, Rearticulando la Memoria e Identidad del Pueblo de San Andrés de Pica (1898–1925)». Obispado de Iquique, Valparaíso, Chile, p 236

Garreud R, Aceituno P (2001) Interannual rainfall variability over the South American Altiplano. J Clim 14:2779–2789

Gilabert M, González-Piqueras J, García-Haro J (1997) Acerca de los índices de vegetación. Revista de Teledetección 8:1–10

Greve ME (1997) Procesos Migratorios, Identidad Étnica y Estrategias Adaptativas en las Culturas Indígenas de Chile: Una Perspectiva Preliminar. Revista Chilena de Antropología 14:55–68

Gunderman H, Vergara J (2009) Comunidad, Organización y Complejidad Social Andinas en el Norte de Chile. Estudios Atacameños 38:107–126

Hauenstein E, González M, Peña-Cortés F, Muñoz-Pedreros A (2002) Clasificación y Caracterización de la Flora y Vegetación de los Humedales de la Costa de Toltén (IX Región, Chile). Gayana Botánica 59(2):87–100

Iglesias M, Barchuk A, Grilli M (2010) Dinámica Estacional e Interanual del NDVI en Bosques Nativos de Zonas Áridas Argentinas. Revista de Teledetección 34:44–54

Instituto de Desarrollo Agropecuario (INDAP) (2012) «Decimo Informe Técnico Emergencia 2012 Daño Efecto de Lluvias Estivales Región de Tarapacá». [s.e.], Iquique, Chile, p 33

Kvale S (2011) Las entrevistas en investigación cualitativa. Colección: Investigación cualitativa. Ediciones Morata, Madrid, España, p 200

Laterra P, Jobbagy E, Paruelo J (2011) Valoración de Servicios Ecosistémicos: Conceptos, Herramientas y Aplicaciones para el Ordenamiento Territorial. Argentina, INTA, Buenos Aires, p 720

Malvárez AI (ed) (1999) Tópicos sobre humedales subtropicales y templados de Sudamérica. UNESCO, Montevideo, Uruguay, p 228

Manson R, Jardel E, Jiménez M, Escalante C (2009) Perturbaciones y Desastres Naturales: Impactos sobre las Ecorregiones, la Biodiversidad y el Bienestar Socioeconómico. Capital Natural de México 2:131–184

Marey M (2013) Caracterización de la Vegetación Acuática del Humedal del Río Cruces por Medio del Análisis de Imágenes Espectrales (Tesis pregrado, Biología Mención en Medio Ambiente). Universidad de Chile, Santiago, Chile, p 72

Páez M, Moreiras S, Brenning A, Giambiagi L (2013) Flujos de Detritos y Aluviones Históricos en la Cuenca del Río Blanco (32°55′-33°10′Y 69°10′-69°25′), Mendoza. Revista de la Asociación Geológica Argentina 70(4):488–498

Resolución Exenta N°98 (2012) Diario Oficial de la República de Chile. Santiago, Chile

Resolución Exenta N°3939 (2012) Diario Oficial de la República de Chile. Santiago, Chile

Romero H, Mendonça M (2011) Ondas de Frío Registradas en Invierno de 2010: Necesidad de una Perspectiva Regional Integrada para la Climatología Latinoamericana. Revista Geográfica de América Central 2(47E):1–13

Romero H, Mendonça M, Méndez M, Smith P (2013) Macro y Mesoclimas del Altiplano Andino y Desierto de Atacama: Desafíos y Estrategias de Adaptación Social ante su Variabilidad. Revista de Geografía Norte Grande 55:19–41

Sarricolea P, Romero H (2015) Variabilidad y Cambios Climáticos Observados y Esperados en el Altiplano del Norte de Chile. Revista de Geografía Norte Grande 62:169–183

Uriarte JD (2013) La Perspectiva Comunitaria de la Resiliencia. Psicología Política 47:7–18

Chapter 11
Watershed Transposition Cycle with Irrigated Biomass

Julian David Hunt and Marcos Aurélio Vasconcelos de Freitas

Introduction

Brazil went through the worst drought in recorded history in the Southeast and Northeast regions during the years of 2014 and 2015 (Barifouse 2014). The drought has a great impact especially because Brazil generates around 80% of its electricity with through hydropower. The Brazilian climate seems to be changing over recent years, either due to global climatic changes or due to changes in regional climate resulting from deforestation. This in turn is affecting the reliability of hydropower generation in Brazil (Hunt et al. 2014). The expansion of the electricity sector has focused on hydroelectric plants in the Amazon, without storage, that will further enhance the electricity sector vulnerability.

Over the next 10 years, the hydroelectric energy storage capacity will not increase as the new hydropower generation (33% increase in 10 years) will be in the Amazon Basin with no storage and generating most of its electricity generated during the wet period (Empresa de Pesquisa Energética 2015). Other alternatives such as wind and solar will partially complement electricity generation in Brazil. The Brazilian wind potential has started to be explored and is foreseen to reach 22 GW of wind power by 2024. This is convenient because it generates more electricity during the dry period, when hydropower generation is reduced. Solar power has less seasonal variations and is set to increase by 7 GW capacity by 2024 (Empresa de Pesquisa Energética 2015).

A promising power generation alternative, with great potential in Brazil, is biomass (Hunt et al. 2016). However, it should be noted that a biomass plantation directly affects the hydrology of the water basin where it is located by consuming large amounts of water which will affect the multiple uses of water (environmental

J.D. Hunt (✉) · M.A.V. de Freitas
Instituto Virtual Internacional de Mudanças Globais (IVIG),
Federal University of Rio de Janeiro (UFRJ), Rio de Janeiro, Brazil
e-mail: julian.hunt@ivig.coppe.ufrj.br

W. Leal Filho and L. Esteves de Freitas (eds.), *Climate Change Adaptation in Latin America*, Climate Change Management,
https://doi.org/10.1007/978-3-319-56946-8_11

requirements, irrigation, industrial, commercial and residential uses) and hydropower generation on the dams downstream. For example, if there is a eucalyptus plantation near the Nova Ponte Reservoir in Minas Gerais, the water consumed by the plantation turns into moisture in the atmosphere, which eventually precipitate in another place with a different hydroelectric generation potential. In this case, water used for growth of biomass would be removed from the reservoir of a hydroelectric cascade with a maximum generation head of 642 m. If this moisture precipitates near the Ilha Solteira Reservoir with a generation head of 199 m, there will be a potential loss of hydroelectric generation of 442 m as the water is consumed by the biomass plantation. This hydroelectricity generation loss in this example is around 10% of the electricity that would be generated when burning the biomass planted near Nova Ponte Reservoir (Hunt et al. 2016). However, there is the possibility of planted biomass in a low-altitude locations, with low potential for hydroelectricity generation, where the moisture generated by biomass transpiration may result in an overall increase in hydropower potential in Brazil. This is detailed in the next section.

The objective of this paper is to create a strategy to provide water for irrigated biomass and agricultural plantations with the intention that the transpired water might result in an increase in water availability in Brazil and result in overall benefits to the hydroelectric generation of the country. This paper presents a possibility of creating an artificial hydrological cycle resulting from the transposition of water from the basins of the Tocantins and Paraná Rivers to São Francisco River and the use of this water for irrigated biomass plantation. The resulting moisture transpired by the irrigated biomass may then return to the Tocantins and Paraná Basins carried by the strong trade winds. This mechanism was called “Watershed Transposition Cycle with Irrigated Biomass” or “Transposition Cycle”.

The transposition projects could be implemented with Seasonal-Pumped-Storage plants (Hunt et al. 2014a). Thus, if feasible, it is possible to pump water from the Tocantins and Paraná Rivers during the wet season, when there is excess electricity in the system, and excess of water in the basins where the water is extracted. During the dry season, the stored water will then be used to generate electricity and enhance agriculture in the São Francisco Basin.

In addition to increasing the overall hydroelectric generation in Brazil, Transposition cycle is able to assist adaptation to climate change, with the control of atmospheric humidity according to the amount of water transposed into the São Francisco Basin and transpired by the irrigated biomass. The agricultural sector, which is also vulnerable to climate change and has great importance in the Brazilian gross domestic product, would also benefit from a mechanism for climate control.

Biomass Irrigation in Northeast Brazil

Focusing on the São Francisco Basin, according to Fig. 11.1, considering the section of the São Francisco River mouth, it can be seen that the direction of the trade winds and the São Francisco River flow are in the opposite directions.

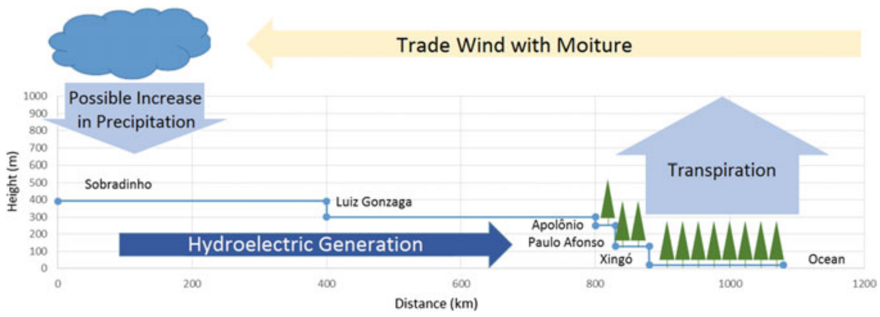


Fig. 11.1 Diagram demonstrating the transposition cycle for the São Francisco River

The Transposition Cycle intends to increase hydroelectric generation with biomass irrigated plantation. For this to occur, biomass may be planted in locations with low hydropower potential thereby not reducing the hydropower generation and increasing the probability of precipitation in high hydropower potential locations.

Biomass, especially eucalyptus, requires large quantities of water to grow. If the plantation is located at the São Francisco River mouth, the water will be removed from the river through irrigation and will be released into the atmosphere as moisture in the air. The strong trade winds, carry the moisture back inland from the mouth of the São Francisco River, in the opposite direction of the São Francisco River flow. This moisture may increase rainfall in the São Francisco Basin and, thus, it may create a partially closed artificial water cycle, as described in Fig. 11.1, increasing the amount of hydroelectric generation in the basin. The hydropower generation head from Sobradinho dam to Xingó dam is 307 m.

The area downstream the Xingó dam near the São Francisco River has an area of approximately 40,000 km^2. Downstream of the Paulo Afonso plant is an area of about 50,000 km^2. It should be noted that the mouth of the São Francisco River has a humid coastal climate. The plantation, would not require intensive irrigation. However, plant biomass would decrease the amount of water that flows towards the river.

However, the water transpired near the mouth of the São Francisco River would probably not only precipitate in the São Francisco Basin. It may also precipitate in the Tocantins, Amazon, Paraná and other basins. It is important to study climatic and hydrological models to establish where the water removed from the plantation might precipitate. This article uses the estimated data from the Winds Atlas developed by CEPEL (Amarante et al. 2001).

Figure 11.2 shows the probability distribution of the wind direction in Brazil at ground height. As can be observed moisture generated by transpiration of biomass at the São Francisco River Mouth and in Sobradinho Reservoir (number 1 on the map) is directed predominantly to the east and northeast directions. This pattern continues predominant up to 4,000 m in the atmosphere (https://www.windyty.com). The wind patterns close to the Três Marias Reservoir (number 2 on the map) are mainly directed to the east.

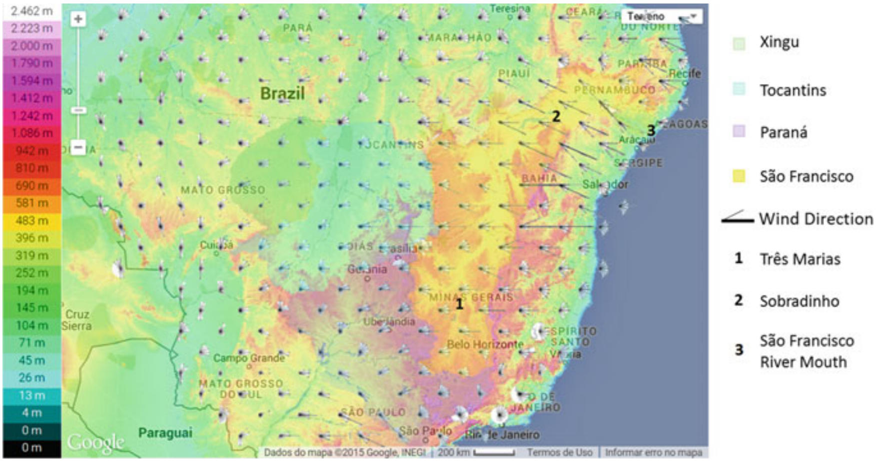


Fig. 11.2 Probabilistic wind direction over the Northeast of Brazil (Amarante et al. 2001)

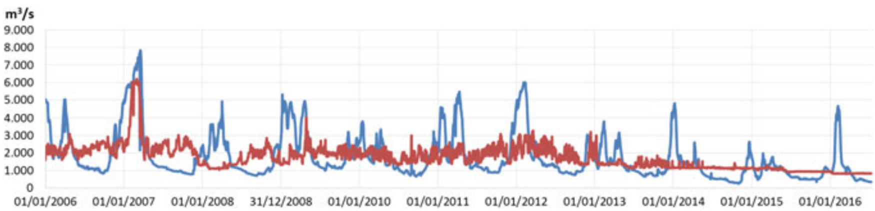


Fig. 11.3 Inflow and outflow of the Sobradinho Reservoir

Figure 11.3 shows the inflow and outflow of the Sobradinho Reservoir. The difference between the inflow and outflow consists of the reservoir storage capacity. As it can be seen, the average inflow has been considerably reduced during the last 10 years. This is because there is a reduction in rainfall and because of the rapid increase of irrigated agriculture in the São Francisco Basin (Valdes et al. 2004; Nys et al. 2015; Comitê da Bacia Hidrográfica do Rio São Francisco 2004). The transposition of water to the São Francisco Basin is an important climate change adaptation measure to reduce its vulnerability to climatic variations and climate change.

The next section presents a preliminary case study of a Transposition Cycle in Brazil.

Water Transposition: Removing Water from Flood Areas to Use It Where There Is Low Water Availability

The Araguaia River Basin is marked by periods of extreme drought and flood throughout the year. It has a very flat geology and suffers from intense silting of the river on the border between the states of Pará, Mato Grosso and Tocantins. This

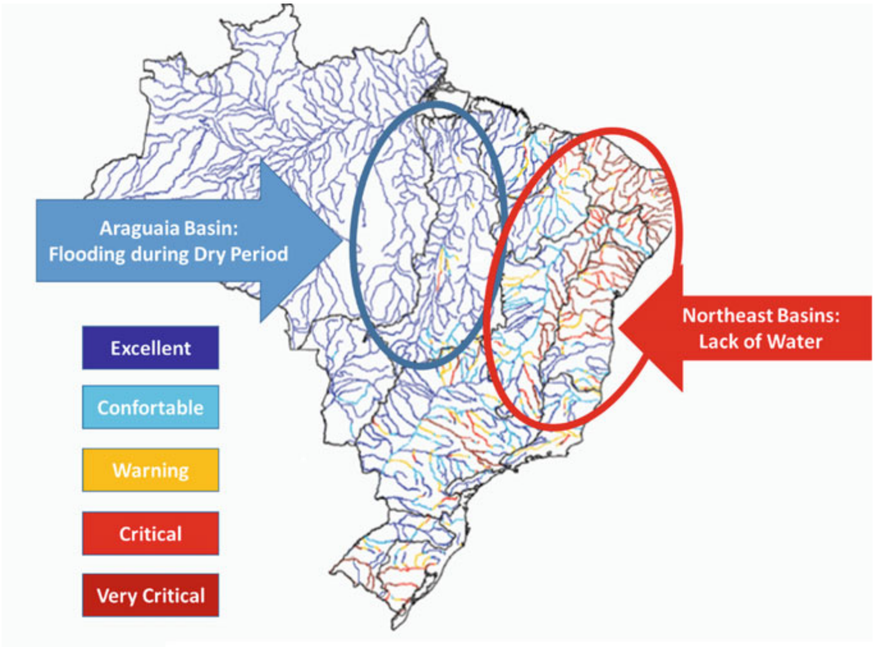


Fig. 11.4 Water demand versus availability in Brazilian river basins (http://arquivos.ana.gov.br/planejamento/estudos/sprtew/2/2-ANA.swf, http://portal1.snirh.gov.br/ana/apps/webappviewer/index.html?id=ac0a9666e1f340b387e8032f64b2b85a)

sedimentation restricts the flow of water, increasing the level of the Araguaia River from 6 to 11 m during the flood period (http://www.snirh.gov.br/hidroweb/), which can cause severe floods in the Mid Araguaia Basin. In addition, there is a 10-year period of large scale floods with severe floods in the years 2013, 2002, 1990 and 1980 (http://www.snirh.gov.br/hidroweb/; Dias 2014). In February 2002, the flooded area in the Mid Araguaia region reached around 60,000 km^2 (https://www.ufrgs.br/hge/modelos-e-outros-produtos/mgb-iph-propagacao-inercial/).

In addition, in Fig. 11.4, there is a reliable supply of water in most location of the Xingú, Araguaia and Tocantins Basins. On the other hand, the Northeast river basins suffers from critical or very critical water availability. A water transposition system would reduce the incidence of floods in the Araguaia Basin and reduce the impact of droughts in the São Francisco basin, functioning as a climate change adaptation measure.

Transposition Cycle Between the Xingú, Tocantins and Paraná Basins, and the São Francisco Basin

Expanding the concept of a Transposition Cycle between different river basins in Brazil further increases its potential. Figure 11.5 shows the water balance and the average flow of the main basins of Brazil. The blue arrows represent the yearly average water flow to the Atlantic Ocean. It shows that the Amazon average water flow is around 130,000 m^3/s, Tocantins flow is 8000 m^3/s, Paraná flow is 12,000 m^3/s, São Francisco flow used to be 2000 m^3/s but has reduced to 800 m^3/s in 2016 (http://www.snirh.gov.br/hidroweb/). The transparent blue arrows represents the predominant trade wind direction bringing humid air into the continent. The trade winds direction is predominant up to a height of 4000 m (https://www.windyty.com).

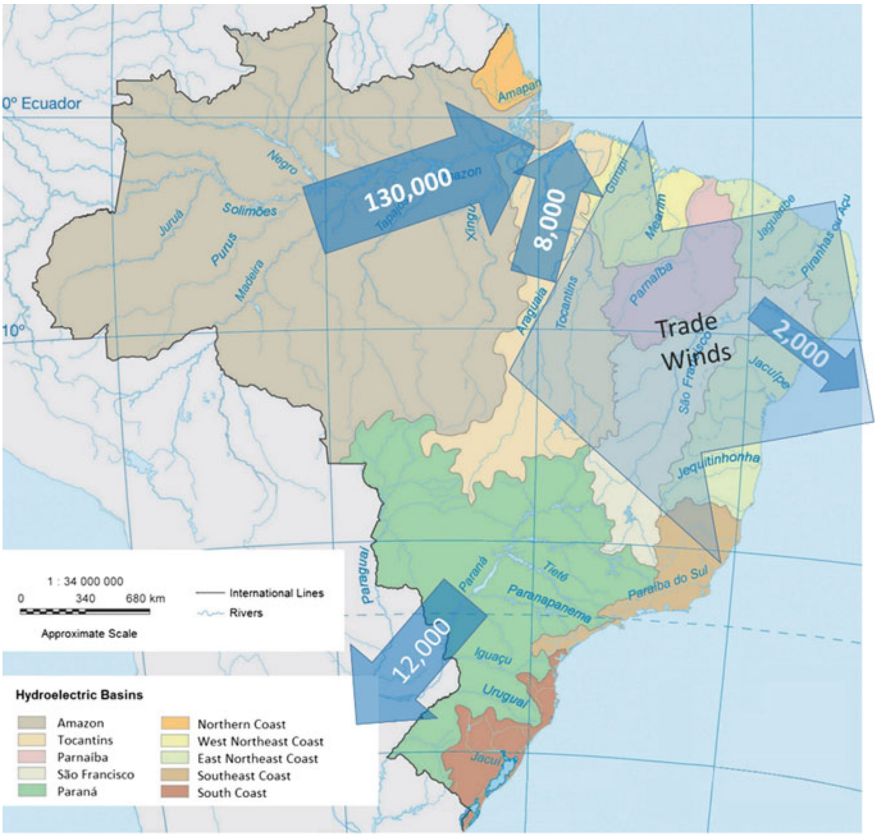


Fig. 11.5 Hydrological and climatic characteristics of major Brazil basins (numbers represent m^3/s) (Operador do Sistema Nacional 2015)

It should be noted that if water is transposed by artificial channels from the Paraná and Tocantins Rivers into the São Francisco Basin and from there it is used for plantation irrigation, a share of the water transposed may return as humidity to the Tocantins, Amazon and Paraná Basins carried by the trade winds, with wind speeds of yearly average of 11 m/s at 1400 m absolute height in some locations on Northeast Brazil (Centro de Referência para Energia Solar e Eólica 2013; http://pt-br.topographic-map.com/places/Brasil-3559915/). This climate change adaptation methodology is suggested because, apart from removing water, from where it causes problems and putting in a region with lack of water availability, the water consumed would return to where it was taken and increase the overall water availability of Brazil. This solution has not been proposed before and is limited to locations with strong and constant trade winds and locations where these trade winds returns the water to where it originally taken from.

An ambitious Transposition Cycle developed by the author is presented in Fig. 11.6. This project involves the basins of Rivers Xingú, Tocantins, Paraná, and the São Francisco River. The transposition of water of the Paraná Basin to the São Francisco Basin is not very complicated. According to Fig. 11.6, nine hydropower plants in the Grande River should be upgraded with reversible turbines to capture the rainfall in the region in purple and pump to Furnas Reservoir. The pumping capacity should guarantee a 1500 m^3/s flow at the Furnas reservoir so that it can be transposed to the São Francisco Basin. The average flow at the Furnas Reservoir is around 1200 m^3/s. However, during the drought in 2015 the flow was reduced to 250 m^3/s.

To connect the Furnas Reservoir, at the Paraná Basin, with the São Francisco River, a pipeline of 15 km is required. In addition, this pipeline has a 100 m head difference, which could be used for hydroelectricity generation. Two more run-of-the-river dams should be built upstream of Três Marias Dam and increase the hydropower generation head in the São Francisco River by 100 m.

Fig. 11.6 Transposition of the Xingu, Araguaia, Tocantins and Paraná to São Francisco River

Figure 11.6 also shows water transposition of the Xingu River to the Araguaia River, Araguaia to Tocantins and Tocantins to São Francisco River. This implementation is not simple, but provides several benefits.

Transposition of the Xingú River to the Araguaia River captures water from the green area in Fig. 11.6. A 120 km canal with an average depth of 15 m, takes water from Xingu River to a conventional storage reservoir in the Araguaia Basin. This reservoir will fill only during the wet season, when there is excess water in the Xingu River and generate electricity during the dry period with a maximum head of 210 m. This water will be transposed into the Tocantins River and then to the São Francisco River.

To facilitate the transposition of water from the Araguaia River to the Tocantins River it is important to control the flow of the Araguaia River in its head to reduce its seasonal flow and allow the transposition system to operate during the wet and dry periods. In order to achieve this, water from the Mortos River will be stored in a Seasonal-Pumped-Storage plant during the wet period and transposed to the Araguaia River during the dry period. The Araguaia River Basin has little investment in agriculture and other activities because it suffers annual flooding during the wet season due to its flat geological formation (Santos 2006; Costa 2012). In addition to Seasonal-Pumped-Storage, a channel will be created to remove sediments and stop the flooding in the Araguaia River. A Sedimentary Basin Storage Dam will control the amount of water stored in the Mid-Araguaia Sedimentary Basin. Sedimentary Basin Storage intends to store water in the sandy ground and control the level of the groundwater with the dam. Flood control in the Araguaia Basin will enable the economic development of the region and the increase in water storage will enable the transposition of water from the Araguaia River to Tocantins River throughout the whole year.

The Southern Transposition Project from the Araguaia River to the Tocantins River will require with the Crixás-Acu River at an altitude of 230 m with a 140 km canal with an average depth of 10 m, followed by a tube with 50 km and pumping facility, a 40 km canal with an average depth 10 m and a run-of-river dam at 490 m absolute height. The Southern Transposition Project will have a 500 m^3/s capacity flow and will make use of the underutilized Serra da Mesa Reservoir storage potential.

The Southern Transposition Project from the Tocantins River to the São Francisco River will require a 20 km tube with pumping facility and a 120 km channel at 1050 m absolute height with an average depth of 10 m. Then a 60 km long tube will connect the channel to the São Francisco Basin. Part of the electricity used to pump the water will be generated at the other end of the transposition. New dams will be built to generate electricity in the São Francisco Basin.

The Northern Transposition Project from the Araguaia River to the Tocantins River will take place after the Araguaia National Park at an altitude of 170 m, where the Araguaia and Javaés Rivers converge. The transposition will require a 140 km canal with an average depth of 15 m with a tube 80 km long with pumping facility to Lajeado Reservoir at an absolute height of 210 m.

The Northern Transposition Project from the Tocantins River (210 m) to the São Francisco River requires a 60 km canal with an average depth of 20 m, tubes with 20 km and pumping facility to a run-of the-river dam at an absolute height of 390 m. Following, another tube 60 km long with pumping facility to a Seasonal-Pumped-Storage reservoir, with its level varying between 750 and 650 m to store water and energy. In addition, two dams at the São Francisco Basin will recover some of the energy used for pumping. The Northern Transposition Project has a 1.500 m^3/s flow capacity.

Additionally, this article suggests the operation of the Sobradinho Reservoir at its lowest level. The Sobradinho Reservoir has a maximum flooded area of around 4200 km^2, which results in an evaporation of around 14% of the São Francisco River flow (Operadora Nacional do Sistema Elétrico 2004). The Seasonal-Pumped-Storage sites proposed will be able to regulate the flow of the São Francisco River. The Sobradinho Dam will not be required and will operate at its minimum level to reduce evaporation.

Figure 11.7 shows the amount of water transposed to the São Francisco Basin, the area where the water can be used for irrigation and a preliminary suggestion of how the moisture might return to the other inland basins. In order to estimate the amount of moisture that would stay in the São Francisco Basin and the amount of moisture that would be carried to the inland basins, a climate and hydrological model should be developed with the intention to estimate the moisture dispersion and how it might affect the Brazilian climate and its rain patterns.

Due to its environmental flexibility, eucalyptus is the most widely used tree for biomass based electricity generation. It has a high productivity (more than 60 m^3/ha/year have been reported (Couto et al. 2011)) and energy characteristics (wood density and heat capacity (Chen et al. 2014)). The tree genus has been acclaimed as one of the best options for energy production due mainly to the large number of

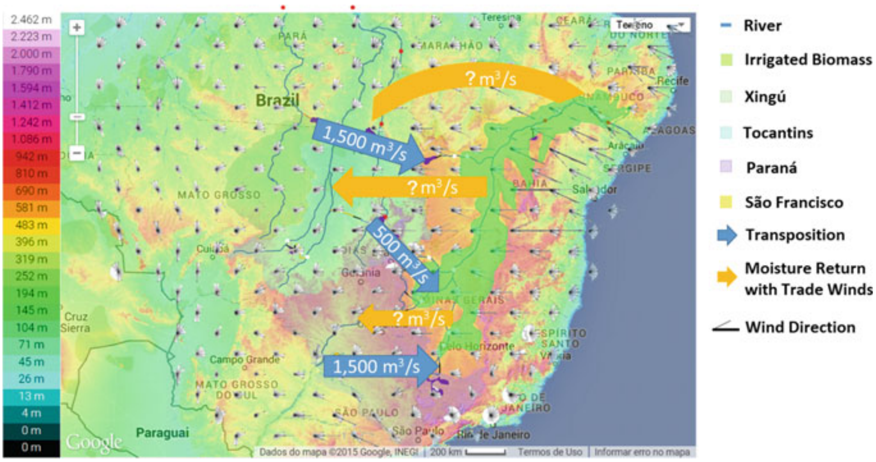


Fig. 11.7 Transposition cycle in Brazil and wind direction probability distribution

species, which enables wide ecological distribution, favouring its introduction in various regions with different soil and climatic conditions (Couto and Müller 2008). Data used to estimate the water transpiration and biomass production assumed the Eucalyptus Grandis species planted with a spacing of 3 m × 3 m at the Três Lagoas Municipality (Sartorio 2014).

Assuming that the annual average precipitation in the São Francisco Basin is 1,200 mm and an water for irrigation of 12,000 m^3/ha year (Confederação da Agricultura e Pecuária do Brasil 2011), and an average growth rate of 60 m^3/ha year (Sartório 2014) (due to high solar radiation and water availability with irrigation). Thus, an approximately 100,000 km^2 of irrigated plantation area would be required to remove 4000 m^3/s of water from the São Francisco River for irrigation.

If all this area was used for the cultivation of eucalyptus, it would result in a production of 63 billion m^3 of eucalyptus per year. If this eucalyptus were used for electricity generation, it would be able to generate around 90 GW of electricity at a 90% capacity factor. The planted biomass could be transported by waterway to the mouth of the São Francisco River and exported to other countries. In addition, the irrigated areas could produce sugarcane, corn, cotton and other crops (giving preference to crops that consume a lot of water).

It should be noted however that this transposition cycle might have a negative net hydroelectric generation. This means that the amount of energy required to pump will be higher than the amount of hydropower generation. This is because there is a great need for pumping and because the hydropower potential of most of the São Francisco Basin (up-river of the Sobradinho reservoir) is high at 307 m and few areas surrounding the São Francisco, where the moisture might precipitate, have a higher hydropower potential.

Discussion

The transfer of water between river basins is a very debatable issue because of the high costs involved and the multiple interests and uses of water. This study presents a new approach to transposition with positive and negative aspects. These aspects are mentioned below:

Positive:

(1) Increase the availability of water in the São Francisco River Basin for irrigated crops.
(2) Increase the energy storage in Brazil with Seasonal-Pumped-Storage (Hunt et al. 2014b).
(3) Facilitate the construction of flood control systems in the Araguaia River Basin, which prevents the development of the region (Santos 2006; Costa 2012).
(4) Create mechanisms to control the climate in the country. When there is a drought, an increase in transposition and biomass irrigation, might increase the humidity of the country.

Negative:

(1) High implementation costs.
(2) Reduction of overall hydroelectricity generation.
(3) Environmental impacts with the construction and operation of the transposition projects and the intense irrigated plantations.
(4) Indirect environmental impact resulted from the changes in climate. For example, it could be the case that the increase of transpiration in the São Francisco Basin creates a climatic condition that pushes the trade winds higher into the atmosphere that will possibly increase the precipitation in the São Francisco Basin.
(5) Ecological consequences of planting many square kilometres of non-native species.

The limitations of this work is the need to develop a climatic and hydrological model to estimate to where the moisture transpired might be carried and where it might precipitate. The constraints which have not been quantified are the construction and operation costs of the transposition systems and the irrigated plantations. In addition, the environmental impacts involved should be quantified.

Conclusion

Climate change and climate adaptation has not been intensively studied and included in the strategic planning of Brazil. Climate change alters the climate behaviour patterns and the frequency of extreme events, which may result in substantial socio-economic and environmental impacts.

This article introduced a new mechanism named Watershed Transposition Cycle with Irrigated Biomass aiming to take water from where it may cause flooding problems and transport it where there is low water availability. The Transposition Cycle is an artificial water cycle generated by the transposition of water to another basin. This water is used for irrigation and then returned by the strong trade winds to the location from where it was removed.

An example of this mechanism is the transposition of the Xingú, Araguaia, Tocantins and Paraná Basins to the São Francisco Basin. The direction of the wind along the São Francisco River Basin carries moisture into Brazil, in the opposite direction of the transposition. This might increase the residence time of the water in the continent, which would increase the availability of water in Brazil.

It was found that an approximately 100,000 km^2 of irrigated plantation area would be required to remove 4000 m^3/s of water from the São Francisco River for irrigation. In eucalyptus plantation, this amount of land would be able to generate around 90 GW of electricity at a 90% capacity factor. In addition to increasing irrigation in Brazil, this mechanism can be used to assist adaptation to climate change, as it would include an artificial variable that would increase the humidity of Brazil's countryside and have a direct impact on the country's climate.

For future work, it is necessary to create a climate and hydrological models in order to estimate the amount of water that can be withdrawn from the São Francisco River with the transpiration of irrigated plantations and to estimate the moisture dispersion and where it might precipitate.

Eventually, it might be shown that Watershed Transposition Cycle with Irrigated Biomass is not a viable endeavour. However, it is important to understand that changes in land use and water use have an impact on the regional climate. It is important to understand the effects of these changes to better plan for future projects and for climate variations.

References

Agência Nacional de Águas, Balanço Hídrico Quantitativo. ANA. http://portal1.snirh.gov.br/ana/apps/webappviewer/index.html?id=ac0a9666e1f340b387e8032f64b2b85a. Accessed 17 July 2016

Agencia Nacional de Águas, "Hidroweb," Sistema Nacional de Informações sobre Recursos Hídricos. ANA. http://www.snirh.gov.br/hidroweb/. Accessed 17 July 2016

Agência National de Águas, Disponibilidade e Demandas de Recursos Hídricos no Brasil. ANA. http://arquivos.ana.gov.br/planejamento/estudos/sprtew/2/2-ANA.swf. Accessed 17 July 2016

Amarante OAC, Brower M, Zack J, Sá AL (2001) Atlas do Potencial Eólico Brasileiro. CEPEL, Brazília

Barifouse R (2014) Sudeste pode 'aprender com Nordeste a lidar com seca'. British Broadcasting Corporation. http://www.bbc.com/portuguese/noticias/2014/08/140820_crise_agua_nordeste_sudeste_rb

Centro de Referência para Energia Solar e Eólica (2013) Atlas do Potencial Eólico do Estada da Bahia. CEPEL, Rio de Janeiro

Chen W, Kuo P, Liu S-H, Wu W (2014) Thermal characterization of oil palm fiber and eucalyptus in torrefaction. Energy 71:40–48

Comitê da Bacia Hidrográfica do Rio São Francisco (2004) Plano de Recursos Hídricos da Bacia Hidrográfica do Rio São Francisco. CBHSP, Aracaju

Confederação da Agricultura e Pecuária do Brasil (2011) Plantio de eucalipto no Brasil: Mitos e verdades. CNA, Brasilia

Costa JA (2012) Desenvolvimento de um sistema de alerta de enchente aplicado aos planos de defesa civil em áreas de risco no Estado do Pará utilizando sistema de informações geográficas (SIG), Caso: Cidade de Marabá. Universidade Federal do Pará, Belém

Couto L, Müller M (2008) Florestas Energeticas no Brasil. In: Biomassa para Energia. São Paulo, UNICAMP, pp 93–111

Couto L, Nicholas I, Wright L (2011) Short rotation eucalypt plantations for energy in Brazil. IEA Bioenergy, Viçosa

Dias P (2014) Análise Espacial Aplicada à Delimitação de Áreas Úmidas da Planície de Inundação do Médio Araguaia. Universidade Federal do Mato Grosso, Cuiaba

Empresa de Pesquisa Energética (2015) Plano Decenal de Expansão de Energia 2024. EPE, Rio de Janeiro

Hunt JD, Freitas MAV, Pereira AO Junior (2014a) Enhanced-pumped-storage: combining pumped-storage in a yearly storage cycle with dams in cascade in Brazil. Energy 78:513–523

Hunt JD, Freitas MA, Pereira Junior AO (2014b) Aumentando a Capacidade de Armazenamento Energético do Brasil. In: IX Congresso Brasileiro de Planejamento Energético, 25 a 27 de Agosto, Florianopolis

Hunt J, Guillot V, Freitas M, Solari R (2016) Energy crop storage: an alternative to resolve the problem of unpredictable hydropower generation in Brazil. Energy 101:91–99

Instituto de Pesquisas Hidráulicas, Hidrologia de Grande Escala. IPH/UFRGS. https://www.ufrgs.br/hge/modelos-e-outros-produtos/mgb-iph-propagacao-inercial/. Accessed 17 July 2016

Marengo J, Liebmann B, Kousky V, Filizola N, Wainer I (2001) Onset and end of the rainy season in the Brazilian Amazon basin. J Clim 14(5):833–852

Nys E (2015) Série Água Brasil: Convivência com o seimárido e gestão proativa da seca no Nordeste do Brasil. World Bank, Brazilia

Operador do Sistema Nacional (2015) Operação Diária do Operador do Sistema Nacional. ONS. http://www.ons.org.br/publicacao/ipdo/

Operadora Nacional do Sistema Elétrico (2004) Evaporação Líquidas nas Usinas Hidrelétricas. ONS, Rio de Janeiro

Santos ME (2006) Estudo Econômico do Rio Araguaia - Região de Aruanã pela demanda turística. Universidade de Goiás, Goiânia

Sartorio IP (2014) Avaliação e Modelagem do Crescimento de Florestas Energeticas de Eucalipto Plantadas em Diferentes Densidades. Universidade Federal do Paraná, Curitiba

Topographic-map, Brasil. Google. http://pt-br.topographic-map.com/places/Brasil-3559915/. Accessed 17 July 2016

Valdes A, Wagner E, Marzall I, Simas J, Morelli J, Pereira L, Azevedo L (2004) Série Água Brasil 5. Impactos e Externalidades Sociais da Irrigação no Semi-Árido Brasileiro. World Bank, Brazília

Windyty. https://www.windyty.com. Accessed 11 July 2016

Chapter 12
An Ecosystem Approach to Indicate Agriculture Adaptive Strategies to Climate Change Impacts

Ana Paula Dias Turetta

Introduction

Climate change poses one of the greatest threats in history to the realisation of sustainable development, as climate hazards are increasingly impacting human communities and ecosystems alike. The world's poorest people and communities are most vulnerable to the impacts of climate change; they are on the frontline of a changing climate with everything to lose and little to cushion the blow (Girot et al. 2012). Climate change is also having a negative impact on traditional coping mechanisms and food security 1 thereby increasing the vulnerability of the world's poor to famine and perturbations such as droughts, floods and diseases (Girot et al. 2012).

As some consequences, climate change impacts on natural resources, species and ecosystems will reduce options for local and national development, and increase the pressure on the remaining terrestrial, freshwater and marine habitats. Losses in land fertility and landscape-level productivity through forces such as erosion and salinisation will affect rural and coastal communities' livelihoods, further reducing opportunities for sustainable development and exacerbating poverty through reduced income opportunities (Girot et al. 2012).

There is need for more integrated approaches to adaptation that adhere both to human rights-based principles and to principles of sound environmental management and propose ways to bridge the artificial divide between adaptation approaches that focus on the role of ecosystems and those that support the role of communities and human rights. It is clear on the Hyogo Framework (Unisdr 2005) "*There is now international acknowledgement that effort to reduce disaster risks must be systematically integrated into policies, plans and programmes for*

A.P.D. Turetta (✉)
National Center of Soil Research - Embrapa Solos, Rua Jardim Botânico, 1024, Rio de Janeiro, RJ CEP 22460-000, Brazil
e-mail: ana.turetta@embrapa.br

W. Leal Filho and L. Esteves de Freitas (eds.), *Climate Change Adaptation in Latin America*, Climate Change Management,
https://doi.org/10.1007/978-3-319-56946-8_12

sustainable development and poverty reduction, and supported through bilateral, regional and international cooperation, including partnerships. Sustainable development, poverty reduction, good governance and disaster risk reduction are mutually supportive objectives, and in order to meet the challenges ahead, accelerated efforts must be made to build the necessary capacities at the community and national levels to manage and reduce risk". In others words: increasing the resilience of both social and ecological systems is therefore imperative in the face of a changing climate.

Recently, there has been a surge in interest surrounding adaptation approaches, but these have tended to be dispersed and narrow in focus. Considering this reality, this chapter will present a study case considering the ecosystem-based adaptation (EbA) approach.

Essentially, EbA addresses the crucial links between climate change, biodiversity, ecosystem services and sustainable resource management (Travers et al. 2012). It can be understood as part of an overall adaptation strategy to help people and communities adapt to the negative effects of climate change at local, national, regional and global levels (Travers et al. 2012).

In addition to protection from climate change impacts, EbA also provides many other benefits to communities, for example, through the maintenance and enhancement of ecosystem services crucial for livelihoods and human well-being, such as clean water and food (Travers et al. 2012). Appropriately, designed ecosystem management initiatives can also contribute to climate change mitigation by reducing emissions from ecosystem loss and degradation, and enhancing carbon sequestration.

EbA involves national and regional governments, local communities, private companies and NGOs in addressing the different pressures on ecosystem services, including land use change and climate change, and managing ecosystems to increase the resilience of people and economic sectors to climate change. The concept of EbA has emerged recently in the international climate change arena, with countries (e.g., Colombia, Sri Lanka), groups of countries (e.g., the African Group) and observers (e.g. the International Union for Conservation of Nature) addressing EbA in their submissions to the United Nations Framework Convention on Climate Change (Vignola et al. 2009).

The guidance 'profiles' EbA measures providing a description of opportunities, limitations, and contexts for use. Further, EbA measures and traditional adaptation technologies are aligned to discrete ecosystem services, to support profiling of adaptation technologies (Travers et al. 2012).

Guidance, has proposed by Travers et al. (2012) proposed a guidance with some steps necessary to apply the EbA approach. The four components (A, B, C and D) are presented individually with associated focus questions. The format of the guidance provided in Components 'C' and D is necessarily discursive in nature while context setting information in A and B lends more to a question-and-answer format (Fig. 12.1).

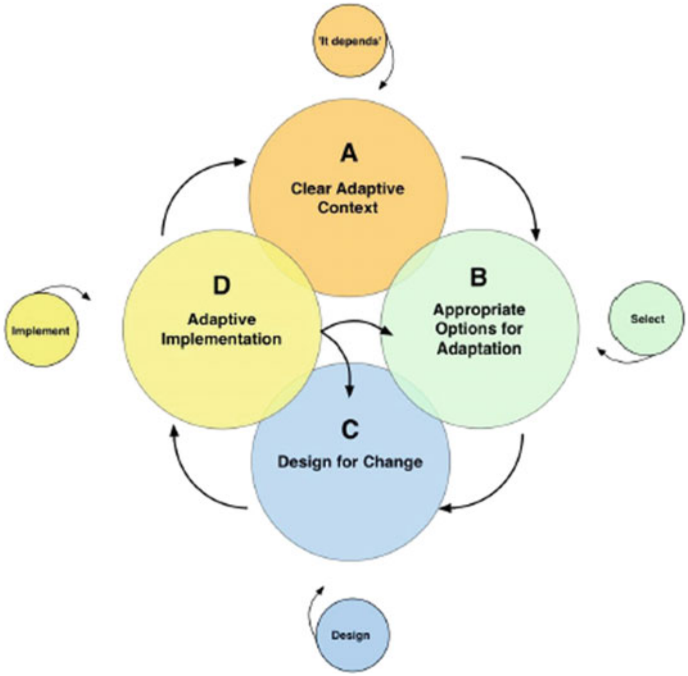


Fig. 12.1 EbA guidance framework (Travers et al. 2012)

Basically, the four components can be described as follow (Travers et al. 2012):

A. Setting the adaptive context: supports selection of the most appropriate options for adaptation in a given context. Component A explores this context with a view to establishing where information gaps exist;
B. Identification of appropriate intervention measures and associated, context specific, adaptive actions;
C. Supports the transition from a list of selected intervention measures, to develop a program that will guide implementation and define a plan to evaluate and reflect on performance;
D. Provides users with guidance to be confident in implementing change if and when required.

Considering EbA Approach in Agriculture

The agroecosystem concept can be used to analyse food systems as wholes, including their complex sets and outputs, as well as the interconections between their components, resulting in benefits for the whole system (Gliessman 2006).

A term that has been widely used to indicate the many functions and benefits provided by agroecosystems is "multifunctional agriculture" (MFA). It recognizes the inescapable interconnectedness between agriculture's different roles and functions, that is, that agriculture is a multi-output activity, producing not only commodities, but also non-commodity outputs, such as environmental services, landscape amenities, and cultural heritages (UNEP 2016). The MFA concept entered definitely in the sustainable development debate after being addressed in the Agenda 21 documents of the 1992 Earth Summit in Rio de Janeiro, Brazil (Rossing et al. 2007). Since then, it has obtained an increasingly important role in scientific and policy debates on the future of agricultural and rural development (Renting et al. 2009). For instance, the MFA is directly linked with the improvement of environmental functionality, acting to minimize the adverse impacts of climate change through integrating new and improved crop varieties and livestock breeds into diversified, resilient, risk—averse farming systems (IAASTS 2008).

Therefore, the MFA is a fundamental issue for ecosystem services (ES) provision, defined as the benefits people obtain from ecosystems. The Food and Agriculture Organization of the United Nations (FAO 2011) stresses that healthy ecosystems provide a variety of vital goods and services that contribute directly or indirectly to human well-being, in economic, social and environmental spheres. These services include: provisioning services, such as food, wood, fiber, and fuel production, as well as fresh water; regulating services, like flood, disease, and water quality control, besides carbon storage, waste treatment (nutrients and pesticides), and climate regulation through greenhouse gas emissions; cultural services, comprising spiritual, recreational, and cultural benefits, associated to scenic beauty, education, recreation and tourism; and supporting services, such as nutrient cycling and primary production, which maintain the conditions for life on Earth (Millennium Ecosystem Assessment 2005; Power 2010).

Although agroecosystems may have low ES values per unit area, when compared with other ecosystems, they offer the best chance of increasing global ES—given the proportion of land devoted to agriculture worldwide—by defining appropriate goals for agricultural and land use management regimes that favor the provision of these services (Porter et al. 2009). In other words, it is possible and essential to improve ES provision from agriculture through agricultural management practices considering, among other things, climate change adaptation.

Research Approach

The case study considered in this chapter is the Pito Aceso watershed, located in Bom Jardim municipality, mountains region of Rio de Janeiro State. This region is characterized by rocky cliffs, thick soil and deforested areas of the Atlantic Forest, making it susceptible to landslides (Dantas et al. 2001). Historically, the region was continuously covered by the Atlantic rainforest, which was significantly removed to give way to vegetable crops, pastures and urbanization. Some parts of the original

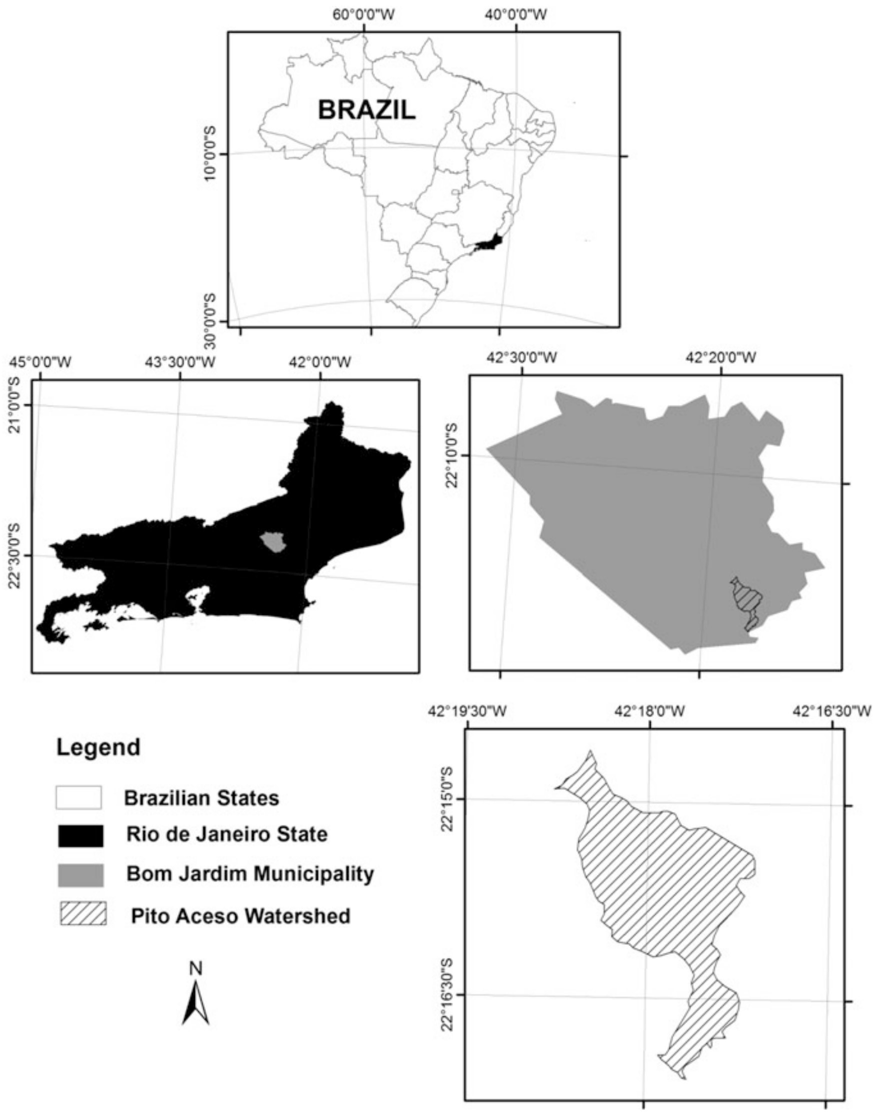


Fig. 12.2 Pito Aceso watershed location

forest remain and in various locations re-colonization by secondary forests have occurred due to their unsuitability to agricultural activities. These regenerated forests permit the entry of water into the soil, however they do not have deep root anchoring systems that increase soil resistance on the slopes. During the expansion of urbanization and rural activity, slopes were cut to enable the implementation of roads and residences (Avelar et al. 2011). This change in land use cover and associated urban development process increased the region's vulnerability to erosion and incidence of floods.

The Pito Aceso watershed has around 500 ha, and presents a mosaic of land use/land covers in its area (Tavora and Turetta 2016; Fig. 12.2). The majority activity is the small farming characterized by the intensive use of fertilizers.

To apply the EbA guidance (Travers et al. 2012), the study of Turetta et al. (2016) in Pito Aceso watershed was used as a reference for the required analyses.

Discussion

Turetta et al. (2016) defined the criteria for the establishment and management of agroecosystems with representatives of agricultural entities, producers, and the research team (Table 12.1). Afterwards, the groups systematized the information and defined the priorities for Pito Aceso watershed concerning agroecosystems, ES provision, and indicators to monitor the proposed changes. Information about public policies was also considered, since these are crucial to enable changes in the agriculture and environment sectors. The improvement of ES provision from agriculture represents a real chance for Brazil to meet the international agreements about climate change.

The information about the criteria for the establishment and management of agroecosystems in the Atlantic Forest (Table 12.1) is an important issue that is part of the component "A" outcome, according the EbA guidance (Travers et al. 2012). The authors suggest as outcome to component "A" a clear adaptation decision making context defined with a particular understanding of the role ecosystem

Table 12.1 Criteria for the establishment and management of agroecosystems in the Atlantic Forest (Turetta et al. 2016)

Criteria for deployment and management	Atlantic Forest
No fire use	Yes
Rational use of agrochemicals (chemical fertilizers and pesticides)	Yes
No use of agrochemicals (chemical fertilizers and pesticides)	No
Permanent litter in the surface of soils	Yes
Agricultural consortium	Yes
Crops rotation	Yes
Native trees	No
Use of irrigation	Yes
Include animal component	No
Strategy of water use in the rural property	Yes

services. To achieve this, it is necessary to add to this information the link with ecosystem services.

Turetta et al. (2016) defined the relationship among the criteria for the establishment and management of the agroecosystems, and the ecosystem services (ES) types, soil functions, potential soil indicator, ES benefits, and policy relevance in the study area (Table 12.2). The information presented in Table 12.2 is important to achieve the component “A” completely, as well as, the component “B”, that predict an appropriate adaptation options prioritised in project context (Travers et al. 2012).

It was observed that the ES that were most affected were the supporting and provisioning types, which showed multifunctionality in agriculture: supporting services, for example, are related to nutrient cycling and primary production, whereas provisioning services include food, wood, fiber, and fuel production, as well as fresh water (Table 12.2). Yahdjian et al. (2015) point out that supporting services, particularly biodiversity and nutrient cycling, are essential to other ecosystem services, since they affect the supply of provisioning, regulating, and cultural services. Furthermore, Lal (2010) highlights that the increase in supporting services improves soil quality and crop yield, and reduces soil erodibility and carbon dioxide (CO_2) emissions into the atmosphere. Schipanski et al. (2014) found that agricultural management may provide supporting services through biological nitrogen fixation by legumes and through nitrogen mineralization from cover crop residues. These factors reflect the potential to support crop production through internal nutrient cycling, reducing the use of synthetic fertilizers and their associated fossil fuel emissions. In addition, excessive nitrogen inputs can increase nitrate (NO_3) pollution in streams and groundwater, and nitrous oxide (N_2O) emissions into the atmosphere, affecting air and water quality regulation. This shows that the ES type regulation is affected by the agroecosystem’s capacity to offer supporting and provisioning services. So, it is possible to say that climate change alters the functions of ecological systems. As a result, the provision of ecosystem services and the well-being of people that rely on these services are being modified.

So, Table 12.2 can be understand as an “adaptation options menu” for Atlantic Forest biome. The proposed managements provide various nutrients to the soil, mitigate the buildup of pathogens and pests that often occur in conventional systems, and improve soil structure and fertility, also affecting soil functioning.

EbA guidance (Travers et al. 2012) still has two othes component, “C” and “D” (Fig. 12.1). As the outcome of component “C” is the plan for implementation and evaluation and the outcome of component “D” is an adaptive approach to EbA implementation. However, it was not possible to achieve these components with the available information of Pito Aceso Watershed so far.

Table 12.2 Relationship among the criteria for the establishment and management of the agroecosystems, in the study areas, and the environmental services (ES) types, soil functions, potential soil indicator, ES benefits, and policy relevance

Criteria for deployment and management of agroecosystem (Table 12.2)	ES type[a]			Soil functions associtated	Soil parameters/potential soil indicator	ES benefits
	Provisioning	Supporting	Regulating			
No fire use	+++	+++	+++	Water infiltration/Habitat	• Soil porosity • Bulk density • Hydraulic conductivity • Retention curve • Biomass carbon stock in soil and litter • Microbial enzymatic activity (carbon cycle) • Microbial enzymatic activity (phosphorus cycle) • Microbial enzymatic activity (sulfur cycle) • Soil macrofauna	• CO_2 mitigation • Stability in crop production • Air purification • Biodiversity protection • Human health
Rational use of agrochemicals (chemical fertilizers and pesticides)	+++	+++	++	Nutrient cycling/habitat	• Phosphorus (P_2O_5) content • Potassium (K_2O) content • Calcium (CaO) content • Magnesium (MgO) content • Sum of bases = S = Ca + Mg + K + Na • Biomass carbon stock in soil and litter • Microbial enzymatic activity (carbon cycle) • Microbial enzymatic activity (phosphorus cycle) • Microbial enzymatic activity (sulfur cycle) • Soil macrofauna	Environmental and human health

(continued)

Table 12.2 (continued)

Criteria for deployment and management of agroecosystem (Table 12.2)	ES type[a]			Soil functions associtated	Soil parameters/potential soil indicator	ES benefits
	Provisioning	Supporting	Regulating			
No use of agrochemicals (chemical fertilizers and pesticides)	+++	+++	++	Habitat	• Biomass carbon stock in soil and litter • Microbial enzymatic activity (carbon cycle) • Microbial enzymatic activity (phosphorus cycle) • Microbial enzymatic activity (sulfur cycle) • Soil macrofauna	Human and environmental health
Permanent litter in the surface of soils	+++	+++	+++	Water infiltration/nutrient cycling/sediment retention/habitat	• Phosphorus (P_2O_5) content • Potassium (K_2O) content • Calcium (CaO) content • Magnesium (MgO) content • Sum of bases = S = Ca + Mg + K + Na • Soil porosity • Bulk density • Hydraulic conductivity • Retention curve • Soil macrofauna	Water supply and food production
Crops rotation	+++	+++	++	Water infiltration/nutrient cycling/carbon sequestration and accumulation/sediment retention/habitat	• Phosphorus (P_2O_5) content • Potassium (K_2O) content • Calcium (CaO) content • Magnesium (MgO) content	• Higher food diversity • Food security • GEE mitigation • Biodiversity protection

(continued)

Table 12.2 (continued)

Criteria for deployment and management of agroecosystem (Table 12.2)	ES type[a]			Soil functions associtated	Soil parameters/potential soil indicator	ES benefits
	Provisioning	Supporting	Regulating			
					• Sum of bases = S = Ca + Mg + K + Na • Soil porosity • Bulk density • Hydraulic conductivity • Retention curve • Biomass carbon stock in soil and litter • Microbial enzymatic activity (carbon cycle) • Microbial enzymatic activity (phosphorus cycle) • Microbial enzymatic activity (sulfur cycle) • Soil macrofauna	
Agricultural consortium	+	++	++	Nutrient cycling/carbon sequestration and accumulation/sediment retention/habitat	• Phosphorus (P_2O_5) content • Potassium (K_2O) content • Calcium (CaO) content • Magnesium (MgO) content • Sum of bases = S = Ca + Mg + K + Na • Biomass carbon stock in soil and litter • Microbial enzymatic activity (carbon cycle) • Microbial enzymatic activity (phosphorus cycle)	• Higher food diversity • Food security • GEE mitigation • Biodiversity protection • Avoid land use change (LUC)

(continued)

Table 12.2 (continued)

Criteria for deployment and management of agroecosystem (Table 12.2)	ES type[a]			Soil functions associtated	Soil parameters/potential soil indicator	ES benefits
	Provisioning	Supporting	Regulating			
					• Microbial enzymatic activity (sulfur cycle) • Soil macrofauna	
Native trees	+++	+++	+++	Nutrient cycling/habitat/water infiltration	• Phosphorus (P_2O_5) content • Potassium (K_2O) content • Calcium (CaO) content • Magnesium (MgO) content • Sum of bases = S = Ca + Mg + K + Na • Biomass carbon stock in soil and litter • Microbial enzymatic activity (carbon cycle) • Microbial enzymatic activity (phosphorus cycle) • Microbial enzymatic activity (sulfur cycle) • Soil macrofauna • Soil porosity • Bulk density • Hydraulic conductivity • Retention curve	• CO_2 mitigation • Air purification GEE mitigation • Biodiversity
Include animal component	+++	+++	++	Nutrient cycling	• Phosphorus (P_2O_5) content • Potassium (K_2O) content • Calcium (CaO) content • Magnesium (MgO) content • Sum of bases = S = Ca + Mg + K + Na	Food security

(continued)

Table 12.2 (continued)

Criteria for deployment and management of agroecosystem (Table 12.2)	ES type[a]			Soil functions associtated	Soil parameters/potential soil indicator	ES benefits
	Provisioning	Supporting	Regulating			
					• Soil porosity • Bulk density • Hydraulic conductivity • Retention curve • Biomass carbon stock in soil and litter • Microbial enzymatic activity (carbon cycle) • Microbial enzymatic activity (phosphorus cycle) • Microbial enzymatic activity (sulfur cycle) • Soil macrofauna	
Strategy of water use in the rural property	++	+++	+++	Water regulation/sediment retention	• Soil porosity • Bulk density • Hydraulic conductivity • Retention curve	Water supply

Policy relevance: Plano setorial de mitigação e de adaptação às mudanças climáticas (Plano ABC), the sector plan for mitigation and adaptation to climate change for low carbon in agriculture (Brasil 2011); Programa produtor de água, the water producer program (ANA 2016); Programa de aquisição de alimentos, the food acquisition program (Brasil 2011); Programa nacional de alimentação escolar, the national school feeding program (FNDE 2016)

[a]The qualitative estimates of the effects of each agricultural practice on ES types are represented by low (+) to high impacts (+++)

Conclusion

This chapter presented an application of EbA approach in Pito Aceso watershed, using available information. The results showed that ES types most affected by the establishment and management of agroecosystems are the supporting and provisioning services, showing the potential of agricultural management in providing multiple services, besides food, fiber, and energy. It also shows that agroecosystem management represent a huge potential for adaptation of climate change, since the water infiltration, nutrient cycling, carbon sequestration and accumulation, sediment retention, and habitat were the functions most affect by the establishment and management of the agroecosystems. These functions are essential in the context of climate change adaptation.

So, the EbA approach proved very promising, since it considers the maintenance and enhancement of ecosystem services crucial for livelihoods and human well-being, such as clean water and food. However, to apply the EbA approach, it is necessary a large set of data to be used in a sequence of components. It is a hard model to be applied in under developed country, as those of Latin America, since it is hard to find public database with surveys of natural resources, economic and social aspects, in different scales.

However, with the results present.

References

ANA. Agência Nacional de Águas (2016) Programa Produtor de Água. http://produtordeagua.ana.gov.br. Accessed 28 July 2016

Avelar AS, Coelho-Netto AL, Lacerda W, Becker LB, Mendonça MB (2011) Mechanisms of the recent catastrophic landslides in the mountainous range of Rio de Janeiro. Second World Landslide Forum, Rome

Brasil (2011) Lei º12.512, de 14 de outubro de 2011. Institui o Programa de Apoio à Conservação Ambiental e o Programa de Fomento às Atividades Produtivas Rurais; altera as Leis nºs 10.696, de 2 de julho de 2003, 10.836, de 9 de janeiro de 2004, e 11.326, de 24 de julho de 2006. Diário Oficial [da] República Federativa do Brasil, Brasília, 17 out. 2011. Seção 1, p 1. http://www.planalto.gov.br/ccivil_03/_Ato2011–2014/2011/Lei/L12512.htm#art33. Accessed 28 July 2016

Dantas ME, Shinzato E, Medina AIM, Silva CR, Pimentel J, Lumbreras JF, Calderano SB, Carvalho-Filho A (2001) Diagnóstico Geoambiental do Estado do Rio de Janeiro, Brasília/CPRM. In: Estudo Geoambiental do Estado do Rio de Janeiro, Rio de Janeiro, Brazil

FAO. Food and Agriculture Organization of the United Nations (2011) Payments for ecosystem services and food security. http://www.fao.org/docrep/014/i2100e/i2100e.pdf. Accessed 28 July 2016

FNDE. Fundo Nacional de Desenvolvimento da Educação (2016) Legislação. http://www.fnde.gov.br/programas/alimentacao-escolar/alimentacao-escolar-legislacao. Accessed 28 July 2016

Girot P, Ehrhart C, Oglethorpe J (2012) Integrating community and ecosystem-based approaches in climate change adaptation responses. ELAN—Ecosystem & Livelihoods Networks. http://cmsdata.iucn.org/downloads/a_eba_integratedapproach_15_04_12_0.pdf. Accessed 1 Dec 2016

Gliessman SR (2006) Agroecology: the ecology of sustainable food systems, 2nd edn. CRC Press, Boca Raton, 388 pp

IAASTD. International Assessment of Agricultural Knowledge, Science and Technology for Development (2008) Towards multifunctional agriculture for social, environmental and economic sustainability. IAASTS, Business Bay

Lal R (2010) Managing soils and ecosystems for mitigating anthropogenic carbon emissions and advancing global food security. Bioscience 60:708–721. doi:10.1525/bio.2010.60.9.8

Millennium Ecosystem Assessment (2005) Ecosystems and human well-being: synthesis. Island Press, Washington, DC, 155 pp

Porter J, Costanza R, Sandhu H, Sigsgaard l, Wratten S (2009) The value of producing food, energy, and ecosystem services within an Agro-Ecosystem. AMBIO: J Hum Environ 38(4):186–193

Power AG (2010) Ecosystem services and agriculture: tradeoffs and synergies. Philos Trans R Soc B 365:2959–2971. doi:10.1098/rstb.2010.0143

Renting H, Rossing WAH, Groot JCJ, Van Der Ploeg JD, Laurent C, Perraud D, Stobbelaar DJ, Van Ittersum MK (2009) Exploring multifunctional agriculture. A review of conceptual approaches and prospects for an integrative transitional framework. J Environ Manag 90:S112–S123. doi:10.1016/j.jenvman.2008.11.014

Rossing WAH, Zander P, Josien E, Groot JCJ, Meyer BC, Knierim A (2007) Integrative modelling approaches for analysis of impact of multifunctional agriculture: a review for France, Germany and the Netherlands. Agr Ecosyst Environ 120:41–57. doi:10.1016/j.agee.2006.05.031

Schipanski ME, Barbercheck M, Douglas MR, Finney DM, Haider K, Kaye JP, Kemanian AR, Mortensen DA, Ryan MR, Tooker J, White C (2014) A framework for evaluating ecosystem services provided by cover crops in agroecosystems. Agric Syst 125:12–22. doi:10.1016/j.agsy.2013.11.004

Tavora GSS, Turetta APD (2016) An approach to map landscape functions in Atlantic Forest—Brazil. Ecol Ind 71:557–566

Travers A, Elrick C, Kay R, Vestergaard O (2012) Ecosystem—based adaptation guidance—moving from principles to practice. Working document, Apr 2012

Turetta APD, Tonucci R, Mattos LM, Amaro G, Balieiro FC, Prado RB, Souza HA, Oliveira AP (2016) An approach to assess the potential of agroecosystems in providing environmental services. PAB, Pesquisa Agropecuária Brasileira 51:9. http://seer.sct.embrapa.br/index.php/pab/article/view/22473. Accessed 1 Dec 2016

UNEP. United Nations Environment Programme (2016) Towards multifunctional agriculture for social, environmental and economic sustainability. http://www.unep.org/dewa/agassessment/docs/10505_Multi.pdf. Accessed 28 July 2016

UNISDR. United Nations Secretariat of the International Strategy for Disaster Reduction (2005) Hyogo Framework for Action 2005–2015: building the resilience of nations and communities to disasters. UNISDR, Geneva

Vignola R, Locatelli B, Martinez C, Imbach P (2009) Ecosystem-based adaptation to climate change: what role for policy-makers, society and scientists? Mitig Adapt Strateg Glob Change 14:691–696

Yahdjian L, Sala OE, Havstad KM (2015) Rangeland ecosystem services: shifting focus from supply to reconciling supply and demand. Front Ecol Environ 13:44–51. doi:10.1890/140156

Author Biography

Dr. Ana Paula Turetta is a Researcher at Brazilian Agricultural Research Corporation—EMBRAPA. She has experience in natural resources management, with emphasis on environmental planning, working mainly with sustainability and environmental services in agricultural landscapes.

Chapter 13
How Much Is a Beach Worth: Economic Use and Vulnerability to Coastal Erosion: The Case of Ipanema and Arpoador Beaches, Rio de Janeiro (Brazil)

Flavia Lins-de-Barros and Leticia Parente-Ribeiro

Introduction

Beaches are environments of great social and economic value. Located, most often, in urbanized areas, which have high population density and diversified uses, they also constitute spaces integrated to multiple economic circuits. Such characteristics, added to the high exposure to climate change and, more specifically, to sea level rise, make beaches the focus of several methodological proposals for the assessment of vulnerability to coastal erosion. At the same time, there is a growing concern that these methodologies should consider, in an integrated manner, the biophysical and socioeconomic aspects in order to contribute to appropriate adaptation policy proposals (Nguyen et al. 2016).

Under an integrated approach, coastal vulnerability denotes a relationship between the degree of exposure to a particular hazard or disturbance and the capacity of adaptation or resilience, associated with both natural and socioeconomic systems (McFadden et al. 2007; Lins-de-Barros 2010a, b). After examining over 50 scientific papers on coastal vulnerability, Nguyen et al. (2016) identified two subsets of variables most often used to evaluate the systems' potential of being affected: one set related to human or demographic sensitivity and another associated with the sensitivity of land use. Regarding adaptability, social indicators and the existing management tools are primarily considered. The presence and diversity of economic activities in coastal areas and the potential for economic losses related to coastal erosion are not a central theme in the works analyzed.

F. Lins-de-Barros (✉)
Laboratório de Geografia Marinha, UFRJ, Rio de Janeiro, Brazil
e-mail: flaviamlb@gmail.com

L. Parente-Ribeiro
Departamento de Geografia, UFRJ, Rio de Janeiro, Brazil
e-mail: leticiapr@ufrj.br

W. Leal Filho and L. Esteves de Freitas (eds.), *Climate Change Adaptation in Latin America*, Climate Change Management,
https://doi.org/10.1007/978-3-319-56946-8_13

In addition, the same authors indicate that only 1/3 of the papers examined correspond to studies on local scale. Lins-de-Barros and Muehe (2010) attribute the low number of local scale research on vulnerability to the scarcity of data, the limitation of time and/or the requirement of highly specialized studies. This fact undermines their effectiveness to support public policies and zoning measures.

In order to fill, at least in part, these gaps, this study aims to explore a set of aspects regarding the economic use of urban sandy beaches relating them to the vulnerability of these systems to current storm events and to coastal erosion, in the event of sea level rise. To this effect, we choose Ipanema and Arpoador beaches, in the city of Rio de Janeiro, as a case study.

Study Area

Located in the southern area of Rio de Janeiro, Ipanema and Arpoador beaches are part of the beach arc of Arpoador-Leblon, a beach barrier with anchored extremities on rocky shores mainly composed of augen gneiss. The formation of this barrier dates back to the last marine transgression, around 5300 years B.P., when sea level was approximately 5 m above the current. To the rear of the beach barrier is Rodrigo de Freitas Lagoon, currently connected to the sea through two tidal channels, one on the west end of the segment, on Leblon beach. The other, called Jardim de Alá channel constitutes the boundary between Ipanema and Leblon beaches. It is currently channeled and is kept artificially open by dredging (Fig. 13.1).

Ipanema and Arpoador beaches also constitute an urban landscape resulting from the process of production and transformation of Rio de Janeiro's seafront. This process relates, to great extent, to the development of the city's seaside function since the mid-nineteenth century, associated, initially, to the therapeutic effect of sea bathing and later, especially since the 1920s, to the beaches' recreational use (Camargo 2013).

From the first decade of the 20th century, a new model of seafront urbanization began to spread toward the city's southern coast (Andreatta 2009). The construction of Avenida Atlântica (*Atlantic Avenue*) in Copacabana, which began in 1906, was part of an integrated urban intervention. The project included not only the opening of the 4 km long and 6 m wide road, but also the alignment of the buildings and the definition of a minimum distance from the seaside, as well as the implementation of a sidewalk adjacent to the strip of sand and another along the houses (O'Donnell 2013). A decade later, the local government adopted the same model, with some variations, in the urbanization of Ipanema and Leblon's seafronts. Its diffusion accompanied the emergence of "a lifestyle that began to abolish the beach-city dichotomy" associated with the transformation of the beaches into "long-stay leisure facilities" (Camargo 2013, p. 7).

Fig. 13.1 Ipanema and Arpoador beaches and beach profiles. *Source* Google Earth 2016

In the 1970s, akin to a major intervention that occurred on Copacabana beach, Ipanema's seaside facade was also redesigned, with the enlargement of vehicle traffic lanes and the expansion of the sidewalk adjacent to the sand strip (currently known as the *calçadão*, i.e., the promenade), assuming a shape similar to the one it has today. New forms of economic exploitation of the urban beaches also accompanied such changes.

The recognition of this peculiar model of seafront urbanization has important consequences for the very choice of the spatial delimitation for the present research. Therefore, when we refer to Ipanema and Arpoador beaches from a geo-economic point of view, we are indeed evoking a heterogeneous but integrated ensemble of morphological elements, which includes, but is not limited to the sand strip, encompassing the *calçadão* and other associated public places and also, as we shall see, in particular circumstances, the traffic lane itself.

Methodology

To assess the vulnerability of Ipanema and Arpoador beaches we conducted this research in three stages. The first concerns the analysis of the economy of these beaches and its spatial dimension. The second stage refers to the assessment of their current and potential physical vulnerability to storm events and to sea level rise. The third step concerns the estimation of economic value loss due to coastal erosion and sediment loss.

The Process of Valorization of Urban Sandy Beaches

When considering economic factors, the studies on the vulnerability of coastal areas tend to emphasize some specific aspects. The financial losses caused by damage or the destruction of existing assets and structures on the beachfront are commonly estimated, as well as the costs associated with recovery or reconstruction (e.g., Lins-de-Barros 2005). Another approach, identified in Coelho et al. (2008), consists of assigning qualitative values to different types of land use existing on the coastal areas, which allows the estimation of the potential economic losses as part of the assessment of coastal vulnerability. Real estate depreciation is also a frequent topic. McLaughlin et al. (2002), for example, assume that, as the population perceive the risks associated with the retreat of the coastline or the aggravation of storms, a growing loss of value of properties near the beach occur.

In this paper, we analyze the economic dimension of the vulnerability of coastal areas from the standpoint of the value generated by the direct economic exploitation of the beaches studied. To get an idea of the magnitude of this market, it is worth mentioning a recent study conducted by the Secretary of Solidary Economic Development of the city of Rio de Janeiro, which estimated at BRL 2 billion the cumulative annual revenues of economic activities in Rio's beaches (O Globo newspaper 2014). Mainly kiosks, beach tents (*barracas*) and street vendors (*ambulantes*) exploit the trade sector. In this case, the weight of seasonality is intense and individual income varies on average by 100% between low and high season. The provision of services has grown, especially in the last decade, largely in the market segment specialized in sports.

However, unlike many studies that focus on the subject, this research assumes that the current "value" of each beach constitutes the result of an ongoing *process of valorization*. In the case of Rio de Janeiro, this process followed the expansion of the urban area to the south sector of the city, the effective occupation of neighborhoods situated therein and the change in the "lifestyles" of the population (O'Donnell 2013). From a geographical perspective, two main aspects of this process concern us. The first relates to the *extent* of the area actually available for economic use. In fact, over time, this area may suffer significant changes, both in spatial and in temporal terms due to urban interventions and regulatory measures. The second refers to the *spatial differentiation* of the beach itself. In this sense, the emergence of new forms of use and economic exploitation of urban beaches reinforces, over time, the internal heterogeneity of these areas.

Data collection for the aspects mentioned above involved two main methodological procedures. Regarding the *extension* aspect, we conducted a research in the *O Globo* newspaper historical collection regarding the major urban interventions and regulatory changes that have occurred over the twentieth and twenty-first centuries. For the analysis of the second aspect, the *internal differentiation*, we conducted an exploratory survey of economic activities existing on the beaches, the areas effectively occupied by each, as well as its estimated revenue, considering the effects of seasonality. For the current study, we considered only the most traditional commercial activities held in kiosks, beach tents and performed by street vendors. Future research will also include the various service activities offered in the two beaches.

Assessment of Current and Potential Physical Vulnerability

Since the early 1990s, numerous methodologies for assessing vulnerability to coastal erosion have been proposed and are often associated with physical vulnerability to sea level rise in regional or national scales (Abuodha and Woodroffe 2006). These different methodologies derived from the pioneer work of Gornitz et al. (1994), in particular the Coastal Vulnerability Index (CVI) proposed by the authors.

In this research, the assessment of current and potential physical vulnerability includes the construction of scenarios related to the sediment loss of Ipanema and Arpoador beaches. Because it is a small stretch of coastline, we estimated the physical vulnerability degree for Ipanema beach as a whole, and not for its different segments. Based on the most accepted methodologies for assessing physical vulnerability, we chose the following indicators: dune configuration, beach profile altitude, the slope of the shoreface, grain size, wave energy and the storm event history with damage and transpositions. The figure below summarizes the indicators and thresholds used in this study. Figure 13.2 summarizes the indicators and thresholds used in this study.

Less vulnerable → **More vulnerable**

vegetable foredunes	foredunes without vegetation	no foredunes
coarse sand	medium sand	fine sand
moderate to low wave energy	high wave energy	very high wave energy
elevated backshore height (over 7m)	medium backshore height (between 4 and 6 m)	low backshore height (under 4m)
high shoreface slope (over than 2°)	medium shoreface slope (between 0,2 and 2°)	low shoreface slope (under 0,2°)
shoreline accretion	stable shoreline	shoreline erosion

Fig. 13.2 Geomorphological parameters and degrees of vulnerability. *Source* Adapted from Lins-de-Barros (2010)

The first three parameters were obtained from two topographic profiles done by UFRJ's Laboratory of Marine Geography along the beach arc in April 2016. The particle size was obtained by sediment analysis in the laboratory of Physical Geography at UFRJ. The wave exposure was qualitatively estimated through the research of storm events that caused damages on the coastline was conducted by means of a survey in the collection of *O Globo* newspaper between 1990 and 2009 (Lima 2015).

Aiming to outline a possible shoreline retreat scenario in the event of sea level rise, we considered the 0.82 m rise forecast for the period between 2085 and 2100, as established by the fifth IPCC report (Church et al. 2013). In general, it is possible to predict the regression of a sandy beach adopting the Bruun rule. This rule states that, once a beach reaches its equilibrium profile, a subsequent rise in sea level would upset this balance, which would then be restored by the migration of this profile toward the mainland (Fig. 13.3).

The magnitude of the resulting regression (R) varies according to the elevation of the sea level (S), the altitude of the beach profile (h + H), the length of the active profile (L) and the proportion of eroded material that remains in the active profile. The Bruun rule owes its notoriety to the possibility of calculating the coastline retreat in meters, based on a few parameters and a relatively simple mathematical formulation.

However, despite predicting the general reaction of the coastline to the rising of sea levels, the Bruun rule does not contemplate some more specific mechanisms that give more complexity to the issue. For instance, the sediment supply by rivers or by erosion of cliffs and terraces or the lateral transport of sediments depending on the direction of wave propagation are not taken into account by the Bruun rule. For this reason, Bruun rule has been widely criticized (Cooper and Pilkey 2004), adapted (Rosatti et al. 2013) or even replaced by other, more sophisticated models (Cowell et al. 2006). However, this does not mean that there will not be an adjustment in the transversal direction as proposed by Bruun. Since Ipanema and Arpoador beaches constitute a beach barrier, a migration towards the continent and

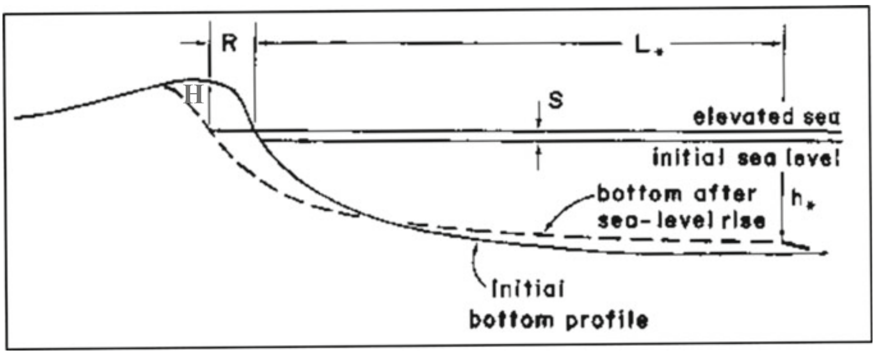


Fig. 13.3 Explanatory diagram of the Bruun rule. *Source* Adapted from Bruun (1962)

a narrowing of the backshore are expected. The precise magnitude of this adjustment must be evaluated judiciously. One must recognize that in the case of Ipanema beach the longitudinal transport of sediment is of great importance due to the alternating undulations of the southeast and southwest directions, as discussed already by Muehe and Neves (2008). However, the residual longitudinal transport appears to be null, i.e. the beach sometimes loses and sometimes gains sediments, but it does not alter its total volume. As such, if the wave climate does not change this longitudinal transport process will probably continue to occur in a balanced manner in the event of sea level rise, but acting on an adjusted beach profile. The Bruun rule also does not consider the transposition of the beach barrier by waves (*overwash*), as pointed out by Rosatti et al. (2013). This could result in changes in the Bruun rule, since there would be a migration of sediments not only to the shoreface but also to the backshore reverse towards the continent.

Although Bruun rule presents many inaccuracies we believe it can be useful because it allows for the construction of approximate scenarios in the event of rising sea level based on few parameters. The application of this model is especially suitable for sandy beaches formed by ridges where the expected effect of sea level rise is a retreat, resulting by a migration of the beach barrier and a decrease in the emerged beach (Bird 1985). Moreover, the application of the Bruun rule provides a more detailed approximation than those that only consider the terrain's altitude, disregarding the beach's adjustment to the new situation. This is the case of the study promoted by the City Planning Institute Pereira Passos (IPP) that produced a map of the areas that could be flooded in case of sea level rise in order to estimate the amount of people potentially affected (Mendonça 2008). This work had a great impact due to its pioneering role regarding to the issue of impacts generated by rising sea level in the city of Rio de Janeiro. Ipanema beach and the whole neighborhood between it and the Rodrigo de Freitas Lagoon are more than 2 m high and therefore, according to this model, would not be a vulnerable to flooding. We believe that a local scale analysis, as the one proposed here, and the adoption of the Bruun rule, even with all its limitations, may help us build new scenarios.

For the application of the Bruun rule, we used the following formula:

$$R = L \times S/(H + h),$$

where R is the maximum retreat of the coastline, L is the length between the highest point of the profile and its depth of closure, S is the value of the sea level rise, H is the maximum height of the emerged profile and h is the profile's closure depth.

In order to obtain the required parameters, we drew a beach profile approximately in the center of the beach arc. To calculate the maximum height of the emerged profile in a precise way, the altimetry quota was set based on the method described by Muehe et al. (2003). We adopted the depth of 7 m as the profile depth of closure following what Muehe (2001) described as the most common figure found in the southeast coast of Brazil. The total length was obtained by adding the emerged profile length with the length of the coastline to the bathymetric 7 m obtained on a bathymetric map donated by PENO/COPPE/UFRJ.

Results

A Century of Changes: Urban Morphology and the Economic Uses of Beaches

As we have pointed out above, the material and symbolic construction of the seafront in the southern sector of the city of Rio de Janeiro resulted from a long process of valorization, which has been intensified from the early twentieth century.

The seaside avenue in Ipanema (Avenida Vieira Souto) was opened in 1893 and doubled in 1915. Although it received improvements in the following decades, the first major intervention in the morphology of the area occurred only in the early 1970s. The seafront urbanization project started in 1974 and included interventions in the traffic lanes and sidewalks, improvements in lighting system and the construction of a marine outfall. Regarding the effective length of the beach, "the tracks of the two avenues will be extended from 7 to 9 m, allowing three lanes of traffic in each direction, and a 10 m wide promenade will be built along the buildings. The central sidewalk should measure 7 m and the sidewalk next to the beach, 4 m" (O Globo newspaper 1973). At the time, the width of the strip of sand was estimated at 60 m, which added to the adjacent thoroughfares, totaling 100 m in length. The sidewalk adjacent to the sand strip acts as a *buffer zone*. Its height was raised to prevent the parking of cars and the sidewalk received 15 cm of concrete for storm protection (O Globo newspaper 1974).

By the early 1980s, the seaside avenue in Arpoador was converted into a promenade. The project also included a new access to the rocks at the end of the beach and the construction of a large recreational area (O Globo newspaper 1980). Although it did not result in a material enlargement, as in the case of landfills, the incorporation of an area of 7200 m^2 to the seafront recreational logic (restricting its former circulation function) meant an effective extension of the beach and of the area available for its economic use. Another intervention, this time strictly normative, was the closure of one of the lanes of Avenida Vieira Souto on Sundays for vehicle traffic, which allowed the periodic extension of the recreation area at the seaside. The measure had enormous support of the population and remains to this day.

In the early 1990s, the local government held a major reurbanization of the city waterfront, known as Rio Orla. The project favored the construction of bike lanes, landscaping, lighting, parking regulation and the standardization of the kiosks. This time, with the improvement of public lighting system on the *calçadão*, there is a temporal extension of the use of the beach creating, in parallel, a new frontier for its economic exploitation, which would add to existing uses.

In fact, on the beaches studied we observed the co-presence of different models of economic exploitation, particularly related to the sectors of trade and services. From a geographical point of view, the analysis of their distribution patterns shows a true economic zoning of the beach. Regarding its actual use, the sand strip displays a clear internal differentiation. With the spread of the habit of sunbathing, especially since the 1920s, this area of the beach was gradually occupied and

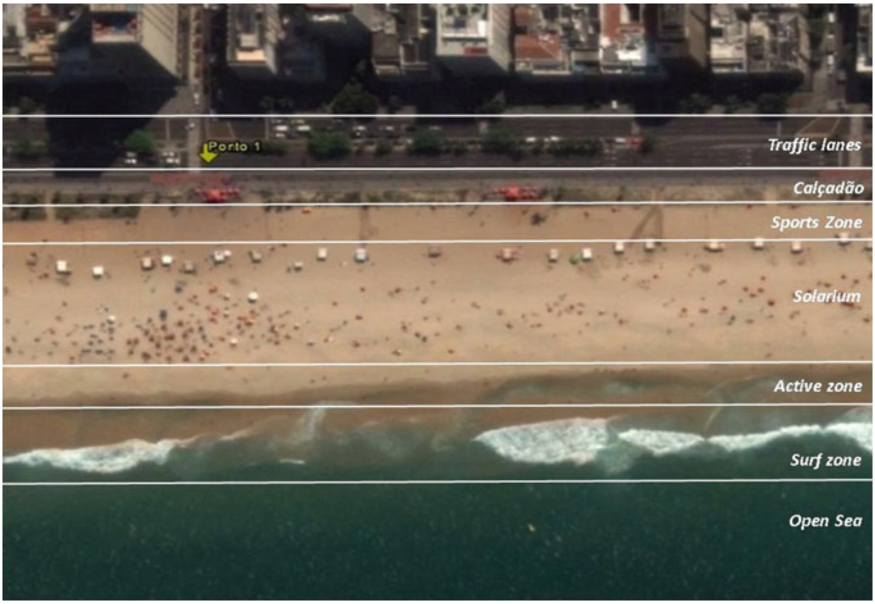


Fig. 13.4 Proposed zoning for Ipanema and Arpoador beaches based on usage criteria adapted from Fuster (1974 *apud* Polette and Raucci 2003). *Image source* Google Earth 2016

valued, particularly the *solarium zone* closest to the *active area* (see Fig. 13.4). In the daytime, the area to the rear of the beach tents is mostly occupied by sports activities (thus, the *sports zone*), in particular the "beach volleyball". These activities became the object of economic exploitation, especially from the 1990s with the spread of small "training centers" aimed at various sports practices. The economic use of this zone also intensified due to the temporal extension of the beach, coupled with the improvement of public lighting system on the *calçadão*.

Beach tent owners and street vendors mostly do the economic exploitation of the solarium area. Products marketed vary significantly although industrialized goods such as beverages and popsicles are more widespread. In the case of beach tent owners, the advantage created by the fixed point of trade allows them to sell beverages but also to rent chairs and umbrellas. Each beach tent establishes an "economic territory" in the *solarium area*, the extent of which depends on its ability to provide the service and on the competition with other adjacent beach tent owners. According to the survey conducted in April 2016, the average monthly revenue of beach tent holders who work on the beaches of Ipanema and Arpoador varies between BRL 5,000 (low season) and BRL 10,000 (high season). From Google Earth images, it was possible to account for 75 tents on a day of low season (April 2016) and about 140 in a day of high season (February 2010) throughout the beach segment considered in this study.

The activity of the street vendors is more susceptible to climate variations than that of the beach tent owners and therefore, in most cases, they do not work on the beach every day of the month. From the survey conducted in April 2016, it was possible to estimate the average daily revenue of beach vendors between BRL 50 (low season) and BRL 150 (high season). Considering a typical month with 20 working days, the monthly revenue of vendors varies between BRL 1,000 (in low season) and BRL 3,000 (in high season). However, we do not have an accurate estimate of the number of vendors who work in Ipanema and Arpoador beaches. The survey carried out by the municipal government in 2013 identified 1,092 vendors who worked in the city's beaches with formal authorization. It is estimated, however, that about 30% of vendors operate informally, mainly in the high season (O Globo 2014). Therefore, in 2013 there would be around 1,400 people exercising this activity. However, since the beaches of the southern sector of the city (from Copacabana to Leblon) have the highest occupation density of the whole seafront, we estimate that at least 200 (low season) to 300 (high season) vendors operate regularly in Ipanema and Arpoador.

Finally, the economical use of the *calçadão*, although quite varied is dominated by the trade in kiosks. There are currently 16 kiosks in operation in Ipanema and Arpoador beaches. The average monthly revenues, according to the data collected in this study, ranges from BRL 40,000 (low season) and BRL 100,000 (high season).

High Physical Vulnerability and the Retreat Scenario

The indicative assessment of the current physical vulnerability shows high overall vulnerability to storm events. One must consider the fact that their natural dynamics have been significantly altered due to the replacement of the frontal dunes by rigid structures, including a wall that limits the backshore along its entire length (Pena and Lins-de-Barros 2015). Thus, much of the beach arc's extension does not include developed frontal dunes and the salt marsh vegetation of the backshore occupies about 50% of the Leblon-Ipanema beach arch. The grain size of the berm of the beach is predominately medium. Considering the wall's interference in the beach's morphodynamic, since it limits the sediment transport in the transversal direction and, on the other hand, defines the highest point of the profile, possibly serving as a natural barrier, one assumes it is part of the geomorphology dynamic of this beach. As observed in the beach profiles, the wall is located at approximately 4.0 m of altitude in relation to sea level and at the time of the topographic survey the point of highest elevation of the backshore was 3.47 m in point 1 and only 1.6 m in point 2. Furthermore, at the time of the survey, the slope of the beach in point 1 was very low, while in point 2 a larger gradient was found. On the day of the survey, wave energy was high due to the arrival of a swell from the south quadrant, which was responsible for the shortening of the beach profile at point 2, which was only 10 m long. The next day at the same point the sea reached the wall directly, a situation that remained for about a month. This assessment of current physical vulnerability proposed herein should be understood as a primary approximation corresponding to what Sharples (2006) defined as the indicative stage of vulnerability. Deeper analysis, such as the evolution of the coastline by interpreting aerial photographs and analysis of wave energy behavior through refraction models, should be advanced. In this paper, we consider this indicative assessment to be sufficient, since it is goal was to point out elements of beaches' physical dynamics that may lead to some kind of economic depreciation (Fig. 13.5).

Beyond these geomorphological features, another aspect that corroborates to the high vulnerability is the exposure to swell arising from the southern quadrant storms. In an inventory held by Lima et al. (2015) of the number of storm events reported by the newspaper *O Globo* between 1990 and 2009 for the entire state of Rio de Janeiro, about 50% corresponded to the Leblon-Ipanema beach arc. This high frequency may be related in part to its strong social and economic value, but also to the aforementioned dynamics of lateral transport of sediment, which results in the accentuated erosion of edges alternately (Fig. 13.6).

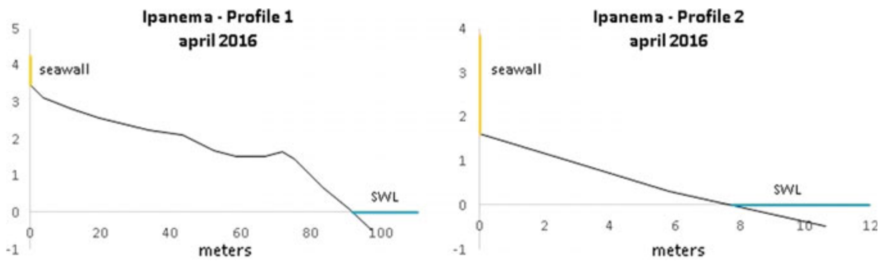


Fig. 13.5 Beach profiles (April 2016)

Fig. 13.6 The *left image* shows Ipanema beach sandless on January 17, 2002 when the swell had south-southeast direction and waves just over 1.0 m height, according to the wave simulation model reanalysis data of WAVEWATCH III (WW3) compiled by Klumb-Oliveira (2015). The one on the *right* shows the reverse situation occurred at Leblon Beach on June 12, 2003 when the swell was oriented to the south-southwest. *Source O Globo* Newspaper 2002, 2003

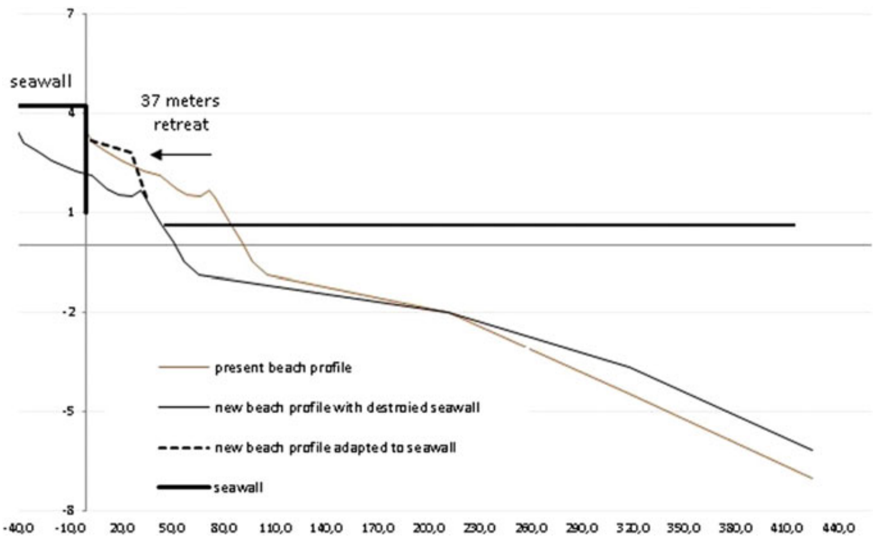


Fig. 13.7 Bruun rule applied for Ipanema beach profile

The result of the application of the Bruun rule to the profile of point 1 points to a 40-m retreat from the shoreline after the sea level rise of 0.82 m, if the beach itself is considered as the altitude profile. This situation would result in the migration of the beach, which would occupy the entire area currently occupied by the *calçadão*, the bike lane and the two lanes of Avenida Vieira Souto. However, one must consider the presence of the wall that protects this beach and that could prevent such migration if it continued to resist the waves' attack. In this case, the beach berm would suffer a reduction of 37 m, but the height of backshore would remain approximately the same. At the time of topographic survey the beach was with 97 m width, representing a good weather situation. Thus, the projected scenario indicates that this emerged beach profile would be reduced by just under half. In a storm situation today, as has been observed, the beach can lose sediment, which will certainly worsen with the scenario of sea level rise and decrease of the beach's width (Fig. 13.7).

So, How Much Are Ipanema and Arpoador Beaches Worth?

Based on the scenarios described above, and considering only the direct use of the beaches of Ipanema and Arpoador by kiosks, beach tents and street vendors, it is possible to estimate the loss of revenue due to the sea level rise. If we do not take into account the presence of the protective wall, the damage would reach all the economic uses contemplated in this research. Considering the effects of seasonality, the sea level rise would affect, in the low season, about 75 tents (BRL 5,000 of monthly revenue each), 200 vendors (BRL 1,000 of monthly revenue each) and 16 kiosks (BRL 40,000 of monthly revenue each). Therefore, the estimated loss of revenue would reach almost BRL 1.2 mi in only one month. In the high season, this amount would rise to about BRL 4 mi per month.

However, if the scenario that contemplates the presence of the protective wall is confirmed, the most affected uses will be the beach tents and street vendors. The *solarium zone*, where the economic use is more intense, should be significantly reduced. Obviously, market conditions would change, with increasing competition among economic players. A decrease in the number of traders, and/or a reduction of their "economic territories" is expected. Revenue loss is expected in both cases. However, to achieve a more precise estimate of the changes resulting from the decrease of the solarium zone on the economic uses of beaches, it is necessary to conduct a more detailed survey in situations where the beach's emerged profile is reduced.

On the other hand, storm events observed nowadays already point out to revenue losses, although partial and temporary. This was the case of Arpoador beach during the storm event that took place in April 2016. The absence of sediment on the beach resulted in the discontinuation of use of the entire stretch of sand for about a month, representing a loss of revenue of approximately BRL 160,000, if we consider only the 16 beach tents usually installed on this stretch of beach during the month (Fig. 13.8).

Fig. 13.8 Sea reaching the wall of the western end of Ipanema beach during a storm the occurred on April 2016. *Source* Tânia Rego/Agência Brasil/Fotos Públicas (28/04/16)

Final Remarks

The peculiar characteristics of coastal areas, especially those located in densely urbanized areas reinforce the multidimensional nature of their vulnerability. In this study, we sought to analyze the physical and economic dimensions of vulnerability from a local perspective with a focus on Ipanema and Arpoador beaches.

The assessment of the potential vulnerability due to the rise in sea level reveals a scenario of retreat that, in the case of Ipanema and Arpoador, could change the entire area comprising the bike path, the promenade and the traffic lanes. From the point of view of its use and its economic exploitation, this area is closely related to coastal dynamics, and therefore was considered as an integral part of the morphology of urban beaches studied here.

However, it is worth noting that we are not dealing with a natural dynamic that operates on an inert socioeconomic space. As previously discussed, over the last 100 years, seafront urbanization of the city of Rio de Janeiro was accompanied by a process of valorization of the beaches, leading to the extension of its area and its growing internal differentiation. It also produced an urban model of co-existence with hazards associated with the contact of the city with the sea. Indeed, the material elements that make up this model are inscribed in the very morphology of the city.

The sea level rise is a slow process and the forecasts considered here apply for the next 100 years. Hence, we can expect that new interventions in the morphology of beaches, regulatory changes as well as changes in their uses should occur in the sense of adapting these areas to the rise of sea levels and/or the increasing intensity of storms. In addition, the variety of uses identified in the beaches suggests that the effects of climate change are not homogeneous and therefore cannot be captured by models that link the depreciation of the beach to sediment loss and to the decrease of their carrying capacity in linear terms.

Acknowledgements We wish to record our thanks to the students of Marine Geography Laboratory from Geography Department of UFRJ whose help with the beaches profiles and the questionnaires. We would also like to thank to the Marine Geological and Geophysical Program—PGGM/Brasil, for encouragement scientific research about coastal and marine process.

References

Abuodha P, Woodroffe C (2006) International assessments of the vulnerability of the coastal zone to climate change, including an Australian Perspective. University of Wollongong, Wollongong

Andreatta V, Chiavari M, Rego H (2009) O Rio de Janeiro e a sua orla: história, projetos e identidade carioca. SMU, Rio de Janeiro

Bird E (1985) Coastline changes. Wiley, New York

Bruun P (1962) Sea level rise as a cause of shoreline erosion. Proc Am Soc Civil Eng 88:117–130

Camargo R (2013) As praias e as transformações de sensibilidade no Rio de Janeiro nos anos 1920. VI CONECO, Rio de Janeiro

Church J et al (2013) Sea level change. Climate change, the physical science basis. Cambridge University Press, Cambridge

Coelho C, Silva R, Veloso-Gomes F (2008) Vulnerabilidades e riscos das zonas costeiras potenciais impactos de alterações climáticas. APRH, Lisboa

Cooper J, Pilkey O (2004) Sea-level rise and shoreline retreat: time to abandon the Bruun Rule. Glob Planet Change 43(3–4):157–171

Cowell P et al (2006) Management of uncertainty in predicting climate-change impacts on beaches. J Coast Res 22(1):232–245

Gornitz V, Daniels R, White T, Birdwell K (1994) The development of a coastal risk assessment database: vulnerability to sea level rise in the US southeast. J Coast Res 12:327–338

Klumb-Oliveira L (2015) Variabilidade interanual do clima de ondas e tempestades e seus impactos sobre a morfodinâmica de praias do litoral sudeste do estado do Rio de Janeiro. Tese (Doutorado em Geografia). Universidade Federal do Rio de Janeiro. 2015, p 105

Lima R (2015) Histórico de eventos de ressaca e seus impactos no litoral do estado do Rio de Janeiro no período de 1990 e 2009. UFRJ, Rio de Janeiro

Lins-de-Barros F (2005) Risco, Vulnerabilidade Física à Erosão Costeira e Impactos Sócio-Econômicos na Orla Urbanizada de Maricá. Rio de Janeiro. Revista Brasileira de Geomorfologia 6:83–90

Lins-de-Barros F (2010a) Gestão costeira e vulnerabilidade: conceitos, abordagens e avanços. Candelária 6:55–70

Lins-de-Barros F (2010b) Contribuição metodológica para análise local da vulnerabilidade costeira e riscos associados: estudo de caso da Região dos Lagos, Rio de Janeiro. Tese de Doutorado — UFRJ, Programa de Pós-Graduação em Geografia

Lins-de-Barros F, Muehe D (2010) Avaliação local da vulnerabilidade e riscos de inundação na zona costeira da Região dos Lagos. Quat Environ Geosci 2:55–66

Mcfadden L (2007) Vulnerability analysis: a useful concept for coastal management? In: Mcfadden L, Nicholls R, Penning-Rowsell E (eds) Managing coastal vulnerability. Elsevier, Oxford, pp 15–28

Mclaughlin S, Mckenna J, Cooper J (2002) Socio-economic data in coastal vulnerability indices: constraints and opportunities. J Coastal Res 6:487–497

Mendonça M, Silva L (2008) Área da cidade passíveis de alagamento pela elevação do nível do mar. In: Gusmão P, Carmo P; Vianna B (orgs) Rio Próximos 100 anos. IPP/SMU, Rio de Janeiro, pp 80–129

Muehe D (2001) Critérios morfodinâmicos para o estabelecimento de limites da orla costeira para fins de gerenciamento. Revista Brasileira de Geomorfologia 2(1):35–44

Muehe D, Neves C (2008) Impactos possíveis da elevação do nível do mar e eventos climáticos extremos na cidade do Rio de Janeiro. In: Gusmão P, Carmo P, Vianna B (orgs) Rio Próximos 100 anos. IPP/SMU, Rio de Janeiro, pp. 50–79

Muehe D, Roso R, Savi D (2003) Avaliação de Método Expedito de Determinação do Nível do Mar como Datum Vertical para Amarração de Perfis de Praia. Revista Brasileira de Geomorfologia 4(1):53–57

Nguyen T, Bonetti J, Rogers K, Woodroffe C (2016) Indicator-based assessment of climate-change impacts on coasts: A review of concepts, methodological approaches and vulnerability indices. Ocean Coast Manag 123:18–23

O'Donnell J (2013) A invenção de Copacabana: culturas urbanas e estilos de vida no Rio de Janeiro. Zahar, Rio de Janeiro

Pena J, Lins-De-Barros F (2015) Gestão de Praias Urbanas e Efeitos dos Eventos de Ressaca: Estudo de caso das praias urbanas oceânicas da cidade do Rio de Janeiro. Anais do XI Enanpege

Polette M, Raucci G (2003) Methodological proposal for carrying capacity analysis in sandy beaches: a case study at Central beach of Balneário Camburiú, Santa Catarina, Brazil. J Coast Res 35:94–106

Rosati J, Dean R, Walton T (2013) The modified Bruun Rule extended for landward transport US Army Research. Paper 219

Sharples C (2006) Indicative mapping of tasmanian coastal geomorphic vulnerability to sea-level rise using GIS line map of coastal geomorphic attributes. Consultant Report to Department of Primary Industries & Water, Tasmania

Chapter 14
Analyzing the Impacts of Climate Adaptation Plans in the Amazon Basin: Resilience and Vulnerability for Whom?

V. Miranda Chase

Introduction

Concerns with environmental protection and human wellbeing have populated political discussions for a long time, being in fact broadcasted during international conferences. In 1972 the UN Conference on the Human Environment was the first major international arena where these issues were discussed (Haas and Haas 1995; Ivanova 2010). Years later, the World Commission on Environment and Development (1987) published the famous Brundtland Report with the most widely-accepted definition of sustainable development. Nonetheless, four decades after many of these debates started, and after several conventions protecting environmental and human resources have been signed, the topic of sustainable development remains a wicked problem and one of the greatest challenges humanity has faced. In 2015 during the COP21 conference, another important milestone was achieved in the road towards climate sustainability (Dimitrov 2016). The Paris Agreement was received with great excitement due to its potential to mitigate climate change and advance sustainable development. However, there are many aspects of its implementations that are still unclear (Hoad 2016).

All countries who participated at the conference were encouraged to submit Intended Nationally Determined Contributions (INDCs). These documents outline how each country plans to cope with climate hazards, and what measures will be taken to reduce carbon emissions. The fact that the INDC plans are *intended*, and that the contributions are *nationally* determined, removes several mechanisms that could potentially provide greater levels of enforcement and effectiveness (Robbins 2016). Dimitrov (2016) contends that in order for the negotiations to succeed, it was necessary to allow countries to autonomously determine their contributions, but this

V. Miranda Chase (✉)
Global Governance and Human Security PhD Program, McCormack Graduate School of Policy and Global Studies, University of Massachusetts, Boston, USA
e-mail: Miranda.chase001@umb.edu

W. Leal Filho and L. Esteves de Freitas (eds.), *Climate Change Adaptation in Latin America*, Climate Change Management,
https://doi.org/10.1007/978-3-319-56946-8_14

does not mean that enforcement mechanisms are entirely removed. He emphasizes that "national policies are subject to a robust international transparency system and global reviews" (Dimitrov 2016, 2), which will ultimately encourage countries to set climate goals and maintain commitments. It is certainly desirable for the international community to establish review panels and transparency assessments that can keep track of how each country is progressing towards their determined goals. Review boards will be able to monitor reduction in carbon emissions, and will show how climate funds are being implemented in adaptation projects. However, these mechanisms are not designed to spot problems that emerge as negative side-effects from successfully implemented goals.

This paper argues that it is possible that countries succeed in implementing their INDC plans, and yet those very measures will have negative consequences for some vulnerable groups in their populations. Climate adaptation plans were design with the intent to increase resilience against extreme weather events, but they omit whose resilience these plans serve. The central concern in this analysis is that successful climate adaptation actions might in fact decrease the resilience and be harmful for some groups or sectors. Sustainable development projects (just as any other enterprise) can have spillover effects that cause unintended consequences which can be detrimental to local communities. The main goal of this paper is to assess the adaptation plans presented by the Amazonian countries in their INDCs and to critically identify unintended consequences that can potentially have negative impacts on local populations.

Governments of developing countries are concerned with maintaining the natural resources and supporting local populations without undermining their national economic development. But striking such balance is hard, as it is possible to see for instance in some social groups living in the Amazon. Part of the population is in fact enjoying the benefits of significant economic development, which was achieved through the extraction and export of natural resources that can no longer be used by vulnerable groups (Tinker Salas 2009; IBGE 2010). Poverty is an enduring problem in the Amazon and now it has some added challenges imposed by climate change (O'Brien and Leichenko 2000). The impacts of climate hazards are felt at different levels across all regions in these eight countries (Moret et al. 2016; Kaenzig et al. 2016). Their governments have urged developed countries to contribute with technologies and financial resources to implement the adaptation measures laid out in their INDC plans. But even if enough resources were available to meet the demands, climate adaptation projects will not necessarily improve the lives of local communities in the Amazon basin.

If the implementation of climate adaptation measures is assessed by international panels as indicted by Dimitrov (2016), and if these boards only evaluate reduction of carbon emissions as a proxy for success, reviewers will miss the fact that climate adaptation projects might be detrimental to the human security of particular groups. Thus, a holistic and integrated analysis is necessary in order to inform future review boards about the importance of not defining success based narrowly on a reduction of carbon emissions, but rather consider the extent to which climate adaptation projects will improve the lives of local populations fostering resilience and sustainable development. In other words, climate adaptation projects have uneven impacts which can increase resilience for some groups whilst making others more vulnerable.

In the literature, there is a growing awareness of the importance to consider environmental issues using holistic frameworks (Biermann et al. 2010; Miller et al. 2008; Lenton and Muller 2009). This papers uses the integrated framework of human security to evaluate how the implementation of INDC plans can come at a cost to the human security of local vulnerable populations. It is important to adopt a holistic framework because human security, resiliency and climate vulnerability are complex and multidimensional. An integrated framework yields to a more nuanced analysis, and a better understanding of potential outcomes that are not explicit in the INDC plans. This analytical framework can be replicated to evaluate INDC plans of any country that participated in the COP21 conference. This paper focuses only on the plans submitted by the eight countries in the Amazon basin (Bolivia, Brazil, Colombia, Ecuador, Guyana, Peru, Suriname and Venezuela).

The article is divided in four sections. First an analytical framework is presented, where the concepts of human security, vulnerability and evaluation of climate adaptation plans are discussed. The second section introduces a holistic and integrated analysis of the use of natural resources in the Amazon, showing the connections between human and environmental vulnerabilities. The third part presents the climate adaptation actions pledged by Amazonian countries in their INDC plans, and it evaluates how climate adaptation projects have different impacts on their populations. Lastly, the section with final remarks discusses how this analytical approach can be replicated to other climate adaptation plans in various regions, and what are the benefits of investigating climate change with a human security lens.

Analytical Framework

Human Security

In international policy, "security" has always been something that concerned national states. When considering climate adaptation, it is common to think about how climate change will impact different countries, but it is also important to recognize that climate change will impact people within countries differently. The security of people is different than the security of countries, and climate change will impact people and countries in different ways. The framework of Human Security is helpful to analyze climate adaptation beyond the national level. This framework can uncover vulnerable populations living in countries that will suffer low impacts from climate change, as well as groups living in vulnerable countries who might not be so severely impacted. The foundation document that defines Human Security is the Human Development Report published by the United Nations Development Programme in 1994 (UNDP 1994). In that document, there are seven forms of security that should be granted to every human being: economic security, food security, health security, environmental security, personal security, community security, and political security (UNDP 1994). In order to analyze climate adaptation at the national, regional and individual levels, it is important to consider who are the people that are most vulnerable to climate change with respect to these seven forms of security. If any one of the seven forms of security is missing in someone's life, this compromises their entire human security. Thus, if a climate resilience project aims to increase environmental security without considering community security for instance, local populations will not become more resilient because their human security will be partly compromised.

Vulnerability to Climate Change

There are many indicators that can be used to evaluate how local populations might be vulnerable regarding some aspects of their human security. For instance, health security can be measured with indicators that show child mortality, the ratio of medical staff per population group, longevity, and access to clean water and sanitation. These indicators can be used to point out how vulnerable a population is with regards to particular aspects of their human security (e.g. health security), but they cannot provide a holistic assessment of that population's human security conditions. Thus, in order to evaluate how climate adaptation projects might impact human security as a whole, it is necessary to combine matrixes that indicate vulnerability in multiple areas. This effort has been undertaken by the University of Notre Dame, in partnership with the Global Adaptation Institute in Washington, D. C., who created the ND-GAIN Index. This is a compilation of several public available indexes and datasets that measures a country's vulnerability and readiness to climate change (ND-GAIN Index 2015b).

The ND-GAIN Index uses public data from more than seventy sources and organizations such as the World Bank, FAO, WHO, the World Resources Institute, and other academic datasets organized by universities such as Yale and Columbia, among others. The different data points are then standardized and combined into indicators that show food production, child malnutrition, fresh water withdrawal rates, urban concentration, ecological footprint per capita, levels of environmental protection, air quality, violence, and access to electricity among others. In total there are 9 indicators that measure readiness, and another 36 indicators that measure vulnerability. They encompass considerations about a country's sensitivity to climate change, its exposure, and its capacity to adapt to climate hazards (Fig. 14.1). Every country receives one score for vulnerability and one for readiness varying between 0 and 1, where zero indicates low levels of readiness and/or vulnerability (ND-GAIN Index 2015b). For example, a country's vulnerability score depends on its exposure to sea level rise, its sensitivity regarding populations living on coastal areas, and its capacity to respond to natural disasters such as ocean storm surges.

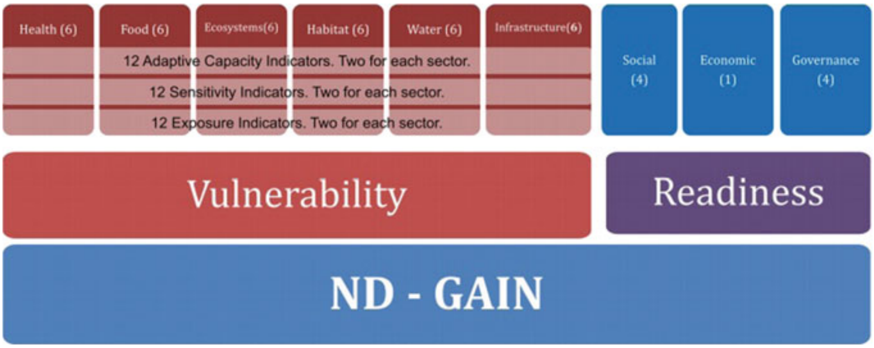


Fig. 14.1 Summary of ND-GAIN vulnerability and readiness indicators (ND-GAIN Index 2015b)

The readiness score depends on a country's ability to organize governance and regulatory mechanisms, innovation and financial resources to adapt to climate change (e.g. providing infrastructure for emergency alerts and evacuation).

Assessing Climate Vulnerability and Human Security in the Amazon Basin

The Amazon basin is crucial for addressing the plight of climate change. This ecosystem is vital for the rain–cloud regime of the atmosphere, and the forest has a significant capacity to store carbon (Barbosa 2015). Millions of people living in the area rely on natural resources for food, building materials, medicinal treatments and cultural practices, and a rich list of other ecosystem services, as defined by Corvalan et al. (2005). Particularly for countries in this region, it would seem to be relatively easy to promote sustainable development because there are plenty natural resources to support a relatively sparse population. However, figuring out an adequate balance between resource extraction and environmental preservation has proven to be puzzling (Barbosa 2015; Fearnside 2016; IPAM 2014). Large development enterprises create jobs, improve infrastructure and bring in financial revenues, but they also pose a significant toll on environmental services. These projects often increase social and environmental vulnerabilities because they carry unintended (yet common) consequences, such as high levels of deforestation, increased rates of prostitution and urban violence (Fearnside 1999, 2016). In order to assess the extent to which development and adaptation projects in the Amazon increase climate resilience, it is necessary to evaluate how these initiatives will impact the human security of local groups.

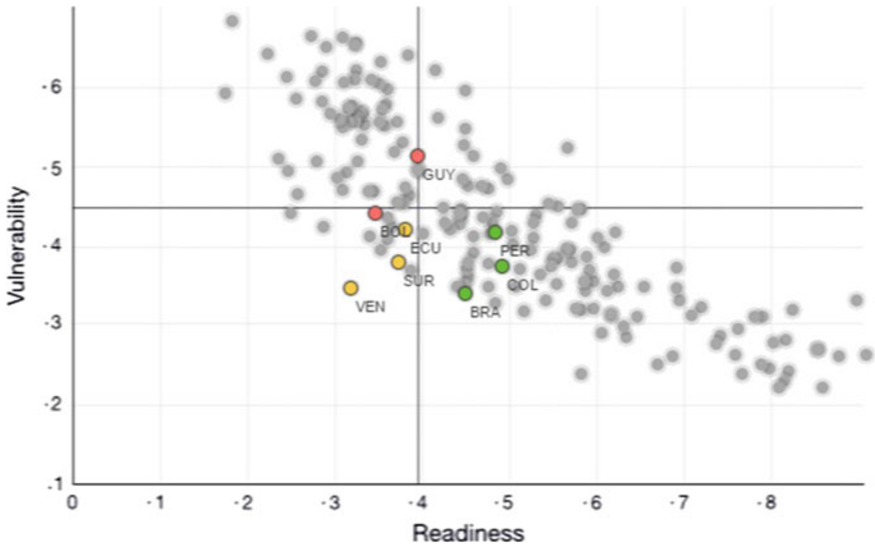


Fig. 14.2 Climate vulnerability and readiness for the Amazonian countries (ND-GAIN Index 2014)

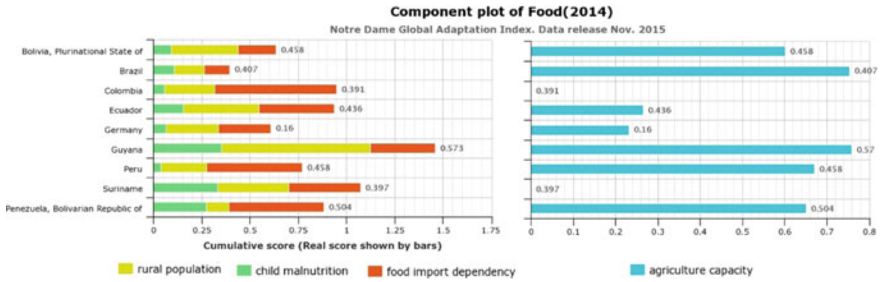


Fig. 14.3 Indicators of food security (ND-GAIN Index 2014)

Figure 14.2 shows where the Amazonian countries rank with regards to vulnerability and readiness to climate change according to the ND-GAIN Index (2014). Guyana is the most vulnerable, followed by Bolivia.

The ND-GAIN Index measures food vulnerability by determining a country's food import dependency, its agricultural capacity, and rates of child malnutrition and rural population (which indicate high dependency on subsistence farming) (ND-GAIN Index 2015a). This paper uses these indicators to evaluate food security (Fig. 14.3). High scores of child malnutrition, rural population and food import dependency, as well as low agricultural capacity indicate greater food insecurity.

The ND-GAIN Index measures environmental vulnerability by determining a country's dependency on natural capital, its ecological footprint and the total area of its protected biomes (ND-GAIN Index 2015a). Here these indicators are used as a

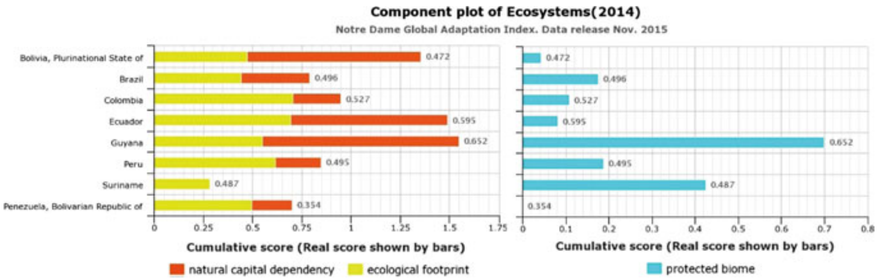


Fig. 14.4 Indicators of environmental security (ND-GAIN Index 2014)

proxy for environmental security (Fig. 14.4). High levels of natural capital dependency and high ecological footprint, as well as low levels of protected biomes indicate greater environmental insecurity.

The ND-GAIN Index measures health vulnerability by determining a country's access to improved sanitation facilities, the ratio of medical staff per population, and the number of people living in slums (which indicates greater health vulnerability due to precarious access to drinking water and safe housing) (ND-GAIN Index 2015a). This paper uses these indicators to assess health security (Fig. 14.5). Low levels of improved sanitation and medical staff combined with high slum population indicate greater health insecurity.

The ND-GAIN Index does not have indicators that measure economic, political, personal or community vulnerabilities (economic, social and governance aspects are measured with readiness indicators which are not the focus of this paper). In order to assess political vulnerabilities, it is more helpful to rely on the Freedom House report "Freedom in the World". Personal and community insecurities are generated by sexual harassment, violence, racial discrimination among others (UNDP 1994), and thus are very hard to be combined in one single indicator. This is, in a sense, the opposite situation with economic security, which can be measured by a host of indicators such as income, employment, standards of living, labor conditions, access to social security and other safety net programs, etc. For these reasons this analysis will focus on general standards of economic, personal and community securities instead of relying on discrete indicators.

Pledges Presented in the INDC Plans by the Amazonian Countries, and Their Impacts on Human Security

Some plans outlined in INDCs are specifically targeted at climate mitigation (i.e. reducing carbon emissions from fossil fuels), or at climate adaptation (e.g. building sea walls to deal with sea level rise). Most projects though meet mitigation and adaptation goals since they reduce carbon emissions and provide more

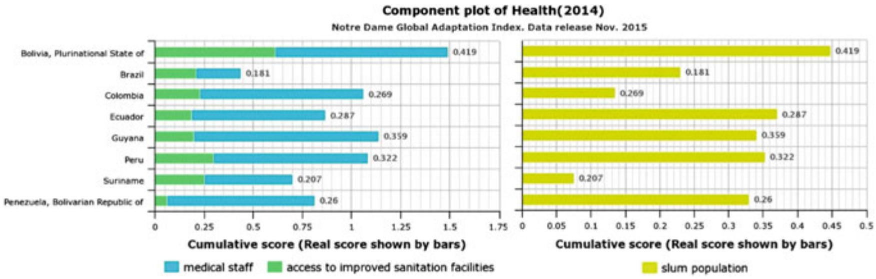


Fig. 14.5 Indicators of health security (ND-GAIN Index 2014)

infrastructure for societies to endure various climate hazards. Dams, for instance, fall into this category because they can produce electricity emitting less carbon and can also be used as water storage facilities for intense droughts. Many INDCs from the Amazonian countries, not surprisingly, emphasize the importance of forestry programs, which also serve mitigation and adaptation purposes. Forests mitigate climate change because they store carbon. They also assist societies adapt to climate change because they house biodiversity stocks which will be increasingly needed to manage environmental services. This sector focuses on mitigation and adaptation projects presented in the INDCs of the Amazonian countries. The focus is less on climate mitigation or adaptation per se, and more on the impacts these projects will have on the human security and resilience of local populations.

Brazil's INDC expresses a clear emphasis on the energy sector. The government has shown several times its pride in the development and production of biofuels (Brazil 2015), in parallel with massive efforts currently being undertaken to expand the production of hydropower (Brazil 2015). As much as it is admirable and encouraged for Brazil to move on with its INDC's pledge to decarbonize the national economy, it is also imperative to consider under what conditions this is being done, and who is being left vulnerable once these projects are implemented. In this regard, the construction of dams is very illustrative. Dams are a double-edge sward with regards to food security, because they can be used as water storage for irrigation, but they also generate negative impacts on the food security of fishing communities living around reservoirs (Winemiller et al. 2016). Furthermore, dams create still water, which become a breeding ground for mosquitos—impacting the health security of surrounding regions (Lenton and Muller 2009). Thus, dams provide electricity and economic benefits for some groups, while harming health and food security of those living in surrounding areas.

Just like hydropower, biofuels can also destabilize regional securities. The conversion of land into large soy and sugarcane plantations for biofuel production in Brazil has had a detrimental impact on biodiversity, and on the country's ecological footprint (Koh and Ghazoul 2008), which threatens environmental security. Declarations on the Brazilian INDC acknowledge the importance of protecting indigenous land and the advantages of creating more protected areas to fight illegal deforestation (Brazil 2015). The document also pledges to achieve zero-deforestation by 2030, by enforcing its Forest Code legislation, and by reforesting degraded areas. This poses a question: who will be managing and living in these protected forest areas? Traditional communities have been guarding the Amazon for centuries, but their ancestral knowledge has been disappearing. This is caused by rapid changes in their lifestyles driven by large development projects. If traditional communities are not valued for their knowledge and for their role in protecting forests, their community security will be threatened in spite of large forest areas being protected. This is true not only for the Brazilian case, but for all other countries in the Amazon basin as well. Colombia is pledging to create another 2.5 million hectares of protected land (Colombia 2015), an enterprise that will also have to incorporate communities already living in territories that will be converted into national parks.

Most significant for the case of Colombia though, is the connection between peace negotiations and climate adaptation. Their civil conflict, which has recently been settled, has costed the lives of many and has also created patterns of forced migration and human dispersal, which have imposed pressures on natural resources (see Fig. 14.4 above on Colombia's sensitivity to natural capital dependency and ecological footprint). The short-term consequence is that Colombia is struggling with the second largest population of Internally Displaced People in the world (Hampton 2014), which indirectly leads to deforestation and further vulnerabilities with regards to food production, sanitation and health care (note in Fig. 14.3 above on Colombia's incredibly low agricultural capacity, and in Fig. 14.5 on its high health insecurity due to low level of medical staff).

The war against the guerrillas had consequences for the population and the environment in Colombia. The civil war has imposed major threats to the personal, community and political securities of its population. The country's INDC clearly expresses peace agreements as a major priority in their fight to mitigate and adapt to climate change. The challenges to address violence and poverty need to be tackled in combination with natural resource management. Their INDC also acknowledges this, and the government has committed to: develop management plans for priority river basins; create information-sharing systems to help farmers with better land-use technologies; and develop integrated and participatory planning policies to support innovative climate adaptation actions in sectors such as transportation, energy, agriculture, housing, health, commerce, tourism and industry (Colombia 2015).

However, there is another aspect of human security that must be taken carefully into consideration by the government when implementing the projects planned in the INDC: gender relations are going to play an important role in rebuilding the Colombian society and in securing sustainable practices of natural resource management. In the literature it has already been widely discussed how women have a crucial role in managing water resources at the household level, in farming subsistence staples, and in using forest products as health medications (Lu et al. 2014; Meinzen-Dick and Nkonya 2007; UNESCO 2006). Given that Colombia's INDC does not explicitly mention the value of women's participation in natural resources management, it is reasonable to consider that their personal security might be jeopardized under the plans the government is promoting in order to adapt to climate change.

Peru is recognized as a "particularly vulnerable" country to climate change (Fraser 2006). This is due to its low-lying coastal zones (Fig. 14.6), which can easily be flooded; to the fact that many areas are arid and semi-arid, which makes them prone to desertification; and above all due to Peru's high dependency on fossil fuels (World Data Atlas 2013). With the vast majority of its population living in urban areas (Fig. 14.6), the energy demand is high and it pushes the government to increase the production of clean energy. Beyond that, the government recognizes that "many economic activities of high economic potential depend on eco-systemic resources" (Peru 2015). Plans to produce clean energy are mostly focused on building hydro dams, which create environmental insecurities as discussed above. Officials are considering to build 15 dams, and there are another 60 locations that are also being evaluated in the region as potential sites for more dams (Aguirre 2016). If, on one hand, hydro energy will decrease carbon emissions, booster industry growth and economic security for urban populations; on the other hand, it is necessary to consider the negative impacts these projects will have on the food and community securities of rural populations.

The INDC presented by the Peruvian government recognizes that "in rural areas and areas inhabited by indigenous people, development is largely based on primary and extractive activities that depend on vulnerable ecosystems" (Peru 2015). The document identifies vulnerable groups as "rural populations [involved with] subsistence family farming and/or weak market linkages, many of them grouped in peasant and indigenous communities; small farmers; artisanal fishermen; native communities; [and] small forest producers" (Peru 2015). It is certainly a good indication that these groups have at least been identified already, but unfortunately very little is being done to empower them. The INDC explicitly says that most climate adaptation planning is being carried at the technical and high political

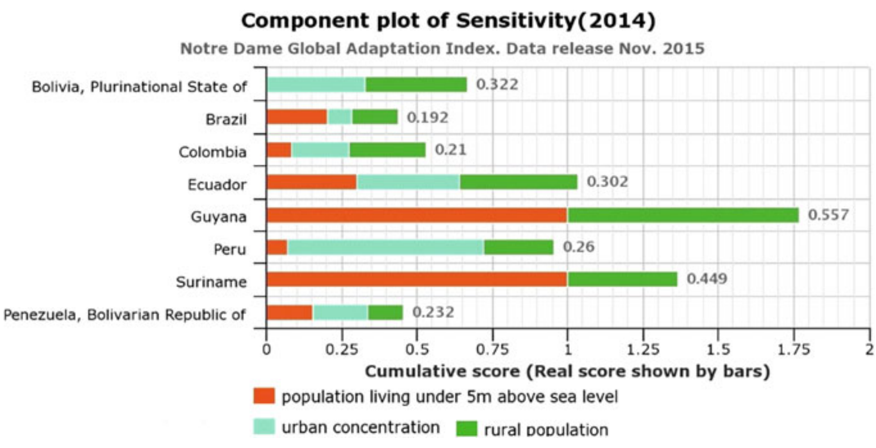


Fig. 14.6 Climate sensitivity to urban concentration and rural population (ND-GAIN Index 2014)

levels, which implies that very little stakeholder engagement is being done. The political security of rural populations is often more fragile than their urban counterparts, given asymmetries in educational levels and access to information. Large development enterprises which are designed for Peru to adapt to climate change, such as building dams, can therefore further compromise the political security of rural populations in several aspects.

Conflicts regarding dams can also be expected in Ecuador, since their INDC has announced that the country "intends to achieve 90% clean energy from hydropower by 2017" (Ecuador 2015). The document does state the goal of recovering 500.000 hectares of degraded land and of converting it into managed forest areas, which will in a sense compensate for the environmental impacts generated by dams. However, the retreat of glaciers forecasted for the region (Vidal 2010) can impose further pressure on water resources. This can cause rivers to be even more vulnerable, since low water flow combined with dams can threaten wildlife and fisheries (Winemiller et al. 2016). The INDC emphasizes that comprehensive risk assessments will be carried in different climate scenarios in order to better plan infrastructure projects for the tourism, energy, water and industry sectors; to create early warning alert systems; and to reduce physical, social and environmental vulnerability nation-wide (Ecuador 2015).

In Ecuador the human right to water is recognized, and water development plans adopt a participatory and basin-wide approach (Ecuador 2015). Integrating water management with land-use and agriculture can assist in mitigating climate change and carbon emissions (Lenton and Muller 2009). Another integrated initiative to reduce carbon emissions is to change cooking facilities, since using wood to cook fosters deforestation and causes health problems (Haigh and Hoffman 2012). In this regard, Ecuador has pledged to distribute 1,500,000 cocking stoves (Ecuador 2015), which will contribute both to climate adaptation and to the health security of a large population. Unfortunately, protecting human rights to water and health security does not guarantee other forms of social empowerment. Ecuador is considered a "partly free" country by the Freedom House, with civil liberties and political rights receiving a score of 3 on a scale of 7–1 (seven being the worst score) (Freedom House 2015). Reduced freedom and political rights hamper political, community and personal securities which also jeopardize climate resilience. This is also the case of Colombia, due to the civil conflict discussed above, as well as the cases of Bolivia and Venezuela. Table 14.1 shows the scores for all countries analyzed here, according to the "Freedom in the World 2015 Report" (Freedom House 2015).

Table 14.1 Freedom, civil liberties and political rights (Freedom House 2015)

	Brazil	Suriname	Peru	Guyana	Ecuador	Bolivia	Colombia	Venezuela
Freedom rating	2.0	2.0	2.5	2.5	3.0	3.0	3.5	5.0
Civil liberties	2.0	2.0	3.0	3.0	3.0	3.0	4.0	5.0
Political rights	2.0	2.0	2.0	2.0	3.0	3.0	3.0	5.0
Overall score	Free	Free	Free	Free	Partly free	Partly free	Partly free	Partly free

Bolivia's INDC blames climate change on the capitalist system, and proposes an International Climate Justice Tribunal, and a Climate Justice Index based on the following indicators: "historical responsibility, ecological footprint, capacity development, and technological capacity" (Bolivia 2015). Even though the country has a relatively small ecological footprint and little historical responsibility, its population has already been impacted by climate hazards, such as "prolonged dry periods and an increase in the frequency and magnitude of floods, flash floods, hailstorms, overflowing rivers, landslides, and frost" (Bolivia 2015). So their INDC proposal addresses these challenges by committing to triplicate water storage capacity, triplicate irrigation surface, duplicate food production from irrigated systems, and to build sewage networks, as well as to eliminate illegal deforestation by 2020 (Bolivia 2015). These actions certainly have the potential to improve food and environmental security for Bolivians. However, the urgency brought by climate adaptation actions might further threaten their political insecurity, given that the government can impose more restrictions on civil contestation under the excuse of securing environmental protection.

The worst case of political insecurity among all countries analyzed here is Venezuela. According to the Freedom House, Venezuela's bad score is due to "the government's repressive response to antigovernment demonstrations, including violence by security forces, the politicized arrests of opposition supporters, and the legal system's failure to protect basic due process rights for all detained Venezuelans" (Freedom House 2015). The Chavez and Maduro administrations do share the responsibility for large carbon emissions, as a result of the economy being so dependent on fossil fuels (Tinker Salas 2009). Nonetheless, the Venezuelan INDC blames the capitalist system for the climate crisis.

Even though the Venezuelan INDC is almost four times longer than the average documents of the other INDC plans analyzed here, it is also the vaguest and most non-committing of all—presenting only bold statements about what the country is already doing in pursuit of eco-socialism. The document lists national policies currently in place, without claiming any new further action in light of the COP21 agreement. National policies aim to increase popular housing programs, public transportation options, and public health; and there are plans to foster the recycling industry with paper mills and wood waste, as well as plans to provide energy to isolated communities using solar and wind systems (Venezuela 2015). All these initiatives were already in place, and the INDC does not present new goals to mitigate or adapt to climate change.

Guyana and Suriname are the only countries in the Amazon that are net carbon-sinks. Suriname has 94% of its territory as forested areas, and in Guyana this figure is 85% (Guyana 2015; Suriname 2015). The INDCs of both countries have emphasized how REDD+ programs can play an important role as a funding mechanism in the conservation of these areas. The economies of these two countries rely heavily on agriculture and mining, activities that put pressure on deforestation. It is certainly plausible that these countries have very low rates of illegal deforestation, and beyond that their governments are also committed to adopt Reduce Impact Logging in their forestry sectors to reduce collateral damage during planned deforestation (Guyana 2015; Suriname 2015). These factors make up for significant environmental security for local forest communities. However, 80% of Suriname's population lives in low-lying coastal zones (Fig. 14.6), above which makes them vulnerable to sea level rise. The population is concentrated in the northeast region, because this is where most of the economic activities are. The national economy is very dependent on gold and bauxite mining (World Bank 2016), and this lack of diversification can have negative consequences on the economic security of the Surinamese people. This can be seen by the high social and income inequalities already present in the country (Slagter 2011).

Guyana and Suriname need to use financial resources to invest in buffer zones to protect their coasts from storm surges. These investments could come from the exports of mining resources, which have problematic consequences for freshwater bodies and economic diversity. Both countries have, nevertheless, committed to increase protected areas and to preserve freshwater resources (Guyana 2015; Suriname 2015). In this scenario, REDD+ programs rise as a promising option to finance climate adaptation infrastructure. These initiatives must be carried with comprehensive engagement of local communities. According to its INDC, "indigenous peoples own and manage some 14% of Guyana's lands" (Guyana 2015), which is certainly a good indication that carbon markets have a potential to succeed and to boost community security for those populations. It is still important to bear in mind, though, that the economic security of local groups becomes more fragile the less diversified it is—so there is a risk in relying heavily on REDD+ programs as well as on mining, and it is imperative to find other forest-based economic options that can diversify income and provide further economic security to these communities.

Vulnerabilities in each sector help identify what areas require priority when governments are designing plans to promote development. In the cases of Suriname and Guyana, for example, it is clear that investments in infrastructure are rather urgent. This problem is further compounded by the fact that these two countries have large portions of their populations living under 5 m above sea level (Fig. 14.6), above which dramatically increases their sensitivity to climate change. Therefore, vulnerability and sensitivity need to be considered with an integrated approach. This can uncover how particular groups inside these countries might be worse-off than others under similar climate hazards.

Conclusions

This paper has analyzed how climate adaptation initiatives planned by governments in the Amazon basin can have uneven impacts on local populations. Some groups might become more resilient to climate hazards after these measures are implemented, whilst others might be left even more vulnerable. In Brazil, Peru and Ecuador the construction of hydro dams will decrease carbon emissions, but rural populations around the dam sites might suffer negative consequences on their food and environmental securities. The paper has also shown how the distribution of impacts can be imbalanced within a group. For instance, the case of Venezuela has shown that local populations might have some aspects of their human security protected by plans described in their INDC (i.e. environmental and food securities are likely to increase); and at the same time the political and personal securities for these same people might be worsened. The main lesson derived from this analysis is the urgent need to evaluate the success of climate adaptation projects not based on a narrow proxy of carbon reduction, but rather to assess such projects with a holistic and integrated framework able to identify possible outcomes that have negative impacts on the human security of local populations.

The governments of Brazil, Peru and Ecuador, pledged in their INDCs to increase the number of hydroelectric power plants as a way to mitigate carbon emissions and adapt to increased droughts. These projects can improve economic security because they generate jobs; but they harm health security (mosquito-vector diseases), environmental security (deforestation and loss of biodiversity) and food security (fishery). The governments of Brazil, Colombia, Ecuador pledged to foster more forestry projects, which can be helpful to store carbon and protect biodiversity (providing environmental security). However, forestry projects will only increase climate resilience for local populations if their traditions and cultural knowledge are respected. Ancient practices can support forestry conservation projects, but these knowledges depend on tight communitarian systems that are currently not valued.

The governments of Colombia, Ecuador, Bolivia and Venezuela offer little and fragile political security to their populations. Civil conflict and social instability impose further stresses on natural resources beyond threats already faced by climate change. In these countries projects that increase environmental security and are implemented without stakeholder participation pose particular challenges to personal and gender securities, because of weak democratic institutions able to safeguard women rights and civil liberties. Populations in Guyana and Suriname enjoy good levels of environmental security, due to well forested areas and high levels of biodiversity. Mining does harm environmental security by contaminating water and soils, but worst of all it fosters economic activities to be centered around this industry. This leads to low levels of economic diversity, which also hampers economic security. The climate actions pledged by these governments such as reduce impact logging and REDD+ maintain environmental security, but do not address social and economic inequalities that are already problematic. Thus, these populations will continue to be vulnerable to climate change, because their resilience depends on greater economic security and not on enhanced environmental protection.

As indicated by the ND-GAIN Index, Guyana and Bolivia are very vulnerable to climate change. This paper has argued that projects presented in their INDCs will not increase their climate resilience because they are not aligned with the aspects of human security that most require attention. Also according to the Index, Ecuador and Suriname are vulnerable in their habitat and ecosystems sectors, which are a factor of high dependency on natural resources and high ecological footprint combined with low infrastructure in dense urban areas (ND-GAIN Index). These conditions create vulnerabilities and human insecurities which need to be addressed by their governments if they are to pursue a genuine effort to increasing climate resilience when implementing their INDCs.

The Human Security framework, paired with independent indicators such as the ND-GAIN Index and the analyses from the Freedom House, are thus a valuable approach to investigate the impacts of climate adaptation projects. This approach can easily be replicated to other countries in order to find out how local groups can become more resilient or more vulnerable to climate adaptation initiatives undertaken by their governments. This integrative and holistic analysis broadens the scope of climate adaptation actions, by considering that impacts will be felt differently depending on each human security aspect that is at stake. Finally, it is important to note that this analytical framework should not be limited by secondary data sources (as it was the case in this paper), and that future enterprises in conducting empirical research can provide a more thorough understanding of how the INDC plans will impact human security on the ground.

References

Aguirre (2016) Peru's energy future. International Rivers. https://www.internationalrivers.org/blogs/233/peru-s-energy-future. Accessed 9 July 2016

Barbosa LC (2015) Guardians of the Brazilian Amazon rainforest: environmental organizations and development. Routledge, London

Biermann F, Betsill MM, Gupta J, Kanie N, Lebel L, Liverman D, Schroeder H, Siebenhüner B, Zondervan R (2010) Earth system governance: a research framework. Int Env Agreem 10 (4):277–298

Bolivia (2015) Intended Nationally Determined Contributions. UNFCCC

Brazil (2015) Intended Nationally Determined Contributions. UNFCCC

Colombia (2015) Intended Nationally Determined Contributions. UNFCCC

Corvalan C, Hales S, McMichael A, Butler C, Sarukhán J (2005) Ecosystems and human well-being: health synthesis in a report of the millennium ecosystem assessment. World Health Organization, Geneva

Dimitrov Radoslav S (2016) The Paris agreement on climate change: behind closed doors. Glob Env Polit 16(3):1–11

Ecuador (2015) Intended Nationally Determined Contributions. UNFCCC

Fearnside PM (1999) Social impacts of Brazil's Tucuruí dam. Environ Manag 24(4):483–495

Fearnside PM (2016) Environmental and social impacts of hydroelectric dams in Brazilian Amazonia: implications for the aluminum industry. World Dev 77:48–65. doi:10.1016/j.worlddev.2015.08.015

Fraser A (2006) The cost of climate change: Peru feels the heat of global warming. Peru Support Group. http://www.perusupportgroup.org.uk/article-174.html. Accessed July 2006

Freedom House (2015) Freedom in the World. In: Puddington A (ed) The annual survey of political rights and civil liberties. Freedom House, USA

Guyana (2015) Intended Nationally Determined Contributions. UNFCCC

Haas PM, Haas EB (1995) Learning to learn: improving international governance. Glob Gov 1 (3):255–284

Haigh N, Hoffman AJ (2012) Hybrid organizations: the next chapter of sustainable business. Org Dyn 41(2):126–134

Hampton J (2014) Internally displaced people: a global survey, 2nd edn. Routledge, USA

Hoad D (2016) The 2015 Paris Climate Agreement: outcomes and their impacts on small island states. Island Stud J 11(1):315–320
IBGE, Instituto Brasileiro de Geografia e Estatistica (2010) Censo Demográfico 1960, 1970, 1980, 1991, 2000 e 2010 edited by Sinopse do Senso Demografico 2010: IBGE
IPAM (2014) Política Tributária Brasileira e sua Pegada Climática: por uma transição rumo à sustentabilidade. Edited by IPAM. Brasil
Ivanova M (2010) UNEP in Global Environmental Governance: Design, Leadership, Location. Glob Environ Polit 10(1):30–59
Kaenzig R, Rebetez M, Serquet G (2016) Climate change adaptation of the tourism sector in the Bolivian Andes. Tour Geograph 18(2):111–128
Koh LP, Ghazoul J (2008) Biofuels, biodiversity, and people: Understanding the conflicts and finding opportunities. Biol Cons 141(10):2450–2460
Lenton R, Muller M (2009) Integrated water resources management in practice: better water management for development. Earthscan, London. http://UQL.eblib.com.au/patron/FullRecord.aspx?p=430026
Lu F, Raeder CO, Crow B (2014) Equitable water governance: future directions in the understanding and analysis of water inequities in the global South. Water Int 39(2):129–142
Meinzen-Dick R, Nkonya L (2007) Understanding legal pluralism in water and land rights: lessons from Africa and Asia. In: Koppen B, Giordano M, Butterworth J (eds) Community-based water law and water resource management reform in developing countries. CAB International, UK
Miller T, Baird T, Littlefield C, Kofinas G, Chapin FS, Charles L (2008) Epistemological pluralism: reorganizing interdisciplinary research. Ecol Soc 13(2):46
Moret P, De Los M, Arauz A, Gobbi M, Barragan A (2016) Climate warming effects in the tropical Andes: first evidence for upslope shifts of Carabidae (Coleoptera) in Ecuador. Insect Conserv Divers 9(4):342–350
ND-GAIN Index (2014) Matrix. http://index.nd-gain.org/matrix. Accessed July 2014
ND-GAIN Index (2015a) Country index technical report. In: Chen C, Noble I, Hellmann J, Coffee J, Murillo M (eds) University of Notre Dame Global Adaptation Index. South Bend, USA
ND-GAIN Index (2015b) Methodology: key definitions. http://index.gain.org/about/methodology#. Accessed Dec 2015
O'Brien KL, Leichenko RM (2000) Double exposure: assessing the impacts of climate change within the context of economic globalization. Glob Environ Change 10(3):221–232
Peru (2015) Intended Nationally Determined Contributions. UNFCCC
Robbins A (2016) How to understand the results of the climate change summit: conference of Parties 21 (COP21) Paris 2015. J Pub Health Policy 37(2):129–132
Slagter Y (2011) The sugar-coated path to economic inequality: a comparative study of Guyana and Suriname, ca. 1600-present. Masters, history: cities, states and citizenship. Utrecht University, Utrecht
Suriname (2015) Intended Nationally Determined Contributions. UNFCCC
Salas MT (2009) The enduring legacy: oil, culture, and society in Venezuela. In: Joseph GM, Rosenberg ES (eds) American Encounters/Global Interactions Durham. Duke University Press Books, US
UNDP, United Nations Development Program (1994) Human development report: new dimensions of human security. Mahbub ul Haq (ed). Oxford, New York, and Toronto, United Nations
UNESCO (2006) Water, women and decision-making. http://www.unesco.org/en/university-twinning-and-networking/access-by-region/arab-states/morocco/unesco-chair-water-women-decision-making-706/. Accessed Apr 2006
Venezuela (2015) Intended Nationally Determined Contributions. UNFCCC
Vidal J (2010) Glacial retreat: Ecuador's ticking environmental timebomb. The Guardian. https://www.theguardian.com/global-development/poverty-matters/2010/sep/22/ecuador-water-climate-change-vidal. Accessed July 2010

Winemiller KO, McIntyre PB, Castello L, Fluet-Chouinard E, Giarrizzo T, Nam S, Baird IG, Darwall W, Lujan NK, Harrison I, Stiassny MLJ, Silvano RAM, Fitzgerald DB, Pelicice FM, Agostinho AA, Gomes LC, Albert JS, Baran E, Petrere M Jr, Zarfl C, Mulligan M, Sullivan JP, Arantes CC, Sousa LM, Koning AA, Hoeinghaus DJ, Sabaj M, Lundberg JG, Armbruster J, Thieme ML, Petry P, Zuanon J, Torrente Vilara G, Snoeks J, Ou C, Rainboth W, Pavanelli CS, Akama A, van Soesbergen A, Sáenz L (2016) Balancing hydropower and biodiversity in the Amazon, Congo, and Mekong. Science 351(6269):128–129

World Bank (2016) Suriname: Country Profile. IBRD/IDA. http://www.worldbank.org/en/country/suriname/overview. Accessed July 2016

World Commission on Environment and Development (1987) Our common future, GH Brundtland (ed). New York United Nations World Commission on Environment and Development

World Data Atlas (2013) Peru: fossil fuel energy consumption. https://knoema.com/atlas/Peru/Fossil-fuel-energy-consumption. Accessed July 2013

Chapter 15
A Successful Early Warning System for Hydroclimatic Extreme Events: The Case of La Paz City Mega Landslide

M. Aparicio-Effen, I. Arana-Pardo, J. Aparicio, M. Ocampo, S. Roque and G.J. Nagy

Introduction

> The effects of climate change are being felt today, and future projections represent an unacceptably high and potentially catastrophic risk to human health. Adaptation measures are already required to adapt to the effects of climate change being experienced today (Haines et al. 2014).

Climate change is one of several direct and indirect factors that affect human life in cities. The urban areas are periodically affected by climate extreme events that are increasing in intensity and frequency (IPCC 2014). The frequency and severity

M. Aparicio-Effen (✉)
Climate Change and Environmental Health Unit (UCCLIMAS),
Facultad de Medicina, Instituto Boliviano
de Biologia de Altura (IBBA), La Paz, Bolivia
e-mail: marilyneffen@gmail.com; marilyneffen@yahoo.com.ar

I. Arana-Pardo
UCCLIMAS, UMSA, La Paz, Bolivia
e-mail: ivar.arana@gmail.com

J. Aparicio
Ecosystem Management, Department of Zoology,
National Natural History Museum, La Paz, Bolivia
e-mail: james.k.aparicio@gmail.com; james.aparicio.e@gmail.com

M. Ocampo
Geographic Information System, Bolivian Fauna Collection, La Paz, Bolivia
e-mail: mauiocampo@gmail.com

S. Roque
UCCLIMAS, UMSA, Facultad de Medicina,
Universidad Mayor de San Andrés, La Paz, Bolivia

W. Leal Filho and L. Esteves de Freitas (eds.), *Climate Change Adaptation in Latin America*, Climate Change Management,
https://doi.org/10.1007/978-3-319-56946-8_15

of extremes inflicting exceptionally high economic and social costs have been linked to climate change. Moreover, there is growing scientific evidence that human action is responsible for warming the atmosphere and oceans, rising sea levels and some climate extremes (IPCC 2012).

Natural disasters are increasing in frequency and intensity. Between 2003 and 2012 there were more than 4000 worldwide; particularly worrying is the much greater incidence of hydrological and meteorological disasters, with a significant increase in hydrological ones. Although fatalities from natural disasters appear to be declining, the number of people affected is increasing (Guha-Sapir et al. 2014). This could be associated not only to the events themselves, but also with both the differential increase in adaptive capacity and exposure.

The need to create the project described in this chapter aroused from the occurrence of an extreme rainfall and mega-landslide event in La Paz city, Bolivia, in February 2002 (Aparicio et al. 2016). Which had a death toll was 63 persons plus 14 missing persons, in addition to losses in housing, public and private transport vehicles, urban infrastructure, and drainage. It also caused soil erosion and affected formal and informal trade. After this disaster La Paz city Autonomous Municipal Government (GAMLP) developed a project to improve the Standing Committee for Municipal Risk Management (SCMRM) which acts through the Special Office for the Integrated Management of Risks (DEGIR). It performs organisational preparedness exercises involving the population, in order to generate a timely response to an adverse event, protect public and private investment and the physical safety of the inhabitants. Accordingly, it has developed the early warning system for heavy rain, floods and landslides (EWS).

La Paz city, which lies in a mountain ecosystem between 3600 and 4000 m above sea level (masl), is experiencing rapid and uncontrolled population growth consisting of informal settlements and slums located on the slopes of the mountains on unstable soils. Extreme events occur within a framework of poverty, socio-economic inequality and climate-induced health inequity, compounded by failures in urban planning, illegal settlements, constraints on basic services and pollution of different environmental systems. The region is prone to soil erosion and the degradation and loss of biodiversity due to prevailing hydro-meteorological patterns, increased frequency and intensity of extreme weather events. La Paz city is at risk of a number of disasters, e.g., landslides, floods and sinkholes, population growth and adverse human activities have increased this vulnerability (Aparicio-Effen et al. 2010, 2016). These problems consist of issues of poor governance, lack of infrastructure and inequity that could increase in the next future.

G.J. Nagy
Environmental Sciences and Global Change, Facultad de Ciencias, Universidad de República, Montevideo, Uruguay
e-mail: gnagy@fcien.edu.uy; gustavo.nagy56@gmail.com

Tackling these issues requires scientific evidence from which to develop, policies, research techniques, tools and methodologies that can be standardised for use in different situations; such as reducing vulnerability and urban inequality, in order to enable socio-environmental systems to adapt and become more resilient.

Despite the continuous development of climate adaptation measures, the existent public adaptation policies and strategies are still insufficient to cope with the severity of impacts reflecting an overall adaptation deficit to climate variability and extremes events in South America (Villamizar et al. 2016; Nagy et al. submitted) in addition to the long-term continuity of adaptation processes (Bo Lim et al. 2005). This socio-environmental condition requires an effective response from the GAMLP through the SCMRM which is responsible for assessing threats, vulnerability and risks facing macro-districts.

The Adaptation Plan called "National Adaptation Bolivian Mechanism" (MNACC) (PNCC 2007) identified current and future vulnerability, encouraging a proactive attitude on the part of national sectorial system and social participation, in order to address climate threats. These elements were used as a basis for the design and implementation of climate adaptation measures focused to achieving urban resilience.

In February 2011 another hydro-climatic extreme event occurred in La Paz, the so-called "mega-landslide" which began on February 24th with cracks in 532 km^2 (26.4%) of urban area, and was followed by the activation of the early warning system (EWS) for the prompt evacuation of inhabitants at risk which prevented the loss of human life (Aparicio-Effen et al. 2016). The main preparedness and response differences with the event of 2002 were: (i) the communication did not fail (in 2002 phone cell lines were impacted), and (ii) the existence of an operational EWS.

Rainfall patterns are apparently changing, with variations in their quantity and frequency, and a greater tendency towards extreme events able to produce over short periods the rainfall that would normally fall over weeks or months, e.g. February 2002 and 2011, the latter during a La Niña event (Aparicio-Effen et al. 2016; Nagy et al. 2016), with serious consequences on the population's morbidity and mortality, leading to increased surface drainage, overflowing water collection systems and lower availability of water resources, since these events can occur during water shortages and droughts.

The work performed by the SCMRM during the mega-landslide of February 2011 led the authors to discuss in this chapter the success of the La Paz city EWS and to propose further VIA assessment focused on risk factors research, a list of adaptation measures to cope with hydro-climatic extreme events, and to improve EWS preparedness. An introduction to this case study was presented by Aparicio-Effen et al. (2016) supported by the South American Climate Vulnerability, Impact and Adaptation Network (CliVIA-Net) initiative (Nagy et al. submitted).

After the introduction the content of the chapter is as follows: the methodology and data used; the description of landslide area and extreme hydro-climatic event characteristics; the landslide risk factors as: the state of biodiversity conservation in the landslide watershed, land coverage and use, water and sanitation in the mega-landslide area; the conceptual framework of urban equity between neighborhoods exposed to same climate extreme event; La Paz city EWS; the hazard, vulnerability and risk maps; the adaptation measures and actions; the summary and conclusions.

The limitations of the work and constraints of the paper are as follows:

- Climate scenarios and the occurrence of La Niña are not enough to have a good forecast of extreme events (Aparicio-Effen et al. 2016) but serve for preparedness of the EWS.
- The lack of updated building regulations based on the knowledge of landslide risks, populations' exposure, and the experience described in this paper.
- The success of the EWS could make it difficult to incorporate further adaptation measures to fill the adaptation deficit to cope with extreme hydro-climatic events.

Methodological Approach and Data Used

An interdisciplinary investigative approach was used to analyse climate-related risk factors and science-based (both natural and social) adaptation which focused on the experience of the EWS performance to prevent human life loses, draw valuable and useful findings for decision-making, and monitoring and evaluation of climate adaptation.

A quantitative multi-phase approach was followed (including the assessment of bio-physical, socio-economic and health factors) to analyse a mega-landslide that occurred from 26 to 28 February 2011. A retrospective study was carried out for climatic time-series analysis, water supply, social, demographic and epidemiological variables in order to perform a comprehensive assessment of the human impacts. Thirty-year time-series of monthly temperature and rainfall variables were compiled for two weather stations, Laikakota and San Calixto. The San Calixto weather station data were used for total precipitation, maximum daily precipitation (representative of maximum concentration), and the number of rainy days, as well as for daily temperature maximum and temperature minimum.

Other analysed landslide risk factor variables were as follows: (i) conservation state of watershed head, (ii) coverage and use of ground, (iii) climate extreme events, (iv) water and sanitation in the area of the mega-landslide, and (v) social variables (education and access to health services). Each one was studied using specific methodology before being compiled and comprehensively analysed in terms of their impact on human vulnerability, such as literature review, meetings with municipal government, national and local organisations, and partner organisations working in the areas of climate change, extreme events and water and sanitation, e.g. PAHO/WHO, UNICEF, GTZ.

The authors made a compilation of demographic and socioeconomic information and analysis (National Institute of Statistics-INE), weather and climate data from National Meteorological and Hydrological National Directorate (SENAMHI 2015), municipal statistics (GAMLP 2011), and epidemiological statistics (La Paz Departmental Health Department (SEDES).

To analyse the State of Biodiversity Conservation in the landslide watershed an exhaustive literature review was carried out and biodiversity samples were lifted, applying standard biological methods for the study of wild flora and fauna (Burnham et al. 1980). The survey began in the highest part of the basin (Ajuan Khota dam) descending to the urban area of Bolognia in an altitudinal transect. It was followed by preparation of maps and images using remote sensing images and geographic information system (GIS) to identify epidemiological risk for human settlements, epidemiological methods and multivariate analysis.

The Urban Health Equity Assessment and Response Tool ("Urban HEART") methodology (WHO 2010) was applied to assess equity, adjusting it to the effects of climate change and variability, in particular to mega-landslides (Aparicio Effen et al. 2016). This research used relevant Municipal databases from 2011 (GAMLP 2011), governance, social and environmental data. The knowledge, attitudes and practices (KAP) surveys (Handicap International 2009) were carried out among a sample of affected families and of a control area (Alto Irpavi neighborhood).

A risk map for 2011 was developed by the GAMLP which combines the vulnerability and hazard maps, obtaining specific geographical areas in which there is a risk of damage due to extreme events based on topography, geology, active geological faults, geo-mechanical characteristics of the soil, and also envisages the potential social, political or economic impact. It determines the probability of each system to be affected facilitating to plan adequate protective measures, to regulate the use of the different geographical areas (depending on the level of risk), and to govern land-use so as to ensure sustainability over time. The landslide-prone areas were assessed by expert judgment of risk-factors of soil instability and landslide risk for building purpose as follows: high soil humidity saturation (40%), the slope (30%), the geomorphology (20%) and geotechnical factors (10%) to the landslide risk which is expressed in the following hazard Eq. (15.1):

$$\text{Hazard} = (\text{Geology} * 0.4) + (\text{Slope} * 0.3) + (\text{Geomorphology} * 0.2) + (\text{Geothechnics} * 0.1) \tag{15.1}$$

Based upon all the above sources of information and tools, participatory methods for climate VIA assessment (Bizikova et al. 2008; Droesch et al. 2008; UNEP 2009; Nagy et al. 2014), as well as EcoHealth (2014) and KAP surveys, as adapted by Aparicio-Effen et al. (2014, 2016) for human well-being and health, were used to propose, select and prioritise a wide range of adaptation measures to address extreme events, climate change and variability.

The participatory methodological approach is based on the following concepts and steps (modified from Nagy et al. 2014) to include human well-being and health according to Aparicio et al. (2014, 2016):

- The application of scientific knowledge on VIA assessment and climatic trends.
- The assessment of the existing capacity and its strengthening allows prioritising measures and identifies windows of opportunity for carrying out the process.
- The elaboration of institutional agreements at several levels.

- The assessment of human well-being and health vulnerability and impact at affected families' camps.
- Semi-structured and in depth interviews with selected identified EWS managers, practitioners and institutional stakeholders (DEGIR, GAMLP, INA, SCMRM SEDES, SENAMHI), experts (La Paz University-UMSA, CliVIA-Net).
- Analysis of adaptation literature review by the authors of the chapter.
- Focus groups meetings and workshops with stakeholders where a multiple question matrix based on the Vulnerability Reduction Assessment (VRA)-UNDP and UNEP guidelines was developed. The matrix included the numerical assessment (scale 1–5) of climatic stressors, threats, harms, obstacles, and supportive factors to implementing adaptation, and written comments.
- A dialogue between natural and social scientists and attendants was held at each step.

The measures were prioritised based on categorisation according to whether they are institutional (I), social (S) and technical capacities (T), and whether they are high-priority (HP), i.e. to be implemented in the short term; medium-priority (MP) or low-priority (LP), i.e. to be implemented in the medium or long-term respectively, for decision-making, management, public policy, institution and La Paz city inhabitants.

Landslide Description Area and Climate Extreme Event Characteristics

The Landslide

The city of La Paz is situated 16°29′ Latitude South, 68°8′ longitude West, at an average altitude of 3640 masl. La Paz is very complex in terms of its geological and geotechnical setting, and steep topography. Up to 35% of the urban area consists of steep terrain on a gradient of more than 50% with high potential instability, which hampers the provision of basic services and generates high urbanisation costs. The southern part of the city is very hilly, the slope is moderate (a gradient between 10 and 49%) in 28% of the land, located in transitional zones between the terraces and steep slopes and consisting of alluvial fans; these areas are now urbanised. The remaining 37% of the land is gently sloping (a gradient of less than 10%), corresponding to the southerly neighbourhoods of Obrajes, Irpavi and Achumani, which are prone to flooding. The urban population of La Paz and El Alto is 1,476,412 which represent 18.94% of the total national population. It has a growth rate of 2.84%/year and an average of 3.9 persons per household.

Influence of Precipitation

One of the causes of the mega-landslide in February 2011 identified by both the inhabitants during the meetings and by the SCMRM was the heavy rainfall. This led the authors to analyse the time-series of total precipitation, maximum daily precipitation (representative of maximum concentration) and the number of rainy days at the San Calixto Observatory from 1919 to 2011 (Figs. 15.1 and 15.2).

February 2011 was the sixth most rainy month of February, with the highest number of rainy days (25), since 1919, and the second most rainy over the last 30 years (157 mm/month), reaching 39.2 mm on 25 February 2011, a day before the mega-landslide. These figures are able to cause flooding and riverbank erosion (Chow 1994, 2004) in addition to non-controlled sewage emissions and upwelling of subterranean water, which saturate the soil, lubricate the slope, and overload it hydraulically, increasing the probability of landslide disaster.

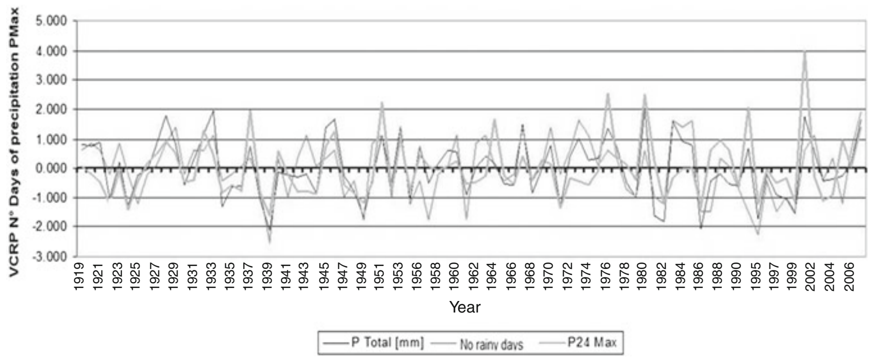


Fig. 15.1 Number of rainy days (*black line*), compared with total precipitation (*dashed line*) and rainfall maximum 24 hours (*grey line*)

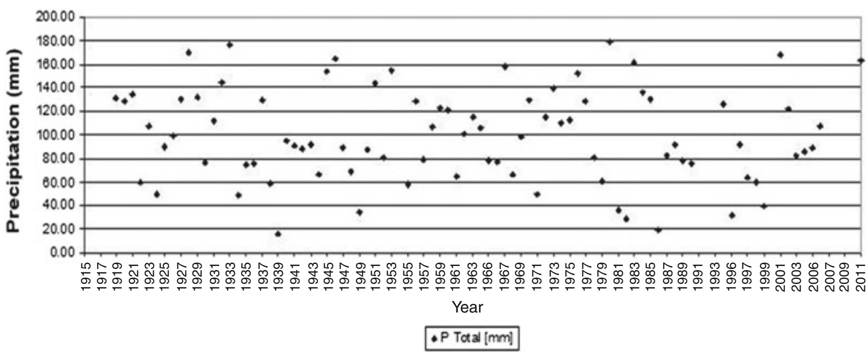


Fig. 15.2 Total past precipitation (for February). Elaborated by the authors from SENAMHI data base

The mega landslide of February 2011 coincided with a moderate to strong La Niña event (CIIFEN 2011). The Intergovernmental Panel on Climate Change suggests some degree of correlation of the tendency of global warming to exacerbate extreme events throughout the world (IPCC 2012, 2014), a factor, which could explain this behaviour as a result of Climate Change. The perception of the inhabitants of the Altiplano was that in recent years the rainy season had become shorter and more concentrated (PNCC 2007), which would provide ideal conditions for the erosion of river beds and slopes.

Landslide Risk Factors

In this section the authors present the state of biodiversity conservation in the land-slide basin, land coverage and use of urban soil, water and sanitation in the area of the mega-landslide.

The State of Biodiversity Conservation in the Landslide

Considering that ecosystem services contribute to human health in multiple ways and can act as buffers, increasing the resilience of natural and human systems to climate change impacts and disasters, an integral assessment of the State of Biodiversity Conservation in the landslide basin of the Irpavi-Callapa river was developed based on biological criteria and its impact on the availability of water resources for local inhabitants, and on biodiversity.

Changes in climate place considerable additional pressure on land ecosystems that have already been affected by human pollution, greenhouse gas emissions, over-exploitation of natural resources, the fragmentation of habitats, and the survival of many species and ecosystems endangered by global warming, changes in humidity or general instability (IPCC 2002; Llorente et al. 2004). These pressures introduce changes in the ecosystem's structure and function (decomposition, nutrient cycle, water flow, composition and interaction of species) and of their distribution in landscapes, with an indirect effect on the population of plants and animals (IPCC 2002; Llorente et al. 2004). Water condensation is closely linked to the state of conservation of woodland in upper basins.

The La Paz valley was formed through the heavy erosion of the Altiplano formations, with debris being carried down to the Amazon basin. The valleys developed their own individual characteristics as the Cordillera Real underwent two strong glacial periods. The valley runs from north to south, with drainage towards the Amazon basin and a marked difference in altitude from 4000 m amsl at the basin headwaters, to 2600 m near the La Paz river. These differences create various natural environments, which determine the varied structure of the vegetations and of the various ecosystem components (Lorini 1991). Zones of potential vegetation are the northern Prepuna, high dry inter-Andean valleys of the upper river Beni basin, and sub-humid–northern humid Puna. The variations in altitude, the different slope gradients, varying exposure of the sides of the valley to the sun, the direction of winds, available humidity and the variable temperatures create various microclimates in the basin, which account for the varied vegetation in this region (Lorini 1991).

The area of Callapa-Irpavi is found in the upper part of the La Paz river basin. Wasson and Barrere (1999) identify two water eco-regions, the glacial Cordillera, above 3400 m, with mountains rising above 5000 m, which result in permanent snow cover being a fundamental factor in the regulation of the rivers' water cycle and the dry valleys, where basins are protected by the axis of the glacial Cordillera and the humid mountains. The gradient of the mountainsides, the highly erodible rocks and the dry climate vegetation contribute to the high erosion levels in these valleys.

Upper Basin (Area of Hampaturi "4203 m"–Ajuankhota "4429 m")

This area is situated on the High-Andean shelf and in the upper Puna (Beck and García 1991) over 4200 m and up to 4500–5000 masl, over periglacial sediments in the highest places (>4500 m) and glacial/interglacial deposits lower down (Calvario formation). A large part of the area above 4500 m is covered by bare ground. Vegetation includes low grasses (very low grasses with plants at ground-level). The vegetation in the lowest regions (4200–4400 m) includes grasslands. Bushes and low grasses also grow here (in rosettes at ground level), often related to larger plants. Below this altitude, vegetation looks drier. At around 3900–4000 m the vegetation contains an increasing number of bushes and a great abundance of grasses. A large number of pre-Columbian terraces can be found at these altitudes and further down. They are still in use today alongside large human settlements, bringing about considerable changes in the natural vegetation. Pine trees, eucalyptus, cypresses and brooms are some of the non-native woody species here, along with smaller plants related to farming.

The Chicani area is located lower down the basin, containing the Irpavi, Chicani and Chinchaya terraces. These are in the highest parts of the dry valley and on the Puna (Beck and García 1991). Below 4000 m, vegetation appears to be drier and below this point bushes are increasingly frequent, along with a great abundance of grasses.

The Mid Basin Area

The Chicani Hill is found halfway up the basin at approximately 3550–3600 masl and is characterised by strong gully erosion (cliffs). There are large urbanised areas on its northern slope, where vegetation is practically non-existent. There are a number of small slopes that create ponds and flooded ditches that are home to

Pleurodema cinereum frogs, which are widely spread in the lower La Paz valley, especially in the rainy season (Fig. 15.3).

The Lower Basin Area

The lower basin contains the Bolognia forest, which lies over a substrate of the heavily urbanised La Paz/Purapurani area, containing remains of open Pinus radiata (pine) forest and examples of other non-native species such as acacias, cypresses and brooms. Some areas are dominated by Stipa ichu tall grasses intermingled with native bushes, which appear as patches on the landscape. The northern slope is home to dry valley or mesothermal species (Beck and García 1991). The basin, in particular the headwaters (area of *Hampaturi and Ajuankhota*), provides an important service for the ecosystem by providing water for the southern region of La Paz. A large number of flora and fauna species have been identified in the basin, including indigenous regional species and introduced or migrant species. The Irpavi-Callapa basin is affected by a number of human activities: agriculture and livestock, urbanisation and the construction of major damn projects. However, a number of areas still preserve their vegetation (both native and introduced species), which supports the native biota of these high-Andean environments. Other semi-natural ecosystems protect the basin from landslides and continue to enable water collection for the city of La Paz.

Land coverage and use of urban soil

Part of the upper basin was analysed in order to identify any significant change in the land coverage and use that might have affected or provided the exposure conditions for the extreme event. Two Landsat 7 (001–071) satellite images were used (www.landcover.org and http://glovis.usgs.gov/) for the months of July 1999 and August 2010 to analyse the land coverage change and use within the basin of the disaster area. The study area was identified and a surface of 10,000 km^2 was defined (Fig. 15.4), using a 90 m resolution digital elevation model (DEM).

Once the area of the basin had been outlined, a classification analysis was carried out for each of the Landsat 7 satellite images (1999 and 2010). The classification of

Fig. 15.3 River Callapa (*left*) and dry vegetation found in Irpavi basin cliff areas (*right*) (Photographs J. Aparicio)

coverage followed the classifications proposed by the Map of Coverage and Actual Usage of the Soil 2010 (preliminary version), provided by the Ministry of Rural Development and Land Vice-Ministry of Land. This analysis indicates two layers of land coverage and use (Fig. 15.5).

These two classifications were used to calculate the areas (km^2) in each of the categories presented in Table 16.1 for 1999 and 2010. To avoid any mistake that might be caused by seasonality (dry or wet season), the two analysed satellite images were taken during the same season.

A decrease in area was observed from 1999 to 2010 in "snow fields" and "water bodies" of 3.33 and 1.13 km^2 respectively, which could be related to annual seasonal changes and/or to an increase in evaporation due to higher temperatures. The human elements, e.g. "farming" and "urban structures" increased by 0.37 and 12.25 km^2 respectively, with farming areas growing to thirteen times their area and urban structures growing to 2.4 times their area. The areas of "Scrubland" and "Scrubland with bushes" decreased by 50%, probably as a result of the growth in the urban area,

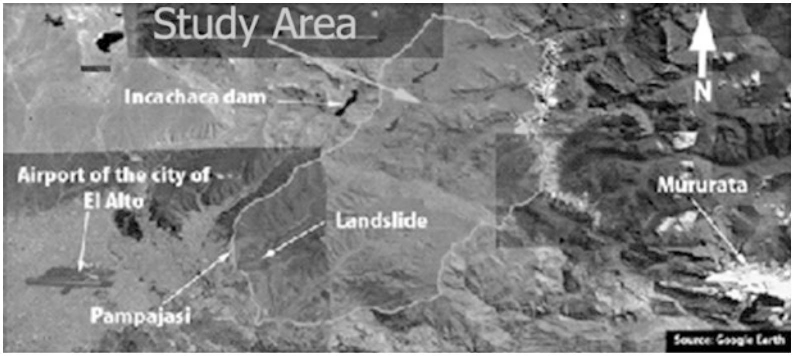


Fig. 15.4 Study area outlined by the limits of the basin. The *red* area shows the landslide area

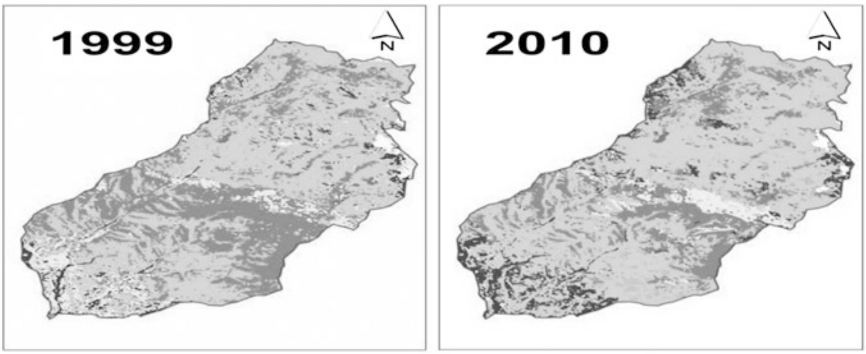


Fig. 15.5 Land coverage and use in 1999 (*left*) and 2010 (*right*)

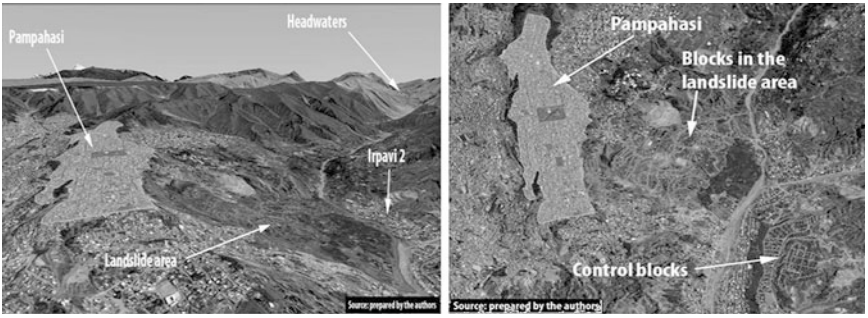


Fig. 15.6 North-easterly view of the landslide area and of the Pampahasi district from a height of 4.17 km (A, in *light grey*) View of the landslide and Irpavi area (B, in *dark grey*)

given that the "Scrubland" lost a significant area to the landslide. Half-way up the basin, "Scrubland" increased but not in proportion to losses, while the "Scrubland and bushes" areas decreased drastically and were replaced by "Scrubland" and "Scattered Vegetation", which may be developing as a result of the loss of vegetation clusters. Lastly, the growth in the area of "Forest Plantations" to almost double the size could be a result of urbanisation, where clusters of eucalyptus or pine trees are planted for their benefits. Alternatively, this could be the result of an error in the interpretation of the model, since the shadows of ravines in the images could be interpreted as "Forest plantations", due to the similarity in their respective reflectivity. The analysis of the direction of water drainage in the landslide area shows that the upper basin had little influence on water levels, since most of the water came from Pampahasi, and flowed at the top of the landslide area from west to east.

The landslide occurred on the Eastern slope in the north of the city of La Paz. Given its characteristics, the Municipal Government had already listed it as a risk area, but did not prevent people from settling there (Aparicio-Effen et al. 2016). To analyse this situation, the built-up section of the landslide area was assessed by comparing constructions at 8-year intervals. To that end, digital images of the blocks of buildings were digitalised with images obtained from Google Earth. The areas were overlapped and shapefiles were used to incorporate the calculation of the area of the blocks. The same method was used to calculate the built-up area on the opposite slope, where the Alto Irpavi district is located, to carry out a comparison and analyse the difference and similarities (Fig. 15.6).

The built-up areas (houses) had almost doubled (1.8 times) in 8 years. This means that the area built in landslide area was of 74,945 m^2 in 2003 and 137,953 m^2 in 2011. The built-up area in Irpavi—selected as the test area being located in the same basin and opposite the landslide area (Aparicio-Effen et al. 2016) has a construction area of 71,983 m^2, slightly less than the area of Callapa in 2003 (Fig. 15.6). In order to analyse the density of the landslide area, the total area of the collapsed blocks (843,267 m^2) was compared with the built-up area (137,953 m^2), which indicated a density of 0.16 m^2 of buildings per m^2 of blocks.

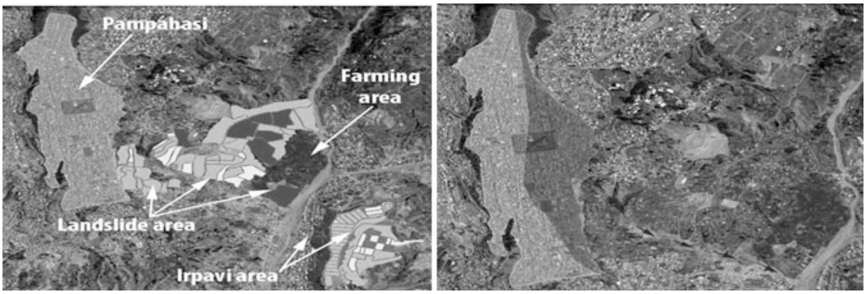


Fig. 15.7 Classification of blocks by construction area (*Left*) Water drainage from Pampahasi to the landslide slope (*Right*). a) small (*light grey*), b) regular. The *dark grey* area is the landslide area receiving water from Pampahasi (in *grey*); the arrows follow the river (in *light grey*), c) medium (*grey*), d) large construction area (in *white*). Irpavi control quarter (*light grey*)

The density of the Irpavi area is of 0.20 m^2 of buildings per m^2 of block, which indicates a greater building load in Irpavi than in the landslide area

The classification of the blocks of building with the largest or smallest built-up areas identified the areas of greatest pressure. Blocks were classified under (a) small built-up area (<500 m^2), (b) regular built-up area (between 500 and 1000 m^2), (c) medium built-up area (between1000 and 5000 m^2), and (d) large built-up area (>5000 m^2). Figure 15.7a shows that the largest proportion of the category "(d) large built-up area", was concentrated in the middle of the area of the landslide in large blocks of buildings. This category was not found in the Irpavi area.

The lower part of the landslide had a large crop area (256,215 m^2) which was sown, consequently the soil was constantly disturbed and irrigated, hence not providing adequate support to the urbanised area higher-up. In comparison, the lower part of Irpavi is well settled with houses and embankments. Lastly, the water running from the district of Pampahasi contributed to the irrigation of the upper part of the area that collapsed due to water drainage. Using the basin model, the drainage area of water running from Pampahasi to the slope where the landslide occurred was calculated at 429,490 m^2 (Fig. 15.7b). This river was not channelled and, according to the inhabitants, its bed was full of solid debris, which could have contributed to the underground infiltration of the water in this area.

Water and Sanitation Services Access Around Landslide Area

The water supply to the landslide area comes from the Pampahasi treatment plant, the sources of which are the Hampaturi and Incachaca basins. It draws on three large-capacity reservoirs, Incachaca, Hampaturi and Ajuankhota, as well as other smaller reservoirs. However, there were also a number of watercourses directed to private individuals and communities. The extreme event damaged a large capacity pipe that provided water to the whole southern area, which was not repaired until three months later due to the scale of the damage.

The knowledge, attitude and practice (KAP) surveys carried out among the persons affected by the mega-landslide showed that 92% benefitted from the municipal waste collection service, 85% of the families had drinking water in their houses, and only 69% had drains at home. Fifty one per cent of the population interviewed had noticed infiltrations in the affected districts over the last 4–7 years, these being only noticeable in the rainy season (90% increase). This had been attributed to the presence of drinking water reservoirs belonging to the company EPSAS.

Of the persons affected, 40% indicated that they did not perceive any decrease in water availability due to climate change, while 30% said that water availability had decreased, 15% pointed to a loss of water sources and 12% referred to increased disease due to global warming. The microbiological water quality of the rivers near the mega-landslide area showed that the sanitary level of the water (from the Jillusaya river) was extremely low, so that the water from the river Jillusaya and its continuation, the Achumani and Irpavi rivers (studied area) were unfit for human consumption and farming (in the case of vegetables) in particular (Flores et al. 2010).

The districts affected by the landslide were poorly served by sanitation facilities which were in any case substandard due to lack of maintenance, therefore uncontrolled sanitary discharges and groundwater outflows might have contributed to the landslide. This was noted by people who were affected by the event.

Urban Equity Assessment in the Area of the Mega-Landslide and in Its Control Area

The Urban Health Equity Assessment and Response Tool (WHO 2010) methodology was applied to assess equity, adjusting it to the effects of climate change, environmental and health determinants, and to mega-landslides based on municipal statistics from 2011 (GAMLP 2011; Aparico-Effen et al. 2016). KAP surveys were carried out among 200 affected families from San Antonio, Sur and Hampaturi macrodistricts and among a representative number of families in the control area (Alto Irpavi). An equity assessment was carried out for the landslide area (9 macro-districts) and it was compared with the opposite slope, in the Alto Irpavi district. Both the landslide area and the control area are found in the same basin and were exposed to the same extreme precipitation event as well as to same governance determinants but with different results. A brief summary of results presented by Aparicio-Effen et al. (2016) is as follows:

- In the affected districts, 50% of the houses were built with bricks (mostly in the Sur macro-district) compared to the other two macro-districts, which used “adobe” and “adobe with brick”, explaining their fragility and their unsuitability in a “very high risk” area.

- About 60% of houses affected by the mega-landslide were "house/shacks". The households in the control district (Alto Irpavi) were often of better quality and their average income was significantly higher.

These results show that the districts where the mega-landslide occurred were in an inequitable situation compared to the control area, due to the higher quantity of cases requiring improvement. In general, the Irpavi-Callapa drainage basin is affected by anthropogenic processes (farming, urbanisation in a number of districts including the construction of large-scale water-retaining dams).

La Paz City Early Warning System: An Adaptation Measure to Hydro-Climatic Extremes

EWS Development

Due to the extreme hydro-climatic event in February 2002, when 63 persons died and 14 people was missing, in addition to 4 million dollars of losses in public and private infrastructure, transport, formal and informal trade, urban infrastructure and landscape services, e.g. surface drainage, soil stabilisation and control of gullies, La Paz municipality risk-management was improved, acting through the Special Office for the Integrated Management of Risks (DEGIR), whereas an Early Warning Operations Centre (EWOC) was created.

The alerts generated and issued by EWOC allow for coordination with authorities and emergency response personnel. The EWS for heavy rain, floods and landslides consists of permanent monitoring systems using rain gauges, radar measurement of rivers water levels, weather stations, video surveillance cameras and a weather radar local area. The equipment generates real-time wind direction speed information, the approach or formation of humid air masses that could cause heavy rain or hail and changes in river levels and other useful data. It performs organisational preparedness exercises involving the population, national police, La Paz Fireman Unit in order to generate a timely response to an adverse event, protect public and private investment, and the physical safety of La Paz inhabitants.

La Paz Early Warning System (EWS) Components

Geodynamic Monitoring

Geodynamic Monitoring through GPS satellite tracks the movement of land in La Paz municipality areas, classifying it as being at high or moderate risk of landslides. The objective of this component is to monitor soil in areas vulnerable to landslides and provide early warning of a likely event. According to the monitoring, DEGIR carries out prevention work in susceptible areas. It uses a variety of techniques including demolition, the main concern being to reduce risk and minimise population danger. The municipality has been divided up and 39 landslide-susceptible areas have been identified, one of which has already suffered a landslide (Pampahasi Central Bajo-Callapa). Surveillance in this area should therefore be stepped up, incorporating advanced techniques.

Technical and Scientific Support

The technical and scientific support facility has a laboratory for analysing cements, soils and water quality. This is a strategic component of EWS which helps to detect possible adverse events, provide data for project development and monitors project quality. The information processing system provides real data to operative emergency teams, to generate a timely response to an adverse event, protect the physical safety of La Paz inhabitants preventing human loss.

Hydro-Meteorological Monitoring

The EWS hydro-meteorological monitoring facility is aimed at generating information in real-time regarding the status of 36 weather stations located in La Paz drainage basin prior to hydrological events. The monitoring responses allows updating hazard, vulnerability and risk maps to incorporate all the threats and vulnerabilities, given the dynamic nature of the risks involved.

EWS Tools

Risk assessment relied on the reinforcement of tools previously developed by the La Paz municipal authorities, taking into account the following maps:

Hazard Maps

The hazard map of La Paz (Fig. 15.8) incorporates endogenous and exogenous geodynamic processes (only the latter are taken into account here); it incorporates large-scale movements, e.g. landslides, flooding and hydrological analysis of the drainage network. The 1:1000 scale geological map of the valley of La Paz was used to draw a geomorphologic and geotechnical map on the same scale. A 10 m pixel digital elevation model was used to draw a slope map. The geological, geomorphological and geotechnical maps were rasterised from the base vector, using a 10 m pixel. The hazard from large-scale soil movements was evaluated using Eq. (15.1) where hazard was weighted on a 1–5 scale, where 1: very low, 2: low, 3: moderate, 4: major and 5: very major hazard.

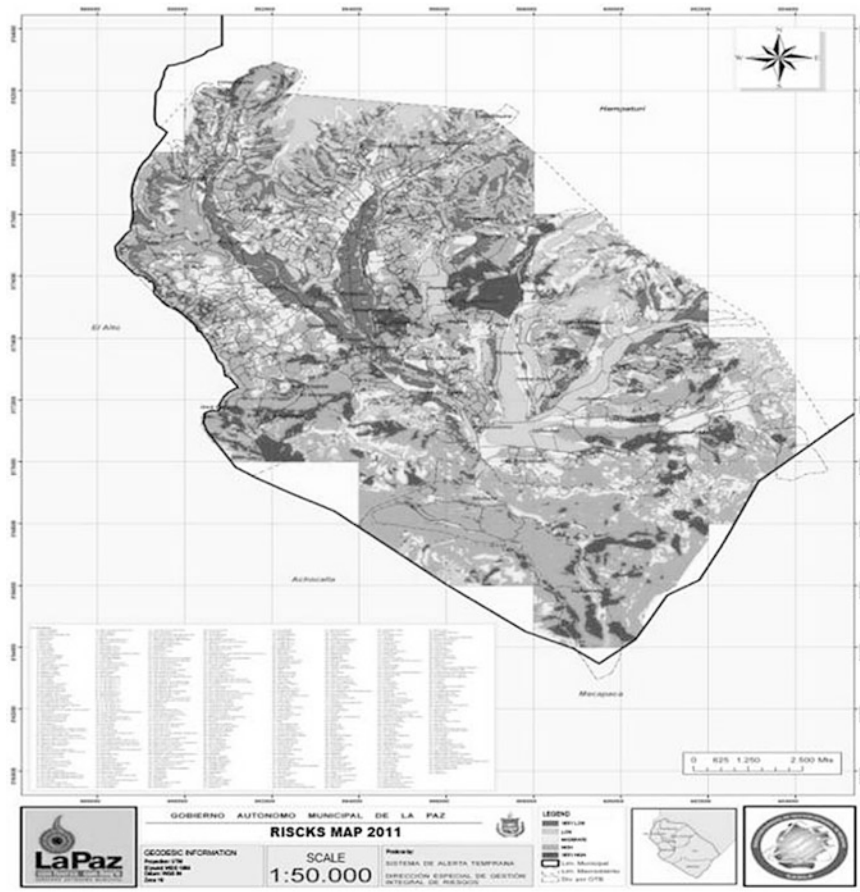


Fig. 15.8 La Paz Hazard map 2011. *Source:* DEGIR 2011

Vulnerability Map

Urban vulnerability is determined by a complex relationship including multiple factors where the level of exposure depends on the sum of economic, political, social, demographic, migratory and cultural elements. These are compounded by unplanned expansion of the city and result in increased population exposure. With these considerations in mind, two analytical approaches were adopted: direct mapping of variables and qualitative mapping (both of which are applied in combination). Direct mapping involved transposition of the INE tables and specialisation of the variables weighted by experts (expert judgment in risk analysis). The most vulnerable macro-districts in La Paz and the factors examined are shown in Table 16.2.

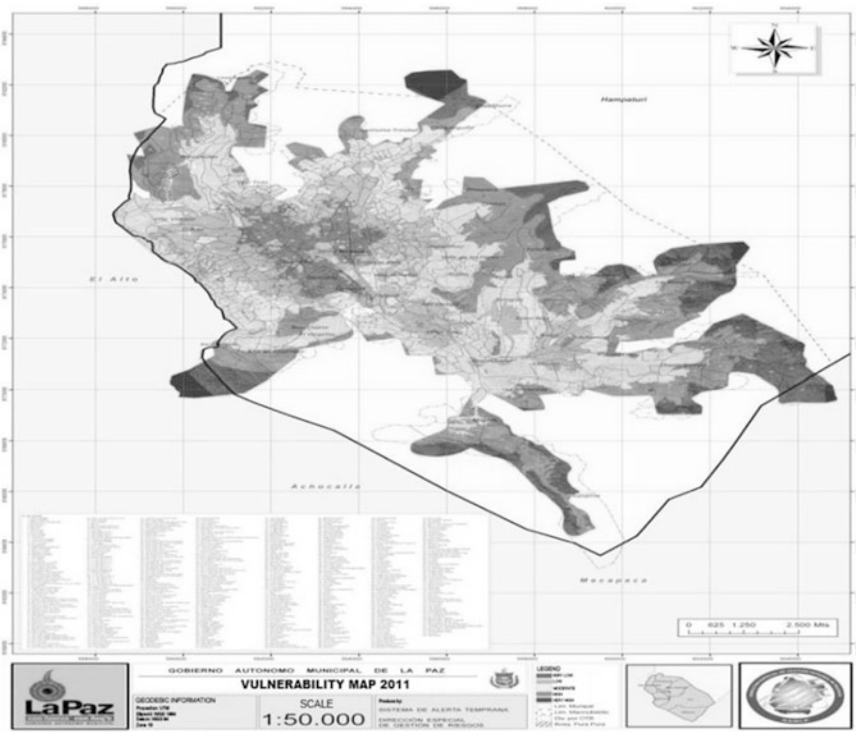


Fig. 15.9 La Paz Vulnerability Map 2011. *Source:* DEGIR

Index of Reclassified Socioeconomic Vulnerability

On the basis of the vulnerability map the values were reclassified into five categories to make it easier to visualise the levels of vulnerability (Fig. 15.9). According to this index the city was classified as follows: moderate: 34.9%, high: 27.1%, very high: 16.3%, low: 16%, very low vulnerability: 5.6%. The areas with a very high level of vulnerability are located on the outskirts of the city.

By combining the hazard and vulnerability maps a risk map was obtained (Fig. 15.10) on which 36 areas of very high risk were identified (10% of the urban area of La Paz). The 2011 risk map determines geographical areas in which there is a risk of damage due to extreme hydro-climatic events and takes into account topography, geology, active geological faults, geo-mechanical characteristics of the soil, as well as the potential social, political or economic impact (Table 16.3). It determines the probability of each system being affected. The risk map makes it possible to plan protective measures, to regulate the use of the different geographical areas, and to govern land-use so as to ensure sustainability over time.

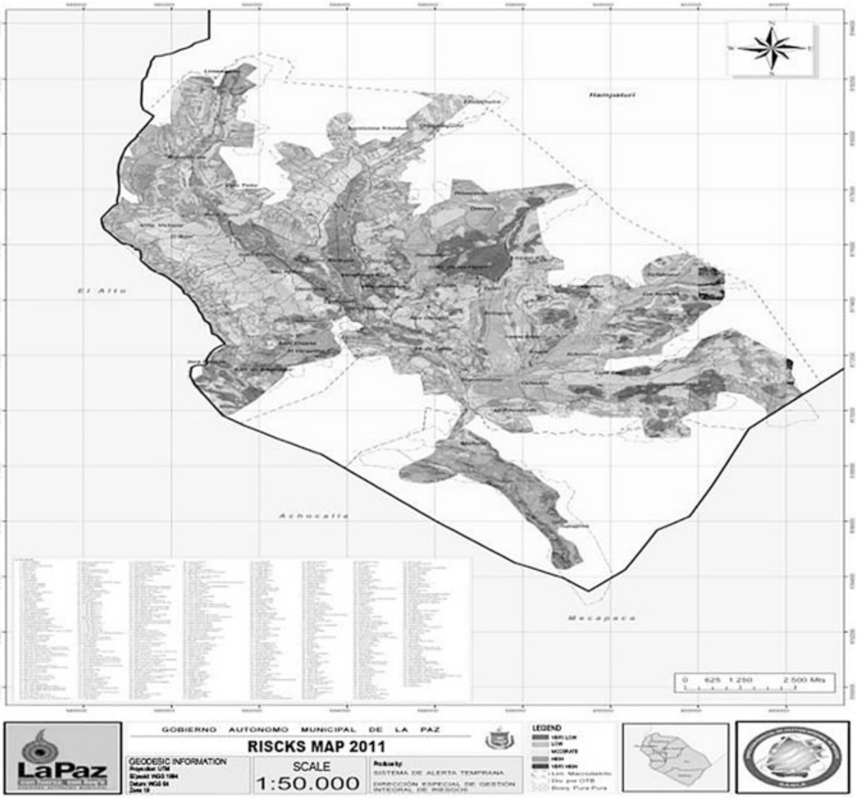


Fig. 15.10 La Paz Risk map 2011. Very high risk: 10% (*dark grey*), high: 21% (*gray* in south and southwest areas), moderate: 41% (*light grey* dispersed in the study area), low: 22% (*light grey* dispersed in the middle of the study area), and very low risk (*grey* in the middle and northwest of the study area): 6% (*dark green*). *Source:* DEGIR

Adaptation Measures

To achieve an integrated adaptation and risk-management approach we intended to inter-link the practices for analysing human and environmental systems, both in the fields of the social and the natural sciences.

Climate adaptation and vulnerability, and risk-reduction remains fragmented given the different scientific approaches and disciplines involved. In order to modify this situation the authors applied an interdisciplinary participatory approach aiming to include multiple stakeholders, population, municipal authorities and researchers. A list of measures has been selected based on consultation with experts, surveys and collaboration with the institutions. Table 16.4 shows a description of the wide range of adaptation measures proposed to address extreme events and climate change and variability, categorised according to whether they are institutional (I), social (S) and technical capacities (T), and whether they are high-priority (HP), i.e. to be implemented in the short term; medium-priority (MP) or low-priority (LP), i.e. to be implemented in the medium or long term respectively.

Conclusions, Main Lessons and Future Prospects

La Paz city is experiencing climate change with hotter summers. A decrease in snow-fields and water bodies has been observed. Also, extreme hydro-climatic events have been recorded in February 2002 and 2011, the latter related to a La Niña event. Rainfall patterns are apparently changing with variations in their quantity and frequency, and a greater tendency towards short-term extreme events.

The quantity of precipitation and soil saturation—attributable to the number of rainy days, possible non-controlled sewage emissions, upwelling of subterranean water, and to the quantity of maximum precipitation registered in the days before the landslide, have very likely been the cause of the landslide. Moreover, there are reports of leaks in the drinking water system, water erosion in the area due to its natural drainage network, the over-exploitation of dry land at the foot of the slope, the construction of housing in the risk area leading to an increase in the weight supported by the foot of the slope, and the area's abrupt and unlevel landscape preventing the consolidation of the slope.

The observed increases in heavy rainfall, overflowing and landslides, in addition to urbanisation, have affected houses at instable soils in addition to the preexistent house deficit. Nevertheless, there are no new building regulations to reduce the impact of landslides. This is a priority planning for La Paz city.

The basin and in particular the headwaters provide an important service for the ecosystem by providing water for the southern region of La Paz. A large number of flora and fauna species have been identified in the basin, including indigenous regional species and introduced or migrant species. The Irpavi-Callapa basin is affected by a number of human activities: agriculture and livestock, urbanisation and the construction of major dam projects. However, a number of areas still preserve their vegetation (both native and introduced species), which supports the native biota of these high-Andean environments. Other semi-natural ecosystems protect the basin from landslides and continue to enable water collection for the city of La Paz.

Several factors played a role prior to the landslide: housing had increased the weight of the soil; there had been a history of landslides since the 1930s; there were leaks from the water system, coupled with an abnormal rainfall profile in February 2011 (thick water films after rainfall, with maxima recorded days before the landslide, combined with soil saturation due in part to 25 days of precipitation), in addition to possible uncontrolled sanitary discharges and groundwater outflows, could all have caused the landslide. Nor should the overexploitation of barren land and agriculture at the foot of the slope be discounted.

The Early Warning System and Mapping developed after the mega-landslide of February 2002 showed to be effective to strongly reduce impacts during the mega landslide of February 2011. The latter led the authors to analyse the success of the EWS and propose further VIA assessment focused on risk factors research, adaptation measures and to improve its preparedness.

The main lessons are:

Professional capacity and leadership of the DEGIR (Risk Management Directorate) of the GAMLP (La Paz city government) enabled the development of an integrated early warning system, which shows the importance of applying before-event science-based knowledge, monitoring, hazard, vulnerability and risk map tools, as well as after-event preparedness. This experience was particularly successful in avoiding the loss of human lifes.

The occurrence of La Niña events—which evolution can be followed on real-time—is useful for preparedness of the EWS, particularly during summer. Nevertheless, the lack of updated building regulations remains as a barrier to achieving a better adaptation.

An expert judgment based on interdisciplinary scientific knowledge and previous mapping was coupled with a participatory process including consultation with municipal experts, and meetings and interviews with stakeholders. As a result, new composed risk maps were produced, and adaptation actions were proposed.

Future prospects:

The integrated VIA assessment approach, tools and actions presented in this chapter should be useful for municipal planning and further decrease of landslide harms and losses. The implementation of the adaptation measures proposed herein will contribute to further reduce infrastructure harms and losses, and the population at risk.

References

Aparicio-Effen M, Espejo E, Torres M, Aparicio J, Ramallo C (2014) Cambio Climático, Agua y Salud (Aparicio-Effen M (ed)) La Paz- Bolivia, p 141. ISBN: 978-99954-2996-6

Aparicio-Effen M (2010) Evaluación de la vulnerabilidad sanitaria nacional y subnacional al cambio climático (incluida su variabilidad), como base para el diseño e implementación de medidas de adaptación. Organización Panamericana de la Salud/Organización Mundial de la Salud, p 128. http://www.ops.org.bo/textocompleto/clima32340.pdf

Aparicio-Effen M, Arana I, Aparicio J, Cortez Pamela, Coronel G, Pastén M, Nagy GJ, Galeano Rojas A, Flores L, Bidegain M (2016) Chapter 26: Introducing hydro-climatic extremes and human impacts in Bolivia, Paraguay and Uruguay. In: Leal Filho W, Azeiteiro, Alvez F (eds) Climate change and health: improving resilience and reducing risks, Climate change management series. Springer, Heidelberg, pp 449–473. ISBN: 978-3-319-244660-26, Hardcover ISBN: 978-3-319-24658-1, Series ISSN: 160-2010. doi:10.1007/978-3-319-24660-4_26. http://www.springer.com/us/book/9783319246581

Beck S, García E (1991) Flora y Vegetación en los diferentes Pisos Altitudinales. In: Forno E, Baudoin M (eds) Editorial Instituto de ecología, Universidad Mayor de San Andrés. La Paz, Bolivia, pp 65–108

Bizikova L, Neale T, Burton I (2008) Canadian communities' guidebook for adaptation to climate change. Including an approach to generate mitigation co-benefits in the context of sustainable development, 1st edn. Environment Canada and University of British Columbia, Vancouver, p 104. Catalogue N°: En 56–226/2008E, ISBN: 978-1-100-10839-1

Bo Lim, Spanger-Siegfried E, Burton I, Malone E, Huq S (2005) Adaptation Policy frameworks for climate change: Development Strategies, Policies and Measures. Published by Cambridge University Press, UNDP, UNEP, GEF. ISBN: 9780521617604, New York, USA, print in Canada, p 251. http://www.cambridge.org/us/academic/subjects/earth-and-environmental-science/climatology-and-climate-change/adaptation-policy-frameworks-climate-change-developing-strategies-policies-and-measures. Accessed 25 June 2016

Burham M, Anderson P, Laake J (1980) Estimation of density from line transect sampling of biological populations. Wildl Monogr 72:202

Chow VT, Maidment DR, Mays LW (1994) Applied hydrology. Mc Graw Hill Interamericana, New York, p 584. ISBN-13:978-0070108103

Chow VT (2004) Hidráulica de canales abiertos. Mc Graw Hill Interamericana, New York, p 337. ISBN: 958-600-228-4

CIIFEN (2011) Boletín Junio 2011. Centro Internacional para la Investigación del Fenómeno de El Niño, Guayaquil, Ecuador. http://www.ciifen.org/index.php?option=com_content&view=article&id=399%3Aboletin-ciifen-junio-2011&catid=65%3Ahistorial-de-boletin-ciifen&Itemid=72&lang=es

Droesch CA, Gaseb N, Kurukulasuriya P, Mershon A, Moussa KM, Rankine D, Santos A (2008) A guide to the vulnerability reduction assessment. Community-based adaptation programme, United Nations Development Programme (UNDP), New York (UNDP Working Paper). http://www.seachangecop.org/files/documents/2008_12_CBA_Vulnerability_Reducation_Assessment_Guide.pdf. Accessed 11 July 2016

EcoHealth (2014) "EcoHealth 2014 Call to Action EcoHealth and Climate Change: Connections for Health, Ecosystems and Society", inbiose and Co-PEH, UQAM. www.ecohealth-live.net

Flores M, Crawford, K, Pullin M, Hall C, Crosier K, Crosier P (2010) Dual oxidase in the intestinal epithelium of zebrafish larvae has anti-bacterial properties. Biochem Biophys Res Commun 400 (1):164–168. http://www.sciencedirect.com/science/article/pii/S0006291X10015238. Accessed 10 Sept 2010

GAMLP (2011) Compendio de Estadísticas Ambientales—bivica. Gobierno Autonomo Municipal de La Paz. http://www.bivica.org/upload/ag_estadisticas-ambientales.pdf

Guha-Sapir D, Hoyois PH, Below R (2014) Annual disaster statistical review 2013: the numbers and trends. CRED, Brussels. http://www.cred.be/sites/default/files/ADSR_2013.pdf. Accessed 3 Jan 2015

Haines A, Ebi KL, Smith KR, Woodward A (2014) Health risks of climate change: act now or pay later. Lancet 384(9948):1073–1075. doi:10.1016/S0140-6736(14)61659-7

Handicap International (2009) Guideline for KAP survey managers October 2009 knowledge, attitudes and practices for risk education: how to implement KAP surveys. ISBN: 978-2-586 909064-21-5. http://www.hiproweb.org/uploads/tx_hidrtdocs/GuideCAPGB.pdf

IPCC (2002) Climate change and biodiversity. In: Gitay H, Suárez A, Watson, RT, Dokken, DJ (eds) Prepared in response to a request of the United Nations Convention on Climate Change. Requested by the United Nations Convention on Biological Diversity and prepared under the auspices of the President of the IPCC, Dr. Robert T. Watson. ISBN: 92–9169–104–7. Geneva, p 97

IPCC (2012) Summary for policymakers. In: Field CB, Barros V, Stocker TF, Qin D, Dokken DJ, Ebi KL, Mastrandrea MD, Mach KJ, Plattner GK, Allen SK, Tignor M, Midgley PM (eds) Managing the risks of extreme events and disasters to advance climate change adaptation. A special report of Working Groups I and II of the intergovernmental panel on climate change. Cambridge University Press, Cambridge and New York, NY, pp 1–19

IPCC (2014) Climate change 2014: impacts, adaptation, and vulnerability. Part A: global and sectoral aspects. In: Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR, White LL (eds) Contribution of working group II to the fifth assessment report of the intergovernmental panel on climate change. ISBN:

978-1-107-05807-1, Hardback ISBN: 978-1-107-64165-5, Paperback Cambridge University Press, Cambridge and New York, NY

Lorini JL (1991) Clima in natural history of an Andean valley: La Paz. In: Forno E, Baudoin M (eds) Editorial Instituto de ecología, Universidad Mayor de San Andrés. La Paz, pp 27–46

Llorente-Bousquets J, Michán-Aguirre L, González González J, Sosa OrtegaV, Espinosa Organista D, Hoffman A, Ramírez Pulido J (2004) Desarrollo y situación del conocimientode las especies. IN El conocimiento acerca de las especies. http://www.biodiversidad.gob.mx/pais/pdf/CapNatMex/Vol%20I/I07_Desarrollosit.pdf

Nagy GJ, Seijo L, Bidegain, M, Verocai JE (2014) Stakeholders' climate perception and adaptation in coastal Uruguay. J Clim Change Strateg Manag 6(1):63–84, Climate Change. doi:10.1108/IJCCSM-03-2013-0035. ISBN: 978-1-78350-517-3

Nagy GJ, Coronel G, Pastén, Báez J, MonteDomecq R, Galeano Rojas A, Flores L Ciganda C, Bidegain M, Aparicio-Effen M, Arana I, Aparicio J (2016). Chapter 27: Impacts on well-being and health of excessive rainfall and floods in Paraguay, Uruguay and Bolivia. In: Leal Filho W, Azeiteiro, Alvez F (eds) Climate change and health: improving resilience and reducing risks, Climate Change Management Series. Springer, Heidelberg, pp 475–514. ISBN: 978-3-319-244660-4_27, Hardcover ISBN: 978-3-319-24658-1, Series ISSN: 160-2010. doi:10.1007/978-3-319-24660-4. http://www.springer.com/us/book/9783319246581

Nagy GJ, Aparicio-Effen M, Arana I, Coronel G, Cabrera C, Lairet R, Villamizar A (submitted) Addressing climate adaptation education, research and networking in South America: The CliVIA initiative. Submitted to International Journal of Climate Change Strategies and Management (IJCCSM)

PNCC (2007) Mecanismo Nacional de Adaptación al Cambio Climático (MNACC), Bolivia. [Writen by Arana-Pardo I, García M, Aparicio Effen M, Cabrera, Eds. M: Paz O, Arana-Pardo I], p 76. ISBN 978-99954-0-254-9. La Paz, Bolivia. http://www.siteresources.worldbank.org/INTCC/Resources/MecanismoNacional. Accessed 28 Feb 2015

SENHAMI (2015) Sis Met official online database of the Meteorological and hydrological national service (SENAMHI), Estado Plurinacional de Bolivia. http://www.senamhi.gob.bo/sismet/index.php. Accessed 26 Feb 2015

Thomas CD, Bodsworth EJ, Wilson RJ, Simmons AD, Davies ZG, Musche M, Conradt, L (2001) Ecological and evolutionary processes at expanding range margins. Nature 411:577–581. doi:10.1038/35079066. http://www.nature.com/nature/journal/v411/n6837/full/411577a0.html

UNEP (2009) Integrated environmental asessment (IEA) training manual, volume two, vulnerability and impact assessments for adaptation to climate change (VIA Module). United Nations Environment Programme, Nairobi, p 58. http://www.iisd.org/pdf/2010/iea_training_vol_2_via.pdf

WHO (2010) Urban health equity assessment and response tool. World Health Organization Centre for health Development (Kobe). ISBN: 9789241500142. http://www.who.int/kobe_centre/publications/urban_heart/en/

Villamizar A, Gutiérrez ME, Nagy GJ, Caffera RM, Leal Filho W (2016) Climate adaptation in South America with emphasis in coastal areas: the state-of-the-art and case studies from Venezuela and Uruguay. J Clim Dev. doi:10.1080/17565529.2016.1146120

Wasson G, Barrere B (1999) Regionalización de la cuenca amazónica boliviana; Las Hidro-ecoregiones de la zona andina. IN Memorias del Congreso Boliviano de Limnología y Recursos Acuáticos 6:111–120

Author Biographies

Marilyn Aparicio-Effen is a M.D., Ph.D. in Development Policies (CIDES-UMSA) International Health Residency PAHO/WHO-WDC-USA. Specialized in Neurology. Climate Courses at NCAR, NSF, IAI Boulder-Colorado—USA, INPE-CPTEC/IAI Brazil. Former Responsible of

Climate Change and Health (Bolivian National Climate Change Program). Head of Climate Change and Environmental Health Unit (CCLIMAS): Universidad Mayor de San Andrés (UMSA), Bolivia. Coordinator of Climate Change Module: "Leadership in International Health Program" PAHO/WHO WDC-USA. Researcher in "Climate Change Health Vulnerability in Bolivia and Colombia" IDRC Project, "Public Goods Regional Tools for Climate Change Health Adaptation" IDB Project and Netherlands Climate Assistant Program (NCAP), "Climate Change Studies Project". Contributor to Chapter 13, IPCC 2007; PAHO-WHO Reports 1 and 2: UNFCCC Bolivian National Reports. Researcher of Climate Vulnerability, Impact and Adaptation Network (CliVIA-Net).

Ivar Arana-Pardo is an Agronomist. UMSA, Bolivia. Post graduated in natural resources management. Former consultant in Bolivian National Climate Change Program. Expert and researcher in Risk reduction and climate change adaptation (Helvetas Swiss Inter cooperation—Bolivia Disaster Risk Reduction Programme; Food Security, Agriculture, Health. Natural Resource Degradation, Climate Change Scenarios. Professor of Climate change and Risk reduction; Research Methods; Statistics for research in health. Lead author: IPCC 2002–2003. Expert Roster UNFCC. Researcher of CliVIA-Network.

James K. Aparicio E. is a Biologist graduated from Universidad Mayor de San Andrés (UMSA), La Paz, Bolivia. Postgraduated in ecology, management and conservation (Brazil, Costa Rica and Colombia), Head of Unit of Zoology of the National Museum of Natural History Biologist. Expert and researcher in biodiversity, wildlife management, ecosystem approaches in climate change and its relationship to human health and local development.

Mauricio Ocampo is a Biologist specialised in Geogrpahic Information System.

Stefannie Roque is a Medicine Student and Junior researcher in Climate Change and Variability Health.

Gustavo J. Nagy is a Ph.D. in Oceanography, University of Bordeaux, France. Expert and researcher in Estuaries; Hydroclimatology/ENSO; Vulnerability, Impacts and adaptation (VIA); Climate scenarios in VIA and Risks Assessments in Coastal, Water resources and Well-Being sectors. Professor of Environmental Sciences; Oceanography; Estuaries; Climate Adaptation and Risks; Earth System Science and Global Change: Universidad de la República (Uruguay) and Universidad Nacional de Asunción (UNA), Paraguay. Member of IPCC (2003–2007); National Research System (2009–2011 and 2016), Basic GeoSciences Research Programme (since 2014). Editorial Board of J of Climate Change Strategies and Management. Reviewer of several International Journals. Coordinator of CliVIA-Network.

Part II
Socio-economic Aspects of Climate Change Adaptation

Chapter 16
Peripheral Urban Territories, Disasters and Extreme Events: The Case of Morro Da Boa Vista (Vila Velha, Espírito Santo, Brazil)

Teresa da Silva Rosa, Marcos Barreto de Mendonca, Acácio Augusto Sebastião, Marcelo Sathler, Ricardo Matos Souza, Túlio Gava Monteiro, Mirian Costa, Maria Araguacy Simplicio, Caterine Reginensi, Michelly de Angelo and Vitor de Angelo

Introduction

Founded in 1535 by the Portuguese, the municipality of Vila Velha (VV) forms part of the Greater Vitória Metropolitan Region (Espírito Santo, ES, Brasil), currently undergoing a process of conurbation, typical of Modernity (Bogus et al. 2010). Being of strategic importance as a metropolitan expansion area, VV is under economic pressure in terms of large-scale development projects which have contributed, since the 1960s and 1970s, to rendering its land area vulnerable.

T. da Silva Rosa · A.A. Sebastião · V. de Angelo
Post-Graduation Programme in Political Sociology (PPGSP), Vila Velha University (UVV-ES), Vila Velha, Espírito Santo, Brazil
e-mail: tsrosaprof@yahoo.com.br

A.A. Sebastião
e-mail: acacioaugusto1980@gmail.com

V. de Angelo
e-mail: vitor.angelo@uvv.br

M.B. de Mendonca (✉)
Civil Construction Department, Polytechnic School, Federal University of Rio de Janeiro (UFRJ), Rio de Janeiro, Brazil
e-mail: mbm@poli.ufrj.br

M. Sathler · R.M. Souza · T.G. Monteiro
Center of Socioenvironmental and Urban Studies, NEUS/UVV, Vila Velha, Brazil
e-mail: marcelosathler.br@gmail.com

R.M. Souza
e-mail: ricardomsouza83@gmail.com

W. Leal Filho and L. Esteves de Freitas (eds.), *Climate Change Adaptation in Latin America*, Climate Change Management,
https://doi.org/10.1007/978-3-319-56946-8_16

Impacted by Modernity, its urban formation is being altered, driven by a project geared towards providing solutions to the "disorganisation" of the former space. The city acquires homogenous spaces in opposition to its tendency of "self-diversification" (Harvey 2004). Such homogeneity thereby becomes evident with the involuntary socio-spatial segregation of less favoured social groups.

Its extensive coastline has ensured such segregation, while the symbolic value afforded to environmental amenities favours property speculation; and, therefore, occupation by the wealthiest in areas of greater value and the marginalisation of low-income groups in areas of low property value—generally speaking, permanent preservation areas (PPAs—such as slopes and floodplain areas[1]) (Siqueira 2010; Mattos and Da-Silva-Rosa 2011; Mattos 2011).

Such occupation process takes place on the basis of scarce public policies which include demands from a majority of the population, thereby contributing to a proliferation of sub-normal agglomerates occupying the PPAs. Such subnormal agglomerates emerge as a response of the most needy population group "…the need for housing, which will occupy spaces less valued by the real-estate and land-ownership sector dispersed across the urban fabric" (IBGE n.d., p. 3). The association of urban expansion to the lack of efficient public policies, coupled with property speculation, is intensifying urban issues in VV.

It is in this modern urban context of vulnerability among the population in risk areas which, ultimately, suffer geohydrological events with a certain intensity. In December 2013, heavy rain caused floods which isolated entire communities in VV

T.G. Monteiro
e-mail: tuliogava@hotmail.com

M. Costa · M.A. Simplicio
Vila Velha University (UVV-ES), Vila Velha, Espírito Santo, Brazil
e-mail: mirian.michelli@gmail.com

M.A. Simplicio
e-mail: marasimp@uvv.br

C. Reginensi
École Nationale d'Architecture de Toulouse/ENSAT, Toulouse, France
e-mail: creginensi@gmail.com

C. Reginensi
PPGSP, UENF, Rio de Janeiro, Brazil

M. de Angelo
Post-Graduation Programme in Public Safety (PPGPS), Vila Velha University, Vila Velha, Espírito Santo, Brazil
e-mail: michelly.angelo@uvv.br

[1]Permanent preservation areas are defined by the Forestry Code (Law No. 12.651, of 25th May 2012), and consist of protected areas "… with the environmental function of preserving water resources, the landscape, geological stability and biodiversity" (BRASIL 2012), including in the urban environment.

over several days; and on 1st January 2016, a mass movement (stone block rolling displacement) occurred at Morro da Boa Vista (MBV), in the neighbourhood of São Torquato (VV). Both events exposed gaps in terms of prevention actions and difficulties around the emergency and in addressing disaster risks on the part of communities and local public authorities, showing their weakness when faced with weather extreme events.[2]

While floods are regular phenomena in ES, no mass movement was recorded between 1991 and 2012 (CEPED/UFSC 2013). The disaster at MBV reveals interesting aspects worthy of explanation, serving as an example case study. The local population was affected by a process whereby stone blocks rolled downslope on the first day of the year, a complex phenomenon which would appear to indicate a set of intervening factors, both in terms of weather and anthropic conditions, which justify a study geared towards understanding the perception of such population groups in respect of tackling this type of event.

The base of this hill (MBV) is occupied by subnormal agglomerates, presenting aspects typical of vulnerable areas and recent disorganised occupation. The mass movement event occurred at the height of summer, during typically rainy months—however, since 2014 an unusual annual dry period has been observed in the VV area, leading the State Civil Defence Department to decree an emergency situation[3] throughout the state. As such, the example mass movement case at MBV is a local event which may reveal the social impacts and human interactions in respect of climate change, such as the dynamics of disorganised urban land occupation and the human consequences of the development model.

This study is aimed at understanding the vulnerable situation of the MBV community, population perceptions of the land use process, socioenvironmental risks and public disaster risk reduction (DRR) management. This study is part of an interdisciplinary research project entitled "Understanding socio-environmental vulnerability construction in modern urban contexts: The case of Vila Velha (ES)", funded by CNPq. The article is divided into three sections. The methodological procedures are presented in the first section. In the second section, the conceptual framework on the modern urbanization process and DRR is discussed. In the third section, results of the public perception survey are presented and discussed.

Methodology

This case study involved residents directly or indirectly affected by the fall of rocks in the MBV area in January 2016. Different methodological procedures were

[2]http://www.cpqrr.fiocruz.br/pg/blog/fiocruz-cria-software-para-avaliar-vulnerabilidade-a-mudanca-do-clima-no-espirito-santo/, accessed on 20 May 2016.

[3]http://www.defesacivil.es.gov.br/files/meta/9c79332b-f0d2-4891-8f9c-b26d981b2258/9c1190db-65a8-46bf-8157-87f307e62998/91.pdf, accessed on 20 May 2016.

employed: semi-structured questionnaire and observation, carried out by the multidisciplinary team of researchers of the Centre for Urban and Socio-environmental Studies/NEUS (UVV-ES).

The questionnaire sought to determine the perception among the affected community, and comprised three parts—a total of 15 questions. Eighteen (18 = n) residents were interviewed during the week of the event, each from a different family. Based on actions conducted by municipal agencies [VV Municipal Authority (PMVV) and the VV Civil Defence VV/DCVV] with the 57 families housed in a local municipal school, this was applied in accordance with the devised schedule.

In parallel, interventions were made in the area with the assistance of residents, seeking to observe conditions in the higher risk area, in order to plot the overall disaster situation, and included visits to households. Written records were made, based on the perceptions of researchers and photographs taken. The action also sought to map the dynamic between organised social actors involved in the event, with special attention between local members of the MBV residents' association and the VV Municipal Authority (PMVV).

Conceptual Framework

Land Use in Modern Urban Development

From the outset, the land occupation and use process in VV appears not to have been concerned with its biogeophysical base when implementing urban layouts. Could the modern city, replacing the small town, have failed to consider the specifics of its land area, of the local environmental aesthetics (Blanc and Lolive 2009)? It is into this context of "absence" of the local geography which fits the urban perspective discussed here, capable of understanding the construction of problems faced today by its community.

The idea of "absence" is adopted in the sense provided by Santos (2002) when, from a perspective of the sociology of absences, it is placed at the margins or "discrediting the alternatives" possible as the only hegemonic possibility imposed by modern western thinking: that of the modern city, which fragments reality, impacting on spaces and exposing its communities to risk. Such "absence" reflects the positivist, Cartesian, western way of thinking about and interpreting the world when one considers oneself able to ignore the Place. What we see is the materialisation of a hegemonic and dominating rationality which breaks with other rationalities, as is the case with environmental rationality (Leff 2006). The space is occupied, then, as if nothing existed originally. The modern city imposes itself upon this "void", emerging as the "indolence of reason" (Santos 2002).

In this sense, the proposal is to transpose from the critique of Santos (2002), at the minimum the ideas below, understood as being capable of sustaining the argument of this study:

(1) the sociology of absences may unveil that which was covered up by hegemonic rationality, i.e., the biogeophysical base on which the city lives and survives—such base as would confer another identity on the urban if it had been "accredited" by the modern urban development process;
(2) the pre-existing "local urban", understood as the impotent reasoning that "nothing" could be done against hegemonic rationality, a hostage of the absence of a really public power, understood as relating to the people;
(3) the "modern urban", perceived as an arrogant reasoning which "imports" a foreign and strange rationality that ignores the "local urban"; and takes a single, hegemonic stance, both from a metonymic reason perspective (id 2002) ignoring what previously existed—natural or ecological rationality inherent in the biogeophysical base, land identity; and from one of proleptic reason (id, 2002) when no thought is given to the future consequences of imposing western hegemonic rationality, ignoring the characteristics of local natural rationality.

Such modern land occupation process has made the modern city possible without initially conceiving the likely consequences of this form of land use, emerging as the expression of a rationality which is modern, though alien to local rationality. This calls for knowledge and respect of environmental aesthetics as "… la base d'une appréhension riche de sens des milieux de vie et, par extension, de l'environnement"[4] (Blanc and Lolive 2009). After all, each environment has its own sense, its own characteristics, differentiating it, where arrogant reason, through "homogenisation" and fragmentation of Modernity (Löw 2013), would have no place.

Giving rise to significant wastage of space, such land homogenisation is considered, by the materialistic aspect of the sociology of space, as typical of the capitalist economy (Lefebvre 2000; Harvey 2011; Löw 2013). At the same time, one acknowledges the role of historicisation as a central element (Soja 1993) of formation of fragmented and homogenous spaces—comparable and controllable—of Modernity. It is thereby understood that the space is a social product (Löw 2013). Going beyond this, it is acknowledged that space is also capable of producing action in terms of its structuring element (Urry 1991 *apud* Löw 2013). As such, space has a dual character: *productive* of the action and its product (Löw 2013). Even from such productive point of view, space is perceived in a highly sociological profile, leaving aside its potential as a biogeophysical *entity* with its own feeling, capable of organising the action of human beings. Such is the approach of Blanc and Lolive (2009) to the idea of environmental aesthetics problematizing the urban, highlighting essential elements for comprehension of the urban space.

[4]The basis of a rich understanding of the senses of living environments and, by extension, the environment itself.

Despite its recent, rapid occupation, VV lacks scientific studies on its occupation process which would explain the vulnerabilisation of communities affected by disasters such as that which occurred on the MBV hillside. This disaster illustrates the case of PPA occupations by a population with low income or greater socioeconomic vulnerability (Araújo and Da-Silva-Rosa 2014). Just as river straightening actions are works of hegemonic rationality, aimed at controlling the space, structural prevention measures may also be seen as such. These measures only make sense, today, if associated to non-structural actions, including environmental education (Mendonça et al. 2016) linked to public policies on land-use regulation and risk management (Tominaga et al. 2015). Occupation of hillsides by communities excluded from the development process, in addition to placing them in a position of socio-environmental vulnerability (Mattos and Da-Silva-Rosa 2011), demonstrates the inadequacy of public policies to deal with complex problems arising from disorganised land occupation and use.

Disaster Risk Management

Disaster risk management is a systematic process of the employment of administrative guidelines, institutions and operational skills and abilities from different sources to implement strategies and policies to reduce the impacts of adverse events (UNISDR 2009).

Risk management actions may be organised according to a cyclic sequence of interrelated stages of prevention, mitigation, preparation, alert, response, rehabilitation and recovery. Such actions basically consist of: risk identification, analysis and mapping; structural actions (engineering works); public information; professional training; actions for public participation in risk management; planning, regulation and reorganisation of land use and occupation; planning for emergency situations; evacuation and treatment of those affected; damage assessment; damage repair and re-establishment of activities in the affected community (Cardona 1996).

The UN Sendai Framework on DRR for the period 2015–2030 (UNISDR 2015), which reviewed and reaffirmed several points of the UN Hyogo Framework (UNISDR 2007), includes priority actions such as "understanding of disaster risk; enhancing governance to manage disaster risk; investment in the reduction of disaster risk for resilience; improvements in disaster preparedness in order to provide an effective response and build back better during recovery, rehabilitation and reconstruction".

In respect of understanding disaster risk, the Sendai Framework stated that disaster risk management policies and practices should be based on a clear understanding of the risk in all its dimensions of vulnerability, capacity, exposure of people and assets, hazard characteristics and the environment. To achieve the above, one should, among other actions, use traditional and local knowledge and practices to supplement scientific expertise in disaster risk assessment and for development and implementation of specific DRR policies, strategies and plans.

Therefore, knowledge of the vulnerabilisation process and of risk perception among the affected community are necessary for planning more efficient disaster risk management.

Results and Discussion

Morro Da Boa Vista: An Announced Tragedy?

At an altitude of 220 m, MBV is located in the Espírito Santo intrusive suite known as *Maciço Vitória* (the Vitória Mass Brazil 2014) and in a well-sited neighbourhood on the southern coast of Vitória Bay, facing the ES state capital (Vitória), some 10 km from the centre of VV and with the largest municipal bus terminal. Such geographical situation influenced the occupation process in the neighbourhood, in parallel with the urban development process in VV, intensified in the second half of the 20th century. São Torquato is a mixed residential and commercial area with few leisure facilities and a high level of social disorganisation, a land area of 11.3 km^2 and approximately 6100 residents. A railway passes through the neighbourhood en route to the industrial and port area in contiguous neighbourhoods, there are three schools (two municipal) and a health centre which services four other neighbourhoods.

As the greater part of the VV land area is a floodplain crossed by rivers, now straightened [transformed into sewage channels, locally known as "valões" (large ditches)], the base of MBV is an option for occupation despite its geophysical characteristics, observed during field studies carried out: the presence of boulders, susceptible to movement, with vegetation stumps, indicating deforestation, denser at the higher hillside points where there were few households. The characteristics of MBV are those of subnormal agglomerates. According to the Jones dos Santos Neves Institute,[5] the majority of residents earn up to half a minimum salary per month. There is neither refuse collection nor a collection point, generating disease focus proliferation, and public lighting is sparse, generating a feeling of insecurity.

The observation found that, within the area defined by the PMVV affected by the rock fall of January 2016, there were households and small bars; channelled sewage, confirmed by 83% of those interviewed; however, there is no record of sewage treatment, and some points were found to be leaking with runoff into alleyways. There was no indication of a fresh water supply on the slope, despite the fact that some residents commented on the existence of springs, which may have been deactivated over time. Along the travel path of the rocks, the presence of relatively large rocks fragments was noted which, with heavy rainfall, may undergo movement and strike the houses below. This area was part of a sector at high risk of mass

[5]Field log notes made during the lecture on the "Social Occupation research project", given by technicians (Lívia Tulli and Thiago Guadalupe) on 17 May 2016, at Vila Velha University, ES.

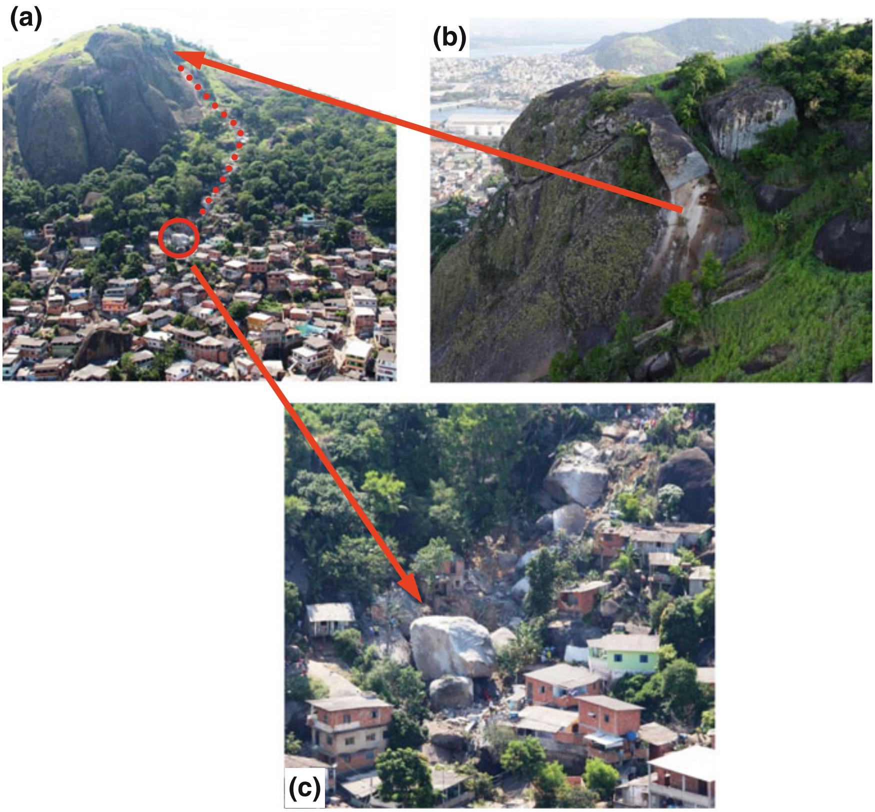


Fig. 16.1 Photos of rock boulder roll: **a** roll trajectory of boulders, **b** detachment point of largest boulder high on the Morro Boa Vista and **c** situation at end of boulder roll trajectory

movements defined in a study conducted by the Brazilian Geological Service (CPRM *apud* VV Contingency Plan 2013), described as a hill featuring fractured granite rock, with large relief fractures, with a significant number of loose or enclosed boulders which could strike residences.

It is in this context of socio-environmental vulnerabilisation that, on 1 January 2016, between 17:40 and 18:00 h, the boulders rolled (the largest of which was approximately 3000 tons in weight), which struck family households situated at the highest part of this precarious occupation, causing material losses and all manner of damages (Fig. 16.1). Four houses were hit, 15 people injured and 400 families left homeless.[6] If those families presented the aforementioned characteristics, how do they perceive the ordeal experienced?

[6] http://g1.globo.com/espirito-santo/noticia/2016/01/ministerio-publico-vai-investigar-desastre-no-morro-da-boa-vista-es.html, accessed on 7 June 2016.

The Interviewed Families

In all, 18 (n = 18) residents were interviewed—family representatives, of which two families had houses in the affected area. Among the respondents, 66.7% were female and 87.6% over the age of 21. Some 83.3% stated that their property was self-owned, and all households were single or multifamily residences (33.3%), with no commercial activity. Up to six people live in the single-family households (66.6%). Whereas all households of those interviewed have access to potable water from the municipal authority or concessionaires, only 38.8% have access to a sewage system and 33.3% stated that they paid urban property and land tax (IPTU), a municipally applied tax. Such levy indicates that real estate in VV is worth more than R$30,000 in a paved street and, without this, the owner may forego exemption. Such data therefore point to vulnerability conditions of 66.7% of the families interviewed.

The Families' Response to the Incident

None of the families interviewed suffered fatalities as a result of the incident. 54.5% Stated that, in the post-incident moment, it was the neighbourhood (understood as neighbours and the resident's association) which provided assistance, followed by the municipal Civil Defence (DCVV, 27.3%). The PMVV was mentioned by 3% of those interviewed. Half considered the response of government institutions unsatisfactory and indicated "failures" of DCVV actions, as they were not sought by any agency. This would appear to refer to possible actions in the preparation phase as provided for in DRR management. However, some information on possible risks of mass movement and new risk mapping to be conducted were provided by those agencies to the residents; i.e., only during the response phase.

Evidently, this type of information should have been provided before, during the response preparation phase. This demonstrates inadequacy on the part of the State in respect of DRR, and this is not due to a lack of information. If, on one hand, the geological map of ES exists (CPRM 2014), its scale of 1/100,000 is not suitable for risk studies. On the other hand, PMVV has had a contingency plan since 2013.[7] On its page 43 there is a map, prepared by the Brazilian Geological Service from reconnaissance of areas subject to high and very high risk of mass movements and floods for the MBV and São Torquato region, with a description of the local situation and an estimate of approximately 400 households at risk—some 2000 people who could be affected. A risk area was defined from the top of the hill to the high part of existing urban occupation—encompassing the area affected by the

[7]http://www.vilavelha.es.gov.br/midia/paginas/PLANO_CONTINGENCIA_2013-2015_21-10-13_assinado(1).pdf, accessed on 20 May 2016.

incident in January 2016. In addition, several suggestions for risk reduction interventions are made:

> … immediate removal of residents closer to the top of the hill, area with a large concentration of stone blocks; containment works in regions where removal is not possible; organisation and capture of rainwater with construction of hydraulic routes; environmental lectures and courses on raising awareness of the requirement for protection of hillside areas; qualification of community leaders, trained to provide guidance in the event of an emergency; revegetation of more exposed areas; refuse collection and group clean-up events. (Contingency Plan, 2013, p. 43)

It is clear that such interventions were ignored. No removal took place. There was no plan for reallocation of residences. There was no containment work or rainwater capture. There was no environmental education geared towards DRR. No revegetation took place. The solidarity demonstrated by the neighbourhood does not appear to have been a result of training for emergency situations. After all, they related that many people were scared at the time, without knowing what to do. Some went to the aid of the injured. In this light, the solidarity demonstrated may be seen more as a spontaneous strategy of adaptation, based on community ties created by the residents themselves—ties reinforced and organised by the residents' association, as identified during field trips.

One observes a scenario of abandonment, reinforcing what the interviewees expressed above: lack of assistance from public agencies. Such feeling is also observed in other states, such as in the case of Mendonça and Pinheiro (2012) in a community in Niterói (Rio de Janeiro State), where 90% of residents state that they do not rely on such agencies in an emergency situation caused by landslides. As a result of such abandonment by the State, in MBV 83.3% of families were temporarily rendered homeless, with 38.8% housed in a shelter set up in the neighbourhood's municipal school. For almost two months, these families were dependant on the State or the solidarity of neighbours, relatives and friends, under conditions of psychological stress, in many cases not easily overcome.

Of the families interviewed, 44.4% were in households, even post-incident, in a risk situation, and 16.6% were directly affected, partially or totally destroyed. Cracks were observed in some residences whose families had been displaced. Based on accounts by residents, there was an air of tension on the days following the incident. Some mentioned the difficulty in sleeping due to flashbacks of the occurrence, primarily the running around on the day of the disaster, with a lot of frightened people running to retrieve their belongings.

Perception of the Incident

Of the total interviewed, 61% were within the community—either in their own homes or in those of neighbours. It was the first day of January, just after the New Year celebrations, where parties can extend into the early hours of the morning. According to the description given, some people were outside at the time of the

Table 16.1 Possible causes of incident according to families interviewed

Possible causes	%
Natural causes	11.11
Heat in the rocks	27.78
Occupation of area	5.55
Act of god	5.55
Bomb	16.67
Excess weight	5.55
Soil erosion	5.55
Don't know	22.22
Total	100

incident and saw the rocks falling. Those indoors felt a tremor and a loud, frightening noise. 83% stated that they did not notice anything which attracted their attention—only 17% said they heard bangs or explosions, which may have been interpreted as a result of rocks breaking loose. One interviewee mentions shocks generated by works at the nearby port as a reason for the rocks coming loose.

In respect of possible causes of the event (Table 16.1), "heat in the rocks" was quoted by the majority, followed by the option of "bomb" and "natural causes". 44.5% of answers allude to what one could call geophysical causes (action of heat on the rocks, soil erosion…). A natural cause for the incident appears as an option alongside occupation of the area as a contributing factor.

Finally, it is worthy of note that the questionnaire was applied during the week following the incident, when rumours about possible causes were circulating in the local media. Even while the more detailed official technical finding was awaited, the media indicated natural processes (meteorisation of the rocks, wear or tension relief), which may have influenced the interviewees' responses.

Fear, Love, Insatisfaction… Reflections Based on the Stance of Families

With an end to giving the affected community a voice, some parts of the questionnaire allowed for free expression of opinions. In respect of a return to the site of their households, 61% stated that they would return even if in a risk area. Some said they would reoccupy provided the local authority gave clearance to do so. Others said they would look for housing in lower areas within the same community, far from the site affected by the incident. "Love for the neighbourhood" is cited by just one person, pointing out the necessity for works in the region despite the fact that, at another time, other personal reasons appear as justification to remain in the area ("leave the house I built", "got used to the place").

"Fear of the rocks" appeared among the reasons for those not intending to return (38.8%). Such fear appears to indicate the psychological impact suffered, accentuating the subject's vulnerability. Living far from a slide risk would be something in the imagination which, at the time of the interviews, was still in a situation of significant psychological stress. Others stated their expectation that PMVV would pay for them to be relocated—either social rental or compensation.

In truth, these people appear to be living a certain dilemma between “love for the place” and “fear of the rock”. Even when fear is not at the forefront in some responses, material losses or psychological impact are not always so easily overcome. Love for the place, in some cases, may be linked to personal or family history in the place or neighbourhood, or proximity to a workplace or accessibility to a bus terminal and services. The neighbourhood was indicated as having been responsible for post-disaster first response, demonstrating the importance of the social fabric as a factor of resilience among the affected community. Mendonça and Pinheiro (2012) stated that, in emergency situations, it is the residents themselves that most assist the community.

It is worth reiterating the dissatisfaction expressed during interviews around the State involvement in this situation—essentially PMVV—and around the lack of an adequate response and housing assistance. It is worth noting the role of DCVV in DRR management, primarily in the preparation phase. It would appear that the opportunity for a more focused action was lost, in terms of what the Brazilian Geological Service (CPRM) identified in the 2013 Contingency Plan. Of significant concern, this factor seems to indicate a lack of alignment in respect of the role of each social actor responsible for prevention in DRR management provided for in the Hyogo and Sendai Framework (Araújo and da-Silva-Rosa 2014). In contrast, what one sees in the operation of this actor is persistence in an outdated DRR management perspective, focused only on the response to the disaster. Araújo and da-Silva-Rosa (2014) draw attention to the fact that the responsibility of this state actor in the DRR scenario is complexified in the process of providing social conditions which, instead of mitigating, create potential for a disaster to occur. By omission…

Final Considerations

This article was primarily aimed at critically evidencing how the urbanisation and development process, established late in Espírito Santo, was a determining factor for creation of risk areas and socially vulnerable spaces, even where this is not the exact perception of communities occupying such areas, as demonstrated in the results discussed. Against the backdrop of this process in VV, the case of MBV was presented and discussed, in terms of the mass movement which occurred at the beginning of 2016, illustrating the manner in which vulnerable communities deal with disaster situations. As a result of this incident, despite the fact that no fatalities occurred, personal injury and psychological trauma were recorded, with a significant amount of people displaced and made homeless.

Based on the study conducted, one could say that these are communities living in a risk situation, with a low capacity for resilience given the difficulty in reacting to the occurrence. This is a warning for other disaster cases related to floods or mass movements triggered by a difficult-to-control element—extreme weather events. Given the lack of assistance from and dissatisfaction with the action of the public authority, residents are compelled to adopt a spontaneous adaptation strategy to face these problems, basically asking their neighbours for help.

It should be noted that if structural containment actions at MBV are important, then non-structural actions such as this community's access to information on DRR and participative management thereof are of paramount importance in the sense of making efforts to tackle disasters influenced by weather events. This is a suggestion of the UN Sendai Framework. In the case of MBV, discussion over the intervention proposal presented by the Brazilian Geological Service in the PMVV contingency plan, including the evacuation of residents. The feasibility study around this last measure is complex in light of the difficulty of knowing disaster trigger mechanisms providing conditions for rock-body movements and their respective trajectories which, in turn, will define the areas to be evacuated. Additionally, the study reveals the dilemma between "love for the neighbourhood" and "fear of the rocks", demonstrating the complexity involved in DRR. Such dilemma complexifies the feasibility analysis for interventions as it demands action not just from the State, but from all the actors involved, giving them an active voice.

In light of this and by way of conclusion, it is clear that issues involving vulnerabilized communities have "…a political and ethical characteristic…." (Da-Silva-Rosa and Maluf 2010) as Sachs (2008) discusses for climate-change related cases. When all is said and done, would we not be dealing with a situation of environmental injustice such as Monteiro (2016) discusses in his work about VV, where disrespect of human beings, as Sachs (2003) reminds us, places at risk the basic living conditions for vulnerabilized communities through a process of development which is socially unjust and ecologically unsustainable? This appears to be the case for residents of MBV, VV.

Acknowledgements The authors thank to the Scientific Initiation Scholarship students at the Centre for Socioenvironmental and Urban Studies: NEUS/UVV, Brazil, specially Tayná Mozine, FAPES: Espírito Santo State Research Foundation, CNPq: National Research Council for Scientific and Technological Development, FAPERJ: Rio de Janeiro State Research Foundation and UVV-ES: Vila Velha University.

References

Araújo RO, Da Silva-Rosa T (2014) Socio-environmental vulnerability and disaster risk reduction: the role of Espírito Santo State (Brazil). Ambiente Soc 17(4):117–132

Blanc N, Lolive J (2009) Vers une esthétique environnementale: le tournant pragmatiste. Nat Sci Soc 17:285–292. doi:10.1051/nss/2009045

Bogus L, Raposo I, Pasternak S (orgs.) (2010) Da Irregularidade fundiária urbana à regularização: análise comparativa Portugal-Brasil. EDUC, São Paulo

Brasil (2012) Lei n° 12.651 de 25 de maio de 2012. http://www.planalto.gov.br/ccivil_03/_ato2011-2014/2012/lei/l12651.htm. Accessed 3 Mar 2015

CPRM – Serviço Geológico do Brasil (2014) Carta Geológica, Folha Sf-24-V-B-I Vitória, Contrato - CPRM - UFES 038/Pr/09. http://geobank.cprm.gov.br/pls/publico/geobank.download.downloadlayouts?p_webmap=N. Accessed 14 May 2016
Cardona OD (1996) El manejo de riesgos y los preparativos para desastres: Compromiso institucional para mejorar la calidad de vida. In: Mansilla E (ed) Desastres para Armar. La RED, México
CEPED/UFSC (2013) Atlas Brasileiro de Desastres Naturais - 1991–2012. Volume Espírito Santo. Centro Universitário de Estudos e Pesquisas sobre Desastres. CEPED/UFSC, Florianópolis. http://150.162.127.14:8080/atlas/Atlas%20Espirito%20Santo%202.pdf. Accessed 20 May 2016
da Mattos RFS (2011) Expansão urbana, segregação e violência: um estudo sobre a região metropolitana da Grande Vitória. EDUFES, Vitória
Da Silva-Rosa T, Maluf R (2010) Populações vulnerabilizadas e o enfrentamento de eventos climáticos extremos: estratégias de adaptação e mitigação. Bol Soc Bras Econ Ecol 23(24):40–48
Harvey D (2004) Condição pós-moderna. Loyola, São Paulo, pp 69–76
Harvey D (2011) Condição pós-moderna: uma pesquisa sobre as origens da mudança cultural, 21st edn. Loyola, São Paulo
Instituto Brasileiro de Geografia e Estatítica, IBGE (n.d) Censo Demográfico 2010 – Aglomerados Subnormais – Informações Territoriais. http://www.ibge.gov.br/home/presidencia/noticias/imprensa/ppts/00000015164811202013480105748802.pdf. Accessed 10 May 2016
Lefebvre H (2000) La production de l'espace, 4th edn. Éditions Anthropos, Paris
Leff E (2006) Racionalidade ambiental: a reapropriação social da natureza. Civilização Brasileira, Rio de Janeiro
Löw M (2013) O spatial turn: para uma sociologia do espaço. Tempo Soc 25(2):17–34. doi:10.1590/S0103-20702013000200002
Mattos R, Da Silva-Rosa T (2011) Reestruturação econômica e segregação socioespacial: uma análise da Região da Grande Terra Vermelha. Anais do I Seminário Nacional do Programa de Pós-Graduação em Ciências Sociais, Vitória, ES, Brazil
Mendonça MB, Pinheiro MTG (2012) Estudo da percepção de risco associado a deslizamentos no bairro do Maceió, Niterói, RJ. Rev Comun Educ Ambient 2:78–94
Mendonça MB, Da-Silva-Rosa T, Monteiro TG, Matos RS (2016) Improving disaster risk reduction and resilience cultures through environmental education: a case study in Rio de Janeiro State, Brazil. In: Walter LF, Ulisses MA, Fátima A (eds) Climate change management, 1st edn. Springer, pp 279–295
Monteiro TG (2016) Do privado ao público em um contexto de injustiça ambiental: um estudo de duas comunidades às margens do canal da costa – Vila Velha. Master Dissertation, Programa de Pós Graduação em Sociologia Política (PPGSP), Universidade Vila Velha, Vila Velha
Sachs W (2003) Environment and human rights. Wuppertal paper 137, September
Sachs W (2008) Climate change and human rights. Development 51:332–337. doi:10.1057/dev.2008.35
Santos BS (2002) Para uma sociologia das ausências e uma sociologia das emergências. Rev Crít Ciênc Soc 63:237–280. http://rccs.revues.org/1285. Accessed 30 Oct 2014
Siqueira P (Org.) (2010) Industrialização e empobrecimento urbano. O caso da Grande Vitória, 2nd edn. Grafitusa, Vitória, p 164
Soja E (1993) Geografias pós modernas: a reafirmação do espaço na teoria social. Zahar Eds, Rio de Janeiro
Tominaga LK, Santoro J, Amaral R (2015) Desastres naturais: conhecer para prevenir. Instituto Geológico, São Paulo
UNISDR (2007) United Nations and International Strategy for Disaster Reduction Hyogo Framework for Action 2005–2015: building the resilience of nations and communities to disasters. Geneva. http://www.unisdr.org/files/1037_hyogoframeworkforactionenglish.pdf. Accessed 15 Dec 2014

UNISDR (2009) Terminology on disaster risk reduction. United Nations International Strategy for Disaster Risk Reduction, Geneva. http://www.unisdr.org/files/7817_UNISDRTerminologyEnglish.pdf. Accessed 6 May 2015

UNISDR (2015) United Nations and International Strategy for Disaster Reduction (Sendai Framework for Disaster Risk Reduction 2015–2030). http://www.wcdrr.org/uploads/Sendai_Framework_for_Disaster_Risk_Reduction_2015-2030.pdf. Accessed 3 Apr 2015

Urry J (1991) Time and space in Giddens social theory. In: Bryant C, Jary D (orgs) Giddens' theory of structuration: a critical appreciation. Routledge, London, pp 160–175

Chapter 17
Climate Change Vulnerability Analysis at the Local Level: Lessons Learnt from Brazil on How to Conduct Participative Processes

Jennifer Viezzer, Mariana Egler, Miguel Fluminhan Filho, Marcio Wixak Vieira, Martin Becher, Patricia Betti, Leonardo Borgmann Campos, Armin Deitenbach, Lukas Hach and Luiz Miguel Stumbo Filho

Introduction

Climate change adaptation is increasingly becoming a pressing issue. That is also mainly the case regarding the application of various methodologies to address climate change on a local level, adjusting methodological guidelines to local realities. Major challenges have been especially identified in the field of vulnerability assessments, which generally do not follow a rigid format, but require methodological adjustments to address local needs. From this starting point, and in order to show methodological alternatives to asses vulnerability, this article aims to document and discuss lessons learnt from two different approaches used in the

J. Viezzer (✉)
Brazilian Ministry of Environment (MMA)/Secretariat of Biodiversity,
SEPN 505 Norte, Bloco "B", Edifício Marie Prendi Cruz, Sala 402,
Brasília, DF CEP 70730-542, Brazil
e-mail: jennifer.viezzer@mma.gov.br

M. Egler
Brazilian Ministry of Environment (MMA)/Secretariat of Climate Change
and Forests, SEPN 505 Norte, Bloco "B", Edifício Marie Prendi Cruz, Sala 301,
Brasília, DF CEP 70730-542, Brazil

M. Fluminhan Filho
Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio)/APA de
Cananéia-Iguape-Peruíbe, Rua da Saudade, 350, Iguape, SP CEP 11920-000, Brazil

M.W. Vieira · L.M. Stumbo Filho
Secretariat of Planning, Housing and Urbanism, Alameda Bartolomeu de Gusmão 85,
Jardim Primavera, Duque de Caxias, RJ CEP 25215-320, Brazil
e-mail: marciovmotta@gmail.com

W. Leal Filho and L. Esteves de Freitas (eds.), *Climate Change Adaptation in Latin America*, Climate Change Management,
https://doi.org/10.1007/978-3-319-56946-8_17

context of the Biodiversity and Climate Change in the Atlantic Forest Project, drawing lessons learnt and enabling readers to reproduce the experiences in their own working context.

The Biodiversity and Climate Change in the Atlantic Forest Project (from now on: Mata Atlântica Project) occurs in the context of the Brazilian-German cooperation for sustainable development, in the context of the International Climate Iniciative (ICI) of the German Federal Ministry of Environment, Nature Protection, Construction and Nuclear Safety (BMUB), implemented by the Brazilian Ministry of Environment (MMA). With technical assistance by the German technical cooperation agency Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, the project aims to contribute to mitigation and adaptation to climate change via the implementation of ecosystem-based adaptation (EbA) measures in the Atlantic Forest in Brazil.

The project's regional focus is on three regions of protected area mosaics, specifically the Mosaic of the Extreme South of Bahia (*Mosaico de Áreas Protegidas do Extremo Sul da Bahia*—MAPES), the Mosaic of Central Fluminense (*Mosaico Central Fluminense*—MCF) in Rio de Janeiro, and the Mosaic Lagamar, in southern São Paulo and coastal Paraná States (see also Fig. 17.1).

The project aims to consider climate change impacts and ecosystem-based adaptation in different land-use planning tools. The proposition of doing so starts from the assumption that considering climate change makes these tools more resilient on the long term.

In order to do so, a compulsory step is to perform a vulnerability assessment. As vulnerability assessments today still do not follow international or national standards, the project offensively explores a variety of different approaches to perform them, adapting existing methodologies to specific local contexts.

To build up technical expertise, the project trained between 2012 and 2014 45 EbA-experts of the three focus regions and the National level in methods and tools to mainstream the approach into land-use planning. These trained experts were accompanied during their first implementation experiences by the project team, which provided technical and methodological input and ensured the systematization of lessons learnt.

This article specifically builds on two experiences on vulnerability assessments for land-use planning instruments. Both assessments followed different approaches and delivered different forms of results. An in-depth analysis will reveal strengths

M. Becher · P. Betti · L.B. Campos · L. Hach
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)
GmbH c/o Brazilian Ministry of Environment (MMA), SEPN 505 Norte,
Bloco "B", Edifício Marie Prendi Cruz, Sala 402, Brasília, DF CEP 70730-542, Brazil
e-mail: martin.becher@giz.de

A. Deitenbach
GFA Consulting Group GmbH, c/o Brazilian Ministry of Environment (MMA),
SEPN 505 Norte, Bloco "B", Edifício Marie Prendi Cruz, Sala 402, Brasília,
DF CEP 70730-542, Brazil

Fig. 17.1 Atlantic Forest within Brazil and three focal regions of the Mata Atlântica Project. *Source* Own production

and weaknesses of both approaches and point out lessons learnt for future vulnerability assessments.

Pursuing to get a common understanding of terminology, ecosystem-based adaptation to clime change is an approach to adapt to climate change. Unlike classical approaches, it focuses less on creating engineering solutions, but it pursues to strengthen ecosystem services, to create assets that allow the society to better cope with climate change. Following the most common definition of the Millennium Ecosystem Assessment, ecosystem services are "the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as regulation of floods, drought, land degradation, and disease; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious and other nonmaterial benefits" (Alcamo et al. 2003: V).

These services can be strengthened by conserving, restoring, or sustainably managing ecosystems. Examples of ecosystem-based adaptation measures are the restoration of riparian forests to better deal with increasing floods, the conservation of forests to allow for a better infiltration of rainwater in a scenario of decreasing rainfall, or the sustainable management of agricultural land by installing agro-forestry, to decrease the impact of future heavy rains.

Due to its positive impacts not only to reduce vulnerability to climate change, but also to increase or ensure the provision of ecosystem-services in a non-climate-change-scenario, EbA measures are often defined as being non-regret measures. However, in order to be considered EbA, adaptation strategies need, among others, to be based beforehand on climate information and scenarios, followed by a vulnerability assessment.

Vulnerability assessments are detailed studies to assess drivers for vulnerability to climate change, and needed to determine the role of ecosystems to reduce them. Vulnerability itself is not measurable as an absolute number, such as precipitation or wind speed, but it "expresses the complex interaction of different factors that determine a system's susceptibility to the impacts of climate change. However, there is no fixed rule defining which factors to consider, nor of the methods used to quantify them. This is why we talk about 'assessing' rather than 'measuring' vulnerability" (Fritzsche et al. 2014, p. 26).

In general, vulnerability assessments still follow IPCC's 2007 terminology. This means that vulnerability "is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity" (Pachauri and Reisiger 2007). Figure 17.2 shows the scheme of our understanding of the vulnerability concept.

While seeming—at first sight—to be quite standardized, vulnerability assessments still are a major challenge worldwide, just because its exact application depends on a variety of variables. The first and most common defiance is the lack of available data. Here, the main challenge is to get quantitative data, both regarding climate projections, and regarding biophysical and socioeconomic variables. In addition, the available resources—human, time, and financial—make a large difference when deciding on how to design the process, also regarding on how to include the participation of the population and experts. Finally, it is key to understand how the generated information will be used.

All this aspects play a major role when designing the exact approach. However, the latter mentioned is the starting point, as it determines both the quality of

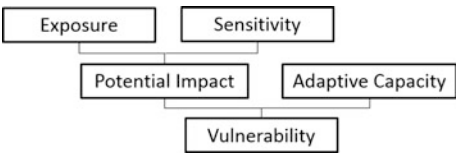


Fig. 17.2 Functions of the vulnerability concept. *Source* Adapted from IPCC (2007)

information needed to be generated in order to be useful, as well as the set-up in which it will be generated. This is due to the fact that vulnerability assessments are usually integrated into larger planning processes, and therefore need to be adapted to their methodology and included into their timeline.

The following two case studies describe the methodologies adopted on Brazil's coastal area that—although following completely different approaches—produced substantial results to identify vulnerabilities to climate change.

Methodology: The Case of the Area of Environmental Protection of Cananéia-Iguape-Peruíbe

Following Brazil's system of Protected Areas (SNUC), Environmental Protected Areas (APA) are part of the group of protected areas for sustainable use. The APA of Cananéia-Iguape-Peruíbe (APA CIP), located in the Mosaic Lagamar (see Fig. 17.3), was created in 1984 and enlarged in 1985. It encompasses six municipalities (Cananéia, Iguape, Ilha Comprida, Itariri, Miracatu and Peruíbe), with a total area of 234.000 ha. Located in Southeast São Paulo State, it is integrally located in the Atlantic Forest biome, with predominance of mangroves, sandbank vegetation and dense ombrophylous forests (Fluminhan Filho et al. 2015).

According to SNUC, all protected areas need to have a management plan, which needs to be developed with a participative approach. The APA CIP's preliminary

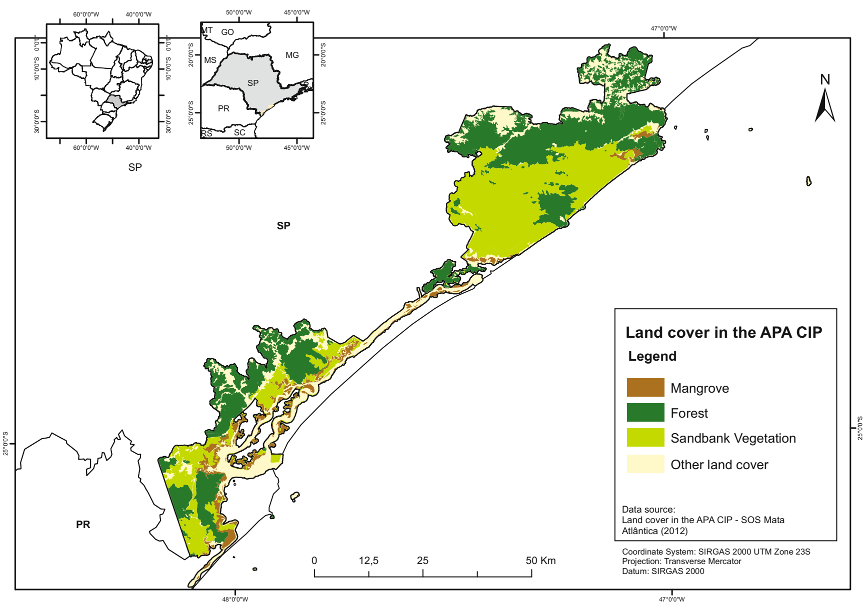


Fig. 17.3 Location of APA CIP in Southern Coastal São Paulo State. *Source* Own production

management plan was prepared in 1996, which included a first draft for zoning. In 2014, Brazil's Environmental Conservation Institute ICMBIO, with financing of the GEF-Facility project "Manguezais do Brasil" and with backup by UNDP, started the design of APA CIP's first complete management plan, which was finally completed and approved in early 2016.

In this context, the Mata Atlântica Project invited APA CIP's management staff to attend a training course on how to consider EbA into land-use planning in 2014. A further participation on a training-of-trainers course resulted in the process design on how to consider EbA into the planning cycle for APA CIP's management plan.

In 2015, the consultancy hired to design the management plan and to conduct the process invited for a first meeting to present the stages that would guide the process. This allowed to identify entry points to assess vulnerability and identify EbA measures within the regular planning processes. These topics were assisted by technicians of the Mata Atlântica Project, and by EbA experts trained by the project, coming from the APA CIP management team, ICMBio´s training centre ACADEBIO, local universities, and NGOs.

During the planning process, it was established that vulnerability to climate change should be considered during (I) thematic diagnosis meetings, (II) a specific workshop to discuss climate change and EbA, and (III) by including a specific chapter in the management plan on climate change and EbA.

During the thematic diagnosis meetings, the topic of climate change was introduced in a ludic and palatable way, pursuing not to divert attention of participants from the main topics of the meeting. Upon arriving, participants were asked to name perceived changes in climate and to identify geographical hotspots on a pin board. By these means, participants should start an individual and group reflection on the role that climate change already plays in their lives. Additional interactive questions during the meetings, including explanation of concepts with well-known tales, instigated participants to reveal their perception on climate change issues and to deliver a first diagnosis about how climate change already affects the local population's life.

However, the strong concentration of topics and activities in meetings with a duration of three to four hours caused exhaustion both for the participants as for the consulting team. Due to this reason, the last meetings only included climate change issues regarding the welcoming activity, and invited all participants to speak in-depth about this topic on the specific workshop.

For this topic-specific full-day workshop, held in May 2015, the main challenge was a strong lack of information regarding climate projections specific for the region. Therefore, it was decided to mainly base the workshop on people's perception, also considering that this is the main driver to increase acceptance on climate-related adaptation measures. Additionally, the workshop had a strong focus on capacity building, intending to create a common knowledge of understanding of climate change, ecosystem services and related terminologies. Although the invitation was open, mainly community leaders, researchers, representatives of the federal, state, and municipal administration, and members of APA CIP's management team participated on the event.

Following this logical path, the first thing that participants were invited to point out was, again, their perception of climate change signals. People were asked to signalize with coloured dots on a map of the APA CIP where they had already perceived specific climate signals.

The next step was a formal short presentation on what climate change is. Additionally, people were shown the short video "Como as Mudanças do Clima mudarão nossas vidas em 2050" ("*How climate change will change our lives in 2050*"; available via https://www.youtube.com/watch?v=0QoZ8hh8-Qg). Additionally, a presentation was held on climate change with a focus on the APA CIP region.

Following the terminology of climate change, the next step was to identify in maps areas where biophysical and socioeconomic impacts had been perceived. Again, coloured dots were used to mark the respective areas into maps (see Fig. 17.4). Subsequently, all three maps generated so far—regarding climate signals, biophysical, and socioeconomic impacts—were compared, pursuing to identify logical chains.

Having identified hotspots for climate change signals and impacts, the next step focussed on sensitizing participants on the concept of ecosystem-based adaptation. People were invited to reflect about the concept of ecosystem services and how these services influence their way of life on pin boards.

This introduction to the concept was key to allow participants to think about measures within the management plan to ensure their way of life. Moderators

Fig. 17.4 *Coloured dots* indicating socioeconomic impacts of climate change in the APA CIP during the workshop. *Source* Own picture

actively asked which nexus the measures had with identified climate change impacts and classified into four categories: conservation, restoration, sustainable use, and others. Finally, participants were invited to propose areas where selected EbA measures should be established within the context of the management plan.

A final plenary session allowed for reflection about the selected measures and how they could be considered in further steps. Participants and the consulting team reinforced the view that a special action programme on climate change should be included into the management plan, with a focus on ecosystem-based adaptation (Fluminhan Filho et al. 2015).

This programme was designed in the following weeks by the consulting team, with inputs by the technical team of the Mata Atlântica Project. Although following a similar model than the other programmes of the management plan, it was established that the climate change programme's actions should be transversal, in order to be considered in all activities and actions of the plan.

Methodology: The Case of the City of Duque de Caxias

According to Brazil's Institute for Geography and Statistics (IBGE 2014), the City of Duque de Caxias has almost 900,000 inhabitants, with an area of 467,62 Km^2. Located at the Guanabara Bay (see Fig. 17.5) and within the region of the Central

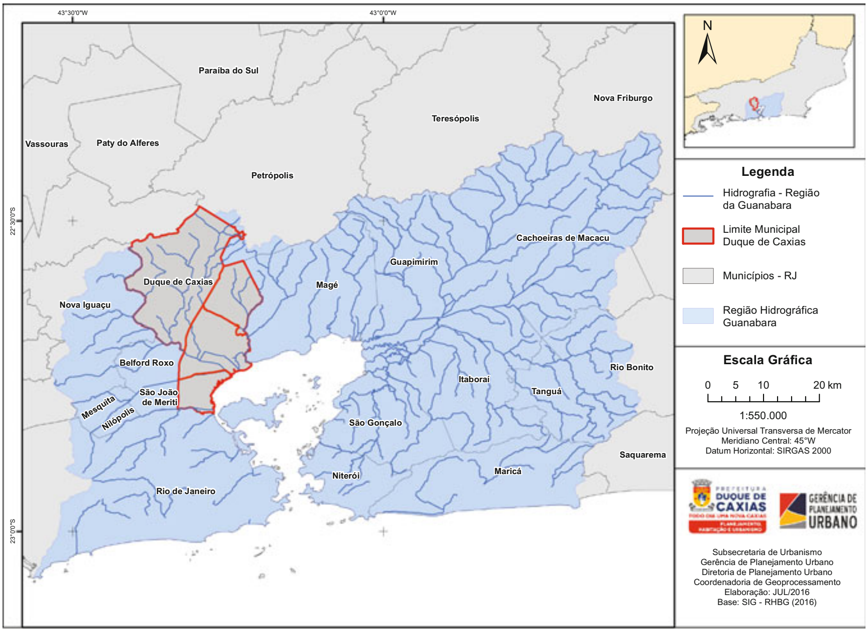


Fig. 17.5 Location of Duque de Caxias within the Guanabara Bay watershed. *Source* Own production

Fluminense Mosaic, it is part of the Metropolitan Region of Rio de Janeiro. From a geographical point of view, it displays a large variety, with a topography ranging between 0 and over 1000 m above sea level and over 50% of its area still under natural land cover.

From an economical point of view, Duque de Caxias has Rio de Janeiro State's second highest GDP, mainly based on petrochemical and logistical activities. Although having large parts of the population working in other cities, the city still experiences strong population growth, what translates into increasing illegal urban expansion. This fact already leads to a number of challenges, like a reduction of natural land cover, insufficient water provision and an increasing percentage of population vulnerable to climate change. An increasing number of flood events and progressive lack of potable water is a mayor challenge for the city administration.

Also considering these pressures, the Municipal Secretary for Planning, Habitation, and Urbanism (SMPHU) decided to implement a climate change vulnerability and ecosystem service assessment, as part of a larger land use appraisement for the municipality. This appraisement shall be the basis to establish a municipal Land Use and Land Occupation Law (*Lei de Uso e Ocupação do Solo*) and review the Municipal Master Plan (*Plano Diretor*) in 2016 and 2017.

After making a first meeting in April 2015 for a preliminary needs assessment, two staffers of the SMPHU were trained by the Mata Atlântica Project as EbA-Experts. In a follow-up coaching event, a detailed work plan to consider climate change and ecosystem services into municipal planning was jointly designed (see Fig. 17.6). This design started from the assumption that most secretariats within the municipal administration did not communicate with one another and that climate change could be a topic to discuss and tackle common challenges jointly.

From this starting point, the first large event was a 2-day workshop in June 2015 with representatives of eight municipal secretaries and other related institutions. One goal was to sensitize and train technicians on the importance of considering climate change and ecosystems in their daily work. This again also took place via capacity building, creating a common understanding on climate change, ecosystems and related terminology. Step two focused on identifying key sectors that are at risk due to climate change. This occurred by group work, where participants working in small groups first identified on maps of the municipal area where climate change already is happening, and then discussed how this eventually could (or already is) influencing different key sectors, mirroring the participatory approach used on the APA CIP management plan. Results were presented in the plenary and validated in open discussions. Finally, the results were considered to convincing that the workshop's participants decided to create an inter-secretary working group on climate change issues, pursuing to create capacities and to strengthen the dialogue on this issue. In order to make this working group's activities efficient, small groups worked on a diagnosis of the municipality's most pressing issues ("capacity development", "create a positive agenda", "communication") to be addressed to make climate change adaptation a priority issue in Duque de Caxias. These issues were defined as the thematic guidelines for the working group's further activities.

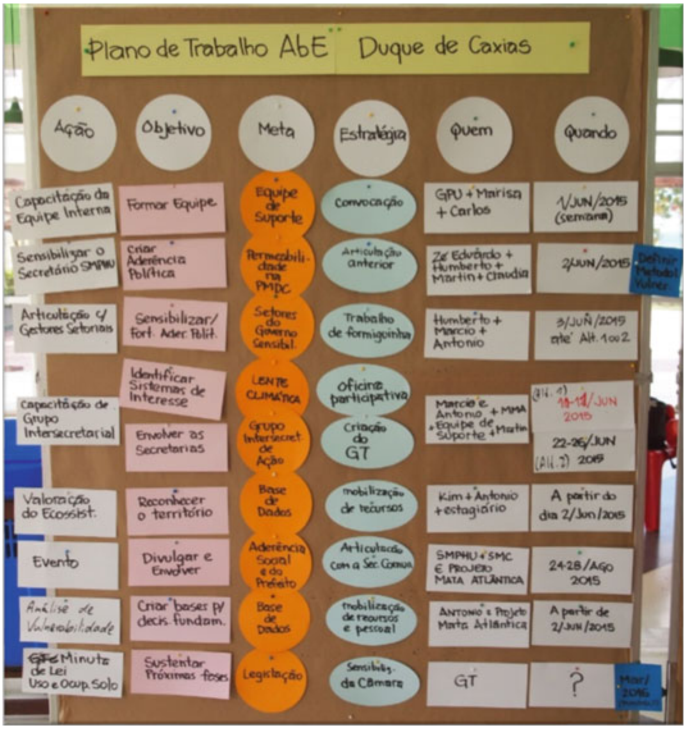


Fig. 17.6 Work plan for Duque de Caxias produced during the coaching event. *Source* Own picture

With a consultancy on ecosystem services mapping occurring afterwards, it was only in November 2015 that two workshops on participative vulnerability assessments took place in Duque de Caxias, pursuing to create a deeper understanding on how climate change creates vulnerability in the municipality. Following the inter-secretary working group's results, a first workshop to assess vulnerability to climate change took the whole area of the municipality into account, while a second workshop focused on the especially vulnerable district of Xerém.

Both workshops had as main goals (I) to understand the terminology of vulnerability, (II) to carry out a vulnerability assessment, focusing on key interest sectors and climate change impacts, and (III) to identify adaptation measures (with focus on EbA) to be considered in future municipal territorial planning.

Pursuing to flatten the level of information and knowledge, the first session of the workshops focused on recounting previous steps. A spotlight here was held on the already identified high-risk sectors and likely potential climate change impacts in Duque de Caxias. Furthermore, the photo documentation of previous works had been handed over to participants prior to the workshops via e-mail.

In order to achieve the workshops' first goal, a moderator introduced to participants via action learning on a pin board on the methodology of vulnerability.

This step proved to be essential, as the concepts presented here accompanied the participants during the whole working day.

Following the terminology of vulnerability, participants were then invited to identify in plenary key climate change signals affecting the city's territory. This information was then complemented and validated by the facilitating team, making use of publicly available quantitative climate data.

The inter-secretary workshop in May had identified four key sectors suffering potential climate change impacts for the municipality as a whole: "Irregular housing and adjacent areas suffering from floods", "Devaluation of areas increasingly suffering from floods and heat waves", "Loss and reduction of biodiversity (mangroves, forests)", and an "Increasing number of industries exposed to climate hazards." For the Xerém district, these impacts and sectors were "Climate Change impacting on industries, commerce, and their access ways", a "Reduction of water intake for different uses", "Mobility being affected by climate change and irregular occupation of land", and "Floods impacting on irregular land occupation."

Taking these potential climate change impacts and the before identified climate signals as starting points, participants—divided into small working groups—were invited to identify intermediate climate impacts that explained the link between the climate signals and the main climate impact. By this means, a first climate causal signal chain was created.

Continuing on the footsteps of the vulnerability terminology, participants were then asked to identify sensitivities that, jointly with climate signals, result in climate impacts. As a next step, they were invited to explore reasons leading to these sensitivities, what lead to a cause-effect relationship chain. These sensitivities were then mapped with coloured dots and markers on high-resolution maps of the respective area.

Having this panorama clear, working groups were invited to identify already existing adaptation capacity for identified exposure, sensitivity and potential climate change impacts.

Once finalizing the assessments, participants' final task consisted in pointing out possible adaptation measures to climate change, contributing to reduce exposure and sensitivity, or to increase the adaptive capacity. In this context, the moderating team actively motivated them to think on measures to conserve, restore or make sustainable use of ecosystems, following the EbA principles.

After each one of the mentioned steps, results (for an example, see Fig. 17.7) were presented to the plenary, seeking to have a transparent process, validated by all participants.

As final steps to conclude the vulnerability assessment in Duque de Caxias, the results were digitalized and handed over to all municipal secretaries as a photo documentation, together with step-by-step documentation of the used information and methodologies, pursuing by these means a high acceptance of their results. In addition, areas indicated by workshop participants as being sensitive to climate change were visited on-site, both to validate the result, and to log in the GPS coordinates, pursuing to have high-quality data for land-use planning.

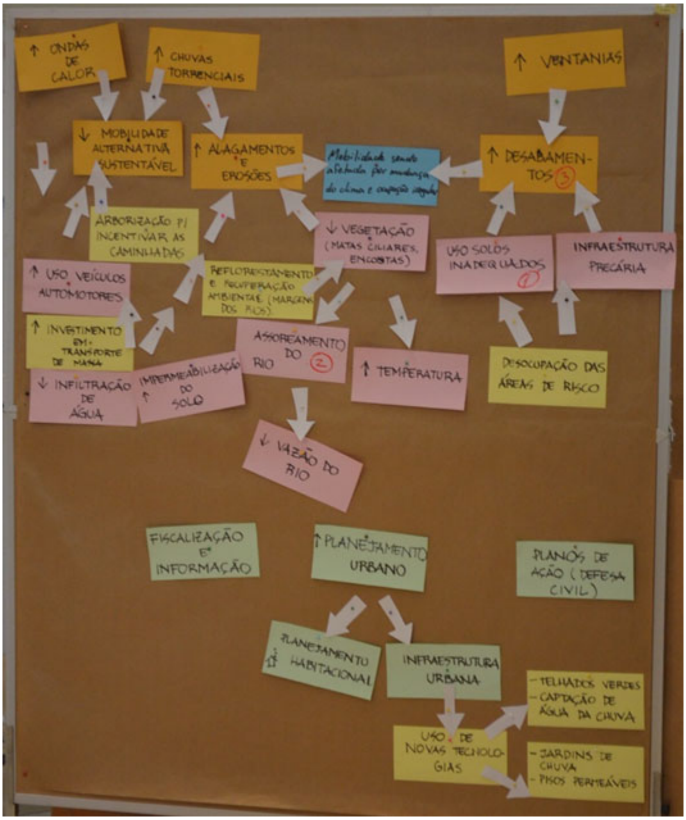


Fig. 17.7 Example for result of vulnerability assessment in the district of Xerém/Duque de Caxias. *Blue cards* represent potential primary impacts, *orange* exposure, *pink* sensitivity, *green* adaptation capacity, and *yellow* suggested adaptation measures. *Source* Own picture

Results and Discussion

This article described different methodologies used in different contexts. However, the number of two case studies only is also quite limited and can under no circumstances considered an overarching analysis. Despite this natural limitation, a more in-depth analysis allows to draw lessons learnt that mainly can contribute to draw pathways for practitioners' own application.

Both case studies presented in this article followed different approaches. As pointed out before, this has less methodological, but more reasons resulting on the set-up in which the vulnerability assessments were conducted: while in the case of APA CIP the suggested approach had to fit into an already existing planning process design, the main challenge in Duque de Caxias consisted in stakeholder engagement. From this point of view, also results and lessons learnt from both case studies are quite different.

The decision to consider climate change adaptation and EbA into APA CIP's management plan turned out to be a correct decision, giving additional consistency to the plan itself.

The perception of participants during the thematic meetings showed that it is common sense that climate change is already happening in the region. In addition, the information gained during these opportunities was a valuable input for the important workshop focusing on climate change and pursuing to deliver inputs to assess vulnerability. However, the climate-related sessions during these meetings took so much time that the consulting team decided by hindsight to reduce climate-related inputs to a minimum, in order to allocate enough time for other topics, as important to the management plan.

The workshop focusing on climate change vulnerability resulted to be essential to gain sufficient information to base adaptation decisions on a stable knowledge foundation. The intense participation of key stakeholders, which were empowered by receiving information and knowledge during the whole day increased acceptance that the outcomes were valuable.

However, the lack of high-value quantitative climate change information on the region was a major challenge, which could be partly overcome by the participants' perception on already happening climate effects, which confirmed available data.

In addition, the lack of formal knowledge of participants forced the moderators to include several inputs to leverage the understanding on climate change and ecosystem services. This additional effort proved to be effective, but also significantly cost time.

This lack of time also partially explains why this vulnerability assessment cannot be considered as being complete: both the existence of adaptation capacity and sensitivity was not fully and systematically explored, as it was the case in Duque de Caxias. Especially a thorough exploration for—eventually not even spatial—sensitivity to climate change and its drivers that eventually could be tackled with EbA-measures would have offered more consistency to the planning procedure.

On the spatial side, the decision to focus mainly on the area of the APA CIP to perform the vulnerability assessment proved not to be ideal. Both a sectoral approach and opening the analysis to areas outside the APA CIP would, on the one hand, opened the view for more challenges that are outside the governance of the natural area. By only analysing reasons for impact, the sole reason for sensitivity located outside de APA CIP were areas where agriculture was being performed in non-sustainable way, increasing the likelihood for erosion. On the other hand, having a larger geographical or sectoral scope would have shown the value of the area to deliver ecosystem services to tackle climate change impacts outside its dominion, increasing the acceptance for the protected area itself being considered an EbA measure.

From a process-oriented point of view, it would also have proven a promising strategy to engage in an early stage ICMBIO's central authority for management plans. Being this entity responsible to release the management plan, it decided to cut off substantial parts related to climate change from the plan's final version. Prior contact to sensitize about its meaning and opportunities would probably even have allowed for upscaling of these experiences within ICMBIO.

Also in the case of Duque de Caxias, the consideration of climate change and ecosystem services proved to be fundamental. It was not only important in order to understand how climate change already is and might impact on the territory and different sectors, therefore allowing to identify measures to reduce vulnerabilities. But it also proved an excellent topic to bring together experts and visions from different stakeholders to work together on common challenges. Additionally, the approach also served to reveal the natural richness of the municipality, contrasting with the vulnerability caused by its geographic location and territorial characteristics.

In this context, a systematic approach of human capacity development and identification of vulnerability proved to be right. The interest on the topic of climate change was confirmed by a relatively low fluctuation of participants, and results of workshops were not contested neither by participants nor by actors from outside.

On the other side, the difficulty to make key actors join the process can still be seen as a challenge. Especially the absence of the Secretary of Environment opened inquiries about the right approach for decisive stakeholders. However, this challenge is not restricted to this particular process and surely needs to be addressed via a broader stakeholder engagement strategy.

For both vulnerability assessments, having a capacity development strategy accompanying the process proved to be essential. It not only proved to be the key for increasing the quality of peoples' participation, but also to assure their ownership, while contributing to the results' sustainability. An especially positive effect was shown by the ludic—and not presentation-centred—training approach, tailored to participants' needs, what eased the learning and contributed to motivate the groups.

Conclusion

Both vulnerability assessments recounted in this article proved that it is a challenge to design appropriate methodologies for different contexts.

Lessons learnt show that key success factors are related to political will and to find the right momentum. The political will is necessary because the inclusion of a vulnerability assessment into a planning process requires additional financial, human, and time resources. To sensitize decision makers beforehand about the importance of considering climate change is therefore an important step. Sadly, climate change impacts already taking place now have proven to be an effective sensitization method. Therefore, sensitized decision makers mostly understand the positive cost-benefit ratio of considering climate change in planning processes. Further—quantitative—studies on this issue would, however, deliver additional arguments for decision makers.

In this context, it also proved that designing together with technicians on when to consider vulnerability to climate change in planning processes and with which intensity lowers the stress of planning teams. Planning teams usually work quite goal and process oriented, and a vulnerability assessment is still being considered a "nice to have", rather than a "must have". Lowering the conflict by introducing vulnerability to climate change as a cross-cutting, rather than an additional topic, increased the likelihood for it to be considered a topic of high-value. In this same line, it is not possible to say if it is more recommendable to speak about climate change and to assess vulnerability in a one-topic event, or to discuss it step-by-step together with other topics: it depends on the context and peoples' preferences.

However, lessons-learnt showed that the described ludic methodologies to focus people's experiences to determine climate change vulnerability, linked with capacity-building, revealed insights that quantitative desk-studies would not have produced. Additionally, instant validation within the plenary ensured a broad acceptance of the results, encouraging decision-makers to consider them in planning.

Finally, the language used to perform vulnerability assessments showed to be key to increase acceptance and participation on participative processes. A language that is as least technical as possible allows for all people to participate and usually does not reduce the quality of the final product.

However, the availability of high-quality quantitative data, including climate modelling, simplifies the process of the vulnerability assessment and increases the acceptance of the result among decision makers, technicians, and the population. While both vulnerability assessments described in this article had to be elaborated with little quantitative information, future assessments in the Brazilian Atlantic Forest will already start with half the work done, thanks to newly finished modelling of potential biophysical impacts of climate change, produced in the context of the Biodiversity and Climate Change in the Atlantic Forest Project.

Nevertheless, a final lesson learnt is the necessity to gain sufficient political backup from decision makers before and during the process to consider climate change adaptation into planning, pursuing both to ensure a good participation of key stakeholders and to endorse the results of vulnerability assessments.

The mentioned lessons learnt will be taken into account when performing additional vulnerability assessments in the project context. This will be necessary to revise a number of management plans of protected areas and to formulate Municipal Plans to Conserve and Restore the Mata Atlântica (*Planos Municipais de Conservação e Recuperação da Mata Atlântica*—PMMA) within the project area. By these means, these plans will be the framework to formulate and implement ecosystem-based adaptation measures. Also, already performed lessons learnt are a valuable input to start the implementation of Brazil's National Climate Change Adaptation Plan (*Plano Nacional de Adaptação*—PNA), which has been released in May 2016 and calls for urgent climate adaptation action.

References

Alcamo J et al (2003) Millennium ecosystem assessment—ecosystems and human well-being: a framework for assessment. Island Press, Washington

Fluminhan Filho, M, Coffani-Nunes JV, Barragana Fernandes M, Jankowski M, Brito Da Paixão RK, Viezzer J, Deitenbach A, Becher M, Hach L, Betti P Brochado Alves Da Silva R (2015) «A Inserção da Mudança do Clima e Adaptação baseada em Ecossistemas no Plano de Manejo da APA Federal de Cananéia-Iguape-Peruíbe (APA-CIP)». VII Seminário de Áreas Protegidas e Inclusão Social. Florianópolis, Brazil

Fritzsche K, Schneiderbauer S, Bubeck P, Kienberger S, Buth M, Zebisch M, Becker D (2014) The vulnerability sourcebook. Concept and guidelines for standardized vulnerability assessments. GIZ, Bonn and Eschborn

Pachauri RK, Reisinger A (eds) (2007) Contribution of Working Groups I, II and III to the fourth assessment report of the intergovernmental panel on climate change. IPCC, Geneva

Chapter 18
"Córrego d'Antas—The Power of Union": A Film to Strength the Culture of Risk Management for Climate Change Adaptation at Córrego d'Antas, Nova Friburgo, RJ, Brazil

Leonardo Esteves de Freitas, Tomás Coelho Netto Duek, Yan Navarro and Ana Luiza Coelho Netto

Introduction

Gravitational mass movements are natural phenomena in mountainous regions of Southereastern Brazil, and chrono-stratigraphic evidences in the state of Rio de Janeiro indicate their occurrences since the Pleistocene-Holocene transition, around

L. Esteves de Freitas (✉)
Laboratory of Geo-Hydroecology at Geography Department, Federal University of Rio de Janeiro and Oswaldo Cruz Foundation (FIOCRUZ), Rio de Janeiro, Brazil
e-mail: leonardofreitas73@gmail.com

T.C.N. Duek
Laboratory of Geo-Hydroecology at Geography Department, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil
e-mail: tomascoelhonetto@gmail.com

T.C.N. Duek
Master Student on Civil Defense, Federal Fluminense University, Niterói, Brazil

Y. Navarro
Colégio Pedro II and Center for Studies and Research Audio-Visual in Geography, Rio de Janeiro, Brazil
e-mail: yannavarro@gmail.com

Y. Navarro
Geography, State University of Rio de Janeiro, Rio de Janeiro, Brazil

This article was made possible due FAPERJ's financial support from and a post doctoral fellowship from CAPES.

W. Leal Filho and L. Esteves de Freitas (eds.), *Climate Change Adaptation in Latin America*, Climate Change Management,
https://doi.org/10.1007/978-3-319-56946-8_18

10,000 ago, when the climate changed from wet and cold to wet and warmer conditions (Coelho Netto et al. 2015).

The authors above point that the lack of rational land use planning and management in the last century led to spread the population onto steep slopes and valley bottoms in the upper mountain areas.

These areas are expected to be susceptible to shallow landslides and debris flows hence large amounts of coarse debris downvalley, in response to extreme rainfall events, particularly during the rainy summer season (Coelho Netto et al. 2014).

The Brazilian Panel in Climate Change and the Intergovernmental Panel on Climate Change Reports are unanimous in revealing that Brazil already have climate change records provided by climate models. They showed increase temperature up to 2.5 °C in the coastal region of Brazil between 1901 and 2012 and increase number of days with over 30 mm rainfall in Southeast (MMA 2015).

While the frequency of rainfall below 20 mm/day is dropping in Southeast Brazil, extreme rainfall totals above 100 mm/day are increasingly more frequent towards to late 1990s (Figueiró and Coelho Netto 2011).

The increase in frequency of extreme rains in Southeastern Brazil was observed by many others authors (Groisman et al. 2005; Marengo et al. 2009; PBMC 2012). This elevation in frequency—probably associated to the recent process of climate change—make the landslides more likely to occur.

In fact, the data indicate a significant increase of mass movements related disasters and their consequences between 1991 and 2010, especially in Southeastern Brazil where there were 81.7% of total brazilian cases (UFSC 2012). The state of Rio de Janeiro was the hardest hit, with 418 official deaths in 505 landslide events in the same period (UFSC 2013).

These data are still modest. They do not include any data from the so-called "Mega disaster of Rio de Janeiro state" (DRM 2011) occurred in the mountains during the very extreme rainfall of January 2011: "*This catastrophic event caused thousands of landslides in the municipalities of Nova Friburgo, Teresópolis and Petrópolis. Extensive debris flows propagated throughout the main valley bottoms, reaching down valley municipalities of the middle Paraíba do Sul river valley* (Coelho Netto et al. 2014)" (in Freitas et al. 2016, p. 314). It is estimated that more than 900 people died and that 350 went missing (Bertone and Marinho 2013).

This event showed an increase in the magnitude of extreme rainfall induced landslides in the mountainous region of Rio de Janeiro state. However, one observes an increasing risk level associated to landslide hazards as the previous

Y. Navarro
Didactic of Social Sciences, University of Valencia, Valencia, Spain

A.L.C. Netto
1A-CNPq and Geo-Hydroecology Laboratory, Geography Department, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil
e-mail: ananetto@acd.ufrj.br

2011 catastrophic disaster left behind quite strong vulnerable socioenvironmental conditions that still prevail nowadays.

The accelerated changes in land use, especially regarding a disorderly expansion of urban areas, potentialize the occurrence of socioenvironmental disasters[1] that can lead to numerous deaths yet (Freitas and Coelho Netto 2016).

Most of people usually ignore these information and think mass movement is not recurrent (Ribeiro 1995; Freitas and Coelho Netto 2016). So they are not concerned about that. It is necessary to get them more involved on the matter of natural hazards and risks, to create a new disaster culture on society. Sociocultural benchmarks can induce preparedness actions to disasters or failure of policies that will compromise the subsequent response in a crisis situation (Ribeiro 1995).

RIMAN-CD

Córrego d'Antas watershed (54 km^2) was one of the most affected areas by landslides in the municipality of Nova Friburgo in January 2011 (Coelho Netto et al. 2011). Many depths took place in there.

In this context, the development of a network for the coordination of institutions and communities dedicated to disaster-related risk management may produce better results than simply strengthening formal management structures (Comfort 2005).

Such strategy becomes even more relevant in a context of climate change, which demands that populations in risk areas adapt to extreme events since these tend to become more frequent and intense.

Therefore, developing and implementing public policies dedicated to disaster management that include an actual level of participation of populations in risk areas, as well as building a culture of disaster management that introduces such discussion in the daily lives of governments and the population, is necessary.

However, despite the recurrence of mass movements and their intensification in association to climate change, the culture of disaster management among the populations in the mountains of Rio de Janeiro is still incipient, and public policies dedicated to the issue have been including a small level of participation, even after the mega disaster of 2011 (Freitas and Coelho Netto 2016).

This perspective was the basis for the development of the Córrego d'Antas Risk Management Network (RIMAN-CD), comprised of a group of institutions and communities in the Córrego d'Antas drainage basin (53 km^2), in the municipality of Nova Friburgo, in the state of Rio de Janeiro (Freitas et al. 2016).

[1]Freitas and Coelho Netto (2016) have defined "Socio-environmental Disaster" as natural phenomena that cause losses and environmental damage, including in this term human values, economic, political and nature. It is noteworthy, however, that despite the natural threats, the society also interferes on a magnitude of a disaster when the society modify landscape without rationality. On the other hand, the magnitude of disaster is also a function of vulnerability of different actors from society to natural phenomena, resulting essentially socio-environmental disaster.

This network has the mission "*To promote the association of knowledge from public, private and community organizations to reduce geo-hydrological risks*" (Freitas et al. 2016, p. 322).

Therefore, RIMAN-CD goal is to influence the formulation and implementation of participatory public policies dedicated to the management of socioenvironmental disasters, as well as strengthening the disaster-management culture in the mountains of the state of Rio de Janeiro.

Production of the Film

The network collectively decided on the production of a socioeducational film dedicated to making people aware of the problem and expanding the disaster-related risk-management culture in the context of climate change (Freitas and Coelho-Netto 2016).

The representation of risk depends on the sources of information the individual or the group lean toward and the perception of vulnerability concerning such risks. That is, people choose their sources of information based on cultural relevance, their motivations, personal concerns and knowledge (Kuhnen 2009).

The management of risk areas starts when the society (or at least part of it) understands that apparent or effective expressions of danger can cause dangerous consequences (Nogueira 2002). Therefore, risk management relates to a decision-making process that includes establishing needs, recognizing acceptable options and choosing adequate strategies (Tobin and Montz 1997).

The development of materials capable of making the society aware of the need to manage disaster risks in areas that are highly susceptible to mass movements is greatly important, especially in a context of adaptation to climate change in which the susceptibility to such phenomena tends to increase. Film is one of these tools and has a great capacity of producing awareness.

The central goal of this paper is discussing the institutional process of collectively developing the film within RIMAN-CD as a means to producing awareness regarding disaster-related risk management linked to mass movements and the adaptation to climate change.

Materials and Methods

The fundamental basis for this paper and for the development of RIMAN-CD is the idea of integrating research and action, defined as participant research in which the understanding of a scientific object of study derives from practice (Ketele and Roegiers 1993; Engel 2000).

Following this approach, it was necessary to establish a dialogue with people living in the territory, especially through neighborhood associations and students of a local school to get them involved in the video production. It becomes mandatory interaction between scientific and popular knowledge to act on the reality. Therefore, this work has followed the concept of Knowledge Ecology, as formulated by Santos (2006), as part of the dialogue between diverse knowledge sources, to which different values are assigned by society, but from a horizontal relationship between this knowledge, in which the value assigned to them is equivalent.

Study Area

The Córrego d'Antas drainage basin (53 km^2) was strongly affected by landslides in 2011, is located in the municipality of Nova Friburgo—in the mountains of Rio de Janeiro—and has a topographic variation of around 1500 m (Fig. 18.1).

This is a pilot area for the Geoheco-UFRJ laboratory, which is dedicated to researching the mechanisms and determinants of mass movements, seeking to methodologically improve the development of susceptibility and risk maps. It should be mentioned that, in the balance of risks, the vision and the perspective of the population under risk should be included.

At the Córrego d'Antas drainage basin there is a prevalence of man-made vegetation, especially grasses. Slopes and valley floors include agricultural areas; urban areas spread on valley floors, especially in the lower part of the drainage basin.

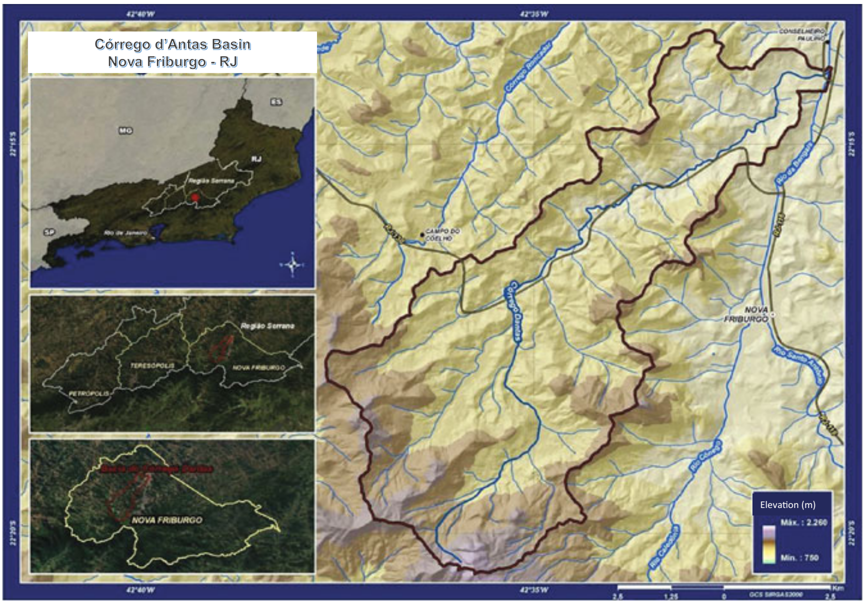


Fig. 18.1 Location of the Córrego d'Antas drainage basin. *Source* Ervatti et al. (unpublished)

Video Production

Firstly, the systematization form of registration included tools such as participant observation, documental and bibliographical analysis. Information was collected in reports on previous seminars and workshops produced by RIMAN-DC regarding the Network development and the film production.

The researchers have direct, frequent and prolonged contact with the video producers. It was a dynamic process in which researchers were at the same time, responsible for the gathering of information that make up this work and the interpretation and analysis of information.

Based on this experience and research, an analysis focused on the interinstitutional relations that made the development of the film possible—from the financing of the process, to the actual establishment of its production, to our presence in the workshops and shootings—was carried out. Moreover, the ensuing conceptual discussion on climate change and its link to the risk of mass movements and the management of such risks within a network of institutions and communities that promotes communities as the main actors in such management was also evaluated.

Results and Discussion

The development of the film did not begin only during the workshops or the shootings, it started almost a year prior to that, soon after the formal creation of Ou RIMAN-CD, on November 17, 2014. The film was collectively coordinated and produced through a process that sought to strengthen RIMAN-DC as a network of institutions and communities, which corroborates Comfort's (2005) idea on the relevance of the development of networks that involve both specialists and the people directly affected or under risk of disasters, so these disasters can be better managed.

On December 2014, the representative of Fiocruz's Center for the Study and Research of Health Emergencies and Disasters (CEPEDES, headed by Dr. Carlos Machado de Freitas) passed on a (R$60 000,00 or US$18,000,00 aprox.) donation of *Deloitte Touche Tohmatsu* for the activities of the network.

It was collectively established—during a seminar on March 2015—that the resources would be used in the production of a film that addressed disasters, in order to strengthen the disaster-management culture in a context of climate change. Such decision related to the existing consensus within RIMAN-CD regarding the need to improve the discussion on disaster management in the mountains of the state of Rio, which improved after 2011, but is still considered incipient by the network, corroborating Freitas and Coelho Netto's conclusions (2016).

The relevance of introducing new sources of information in the daily lives of the people living in risk areas in the mountains was addressed since it motivates people to be concerned with the management of disasters (Kuhnen 2009). The development of the film should be understood as an opportunity of disseminating a new and powerful source of information for the population in the area.

It was established that the film should be produced with the participation of the local youth in order to raise awareness among a part of the communities that remain distant of the discussion.

A commission of RIMAN-CD representatives that were interested in contributing with the initiative was established for the work to begin.

This commission gathered in April 23, 2015, at the Federal University of Rio de Janeiro (UFRJ), with the presence of representatives from five institutions or groups: Colégio Pedro II (CPII), Geoheco/UFRJ, UFRJ's Polytechnic School, the Oswaldo Cruz Foundation and the NGO Vivario. That was the moment to establish the institutional methodology and an initial agenda for the production of the film.

This first moment allowed the goal of the film to be established: making the people in the mountains aware of the discussion on disaster management, showing that these events are natural and recurrent in the region, as shown by Coelho Netto et al. (2015), and that they tend to get worse in a context of adaptation to climate change in which extreme precipitation events—and, consequently, mass movements—tend to become more frequent and intense. However, the contents of the film were not defined at that moment, only the goal in what relates to RIMAN-CD's objectives.

Through an articulation carried out by the Córrego d'Antas Neighborhood Association (AMBCD), in May 2015, a representative of Geoheco-UFRJ contacted Etelvina Schottz State School (E.E. Etelvina Schottz), located at the drainage basin of Córrego d'Antas, to select students that may be interested in the project. A selection was carried out with the support of the school. At first, nine students showed interest. However, since it took long for the resources to come through, when the work was about to start, four months after the students were selected, only three of them were able to participate.

Therefore, the documentary was produced by three youths of E.E. Etelvina Schottz and three youths of the CPII's Center for the Audiovisual Research and Study of Geography (NEPAG)—who had previous experience in film production. They were supervised by CPII and VivaRio teachers, and with the executive production of a member of the Fluminense Federal University (UFF) and UFRJ's Geoheco. It also included a process of institutional articulation with members of Geoheco-UFRJ, AMBCD and Fiocruz (Table 18.1).

The initial workshop for the development of the film took place on September 26, 2015, with 16 participants from six institutions: four from NEPAG/CPII, three from E.E. Etelvina Shottz, two from NGO VivaRio, three from AMBCD, two from Fiocruz and two from UFRJ's Geo-Hydroecology Laboratory (Geoheco). Then, the participants were introduced, the goals of the film was discussed and an agenda of work was established.

The second workshop took place on January 12, 2016, with 11 participants from six institutions: five from NEPAG/CPII, two from E.E. Etelvina Schottz, two from NGO Vivario, one from the UFRJ's Geo-Hydroecology Laboratory (Geoheco) and one from UFF. AMBCD contributed by allowing their Cultural Center to be used.

Table 18.1 Institutions participating directly in the production of the film at different moments and at different

Institutions	Functions in the project	Presence					
		2015			2016		
		03/13	04/23	09/26	01/12	02/04	03/11
Center for the Study and Research of Health Emergencies and Disasters from Fiocruz	General idea of the film's development process	x	x	x	–	–	–
	Institutional articulation						
	Raising resources and rendering of accounts						
	Dissemination						
Geo-Hydroecology Laboratory from UFRJ	General idea of the film's development process	x	x	x	x	x	x
	Political-institutional articulation						
	Support to production						
	Selection of students						
	Support to the training of participants						
	Executive production						
	Dissemination						
Federal Fluminense University	Executive production	x	–	–	x	x	x
	Dissemination						
Polytechnic School/UFRJ	General idea of the film's development process	x	x	–	–	–	–
Center for the Audiovisual Research and Study of Geography/Pedro II School	General idea of the film's development process	x	x	x	x	x	x
	Institutional articulation						
	Support to the training of participants						
	Directing						
	Editing and camera						
	Screenwriting and camera						
	Editing and shooting						

(continued)

Table 18.1 (continued)

Institutions	Functions in the project	Presence					
		2015			2016		
		03/13	04/23	09/26	01/12	02/04	03/11
Córrego d'Antas Neighborhood Association	General idea of the film's development process	x	–	x	–	–	–
	Political-institutional articulation						
	Support to the training of students						
	Support to production						
Etelvina Schotzz State School	Support to the selection of students	–	–	x	x	x	x
	Camera						
	Dissemination						
NGO Vivario	General idea of the film's development process	x	x	x	x	–	–
	Support to the training of participants						
	Text formatting						
	Audio						
Deloitte Touche Tohmatsu	Financing	–	–	–	–	–	–

This workshop started with a presentation from the members of Geoheco on the mega distaster of 2011 in the mountains of Rio de Janeiro, focusing on the Córrego d'Antas drainage basin and the creation of RIMAN-CD as an alternative to the integrated management of disaster risk, which includes specialists in disasters, the government and the community (Freitas et al. 2016). Climate change was considered crucial to understanding the recurrence of extreme precipitation events and the need for the population to adapt to it.

Afterwards, there was a presentation from Viva Rio's technicians—in a discussion with CPII teachers—on the process of developing a film. In this context, the role of film as an alternative source of information for the population of the mountains of Rio de Janeiro—and, consequently, the role of this work to motivate and make people aware of the need for disaster management—was addressed. This is fundamental for the issue to gain space in the regional agenda (Kuhnem 2009).

In the afternoon, the script and the following steps to be taken were established.

The third and fourth workshops—February 4 and March 11, 2016, respectively —were also carried out at AMBCD's Cultural Center, but also visited other areas at the Córrego d'Antas drainage basin. Both had seven participants from the four institutions participating directly in the technical production of the film: four members from NEPAG/CPII, two from E.E. Elevina Schottz and one from UFRJ's Laboratory of Geohydroecology (Geoheco) and from UFF.

These last two workshops focused on the actual process of producing the film, such as writing the script and training participants in filming, as well as the actual shootings. Based on semi-structured scripts, participants interviewed people from the drainage basin and key actors in the management of disaster risk, both technicians and members of the community. They also shot relevant elements for discussing disasters, such as slope stabilization works, homes destroyed by previous disasters, etc.

That was a special moment for discussing disaster management in the group that produced the video. While doing the work, these youths got in contact with new sources of information and awareness for disaster management. Since the management of risk areas depends on the perception that a certain risk or threat can cause serious consequences (Nogueira 2002), the process made these youths multiplier agents of this discussion.

Besides these workshops, there was the shooting of interviews and other important elements for the film without the participation of all participants. However, in these cases, the shootings were based on the collectively-established script, which included such activities.

Another important element for the collective production of the film was the WhatsApp group, which assured a constant exchange of information among the participants more directly involved in the production of the video. In fact, the title of the film (**Córrego d'Antas: the power of union**) was decided in the group after a discussion occurred during the workshops.

Based on Table 18.1, one can observe that the documentary directly involved a total of nine institutions. Eight of them are members of RIMAN-CD and carried out different functions on different levels, from promoting institutional articulation and raising resources to operating cameras, each using the human and material resources they had at hand, directly receiving no extra financial resources. The private company, Detoile, did not participate directly in the film and, therefore, was not in any meeting, but made resources available, which were directly used in for the film production of the, fulfilling the financial needs that could not be met by any of the institutions in RIMAN-CD.

The number of institutions attending the meetings during the film production varied according to the goal of each meeting. In the first meeting, seven out of the eight institutions participated. The process reduced the burden on some RIMAN-CD members as the political-institutional articulation became unnecessary, allowing the coordinators of the Network to carry out other tasks.

Moreover, such reduction in the participation of the institutions allowed an increasing participation of the youths in the development of the film, since the technical execution of the project was their responsibility. Therefore, the final result expresses what these youths learned from the discussions occurred during the workshops and meetings on RIMAN-CD and on disaster management in a context of climate change, which tends to increase the risk of mass movements.

Launching and Disseminating the Film

After the production of the video, the articulation with the institutions and communities to disseminate the video for the community at Córrego d'Antas and other institutions and communities in the mountains of Rio de Janeiro had to be reestablished.

Once again, RIMAN-CD and AMBCD played a fundamental role in the process. The first step was the launch of the film in a Folk Party (a typical Brazilian celebration taking place in the middle of the year) (Fig. 18.2) at the community of the Bairro de Córrego d'Antas in a partnership with people from other neighborhoods in the Córrego d'Antas drainage basin and with RIMAN-CD institutions.

The party took place on July 30, 2016 and was organized by the community to celebrate the launch of the film and other RIMAN-CD actions (especially the creation of a network of amateur radio communications among dwellers of all neighborhoods within the Córrego d'Antas drainage basin). Since it was organized by the communities and by RIMAN-CD, the party had a great impact. More than two hundred people from all the neighborhoods in the Córrego d'Antas drainage basin and from the institutions that make up RIMAN-CD participated.

The video gained a significant level of exposure in the party, which effectively impacted the development of a culture of disaster management and adaptation to climate change. Afterwards, the communities that organized the party and RIMAN-CD's institutions disseminated the film in their partner networks, producing a very broad dissemination process, which was still in course when this paper was written. Agencies of the municipal government of Nova Friburgo, such

Fig. 18.2 Folk party during the presentation of the film "Corrego d'Antas: A Força da União" in July 30, 2016

as the Secretaries of Civil Defense, Education, Environment and Health, as well as schools and neighborhood associations still played a fundamental role for the local and regional dissemination of the film. Research and education institutions, NGOs and neighborhood associations play a major role in the regional and national dissemination of the film. Therefore, the film has been disseminated by many more than the nine institutions directly involved in its production, which expands RIMAN-CD's network character.

Final Remarks

The development of the video was institutionally collective, indirectly involving the 21 institutions and the seven communities in Reger-CD and directly involving nine of these institutions. The final product was able to produce an institutional discussion.

Even so, it was made by the youths that developed it since the technical production of the video was their responsibility.

During the process, the dissemination of a culture of disaster risk management in a context of adaptation to climate change was observed in Reger-CD's institutions, such as E.E Etelvina Schottz and CPII.

Moreover, youths are disseminating this culture to the families within the Córrego d'Antas drainage basin. The training of these youths influenced their relatives, increasing their level of awareness concerning the risk they are under and their resilience regarding future disasters. Consequently, it also contributed to the adaptation of this population to climate change by reducing their vulnerabilities to mass movements. After all, risk management is directly related to the population in risk areas having decision-making mechanisms. Consequently, it depends on how risk-related needs are defined, on the recognition of acceptable options and on choosing adequate strategies (Tobin and Montz 1997). Therefore, it also depends on the knowledge on disasters and on a disaster-management culture that constantly fosters discussion and the development of such strategies.

It could be observed that, through the process of filming and editing the film, the issue became an issue for the youths, so the production itself of the film already contributed for an improvement in the culture of disaster risk management.

The informality and playfulness of the workshops contributed to an effective and curious level of participation, which delighted participants causing a desire to know and to experience to emerge.

Córrego d'Antas: the power of union became a fundamental element in the dissemination of the issue for the institutions comprised in Reger-CD and for the communities in the mountains of Rio de Janeiro, which decisively contributes to increasing the level of adaptation of these communities to climate change and its consequences.

Acknowledgements To FAPERJ/Fundação Carlos Chagas Filho de Amparo à Pesquisa do Estado do Rio de Janeiro and to CAPES/Coordenação de Aperfeiçoamento de Pessoal de Nível Superior for the Post Doctoral fellowship of the first author.

References

Bertone P, Marinho C (2013) Gestão de riscos e resposta a desastres naturais: a visão do planejamento. Anais do VI Congresso CONSAD de Gestão Pública, Brasília, p 27

Coelho Netto AL, Sato AM, Freitas LE (2015). Land use-vegetation-landslide interactions in the mountainous region of Rio de Janeiro State: scientific basis for risk assessment and management. Anais Regional Conference of International Geographical Union. Moscow

Coelho Netto AL, Avelar AS, Sato AM, Fernandes MC, Oliveira RR, Costa RVC, Barbosa LS, Lima PHM, Lacerda WA (2014) Landslides Susceptibility and Risk Zoning at Angra Dos Reis, Rio de Janeiro State, SE-Brazil: a quali-quantitative approach at 1:5000 scale. In: Willy Alvarenga Lacerda; Ennio Marques Palmeira; Ana Luiza Coelho Netto; Maurício Ehrlich. (Org.). Extreme Rainfall Induced Landslides: an international perspective vol 1, 1st edn. Oficina de Textos, São Paulo, pp 262–296

Coelho Netto AL, Sato AM, Avelar AS, Vianna LG, Araújo I, Ferreira DLC, Lima PH, Silva APA Silva RP (2011). January 2011: the extreme landslide disaster in Brazil. Proceedings of the Second World Landslide Forum, 3–7, Rome, Italy

Comfort LK (2005) Risk, security, and disaster management. Annu Rev Polit Sci 8:335–356. doi:10.1146/annurev.polisci.8.081404.075608

DRM-RJ (2011). Megadesastre da Serra, disponible. http://www.drm.rj.gov.br/index.php/downloads/category/13-regio-serrana/download=48%3Amegadesastre-daserrajan-2011-pdf

Engel GI (2000) Pesquisa-ação. Educar, n. 16, pp 181–191. Curitiba Editora da UFPR

Figueiró AS, Coelho Netto AL (2011) Climatic variability and pluviometric trends in a humid tropical environment at Resende municipality- middle Paraíba do Sul river valley (Rio de Janeiro- Brazil). Braz Geogr J 2:256–273

Freitas LE, Coelho-Netto AL (2016) Reger Córrego Dantas: uma ação coletiva para enfrentamento de ameaças naturais e redução de desastres socioambientais. Ed Massangana, Rio de Janeiro. Ciência and Trópico, vol 40.1, pp 165–190

Freitas LE, Sato AM, Carvalho NL, Schottz S, Coelho-Netto AL (2016) Community, University and Governmental interactions for disaster reduction in the mountainous region of Rio de Janeiro, SE, Brazil. In: Filho WL, Azeiteiro U, Alves F (eds) Community, University and Governmental interactions for disaster reduction in the mountainous region of Rio de Janeiro, 1st edn, pp 313–328 (in press)

Groisman PY, Knight RW, Easterling DR, Karl TR, Hegerl GC, Razuvaev VN (2005) Trends in intense precipitation in the climate record. J Clim 18:1326–1350

Ketele J, Roegiers X (1993) Méthodologie du recueil d’informations: fondements de méthodes d’observations de questionaires, d’interviews et d’étude de documents, 2nd edn. De Boeck Université, Bruxelles, p 99

Kuhnen A (2009) Meio ambiente e Vulnerabilidade. A percepção ambiental do risco e do comportamento humano. http://www.ceped.ufsc.br/wp-content/uploads/2014/07/meio_ambiente_e_vulnerabilidade_a_percepcao_ambien

Marengo JA, Jones R, Alves LM, Valverde MC (2009) Future change of temperature and precipitation extremes in South America as derived from the PRECIS regional climate modeling system. Int J Climatol 15:2241–2255

Ministério do Meio Ambiente - Grupo Executivo do Comitê Interministerial de Mudança do Clima (2015) Plano Nacional de Adaptação à Mudança do Clima, Volume I: Estratégia Geral, Versão Consulta Pública. Brasília, p 67

Nogueira FR (2002). Gerenciamento de riscos ambientais associados a escorregamentos: contribuição às políticas públicas municipais para áreas de ocupação subnormal. Tese de Doutorado. Universidade Estadual Paulista, 260 pp
Painel Brasileiro de Mudanças Climáticas (2012). Sumário Executivo do Volume 1 - Base Científica das Mudanças Climáticas. Contribuição do Grupo de Trabalho 1 para o 1 o Relatório de Avaliação Nacional do Painel Brasileiro de Mudanças Climáticas. Volume Especial para a Rio+20. PBMC, Rio de Janeiro, Brasil, p 34. ISBN 978-85-285-0208-4
Ribeiro MJ (1995) Sociologia dos desastres. In: Revista Sociologia – problemas e práticas, n.18. CIES/ISCTE
Santos BS (2006) A gramática do tempo: para uma nova cultura política. Cortez, São Paulo
Tobin GA, Montz BE (1997) Natural hazards: explanationand integration. The Guilford Press, New York, p 388
Universidade Federal de Santa Catarina/Centro Universitário de Estudos e Pesquisas sobre Desastres (2012) Atlas brasileiro de desastres naturais - Volume Brasil. Florianópolis, 94 pp
Universidade Federal de Santa Catarina/Centro Universitário de Estudos e Pesquisas sobre Desastres (2013) Atlas brasileiro de desastres naturais - Volume Rio de Janeiro. Florianópolis, 120 pp

Chapter 19
Strategic Management to Strengthen the Lifestyles of Traditional Communities Towards Climate Change Adaptation: The Advisory Role Regarding Strategic Management of the Observatory for Sustainable and Healthy Territories (OTSS)

Leonardo Esteves de Freitas, Cinthia Cristo, Cristiano Lafetá, Érica Mazzieri, Marcela Cananea, Pedro Chaltein, Vagner do Nascimento and Edmundo Gallo

Introduction

Adaptation to climate change necessarily involves questioning the hegemonic mode of production and consumption, which is responsible for the form of development that causes climate change and its negative social and environmental impacts, concentrates wealth in the hands of a few—even though its consequences affect the

This article presents part of the results of the following projects: (1) Sustainable Territories and the Promotion of Equity and Health in Traditional Communities of the Bocaina Mosaic; (2) Sustainable and Healthy Territories: a sewage treatment system for the Caiçara Community of Praia do Sono, in the municipality of Paraty, Rio de Janeiro, both funded by Open Call 2/2012 of the National Health Foundation—Funasa; and (3) Observatory of Sustainable and Healthy Territories of Bocaina, funded by Cooperation Agreement 75/2013 between Funasa and the Oswaldo Cruz Foundation.

L. Esteves de Freitas (✉)
Laboratory of Geo-Hydroecology at Geography Department, Federal University of Rio de Janeiro and Oswaldo Cruz Foundation (FIOCRUZ), Avenida Athos da Silveira Ramos 149 - Ilha do Fundão CCMN, Sala H1-015, Rio de Janeiro CEP 21941-909, Brazil
e-mail: leonardofreitas73@gmail.com

C. Cristo · C. Lafetá · É. Mazzieri · P. Chaltein
Oswaldo Cruz Foundation (FIOCRUZ), Rua Araponga – no 502, Gleba 01, Lt 16-A, Caborê - Paraty, Rio de Janeiro CEP 23970-000, Brazil
e-mail: cinthiacristo@gmail.com

W. Leal Filho and L. Esteves de Freitas (eds.), *Climate Change Adaptation in Latin America*, Climate Change Management,
https://doi.org/10.1007/978-3-319-56946-8_19

entire global population, especially the most vulnerable populations, which are exposed to climate-related risks (Magrin et al. 2014).

Solving or reducing such problems will require that counter hegemonic modes of development—based on human well-being, cooperation and solidarity—are stimulated, strengthened and disseminated. Only by promoting sustainable ways of life that help mitigating and adapting to climate change, it will be really possible to place sustainability at the core of human development.

In line with that perspective—although not explicitly including a critique of capitalism,—the United Nations document "*Transforming our world: The 2030 Agenda for Sustainable Development,*" already considers the transformation of unsustainable modes of production and consumption as fundamentally necessary. "*We commit to making fundamental changes in the way that our societies produce and consume goods and services. Governments, international organizations, the business sector and other non State actors and individuals must contribute to changing unsustainable consumption and production patterns, including through the mobilization, from all sources, of financial and technical assistance to strengthen developing countries' scientific, technological and innovative capacities to move towards more sustainable patterns of consumption and production"* (ONU 2015, p. 10).

On the other hand, those with great social power trust that technology will be capable, on its own, of solving these problems, changing the current hegemonic model of development into a sustainable one. However, those opposing the hegemonic order doubt that such model will be capable of fighting environmental and social problems, since it itself is responsible for such problems. They consider it crucial to change the current mode of production and consumption: "(...) *sustainable societies can only exist if production and consumption structures are changed*

C. Lafetá
e-mail: cristiano.lafeta@gmail.com

É. Mazzieri
e-mail: ericamazzieri@gmail.com

P. Chaltein
e-mail: pedro.chaltein@gmail.com

M. Cananea · V. do Nascimento
Forum of Traditional Communities of the Municipalities of Angra dos Reis, Paraty and Ubatuba, Rua Araponga - no 502, Gleba 01, Lt 16-A, Caborê - Paraty, Rio de Janeiro CEP 23970-000, Brazil
e-mail: marcela.cananea@gmail.com

V. do Nascimento
e-mail: vnquilombo@gmail.com

E. Gallo
Center for Functional Ecology of the University of Coimbra, Oswaldo Cruz Foundation (FIOCRUZ), Rua Araponga - no 502, Gleba 01, Lt 16-A, Caborê - Paraty, Rio de Janeiro CEP 23970-000, Brazil
e-mail: gallo@fiocruz.br

and linked to well-being and values such as happiness, cooperation and solidarity" (Freitas et al. 2016, p. 355).

In opposition to multinational corporations and major groups of interest, different actors sustain that the type of sustainable development linked to the so-called "green economy" and its practices is nothing but an update of capitalism sustained by the interests of transnational economic conglomerates, of large corporations and their allies in governments, focusing their discourse on the use of state-of-the-art technology as a solution for the "brown economy," and avoiding discussing the roots of the problem, that is the social and economic organization of capitalism (Gallo and Setti 2012).

In this perspective, technology is the solution for climate problems and social issues, especially hunger and food distribution. Such technologies include nanotechnology, geoengineering, robotics, biotechnology, among others (ETC 2011). Therefore, hunger could be fought with biotechnology; geoengineering would be the solution for global warming; synthetic biology would substitute oil and transform biomass. "Half a century after the birth of the modern environmental movement, all social problems seem to demand not political but technological solutions" (Wetter 2012).

However, one cannot simply say technology will solve problems whose cause is a politically-established model of economic development. Hegemonic technologies play a central role in the maintenance of the *status quo* (Adorno and Horkheimer 1985; Habermas 1985), promoting the interests of large corporations. Therefore, technology cannot promote social inclusion (Dagnino 2004), so it is not capable—nor will be capable—of assuring the existence of a sustainable model of development.

Although the legitimacy of the capitalist mode of production and of post-industrial economic development is still based on the progress of technology and science, they also find legitimacy in the social organization it produces, which, generally speaking, not only do not promote empowerment, but also worsens inequalities, social asymmetries and exploration.

Various critics of capitalism (such as H. Lefebvre, D. Harvey and M. Castells), evaluating social processes (such as the enhanced reproduction of capital and the political conflicts that emerged in the 1960s in many countries), suggest a reinterpretation of geographic space as a "territory", that is, an object of dispute and domination of social relations of production (Dematteis 2005).

"Territories" are not just juxtaposed systems. Territories are "used territories," not territories themselves. "Used territories" mean land plus identity. Identity is our sense of belonging to something that belongs to us. Territories are the basis of labor, places of residence, spaces for material and spiritual exchanges, and where life takes place (Santos 2000, p. 47).

Therefore, territories are instances of individual and collective identity, where bonds are strengthened and where peoples and communities self-affirm. Territories are "*the space in which specific communities recognize themselves and find solutions to experience and recreate their own modes of existence and to reproduce their history, their knowledge and, especially, their values.* Territories are ultimately, the physical-cultural space where the dignified life of a community can develop" (Cappucci 2016, p. 107).

Analyzing the relations between money and territory in the late 20th century, Milton Santos shows that "*ultimately, this is the result of the influence of money, in its purest form, over the territory. International finances not only go against current structures, but also impose other structures. If it is autonomous—that is, if it doesn't have to go through anyone,— it works despite other actors, producing a non-autonomous existence. Certainly, there are barriers to such actions of the money in its purest form, that is, ways of reorganizing the territory, such as the European Community. Citizenry also resists the blind actions of money. This is serious in Brazil because, since we never truly had citizenry, the fluidity of such forces of disorganization establishes itself very fast*" (Santos 1999, p. 13).

Traditional Communities and Sustainable Ways of Life

Strengthening modes of production and consumption based on "solidarity economy" and the promotion of well being is, therefore, vital for sustainable models of development (Gallo and Setti 2012, 2014).

Each group of people or community socially constructs their territory at their own manner, based on the conflicts they experienced, which implies a differentiated relationship with the available natural resources. The way through which indigenous, maroon and Caiçara communities commonly use natural resources—involving a network of complex social relations and assuming simple levels of cooperation in the productive process and other daily activities—defines their process of territorialization and construction of specific identities (Almeida 2008).

Although traditional ways of life are usually more harmonic with the environment, they have been threatened by excluding environment policies, by real-estate speculation, disorganized tourism, megaprojects, urbanization, climate change and other elements. The territories of traditional communities are associated with the largest remnants of biodiversity, are important for environmental conservation and include great scenic beauty. This context has been responsible for various communities to be expelled from their traditional territories, leading them to occupy hillsides and favelas and live under precarious living conditions (Toledo 2001, Diegues 2016).

Access to land and natural resources—and well as the security to access them—determine the ability of these populations to deal with changes in their territories and ways of life (Adger and Kelly 1999). Moreover, Arruda (1999) highlights that, throughout time, traditional communities developed a large amount of empirical knowledge on nature through observation and experimentation in their daily activities.

Therefore, maintaining the ways of life of traditional communities depends on land ownership and the assurance of their domain over their traditional territory and its natural resources, which can be fought for through differentiated productive practices, education methods that value such practices, strengthening forms of tourism in which communities are the main actors and buttressing their capacity of managing their own social representation. This would provide them with actual citizenry, which Milton Santos highlights as a possible barrier to the destructibility of the money rationale applied to the reorganization of their territories (Santos 1999).

The ways of life of traditional communities in the municipalities of Angra dos Reis and Paraty (in the state of Rio de Janeiro) and Ubatuba (in the state of São Paulo)—which include Guarani indigenous communities, as well as maroon and Caiçara communities—is based on the shared used of their territories and natural resources. It involves a network of social relations that includes members of various communities and is based on cooperative models of production and solidarity, driving the development of specific local territorialized identities (Almeida 2008).

These communities developed a territorialized and sustainable way of life in which production and other daily activities are weaved together in the same social process. Stimulating such ways of life means valuing counter-hegemonic, sustainable models of development.

Since their ways of life are counter hegemonic, such communities are under constant threat, especially regarding conflicts related to public environmental conservation units and real-estate speculation (Freitas et al. 2016).

Strengthening the management of these communities, stimulating and disseminating their ways of life are, therefore, crucial for them to engage in necessary political disputes to assure their sustainable modes of development.

Counter Hegemonic Mechanisms of Territorial Management: FCT and OTSS

Strengthening these communities, assuring their ownership of their territories and that their ways of life are reproduced are central goals of the Forum of Traditional Communities of the Municipalities of Angra dos Reis, Paraty and Ubatuba (FCT), a political movement created in 2007 by the Caiçara, Guarani and maroon communities. These are also the goals of the Observatory of Sustainable and Healthy Territories (OTSS), a partnership between the FCT and the Oswaldo Cruz Foundation (Fiocruz) with the National Health Foundation (Funasa).

OTSS emerged from the development of an integrated and participatory territorialized agenda based on the demands of FCT members and under a counter hegemonic perspective (Gallo and Setti 2012). Based on that agenda, OTSS was developed as a "*technical-political space for the development of territorialized solutions in coordination with other scales (regional, state, national and global), based on the ecology of knowledge, with the potential of becoming regional alternative strategies and with the goal of assuring the rights of traditional communities, especially those related to the territory, the culture, traditional activities, health and quality of life*" (http://otss.org.br/observatorio/, accessed on June 2, 2016).

All of OTSS's actions and its processes of developing technological innovations (especially social technologies) are based on the three dimension of Carlos Matus's Government Triangle: the Project, the Governability and the Governing Capacity. Therefore, OTSS is understood as a subject, a collective social actor. Such perspective calls attention to the context in which organizational goals will try to be attained, as well as the knowledge and the tools it will evoke for such. "Project" relates to the worldview the social actor expresses in its propositions; "Governability" refers to the relationship between variables and resources the actor controls or does not control; and "Governing Capacity" is the result of the use of adequate methods, techniques, knowledge and experience for the social process in the "Project", considering the "Governability" of the system. These dimensions are different from one another, but they have to condition to one another and cannot be inferred in abstract (Gallo 2009a, p. 23).

Participatory Management at the OTSS

To reach its goals, OTSS has been implementing communicational/strategic management models that assure that the Project's strategy is implemented, that its actions are integrated and that its decisions are democratic, which allows the knowledge of academic researchers to dialogue with the knowledge of community researchers. New knowledge and practices emerge from this dialogue. This knowledge and these practices can help the management of OTSS to make the best decisions because they directly relate to the needs of traditional communities and to the limitations and potential of Fiocruz, which characterizes an ecology of knowledge, an idea originally developed by Santos (2006).

However, developing horizontal, participatory management models in public institutions is challenging, because it means changing current organizational theories and practices. Often it means changing paradigms to promote renewed forms of institutional organization: "*the challenge put forth (…) is developing theoretical/practical alternatives for organizational innovation. Categories such as emancipation, organizational culture and autonomy have been promoting a resignification of other traditions, such as efficiency, efficacy and effectiveness* (Ott 1989; Tavares 1993; Gallo et al. 1996)" (Gallo et al. 2006, p. 62).

Management approaches and processes need to change to give organizations the necessary instruments to materialize democratizing guidelines, improving the quality of production processes, of the planning and the administration and democratizing both these processes and the access to their final products (Gallo et al. 2006; Gallo 2009a, b).

Therefore, it is imperative that organizations are politically, administratively and financially decentralized, which would create systems of accountability and autonomy that expand their management capacity (Gallo et al. 2006; Gallo 2009a, b).

OTSS seeks to innovate in terms of management (Gallo and Setti 2014), and projects like that promote improvements through the implementation of a new organizational culture, a new relationship model for people and collectives. "*However, in order for that to happen, developing the conditions that allow such project to be updated is fundamental, and that is done through organizational innovations that rely on incentivizing the development of autonomous and critical subjects/managers*" (Gallo et al. 2006, p. 64).

In order for such innovative projects to really enhance management capacity and to allow organizational strategies to be attained, it is fundamental to develop mechanisms that assure that management strategies (development, agreement, implementation, monitoring and evaluation) are integrated. This way, the autonomy of professionals will not generate products that are unrelated to the strategic guidelines, which would be inefficient and inefficacious concerning the promotion of the goals of the organization. This implies developing both individual and collective mechanisms of accountability constantly feeding back into the management.

This paper introduces an innovative management experience that is being developed by OTSS, based on such principles. More specifically, it discusses the role of the Strategic Integration Advisory Board (AIE) in the process. AIE is the instance in OTSS's management system dedicated to integrating processes and assuring that strategic guidelines are being followed in management procedures and activities carried out by OTSS's different centers.

Considering OTSS's goals and action guidelines, two of its responsibilities have been gaining relevance: (1) to observe, care for and promote the development of an innovative culture of communicational strategic planning based on the idea of the Ecology of Knowledge within OTSS; and (2) to coordinate the development and implementation of monitoring and evaluation processes regarding the sustainable development goals of the United Nations' 2030 Agenda, which is an innovation, especially because it resignifies the 2030 Agenda from a territorialized perspective.

Methods

This paper evaluates OTSS's management process with a special focus on its Strategic Integration Advisory Board. This paper and all of OTSS's actions are based on research action. The idea of "research action" assumes a relationship between researchers and objects in the exercise of the researchers' activities. Therefore, the quest for knowledge is associated with action on reality (Ketele and Roegiers 1993; Engel 2000; Thiollent 2006; Gallo and Setti 2012, 2014). Using research action methods with traditional communities assumes five central categories: ecology of knowledge, territory, systematization, a communicational-strategic-ecosystemic approach and daily life.

Ecology of Knowledge An integration between scientific and traditional forms of knowledge is required, the latter having a fundamental role in the interpretation of and action over reality. Dialoguing with the territory and empowering the traditional communities that make up FCT is necessary. The interaction between scientific and traditional forms of knowledge is mandatory in the evaluation of reality.

The Ecology of Knowledge assumes a dialogue between different forms of knowledge. This represents a break from conventional thinking according to which different forms of knowledge are worth more or less than one another. The Ecology of Knowledge is based on a horizontal relationship between these "knowledges", which are autonomous and are worth the same, and seeks, through this dialogue, to produce knew knowledge and develop practices capable of dealing and interpreting that specific reality (Santos 2006, 2007).

Territory All the research and/or ideas systematized here emerged from a living territory, from a territoriality, understood here as a set of values and practices associated to a specific space and a certain period of time. These values and practices are their "social production," which takes place through the struggle between a dominating rationality and the emergence of other forms of being. This requires projects and actions capable of not only understanding, but also changing social practices associated to different territories, thus generating individual and collective empowerment (Akerman et al. 2002; Gallo et al. 2006; Gallo 2009a, b; Gallo and Setti 2012; Santos 2003).

Systematization Systematization was used in this paper as a form of record. Tools such as participant observation, document and bibliography analysis (of periodical reports of the actions carried out in the project, the biannual strategic planning reports, reports of the Coordination and Advisory meetings and the scientific papers produced), the triangulation of data and the analysis of evidence were used during the discussion and before conclusions were made. Researchers were in direct and frequent contact for an extended period of time with the object of their research, that is, OTSS's management process. It was a dynamic process in which researchers were responsible, at the same time, for raising the information included in this paper and the interpretation and analysis of this information.

Communicational-strategic-ecosystemic approach Both in the implementation and the evaluation of OTSS's actions, researchers were guided by the idea of an ecosystemic/communicational approach of the strategic-situational planning. The goal of this approach is to produce sustainable development, so it is suitable because it include social participation in policy management at the level of the local community and based on a situational/strategic analysis, producing and using information from different sources and forming interfaces between the goods and services of various ecosystems. This approach also seeks to establishing governance models that incorporate environmental, social and economic policies and that produce integrated forms of management, based on the development and effectiveness of programs, policies and projects (Gallo and Setti 2012, pp. 1436–1437).

Daily life The researchers of this paper have dared to think about social everyday life. This is daring because thinking about daily life means going beyond the macro-explanatory systems of social objects (Maffesoli 1984). According to Heller, it is daring because it means thinking about a dimension that gives meaning to existence, "(…) the 'center stage' of History […] the true 'essence' os social substance," where people acquire the necessary abilities for life, which, in turn, mediate the social relations they end up incorporating (Gallo 2009a, b, p. 27).

Development

The Evolution of OTSS's Management Model and the Creation of the Advisory Board

In 2009, the FCT carried out its first strategic-situational planning process, which resulted in the prioritization of the establishment os sustainable and healthy territories in the traditional communities: assuring the territory, in the full sense of the word; promoting ecological sanitation schemes; and supporting local production arrangements and differentiated education. This first workshop was moderated by Fiocruz researchers, marking the beginning of a relationship that resulted in a partnership between a public science and technology institution and organized social movements.

Based on FCT's demands, a partnership with the Oswaldo Cruz Foundation (Fiocruz), supported by the National Health Foundation (Funasa), was established for the implementation of OTSS and for the development of social technologies dedicated to the promotion of sustainability and health in the territories of traditional communities linked to FCT. To materialize this perspective and deepen territorialized inter-institutional cooperation, the creation of an observatory was identified a more adequate arrangement. The observatory was understood as a new social actor that generates technologies (the systematization of knowledge, the production of information and diagnosis, the mapping of community dynamics, the history of population groups) capable of capturing, treating and disseminating information and knowledge that support the decision-making process in a network of actors involved in the management processes.

The creation of OTSS was dynamic and continuously changed by territorial processes and the innovative partnership between an organized social movement (comprised of a strategic convergence of three ethnic groups) and a public education, research, production and innovation institution.

Since its inception, the development of theme-based centers or coordinations was identified as the best arrangement for the governance of OTSS, always with the participation of both community and academic researchers. The goal was to develop an innovative management model, aiming at the promotion of empowerment. This form of organization goes against conventional structures of management through inflexible work units in an alienating assembly line. Classical Management Theory —based either on Positivism or Utilitarianism—seeks to apply mathematical rationality to management processes, ignoring the surroundings of the production process and, therefore, ignoring the territory. The Classic School is overcentralizing in terms of decision processes and greatly segmentational regarding the division of labor (production line). It denies the existence of internal and external conflicts the process necessarily includes and, therefore, since it is blind to the structure of work relations, usually misses opportunities.

OTSS's governance structure (structuring governance) is dedicated to the promotion of peoples' autonomy and protagonism and the empowerment of the community towards more sustainable and healthy territories. There is a permanent debate around how to better structure governance in order to incentivize autonomy and promote accountability and solidarity. This dialogue takes place in the collective spaces of the coordinations, centers and councils, during the meetings dedicated to strategic planning (biannual) and monitoring (monthly), the meetings of the coordination collegiate (monthly) and of the Strategic Integration Advisory Board (monthly).

The following coordination centers were created, at first, to handle the complexity of the project, promoting the sharing of views and knowledge between academic and community researchers about a number of issues, ranging from the defense of the territory to differentiated education, from ecological sanitation to the development of local production arrangements: (a) Executive coordination; (b) Coordination of Technological Transition; (c) General Coordination and (d) Coordination of Strategic Guidance; as well as two advisory boards: (a) Strategic Planning and (b) FCT Development. Coordinators and board members composed OTSS's Management Collegiate (Fig. 19.1).

The Coordination of Technological Transition had the responsibility of carrying out endpoint, structural and structuring actions. The other coordinations and boards are responsible for the "means," activities necessary for the governance of the Project and dedicated to strengthening the FCT. At this point of development, the "means" were prioritized in order to promote the improvement of the FCT, to generate and manage knowledge, to promote work in networks and to organize activities related to the board of communication and information and to strategic planning. Moreover, this coordination was made responsible for strategic-participatory monitoring, the integration between coordinations and political-institutional relations.

The progress of the process of implementation and monitoring of OTSS was more complex than previously anticipated. Thematic groups—still called

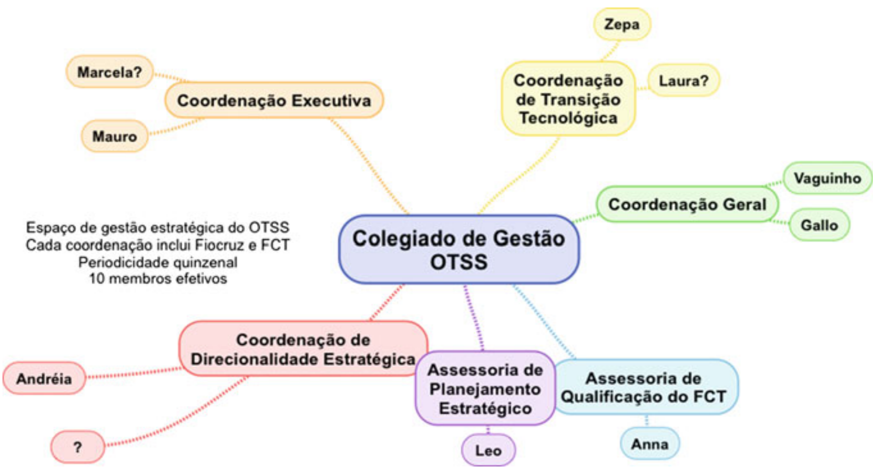


Fig. 19.1 Mind map in April 2014

"coordinations" then—were restructured, and several boards were incorporated to the governance structure, with the specific goals of supporting the coordinations. A few examples include the Legal Assistance Board, whose goal is to support traditional communities in territorial disputes, the Board of Institutional Relations, whose main function is to promote the dialogue with partner institutions, and the Board of Strategic Planning, which was responsible for carrying out processes directly related to the planning and monitoring of actions (Fig. 19.2).

However, during the strategic planning activities carried out in July 2015, the term "center" was used, instead of "coordination." Only the General Coordination —comprised of one of Fiocruz's academic researchers and one community researcher, FCT's coordinator—kept the original terminology.

The Strategic Integration Advisory Board (AIE) was being devised right before the workshop. During the workshop, the management structure was reconfigured. The Strategic Guidance Center became the AIE and a Knowledge Management Center. The latter took on the responsibility for the Social Cartography and the Georeferencing of communities; internal training processes, such as the Open Mind and Throbbing Hearts workshops; and the systematization and organization of the knowledge accumulated during the implementation of OTSS.

There were even more changes in the structure of governance in July 2015. It coincides with two important factors in the history of the Project: the inauguration of its headquarters in Paraty and the launch of the ecological sanitation plan at Praia do Sono, with the inauguration of the first evapotranspiration cesspit, close to the Martin de Sá Municipal School.

Such changes in the structure not only were justified by the project gaining importance and by the constance development of democratic decision-making processes, but also led to the creation of the Political-Institutional Articulation Center (NAPI), with a strong connection to AIE. This center emerged from the existing Board of Institutional Relations. Figure 19.3 shows OTSS's management structure in July 2015.

AIE was then created in a context of actions over the territory gaining prominence and, therefore, an increase in the number of both academic and community researchers dedicated to the Project. The strategic monitoring, the situational strategic planning workshops, the internal communications and with the public, financial planning, and fundraising are responsibilities of AIE.

The strategic planning workshop carried out in December 2015 confirmed that structure. One of the activities required participants to playfully mention the responsibilities of each "collective space" and/or each OTSS team member. This exercise showed that almost all of the researchers that made up OTSS then were fully aware of the structure, the responsibilities and the importance of each one of them in the project.

Up until July 2016, therefore, OTSS was composed of the following centers: Technological Transition and FCT Development. The first is responsible for the implementation of the Incubator of Social Technologies, supporting Local Agroecological Production Arrangements and Community-Based Tourism, as well as the implementation of ecosanitary technologies. The latter includes community

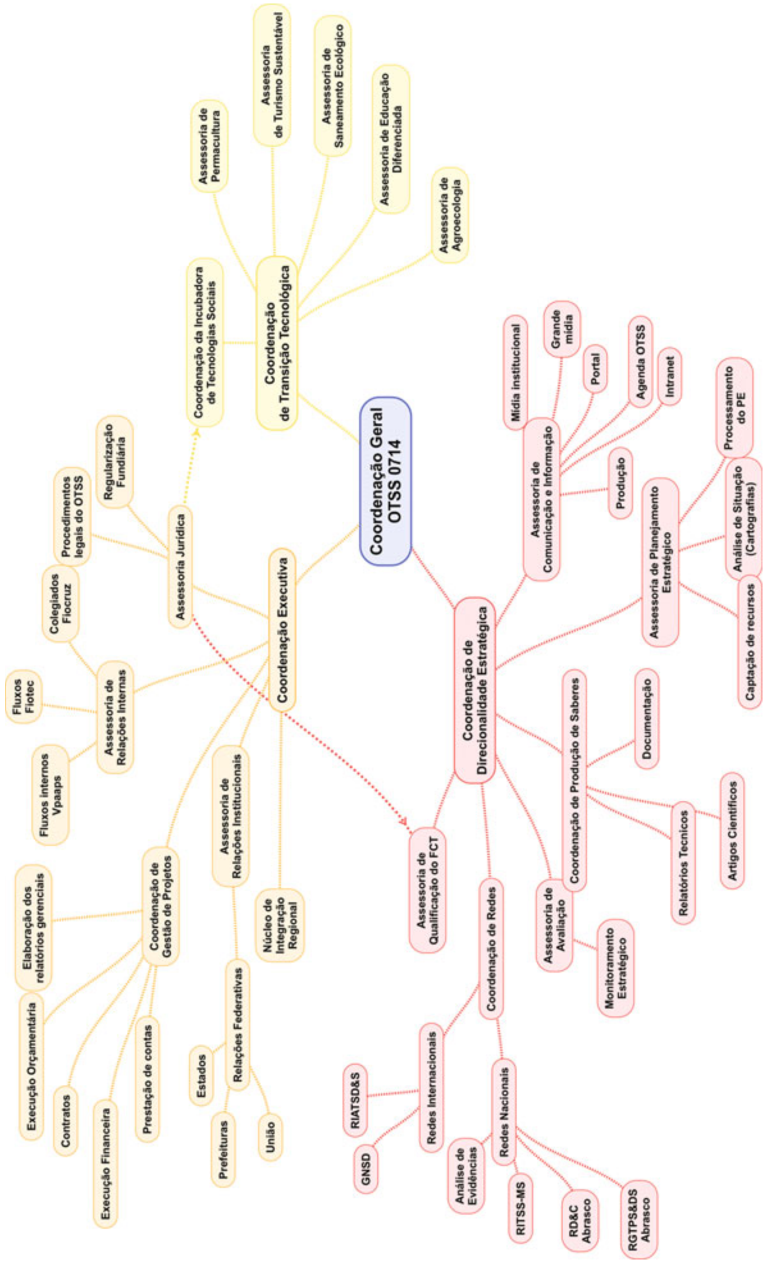


Fig. 19.2 Mind map on July 2015

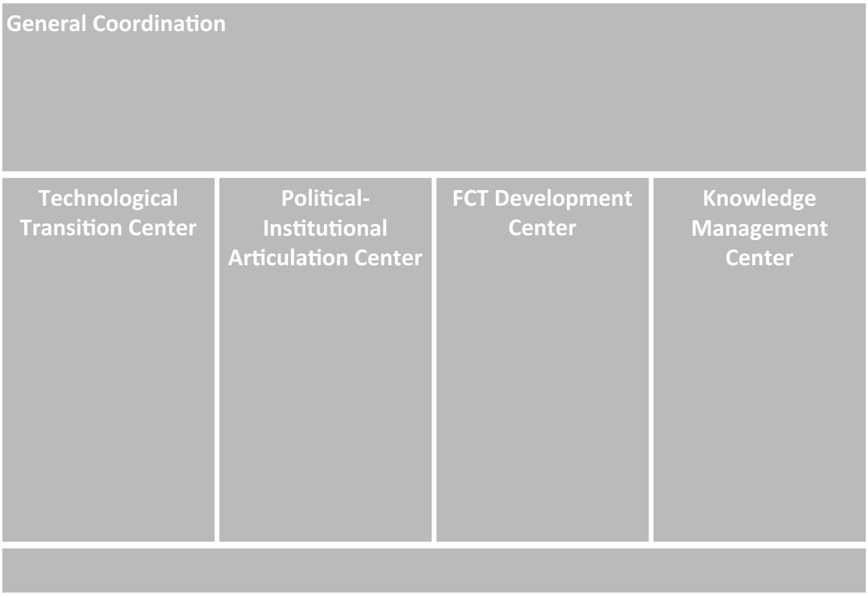


Fig. 19.3 OTSS's management scheme between July 2015 and 2016. It was formed by centers that fed information into the general coordination, and by the AIE, whose goal is to integrate actions and the decision-making process

mobilization and coordination, both in the territory and at other scales; strategic socioenvironmental justice actions and the legal assistance board as means to strengthen communities and their associations; and differentiated education schemes, aimed at promoting the cultures gathering around the FCT.

There are also two centers with "means" activities: the Knowledge Management Center and the Institutional Political Articulation Center, already-mentioned. Besides the centers there are the General Coordination and the Coordination Collegiate. There is also the Executive Secretariat, responsible for the financial and administrative management, providing a fundamental level of supporting to the development of the Project.

The AIE dialogues with all spaces and guides the flow of information, seeking to assure that all voices are heard, that internal conflicts are solved and that opportunities are identified.

The Role of the Advisory Board in the Management of OTSS

The evolution of the center responsible for the planning, the monitoring, the evaluation and the social communication—now called Strategic Integration Advisory Board (AIE)—has to do with a progressive change in its role, which continuously became more clear and broad since its creation. Such changes were put through intentionally based on a collective perception of the needs of the management process and the communication/strategic approach adopted.

Despite the intention, the process demanded a great level of flexibility of the structure of the organization regarding restrictions and opportunities presented in the actual objective reality, especially because, since OTSS's management model is based on the idea of an Ecology of Knowledge and on management centers composed of both academic and community researchers, the resulting management process is quite complex. The flexibility had to be (1) communicational—because of the existence of autonomous (although coordinated) collegiate management spaces where strategic decisions are made based on legitimacy—and (2) strategic—because of mechanisms dedicated to strategic alignment, to the monitoring of the strategic alignment and the evaluation of the effectiveness of its actions, which is not common in projects carried out by large governmental research institutions, such as Fiocruz (Gallo and Setti 2012, 2014). This evolution depended both on the continuous evaluation of OTSS's management structure and on the conscious use of a different management approach that demanded constant willingness to reassess responsibilities and tasks.

Currently, AIE has taken on the role of the discontinued Strategic Guidance Center, assuring strategic management guidance, that is, coordinating the strategic planning, carrying out periodical monitoring actions and evaluating the planning. It also took on other crucial roles: integrating OTSS's management centers, preprocessing issues discussed at the coordination collegiate and the essential fundraising activities for the maintenance and development of OTSS's activities.

The integration between centers has proven fundamental, especially because the management of OTSS involves a process in which strategic and operational decisions are made throughout four different centers, demanding integration and synergy between discussions and the decision-making processes occurred in all centers, disallowing contradictory decisions or a waste of resources during the implementation of the actions.

Because it includes academic and community researchers who have very different paces, trainings and perspectives on management, the management of OTSS always goes through conflicts (Gallo and Setti 2014) arising from the radical use and practice of the ecology of knowledge and of the communicational-strategic form of governance (Santos 2006; Gallo et al. 2006). A management instance responsible for integrating actions within OTSS has been mediating conflicts and reducing the level of tension of the decision-making processes.

The preprocessing of issues to be decided by the coordination collegiate has also proven essential for the management of OTSS. First because it assures the focus on strategic issues during the decision-making process and increases the agility of the process, since the coordination collegiate receives information that has already been technically processed, so there is no need to discuss the tactical or operational details of each issue that is relevant for the actual management. Second because it helps reducing tensions between decisions made in OTSS's collegiate management spaces—OTSS's collectives, centers and coordination collegiate—since AIE's professionals have more time to analyze the decisions made by the centers and, based on that analysis, to introduce their rationales to the coordination collegiate, as well as explain the decisions of the collegiate to the centers.

Lastly, one of AIE's responsibilities has always been protecting the strategic orientation of OTSS's processes, even when the board had a different name and format. However, only with AIE's current format these responsibilities have actually effectively been carried out, because the degree of integration attained between the collective, the centers and the coordination is essential for assuring the strategic orientation of OTSS's management process (which is split in different centers).

It has been said that AIE's new structure and roles materialized some of OTSS's democratic guidelines without drifting away from its strategic guidelines or producing a low-efficacy or low-efficiency decision-making process. Therefore, a management model for OTSS based on organizational flexibilization, autonomy and individual and collective accountability—as suggested by Gallo et al. (2006) and Gallo (2009a, b)—was developed, despite differences in context; and AIE plays a fundamental role in the process.

The Role of AIE in Strategic Planning, Monitoring and Evaluation

Such expanded roles allowed AIE's primary functions—including the coordination of the Strategic Planning and the implementation of OTSS's monitoring and evaluation processes—to be better executed. After all, by integrating centers and mediating the relations between the centers and the coordination, AIE gets closer to the actions of each center. And by discussing the set of strategies and actions taking place within OTSS, AIE is provided with a more general view of the events, which facilitates the implementation of the strategic-situational planning, as well as of the monitoring and the evaluation of the planning.

The evolution of AIE's management processes have been reflected in the improvement of the biannual strategic planning workshops and the meetings of the coordination collegiate.

Since AIE's creation in 2014 (with a different name and format), five strategic planning workshops were carried out with the entire OTSS team. For all of them, the general structure was the same: at a certain moment, the centers gathered to establish which actions had to be taken, and, at another moment, such actions were validated in plenary sessions, with all team members. These moments were interspersed with activities dedicated to generating a greater level of interaction between team members or discussing specific issues (such as, for example, the role of each center or person on the team).

The first two workshops, carried out in July and December 2014, included only establishing strategies and actions at different levels of complexity (called "operations," "actions" and "activities"), as well as deadlines and the people responsible for such elements in the 12 months following the planning date. Table 19.1 shows a model of the process, with a few of the results obtained during the workshop.

During these first workshops, two types of actions were carried out: strictly operational (top two rows of Table 19.1) or more strategic, although less objective, actions (row 3). Few actions were strategic and objectively defined, which reflected the maturity of the collective discussion of the strategy within OTSS.

The evolution of the management process—starting at the third meeting in July 2015—allowed planning to discuss strategic issues rooted at an objective planning of actions, which is fundamental to assure that the strategic guidelines of the governance Project are being followed.

Table 19.2 introduces the planning utilized during the workshop as an example of and objectively-formulated strategic discussion. The table includes a fundamental strategy (characterizing communities) for the territorial disputes traditional communities usually face (Freitas et al. 2016). Actions established are very objective, and this objectiveness caused it to progress greatly since July 2015. The passage from a normative planning—expressing OTSS's collective wishes—to a strategic form of planning—based on reality and aimed at promoting actions based on the territory—is clear.

Table 19.1 Planning used during OTSS's first two planning workshops, with actions established in July 2014

Strategies	Operations	Actions	Deadline	Responsible team member
Facilities	Real estate—to make an inventory of spaces	Renting the venue	By late September	Flávia and Marcela
	Furniture–furniture with local features	Listing local needs	By late October	
Supporting FCT's improvement	Supporting FCT's institutional development: communication—making visible and communicating OTSS's and FCT's actions	Create OTSS's visual identity	By August 23	Thereza and Edu
		Launching, maintaining and occupying spaces of the campaign "Preserving is Resisting"	By August 2014	Edu and Thereza
Supporting strategic management	Consolidating sustainable, community-based tourism	Establishing and elaborating activities	By October 2014	Érika

With more objective actions, having a budget planning was possible. Table 19.2 includes a more objective strategy and represents a more complex planning tool, because of budget provisions.

That is, it was possible to collectively develop the physical and financial planning of each center for the 12 months between July 2015 and 2016 (the table includes only 6 months to fit the page), including objective strategies and actions at various levels, months in which they would be carried out, necessary resources, resource amounts, as well as the total amounts—with the flexibility to include resources other than that included in the Table (human resources), because the costs of frequently used services and products had already been preprocessed, which helps deciding on the budget.

At that moment, actions already included a significant level of detail. However, the establishment of actions and their respective budgets were not efficient. At the end of 2015 and in the middle of 2016, the budget implemented was only 48% of the budget planned for OTSS, in the first period and 51% in the second period. Moreover, except for NUGES, no center executed more than 50% of the budget planned. The budget had been overestimated because a large part of the actions planned were not implemented.

However, the idea of developing objective actions to address OTSS's project strategies, of linking strategies and actions to the budget and of monitoring its implementation increased the organization's management capacity, effectiveness, efficiency, accountability and solidarity, promoting individual and collective autonomy.

In July 2016, the planning incorporated two methodological advances: a budget ceiling for each center based both on previous expenditures and on the total available expenditures for OTSS as a whole, and the combined planning of NTT and NQFCT, the centers carrying out the most actions and establishing the actions of other centers, which are means to attaining the results planned.

Establishing a budget ceiling was essential for transforming a normative form of planning into a strategic one, because with maximum expenditures, centers started planning based on the desires of academic and community researchers in each center, as well as within the realm of possibility, establishing which priorities should receive the resources first.

Moreover, the joint planning of the final areas increased the synergy between NTT and NQFCT, reducing competition and optimizing efforts. However, that was only possible due to the integration implemented by AIE, which made it aware that the planning of the centers required integration and caused it to suggest a work methodology that assured such integration.

Such changes in planning methodology represented both a theoretical and a practical innovation in OTSS's management processes, which has been promoting the political, administrative and financial decentralization and strengthening accountability and autonomy, which is crucial for expanding its management capacity in a democratic and participatory management (Gallo et al. 2006; Gallo 2009a, b).

Table 19.2 Planning used during OTSS's last three Planning workshops

Strategies	Operations/actions	Team	2015/2						Resources needed		
			J	A	S	O	N	D	# of people	Daily rate	Total
Characterization of traditional territories	Characterization trindade	Anna, João e Natália	x	x	x	x			3	250.00	750.00
	Characterization two other communities						x	x			

There has also been a consistent evolution in the monitoring and evaluation of what was planned, which was mainly responsible for the changes introduced in the planning process, having allowed the problems researchers had been having during planning and implementation to be understood, which, in turn, produced a positive feedback.

The first relevant monitoring and evaluation tool was OTSS's platform, the team's internal website that hosts results and allows the online monitoring of the implementation of the planning of each center.

The monitoring is carried out through another planning tool (Table 19.3), available in the platform. Every month, the AIE team meets with the coordinators of the centers and evaluates the implementation of the biannual planning, discussing achievements, problems and difficulties, as well as possible course corrections.

Afterwards, the process is discussed with the whole AIE team in monthly meetings, where the issues that should be taken to the monthly coordination meetings—because they require a discussion with all coordinators of the centers and OTSS's general coordinators—are established.

Issues requiring quick responses obviously do not go through all these stages and are resolved directly with the coordinators of the centers, with the general coordinators or in extraordinary coordination meetings.

Therefore, various instances discuss the issues, which allows for greater integration in the decision-making process and a greater level of participation of the team as a whole, without decreasing the agility of decisions, thus assuring both their legitimacy and efficacy.

This is crucial for management because projects in which the territory is as essential as it is for OTSS need participatory decisions and have limited managerial implementation capacity due to legally-established deadlines—which occurs with publicly-financed projects—but its decisions cannot depend on a bureaucratic process. After all, territories demands urgent measures that need to be taken after participatory, but quick, decisions. The agility, the legality and the participation is what has been allowing OTSS to promote a form of management that empowers its team (including the researchers that are members of the traditional communities) without losing efficiency, efficacy and effectiveness, providing a new meaning to traditional categories in management procedures, producing organizational innovation (Ott 1989; Tavares 1993; Gallo et al. 1996, 2006).

Table 19.3 Monitoring tool filled monthly by the coordinator of each center with the support of AIE's team

Activities	Responsible team member	Deadline	Cost (R$)	30/APR—2016	
				Stage	Coordinator justification
Characterization of traditional territories—finishing material to deliver to the NCS Trindade team and validating it with the community—NFCT (defense of the territory)	Natália	JAN to JUN	4140.00	Ongoing	Should be finished by May
Articulation with the new social cartography project—coordination and follow-up of the publishing of the fascicle. Beginning of a new possible partnership for social cartography in Africa	Anna	MAR to JUN	3050.00	Finished	The material will be sent for publishing of the NCS fascicle

The Need to Incorporate Community Members in the Board as a Strategy to Expand the Dialogue Between Communities and the Management of the OTSS

OTSS's centers and coordinations are composed of both academic and community researchers. The AIE, until December 2015 had only academic researchers. Two causes for this were highlighted. On the one hand, AIE's process are essentially management processes and, therefore, serve as means to support the final actions of other centers. The participation of community members in the AIE tends to drive them away from final actions and, consequently, from the actions that take place in the communities. Since these actions heavily depend on the participation of community researchers, it would be hard for them to find more time to participate in the AIE. On the other hand, the training of community researchers aims at endpoint actions, so their interests and abilities relate to the development of solutions for the communities' more tangible problems, that is, to the creation of territorialized social technologies.

However, the need to incorporate the participation of community members in the AIE had been observed within OTSS. Their absence caused problems with integration, making the dialogue between the processes of planning, monitoring and evaluation and the representatives of traditional communities more difficult. It promoted a more technical/academic and less community-oriented agenda.

Moreover, the participation of community members in management process allows them to be trained, which is crucial for the empowerment of communities and to better prepare them for future political disputes. Participating in management activities assures that they truly understand political, administrative, financial and strategic processes from which underprivileged populations have historically been cast out from, which weakens their political strength. Therefore, to generate autonomous and critical traditional community members capable of fighting for the maintenance and the strengthening of their sustainable ways of life and truly impacting processes linked to climate change, it was necessary to include community members in the management process.

The incorporation of community researchers in AIE's management process was also essential for allowing a greater approximation to the demands and issues of the communities, more directly observing the territory's pace and management modes. Since AIE is responsible for the dialogue between centers, incorporating community members in this instance of management is crucial for an Ecology of Knowledge that truly promotes the dialogue between academic and community forms of knowledge and between centers, not only within them.

The process was implemented in OTSS with the incorporation, in January 2016, of a Caiçara at the AIE and the collegiate board that coordinates the project, and will be expanded with the inclusion of a Guarani in these two management instances, which should happen in September 2016. New community researchers should also be incorporated to these management instances. The challenge is to do that without negatively influencing the production of territorialized solutions in the communities and without losing the timing of executive processes.

The inclusion of community members is essential for OTSS's goals, because, only after providing management training for community researchers, the OTSS will be able to empower communities and transform social practices in the territory, which is crucial in the promotion of individual and collective autonomy (Akerman et al. 2002; Gallo et al. 2006; Gallo 2009a, b; Gallo et al. 2012; Santos 2003). Only after academic researchers will truly incorporate traditional knowledge, strengthening the relationship between the management level and the demands of the territory, which will make this knowledge more legitimate in the society as a whole. The AIE's responsibilities and the inclusion of community members in it were key in the management of OTSS.

However, with the increase of the number of professionals on the team, of institutional partners and actions implemented, AIE began having operational difficulties carrying out these tasks.

Therefore, in July 2016, a General Governance and Management Coordination (CGG) was created, taking on part of AIE's functions and keeping a close relationship with the Board. CGG's role is to support the general coordination in the management of OTSS, coordinating the operationalization of the relations between OTSS and project partners (thus giving NAPI a more political and strategic role) and supporting the Executive Secretariat in the management of the people working on the team. Consequently, AIE went on to play a more internal articulation role

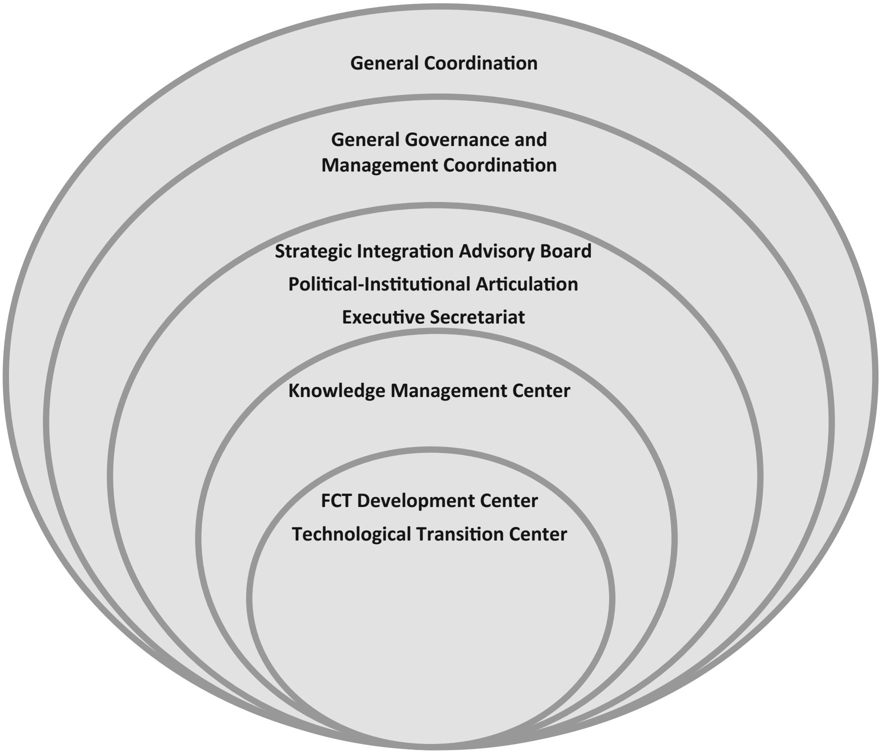


Fig. 19.4 Governance flow starting in July 2016

between the project's centers and to assure a permanent dialogue between them. Figure 19.4 shows this management structure.

The consequences of this new form of management for OTSS's reach still needs time to be critically evaluated, since it was established a little prior to this paper being finished. Future papers will try to address the issue.

Monitoring and Evaluation Tool to Support AIE's Actions

Besides the periodical meetings and the monitoring tools—which allow AIE to carry out a continuous process of monitoring and evaluation—an evaluation method based on analytical dimensions, evaluational parameters, indexes and indicators was established for OTSS (Gallo and Setti 2012, 2014). This tool—which is being applied in partnership by AIE and the General Coordination—informs whether OTSS's Project's goals are being met and how the achievement of these goals have been evolving. It also allows the monitoring of the fulfillment of the Sustainable Development Goals (SDGs), established in the 2030 Agenda, in the territory, since the indicators in the methodology here are strongly related to the indicators in the 2030 Agenda.

The evaluation methodology is based on three analytic dimensions that are basic for the evaluation of territorialized sustainable development projects: sustainability, equity and autonomy. The goal is to evaluate whether OTSS and the strategies and actions it develops impact these three dimensions (Gallo and Setti 2012, 2014). The principle is the following: if OTSS's actions promote the sustainability of traditional communities, greater equality and autonomy for community members, then these actions generate sustainable development and, therefore, the goals of the Project are being met.

To understand whether these dimensions are actually being met, each of them is split into relevant evaluational parameters. The dimensions are not very objective to be evaluated, so we need to split them up in order for them to reach a more objective level and be able to be evaluated. Each parameter is split into indices. Indices are split into indicators (Table 19.4). The level of discussion is easier to understand then. After all, it is easier to evaluate whether there is an equal number

Table 19.4 Evaluation tool

Analitic dimensions	Evaluation parameters	Indexes	Indicators
Sustainability	Intersectoriality	Convergence of agenda	In preparation
		Stakeholder integration	
		Intercalary integration	
	Solidarity network	Insight into networks	
	Territorialization	Needs of the territory	
		Hierarchy of priorities	
	Ecology of knowledge	Collective management spaces	
		Mechanisms of knowledge production	
Equity	Diversity	Race	
		Gender	
		Biodiversity	
	Vulnerability	Income	
		Life cycle	
		Access	
	Integrality	Host	
		Bond	
Autonomy	Social participation	Ability to claim	
		Intensity of participation	
	Empowerment	Formulation capacity	
		Network coordination	
		Management capacity	
		Resilience	

of women and men participating in management activities in specific communities than evaluating (more generally speaking) whether there is equity in that community.

This allows understanding whether the creation of AIE and other changes related to it have been effectively causing an impact in the goals established in OTSS's Project.

The use of this methodology to check whether OTSS's actions have been impacting the reality of traditional communities has been legitimizing OTSS as a political-institutional project that strengthens sustainable life styles, which is crucial for climate change adaptation.

Conclusion

Climate Change prevention and adaptation is conditioned to radical changes in the world's hegemonic modes of production and consumption. Counter-hegemonic modes of production, such as the ones of traditional communities associated to FCT, should be valued.

OTSS seeks to empower these traditional communities to strengthen their life styles, thus helping the goals in the 2030 Agenda to be met and to prevent climate change.

Improving the management of OTSS, therefore, strengthens traditional communities and their sustainable life styles, especially when this improvement includes integration and democratization—attained through the inclusion of representatives of these communities in management processes.

This inclusion allows community representatives to participate in processes they historically have been excluded from, such as the management of projects carried out by public research institutions. It also allows academic researchers to better understand the pace and management modes of the territory, making it possible for a true Ecology of Knowledge to take place (Santos 2006).

The creation of AIE meant a great evolution in OTSS's management model towards the integration of the project's centers and between academic and community researchers, which benefits the Ecology of Knowledge. The inclusion of community researchers at the AIE was crucial because it facilitated the dialogue between different forms of knowledge and the generation of new knowledge, aiming at the individual and collective autonomy of community researchers and traditional communities.

The consolidation of AIE further expanded the dialogue between OTSS's centers and the coordination of the project, promoting the empowerment of the management centers composed of academic and community researchers and, consequently, of all researchers. This led to a more effective dialogue between the OTSS and the traditional communities. Moreover, due to the flow of strategic information between the project's coordination and centers dealing with endpoint activities, it also assures that OTSS as a whole maintains the strategic guidelines of its management Project.

The change in AIE's roles improved planning, monitoring and evaluation processes to focus on the SDGs and the development of indicators that show whether community members and traditional communities have gained autonomy and whether territorial actions have been strengthened.

Therefore, AIE's actions have been relevant to materialize democratizing guidelines within OTSS and increase the efficacy and the efficiency of the decision-making process, which is central for the development of innovative and participatory management models (Gallo et al. 2006).

OTSS's democratization and greater management integration—empowering community researchers in all the groups that form the project—has been strengthening the dialogue between OTSS and the traditional communities. Consequently, the life styles of traditional communities are being empowered in OTSS's actions, which increases these communities' power in disputes with the hegemonic model of production and consumption, which, in that specific territory, is mainly represented by real-estate capital and the capital of the federal and state governments, which control the Conservation Units (Freitas et al. 2016).

Therefore, AIE's structure indirectly reflects the promotion of policies that play a relevant role in the SDGs, including climate change prevention and adaptation.

Such results could be adequately measured through OTSS's methodology to evaluate whether the project's actions actually strengthen the life styles of traditional communities and, consequently sustainable actions toward climate change (Gallo and Setti 2012, 2014). This shows that AIE has been assuring a greater level of autonomy in communities, since it includes community researchers in the actual management process, training them to discuss issues usually restricted to academic researchers. Moreover, this model has been allowing academic researchers to keep a constant dialogue with community researchers and incorporate their empirical knowledge in management process, which socially legitimizes their form of knowledge, which is essential for the autonomy of traditional communities. According to the analytical parameters that make up the dimension of autonomy (Table 19.4), we see that AIE has been not only expanded the social participation of community members, but also empowering them to discuss territorial management.

As to the sustainability of traditional communities, since AIE's actions include community members and promotes the dialogue between OTSS's endpoint centers and management centers, they also allow for a better understanding of the needs of the territory, promoting the territorialization of OTSS and a more comprehensive comprehension of the demands of communities, which is crucial for sustainability. Looking at analytical parameters, it can be observed that this action especially impacts not only the ecology of knowledge, because it opens space for traditional communities to express themselves and to influence decision-making processes, but also for the issue of territorialization, because it allows for a better understanding of the needs and demands of the territory.

Moreover, it promotes equity—since it supports a reduction in the vulnerabilities of traditional communities, expanding the access of these communities to decision-making processes—and diversity, since different groups (Caiçara, indigenous and maroon) gain space to discuss decisions.

References

Adger WN, Kelly PM (1999) Mitig adapt strategies glob chang 4(3/4):253–266

Adorno TW, Horkheimer M (1985) Dialética do Esclarecimento: fragmentos filosóficos. Trad. G. A. de Almeida. Jorge Zahar Ed, Rio de Janeiro

Akerman M, Mendes R, Maria Bógus C, Faria Westphal M, Bichir A, Lyra Pedroso M (2002) AvaliaÃ§Ã£o em promoÃ§Ã£o da saÃºde: foco no “municÃ pio saudÃ¡vel”. Revista de SaÃºde PÃºblica 36(5):638–646

Almeida AWB (2004) Terra de quilombo, terras indígenas, “babaçuais livre”, “castanhais do povo”, faixinais e fundos de pasto: terras tradicionalmente ocupadas. PGSCA/UFAM, 2008, Manaus

Arruda R (1999) “PopulaÃ§Ãµes tradicionais” e a proteÃ§Ã£o dos recursos naturais em unidades de conservaÃ§Ã£o. Ambiente & Sociedade 5:79–92

Cappucci M (2016) Aspectos fundiários das comunidades caiçaras. In: Neto PS (Org.) (ed). Direito das comunidades tradicionais caiçaras. Ed. Café com Lei, São Paulo, pp 105–131

Dagnino RA (2004) Tecnologia social e seus desafios. In: Lassance A Jr et al (eds) Tecnologia social—uma estratégia para o desenvolvimento. Fundação Banco do Brasil, Rio de Janeiro, pp 187–209. http://www.oei.es/salactsi/Teconologiasocial.pdf

Dematteis G (2005) Geografia democrática, território e desenvolvimento local, Formação, no. 12, vol 2, pp 11–26. ISSN: 2178-7298, ISSN-L: 1517-543X. http://www.revista.fct.unesp.br/index.php/formacao/article/viewArticle/1142. Accessed 30 July 2016

Diegues AC (2016) Prefácio. In: Neto PS (Org.) (ed.) Direito das comunidades tradicionais caiçaras. Ed. Café com Lei, São Paulo pp 11–19

Engel GI (2000) Pesquisa-ação. Educar em Revista 16:181–191. Universidade Federal do Paraná, Paraná, pp 3–4

ETC Group (2011) Tackling technology: three proposals for Rio contribution to the Rio+20 zero draft

Freitas LE, Cruz JCHO, Cortines AC, Gallo EN (2016) Observatory of sustainable and healthy territories (OTSS) GIS: geo-information for the sustainability of traditional communities in southeastern Brazil. In: Walter LF, Azeiteiro UM, Alves A (eds) Climate change and health improving resilience and reducing risks, vol 1, 1 edn. Springer, New York, pp 353–367

Gallo EA, Freitas LE, Reis R (2006) A flexibilidade, responsabilização e autonomia: o caso da diretoria de investimentos e projetos estratégicos do ministério da Saúde (DIPEMS). Saúde em Debate 72:58–79. ISSN: 0103-1104. http://www.redalyc.org/pdf/4063/406345257007.pdf. Accessed 18 Aug 2016

Gallo E (2009a) Gestão pública e inovação. tecnologias de gestão e a reinvenção do cotidiano organizacional [tese]. Escola Nacional de Saúde Pública da Fundação Oswaldo Cruz, Rio de Janeiro. http://www.bvssp.icict.fiocruz.br/pdf/25521_Galloed.pdf. Accessed 18 May 2016

Gallo (2009b) Alienação, inovação e cotidiano organizacional: teses e hipóteses. In: Mandarino ACS, Gomberg E (eds) Novas tecnologias e saúde. vol 1, pp 01–264 EDUFBa, São Cristovão-Salvador

Gallo E, Setti AFF (2012) Abordagem ecossistêmica e comunicativa na implantação de agendas territorializadas de desenvolvimento sustentável e promoção da saúde. Ciência e Saúde Coletiva 17:1433–1446. doi:10.1590/S1413-81232012000600008. Accessed 3 June 2015

Gallo E, Setti AFF (2014) Efetividade em desenvolvimento sustentável: o caso do Projeto Bocaina. In: Anais do GeoSaude 2014: a geografia da saúde no cruzamento de saberes, Coimbra, pp 696–699. http://www.redalyc.org/pdf/630/63032416011.pdf. Accessed 20 July 2016

Gallo E, Setti AFF, de Paiva Magalhães D, Mesquita Huet Machado J, Forsin Buss D, de Abreu Franco Netto F, Marchiori Buss P (2012) SaÃºde e economia verde: desafios para o desenvolvimento sustentÃ¡vel e erradicaÃ§Ã£o da pobreza. CiÃªncia & SaÃºde Coletiva 17 (6):1457–1468

Gallo E, Vaitsman J, Campos Filho AC (1996) Gestão Inovadora e Cultura Organizacional. In: Costa N, do R, Ribeiro JM (eds) Política de saúde e inovação institucional. Escola Nacional de Saúde Pública Sérgio Arouca, Rio de Janeiro

Habermas J (1985) Der philosophische diskurs der moderne. Suhrkamp, Frankfurt am Main

Ketele J, Roegiers X (1993) Méthodologie du recueil d'informations: fondements des méthodes d'observation, de questionnaire, d'interview et d'étude de documents, 2nd edn. De Boeck Université, Bruxelles

Maffesoli M (1984) A conquista do presente. Rio de Janeiro. Ed. Rocco

Magrin G, Marengo J, Boulanger JP, Buckeridge M, Castellanos E, Poveda G, Nobre C, Scarano F, Vicuna S (2014) Central and South America, chap 27. In: Barros VR, Field CB, Dokken DJ, Mastrandrea MD, Mach KC, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR, White LL (eds) Climate change 2014: impacts, adaptation and vulnerability. Part B: Regional aspects, Contribution of Working Group II to the fifth assessment report of the Intergovernmental Panel on Climate Change IPCC, 2014. Cambridge University Press, Cambridge, pp 1499–1566. http://www.ipcc-wg2.gov/AR5/report/citations/. ISBN: 978-1-107-68386-0. http://www.ipcc-wg2.gov/AR5/images/uploads/WGIIAR5-Chap27_FINAL.pdf. Accessed 02 Aug 2016

ONU (2015). Transforming our world: the 2030 agenda for sustainable development. Avaiable in https://sustainabledevelopment.un.org/post2015/transformingourworld

Ott JS (1989) The organizational culture perspective. Dorsey, New York

Santos BS (2006) A gramática do tempo: para uma nova cultura política. Cortez, São-Paulo

Santos BS (2007) Para além do pensamento abissal: das linhas globais a uma ecologia de saberes. Novos estudos—CEBRAP n. 79, São Paulo. http://www.scielo.br/scielo.php?pid¼S0101-33002007000300004andscript¼sci_arttext. http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0101-33002007000300004. Accessed 20 May 2016

Santos M (1999) O Dinheiro e o Território. Universidade de São Paulo- USP. GEOgraphia, ano. 1, n. 1, São Paulo

Santos M (2000) Por uma outra globalização - do pensamento único à consciência universal. Record, Rio de Janeiro

Santos M (2003) Por uma outra globalização: do pensa- mento único à consciência universal. 10a edn. Record, Rio de Janeiro

Tavares MGP (1993) Cultura organizacional: uma abordagem antropológica. Qualitymark, Rio de Janeiro

Thiollent M (2006) Metodologia da pesquisa-ação. Cortez, São Paulo. ISBN: 9788524911705

Toledo (2001) Indigenous people and biodiversity. Encyclopedia of biodiversity, vol 3. Academic Press, pp 451–463

Wetter KJ (2012) Rio+20: os equívocos da economia verde e das tecnologias. [acessado 2012 abr 17]. Dispo- nível em: http://www.yhu.unisinos.br/entrevistas/ 505705-rio20-os-equivocos-da-economia-verde-e- das-tecnologias-entrevista-especial-com-kathy-jo- wetter

Chapter 20
Climate Vulnerability Index: A Case Study for the City of Belo Horizonte, Brazil

Felipe Bittencourt, Marco Follador, Virgílio Pereira, André Rocha, Ciro Vaz, Thiago Vieira, Melina Amoni and Fabio Bicalho

Introduction

Over 80% of the population lives in cities in Brazil. This figure is expected to increase in the next decades due to internal migration from rural areas, a dynamic that reinforces the processes of spatial segregation, social inequality and environmental degradation. In the context of climate change, urban densification may lead to higher propensities to economic, social and environmental loss and damage. In contrast, the capacity of a city to deal with situations arising as direct and indirect impacts of climate change is also strongly influenced by social and economic inequalities. Divergences within urban areas create more vulnerable population groups, with limited capacity to adapt.

Urban growth and its consequent environmental impacts have been widely discussed (Oke 1982; Montgomery 2008; Grimmond et al. 2010; Baklanov and Nuterman 2009; Gosset et al. 2015; Baklanov et al. 2016; Su et al. 2016). Some of the consequences of rapid growth and lack of planning in cities consist of rising local temperatures and changes in wind circulation and other positive feedbacks of climate changes (Baklanov et al. 2016). In this context, city-level assessment of vulnerability to climate change essential to indicate adaptive measures at appropriate scales.

F. Bittencourt (✉) · M. Follador · V. Pereira · A. Rocha · C. Vaz · T. Vieira · M. Amoni · F. Bicalho
WayCarbon, BH-TEC, Parque Tecnológico de Belo Horizonte, R. Prof. José Vieira de Mendonça, 770, Belo Horizonte, MG CEP 31310-260, Brazil
e-mail: fbittencourt@waycarbon.com

W. Leal Filho and L. Esteves de Freitas (eds.), *Climate Change Adaptation in Latin America*, Climate Change Management,
https://doi.org/10.1007/978-3-319-56946-8_20

Analyses of vulnerability to natural hazards in the context of climate change and the need for adaptation have been carried out in other Brazilian cities, such as Goiânia (Goiás), Florianópolis (Santa Catarina), João Pessoa (Paraíba), Vitória (Espírito Santo) and Palmas (Tocantins), initiatives undertaken as part of the Emerging and Sustainable Cities (ESC) promoted by the Inter-American Development Bank (IDB).[1] Such studies have taken specificities of each city into consideration. In general, there is significant delay in the decision to invest in city infrastructure for bearing the acceleration of urban growth and the effects of climate change (Birkmann et al. 2010). However, this type of analysis granted city authorities access to appropriate information for making decisions about the future development of urban and social infrastructure at city level. It is important to note that such studies indicated the main features of climate vulnerability in Brazil being impacts related to fluvial and/or coastal flooding, landslides, forest fires, droughts and disease vectors.

Belo Horizonte is the capital of the state of Minas Gerais and is one of the most advanced cities in Brazil regarding climate change mitigation. For instance, the city diligently monitors greenhouse gas (GHG) emissions since 2008. Additionally, it published a 2020 GHG reduction target and implemented projects such as: (i) methane recovery and renewable energy production at the landfill and wastewater treatment plant, (ii) photovoltaic energy production at Mineirão stadium and (iii) bus rapid transit (BRT) system.

Even though Belo Horizonte has a comprehensive mitigation policy it still does not have a climate change adaptation plan. Therefore the city decided in 2015 to invest in a climate change vulnerability study, which is the topic of this paper.

The overall objective of this study is to perform an analysis of climate change vulnerability in the city of Belo Horizonte, considering both the municipality's current situation and projections for the year 2030 for the following impacts: flood, landslides, dengue and heat waves. Droughts were not considered because of data availability. This vulnerability assessment will serve as a basis for the Climate Change Adaptation Plan in Belo Horizonte, which shall optimize investments and reduce costs in accordance with the priorities of the municipal government.

Data and Methodology

Study Area

The study site for this analysis is Belo Horizonte, capital of the Brazilian state of Minas Gerais. Besides being a relevant economic center in Brazil, it is the country's sixth largest city in number of inhabitants (2,502,557 inhabitants) (IBGE 2015). The area of Belo Horizonte amounts to 331 km^2.

---

[1]Reports available at http://www.iadb.org/en/topics/emerging-and-sustainable-cities/emerging-and-sustainable-cities-initiative,6656.html.

Theoretical Framework of Vulnerability Assessment

According to the IPCC Fourth Assessment Report, vulnerability is defined in terms of the exposure of a system, its sensitivity to climatic stimuli and adaptability to their effects (AR4 IPCC 2007). In turn, the IPCC Fifth Assessment Report, recently published, provides a slightly different terminology; the climate change vulnerability approach is replaced by a climate change risk approach through the incorporation of community-based disaster risk concepts (AR5-IPCC 2014).

As this work adopts a vulnerability-based approach and does not comprise risk assessment, definitions given by AR4-IPCC 2007 are adopted (Fig. 20.1). A vulnerability index is calculated based on the available information on exposure to climate change, physical and environmental sensitivity to climate stimuli and the ability of the system to adapt to new conditions (Heltberg and Bonch-Osmolovsky 2011).

Modeling Framework

All the explanatory variables selected to represent climate change impacts and adaptability were geo-referenced and normalized to become spatially comparable and possible to be aggregated in a weighted average index. The choice of weights

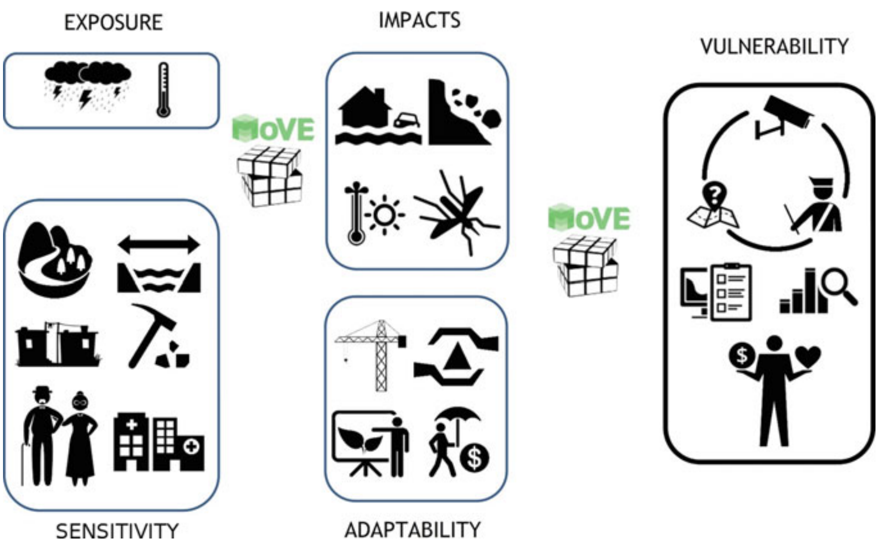


Fig. 20.1 The vulnerability of climate change is defined by the combination of the potential impacts incurred by the system and its adaptability to climate extremes and variability (IPCC 2007)

for each variable was based on the literature review and on results of the model calibration.

For the analysis of potential impacts of climate change in Belo Horizonte, the results of the most recent region climate downscaling model available (Eta-CPTEC, developed by Centro de Previsão de Tempo e Estudos Climáticos—Instituto Nacional de Pesquisas Espaciais/CPTEC-INPE) were coupled to global models HadGEM2-ES. Data used for the calculation of exposure had 5×5 km^2 spatial resolution.

Regarding sensitivity and adaptive capacity, calculation of each index and the choice of the most appropriate variables to characterize them relied on socio-economic and biogeographic attributes of the local context, data availability and priorities established by the Department of Environment of the Municipality of Belo Horizonte.

Equal weighting was applied to indicators of exposure, sensitivity and adaptive capacity, in order to group them into specific vulnerability indexes—one per type of impact assessed. That procedure was performed through the Model for Vulnerability Evaluation (MOVE),[2] an integrated platform that evaluates vulnerability associated with climate change. Finally, the average of vulnerability indexes was calculated in order to render one single vulnerability index for the city of Belo Horizonte.

A spatial approach was adopted in order to identify the regions where climate change impacts are concentrated, pointing out vulnerability hotspots (Oppenheimer et al. 2014). The attributes of the identified hotspots were analyzed with a higher degree of detail: more specific information on the characteristics of hotspots ensure better understanding of the causes leading to high levels of vulnerability and provide answers to questions such as where and how to intervene, as well as how much to spend on adaptation.

The modeling framework and the Input/Output fluxes are displayed in Fig. 20.2.

Floods

Information related to environmental sensitivity to flood occurrence were produced by crossing three indicators: morphometric flood susceptibility index; flood occurrence predisposition; and urban drainage index, all of which quantify characteristics associated to the physical susceptibility to flooding.

The exposure analysis was carried out based on local observations about maximum historical rainfalls and the outputs of climate simulations. Statistical analysis of extreme events of rainfall in different areas of the municipality was performed for different return periods by building frequency-intensity-duration curves (FID curves), according to the distribution of extremes of Gumbel type (Chow et al. 1994).

[2]www.moveonadaptation.com.

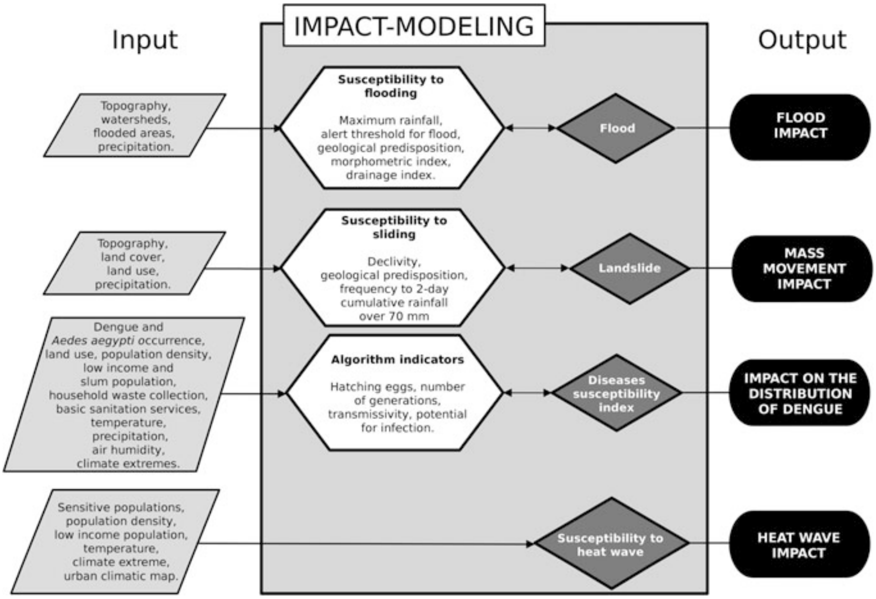


Fig. 20.2 MOVE modeling framework for the analysis of potential impacts of climate change in Belo Horizonte

Information on reference rainfall for macro drainage provided by the municipality was analyzed. The resulting rainfall levels (mm) associated with emergency alerts for events with 1 h of occurrence were then tabulated according to the municipal sub-basins. Finally, information about return periods of rain and rainfall levels (mm) leading to emergency alerts for 1-h-duration events were crossed. As a result, information on the probability of occurrence of flood events along the sub-basins of Belo Horizonte were produced both for climatic simulation and for the historical period, thereby constituting the climate exposure maps.

Adaptive capacity was mapped for two time periods (2016 and 2030) by crossing five indicators: population residing in slums in relation to total population of the sub-basin; low-income population; existence of rain alerts systems; presence of drainage infrastructure; and localization of reservoirs for flood control.

Recent records of flood occurrences in the city of Belo Horizonte were used to validate the model outputs.

This approach fills gaps in research in the field of vulnerability assessment, because it provides cartographic information of the probability of flood events in climate change scenario.

Landslides

Landslides are such a complex phenomenon that, until the present, there is no consensus on the main factors leading to their occurrence. However, inter-related aspects provide guidance on the elements that should be focused in order to allow for better understanding of that impact, namely: climate, physical environment and social (Cunha and Guerra 2003; Canavesi et al. 2013).

Selection of the method was performed based on the relevance, availability and quality of information. Thus, the physical elements selected were the ones with consistent scale and quality. The climate exposure indicator was calculated according to the Civil Defense's warning system scale. The adaptive capacity metrics were selected from indicators provided by the city.

The elements of climate and physical environment, together, form the base of the potential impact, whereas elements of the social environment form the base of adaptation.

Regarding the potential impact, bases were normalized and crossed against each other through weighted average (Crepani et al. 2001; Moro et al. 2011). A weight was assigned to each factor composing the impacts of landslides. In that sense, geological factors, climatic exposure and land cover received a weight of 0.2, whereas land declivity received a weight of 0.4. This classification considered the high degree of influence exerted by gravity on the landslide phenomenon. Adaptation index was calculated by simple average; thereby, housing quality indicators and the number of rain alerts received each a weight of 0.5.

Vulnerability to landslides was estimated by crossing data of climatic exposure (climate), declivity and geology (physical environment), land use, housing quality indicators and number of rain alerts.

Records of recent landslide occurrences provided by the Civil Defense of Belo Horizonte were used to validate model outputs.

Dengue

According to the World Health Organization (WHO), *Aedes aegypti* is the most important mosquito vector transmitting human diseases. Currently, dengue is considered the most important disease transmitted by mosquitos and estimates indicate there are between 50 and 100 million annual cases of dengue infection worldwide.

The increase or redistribution of rainfall as a result of climate change has the potential to increase the number and quality of the vector breeding sites. There is evidence that temperature extremes have already been slowing down or speeding up the development and survival of these insects.

While a number of tools exist to measure vulnerability to disease, most of them focus on when and where environmental conditions are optimal for an outbreak to occur; with little or no consideration of the role social determinants play in shaping vulnerability. This methodology was developed to assess vulnerability by integrating disease-specific measures of environmental exposure (i.e., temperature, precipitation, land cover etc.) with disease-specific measures of social susceptibility (i.e., life expectancy, educational attainment, access to healthcare etc.) to provide a holistic picture of vulnerability to disease. This is a practical disease-specific methodology for assessing vulnerability at a range of different spatial and temporal scales using publicly available data. It provides a new way of conceptualizing and communicating vulnerability to disease and, in this instance, demonstrates clear patterns of dengue vulnerability and how these may change over time. This methodology should be used to inform mid- to long-term allocation of resources to reduce or eradicate the burden of dengue.

It is possible to draw up a spatial representation of the potential distribution of the tropical disease vector in climate change scenarios, including future exposure data. The result is shown by an index composed by five indicators that represent regional susceptibility to this vector (*Aedes aegypti*). The first indicator presents the probability of occurrence generated by the MAXENT algorithm (Phillips et al. 2004). The second reports the likely number of vector generations according to temperature limits. The third indicator sets the transmission potential, also related to temperature data. The fourth indicator designs positivity for hatching eggs, associated with rainfall, temperature and relative air humidity. In addition, the fifth indicator is known as General Susceptibility Index, a methodology for quantitative assessment of susceptibility. The indicators were crossed at the same weight through map algebra procedures. As a result, a spatial representation of the potential impact of tropical diseases in climate change scenarios is drawn through a normalized ratio vector distribution.

Temperature is one of the main factors affecting the survival of *Aedes aegypti*. This parameter has been associated with seasonal changes in mosquito populations and has limited their geographical distribution (Fernandes et al. 2006). The amount and frequency of rainfall is also a known factor related to the distribution of the mosquito vector, although with less influence. That is due to the fact that temperature determines breeding, which can overflow under excessive rainfall, affecting laying and hatching of eggs. In contrast, casual rain can increase air humidity, an important factor leading to the increase in hatching of eggs.

Heat Waves

Regional climate change projections indicate a substantial increase in temperature extremes. Furthermore, they suggest that the length, frequency, intensity and magnitude of heat waves will experience a “large increase” over most of South America (IPCC 2012, 2014; Marengo et al. 2012). The evaluation of this phenomenon is given by the WSDI extreme[3] (Warm Spell Duration Index). In the

[3]Annual count of days with at least 6 consecutive days when daily maximum temperature exceeds the 90th percentile.

context of large cities in Brazil, adverse effects caused by heat waves are emphasized as a direct result of urbanization through heat islands, given the high capacity of urban surfaces to absorb heat (Nobre et al. 2011). In order to capture the spatial variability of heat waves at the local level, the urban climatic map of Belo Horizonte was used.[4]

High mortality rates during heat waves in cities are the result of longstanding periods of high temperature in combination with sensitive populations living in inappropriate housing conditions (IPCC 2007). Sensitive people, in turn, are defined by child population (below 5 years), elderly population (above 65 years) and population density.

Adaptability describes the population's resilience to heat waves and is measured as a combination of nominal income and access to health care. Poor people have low adaptability due to limited access to financial resources and inappropriate housing conditions (Monzoni 2009).

Results and Discussion

Floods

An increase in climate exposure to floods is expected by 2030 as a result of more intense events, with hourly rainfall of greater volume and more likely to generate damage and impacts, because increased extreme precipitation events can cause tangible changes in hydrological cycle (Trenberth 1999; Roy and Ballin Jr. 2004; Shaw et al. 2011). In this sense, regions showing the highest increase in exposure across time were North, Venda Nova and Pampulha.

Regarding adaptability to flooding in Belo Horizonte, results indicate that Venda Nova region has the best resilience, followed by Barreiro. Regions North, Northeast and East display the lowest values of adaptability to floods.

Overall, the most vulnerable areas to flooding are: Northeast, East, South-Central and North.

We assessed the vulnerability index in 2030 by simulating the operationalization of adaptation measures already planned by the city government in the next years. In this sense, the regions showing downward trends in vulnerability in that scenario were: Barreiro, Venda Nova, Northwest, Pampulha, South-Center and Northeast. Barreiro is the region that will benefit the most from those measures, presenting the most significant reduction in vulnerability.

[4]Urban climatic map for the purpose of Urban Planning of the Municipality of Belo Horizonte developed by Daniele G. Ferreira, Eleonora S. Assis e Lutz Katzschner, Architecture School of the Federal University of Minas Gerais/University of Kassel, project FAPEMIG TEC-APQ-00146-12. Preliminary result.

Landslides

Results demonstrated that regions East, Barreiro, Northeast and North had the biggest concentration of vulnerability in both the periods. However, the northern regions (Venda Nova, Pampulha and Northwest) showed the greatest variation between 2014 and 2030.

The assessment of vulnerability to landslides in Belo Horizonte indicated that the phenomenon is influenced by region peculiarities. The area of the municipality located in the limits of the Ferriferous Four-Side (Serra do Curral and Serra do Rola-Moça) has high vulnerability, influenced by steep declivity and geology. The high vulnerability index of northern regions is due mainly to the low levels of capacity of adaptation and an increasing level of exposure.

Dengue Distribution

Overall, the Northern sector of the municipal territory is more affected by Dengue than the Southern portion. Currently, regions North and Venda Nova are subject to greater impacts of dengue; these areas are more environmentally, economically and socially sensitive, besides being more climatically suitable for the development of the mosquito.

In 2030, such condition is expected to grow across regions East, Northeast, Northwest and Pampulha. Among these regions, the North presents the highest adaptation deficit and is the least able to cope with the impacts. In terms of area, region Venda Nova is the most vulnerable hotspot to dengue. Regarding intensity, several points are distributed in the municipal territory with some relevant spots in regions North, Northeast, East and even South-Central.

The increase of the average potential impact in the city across time seems to be directly linked to increases in minimum temperature and extreme precipitation events. While current temperatures would be limiting for the development of the range of the vector, temperature in the projected scenario is favorable for the vector development. The increase in average temperature favors the mosquito activity even in the winter in regions located in the South portion of Belo Horizonte. Therefore, investments in monitoring and controlling the breeding, reproduction and development of the mosquito will have to take place throughout the year, not only during rainy seasons.

Heat Waves

The assessment of vulnerability to heat waves in the urban context shows that hotspots in the territory of Belo Horizonte present similar population features: they are usually highly populated, have low socio-economic standards and concentrate large populations of children and elderly, often in slums. Moreover, the most vulnerable areas lack adaptability (in the form of access to health care and higher household income levels). The North region displayed the highest vulnerability index to heat waves, due to intensification of the temperature extremes in 2030.

Vulnerability Analysis in Belo Horizonte

The Vulnerability Index of Belo Horizonte was calculated as the simple average of the following vulnerabilities: flood, landslides, dengue and heat waves. The vulnerability index computed for the current period (2016) and for 2030 indicates, in both scenarios, that regions North, Northeast and East are the most vulnerable. Regional North, in turn, would be the one suffering the largest relative change in vulnerability (more than 10% in 2030). Regions Barreiro and Venda Nova have the lowest vulnerability, and the former is the one experiencing the smallest relative change in its vulnerability index (a 5% variation) (Table 20.1).

It is expected that, by 2030, the number of districts with high vulnerability will increase by 124 neighborhoods, being regions Northwest, West and Northeast the ones with the largest increase. It is noteworthy that the majority of neighborhoods within regions North, Northeast and East will be part of hotspots. Region Barreiro, despite having a few neighborhoods in that situation in both scenarios, is expected to experience a three-fold increase in the number of neighborhoods in with high vulnerability.

The composition of vulnerability indexes of the main hotspots in Belo Horizonte (which are concentrated in regions Central-South, East and the borders of regions North/Northeast and Pampulha/North) is detailed in Table 20.2. Between 2016 and 2030 we only registered an increase of surfaces of hotspots of vulnerabilities, whilst the composition remains unaltered (Fig. 20.3).

Table 20.1 Vulnerability in Belo Horizonte—Administrative regions

Region	2016		2030		Relative variation (%)
	Max	Average	Max	Average	
North	0.58	0.47	0.63	0.52	10.64
Northeast	0.56	0.47	0.62	0.51	8.51
East	0.60	0.47	0.63	0.50	6.38
Central-South	0.62	0.42	0.62	0.45	7.14
Barreiro	0.52	0.40	0.53	0.42	5.00
West	0.53	0.42	0.57	0.46	9.52
Northwest	0.55	0.43	0.56	0.46	6.98
Pampulha	0.57	0.41	0.62	0.45	9.76
Venda Nova	0.57	0.40	0.62	0.44	10.00

Table 20.2 Composition of the main Belo Horizonte vulnerability hotspots in 2016 and 2030

Region	Vulnerability to floods	Vulnerability to landslides	Vulnerability to Dengue	Vulnerability to heat waves
Central/South	High	High	Medium–high	Medium–high
North/Northeast	Medium	High	High	High
Pampulha/North	High	Medium–high	High	Medium
East	High	High	High	High

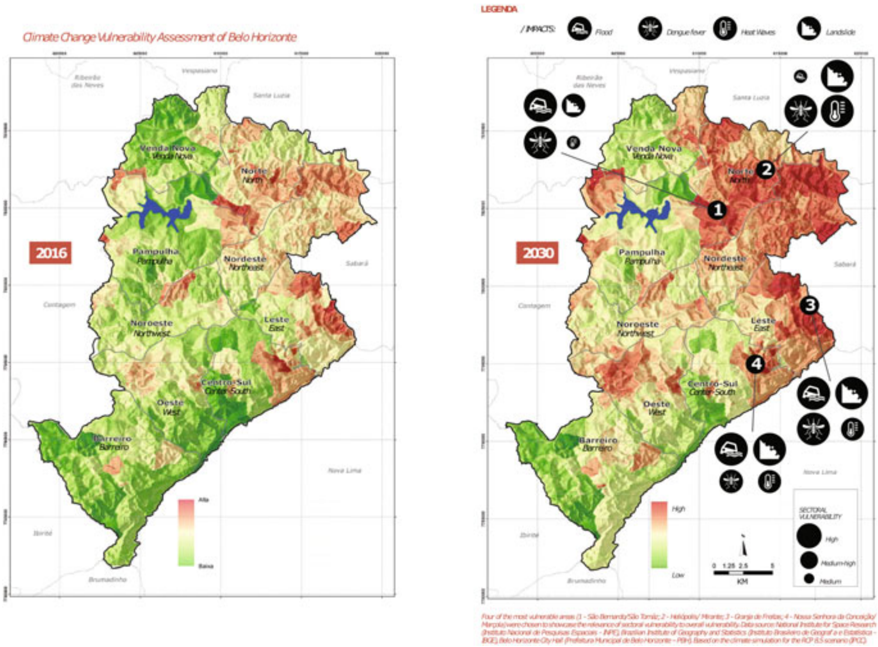


Fig. 20.3 Belo Horizonte vulnerability index for 2016 (baseline) and 2030 (scenario RCP 8.5)

Conclusions

The Climate Change Vulnerability Assessment of Belo Horizonte identified the most vulnerable areas of the city to climate change. Vulnerabilities to flooding, landslides, spatial distribution of Dengue and heat waves were calculated by crossing Potential Impact Indexes and Capacity of Adaptation Indexes according to current climate variability and projected RCP 8.5 climate scenario in 2030.

The main lesson from this paper is that there is a general trend that the northern portion of the city is more affected by temperature increases than the South, which influences dengue occurrence and heat waves. In the southern region the variation of vulnerability is mainly due to geological and geomorphological characteristics (which includes rough terrain and steep slopes).

This assessment pointed out well-defined areas where adaptation measures are needed. Proactive actions should be designed in line with the city mid and long-term planning in order to optimize the investment and decrease future losses and damages. The study pointed out that vulnerable areas often host low-income communities, characterized by low capacity of coping with climate change impacts. Usually, priority areas for adaptation measures are those inserted in shantytowns.

The most vulnerable areas to flooding were: North-East, Central-South and North. In general, an increase of climate exposure to flooding generates a higher propensity to damage and impacts. In order to reduce flooding, improvements of infrastructure, warning systems and macro-drainage are needed. The assessment of vulnerability to landslides indicated that the phenomenon is influenced by different factors among regions. The portion of the city located on the edge of Serra do Curral and Serra Rola-Moça is usually very vulnerable, influenced by their physical sensitivity (steepness and geology). The high vulnerability observed in region North and parts of the Northeast is due to a lack of capacity of adaptation (low number of warning centers and low-quality housing), together wit an increasing climate exposure in 2030.

Regarding the potential impact of dengue, the Northern region of Belo Horizonte is more affected than the Southern region due to climate and socio-environmental characteristics. Humidity and the increase in minimum temperatures during the evening are the main climatic factors contributing to the survival of Aedes Aegypti. In 2030, the high vulnerability of the Northern region is related to its low capacity of adaptation. Social and educational measures, as well as continuous monitoring of vector development, are presented as forms of proactive actions to address this issue.

The Northern region of Belo Horizonte is the most vulnerable to extreme temperatures, which are predicted to become more intense by the year 2030. Vulnerability associated with heat waves is concentrated on areas where socioeconomic characteristics are less favorable and the capacity of adaptation (e.g., access to health facilities and income availability) is more limited. Hence, proposals for adaptation measures should be designed and implemented for multiple benefits, such as improved air quality, better human health conditions, thermal comfort, reduced energy demand and reduction in greenhouse gas emissions.

Future researches in Belo Horizonte's area should consider climate change impacts on water availability as well as risk analysis by including assets and population affected and potential hazards.

Acknowledgements This study was partially funded by FINEP, FAPEMIG and CNPq.

References

Baklanov AA, Nuterman RB (2009) Multi-scale atmospheric environment modeling for urban areas. Adv Sci Res 3(1):53–57. doi:10.5194/asr-3-53-2009

Baklanov A, Molina LT, Gauss M (2016) Megacities, air quality and climate. Atmos Environ. doi:10.1016/j.atmosenv.2015.11.059

Birkmann J, Garschagen M, Kraas F, Quang N (2010) Adaptive urban governance: new challenges for the second generation of urban adaptation strategies to climate change. Sustain Sci 5:185–206. doi:10.1007/s11625-010-0111-3

Canavesi V, Camarinha PIM, Algarve VR, Carneiro RIC, Alvalá RCS (2013). Análise da susceptibilidade a deslizamentos de terra: estudo de caso de Paraibuna, SP. In: Simpósio Brasileiro de Sensoriamento Remoto, 16. (SBSR), Foz do Iguaçu. Anais… São José dos Campos: INPE, 2013, pp 5251–5258. DVD. ISBN: 978-85-17-00066-9 (Internet), 978-85-17-00065-2

Chow V, Maidment D, Mays I (1994) Hidrologia Aplicada. Santa Fe de Bogotá. Mc Graw-Hill, Colombia, p 584

Crepani E, Medeiros JD, Hernandez Filho P, Florenzano TG, Duarte V, Barbosa CCF (2001) Sensoriamento remoto e geoprocessamento aplicados ao zoneamento ecológico-econômico e ao ordenamento territorial. Inpe, São José dos Campos

da Cunha SB, Guerra AJT (2003) Geomorfologia e Meio Ambiente. Bertrand Brasil, Rio de Janeiro

Fernandes C et al (2006) Biologia e exigências térmicas de Aedes aegypti (l.)(diptera: Culicidae) provenientes de quatro regiões bioclimáticas da Paraıba. Neotrop Entomol 35:853–860

Gosset A, Ferro Y, Durrieu C (2015) Methods for evaluating the pollution impact of urban wet weather discharges on biocenosis: a review. Water Res 89:330–354. doi:10.1016/j.watres.2015.11.020

Grimmond CSB, Roth M, Oke TR, Au YC, Best M, Betts R, Voogt J (2010) Climate and more sustainable cities: climate information for improved planning and management of cities (producers/capabilities perspective). Proc Environ Sci 1:247–274. doi:10.1016/j.proenv.2010.09.016

Heltberg R, Bonch-Osmolovskiy M (2011) Mapping vulnerability to Climate Change. Policy research working paper No 5554. The World Bank

IPCC (2007) Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE (eds) Cambridge University Press, Cambridge

IPCC (2012) Managing the risks of extreme events and disasters to advance climate change adaptation. In: Field CB, Barros V, Stocker TF, Qin D, Dokken DJ, Ebi KL, Mastrandrea MD, Mach KJ, Plattner GK, Allen SK, Tignor M, Midgley PM (eds) A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York

IPCC (2014) Climate change 2014: impacts, adaptation, and vulnerability part A: global and sectoral aspects. In: Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR, White LL (eds) Contribution of working group II to the fifth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, UK and New York

Marengo J, Chou SC, Kay G, Alves LM, Pesquero JF, Soares WR, Santos DC, Lyra A, Sueiro G, Betts R, Chagas DJ, Gomes J, Bustamente JF, Tavares P (2012) Development of region future climate change scenarios in South America using the Eta CPTEC/HadCM3 climate change projections: climatology and region analyses for the Amazon, Sao Francisco and the Parana River basins. ClimDyn 38:1829–1848

Montgomery MR (2008) The urban transformation of the developing world. Science 319 (5864):761–764. doi:10.1126/science.1153012

Monzoni M (2009) Diretrizes para formulação de políticas públicas em mudanças climáticas no Brasil. São Paulo, Observatório do Clima. www.fgv.br/ces/oc

Moro GT, de Souza LVMP, Almeida ES (2011) Levantamento de susceptibilidade a deslizamento e erosão em encostas–estudo de caso: Morro da Cruz–Itajaí–SC. XV Simpósio Brasileiro de Sensoriamento Remoto (SBSR). Anais… Editor INPE. Curitiba, pp 4162–4169

Nobre CA, Young AD, Salvida PH, Marengo JA, Nobre AD, Ogura A, Silveira AC (2011) Vulnerabilidade das Megacidades Brasileiras as Mudanças Climáticas: Região Metropolitana de São Paulo, Relatório Final. Instituto Nacional de Pesquisas Espaciais-INPE, São José dos Campos

Oppenheimer M, Campos M, Warren R, Birkmann J, Luber G, O'Neill B, Takahashi K (2014) Emergent risks and key vulnerabilities. In: climate change 2014: impacts, adaptation, and vulnerability. Part A: global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Cambridge University Press, Cambridge, United Kingdom and New York, NY, pp 1039–1099

Oke TR (1982) The energetic basis of the urban heat island. Quart J R Meteorol Soc 108(455):1–24. doi:10.1002/qj.49710845502

Phillips, S. J. Dudík, M. Schapire, R. E. (2004). A maximum entropy approach to species distribution modeling. In: Proceedings of the twenty-first international conference on machine learning, pp 655–662

Roy SS, Balling RC Jr (2004) Trends in extreme daily precipitation indices in India. Int J Climatol 24:457–466

Su M, Chen C, Yang Z (2016) Urban energy structure optimization at the sector scale: considering environmental impact based on life cycle assessment. J Clean Prod 112:1464–1474. doi:10.1016/j.jclepro.2015.01.059

Shaw SB, Royem AA, Riha SJ (2011) The relationship between extreme hourly precipitation and surface temperature in different hydroclimatic regions of the United States. J Hydrometeorol 12:319–325

Trenberth K (1999) Conceptual framework for changes of extremes of the hydrologic cycle with climate change. Clim Change 42:327–339

Chapter 21
Assessing Ecosystem Integrity in the Brazilian Amazon Rainforest to Indicate Biodiversity Loss and Highlight Areas for Adaptation Policies

Margareth Simões, Rodrigo P.D. Ferraz and Andrei O. Alves

Introduction

Unlike most developed countries or even some BRICS countries whose greenhouse gas emissions are mostly related to the burning of fossil fuels, in Brazil almost 80% of emissions are due to deforestation or land use change and only 17% come from the burning of coal, oil and natural gas (Nobre 2008). This situation places Brazil in a special position, since it holds around 30% of the world's tropical forests (FAO 2006), most of them located in the Amazon Region, the country presents a great opportunity to overturn this scenario through the implementation of REDD (*Reducing Emissions from Deforestation and Forest Degradation*) mechanism and also through the incentive to the adoption of low-carbon agricultural systems (Plano ABC—BRASIL 2012).

This situation draws the attention of the world to the Brazilian Amazon region and highlights all issues related to land use impacts and forest conservation, resurging the discussions about the necessity of implementing more sustainable—economic, social and environmental—development systems. In this context, climate change represents a new environmental factor that brings more complexity into the equation to achieve the desired sustainability. The climate change warning also brings the discussion about the vulnerability of ecosystems (socioeconomic

M. Simões (✉) · R.P.D. Ferraz
Embrapa Solos, Rua Jardim Botânico 1024, CEP 22460-000 Rio de Janeiro, Brazil
e-mail: margareth.simoes@embrapa.br

R.P.D. Ferraz
e-mail: rodrigo.demonte@embrapa.br

M. Simões · A.O. Alves
Programa de Pós-Graduação em Meio Ambiente (PPGMA),
Universidade do Estado do Rio de Janeiro—UERJ, Rua Maracanã 524,
Rio de Janeiro, RJ CEP 20550-013, Brazil
e-mail: kaageo@gmail.com

W. Leal Filho and L. Esteves de Freitas (eds.), *Climate Change Adaptation in Latin America*, Climate Change Management,
https://doi.org/10.1007/978-3-319-56946-8_21

and natural ecosystems), risks of biodiversity loss and mitigation/adaptation to the imminent and inevitable impacts.

The vulnerability of a natural or anthropic system can be described, according to the IPCC (2007), as a function of the likelihood of exposure to risk factors (climate change), the susceptibility of the system due to its intrinsic natural characteristics (biophysical or socioeconomic), which determines the degree of resistance to external changes (resilience) and adaptability that means the system ability to modifying their internal properties in order to maintain its functionalities (adaptation).

According to Nobre (2008), all socioeconomic and environmental systems present a variety degree of vulnerability to climate changes and most of the impacts will be negative and will require adaptation policies.

With a strong dependence on renewable natural resources, the Brazilian economy is potentially vulnerable to climate change that may eventually alter the environmental services provision related to these resources. Moreover, it should be highlighted that climate change and the resulting extreme weather effects will stress the social vulnerability of the poorest, because they have less adaptive capacity due to their structural difficulties to cope with extreme events. With more than 50% of the population in a state of poverty, the country still faces a great social and regional inequality, making it particularly vulnerable to the forecasted climate change, especially the rural populations of the semi-arid region of the Northeast and riverside populations of the Amazon (Nobre 2008).

From the biodiversity vulnerability point of view the adaptation of forest species to climate change can occur through genetic evolution or migration to more appropriate locations and, perhaps, the vegetation migratory dynamics was the most common adaptive answer in the past climate changes. Although, evolutionary history shows that forests have a high degree of resilience to climate changes, the majority of the vegetation does not have the intrinsic ability to adapt to climate fluctuations on the time scale of current climate changes (Nobre 2008). Moreover, currently, forests fragmentation and degradation make them more vulnerable to climate changes due to the reduction of their capacity to adapt (Krug 2008).

According to the Convention on Biological Diversity (CBD) there are clear connections between biodiversity and climate change. Biodiversity supports many ecosystem services that are very important for climate change mitigation and adaptation, such as the capacity of tropical forests for carbon uptake and storage. The maintenance of biodiversity and ecological functions is crucial to mitigate the effects of the ongoing climate change. In this way, protecting primary forests, containing fragmentation, reducing degradation and low-intensity forestry constitute land use and management practices that are necessary to increase climate change mitigation and adaption to adverse weather conditions in the future (Krug 2008).

However, changes caused by deforestation, logging and agricultural expansion reduce biodiversity and consequently the ecosystems' integrity, modifying the functions directly related to ecosystem services. The relationship between biodiversity loss and the ecosystem services in tropical forests, in the face of the ongoing global climate change, has been quite accepted by the scientific community, nevertheless, it is not easy to measure precisely to what extent it occurs.

The concept of biodiversity is quite diverse, and it is related to different levels of biological systems ranging from the level of genes, species taxonomic richness to functional groups (CBD 1992). In this way, depending on the approach, several indicators, conceptually unrelated, can be used to characterize and quantify the biodiversity of a given natural system. However, in practical terms, the biodiversity, as a characteristic of ecosystems, is an indicator of the ecosystem´s stage regarding its pristine conditions. Thus, the concept of biodiversity can guide the definition of indicators that characterize the state of a given natural system with regard to its capacity for self-regulation or maintenance of ecosystem processes (Simões et al. 2014). According to De Groot (2005) the ecological value of a particular ecosystem is thus determined by both the integrity of regulatory functions and by environmental parameters, such as its complexity, diversity and rarity.

The concept of Ecosystem Integrity (EI) is however heavily discussed and a huge amount of definitions are used. In general EI is used as a synonym for intactness, completeness and integration of ecosystems. Jorgensen and Müller (2000) describe EI as a balanced, integrated adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of a natural habitat of a region. Supporting and maintaining such an ecosystem requires indicators to assess its state, as a way to operationalize the concept of EI. Indicators used to assess EI are e.g. sun energy input (radiation balance, production of biomass) and export (respiration, transpiration), storage capacity of plants, biotic water flow (transpiration), nutrient flows (mineralization) and biotic diversity (species number). Still, the causality of the relations between these indicators and the state of EI are not clear and as understanding of the ecosystems is incomplete the responses from human actions are highly uncertain.

The integrity state is a characteristic of the ecological systems which keeps its biodiversity level—functional, structural and taxonomic—close to the pristine stages. Ecosystem Integrity can, consequently, be understood as a dynamic state of natural ecosystems in which it is observed maximum capacity of resilience and self-organization, maintaining many ecosystem processes related to most terrestrial biogeochemical cycles.

Ecosystem Integrity can be considered as an indicator representing the state of biodiversity and, consequently, can also represent ecosystem state in terms of the processes that maintains the stability. In this way, a value extremely high of Ecosystem Integrity represents a hypothetical state in which the ecosystem processes and biodiversity are virtually untouched. The different degrees of EI represent different level of ecosystem degradation, caused by the loss of biodiversity and the instability of ecosystem processes.

However, despite being an integrative indicator, Ecosystem Integrity is a latent property of ecosystems that is not directly observable (Equihua et al. 2013). As an unobservable variable, EI can be evaluated through indirect variables considered as evidence of the phenomenon under analysis. This limitation may cause a relative degree of uncertainty and therefore the best way to lead with it is to work with probabilistic approaches like Bayesian Belief Networks (BBN) models.

Bayesian Belief Networks (BBN) are models that probabilistically represent correlative and causal relationships among variables. BBNs have been successfully applied to natural resource management to address environmental management problems and to assess the impact of alternative management measures. By training the probabilistic relationships using field data and/or Remote Sensing and GIS datasets the BBN can provide important information on the ecosystems as, for example, ecosystem integrity and their likely response to climate change or alternative management actions.

BBNs have been used mainly to study results from deliberative participatory questionnaires linked to GIS data (e.g. Gret-Regamy et al. 2013) with a very small amount of spatial entities (e.g. Haines-Young 2011). In fact, only a few studies have fully integrated BBNs and GIS and explored the resulting benefits (Stelzenmuller et al. 2010).

In this chapter, it is proposed the use of "Ecosystem Integrity Index" (EI) as an indicator of biodiversity loss and as a mean to assess the state of ecosystems processes. The Bayesian Belief Networks (BBN) was integrated with GIS, using them to map a large number of spatial entities and multiple iterations, in order to study the Ecosystem Integrity for the Brazilian Amazon rainforest. It is worth mentioning that this is approach is based, exclusively, on the use of free web-available satellite products, what is especially important for regions where there is a lack of updated systematic mapping, inventory or data collected in the field. This methodology is particularly important for countries with no or low field data availability.

On the other hand, the use of EI spatial index allows the establishment of several relationships with representative variables of ecosystem processes as well as with socioeconomic data in order to come up with different scientific studies. It is possible to establish, for example, correlations with the carbon stocks (aboveground biomass) and evapotranspiration fluxes to study the relationships with processes that can mitigate the effects of climate change. Or even establish relationships with loss of ecosystem integrity and socioeconomic parameters, for example, to study issues related to socioeconomic vulnerability and possible adaptation alternatives.

Finally, the progressive loss of biodiversity, declining ecosystem services, degradation of natural resources, climate change and socio-economic sustainability are intrinsically linked, creating a vicious cycle that increases the vulnerabilities of socio-economic and environmental systems. Spatial indexes such as "Ecosystem Integrity" can help to understand these complex interactions, making it possible to prioritize areas where adaptation or mitigation policies should be applied.

Methodology for Generation of Ecosystem Integrity Index

The methodological approach consists in the generation of a spatial model based on the probability distribution of the variables considered as Ecosystem Integrity evidence, using Bayesian Belief Network (BBN) and the learning Expectation Maximization algorithm (EM-Expectation Maximization). By training the probabilistic relationships using Remote Sensing or GIS data, the BBN can provide metrics for the generation of ecosystem integrity index and their likely response to climate change or alternative management actions. Three factors are essential to the success of this approach: choose the evidence of Ecosystem Integrity; draw a representative network and define the evidence thresholds. The modeling was based on learning from the parameters (data-driven model) through the use of the Expectation Maximization algorithm. For the validation of this probabilistic model, an evaluation was carried out in controlled areas, with field observation and a comparison with the EI model based on knowledge prepared by experts (knowledge driven).

Bayes (Bayesian Belief Network—BBN)

Bayesian Belief Networks (BBN) are models that probabilistically represent correlative and causal relationships among variables. Bayesian networks are directed acyclic graphs whose nodes represent random variables in the Bayesian sense: they may be observable quantities, latent variables, unknown parameters or hypotheses. The Bayesian method is based on the concept of a priori and a posteriori probability and consists of determining the probability of a given event considering the presence of a condition or evidence, for example, a Bayesian network could represent the probabilistic relationships between diseases and symptoms. Given symptoms, the network can be used to compute the probabilities of the presence of various diseases. The method makes use of mathematical sets to generate conditional probability functions, based on the principles introduced by Bayes.

The mathematical modeling of Bayes' theorem connects the rational inference (probability a posteriori) to the subjectivity (a priori probability) and the empirical experience (conditional probabilities). Bayesian Networks are probabilistic models that represent causal relationships between variables. In other words, describes the probability distribution between the variables considered as evidence and the phenomenon of interest. Detailed information about the Bayesian method can be found in Lindley (1972) and Lauria and Duchessi (2006).

Expectation Maximization (EM)

The Expectation Maximization algorithm can be described as a generalization of the maximum likelihood estimation algorithm for the case of incomplete data. The algorithm EM searches the parameters $\hat{\theta}$ that maximize the log probability $\log P(x; \theta)$ of the observed data. Basically, the optimization problem addressed by EM is more complex than the optimization performed by the maximum likelihood algorithm (Do and Batzoglou 2008).

Evidence and Conditions of Ecosystem Integrity (EI)

Evidences area variables that describe the phenomenon, choose the representative evidences is a key factor in the process of generation of EI. Evidence can be originated from remote sensing data, systematic mappings, collected field data, among others. However, it is important to emphasize the need to obtain data from reliable sources, with high quality standards, covering much of the area examined and allowing the continuous mapping in future. Still, the evidence must be compatible with each other considering temporal resolution (day, month or year), spatial resolution or scale and, obligatorily, must be of significant importance for the generation of Ecosystem Integrity.

In this work, we propose the use, as evidence, data from Terra/Modis—Moderate-Resolution Imaging Spectroradiometer—satellite products. Terra/MODIS satellite products are free and have shown in our studies to be sufficient to provide evidence for mapping the Ecosystem Integrity for countries with low data availability.

The MODIS sensor is an instrument aboard the Terra and Aqua satellites, both designed and managed by EOS—Earth Observing System from NASA-National Aeronautics and Space Administration. Both sensors Terra/MODIS and Aqua/MODIS are re-visiting the entire surface of Earth each 1–2 days, acquiring data in 36 spectral bands. These data is been aiding researchers to understand global dynamics and Earth processes. We defined as evidence coming from remote sensing data, the following products:

- EVI—Enhanced Vegetation Index: The Enhanced Vegetation index is an index that highlights the areas with greatest amount of vegetation. In comparison with the NDVI (Normalized Different Vegetation index), the EVI minimizes the variations of the canopy and maintains the sensitivity about the conditions of dense vegetation. Also, use the blue range of the spectrum to eliminate the residual atmosphere contamination caused by smoke and thin clouds sub-pixels.

- LAI—Leaf Area Index: The leaf area index is a product generated from the MODIS data by the Center for Global Change Data Processing and Analysis of Beijing Normal University. Basically, the index represents leaf area unit per unit area of land.
- VCF—Vegetation Continuous Fields: percent tree cover. The Continuous Fields of vegetation index: percentage of tree cover is a product derived from MODIS data and represents, the percentage of area covered by greenery per pixel.
- GPP—Gross Primary Productivity: The Gross primary productivity index corresponds to the amount of organic matter produced by the ecosystem in certain area, within a specific time interval.

It is important to note that although some evidences mentioned appear to provide similar results, they provide different spectral responses for a particular area and, also, for different types of physiognomies, allowing a good differentiation of regions. Figure 21.1 shows an example of this differentiation to the Tapajós National Forest area-Para Sate, Brazilian Amazon Region.

In addition to the evidences coming from Remote Sensing products, conditional factors of Ecosystem Integrity were used. The purpose of the use of those conditions factors is to insert spatial limits in the probabilistic model to separate areas with different phytophysionomics characteristics. Doing that, we can even model a network for each type of phytophysiognomy, making it possible to set thresholds in accordance with the characteristic of each region.

In this approach, as conditional factors Phyto-Ecological Potential Zone (PPZ) limits were established by experts for the Brazilian Legal Amazon Region. Unlike the current Phyto-Ecological Zones, the Phyto-Ecological Potential zones refer to the past, where in a pristine environment all phytophysiognomies were preserved and intact. Depending on the country or region, other spatial zoning, able to identify different phyto-physiognomy or potential vegetation boundaries, can be used, such as the Holdridge bioclimatic zoning (Holdridge 1977).

In the context Ecosystem Integrity, considering the evidences used, given a phytophysiognomy, areas presenting high vegetation index, high leaf area index, higher percentage of area covered by greenery and with higher amount of organic matter produced, are areas presenting a higher probability of an ecosystem remain with higher integrity than regions where the values of the evidences are low. It is worth mentioning that, what defines if the value of evidence is high or low (in the context of EI) is a cutting threshold previously reviewed and established by an expert.

Bayesian Network Modeling

Bayesian Networks are represented by graphs that denote a relationship of cause and effect between random variables interdependent in probabilistic models.

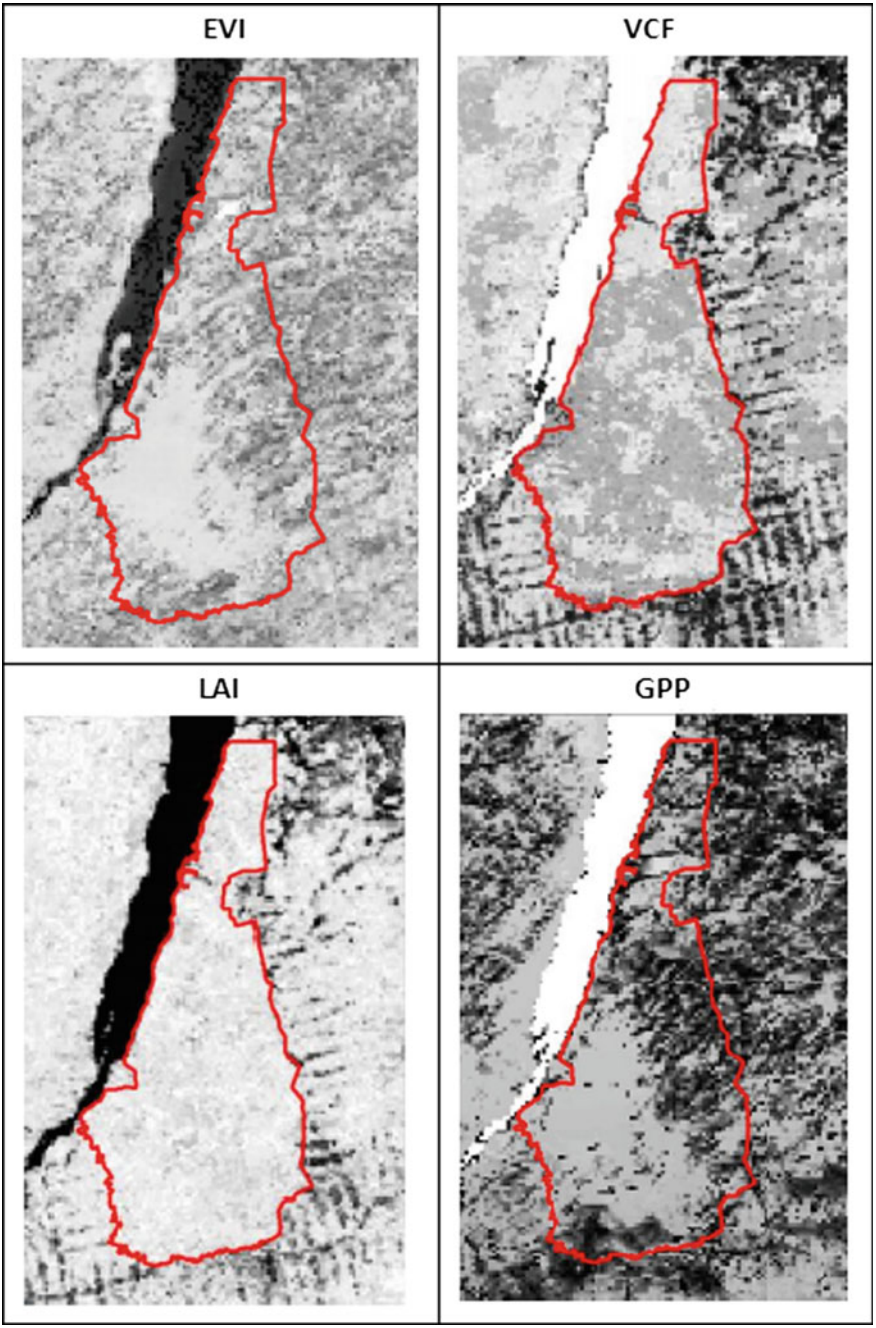


Fig. 21.1 Example of satellite products used as evidence in Tapajós National Forest-Pará State, Amazon Region, Brazil

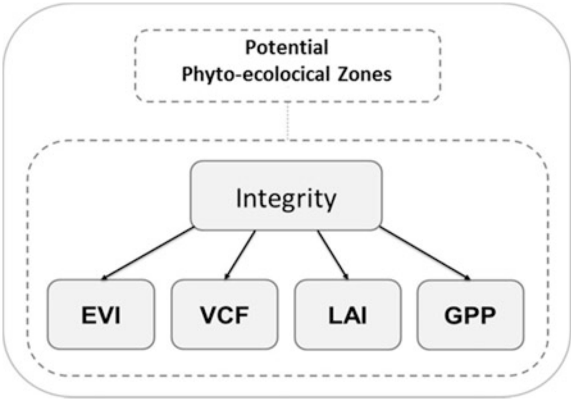


Fig. 21.2 Bayesian network applied for each phyto-ecological potential zone

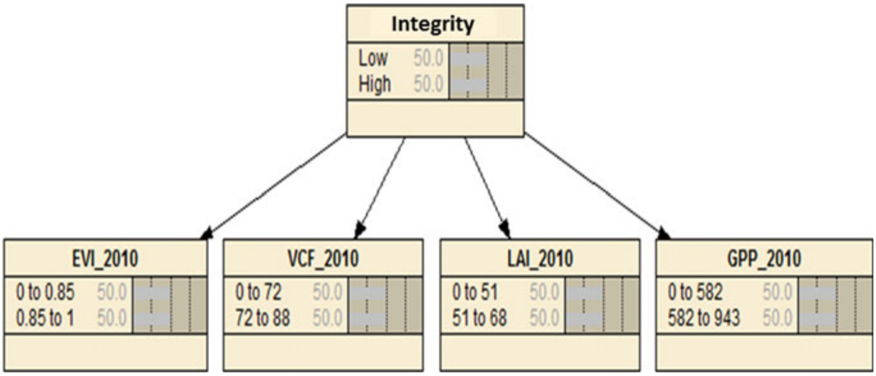


Fig. 21.3 Example of network modeled

The final network proposed in this work was created based on the knowledge of various specialists (ecologists, biologists, geographers, foresters and specialists in GIS and Remote Sensing). Experts adjusted and improved the conceptual model of the network, taking into consideration the theoretical assumptions and data availability.

Based on the improvement of model, there was a consensus that to get the best response to different phytophysiognomics features of the region, it would be necessary to run the model independently for each Potential Phytoecological Zone of the Brazilian Legal Amazon region, allowing the definition of threshold for each evidence, as exemplified in Fig. 21.2.

The network structure was designed so that the node "Integrity" represented a direct cause of the evidence, that are the ecosystem attributes obtained freely from satellite products (EVI, VCF, LAI, and GPP). Thus, the change of State of each of the ecosystem attributes entail directly in Ecosystem Integrity probability.

Network Modeling

For the network modeling, the data of each evidence were discretized in two classes (low and high integrity Integrity), using as a reference the previously defined thresholds. After the modeling stage, following the model shown in Fig. 21.2, the networks were performed using the learning algorithm. Figure 21.3 shows an example of the network created.

Study Area

Due to the global importance of the Amazon rainforest ecosystem and in order to carry out an analysis on a regional scale, the methodological approach was applied to the area of the Brazilian Legal Amazon, which includes nine Brazilian States: Acre (AC), Amazonas (AM), Amapá (AP), Maranhão (MA) (partially), Mato Grosso (MT), Pará (PA), Rondônia (RO), Roraima (RR) and Tocantins (TO). It is important to note also, that we took into account the various phytophysiognomics characteristics presented in this region showed in Fig. 21.3, allowing evaluating the methodological approach in bio-diverse regions.

Data Acquisition and Preprocessing

The remote sensing data used as evidence of the model are presented in Table 21.1.

To evaluate the results comparing the EI with ecosystem services were used the following data presented in Table 21.2.

The vector data used in the approach are presented in Table 21.3.

Phyto-ecologic Potential Zones have been used as conditions of EI, separating the areas in zones according to their phytofisionomics characteristics, topography features (relief) and climate in order to decrease the environmental heterogeneity and allow better adjustment of the model. The data of Brazil's Conservation Units were used in the definition of thresholds of evidence. The limit of the Legal Amazon was used as a mask to cut the data in raster format. The State administrative boundaries were only used as reference data for policy analysis.

Table 21.1 Data used as evidence of the model

EVI—enhanced vegetation index (enhanced vegetation index)
• Product: MODIS-3,005 MOD13A (Monthly L3 Global 1 km) • Frequency: monthly • Date: 1/1/2010 • Pixel: 1 km • Format of the file: HDF • Subdataset 1 | Variable: "1_km_monthly_EVI" • Source: USGS-NASA • General information: "https://lpdaac.usgs.gov/dataset_discovery/modis/modis_products_table/mod13a3"
LAI—index of leaf area (leaf area index)
• Product: MODIS-MOD09A1 • Periodicity: 8 days • Date: 1/1/2010 to 1/8/2010 • Pixel: 1 km • Format of the file: HDF • Subdataset 0 | Variable: "LAI" • Source: LIANG and XIAO, 2012/USGS-NASA • General information: "http://glcf.umd.edu/data/lai/"
VCF—percentage of tree cover (vegetation continuous fields-percent tree cover
• Product: MODIS-MOD44B_V5 • Periodicity: Annual • Date: 2010 • Pixel: 250 m • File format: GEOTIF • Subdataset: TRE-Percent tree cover • Source: DIMICELI et al., 2011-USGS/NASA • General information: "http://glcf.umd.edu/data/vcf/"
GPP—gross primary productivity (gross primary productivity)
• Product: MODIS-2,005 MOD17A (8-Day L4 Global 1 km); • Periodicity: 8 days • Date: 1/1/2010 to 1/8/2010 • Pixel: 1 km • Format of the file: HDF • Subdataset 0 | Variable: "Gpp_1 km" • Source: USGS-NASA • General information: "https://lpdaac.usgs.gov/dataset_discovery/modis/modis_products_table/mod17a2"

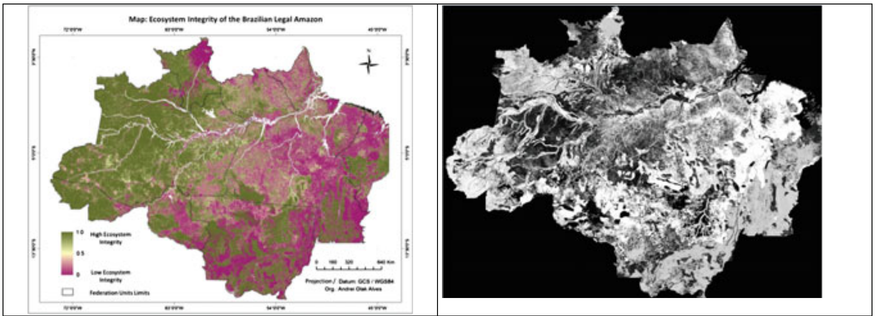
Table 21.2 Ecosystem services data to evaluate/comparing the EI results

ET-evapotranspiration (evapotranspiration)
• Product: MODIS-3,105 MOD16A (mm/year) • Periodicity: Yearly • Date: 2010 • Pixel: 1 km • Format of the file: HDF • Subdataset 0 | Variable: "ET_1 km" • Source: MU et al., 2013/USGS-NASA • Gene general information: "http://www.ntsg.umt.edu/project/mod16"
Biomass (biomass)
• Product: field/data Deal (GLAS)/MODIS • Periodicity: Yearly • Date: 2008 to 2010 • Pixel: 500 m • File format: GEOTIF • The Subdataset • Source: BACCINI et al., 2012 • General information: "http://www.ntsg.umt.edu/project/mod16"
Carbon in vegetation (vegetation carbon stock)
• Item: LPJmL-Lund-Potsdam-Jena Land Management • Periodicity: Yearly • Date: 2010 • Pixel: 5 km • Format of the file: NC • Subdataset • Source: SITCH et al. 2003 • General information: "https://www.pik-potsdam.de/research/projects/activities/biosphere-water-modelling/lpjml"
NPP—net primary productivity (net primary production)
• Product: MODIS-MOD17A 3,055 (Yearly L4 Global 1 km) • Periodicity: Yearly • Date: 2010 • Pixel: 1 km • Format of the file: HDF • Subdataset 1 | Variable: "Npp_1 km" • Source: USGS-NASA • General information: "https://lpdaac.usgs.gov/dataset_discovery/modis/modis_products_table/mod17a3"

Table 21.3 Spatial vector data

Potential phyto-ecologic zones
• Year: 2008 • Scale: 1:250,000 • Primary source: IBGE • Secondary source: adapted from PROBIO, 2008
Protected areas of Brazil
• Year: 2014 • Scale: 1:5,000 to 1:100,000 • Source: Ministry of the environment
Limit the legal Amazon
• Year: 2008 • Scale: 1:250,000 • Source: IBGE.
Brazil's federation units (UF)
• Year: 2008 • Scale: 1:250,000 • Source: IBGE

(a) **(b)**



Ecosystem Integrity of Brazilian Legal Amazon rainforest in 2010	EI loss = $EI_{actual} - EI_{Pristine}$

Fig. 21.4 **a** Ecosystem integrity map. **b** Loss of ecosystem integrity in 2010

Results

Ecosystem Integrity Maps

The Ecosystem Integrity map generated by using the presented methodological approach based on satellite products and BBN is shown in Fig. 21.4a. In order to quantify the areas presenting high or low integrity, the outputs were classified into 3 classes: 0.00–0.35—Low EI; 0.35–0.60—Intermediate EI; 0.60–1.00—High EI.

The results showed that 53.22% of the Legal Amazon rainforest presents EI High, 15.21% presents Intermediate EI and 31.57% is in a stage of Low EI, using 2010 satellite products.

The methodology also allows monitoring the ecosystem integrity loss. Figure 21.4b shows a map of loss of Ecosystem Integrity of the Brazilian Legal Amazon rainforest in comparison to the pristine (almost pure state) vegetation.

Table 21.1 presents the percentage of EI per State of Brazilian Amazon region, taking into consideration the total area of the Legal Amazon while the Table 21.4 presents the percentage of EI per State considering the total area of each State.

When considered the total area of the Legal Amazon, States with largest area (AM, PA, MT) have a higher percentage of EI High when analyzed the result taking into account the area of each State, the Acre, Amazonas and Rondônia States present more than 50% of EI High, followed by the Rondônia and Mato Grosso States.

Table 21.5 presents the demographic density (inhabitants/km^2) of each State. Although the States of Amazonas and Roraima present the lowest population

Table 21.4 EI percentage by state considering the total area of the Brazilian Legal Zmazon

States	%IE high	% IE intermediate	% IE low
AM	45.24	26.55	7.76
MT	16.50	12.92	25.59
PA	14.23	40.87	33.45
RR	5.32	1.23	4.53
AC	5.18	1.84	1.08
RO	4.49	5.29	5.27
TO	4.08	2.81	9.37
MA	3.56	3.77	8.77
AP	1.40	4.73	4.18

States: *AM* Amzônia, *MT* Mato Grosso, *PA* Pará, *RR* Roraima, *AC* Acre, *RO* Rondônia, *TO* Tocantins, *MA* Maranhão, *AP* Amapá

Table 21.5 EI percentage by State considering the total area of each state

States	% IE high	% IE intermediate	% IE low	Area (km^2)	D. density (Inh/km^2)[a]
AC	81.64	8.29	10.08	165,762	4.47
AM	78.77	13.21	8.02	1,501,522	2.23
RR	63.65	4.20	32.16	218,474	2.01
RO	49.20	16.57	34.23	238,620	6.58
MT	46.65	10.43	42.92	924,896	3.36
TO	39.09	7.68	53.23	273,154	4.98
MA	36.21	10.95	52.84	257,395	19.81
PA	31.10	25.53	43.37	1,196,135	6.07
AP	26.79	25.80	47.40	136,856	4.69

[a]Source of demographic density data: IBGE, Censo 2010

States: *AM* Amazônia, *MT* Mato Grosso, *PA* Pará, *RR* Roraima, *AC* Acre, *RO* Rondônia, *TO* Tocantins, *MA* Maranhão, *AP* Amapá density of the region, the data show that, Brazilian Legal Amazon, the number of inhabitants per km^2 is not an indicative that allows a direct relationship with the Ecosystem Integrity.

Table 21.6 presents the percentage of Ecosystem Integrity by Phytoecological Potential Zone, taking into account the total area of the Brazilian Legal Amazon.

Table 21.7 presents the description of each Phytoecological Potential Zone.

The results show that the regions have a higher index of Ecosystem Integrity are the “Low Ground Ombrophylous Tropical Forest with Dense Canopy” (LOFd), “Low Ground Ombrophylous Tropical Forest with Sparse Canopy” (LOFs), and the transition regions between “White-Sand Forest” and “Ombrophylous Tropical Forest” (WSF/OTF), when analyzed the ratio of High and Low IE.

Validation of the probabilistic model was assessed through: the evaluation of controlled areas, field observation and, as shown in Figs. 21.5 and 21.6, through a comparison of the Ecosystem Integrity derived from probabilistic Bayesian Model (data driven) with the EI generated using expert knowledge (knowledge driven). The result of the EI was also assessed using validation by statistical methods on reference data.

Table 21.6 Percentage of ecosystem integrity by phytoecological potential zone considering the total area of the Brazilian Legal Amazon

Zone	% IE high	% IE intermediate	% IE low	Area (km^2)
LOFd	25.11	17.59	11.27	962,757
HOFd	12.79	31.19	23.57	932,942
SFF	11.68	4.44	11.69	519,791
LOFs	11.12	6.38	3.65	395,212
WSF/OTF	6.71	1.24	0.82	197,395
HOFs	5.62	23.36	11.77	504,037
OTF/STF	4.77	2.08	6.03	233,802
SWFs	3.53	2.53	6.02	204,536
AOFd	3.49	3.02	2.81	157,302
SF/OTF	3.42	3.46	3.21	165,099
SF/STF	2.74	0.07	9.72	222,777
WSFd	2.29	0.71	0.80	77,445
PVF	1.56	1.27	2.07	82,296
AOFs	1.44	1.15	0.83	59,095
MOFd	1.07	0.21	0.46	36,751
STF	0.87	0.35	3.19	74,794
DTF	0.66	0.47	0.57	29,532
WSFs	0.63	0.18	0.63	27,738
SWFd	0.44	0.27	0.82	26,283
HMV	0.07	0.04	0.07	3,230

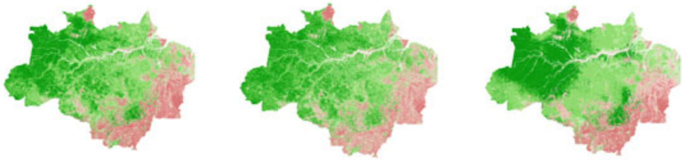
Note The description of each phytoecological potential zone can be observed in the Table 21.7

Table 21.7 Description of each phytoecological potential zone

Acronym	Phytoecological potential zone names	Area (km^2)	Area (%)
HOFd	High ground ombrophylous tropical forest with dense canopy	932.942	18.99
LOFd	Low ground ombrophylous tropical forest with dense canopy	962.757	19.60
AOFd	Alluvial ombrophylous tropical forest with dense canopy	157.302	3.20
MOFd	Mountain ombrophylous tropical forest with dense canopy	36.751	0.75
DTF	Deciduous tropical forest	29.532	0.60
STF	Semi-deciduous tropical forest	74.794	1.52
OTF/STF	Ombrophylous tropical forest/semi-deciduous tropical forest	233.802	4.76
LOFs	Low ground ombrophylous tropical forest with sparse canopy	395.212	8.04
HOFs	High ground ombrophylous tropical forest with sparse canopy	504.037	10.26
AOFs	Alluvial ombrophylous tropical forest with sparse canopy	59.095	1.20
WSF/OTF	White-sand forest/ombrophylous tropical forest	197.395	4.02
WSFd	White-sand forest with dense canopy	77.445	1.58
WSFs	White-sand forest with sparse canopy	27.738	0.56
SF/OTF	Savannah formations/ombrophylous tropical forest	165.099	3.36
SF/STF	Savannah formations/semi-deciduous tropical forest	222.777	4.53
SWFd	Savannah woody formations with dense canopy	26.283	0.53
SWFs	Savannah woody formations with sparse canopy	204.536	4.16
SFF	Secondary forest formations	519.791	10.58
PVF	Pioneer vegetation formations	82.296	1.68
HMV	Hideaways montano vegetation	3.230	0.07

	Very sparse	Sparse	Average	Dense	Very dense
Very low	Very poor	Poor	Acceptable	Rich	Very rich
Low	Very poor	Poor	Acceptable	Rich	Very rich
Medium	Poor	Poor	Acceptable	Rich	Very rich
High	Very poor	Poor	Acceptable	Very rich	Very rich
Very high	Poor	Acceptable	Acceptable	Rich	Rich
Extreme high	Poor	Acceptable	Rich	Rich	Acceptable

Fig. 21.5 Knowledge rule defining ecosystem integrity based on evapotranspiration categories (displayed on the *row headers*) to vegetation cover categories (displayed on the *column headers*)



	BBN – Highest probability	BBN – sample from probability distribution	Knowledge rule
Very Poor	30 %	30 %	30 %
Poor	37 %	34 %	33 %
Acceptable	8 %	11 %	11 %
Rich	9 %	12 %	12 %
Very Rich	16 %	12 %	13 %

Fig. 21.6 Ecosystem Integrity maps of each alternative with occupied area per ecosystem integrity category

An EI map using a mechanistic knowledge rule was built by the same experts and used to compare results with EI map based on BBN's model. The experts discussed each unique combination and appointed an ecosystem integrity category to it (see Fig. 21.5).

Three resulting Ecosystem Integrity maps based on three alternative approaches (Verweij et al. 2014) were created (Fig. 21.6). The areal distribution per EI category is quite similar in all approaches. Especially in the alternatives "*sample from probability distribution*" and "*knowledge rule*" the areal distribution is almost exactly the same. However, the spatial pattern is different. Where '*knowledge rule*' tends to cluster categories, "*sample from probability distribution*" is shows a more scattered image.

Final Consideration

This work presented a methodological approach developed for the generation of an index denominated "Ecosystem Integrity" on a regional scale, for different phyto-ecological zones using a probabilistic model based on Bayesian Networks (BBN) and Remote sensing products. In this approach, it was considered "Ecosystem Integrity" (EI) as a proxy of biodiversity preservation state, which means the ecosystem ability of self-organization and keeping the ecosystems process. The EI, in general, can be used as an indicator of the level of biodiversity loss.

In terms of evaluation of the results of the proposed model, it can be observed that phytophysiognomies with dense forest formations (Tropical Ombrophylous

Forest) presented better results (more accurate and less uncertainty) than those with more scarce forms such as savannas (closed formations).

The use of freely available Remote Sensing products makes it possible to monitor regions or countries with low data availability, especially for tropical forests.

Updating the satellite data using the same Bayesian network makes it possible to monitor the Ecosystem Integrity over time as well as monitor the EI loss. The methodological approach may serve to establish a protocol for monitoring the EI changes in tropical forest at regional scale.

Allowing observing trends, assess the effectiveness of policies, study the impact of the ecosystem impairment and assess biodiversity loss and decrease in ecosystem services provision (carbon and water), it might be used as a tool to contribute to the planning and implementation of adaptation policies.

Acknowledgements This work is part of ROBIN Project—“Role of Biodiversity in Climate Change Mitigation” sponsored by the European Union (FP7 Edict ENV. 2011.2.1.4-1: Potential of biodiversity and ecosystems for the mitigation of climate change) and ODYSSEA Project “Observatory of the dynamics of interactions between societies and environment in the Amazon” financed by European Commission, Horizon 2020.

References

BRASIL (2012) Plano setorial de mitigação e de adaptação às mudanças climáticas para a consolidação de uma economia de baixa emissão de carbono na agricultura (Plano ABC)/ Ministério da Agricultura, Pecuária e Abastecimento, Ministério do Desenvolvimento Agrário, Coordenação da Casa Civil da Presidência da República.—Brasília: MAPA/ACS, 2012. http://www.agricultura.gov.br/arq_editor/download.pdf. Accessed 23 April 2015

Convention on Biological Diversity (CBD) (1992) Text of the CBD—Article 2, use of terms. http://www.cbd.int/convention/text/. Accessed 10 Aug 2015

De Groot R (2005) Function-analysis and valuation as a tool to assess land use conflicts in planning for sustainable, multi-functional landscapes. Landsc Urban Plan 75:175–186

Do CB, Batzoglou S (2008) What is the expectation maximization algorithm? Nat Biotechnol 26 (8):897

Equihua M, Maeda PD, Equihua J, Alaniz NG, Kolb M, Schmidt M (2013) ROBIN—role of biodiversity. In: climate change mitigation. 1st report 15th of March 2013

FAO (2006) Global forest resources assessment 2005. FAO forestry paper no. 147 UN Food and Agriculture Organization, Rome. http://www.fao.org/docrep/008/a0400e/a0400e00.htm. Accessed 11 Sep 2016

Gret-Regamy A, Brunner S, Altwegg J, Bebi P (2013) Facing uncertainty in ecosystem services-based resource management. J Environ Manage 127:145–154

Haines-Young R (2011) Exploring ecosystem service issues across diverse knowledge domains using Bayesian Belief Networks. Prog Phys Geog 35(5):681–699

Holdridge LR (1977) Life zone ecology. In: II CA. Tropical science center, San José, Costa Rica. Anais, p 118

Intergovernmental Panel on Climate Change (IPCC) (2007) Climate change 2007. Cambridge University Press, Cambridge. v. I: The physical science basis; v. II: Impacts, adaptation and vulnerability; v. III: Mitigation of climate change. https://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml. Accessed 05 May 2014

Jorgensen S, Müller F (2000) Handbook of ecosystem theories and management. CRC Press, Boca Raton

Krug T (2008) Mudanças climáticas e o Brasil—Contextualização. Parcerias Estratégicas 27:43–49

Lauria EJM, Duchessi PJ (2006) A methodology for developing Bayesian networks: an application to information technology (IT) implementation. Eur J Oper Res 179:234–252

Lindley DV (1972) Bayesian statistics, a review. SIAM, Philadelphia [A sharp comprehensive review of the whole subject up to the 1970's emphasizes its internal consistency]

Nobre CA (2008) Mudanças climáticas e o Brasil—Contextualização. Parcerias Estratégicas 27:7–17

Simões M, Ferraz RPD, Verweij P, Equihual M, Maqueo O, Alves AO (2014) Modelo Bayesiano de dados espaciais aplicado ao mapeamento da integridade ecossistêmica da Amazônia brasileira. In: Environnement et géomatique: approches comparées France -Brésil. Anais. Universidade de São Paulo/Université Rennes, São Paulo

Stelzenmuller V, Lee J, Garnacho E, Rogers S (2010) Assessment of a Bayesian belief network-GIS framework as a practical tool to support marine planning. Mar Pollut Bull 60:1743–1754

Verweij P, Simões M, Alves AO, Ferraz RPD, Cormont A (2014) Linking Bayesian belief networks and GIS to assess the ecosystem integrity in the Brazilian Amazon. In: Ames DP, Quinn NWT, Rizzoli AE (eds) 7th international congress on environmental modelling and software, International Environmental Modelling Society (iEMSs), San Diego, CA, USA

Chapter 22
Strategies and Difficulties in Living Alongside a Channel: From Spontaneous Strategies to Publicization

Túlio Gava Monteiro

Introduction

In accordance with modern city formation, the urbanization process in Vila Velha (ES, Brazil) occurred regardless of the natural landscape elements. Subsequent irregular occupation of the space created defined socio-environmental spaces with socially vulnerable groups tending to live in environmental risk areas. In this scenario, the banks of the current Costa Channel, specifically with regard to the Itapoã neighborhood, became areas of these groups' appropriation which, due to the location, had to coexist with regular floods. Due to climate change such events are subject to modifications over the years with the relative increase of heavy rainfall. The declaration of public calamity during the last flood that hit the city, between December 2013 and January 2014, exemplifies this new situation afflicting the city dwellers.

This article takes into account the context set out above as background and presents as a case study two communities of the Itapoã neighborhood, known as Bem-te-vi and Beija-flor. It represents a modified part of the master thesis which aimed to analyze, through the notion of environmental injustice, the social-environmental situation of vulnerability in which both find themselves, and to understand how they deal with their environmental problems, highlighting the effect of the absence and presence of publicization.

For around ten months during the year 2015 it was possible to observe, through the ethnographic inspiration method, how people live with each other and their environment, enabling a deeper understanding of the relationships established, including with environmental elements. In addition, semi-structured interviews

T.G. Monteiro (✉)
Programa de Pós-Graduação em Sociologia Política, Núcleo de Estudos Urbanos e Socioambientais (NEUS), Universidade Vila Velha, Vila Velha Espírito Santo, Brazil
e-mail: tuliogava@hotmail.com

W. Leal Filho and L. Esteves de Freitas (eds.), *Climate Change Adaptation in Latin America*, Climate Change Management,
https://doi.org/10.1007/978-3-319-56946-8_22

were also carried out on the streets, either individually or collectively, in which the expressions, gestures and attitudes served as indicative of how residents felt about the issues under discussion. During a similar period, participation in meetings of the Itapoã Neighborhood Association (INA) helped to understand how the political participation of those communities would be influencing their situation of injustice.

Living alongside the channel, those groups are in a problematic situation requiring, therefore, an active attitude in terms of solutions. Once the situation is discussed and the collectives overcome the reactive posture required in disasters, adaptive strategies are put into place. Such measures can range from one-off and immediatist strategies for publicization, and even spontaneous actions. However, these are questions concerning the configuration of that initial situation into a problem. And this latter, in turn, can be private, when the attitudes are individualized or restricted to the family nucleus, or it can be public, if a community, connected by common emotions and interests, mobilizes and acts publicly, accessing public arenas. With this in mind, the purpose of the article is to unveil the scenario in which they inserted and to discuss the way in which they cope with the troubles arising from the channel. In other words, whether their troubles are problematized and how the problem that emerges can be solved or mitigated, given the limitations resulting from their social vulnerability.

From the Origin to the Vulnerability of Bem-te-vi and Beija-flor Communities

In the twentieth century, Vila Velha was part of an urbanization process which reflected the structural changes occurring in Brazil and, more specifically, in Espírito Santo economies, leading to disproportionate social, spatial and environmental transformations. The occupation of territory closer to the seafront, as is the case with the current Itapoã neighborhood, consisted in a process connected to the interests of those landowners (Santos 1999). Thus, private interests took precedence over those of the city, leading to an unequal occupation closely related to speculation. Some factors, such as the distance from the capital (Vitória), lack of infrastructure and plentiful offer of lands induced the concentration of low-income people in Vila Velha, mainly in areas far away from the seafront (Chalhub 2010).

From the second half of the century, Vila Velha became one of the main migrant targets in pursuit of the opportunities provided by industrial projects and the belief in the chance of a better life. Nevertheless, even though it had shown a trend of middle-class absorption (Santos 1993), the city, over time, received a number of low-income people higher than in the state capital. This socially vulnerable population was spread through Vila Velha urban territory occupying the marginal areas of mangrove and hills, on river/channel banks, many of them without appropriate infrastructure (Siqueira 2010), while the sector with higher purchasing power tended to occupy areas closer to the seafront.

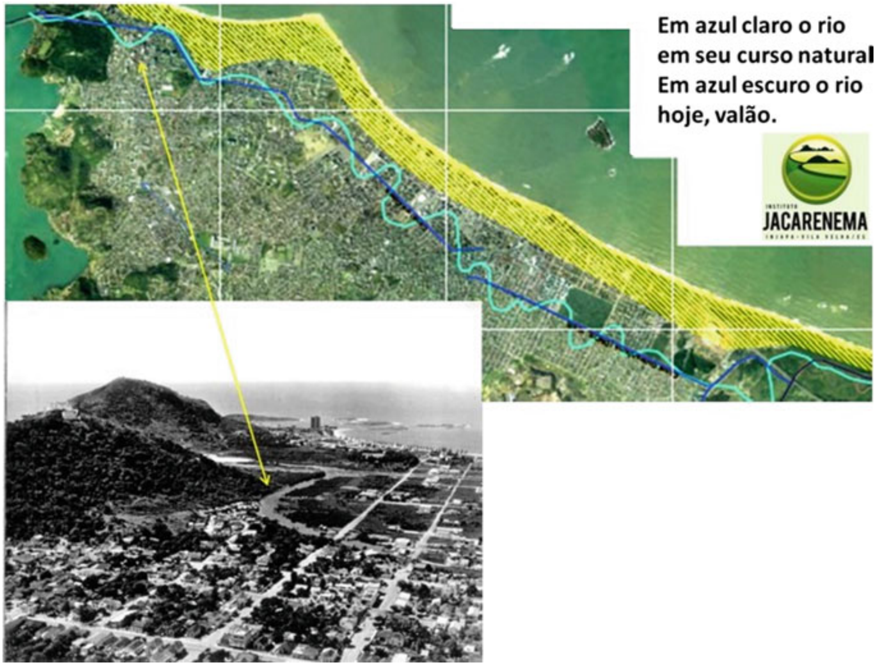


Fig. 22.1 Costa River in the 1950s on its natural course (*light blue*) and the current channel (*valão)* (*dark blue*) (Instituto Jacaranema 2012)

At the same time, the Costa River, which ran parallel to the seafront (Fig. 22.1), was almost completely straightened. The land subdivision of that area and the reduction of urban property tax on the lots resulted in the reservation of non-occupied areas, with a view to their valuation (Chalhub 2010). Thus, Itapoã neighborhood became an area of land speculation, contributing to the unequal occupation of its territory. As such, the low-income population, although benefiting from the government housing policy, was forced to occupy unsuitable areas.

Due to the conjuncture in Vila Velha, especially from the 60s, some socially vulnerable communities established themselves in potential risk areas, as happened with Bem-te-vi and Beija-flor (Fig. 22.2). Both of them are located alongside the Costa Channel, at the western edge of Itapoã—a neighborhood in which most inhabitants are from the middle class due to high coastline valuation. While Bem-te-vi established itself on Sta. Teresinha street, Beija-flor originated on Sinval Moraes street (central street that passes through almost the entire community) and expanded beyond it, occupying an area of few streets.

As previously mentioned, both of the communities are in a situation of social vulnerability, and such classification indicates a scenario of social injustice originated in socio-economic and cultural issues (Fraser 1996), which subject them to unfair actions and increase their environmental vulnerability. One of the reasons for these two communities being considered as social vulnerable groups is the

Fig. 22.2 Bem-te-vi (*above*) and Beija-flor (part facing the gallery) (*below*)

deprivation of material goods that puts their conditions of survival at risk. Income, for instance, is one of the factors that contribute to characterize such vulnerability, since depending on its amount, it provides to people a higher or lower range of choices (or capabilities). In fact, in the majority, their members are low-income individuals, mainly people from Bem-te-vi who, among themselves, tend to be more homogeneous. In contrast, in Beija-flor there is a somewhat higher difference of income between its inhabitants, with lower income in its *core region* (central area and closer to the channel).

The point that highlights the income insufficiency of both communities' residents is the occupation that, in turn, is often related to low-paid jobs such as housekeeper and packer in a supermarket chain, as observed in the area studied. Besides these formal employments, there are people, in both collectivities, that open small businesses or work informally, for example as wagoners. Moreover, in the two communities, there are people who resort to alternatives to obtain money or to add some extra income. When they cannot count on social programs as *Bolsa Família* (Family Allowance), a usual option is to do casual work and this is part of the population's reality. For instance, Juliana who lives in Bem-te-vi, earns money taking care of her neighbor's child and, sometimes, sells popsicles in front of her house. In Beija-flor, two people appropriated the wide and empty space provided for the gallery construction to create a car wash. Jointly, these are situations that show, at least, the low wages and discontinuity in employment periods which Sá (2010) considers as characteristic elements of employment precariousness.

The low income of the two communities itself does not say very much, since income is a means by which it is possible to obtain such goods that each person and collective consider relevant to their welfare (Sen 2003). Nevertheless, the socio-environmental vulnerability situation of both communities is, at least in part, in the scope of action provided by their purchasing power. This is apparent, for example, in the common desire that inhabitants have to move to an area away from the channel, but that is not possible due to the lack of income to go to a region with the same accessibility found in the current place where they live (near to the beach, shopping malls, supermarkets and health centers, among others).

It is worth highlighting the residential properties as another factor of socio-environmental vulnerability, since their quality, value, density and even their simple existence are directly related to the level of system loss and recovery (Cutter et al. 2003). In Bem-te-vi and Beija-flor—chiefly in the core region—the majority of houses are sub-standard, that is, self-help built, multifamily, semi-detached units and, when they do not have exposed brickwork, their surface is degraded.

The vulnerability of such communities is maximized when the focus is the infrastructure and utilities to which they have access. In the scope of such factors, they demonstrate the indifference of public authorities in relation to people's occupation of such places, since it is only after the informal and disorderly appropriation of such areas that the government acts. The infrastructure was built very late and adapted itself to the place, resulting in street lighting posts and wiring very close to the houses, streets paved with cobblestones, short or nonexistent sidewalks, among other characteristics found in the two communities. In other words, these are territories that follow the same logic of peripheral allotments in which the improvements come from timely and corrective works that overlap to a context which does not meet an urban standard (Jacobi 2006).

The Channel as a Problem Amid Climate Change

The reduction of rivers to mere channels, when they are not completely moved from the urban landscape, intensifies the flood problems. For example, the Costa River riverbed was shortened, straightened and, in some parts, channeled, giving rise to avenues and streets. Upstream, from Itapoã neighborhood and beyond, urban intervention gave rise to the occurrence of floods due to the removal of river meanders, so necessary to reduce the flow rate (Bontempo et al. 2012). Furthermore, river-bank impermeabilization, due to vegetation grubbing, paving and human occupation, reduced water infiltration into the soil, increasing the speed of surface runoff and consequently increasing the river volume more quickly and intensely in rainy periods. Thus, floods become an even more serious problem when anthropic activity does not respect the limits and dynamics of water bodies.

The bankside occupation of Costa Channel by the communities Bem-te-vi and Beija-flor reflects what Baptista and Cardoso (2013) call "informal city", mainly due to the problems that the appropriation of such places causes. While Bem-te-vi residents live with an open channel approximately three meters away from their houses, the other community has a different relation with it. Nowadays, most of the channel bed in Beija-flor community is covered by a gallery, leaving only a small visible part. However, even with such differences, floods are common for both of them, and this problem is worsened by a poorly implemented sewage network. According to inhabitants, these are events that occur almost every year, in the rainy period from December to March. Water rises in the channel, which overflows and enters their houses. It also emerges from the drains due to the fact that many residents do not connect the house sewage system to the network.

In a context of climate changes, in which, as Marengo (2008) says, the Brazilian southeast region presents a large increase of precipitation in the last fifty years, both communities are facing an increasing and even less predictable problem due to the uncertainty of this new conjuncture. A situation which Silva et al. (2012) claim can be observed in Vila Velha, since even with the lower rainfall regime for the 1990–2008 period in comparison with the two previous decades analyzed, there was a relative increase in more intense rainfalls. This observation is consistent with the adverse situations faced by Vila Velha inhabitants in the last years. For instance, the rainfalls occurred in December, 2013 and January, 2014 were responsible for a calamity situation throughout Espírito Santo state. In Vila Velha, this was the last flood faced by the population, being followed by a dry season that persists until today.

It is possible to observe, in the Bem-te-vi community, the mark left by the last flood, either by the dark color or by the paint blisters and peeling process of some walls due to the contact with water. It was a sequence of events that, according to the inhabitants, contributed to raise the water level to approximately one meter in some houses. Marina says that "the telephone booth was this way (indicating above the middle part of it). And I went to my mother's home in Itapoã". This is a kind of disaster which causes the residents, as they move, to come into contact with the contaminated water. At the same time, floods jeopardize them even more, since their furniture is destroyed and their house structures are weakened. As Sara says: "I have nothing. I have an old sofa in the living room. I have an old *recozinho*: the refrigerator. […] But I don't have a wardrobe. The wardrobe is falling to pieces… bed… Everything. I have nothing. Everything is gone."

Despite these problems, both communities, and in particular Bem-te-vi, are still forced to live with bad smells, flies, rodents and all those problems arising from unsanitary conditions worsened by floods. Thus, populations exposed to contaminated water risk are more likely to contract potentially endemic diseases after such events, in the same way that moisture, which penetrates through their house structure and furniture, weaken them physically and promote worsening of their health problems (Freitas and Ximenes 2012). The material deterioration is evidenced by the cracks and holes distributed over the house's surface. One example is the situation in a house with its back to the channel which, after the dredging of the channel, started to develop serious cracks that further threatened its structure and increased the risk of landslide. Moreover, those communities' residents frequently lose their furniture and, due to income insufficiency, have to live deprived of certain goods, having to use broken furniture.

Even though both communities have access to the sewage network, not all the inhabitants' houses are connected to it. Even for those that are, proximity to the channel jeopardizes them in flood seasons insofar as the sewage water is even ejected through the houses' piping. Furthermore, it is worth highlighting that in Bem-te-vi, the channel opening and the lack of protection on the street cause problems that even full access of the residents to the sewage network would not prevent, such as the risk of falling into the channel—a common situation. In the same way in Beija-flor, the gallery building creates a kind of dam, exacerbating the vulnerable situation of the population. In this community, many houses that in the past were at the channel level, are now about forty centimeters below the gallery level. Water does not correctly flow off due to the inefficiency of the drainage infrastructure.

In general, the socio-environmental conditions of such communities render them unable to provide to their inhabitants what Nussbaum (1997) denominates as physical health, since they are not able to be healthy due to the risks to which they are exposed, nor to have decent housing because of the discomfort of their homes. The exposure to risks is, perhaps, a kind of physical abuse against residents, since their bodily control is appropriated against their will (Schlosberg 2009). In addition, physical abuse, depriving people of free use of their bodies, becomes a typical form of denial of acknowledgement. Thus, coexistence amongst environmental bads is a means of personal degradation which prevents the access of the residents of such *communities* to welfare.

From Inaction to a Fragile Publicization: Problematization as a Resiliency Issue

The vulnerability of both communities leads to a situation, although not exclusively, of social asset deprivation which converges with the risks presented by the channel. Nevertheless, it is worth pointing out that such category, even expressing a condition of fragility before a situation of risk (Porto 2007), also includes in its concept the capacity of absorption and recovery of the groups or individuals exposed to the risk, known as resilience (Timmerman 1981). Thus, this category refers to the way by which a collective or individual copes, in this instance, with the environmental problems.

In this sense, problem perception is important because it demonstrates *if* and *how* someone deals with a problematic situation. In fact, before the process of problem constitution there is the term called trouble, a disorder that settles "[…] when the types of customary and standardized answers given by a collective to its environment become misadjusted, improper or insufficient […]" (Cefaï 2015). It consists in an emotional relation, in which the action for a solution, whether individual or collective, is not put in process.

Based on Cefaï (2003), it can be concluded that a joint action of investigation, experimentation and problematization is defective in both communities. It is common to observe that the channel and the troubles arising from it are seen more as personal troubles than as problems. This is observed with greater emphasis in Bem-te-vi, where the lack of interest in knowing the cause and who is to blame, and even in facing the situation, was more apparent. It can be noted in the content of the inhabitants' speech, the way they expressed themselves and their behavior before the attitudes of others that the lack of interest is associated to resignation and impotence. Such feelings are clear from the speeches related to the saying "nothing will come of this", in situations where demands were addressed to public authorities —such thinking that can manifest itself in apathy (Gaventa 1975) which, in fact, occurred.

Bearing out such feelings, there is a weak feeling of belonging to the place, which directly impacts on their political participation (Vidal 1996). The people's desire to move was common, an issue that seems to be related to the floods and to government neglect in these situations. Such scenario makes clear the propensity of many residents to take no initiative to understand these situations. These are feelings that seem to become distinct and, therefore, prevent people from recovering or facing the reasons for their problems (Stavo-Debauge 2012).

In addition, the intense dry season that has impacted Espírito Santo state over recent years reveals itself as a factor for resident inaction, since many of them count on the natural/holy element to work in their favor. As Sara says: "Oh my God! Do not talk about overflow, please. God bless that it always be like that, it rains a bit and stops". The environmental perception, seen as a process that selects, receives, organizes and interprets the stimulus according to the cultural and historical reality of the receiver (Maria et al. 2011), contributes to explain the naturalization process, at least, in relation to the floods. The problem naturalization is one of the reasons for the inhabitants' passiveness, since it refers to the acceptance of or, perhaps, resignation to the situation.

Such situations demonstrate a sensation of *feel as a whole* which, even though it can frequently be translated as passiveness, in other moments, it is followed by an active attitude of some residents from both communities. During the floods, for example, both communities' residents focus on saving what they can, using boxes, chairs and planks as support. Debilitated people tend to be moved first. In addition, during the event, they advise and help each other but, in the majority, such help is restricted to the closer family and circle of friends.

In other situations, with a more limited time, the residents use measures that can be understood as coping strategies, an interaction process of adaptation between people and the environment to deal with stress situations (Antoniazzi et al. 1998). Some Beija-Flor residents, when there was sufficient income, carried out earthworks to grade the house to the gallery level, and others did the same in order to raise the level of the houses; while those who cannot do the same make small barriers in their doors. These are both spontaneous and private strategies which were taken by the individuals as an answer given by and for *themselves*. They are adaptive measures which contribute to reduce the residents' vulnerability to floods, but that do not completely solve the problem, since even with raising, householders not connected to the sewage network continue to be affected by the water that emerges from the piping. It is an adaptation with palliative results.

Modifications made by the residents aimed at adaptation to floods (Fig. 22.3) create disfigured houses that prevent a comfortable living experience. This occurs because the earthwork reduces the ceiling height, causing some people to hit their heads on door frames; some rooms, especially bathrooms, are one level below the new height; and sometimes, prominences appear on the doors preventing people from walking freely. In such context, discomfort would be related to the insecurity provided by the lack of protection against bad weather conditions and the space inefficiency due to the maneuvers required to live in the houses (Silva and Santos, N/D). In Beija-flor, this situation is a more evident worry, since residents highlight the need to renovate their houses, as Lara says: "How can we live? The house could fall down, so we MUST repair it, mustn't we?" A question that reveals the needs of

Fig. 22.3 Raising, prominences and barriers as measures against floods

the residents, as a demand, for an action from the public authorities to do something about the house evaluations carried out more than three years ago, which prevents the majority of them from recovering or rebuilding their homes.

Whether by one-off and immediatist measures, such as raising furniture in the flood periods, or by spontaneous adaptation strategies, such as making barriers and raising house levels, those people embark upon a process of problem solution without the intervention of other actors. As a result, the trouble provided by the channel is considered a problem because those people make efforts to find a solution.

However, these attitudes of tackling the problem consist in a set of private actions which occurs due to a common knowledge shared by the inhabitants of those places. They are strategies copied by the residents, which are part of the common sense. Such strategies were reproduced because they present some efficiency, but they do not solve the problem itself. Hence, they are not collective actions since they do not demonstrate work in pursuit of a mutual benefit, of which people tend to take advantage even when they do not actively participate in it (Olsen 2002). This means that the benefit of house raising, for example, is enjoyed only by their owners/users and not by the collective as a whole—even when identified as community knowledge. Thus, the channel is presented as a private problem that does not become public, because people tend to act individually to solve it.

In Beija-flor, however, publicization is used as another mechanism of adaptation, since the usage of such strategy brings out debates and business, in addition to contributing to determine responsibilities (Veyret and Richemond 2007). This group includes people that acquire some status of representative acting in the best interest of the community. These same actors that demonstrate a personal engagement in this community are those who, being part of INA (Itapoã Neighborhood Association), bring this entity front and center as a (collective) actor amidst the conflict. But INA proves to be an unstable intermediate due to the low efficiency of its actions.

Nevertheless, there is a detachment of those actors' roles as representative of the neighborhood residents in favor of engagement in the community interest. When such actors struggle to ensure that the community drainage infrastructure efficiently works, their actions are inserted between the general interest (of neighborhood) and the private one. These are attitudes that point to a consequence of personal engagement, since their actions are justified when desingularized (Ion and Ravon 1998) before the community (Beija-flor). Such actions become generalized because the actors' positions and decisions are taken in relation to the absorption of their neighbors' afflictions and complaints. It seems to be easy to find a solution acting in such a manner rather than through a collective process of problematization and mobilization, since the inhabitants complain but do not unite to demand an answer from the public authorities.

Putting their actions in progress, those protagonists—highlighting Rodrigo's case—give a public character to the problem presented by the channel. They question the public authorities (in this case, basically restricted to the city hall) and public opinion through private calls/messages; by personal contact with the city hall or on the streets, where they are inserted in situations of physical co-presence with other publics (mayor, advisers, secretaries, public servants in general); and by services make available by INA or in its name through their directors. They characterize an inherent active posture of a complete citizenship experience of living, since those actors are aware of what occurs around them and act in favor of collectivity interests of which they are part (Herculano 2001), even though, in the community, their legitimacy as representatives is conflicting.

Nevertheless, the process of collective problem definition is fragile, since it develops through informal conversations behind the scene of the protagonists' personified actions. It refers to a field of weakened collective experience which does not exist in Bem-te-vi, mainly due to the disorganization and absence of its own association (*between* and *for* the residents). In fact, this scenario of disarticulation between the residents of both communities is found in their lack of commitment. At the same time, however, it is intensified by a defective channel of communication established between the leaders/representatives and those groups.

Even though immersed in interests in favor of community assets, INA seems to give shape and content to a public group because it validates what its members claim (Quéré 2003) amidst the conflict faced by Beija-flor inhabitants. But, such public manifestation over the channel is fragile. Not in the sense developed by (Stavo-Debauge 2012), that refers to fragility due to a "state of shock" preventing people to take a combative attitude—this fragility arises due to the low-level and weak political participation and the lack of coordination between the actors.

The weakness of the communication channel between the representatives and those groups—and between the leadership and Beija-flor community—can be pointed out as the reason for the low capability of community organization and engagement, the almost non-existence of collective actions and, therefore, the low efficiency of their strategies. In turn, the low efficiency associated to other difficulties of confrontation, arising, for example, from the naturalization of problems, nurtures a feeling of banality by people in relation to public deliberation (Eliasoph 2003). Such disorganization, associated to poverty, contributes to a more short-lived public life (Fuks 1998) of both communities, and hugely intensifies their vulnerability, primarily in Bem-te-vi.

Finally, instead of the lack of personal interest shared by members of both communities, when such (individual or collective) protagonists do not show possible reasons and solutions to the problem and the potentialities of the collective actions, those *potential publics* (the communities) lose the chance to understand publicization as an answer to their problems. And, in general, when they individually engage, their actions are limited by their social vulnerability, and their capacity of putting pressure on public authorities is decreased, reasons for which they weaken or suffer even before results are obtained. In other words, the fragile public in Beija-flor is responsible for weakening the publicization, but it contributes, even if minimally, to mitigate the problem presented by the channel. Comparatively, the inexistence of publicization in Bem-te-vi, precisely because its residents do not even represent a public before this problem, reveals an adaptive capacity even lower than that in Beija-flor, which also makes the Bem-te-vi community more vulnerable.

Final Considerations

The paper sought to evidence areas socially determined due to the unequal process of urban space appropriation of Vila Velha, in which both Bem-te-vi and Beija-flor communities are representative of a social group that occupied areas due to the precarious socioeconomic conditions. They are low-income collectives, composed mainly of black people, whose houses are self-help built, with the typical *puxadinho* (extension) being built on to accommodate their family. The poor structure or flood damage to houses is associated with a poorly implemented public infrastructure, with wiring close to the houses and an inefficient sewage network, chiefly in Bem-te-vi.

Occupying the Costa Channel banks, both communities are at the mercy of not only recurrent floods, but also of a putrid smell emanating from the channel and diseases spread due to contact with the contaminated water. Such hydrological phenomena still contribute to increase the social vulnerability of people living in those communities, since they normally lose their furniture and cannot replace it. This is a situation which is likely to persist because, even with a reduction in rainfall regularity, extreme events will tend to intensify in the coming years.

In both cases, apathy towards the troubles caused by the channel reigned—a situation that tended to appear among feelings of resignation and impotence, inasmuch as their residents sense that the government is not committed to solving their problematic situation. However, the *brief* status of private problem acquired, primarily by the floods, forced many community inhabitants to implement palliative changes, such as prominences and raising in their houses. Nevertheless, the naturalization of such phenomena, as well as certain factors of the communities' social vulnerability, such as the income and their capability to publicize, reveal a reduced resilience. Despite this, the existing, albeit fragile publicization in Beija-flor, demonstrates that there is potential in turning a problem public. In this case, even though the INA represented a weak public in the conflicts emerging in the neighborhood, the participation of few members of Beija-flor in such representative body enabled their community to have a wider range of resources and, consequently, a greater capacity to pressure the government. Hence it follows that in a context with marked regularity of extreme events, publicization is a strategy that can be used to put pressure on the public authorities for more efficient changes, mainly in a context where income represents limitations.

Overall, although representing a part of what was conducted in the master thesis, the article shows a set of characteristics of vulnerable communities that are in play when dealing with environmental problems, such as the floods. In a scenario of climate change, it is important to be aware of those in order to be able to focus on better strategies. At the same time, revealing the lack and the potentiality of publicization, it indicates that resilience requires recognition of rights and a posture of complete citizenship experience. Nevertheless, since this research was conducted over one year through a qualitative method, the application of a quantitative or a longer ethnographic study would fill some gaps, such as those imposed by the impossibility of being present in the period of floods; additionally, it would improve the capacity of generalization.

References

Antoniazzi AS, Dell'Aglio DD, Bandeira DR (1998) O conceito de coping: uma revisão teórica. Estud de Psicol 3(2):273–294

Baptista M, Cardoso A (2013) Rios e Cidades: uma longa e sinuosa história…. Revista UFMG 20 (2):124–153

Bontempo VL, Olivier C, de Moreira CWS, GOliveira G (2012) Gestão de águas urbanas em Belo Horizonte: avanços e retrocessos. REGA 9(1):5–16

Cefaï D (2003) Acción asociativa y ciudadanía común: ¿La sociedad civil como matriz de la res publica? In: Benedicto J, Morán ML (Orgs). Aprendiendo a ser ciudadanos: Experiencias sociales y construcción de la ciudadanía entre los jóvenes, 1st ed., INJUVE, Madrid, pp 91–115

Cefaï D (2015, probable date) Arène publique: un concept pragmatiste de sphère publique (version française d'un article soumis à Sociological Theory). http://cadis.ehess.fr/docannexe/file/2378/cefai_arene_publique_concept_pragmatiste_cadis.pdf. Accessed 7 May 2015

Chalhub A (2010) O Imaginário da Cidade no Pacto Socioambiental de um Plano Diretor Municipal: o planejamento urbano e a lei em Vila Velha—ES 1948/2008, 1st edn. Saberes Instituto de Ensino, Vitória/ES, p 420

Cutter SL, Boruff BJ, Shirley WL (2003) Social vulnerability to environmental hazards. Soc Schience Q 84(2):242–261

Eliasoph N (2003) Publics fragiles: une ethnographie de la citoyenneté dans la vie associative. In Cefaï D, Pasquier D (org.). Le sens du public. PUF, Paris, pp 225–268

Fraser N (1996) Social Justice in the Age of Identity Politics: Redistribution, Recognition, and Participation. The Tanner Lectures on Human Values, Delivered at Stanford University, April 30–May 2, 1996

de Freitas CM, Ximenes EF (2012) Enchentes e saúde pública: uma questão na literatura científica recente das causas, consequências e respostas para prevenção e mitigação. Ciênc. Saúde coleti 17(6):1601–1616

Fuks M (1998) Arenas de Ação e Debate Públicos: Conflitos Ambientais e a Emergência do Meio Ambiente enquanto Problema Social no Rio de Janeiro. Dados 41(1). doi:10.1590/S0011-52581998000100003

Gaventa J (1975) Power and Powerlessness: quiescence and rebellion in an appalachian valley. Doctoral dissertation, University of Oxford, Oxford

Herculano S (2001) Associativismo, Sociedade Civil, Estado e Construção da Esfera Pública: notas para o estudo da cidadania brasileira. Rev Plúrima 5:247–271

Instituto Jacaranema (2012) Vila Velha ontem e hoje. http://injapa.blogspot.com.br/2012/08/rio-da-costa.html. Accessed 15 July 2015

Ion J, Ravon B (1998) Causes publiques, affranchissement des appartenances et engagement personnel. Lien Soc et Polit 39:59–71

Jacobi P (2006) Dilemas socioambientais na gestão metropolitana: do risco à busca da sustentabilidade urbana. Polít Trab 25:115–134

Marengo JA (2008) Água e mudanças climáticas. Estudos Avançados 22(63):83–96
Maria JA, Cavalcanti I, Eiró FH (2011) Percepção Ambiental e Mudanças Climáticas. Presented at Políticas Públicas e a Perspectiva da Economia Ecológica at the Encontro Nacional de Economia Ecológica, Brasília, DF, Brasil
Nussbaum MC (1997) Capabilities and human rights. Fordham Law Rev 66(2):273–300
Olsen M (2002) The logic of collective action, 20th edn. Harvard University Press, Massachusetts e London, Cambridge, England
de Porto MFS (2007) Uma ecologia política dos riscos: princípios para integrarmos o local e o global na promoção da saúde e da justiça ambiental. Fiocruz, Rio de Janeiro, p 270
Quéré L (2003) Le public comme forme et comme modalité d'expérience. In Cefaï D, Pasquier D (eds) Les Sens Du Public. PUF, pp 113–134
Sá T (2010) "Precariedade" e "trabalho precário": consequências sociais da precarização laboral. Configurações: Rev de Sociol 7:91–105
Santos J (1999) Vila Velha: onde começou o Estado do Espírito Santo, vol 1. Arte Visual, Vila Velha
Santos M (1993) A Urbanização Brasileira. HUCITEC, São Paulo
Schlosberg D (2009) Defining environmental justice: theories, movements, and nature. Oxford University Press, Oxford
Sen A (2003) Capability and well-being. In Nussbaum M, Sen A (eds) The quality of live. Oxford Scholarship Online, Oxford
da Silva HS, de Santos MCO (n.d.) O significado do conforto no ambiente residencial. Cad Rev Proarq 18:138–151
da Silva JGF, Cairo CT, da Silva BFP, dos Ramos HEA (2012) Análise da frequência de chuvas no município de Vila Velha. Revista FACEVV (7):64–77
da Siqueira MPS (2010) Industrialização e Empobrecimento Urbano: o caso da Grande Vitória (1950–1980), 1st ed., vol. 2. Grafitusa, Vitória
Stavo-Debauge J (2012) Des "événements" difficiles à encaisser: un pragmatisme pessimiste. In D. Cefaï & C. Terzi. L'expérience des problèmes publics (pp 191–223). UCL—SSH/IACS
Timmerman P (1981, April) Vulnerability, resilience and the collapse of society: a review of models and possible climatic applications. Environmental Monograph, Institute for Environmental Studies, University of Toronto, Toronto, Canada
Veyret Y, de Richemond NM (2007) Definições e vulnerabilidades do risco. In: Veyret Y (ed) Os riscos: o homem como agressor e vítima do meio ambiente, 1st edn. Contexto, São Paulo, pp 25–46
Vidal D (1996) Décentralisation infra-municipale, associations d'habitants et pouvoir local: dépasser l'opposition entre clientélisme et participation politique—l'exemple de Recife (Brésil). Habita. Conférence, pp 131–146

Chapter 23
Conflicts After the Tragedy in the Mountains of the State of Rio de Janeiro in 2011: The Relationship Between Residents of Córrego d'Antas and the Zoning of Evacuation Areas for an Adaptation to Climate Change

Leonardo Esteves de Freitas, Annita Vicente Neves, Sandro Schottz and Ana Luiza Coelho Netto

Introduction

Global climate change has been increasing the frequency and the intensity of extreme precipitation events, affecting a vast slice of the world population, especially the most vulnerable, living in the most exposed areas (Magrin et al. 2014). In

This article was made possible due FAPERJ's financial support from and a post doctoral fellowship from CAPES.

L. Esteves de Freitas (✉)
Laboratory of Geo-Hydroecology at the Geography Department,
Federal University of Rio de Janeiro and the Oswaldo Cruz Foundation (FIOCRUZ),
Avenida Athos da Silveira Ramos, 149 - Ilha do Fundão, CCMN, Sala H1-015,
Rio de Janeiro, RJ CEP 21941-909, Brazil
e-mail: leonardofreitas73@gmail.com

A.V. Neves · A.L.C. Netto
Laboratory of Geo-Hydroecology at the Geography Department,
Federal University of Rio de Janeiro, Avenida Athos da Silveira Ramos,
149 - Ilha do Fundão, CCMN, Sala H1-015, Rio de Janeiro
RJ CEP 21941-909, Brazil
e-mail: annita229@hotmail.com

A.L.C. Netto
e-mail: ananetto@acd.ufrj.br

S. Schottz
Córrego Dantas Neighborhood Association, Rua Luiz Shottz, 295 – Córrego d'Antas,
Nova Friburgo, RJ CEP 28630-260, Brazil
e-mail: sandroschottz@gmail.com

W. Leal Filho and L. Esteves de Freitas (eds.), *Climate Change Adaptation in Latin America*, Climate Change Management,
https://doi.org/10.1007/978-3-319-56946-8_23

Latin America, the increasing frequency of extreme rainfall events took place in various areas of different countries, including the southeastern region of Brazil (Groisman et al. 2005; Marengo et al. 2009; Figueiró and Coelho Netto 2011). This situation was observed in the mountainous areas of Serra do Mar, in the state of Rio de Janeiro, where precipitation events greater than 50 mm have become more common, despite a reduction in the number of rainy days (Silva et al. unpublished).

Consequently, mass movements induced by extreme rainfall have increased both in frequency and magnitude. In Brazil mass movements increased more than 21 times between the 1990–2000 and 2000–2010 decades, mainly in the mountainous areas of Serra do Mar, especially in its Atlantic slopes (UFSC 2013).

The number of people directly affected, as well as the number of related deaths, is also increasing due to the lack of preparation to face these natural phenomena. In the state of Rio de Janeiro, i.e., official data shows that 418 people died between 1991 and 2010 due to mass movements, out of a total of 539 deaths throughout Brazil (UFSC 2010). Most of them died after 2001, specially in 2009 and 2010 (UFSC 2010, 2013).

In response to the extreme landslide event that reached this region in January 2011, official data points to 900 deaths and 350 missing people (Bertone and Marinho 2013), as well as R$4.8 billion in losses (World Bank 2012). However, locals mention a few thousand deaths and missing persons based on the number of destroyed houses.

The Mega Disaster of January 2011 in the Mountains of the State of Rio de Janeiro

This mega event had a profound impact in the field of disaster management in Brazil, especially in the mountains of Rio de Janeiro, which drove the beginning of a culture on disasters and reflected the emergence of a legal and institutional framework on disaster management (Freitas and Coelho Netto 2016).

Such change in perception on disaster management includes the notion that these disasters are not natural, which is crucial for discussing management processes that increase the adaptation to disasters. The energy input that causes this type of disaster is a natural phenomena that may trigger severe rapid gravitational mass movements or landslides. Inadequate land-use management and territorial planning, together with population concentration in urban areas, tend to potentially increase the magnitude of the disaster. All this points to the urgent need for new procedures to advance in risk management.

Today, people in the mountains of the state of Rio de Janeiro see much more clearly that human action on nature affects the causes and consequences of natural phenomena (Freitas and Coelho Netto 2016). Humans influence natural ecosystems and natural phenomena such as mass movements. Moreover, social relations condition the use of the land and the possibilities of responding to natural events, which decisively affect the consequences of such phenomena. Therefore, disasters derived from mass movements and floods cannot be fully considered "natural" disasters.

These disasters are "socioenvironmental," because they are the result of the impact of a natural phenomenon over a social system, generating losses that exceed the capacity of those affected to manage the impact (Freitas and Coelho Netto 2016). So, a disaster has to be seen as a "*process of socio-historical nexus that was exposed to the environmental events of rains, floods and landslides*" (Oliveira et al. 2016, p. 14).

Therefore, the management of the risks of such disasters involves reducing the vulnerability of social systems and increasing the level of adaptation of these systems to resist disasters. However, knowing the physical nature of the phenomena that cause such disasters is not enough. To avoid deaths and losses, involving the affected populations in the decision-making processes—promoting the dialogue between multiple forms of knowledge, including local forms of knowledge—is crucial.

Recognizing the situation, post-2011 disaster-related law in Brazil advocates the need for popular participation in the decision-making process related to the management of risks associated to disasters, as mentioned in the National Protection and Civil Defense Policy, whose guidelines include the "participation of the civil society."

However, even after the creation of a legislation dedicated to participatory management, the decision-making processes dedicated to managing the risks of disasters have been marked by a low level of dialogue between the public sphere and communities, making the development of a bond of trust more difficult (Santos 2012; Freitas et al. 2016) and delaying the implementation of projects due to conflicts between managers and affected parties (Petts 1995; Innes et al. 1994). Moreover, the decisions are generally inadequate because of a lack of popular knowledge, which may complement the technical knowledge (Global Environmental Change Program 1999; Sach 1986).

The Mega Disasters in the Córrego d'Antas Drainage Basin

There was a mega disasters in the Córrego d'Antas basin area in 2011. The public sphere has been acting there, but allowing little participation (Freitas et al. 2016; Carvalho 2016).

Governmental institutions followed a top-down model to implement measures for landslide/flooding risk reduction and produced the low adherence of dwellers to the disaster-management policies such as in the case of the risk evaluations issued by the government concerning these houses and other constructions and the implementation of an alarm and alert system (Carvalho 2016).

Moreover, during the post-disaster phase of social reconstruction/development,[1] the government and part of the society began recovering the affected areas with the previous rationale, which had been responsible for the tragic consequences observed in 2011 (Freitas and Coelho Netto 2016). This is common after disasters all over the world, but it produces serious conflicts with the affected population, a new reconstruction rationale capable of minimizing the consequences of future disasters (Ribeiro 1995).

A very common problem related to the reconstruction of areas affected by disasters throughout Brazil, which is directly related to the top-down management model, refers to the withdrawal and reallocation of the affected population that remains in an area of risk. Usually this process is carried out without dialogue between public power (responsible for the reallocation process) and communities. So, there are decisions that directly affect the lives of survivors being carried out without the participation of these people (Ribeiro 1995; Freitas and Coelho Netto 2016).

The absence of dialogue related to the reallocation process has generated intense conflicts in different areas affected by disasters, which is extremely relevant for studies that seek best disaster-management practices and better adaptation of social systems to social and environmental disasters.

The same took place in many areas in the mountains of the state of Rio de Janeiro, like the Cuiabá Valley (Pinheiro 2015) and the Córrego d'Antas basin (Freitas et al. 2016; Freitas and Coelho Netto 2016).

One of the major conflicts in this basin was regarding the zoning of Evacuation Areas, carried out by Rio de Janeiro state's Environment Institute (INEA), which established—with no discussion with the population—the areas that should compulsorily be unoccupied (Freitas and Coelho Netto 2016).

Besides the methodological problems of the zoning (Coutinho and Bandeira 2012a, b), the population did not take the removal process established by the government passively. Several dwellers simply refused to leave their homes, which made the management of the removal process extremely difficult. Others organized around neighbors associations and the Network for Corrego d'Antas's Risk Management (RIMAN-CD), which gathers community associations, research and education institutions, as well as the public sphere (Freitas et al. 2016).

This network has been discussing this process, but it lacks information on the situation of the constructions. This demand is partially addressed by this paper, whose goal was to evaluate INEA's zoning and the current situation of the constructions that were considered unfit for occupation. Based on this specific case, the present work makes a general discussion about the top-down relationship

[1]According to Ribeiro (1995), the social reconstruction/development phase starts after the emergency phase. In this phase, the strategies that will guide the socioeconomic and political process related to the recovery of the social system are established. Therefore, during this phase, there is confrontation between social actors with differing interests and levels of power, which influences the reproduction of different models and perspectives of social intervention (Ribeiro 1995).

established between governments and communities affected by disasters regarding the processes of defining areas of risk and consequent ly establishing the evacuation of residents.

Materials and Methods

This study was methodologically based on the idea of action research, defined as participant research in which an object of science is understood in practice (Ketele and Roegiers 1993; Engel 2000). The object of study was established after a discussion with the community involved in RIMAN-CD (a network with specific knowledge demands to aid their political disputes).

One of the demands refers to the support to home owners who have been compulsorily determined by INEA to vacate their homes in the Córrego d'Antas drainage basin. Our research interests were convergent to their needs for a better understanding of the official arguments that justified the immediate evacuation of their homes.

It was established that the Córrego d'Antas drainage basin would be a pilot study area and that the first goal would be to find out which constructions remained occupied and to evaluate the possibility of them remaining occupied as a basis for a further discussion with INEA. The guiding principle is that the dwellers/owners would like to stay, as long as risk is acceptable.

During a meeting with INEA's technicians, a report of the situation of the constructions in the compulsory evacuation zone was requested to them so that community members and technicians could know who was still there and to support the negotiation between these owners and the government. However, the information could not be obtained.

Therefore, a methodology that could raise such information was devised using INEA's risk zoning for the middle-to-lower Córrego d'Antas canal, which drains northeasterly into the Bengalas river that runs across the center of Nova Friburgo. This drainage system converges to the Paraíba do Sul river.

INEA produced a three-level risk zoning (using a semaphore color code):

- Red—mandatory evacuation (immediate risk of flooding)—total restriction on occupation.
- Yellow—optional evacuation (high risk of flooding)—may remain if a term of responsibility is signed.
- Green—construction may remain occupied, being under a moderate or low risk of flooding.

The maps made by INEA were accessed through their website (http://www.inea.rj.gov.br) on August 3, 2014 as a .pdf file. A total of 15 maps were made available with the title: "Map of Córrego d'Antas's occupation restriction areas."

The specific dates of the images in which the maps were based were not officially informed. The .pdfs show a date of July 8, 2011 and indicates the scale as 1: 1,000, without a clear reference, however.

The .pdfs were georeferenced using Datum SAD69. The hydrography was reconstituted based on the .pdfs. Z ones were produced based on the images, and red, yellow and green shapes were created for each zone.

Buildings and houses were mapped within each zone, highlighting those that needed to be unoccupied. A similar mapping procedure was carried out using 2014 images from Google Earth Plus (georeferenced in ArcGis 10.1) to identify the number of constructions that had not been unoccupied until the current date.

The 2014 images were overlapped with the shapes of the constructions that mandatorily needed to be unoccupied. The outer limits of the river channel were marked in the 2014 image to delete the markings that referred to the constructions that had already been unoccupied. To confirm and verify the work, INEA's work was used for comparison.

Field work to check on the permanence of the dwellers was carried out afterwards, in April and June 2016. All buildings located in the red area, according to the 2011 INEA map, were classified as: demolished (when destroyed), abandoned (when they were standing, but without occupation) or occupied (when there were people occupying the building at the date of the field work).

Between June 2015 and March 2016, interviews were conducted with key actors from the Córrego d'Antas neighborhood to understand the residents' views on INEA's removal policy. These interviews were based on a semi structured questionnaire and were applied to the president of the Córrego d'Antas Neighborhood Association and to four other leaders of the neighborhood who are also members of the Management Committee of the Association.

Results and Discussion

Even in a context of climate change—in which an increase in the frequency of extreme rainfall events is expected (with their ensuing gravitational mass movements)—there was neither a disaster-prevention culture in the mountains, nor sufficient institutional preparedness for the management of such disasters before the extreme event of January 2011 (Freitas and Coelho Netto 2016).

Such unpreparedness reflected in all disaster management phases, including in the social reconstruction/development phase. At Corrego d'Antas, as well as in many other areas in the mountains, besides the tragedy of the event itself, there was a very complicated reconstruction process that was carried out by the state with very little participation of the population and, often, in an authoritarian way.

One example of the government rationale—which was questioned by dwellers and owners—was INEA's process of establishing the zones of compulsory and optional evacuation in the surroundings of Córrego d'Antas. The zoning had a profound impact on the survivors of the tragedy, many of them leaving the place they lived their whole lives.

The zoning split the areas at the margins of the Córrego d'Antas in three risk zones, which, in turn, led to the classification of constructions in three types, depending on where they were located. If constructions were entirely or partially in *Compulsory Evacuation*, they must be unoccupied and, eventually, demolished. If constructions were partially or entirely in the *Partial Restriction to Occupation Area*, the dweller/owner needs to sign a term of responsibility to continue there. If constructions were outside of these zones, they could continue there (Fig. 23.1).

Dwellers/owners then tried to understand the criteria used to classify the areas, but INEA did not provide such explanations, which outraged them. After all, such classification had a direct impact over their lives, and the criteria was not clear. No report introducing the methodology used for the zoning was made available.

Fig. 23.1 Map of INEA's zoning. *Red* compulsory evacuation area and compulsory evacuation constructions. *Yellow* partial restriction to occupation area and partial restriction to occupation constructions. *Green* constructions allowed to be occupied

After three years of negotiation between INEA and the owners of the constructions in the *Compulsory Evacuation* and *Partial Restriction to Occupation Areas* and the displacement of many dwellers/owners, through RIMAN-CD, researchers from federal universities started supporting dwellers/owners in different fronts, including in trying to understand the criteria utilized in INEA's zoning (Freitas et al. 2016).

The analysis of INEA's maps showed that the belt at each side of the river banks was discontinuous and of variable thicknesses along the river, prompting discussions between dwellers and technicians about the methodology and the development of the maps, as well as the implementation of policies based on these maps.

In these processes, technicians and residents went after—but could not find it, whether on the internet or through INEA's technicians—the reports explaining the methodology used to develop the zoning, what exactly each of the classifications meant and what level of risk did they pose.

To make matters worse, it was impossible to derive the criteria of the zoning from the maps available. There was no information on the basis used for the study. The geodesic data used for the development of the maps was not on the .pdfs.

Despite these difficulties—which illustrate the small level of participation included in the negotiation between the government and the communities—, it was possible to note that there are important differences in the number of constructions in the *Compulsory Evacuation Area* between 2011 and 2014 (Fig. 23.2 and Table 23.1).

Fig. 23.2 Shows that, in 2011, 260 constructions were in the compulsory evacuation area

Table 23.1 Number of constructions in each level of risk according to the INEA's 2011 zoning

Level of risk	Total	%
Compulsory evacuation constructions	260	35.9
Partial restriction to occupation constructions	247	34.1
Constructions under moderate or low risk occupation	217	30.0

Table 23.2 Situation of constructions in the compulsory evacuation zone in 2011 and 2016

Compulsory evacuation constructions	Total	%
2011	260	100
2016	142	54.6
Demolished between 2011 and 2016	118	45.4

In 2016, 113 constructions had been demolished (Table 23.2), that is, 45.4% of the ones that had to be demolished according to INEA's zoning study. Therefore, there were 142 constructions still standing, or 54.6% of the total of constructions in the *Compulsory Evacuation Area*.

Out of the constructions that had not been demolished, 124 are still occupied (Table 23.3). That means that 47.7% of the *Compulsory Evacuation Constructions* are still occupied, despite the risk—according to INEA's zoning.

Many of these constructions are high-standard, as noted in the field. Therefore, dwellers must have material conditions to leave if they understand they are under risk. Since around half of the dwellers remain in their homes, it means they are skeptical toward the government.

Such mistrust was also observed by Carvalho (2016) in her studies about the alarm and alert system at Córrego Dantas. The author showed that the dwellers do not trust the former analysis conducted by the governmental institution (INEA) regarding the risk of mass movements or flooding in their homes. Almost 60% of the dwellers interviewed said they do not trust the reports and maps produced by the government (Carvalho 2016).

Such mistrust gets even more serious in the current context of these communities. Since 2011, there has been an increase in the perception that mass movements and floods are recurrent in the region (Freitas and Coelho Netto 2016) and that they tend to get worse with climate change. Even so, dwellers do not trust the results put forth by the government.

Table 23.3 Situation of constructions under compulsory evacuation in 2016

Construction under compulsory evacuation in 2016	Total	% of constructions under compulsory evacuation in 2011
Occupied	124	47.7
Unoccupied	18	6.9
Demolished or unoccupied	136	52.3

This situation fits perfectly in the relationship between the community and INEA's zoning. The hurry in which the zoning was made—as a response to the disaster in 2011—and the lack of dialogue with the dwellers produced a lack of trust to the technicians. Their maps do not include any complementary information that allows dwellers to understand the methodology used and to evaluate whether it is in fact adequate to the purposes of the map.

What makes things worse is that the risk maps include a shadow in the areas with the greatest risk, as well as a caption explaining the degree of risk, meaning that a high-risk area may eventually include constructions that are not under high risk (Coutinho and Bandeira 2012a). Therefore, Coutinho and Bandeira (2012b) consider that there a generalization may have been included in these maps.

Despite the situation, the result (represented by the color-coded maps) was imposed to the communities in the Córrego d'Antas drainage basin, thoroughly changing their lives and perpetuating the tragedy, since the eviction of individuals from where they live in always generates resistance.

There is yet another relevant aspect to be considered, which helps explaining why almost half the dwellers are still in their homes. The compensations paid for the owners with constructions in compulsory evacuation areas are lower than the market value, which increases the conflict between the dwellers and INEA. The situation—together with the mistrust toward the Institute—has been delaying the evacuation of the homes and—if one considers INEA's zoning valid—increasing the risk to these people, since they continue in a high-risk area.

Conclusions

The establishment of risk zones is crucial to guide land use and occupancy policies, especially where socioenvironmental disasters are recurrent. Based on these zonings, it is possible to reduce the vulnerability of communities due to the non-occupation of high risk areas or adequate preparation for the occupation of these areas.

However, the establishment of these zones has to include a dialogue with the communities, as well as local forms of knowledge and demands, because a lack in dialogue increases conflicts between the public power and communities (Freitas and Coelho Netto 2016).

Results need to be clearly communicated to the society, so that it understands which zones should be avoided, which allows safe occupation and the methodology behind the classification of risk. Without this, dwellers will not trust the analysis of governmental institutions, as explained by Carvalho (2016) in her work about Corrego d'Antas.

With dialogue, it is possible to reduce conflict and to disseminate a risk management culture—especially when the zoning is used in evacuation policies.

However, there was a lack of dialogue and explanation regarding the methodology used in the zoning of Córrego d'Antas and in other areas. Consequently, results were not considered reliable, which amplified the conflicts. Even today, five years after the tragedy, almost half the constructions in the *Compulsory Evacuation Area* have not yet been unoccupied, which poses a high risk for the local population.

Understanding whether these constructions can really be occupied—given the true level of risk they are under—is still a challenge faced by this project, which is carried out with the help of RIMAN-CD, the network that is stimulating the dialogue between community members, researchers and the government. However, evaluating the level of risk under which the constructions that are still occupied are and understanding what their owners intend to do in terms of their relationship with INEA is necessary.

References

Bertone P, Marinho C (2013) Gestão de risco e resposta a desastres naturais: a visão do planejamento. Anais do IV Congresso CONSAD de Gestão Pública, Brasília, 27p

Carvalho NL (2016) Políticas públicas para a gestão de riscos a deslizamentos e inundações: a adesão comunitária ao sistema de alerta e alarme, Nova Friburgo/RJ. Dissertação de Mestrado, Programa de Pós Graduação em Geografia, Universidade Federal do Rio de Janeiro

Coelho Netto AL, Sato AM, Avelar AS, Vianna LG, Araújo IS, Ferreira DLC, Lima PH, Silva APA, Silva RP (2013) January 2011: the extreme landslide disaster in Brazil. In: Margottini C, Canuti P, Sassa K (eds) Landslide Science and Practice, 1ed. Springer, Berlin, 6, pp 377–384

Coutinho RQ, Bandeira APN (2012a) Gerenciamento de Áreas de Riscos: Ações Estruturais e não Estruturais. In: Lacerda WA, Palmeira EM, Coelho Netto AL, Ehrlich M (eds) Desastres naturais: susceptibilidade riscos, mitigação e prevenção, gestão e ações emergenciais. COPPE/UFRJ, Rio de Janeiro, pp 163–178

Coutinho RQ, Bandeira APN (2012b) Processos de Instabilização de Encostas e Avaliação do Grau de Risco: Estudo de Caso nas Cidades de Recife e Camaragibe. In: Lacerda WA, Palmeira EM, Coelho Netto AL, Ehrlich M (eds) Desastres naturais: susceptibilidade riscos, mitigação e prevenção, gestão e ações emergenciais. COPPE/UFRJ, Rio de Janeiro, pp 41–61

Engel GI (2000) Pesquisa-ação. Educar, Curitiba, Editora da UFPR 16:181–191

Figueiró AS, Coelho Netto AL (2011) Climatic variability and pluviometric trends in a humid tropical environment at Resende municipality—middle Paraíba do Sul river valley (Rio de Janeiro- Brazil). Braz Geogr J 2:256–273

Freitas LE, Coelho-Netto AL (2016) Reger Córrego Dantas: uma ação coletiva para enfrentamento de ameaças naturais e redução de desastres socioambientais. Ciênc Tróp 40: 165–190. Ed. Massangana, Rio de Janeiro

Freitas LE, Sato AM, Lacerda N, Schottz S, Coelho Netto AL (2016) Community, University and Government Interactions for Disaster Reduction in the Mountainous Region of Rio de Janeiro, Southeast of Brazil. In: Leal Filho W, Azeiteiro UM, Alves F (eds) Climate change and health: improving resilience and reducing risks. Springer, New York, pp 313–328

Global Environmental Change Programme (1999) The politics of GM food: risk, science and public trust. Special briefing nº 5. SPRU, University of Sussex

Groisman PY, Knight RW, Easterling DR, Karl TR, Hegerl GC, Razuvaev VN (2005) Trends in intense precipitation in the climate record. J Clim 18:1326–1350

Innes J, Gruber J, Newman M, Thompson R (1994) Coordinating growth and environmental management through consensus building. Policy research program report, California Policy Seminar, University of California, USA

Ketele J, Roegiers X (1993) Méthodologie du recueil d'informations: fondements de méthodes d'observations de questionaires, d'interviews et d'étude de documents. 2ed. Bruxelles: De Boeck Université, p 99

Magrin G, Marengo J, Boulange JP, Buckeridge M, Castellanos E, Poveda G, Nobre C, Scarano F, Vicuna S (2014) Central and South America. In: Barros VR, Field CB, Dokken DJ, Mastrandrea MD, Mach KC, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR, White LL (eds) Climate change 2014: impacts, adaptation and vulnerability. Part B: regional aspects, contribution of working group II to the fifth assessment report of the Intergovernmental Panel on Climate Change IPCC, 2014. Cambridge University Press, Cambridge, pp 1499–1566. http://ipcc-wg2.gov/AR5/report/citations/. ISBN 978-1-107-68386-0

Marengo JA, Jones R, Alves LM, Valverde MC (2009) Future change of temperature and precipitation extremes in South America as derived from the PRECIS regional climate modeling system. Int J Climatol 15:2241–2255

Oliveira SS, Portella SS, Freitas M (2016) Desnaturalização dos desastres e mobilização comunitária: redes e rodas. Ciência Trópico 40:13–26. Ed. Massangana, Rio de Janeiro

Petts J (1995) Waste management strategy development: a case study of community involvement and consensus building in Hampshire. J Environ Plan Manage 38(4):519–536

Pinheiro FD (2015) A atuação do INEA no Vale do Cuiabá, Petrópolis, RJ: remoções e violações de direitos como justificativa de proteção à vida dos afetados. O Social em Questão - Ano XVIII - nº 33, pp 215–238

Ribeiro MJ (1995). Sociologia dos desastres. In: Revista Sociologia—problemas e práticas, 18: 23–43. CIES/ISCTE

Sachs I (1986) Espaços, tempos e estratégias de desenvolvimento. São Paulo. Ed. Vértice

Santos R (2012) Gestão de desastres e Política de Assistência Social: estudo de caso de Blumenau/SC. Tese (Doutorado em Sociologia Política). Centro de Filosofia e Ciências Humanas. Programa de Pós-Graduação em Sociologia Política. UFSC. Florianópolis, p 233

UFSC—Universidade Federal de Santa Catarina/CEPED—Centro Universitário de Estudos e Pesquisas sobre Desastres (2010) Atlas brasileiro de desastres naturais 1991 a 2012. Volume Brasil. 2° Edição revisada e ampliada. Florianópolis, 126 p

UFSC—Universidade Federal de Santa Catarina/CEPED—Centro Universitário de Estudos e Pesquisas sobre Desastres (2013) Atlas brasileiro de desastres naturais 1991 a 2012. Volume Rio de Janeiro. 2° Edição revisada e ampliada. Florianópolis, 120 p

World Bank (2012) Studies on natural disasters. http://www.worldbank.org/pt/country/brazil

Chapter 24
Climate and Environmental Perception and Governance in Coastal Areas: The Case of Ilha Comprida, São Paulo, Brazil

Francine Modesto dos Santos and Silvia Serrao-Neumann

Introduction

There is growing recognition that anthropogenic-led climate change is real making adaptation an imperative (Wong et al. 2014). In particular, the International Panel on Climate Change (2014) warns in its last report that climate change will exacerbate current natural hazards risks and create new ones that will threaten both natural and human systems. Additionally, those risks are likely to be unevenly distributed and have greater impact upon disadvantaged people and communities (IPCC 2014).

Urbanized coastal areas are particularly vulnerable to future climate change impacts. Hosting a significant proportion of the world's population and economic activities, coastal areas are likely to be affected by increased and more frequent extreme weather events, and sea level rise leading to coastal inundation and erosion (De Sherbinin et al. 2007; Silva and Modesto 2012). While coastal hazards are naturally occurring phenomena (MMA 2008), an increase in sea level of 82 cm, coupled with human induced changes such as urbanisation processes, is likely to intensify coastal erosion in low-lying areas worldwide (IPCC 2013; Souza 2009a, b, 2012a; RIJN 2011; Rudorff and Bonetti 2010).

In the last 50 years, a sea level rise of 40 cm/century, or 4 mm/year, has been observed along the Brazilian coastline (Mesquita 2007; Mesquita et al. 2004), in comparison with a world average of 20 cm/century (IPCC 2013). Marengo (2007)

F.M. dos Santos (✉)
Demography Department, Institute of Philosophy and Human Sciences,
University of Campinas, Campinas, Brazil
e-mail: fran_modesto@yahoo.com.br

S. Serrao-Neumann
CRC Water Sensitive Cities, Cities Research Institute, Griffith University,
Brisbane, Queensland 4111, Australia
e-mail: s.serrao-neumann@griffith.edu.au

W. Leal Filho and L. Esteves de Freitas (eds.), *Climate Change Adaptation in Latin America*, Climate Change Management,
https://doi.org/10.1007/978-3-319-56946-8_24

suggests that the loss of Brazilian beaches can be attributed to observed sea level rise, along with recently increased frequency and intensity of storm surges and unplanned coastal development. These coastal hazards are further compounded by the lack of appropriate coastal management legislation and governance arrangements (Souza 2009c). Thus, in the Brazilian context, the intensification of coastal hazards will continue to challenge decision-making processes and requires both improved policy responses to address risks as well as increased adaptive capacity of at risk communities.

This paper aims to provide insights that can inform policy responses seeking to minimise coastal hazards impacts on vulnerable communities. To this end, the paper takes a case study approach and focuses on the coastal-estuarine environment of Ilha Comprida, Sao Paulo, Brazil, to investigate how citizens and government personnel perceive environmental hazards and actions taken to deal with coastal erosion and other coastal hazards. The paper is structured in three parts following this brief introduction. The first part presents key concepts derived from the literature review with respect to environmental perception, vulnerability and adaptation. The second part describes the research approach. This includes a description of the case study area of Ilha Comprida, methods used in the data collection (i.e., qualitative semi-structured interviews with residents, visitors, government personnel and experts) and data analysis (i.e. qualitative analysis through coding of interview transcripts). Based on the findings from empirical data the last part offers insights for advancing locally-based climate change adaptation in vulnerable urbanised coastal areas through improved risk understanding and management.

Key Concepts

Hazard, Risk, and Environmental Perception

For the purpose of this study, risk is understood as the probability with which an individual, residence, community or place is exposed to harm; whereas hazard is the phenomenon that causes harm at the social-ecological interface—hazards are tangibles and defined by people's experiences (Hogan and Marandola Jr. 2007a, b). In understanding how people perceive the environment where they live, it is possible to gain insights into their sense of place and belonging, and individual and/or collective actions they take to address environmental hazards (Pinheiro 1997 cited in Marandola Jr. and Modesto 2012, p. 13).

According to Slovic (1987), the understanding of risk perception has its origins in several fields of knowledge, including Geography, Sociology, Political Sciences, Anthropology and Psychology. In particular, social and anthropological studies show that risk perception and acceptance are influenced by social and cultural factors. Taking a cultural approach to risk perception, Douglas and Wildavsky (1983) argue that risks are socially constructed and can only be understood from that perspective. Hence, these authors suggest that risk acceptance, including the identification or discharge of a particular risk, is a result of cultural and social processes.

In parallel, Renn (2008) considers technical analysis a critical component of risk perception and its social construction. In his perspective, risk understanding, both real or calculated risk and socially constructed risk, is a result of multiple factors. Factors include people's experiences of risk, the social context in which risk perceptions are formed, and technical analyses of risks. For Renn (2008), the term risk perception implies judgment about the seriousness, probability and acceptance of specific events. He argues that as people interpret physical signals and information about specific events or activities, they create their own risk perception as a result of what they observe in reality and what they experience.

With respect to environmental perception, Ingold (2000) suggests that it is inherent to people's engagement with their immediate environment. This includes how people relate to the environment where they live, including environmental attitudes that can transform their own place. Hence, studies about environmental perception enable the understanding of how individuals perceive, analyse and relate to the environment where they live, especially how they respond to existing environmental hazards.

Vulnerability and Adaptation

Vulnerability is a critical concept in hazards research and for the development of mitigation and adaptation strategies at local, national and international levels. There are multiple definitions and understandings of vulnerability. For example, some scholars (Cutter et al. 2003; Blaikie et al. 2004) suggest that vulnerability is usually determined by social-economic factors, including the lack of access to resources. Others (Adger 2006) claim it is also an analytical tool that assists in the description of the level of harm, loss, incapacity and marginalisation of both physical and social systems to different hazards.

In the social sciences, vulnerable populations are often described as the status of a particular social group in relation to their lack of capacity or empowerment (Levine 2004). Levine (2004) suggests that the concept of vulnerability is flexible and it can be applied to an individual, social group or situation. Hogan et al. (2000) take vulnerability as a process that involves both social dynamics and environmental conditions. Kelly and Adger (2000) call for a greater focus on social vulnerability, initially neglected by earlier vulnerability studies. To this end, this paper adopts the definition of social vulnerability proposed by Cutter and Finch (2008), which offers a multidimensional perspective to the concept:

> Social vulnerability is a measure of both the sensitivity of a population to natural hazards and its ability to respond to and recover from the impacts of hazards. It is a multidimensional construct, one not easily captured with a single variable. There is ample field-based evidence for understanding the characteristics of people and social groups that make them

> more sensitive to the effects of natural hazards and reduce their ability to adequately respond and recover. (Cutter and Finch 2008, pp. 13–14)

With respect to climate change, the interconnected concepts of adaptation, adaptive capacity, vulnerability, resilience and exposure are largely used (Smit and Wandel 2006). In this context, adaptation is referred to as a 'process, action or outcome in a system (household, community, group, sector, region, country) in order for the system to better cope with, manage or adjust to some changing condition, stress, hazard, risk or opportunity' (Smit and Wandel 2006, p. 282). Adaptation is therefore seen as 'process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities' (IPCC 2012, p. 5).

Research Approach and Context

Case Study Area

Taking a case study approach (Flyvberg 2006), the Ilha Comprida (Long Island) was selected as the focus for this research because it offers a recurrent example of challenges confronting coastal urban development in the Brazilian context. The case highlights the difficulties in reconciling economic development and environmental conservation in urbanisation processes, including its impacts on socio-ecological systems and threats posed by climate change through intensification of coastal hazards. A brief description of these challenges is provided next.

Located at the southern end of the São Paulo State coast, Ilha Comprida is a popular tourist destination where its local population swells from 9,000 to 250,000[1] people during the summer season (Fundação IBGE 2010a). Urbanisation in the island has increased over the last few decades to both accommodate increased number of tourists and new residents (Faustino 2006; Mendonça 2007). Many new developments occurred without adequate urban planning and did not consider environmental constraints (e.g., coastal erosion and inundation) and their impact on ecological systems (Queiroz and Pontes 1999).

The island is part of the Iguape-Cananéia-Paranaguá Estuarine-lagoonal System, also called Lagamar, which spans over several municipalities. This coastal system is bounded on the west by the Serra do Mar mountain range and its northern part connects to the Atlantic Ocean by a natural passage called Mar Pequeno (see Fig. 24.1). The northern part of the system has been significantly impacted by coastal erosion, largely attributed to interventions in the natural course of the Ribeira de Iguape River (Becegato and Suguio 2007). Among such interventions was the opening of an artificial channel called Valo Grande in 1852. Since then, the

[1]Estimated number of visitors for the period of January and December 2013 based on the number of vehicles that crossed the bridge that connect the island with the continent. Source: Bimunicipal.

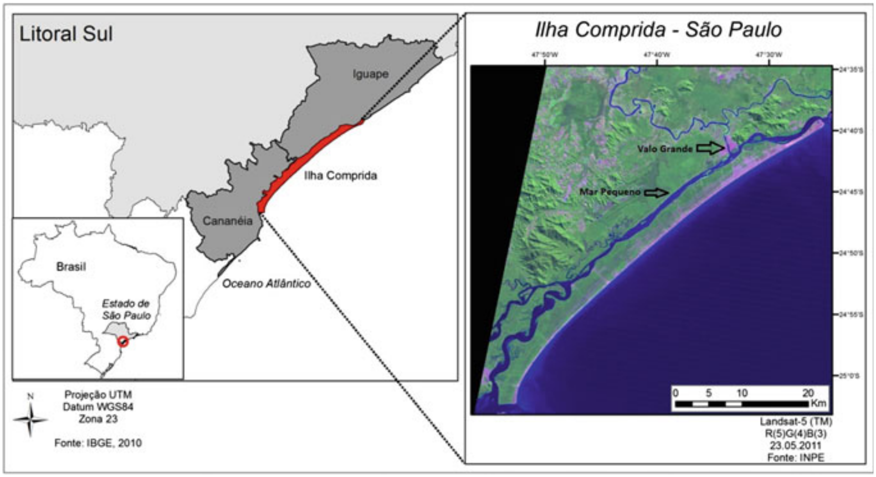


Fig. 24.1 Municipalities located on the southern coast of São Paulo state. *Source* Fundação IBGE (2010b)

lagoonal system has exhibited significant environmental changes, including changes in salinity levels and sedimentation of the natural passage (Mahiques et al. 2009). Additionally, in 1978, the State Government artificially closed the channel to impede fresh water from entering the estuarine system, further altering its ecosystem (Cunha-Lignon 2001). The closure of the channel led to widespread inundation impacting agricultural activities and communities inhabiting the floodplain of the Ribeira de Iguape River (Souza 2012b). Moreover, it exacerbated coastal erosion and inundation on the northern part of the island (Ponta Norte and Ponta da Praia), destroying residences, natural vegetation, and forcing the retreat of residents and visitors (Figs. 24.2 and 24.3).

Data Collection and Analysis

This study adopted a multi-methods approach. Firstly, a systematic literature review was carried out to gather information about geological and physical characteristics of the study area, including studies on coastal dynamics. Secondly, census data was analysed to gain an understanding of the socio-demographic characteristics of the population at risk of environmental harm. Thirdly, 39 qualitative interviews were conducted with two different social groups. Group 1 comprised residents (23) and visitors (8), and Group 2 comprised government personnel (6) and technical experts (2).

Fig. 24.2 Houses destroyed by coastal erosion in Ponta Norte of Ilha Comprida (2013)

Interviews aimed to collect information regarding people's understanding of and experience with hazards, their response strategies to address these hazards, and their adaptive capacity to confront environmental changes they have been exposed to. A different interview protocol was used for each group. Seven themes comprised the interview protocol for Group 1 (see Fig. 24.4). Five themes were investigated in interviews with informants from Group 2: key environmental hazards and vulnerable areas; issues related to the artificial channel; climate change and its institutional consideration; adaptation and response strategies to environmental hazards; environmental governance; and environmental planning.

Interviews with the both groups were transcribed verbatim, coded and analysed and the interviews of the Group 1 were analysed using NVivo software. Coding was carried out based on Grounded Theory (Moreira 2007; Dantas et al. 2009). Grounded Theory was chosen to guide data analysis as it enables the understanding of a phenomena (i.e., environmental hazards) from the perspective of the informants (Nico et al. 2007).

Given its case study approach and number of informants, findings elicited by this research are not exhaustive of the whole Ilha Comprida community, and can only refer to this point in time and may not be used to outline future trends. Findings are context specific and are not transferable to other localities subject to similar

Fig. 24.3 Houses destroyed by coastal erosion in Ponta Norte of Ilha Comprida (2014). *Source* Roberto Frozza 2014

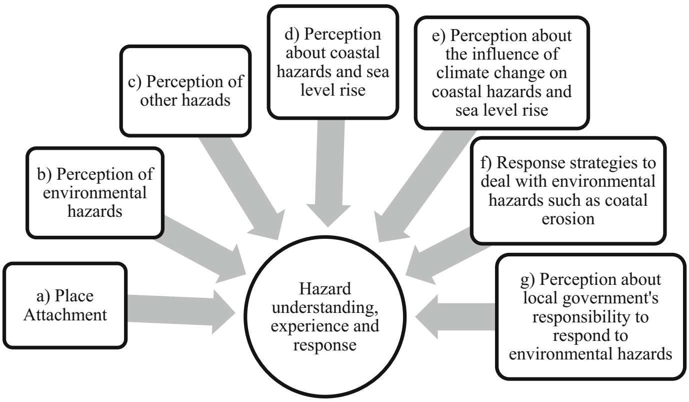


Fig. 24.4 Themes explored by interviews with informants from Group 1

environmental and climate risks. Hence, future research may be required to extend the study's scope to the wider community, both spatially and temporally, as well as similar coastal locations.

Key Findings

Ilha Comprida is part of a complex urbanised coastal system characterised by high biophysical sensitivity to both coastal hazards and urbanisation rates. It also presents a diverse group of stakeholders (residents and visitors) who are exposed to a range of environmental hazards and have distinct adaptive capacity to address such hazards. To some extent, this capacity is also determined by their sense of place. For example, visitor-owners of holiday homes destroyed by coastal erosion often neither rebuilt damaged structures nor built a new home within the island. Conversely, residents rebuilt their destroyed properties within the same area because they wanted to continue to live in the area, and highly valued its environmental qualities and the serene lifestyle it can offer.

> I know some people that had their house affected. But they just retreated further back their houses and remain in the same neighbourhood. (Interview# 2.17, resident – translated from Portuguese by the authors)

> The biggest advantage to live here is the nature, quiet. I have seen dolphins here, it is really beautiful. (Interview# 3.01, visitor – translated from Portuguese by the authors)

Overall, both residents and visitors (Group 1 informants) did not believe that local authorities had any intention to address environmental hazards affecting the island, including coastal erosion.

> The Local Government should provide support for residents with damaged houses, because it is the authority (Interview# 2.16, resident – translated from Portuguese by the authors)

> We believe that the Local Government should help us. But we are working on our own because we have already tried to talk to them, we contacted the staff responsible for the city and we didn´t receive any reply. It didn´t work. (Interview# 3.03, visitor – translated from Portuguese by the authors)

At the time fieldwork was conducted, there was no coordinated and/or effective strategy to address these hazards through either adaptation or environmental rehabilitation. As a result, individual residents and visitors with a stronger place attachment predominantly carried out responses to environmental hazards, especially to deter risks from recurrent coastal erosion to protect their properties. Responses were essentially self-funded and included construction of retaining walls using discarded tires and reconstruction of damaged building structures.

> Warning the population that they should not build houses in the areas at risk would also be important, but we are also working to contain erosion by placing tires on the embankment. All measures that are taken we do together with other residents and visitors. For me, the Local Government should pick up the debris of houses that were destroyed and use them to do the works on the river side [Mar Pequeno], because the concrete helps to hold, the sand not. (Interview# 3.07, visitor – translated from Portuguese by the authors)

Neves and Muehe (2008) note that coastal adaptation needs to consider not only integrated coastal management but also the revision of land-use planning (if available), monitoring of geomorphological and social-economic changes, and environmental awareness and education programmes for the population. However, information provided by Group 2 informants (government personnel and experts) confirmed international trends in coastal management (Nicholson-Cole and O'Riordan 2009) such as the lack of institutional integration to address environmental hazards, including local government and state environmental agencies.

> I think institutions are slow to do upgrading works because the information is dynamic, so the process is dynamic, it is not only the erosion, but the sea level rise, the climate change, etc. It lacks a connection between us researchers and them managers. Greater participation in these management committees, but in terms of legislation it is adequate, but can be improved and should, because it must be dynamic. (Interview# 2.06, expert – translated from Portuguese by the authors)

> There is a very big clash with the State due to their absence and because of a [environmental] restriction that was introduced a long time ago, and my understanding is that it is unconstitutional, but it is working until today. The island is all protected by Protected Conservation Units and one of them covers 100% of the island´s territory. Although it was created before the municipal emancipation, etc… in about 70% of this protected area there is a very similar restriction to an Ecological Station or park which provides for the right to compensation, i.e., provides for the State's obligation to indemnify those who have properties there. (Interview# 2.04, local government – translated from Portuguese by the authors)

Similar to many Brazilian urbanised areas, land-use planning in the island is often uncoordinated and, when planning schemes are available, not enforced by authorities (Araripe et al. 2008; Caus Junior 2010). This is despite the availability of information from monitoring studies that identify existing environmental changes such as the ones affecting Ilha Comprida.

> In terms of vulnerable areas I would say that it is the northern end of the island, in terms of the erosion process and it includes the region of Valo Grande, because all this will move with sediment dynamics. And all this involves people who are living there, but they are not living in the 'right place'. Neither in the northern of the island nor along the Ribeira river, since in the Alto Ribeira all occupations are irregular, because there are many farmers in these areas. Also there is a very serious matter of lack of sewage treatment, so it releases sewage into the Rio Ribeira going by Valo also and, this untreated sewage facilitates the proliferation of aquatic weeds. (Interview# 2.06, local government – translated from Portuguese by the authors)

> It is a region with a dynamic estuarine system, it is a very dynamic area in terms of deposition and erosion that we can see both in the far north, in the region of Cananéia and also at Southernmost on the Ararapira bar, everything is eroding and depositing all the time, so sometimes it loses on one side, sometimes the other wins. But the erosion process at the northern end of the island it is well marked by the influence of the river. The river fails to drain and currently around 70% of the Ribeira river water flows through Valo Grande, within the coastal system, then it is too much sediment into the system and plenty of fresh water. So, I see that this whole process is very anthropic, this whole dynamic is being heavily influenced by human issues because of Valo. The Valo Grande was made in the 19th century, but it was 4 meters, now it is 300 meters wide and there is plenty of fresh water in the system. (Interview# 2.06, local government – translated from Portuguese by the authors)

Further, although environmental awareness and education programmes for the population are important to inform them about how they impact on, and are impacted by, environmental conditions, government agencie' personnel also need specific programmes to build their capacity do deal with climate change impacts affecting coastal areas (Harvey and Caton 2003). A capacity that also includes financial resources to deal with the legacy of past interventions such as the opening and subsequent closure of the artificial channel.

Additionally, while Local Government and State environmental agencies were responsible for managing identified environmental hazards affecting the area, there was no programme specifically targeting risk analysis and risk communication. This indicates the absence of risk governance arrangements supporting the engagement of stakeholders in decision-making and enabling participative processes and mechanisms for risk analysis and communication (Renn 2008).

Discussion

Taking the work of Adger et al. (2005) on successful adaptation, there are several implications for addressing climate change impacts, particularly coastal hazards, that can be gleaned from key findings reported in the previous section. These authors define four criteria that are critical to support sustainability under a changing and uncertain future due to climate change: effectiveness, efficiency, equity and legitimacy. Effectiveness refers to the capacity to act and adapt to reach intended goals. Efficiency implies that, albeit financial costs imposed by adaptation measures, there are significant benefits which do not have an economic character such as the preservation of cultural traditions and environmental conservation for future generations. Equity and legitimacy speak to the core of winners and losers of adaptation measures, as well as the values and vested interests of stakeholders that have uneven power in decision-making processes.

The uncoordinated character of measures deployed to address coastal hazards in the island is certainly not conducive to successful adaptation from an effectiveness viewpoint. Managing coastal hazards, or coastal management broadly, requires integrated approaches (Nicholson-Cole and O'Riordan 2009) which are not achieved through the observed individual-led coastal erosion containment attempts, nor through the absent response from authorities to deal with the existing hazards. Additionally, from an efficiency perspective, it is possible that investing in coastal adaptation in the area severely affected by the erosion process may not result in significant economic benefits, as the majority of the population inhabits the centre of the island and is not directly affected by the erosion. However, it would contribute to maintaining a landscape which is greatly valued by both residents and visitors, and enhancing the environmental quality of the estuarine system.

The fact that current adaptation initiatives are carried out by individuals using their own resources, given the lack of institutional responsibility and response to address existing hazards, raises serious equity and legitimacy issues. While local authorities allow development to continue to occur in hazardous areas and, to some extent, economically benefit from it, they do not exercise their duty of care not only in terms of protecting those properties but also by failing to communicate environmental risks appropriately.

The situation provided by this case study highlights how climate change will continue to challenge coastal areas and the governance systems that manage them. Muehe (2006) suggests that as coastal development continues to intensify so is the impact of coastal hazards such as coastal erosion. It is a problem that requires specific local analysis seeking to identify adequate solutions. Despite existing international experience in coastal management measures targeting coastal erosion, these are relatively rare in the Brazilian context (Souza 2009c). In the case of Ilha Comprida, and other complex coastal systems in Brazil and elsewhere, impacts from coastal erosion can only be minimised under the implementation of coastal dynamics monitoring and management programmes across all jurisdictions to enable the identification of areas that should not be further developed (Neves and Muehe 2008).

While the management of the biophysical environment may be a straightforward process, this is not the case for the social system. As highlighted earlier, environmental perception is strongly associated with the way in which people interact with their surrounding environment, including actions that lead to changes in this environment (Ingold 2000). In the case of Ilha Comprida, affected residents are reluctant to retreat from at risk areas because they not only built their house in these areas but also their own history. In this case, planned retreat is likely to be successful only when the threats posed by permanent coastal inundation become unavoidable. Hence, a holistic land-use planning is needed whereby the whole social-ecological system is taken into account, including people's past, current and future relationship with the landscape.

Conclusion

This paper investigated responses to coastal hazards in the island of Ilha Comprida, Sao Paulo, Brazil. Findings indicated that there is absent institutional response from Local and State Government agencies to address current and future coastal hazards that are likely to be exacerbated by climate change. It was also found that individuals predominantly carried out responses and also borne the full financial costs of dealing with coastal hazards threatening their properties.

Climate change uncertainty has often been used to justify the lack of institutional action to deal with current and future impacts. However, situations such as the one observed in Ilha Comprida indicate that some coastal hazards are already real and therefore demand responses. Moreover, these observed threats should be used as opportunities to rethink land-use planning and coastal development to ensure populations are not placed at increased risks from coastal and other natural hazards likely to become more frequent and intense under climate change.

This proactive approach to adaptation can only be enabled if decision-making processes account for long-term implications of future climate change risks rather than their current short-term vision. Additionally, it is important to invest in capacity building programmes that will provide Local and State Government agencies personnel adequate training and ability to improve coastal management broadly as well as support for climate change adaptation. Last, authorities need to invest in risk analysis and communication mechanisms that both involve the population that is likely to be affected by climate change impacts and also improve their understanding of the risks so as to avoid inhabiting at risk areas.

References

Adger WN (2006) Vulnerability. Glob Environ Change 16:268–328
Adger WN, Arnell NW, Tompkins EL (2005) Successful adaptation to climate change across scales. Glob Environ Change 15:77–86
Araripe C, Figueiredo P, Deus A (2008) Zoneamento de APA. Preocupação com a capacidade de suporte ou garantia da ação antrópica capitalista? O caso de Ilha Comprida, Litoral Sul de São Paulo. Paper presented at the IV Encontro Nacional da ANPPAS, Brasília, DF
Becegato JL, Suguio K (2007) Impacto ambiental antrópico na APA da Ilha Comprida (SP): da Pré-história à atualidade. Revista UnG – Geociências 6:107–117
Blaikie PM, Cannon T, Davis I, Wisner B (2004) At risk: natural hazards, people's vulnerability and disaster, 2nd edn. Routledge, New York
Caus Junior C (2010) Breve estudo sobre a situação fundiária e registraria da comarca de Iguape – SP. Oficial de Registro de Imóveis, títulos e documentos e registro civil de pessoas jurídicas da comarca de Iguape – SP. http://www.cartorioiguape.com.br/loteamentos/. Accessed 29 Jan 2015
Cunha-Lignon M (2001) Dinâmica do manguezal no sistema Cananéia Iguape, Estado de São Paulo – Brasil. Dissertação (Mestrado em Ciências, área de Oceanografia Biológica) – Instituto Oceanográfico da Universidade de São Paulo, São Paulo
Cutter S, Finch C (2008) Temporal and spatial changes in social vulnerability to natural hazards, Hazards and Vulnerability Research Institute, Department of Geography, University of South Carolina, Columbia, SC 29208. PNAS 105:2301–2306
Cutter S, Boruff BJ, Shirley WL (2003) Social vulnerability to environmental hazards. Soc Sci Q 84:242–261
Dantas CDC, Leite JL, De Lima SBS, Stipp MAC (2009) Grounded theory—conceptual and operational aspects: a method possible to be applied in nursin research. Revista Latino-Americana de Enfermagem 17:573–579
De Sherbinin A, Schiller A, Pulsipher A (2007) The vulnerability of global cities to climate hazards. Environ Urban 19:39–64
Douglas M, Wildavsky A (1983) Risk and culture: an essay on the selection of technological and environmental dangers. University of California, Berkeley
Faustino L (2006) Blog História de Iguape. http://my.opera.com/. Accessed 8 Feb 2013
Flyvberg B (2006) Five misunderstandings about case-study research. Qual Inq 12:219–245
Fundação IBGE (2010a) São Paulo. Ilha Comprida. http://cidades.ibge.gov.br/xtras/perfil.php?lang=&codmun=352042. Accessed 28 Aug 2014
Fundação IBGE (2010b) Censo Demográfico. Sinopse por Setores. http://censo2010.ibge.gov.br/. Accessed 12 March 2014
Harvey N, Caton B (2003) Coastal management in Australia. Oxford University Press, South Melbourne

Hogan D, Marandola E Jr (2007a) Vulnerabilidade a perigos naturais nos estudos de População e Ambiente. In: Hogan DJ (ed) Dinâmica populacional e mudança ambiental: cenários para o desenvolvimento brasileiro. Núcleo de Estudos de População – Nepo/UNICAMP, Campinas, pp 73–86
Hogan D, Marandola E Jr (2007b) Vulnerability to natural hazards in population-environment studies. Background paper to the Population-Environment Research Network (PERN). Cyberseminar on Population & Natural Hazards, pp 5–19. http://populationenvironmentresearch.org/seminars.jsp. Accessed 5 Nov 2007
Hogan D, Cunha JMP, Carmo RL, Oliveira AAB (2000) Urbanização e vulnerabilidades socioambientais diferenciadas: o caso de Campinas. Paper presented at the Encontro Nacional de Estudos Populacionais, ABEP, Caxambu. http://abep.nepo.unicamp.br/docs/anais/pdf/2000/Todos/ambt15_2.pdf. Accessed 5 Nov 2007
Ingold T (2000) The perception of the environment: essays on livelihood, dwelling and skill. Routledge, London
IPCC – Intergovernmental Panel On Climate Change (2012) Managing the risks of extreme events and disasters to advance climate change adaptation. A special report of working groups I and II of the intergovernmental panel on climate change. Cambridge University Press, Cambridge
IPCC (2013) Summary for policymakers. In: Stocker TF et al (ed) Climate change 2013: the physical science basis. Contribution of working group I to the fifth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge
IPCC (2014) Summary for policymakers. In: Climate change 2014: mitigation of climate change. Contribution of working group III to the fifth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge
Kelly PM, Adger WN (2000) Theory and practice in assessing vulnerability to climate change and facilitating adaptation. Clim Change 47:325–352
Levine C (2004) The concept of vulnerability in disaster research. J Trauma Stress 17:395–402
Mahiques MM, Burone B, Figueira RCL, Lavenére-Wanderley AADO, Capellari B, Rogacheski CE, Barroso CP, Santos LAS, Cordero LM, Cussioli MC (2009) Anthropogenic influences in a lagoonal environment: a multiproxy approach at the Valo Grande mouth, Cananeia-Iguape system (SE Brazil). Braz J Oceanogr 57:325–337
Marandola E Jr, Modesto F (2012) Percepção dos perigos ambientais urbanos e os efeitos de lugar na relação população-ambiente. Revista Brasileira de Estudos Populacionais 29:7–35
Marengo JA (2007) Caracterização do clima no século XX e cenários no Brasil e na América do Sul para o século XXI derivados dos Modelos de Clima do IPCC. Relatório n.1, CPTEC/INPE. São Paulo, Brazil
Mendonça JT (2007) Gestão dos recursos pesqueiros do complexo estuarino-lagunar de Cananéia-Iguape-Ilha Comprida. Litoral Sul de São Paulo, Brazil. Tese (Doutorado em Ecologia e Recursos Naturais) – Universidade Federal de São Carlos, São Carlos, SP
Mesquita AR (2007) Nível do Mar no Estado de São Paulo. Instituto Oceanográfico da Universidade de São Paulo – IO/USP. Palestra proferida no seminário “Impactos das Mudanças Climáticas e Cenários no Estado de São Paulo”, SMA/CETESB, São Paulo
Mesquita AR, Franco ADS, Harari J, França ADS (2004) On sea level along the Brazilian coast. Afro Am Gloss News 8. http://mares.io.usp.br/aagn/aagn8/ca/sea_level3_partii.html. Accessed 6 Dec 2011
Ministério Do Meio Ambiente (MMA) (2008) Documento Síntese do I Simpósio Nacional sobre Erosão Costeira, Brasília, Brasília-DF
Moreira DA (2007) O uso de programas de computador na análise qualitativa: oportunidades, vantagens e desvantagens. Revista de Negócios 12:56–58
Muehe D (2006) Erosão e Progradação no Litoral Brasileiro. Ministério do Meio Ambiente, MMA/PGGM, Brasília
Neves C, Muehe D (2008) Vulnerabilidade, impactos e adaptação a mudanças do clima: a zona costeira. Parcerias Estratégicas, Brasília, p 27

Nicholson-Cole S, O'Riordan T (2009) Adaptive governance for a changing coastline: science, policy and publics in search of a sustainable future. In: Adger N, Lorenzoni I, O'Brien K (eds) Adapting to climate change: thresholds, values, governance. Cambridge University Press, Cambridge, pp 368–383

Nico LS, Bocchi SCM, Ruiz T, Moreira RS (2007) A grounded theory como abordagem metodológica para pesquisas qualitativas em odontologia. Ciência & Saúde Coletiva 12: 789–797

Pinheiro JQ (1997) Psicologia Ambiental: a busca de um ambiente melhor. Estudos de Psicologia 2:377–398

Queiroz OTMM, Pontes BMS (1999) O (re)arranjo de Iguape e Ilha Comprida sob o advento do turismo e da exploração dos recursos naturais. In: Lemos AIG (ed) Turismo: impactos socioambientais, 2nd edn. Hucitec, São Paulo

Renn O (2008) Risk governance: coping with uncertainty in a complex world. Earthscan, London

Rudorff FM, Bonetti J (2010) Avaliação da suscetibilidade à erosão costeira de praias da Ilha de Santa Catarina. Braz J Aquat Sci Technol 14:9–20

Silva CAM, Modesto F (2012) Cidades em zonas costeiras brasileiras: rumo à resiliência?. In: Paper presented at the VI Encontro Nacional da ANPPAS, Belém, PA

Slovic P (1987) Perception of risk. Science 236(17):280–285

Smit B, Wandel J (2006) Adaptation, adaptive capacity and vulnerability. Glob Environ Change 16:282–292

Souza CR de G (2009a) A erosão costeira e os desafios da gestão costeira no Brasil. Revista da Gestão Costeira Integrada 9:17–37

Souza CR de G (2009b) A Erosão nas Praias do Estado São Paulo: Causas, Conseqüências, Indicadores de Monitoramento e Risco. In: Bononi VLR, Santos Junior NA (eds) Memórias do Conselho Cientifico da Secretaria do Meio Ambiente: a síntese de um ano de conhecimento acumulado. Instituto de Botânica—Secretaria do Meio Ambiente do Estado de São Paulo, São Paulo, pp 48–69

Souza CR de G (2009c) Erosão Costeira. In: Tominaga L, Santoro J, Do Amaral R (eds) Desastres Naturais: conhecer para prevenir. Instituto Geológico, São Paulo, pp 71–84

Souza CR de G (2012a) Praias arenosas oceânicas do estado de São Paulo (Brasil): síntese dos conhecimentos sobre morfodinâmica, sedimentologia, transporte costeiro e erosão costeira. Revista do Departamento de Geografia—USP 30:pp 307–371

Souza EP de (2012b) Canal do Valo Grande: governança das águas estuarinas na perspectiva da aprendizagem social. 2012. 161f. Dissertação (Mestrado)—Programa de Pós-Graduação em Ciência Ambiental/PROCAM da Universidade de São Paulo, São Paulo

van Rijn LC (2011) Coastal erosion and control. Ocean Coast Manag 54:867–887

Wong PP, Losada IJ, Gattuso JP, Hinkel J, Khattabi A, McInnes KL, Saito Y, Sallenger A (2014) Coastal systems and low-lying areas. In: Climate change 2014: impacts, adaptation, and vulnerability. Part A: global and sectoral aspects. Contribution of working group II to the fifth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, pp 361–409

Chapter 25
Managing Water (In)Security in Brazil—Lessons from a Megacity

Claudia de Andrade Melim-McLeod

Introduction

As a concept, water security is subject to much debate, and the term has been used in the context of very distinct analytical frameworks in studies on topics from bio-terrorism to public health (Cooker and Bakker 2012). For the purposes of this study, however, water security is defined as "the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability" (UN-Water 2013).

While such capacity can be threatened for a variety of reasons, climate change can aggravate the dimensions of the problem in a number of ways. As Conway notes, "[h]owever water security is defined, it is clear that through potentially rapid and large changes in socially critical aspects of the hydrological cycle, climate change represents a major cross-cutting challenge, in terms of availability, exposure to hazard, management capacity (supply and demand), and individual well-being" (Conway 2013, pp. 80–81).

Most recent climate change studies, including the latest report by the Intergovernmental Panel on Climate Change on Water (IPCC 2008) focus on the physical changes that particular locations are undergoing or the solutions necessary to address water insecurity. In the case of drought, possible adaptation interventions include water rationing, desalination plants, water reuse technologies, investments in climate-smart agriculture, etc. However, *the vested political and economic interests* that underpin the choice of adaptation interventions adopted, and how

C. de Andrade Melim-McLeod (✉)
Vestre Vei 102 c, 1397 Nesøya, Norway
e-mail: claudia@melim-mcleod.com

W. Leal Filho and L. Esteves de Freitas (eds.), *Climate Change Adaptation in Latin America*, Climate Change Management,
https://doi.org/10.1007/978-3-319-56946-8_25

effective they are for the populations concerned, are not frequently discussed. This is the subject of this paper.

From 2013 to 2015, Brazil faced a severe water crisis. The country had its worst drought in 84 years, which led 1485 out of its 5561 municipalities to declare a state of emergency (Targa and Batista 2015). The drought affected over 20 million people in the São Paulo Metropolitan Area (SPMA) alone as the volume of the city's main system of reservoirs started to decrease in mid-2013, and was depleted in the following year (Coutinho et al. 2015). As a consequence, millions of residents, particularly the poorest, were deprived of regular water supply for several months, due to strict water rationing imposed by the state government.

The purpose of this paper is to provide an answer to the question "What caused the water crisis in São Paulo?" from a political economy perspective. While the state governor of São Paulo blamed climate change for low rainfall and subsequent disruptions in the water supply and the media focused on the drought (Jacobi et al. 2016) as the main reason behind water scarcity, a number of studies have discussed the consequences of near-sighted urban planning, poor decision-making and governance failures as the main causes behind the water crisis: Anelli (2015) provides a historical overview of the current urban landscape and explains how past decisions make sanitation a major challenge in São Paulo, Martins et al. (2015) analyse the crisis from a human rights perspective, and Jacobi et al. (2015) discuss failures in governance as well as in participation and social accountability structures.

This paper builds on this body of work and argues that the effects of the 2013–2015 drought were aggravated by vested interests that contributed to amplify pre-existing dysfunctions in the water governance system.

It will identify the causes of the crisis by disaggregating its main building blocks, which include climate-related factors, urban growth, the water governance framework and the roles of the São Paulo water utility company Sabesp and the state government. Further, it will demonstrate that policy choices were underpinned by political considerations and that the lack of transparency and failure of accountability structures within the government itself played a significant role in failing to prevent the crisis. It will conclude with a discussion and recommendations to address the failures identified and contribute to averting future crises in São Paulo.

Methodology and Constraints

The present paper is based on research carried out at the London School of Economics' Department of International Development, where the author was a Visiting Senior Fellow from November 2015 to September 2016. An initial literature review of secondary sources was complemented with interviews conducted between March 29 and April 20, 2016 with key informants from the University of São Paulo (USP), Sabesp, the São Paulo state government, the NGO umbrella organisation Aliança Pela Água, Associação Águas Claras do Rio Pinheiros, the Ethos Institute, Fundação Getúlio Vargas, Greenpeace, the Federation of Industries of the state of São Paulo (FIESP) and the Piracicaba Capivari Jundiaí (PCJ) River Basin Committee, as well as group discussions at the Workshop on Decision Making for Climate Change Risks and Management, held at the University of São Paulo Institute for Energy and the Environment on April 12–13, 2016. Findings from the field work were then triangulated with other sources and authors between April and July 2016.

As a case study, this paper is meant to illustrate the incentives behind climate change adaptation policy choices, and how these may be embedded in formal institutions and subject to vested interests. Although the recommendations offered here are context specific, this piece of research seeks to stimulate a debate within the climate change adaptation community about how particular adaptation interventions are selected, by whom, and who are their ultimate beneficiaries, in order to promote greater accountability and effectiveness in decision-making.

It is important to note that there are other issues that are key to ensuring effective governance of water resources, such as pricing mechanisms, early warning systems, citizen awareness, and the role of the media and of citizens'groups. However, they are beyond the scope of this paper and will not be addressed here.

Managing Water in a Growing City: A Historical Overview

There is by now widespread consensus among the scientific community that climate change is happening and that it is going to affect water security around the world, including in Brazil (IPCC 2008; PBMC 2012; SAE 2015). A series of scientific studies commissioned by the former Brazilian Secretariat of Strategic Affairs shows that 2010 precipitation levels can decrease up to 55% by 2040 and by 85% by 2100 (SAE 2015).

Brazil has approximately 12% of the freshwater of the planet, across 200,000 micro basins. The country's resources should be sufficient to provide 19 times the amount of water for its entire population of 204 million, based on the UN standard of 1700 m^3 per second per capita annually (MMA 2016). However, they are unevenly distributed and only 20% of its water is available in the Southeast, South and Northeast regions, which concentrate 78% of the population (IBGE 2011 quoted in Targa and Batista 2015).

The SPMA is currently served by systems of independent reservoirs which together, supply water to over 20 million people. The largest of them, the Cantareira system, produces 31 m^3 of water per second under normal operating conditions, of which 24.8 m^3 are destined to human consumption, and the remainder is used by the agricultural and industrial sectors. However, the drought led its volume to decrease exponentially from mid-2013 and by July 2014 the reservoir had been depleted (Coutinho et al. 2015).

The year of 2014 was the driest in the history of São Paulo since metereological data started to be collected in 1930 (Sabesp 2014). Low rain levels, however, were only part of the reason for the water crisis. A much earlier contributing factor is found in the decision-making processes that originated in the 1920s, when urban planners sought to maximize residential areas and roads to serve a growing urban population. Rivers were first channelled, then covered so the sewage systems into which they were transformed would remain conveniently hidden and out of sight. This practice remained and was institutionalized as a public policy in the 1970s. It was therefore not the consequence of a random process of urban growth, but rather of deliberate decisions to manage water resources in order to prioritize housing and transport sectors and serve the urban population needs for easy waste disposal (Anelli 2015).

In the 1960s and 1970s the city's population grew exponentially as a result of rapid economic growth and the industrialization process, which attracted migrants from other regions in Brazil, mainly the poorer North-eastern states. In the absence of affordable housing, migrant workers occupied the city's surrounding areas, including officially designated *áreas de preservação permanente*, or "permanent conservation areas" where springs for the rivers serving the city were located. These illegal occupations became large slums without any sanitation infrastructure, which led to the pollution of nearby water sources, compromising the quality of their own drinking water and that of downstream city dwellers (Silva and Porto 2003).

In order to address the many problems brought about by rapid urbanization and manage the city's water resources in a sustainable manner, more integrated planning involving the housing, transport and water sectors was required. This was first attempted in the 1970s through legislation that sought to integrate water resource management and urban planning, but to no avail. As more and more migrants settled in the conservation areas, the military government's response was at first to remove them by force.

When Brazil became a democracy again in 1985 following 21 years of military rule, there was a shift in urban planning toward improving conditions in these areas. A number of infrastructure, housing and water cleaning programmes were implemented from the 1990s onwards in order to provide some infrastructure to slums near springs, limit the pollution of water sources areas, move other slums away from streams and recuperate polluted streams (Anelli 2015).

However, demand far outstripped supply and by 2003, the fastest growing illegal settlements were located in spring protection areas, bringing domestic sewage and chemical waste directly into springs, and jeopardizing the use of water for human consumption. In addition, more roads were built over areas that were previously occupied by rivers in order to provide additional sewage outlets for a growing population.

By 2013, the SPMA had over 20 million inhabitants, and illegal settlements in protected areas had mushroomed to become a threat to water sources. Furthermore, deforestation in areas surrounding the city has also contributed to water insecurity, as forested areas helped build stocks of groundwater that contributed to nearby reservoirs. In some areas near reservoirs, cattle farms replaced forests, adding another layer of complexity and another priority—food security—to decisions regarding land use.

The fact that water and sanitation, housing, transport, agricultural and industrial sectors are housed in different departments at municipal and state levels represents enormous challenges to the integrated management of water resources. In addition, even within the water sector, present governance arrangements make coordination difficult at the municipal, state and national levels, as will be explained below.

Responsibilities for Water Governance at Local, State and Federal Levels

The right to water was officially recognized internationally by the United Nations General Assembly in 2010 (UN 1992). The Brazilian legal framework reflects the universal right to water in several instances, at the federal, state and municipal levels. Paradoxically however, the plethora of public institutions involved in ensuring that good quality water is accessible to all, can in times of crisis contribute to ensuring that it is not. This happens partly due to overlapping mandates, partly due to political reasons.

After the demise of military rulers, Brazil adopted a new Constitution in 1988. The Constitution protects both human rights and natural resources, including water resources. Article 225 defines the environment as a public good and states that public authorities have a duty to defend it and preserve it for present and future generations. Article 23 XI states that registration, monitoring and supervision of water concessions and licenses are the joint responsibility of the federal, state and municipal governments (Brasil 1988).

According to the Constitution, the federal government owns water resources such as rivers and lakes that cut across more than one state or that constitute a border with another country, as well as the rights to the hydroelectric power that may be derived from them, although states are granted a share of the revenues. States on the other hand have jurisdiction over water within their own territory. Either way, the legal nature of water is that of a public good and in case of scarcity, federal and state authorities must ensure that priority is given to human and animal consumption (Brasil 1988).

The responsibilities for water management are divided thus:

Level	Responsibilities
Federal Government	• Manages the implementation of the National Water Resource Policy and the National Water Resources Plan • Supervises the management of water resources through the Ministry of Environment and the National Water Agency (*Agência Nacional de Água*) • The National Council of Water Resources regulates relevant policies with representatives from the Federal Government, states, the Federal District (Brasilia), various sectors and civil society representatives • Manages federal and interstate River Basin Councils

(continued)

(continued)

Level	Responsibilities
	• Monitors water quality through the National Agency of Health Control (*Agência Nacional de Vigilância Sanitária*)
States	• Are responsible for water management within their territory • Formulate legislation for their territory • Set up a State Council for Water Resources and ensure the functioning of River Basin Committees (with representatives from the state government, the private sector, and civil society) within their jurisdiction • Monitor the quality of water for human consumption through the State Agency for Health Control
Municipalities	• Manage the integration of policies related to the environment, land use and conservation and sanitation with federal and state water resources policies • Have seats at River Basin Committees in order to promote inter-sectoral and federal policies with local policies • Monitor the quality of water for human consumption through the Municipal Health Agency

Source Aith and Rothbarth (2015, p. 169)

As the table above shows, there are a number of policies and laws regulating the management of water resources at various levels. The legal framework itself is complex and an analysis of it is beyond the scope of this paper, but two laws in particular merit attention. Law 9.433/1997 provides for the management of water in a decentralized and participatory manner through River Basin Committees (Presidência da República 1997). These have representatives from state and municipal governments, the private sector, civil society, academia and representatives from user groups, industry, agriculture, etc. Thus, each river basin is the primary unit where water resource planning is carried out and this gives River Basin Committees a critical role because they are meant to be a forum for policy coordination that connects different municipalities (each having its own locally elected government), across a common river basin. It also connects state-level actors, in cases where the same river basin is shared by two different states (Aith and Rothbarth 2015).

The other key piece of legislation for the purposes of this paper is Law 11.455/2007, known as the Sanitation Law (Presidência da República 2007). The law establishes national guidelines for basic sanitation, including the set of services, infrastructure and facilities needed for ensuring the supply of clean water, sanitation and sewage systems, solid waste management and the management of drainage and rain water in urban areas. However, it lacks a clear definition on ownership for sanitation service provision, which may lead to overlaps in the roles of states and municipalities. This leads to problems in service delivery, as the 'owner' of the service is also in charge of formulating public sanitation policies and of regulating and providing or delegating the provision of such services (Aith and Rothbarth 2015).

In order to understand the implications of the water management system to service provision, it is important to keep in mind that Brazil is a federation where fiscal, administrative and political powers are fully decentralized. It has 26 states excluding the Federal District where the capital Brasília is located, and over 5000 municipalities. Therefore, when national, state and municipal government offices are held by different political parties, the type of collaboration and collegial decision making envisaged in the Constitution become all but wishful thinking in practice. More often, relationships between national, state and municipal authorities can be tense and adversarial depending on their political affiliation and alliances.

For example, the state-run water utility company Sabesp should provide sanitation services in roughly half of São Paulo's 645 municipalities, but Sabesp depends on municipal sanitation plans being available and approved. In municipalities that are run by a mayor belonging to a different party from that of the state governor, there is deep suspicion to hand over sanitation services to Sabesp and as a consequence, integrated planning becomes very difficult.

Therefore, although state and municipal water governance constitutional responsibilities are grounded in good intentions from the point of view of revenue sharing, widening participation and fostering inclusion in decision making processes at the local level, their implementation is challenging due to the multitude of stakeholders and regulations involved, which leads to a series of dysfunctions. These, in turn, present major obstacles to the type of coherent water management that would be needed to safeguard water supply in times of scarcity and prevent a full-blown crisis as the one observed in São Paulo in 2013–2015.

Anatomy of a Preventable Crisis

There is a recent and growing body of literature on how the water crisis could have been alleviated, if not prevented altogether, with better planning and a different approach to the management of water resources (Côrtes et al. 2015; Martins et al. 2015; Jacobi et al. 2015).

Over the past years, the availability of spring water and the capacity of water treatment stations has decreased, leading to less water availability per capita, and the water supply system has been working above their operational capacity, particularly in the hottest months of the year (Côrtes et al. 2015). Moreover, several meteorological stations in Brazil monitor the El Niño and La Niña phenomena, and can therefore make projections on the rainfall to be expected. By heating or cooling the waters in the Pacific Ocean, these phenomena would normally lead to an increase or decrease of rainfall in the southern part of Brazil, respectively, and affect the SPMA, albeit with less intensity. Given that prognostics for the phenomena are available at least six months in advance, by mid-2013 it was already known that the Cantareira system would fail to deliver water for its 9 million users in the second half of the year (Côrtes et al. 2015). Indeed, there have been studies and warnings on the need to preserve water resources in São Paulo since the 1970s (Jacobi et al. 2015).

In 2015, a report by the State Audit Institution (*Tribunal de Contas*) of São Paulo concluded that decisions could have been made to prevent the aggravation of the crisis and its impacts and stated that the state governor "should have taken measures for the effective prevention and protection from extreme hydrological events" and recommended the development of an emergency plan to handle water scarcity risks (Martins et al. 2015, p. 6).

During the water crisis, however, none of the existing structures with a coordination role were used to develop such a plan, according to the key informants interviewed. The State Council for Water Resources was bypassed and the state government did not call on its members to discuss the crisis. Rather, a "Crisis Committee" was appointed by the state governor with carefully chosen members from different camps (Pio 2016). River Basin Committee members were not included in the governor's Crisis Committee and the criteria for membership in it was never made public. A leading water security expert at the University of São Paulo said that the government "deliberately hid the gravity of the situation from the population" (Jacobi 2016).

The bypassing of existing coordination governance structures at local and state levels is pointed by civil society representatives as one of the most salient governance failures during the crisis (Martins et al. 2015; Pio 2016; Whately 2016). Why did an elected state official choose to ignore his own State Council, which had legitimacy and broad representation from different sectors? Part of the answer lies in that the main water utility company in the state as well as its own regulatory agency are accountable to the governor himself, and they are key pieces of the puzzle leading to the aggravation of the crisis.

The São Paulo State Water and Sanitation Company—Sabesp

The São Paulo State Water and Sanitation Company (*Companhia de Saneamento Básico do Estado de São Paulo*), known as Sabesp, was created in 1973 under military rule, as a public company. In 1994, nearly 10 years after redemocratization and the wave of privatizations that followed, the company opened for private investment and in 2002, it was listed in the New York Stock Exchange. The company has a monopoly to sell water and provide sanitation services in 364 of the state's 645 municipalities, including in the SPMA.

Unlike other companies in key sectors, there was no regulatory agency enforcing minimum quality standards or compliance with legal norms until 2007, when the São Paulo State Regulatory Agency for Sanitation and Energy (*Agência Reguladora de Saneamento e Energia do Estado de São Paulo*), ARSESP, was established under the state Water and Energy Department.

However, a critical accountability failure for the enforcement of legal norms lies in the fact that the state government is Sabesp's majority shareholder with 51% of shares and it is also responsible for the nomination of ARSESP leadership, which constitutes a clear conflict of interest. If Sabesp fails to deliver quality water or comply with the sanitation law, the regulatory agency ARSESP should step in, play its oversight role, and enforce compliance with the relevant legal norms. But ARSESP also reports to the state governor, so its effectiveness only goes as far as the governor's willingness to hold Sabesp accountable.

The limited effectiveness of ARSESP was evidenced by its inability or unwillingness to enforce a 2004 requirement by the state Water and Energy Department for Sabesp to carry out studies and projects to reduce the dependency of the company to supply water on the Cantareira reservoir. The first version of such a study was submitted in 2006 and deemed incomplete by the Department. Additional studies were requested and they were only submitted in 2014, when the reservoir had been all but depleted. In addition, Sabesp failed to deliver on its contractual commitments to provide sanitation services—while still charging consumers for them—and clean the water in key river basins that supply the reservoir and was neither held accountable by the Water and Energy Department nor by ARSESP;

Currently, in the state of São Paulo, 10% of all sewage is not collected and 39% is not treated (Martins et al. 2015). Explaining Sabesp's position, a manager in the company clarified that "Sabesp depends on municipal authorities, as only they can approve sanitation plans for us to implement. Very few actually have those plans. We cannot build infrastructure in conservation areas… if we do that, the Public Prosecutor's Office (*Ministério Público*) will come after us" (Sabesp 2016).

One of the main measures taken by Sabesp to address the crisis was to encourage reductions in household consumption. In February 2014, the company announced discounts in tariffs for households that reduced their consumption by 20% in relation to the previous year. Other measures consisted in bringing in water in from other river basins through expensive public works, curbing the loss of water through pipe leaks, and using the so-called "technical reserve" from reservoirs in order to extract the amount of water at the bottom that requires special pumps. According to Sabesp, two water treatment stations had their capacity increased and 13.7 million m^3 of "reused water "(water that has not been treated as to be fit for human consumption but that can be reutilized for other uses, for example cleaning) were sold in the SPMA in 2013 (Sabesp 2014).

However, in June 2014, it emerged that Sabesp had invested less than it had planned in sanitation infrastructure to increase the water supply between 2008 and 2013, which could have minimized the impact of the crisis. This led Catarina de Alburquerque, the United Nations Special Rapporteur on the human right to safe drinking water and sanitation, to attribute responsibility for the water crisis to the state government, naming lack of planning, investment, and actions to reduce leakages which led to losses estimated at 35% (Jacobi et al. 2015)

By mid 2014, Sabesp began interrupting the supply of water in the poorest areas of the city, without previous communication to households, in breach of the national Sanitation Law. Those who complained were told that the system was undergoing maintenance. When interruptions reached middle class households, the company confirmed it had reduced water pressure in its pipes through special valves. Even in the face of ample evidence that some areas had no water for several days, the company never admitted carrying out cuts in the system. It was eventually forced to do so when the Brazilian Institute for Consumer Protection (*Instituto Brasileiro de Defesa do Consumidor*) got involved and the Access to Information Law was invoked to force Sabesp, ARSESP and the State Government to provide information on water cuts (Martins et al. 2015).

In November 2014, Sabesp increased water tariffs by 6.49% and initiated a policy of providing discounts to consumers who saved water as well as issuing a fine to those who used more. This successfully decreased water consumption in 82% of households (Sabesp 2014). In May 2015, another tariff readjustment of 15.24% was requested by the company to ARSESP in order to "balance accounts". This enabled the company to pay its shareholders dividends in the order of BRL 252.3 million (approximately USD 100 million) in 2013 (Martins et al. 2015) although the main product it sold-water—had become scarce and "discounts" were offered to those consumers who saved water throughout the municipalities it served.

The State Government

Although reduced rainfall, poor land use planning, overlapping legal mandates and Sabesp's own interests played an important role leading up to the water crisis, the single most damaging factor was perhaps the response of the state government to cope with the drought.

In 2011, Geraldo Alckmin won the election for governor of the state of São Paulo with 50.63% of the vote. Alckmin, who started his political career in 1973 as a local councillor, is at the time of writing a strong contender for the nomination of his party, the Brazilian Social Democracy Party—PSDB (*Partido da Social Democracia Brasileira*), to the 2018 presidential elections. Rather than espousing the same type of left wing ideology of its European counterparts with similar names, PSDB is viewed as a right-wing party in Brazil.

Adding to all the factors that contributed to the aggravation of the water supply in São Paulo, Alckmin's efforts to be re-elected and deliberately misleading the public with regard to the situation of the state's water resources had particularly devastating consequences.

As mentioned above, the state Water and Energy Department had sounded the alarm as early as 2004 regarding the need to invest in the water supply system in order to meet growing demand, and state guidelines for water resources (*Plano Diretor de Aproveitamento de Recursos Hidricos para a Macrometrópole Paulista*) published in 2013 pointed to the need of increasing supply and formulating an emergency plan with well-structured measures, with examples from other countries (Jacobi et al. 2015).

However, none of this was done. In September 2014, the President of ANA, the National Water Agency, intervened and declared that the management of the crisis in São Paulo was putting the water supply for 2015 at risk and that there was "no effort to communicate the gravity of the situation to the population." He criticized

Sabesp for failing to put in place an emergency plan to address the crisis, and accused the State Secretary for Water Resources of merely putting in place measures "to gain time" (Gomes 2014).

Indeed, admitting that there were serious problems in the management of water resources in the state that would lead to an interruption of the water supply for 20 million voters and consumers would have presented a blow to Ackmin's re-election campaign as well to Sabesp's shares—51% of which he controlled through the state government. For these reasons, in spite of warnings and intense questioning from ANA, experts, civil society and the media, Alckmin blamed "climate change" for the crisis until throughout his campaign (RBA 2014) and denied that water rationing would be necessary.

Having deliberately withheld information from the public as to the seriousness of the water scarcity and the rationing that was already being unofficially implemented (Jacobi et al. 2015; Martins et al. 2015), Alckmin circumvented existing government structures and laws, and was re-elected governor in November with 57% of the vote. Water rationing was officially announced shortly after.

Conclusion: Lessons Learned and the Way Forward

There is now ample evidence that there had been plenty of information about the prognostics of reduced rainfall in São Paulo in the summers of 2013–14. However, rather than invest in water treatment and sanitation for locally available water, the state government and Sabesp chose river transposition—involving extensive public works intended to bring water from another river basin—as the main adaptation strategy to the water scarcity that is projected to increase with climate change. This raises questions about the long-term sustainability of adaptation interventions chosen, and whether having a water utility that has a monopoly over water supply and sanitation and must yield a profit to its shareholders is the best model in water scarce environments.

In spite of a robust legal framework and of several institutions on various levels mandated to provide it, the São Paulo crisis left millions without regular water supply for months. The explanation for the shortcomings in actually leveraging the knowledge, rules and institutions available lie in the political economy of water governance in the state, and the various interests and incentives at play that prevented—and still prevent—a coherent approach to the problem and the development of sustainable solutions.

As discussed above, this is due to a series of distinct, yet inter-related factors:

Lack of affordable housing and growing migration, leading to large illegal settlements in areas where water springs are located and jeopardizing the availability of water that feeds critical reservoirs;

A system of governance that would require seamless collaboration between municipalities, cities, state and national level actors to be effective—which, in face of political tensions between political leaders at these levels, becomes difficult in practice;

Lack of effective coordination between municipalities, the state government and Sabesp, particular with regard to the provision of sanitation services and emergency measures to tackle the crisis;

Conflicts of interest within the state government, which oversees the water regulatory agency ARSESP while being the majority shareholder of the public-private water utility company Sabesp;

Sabesp's prioritization of investments in public works and river transposition to ensure water supply, rather than invest in sanitation services and water recycling;

Lack of transparency and accountability on the part of the state government, which has failed to communicate the gravity of the crisis to the population and to involve existing bodies such as River Basin Committees or the State Water Resource Council in devising solutions to the 2013–2015 crisis and strategies to cope with water scarcity in the future.

The water crisis is structural and climate models predict water scarcity for years to come (IPCC 2008). Therefore, averting future crises will require the following:

Enforcement of environmental protection norms, to protect or reforest conservation areas near rivers and reservoirs, and ensure that water springs can continue to feed them with high quality water. At state and municipal levels, there needs to be policy coherence and budgetary allocations to manage water security, housing, and environmental priorities;

Specific provisions on water scarcity management in the State Plan for Water Resources and *integrated crisis management between state and municipal governments, and River Basin Committees* irrespective of the political party in power at different levels, to ensure coherence in interventions made above party politics;

A prominent role for the State Council on Water Resources and River Basin Committees in Sabesp's planning and decision-making. These participatory bodies enjoy legitimacy, ownership, and broad representation. Their mandates and local knowledge must be leveraged so they play an active role with regard to early warning systems and setting up any required emergency measures;

More investments in sanitation, less in public works. According to the Sanitation Law, sanitation concession rights must include provisions for emergency sanitation services in all municipalities but many municipalities lack these plans altogether. The São Paulo municipality Plan of 2010 is outdated and has no contingency measure. The state government, municipalities and Sabesp need to work together to implement legislation on sanitation as a priority;

A firewall protecting ARSESP, the water regulatory agency, from interference from the state government. A system where a public-private water utility and its government regulator report to the same entity that controls 51% of the shares of the company has structural flaws in the checks and balances necessary to ensure accountability. As long as Sabesp has a monopoly in SPMA and the government accumulates the functions of water provider and shareholder (through Sabesp) and regulator (through ARSESP), this is unlikely to change. ARSESP should not report to the state governor through the Water and Energy Department, but rather, a Board or an existing independent, multi-stakeholder body such as the State Council on Water Resources;

Continued efforts to promote citizen awareness. Citizens have demonstrated that they can reduce their consumption significantly when given the proper incentives. It is important to continue to offer discounts in tariffs for reduced consumption, stimulate water recycling and promote awareness in schools and the work place.

Climate change adaptation is not only about desalination plants, transposition of river beds, development of drought resistant seeds, etc. It is equally important to look at the governance structures and decision making processes on how to deal with severe weather events and ensure that they are made more apt to handle water scarcity in order to increase resilience in the growing number of water stressed areas across the globe.

It is often challenging to draw replicable recommendations from isolated case studies, as every context has its specificities. However, the case of São Paulo shows that the rationale and choice of climate change adaptation interventions adopted by governments needs to be scrutinized in detail to ensure that solutions are efficient and satisfy the needs of the population that they are intended to serve in the long term.

References

Aith F, Rothbarth R (2015) O estatuto jurídico das águas no Brasil. Estudos Avançados 29(84): 163–177. http://dx.doi.org/10.1590/S0103–40142015000200011. Accessed 20 June 2016

Anelli R (2015) Uma nova cidade para as águas urbanas. Estudos Avançados 29(84). http://dx.doi.org/10.1590/S0103–40142015000200005. Accessed 15 June 2016

Araújo P (2015) Nem Privada nem pública nem nada: a estranha história da "privatização" da Sabesp, Diário do Centro do Mundo. http://www.diariodocentrodomundo.com.br/nem-privada-nem-publica-nem-nada-a-estranha-historia-da-privatizacao-da-sabesp/. Accessed 20 June 2016

Brasil (1988) Constituição da República Federativa do Brasil de 1988. http://www.planalto.gov.br/ccivil_03/constituicao/constituicao.htm. Accessed 20 June 2016

Conway D (2013) Securing water in a changing climate. In: Wolanski B et al (eds) Water security principles, perspectives and practices. Routledge, London

Cooker C, Bakker K (2012) Water security: debating an emerging paradigm. Global Environmental Change no. 22, 2012. http://web.mit.edu/12.000/www/m2017/pdfs/watsec.pdf. Accessed 19 Jan 2016

Côrtes P et al. (2015) Crise de abastecimento de água em São Paulo e falta de planejamento estratégico. http://dx.doi.org/10.1590/S0103-40142015000200002. Accessed 20 June 2016

Coutinho RM et al. (2015) Catastrophic regime change in water reservoirs and São Paulo water crisis. http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0138278. Accessed 20 June 2016

G1 (2015) Crise da Água. Nível dos reservatórios. http://especiais.g1.globo.com/economia/crise-da-agua/nivel-dos-reservatorios/. Accessed 20 June 2016

Goldestein S (2015) Para combater crise da água ações imediatas não serão suficientes. Instituto Brasileiro de Defesa do Consumidor. http://www.idec.org.br/em-acao/noticia-do-consumidor/para-combater-crise-da-agua-aces-imediatas-no-sero-suficientes. Accessed 20 June 2016

Gomes R (2014) Alckmin está comprometendo o futuro das reservas de água de São Paulo, diz ANA. Rede Brasil Atual. http://www.redebrasilatual.com.br/politica/2014/09/gestao-da-crise-da-agua-pelo-governo-alckmin-esta-comprometendo-o-futuro-diz-ana-8508.html. Accessed 20 June 2016

IBGE (2011) Instituto Brasileiro de Geografia e Estatística IBGE. Censo demográfico 2010: características da população e dos domicílios. http://www.ibge.gov.br/home/estatistica/populacao/censo2010. Accessed 22 March 2015
IPCC (2008) Intergovernmental panel on climate change IPCC. Climate change and water. Technical report VI. Bates BC et al (eds), IPCC Secretariat, Geneva. https://www.ipcc.ch/pdf/technical-papers/climate-change-water-en.pdf. Accessed 6 July 2016
Jacobi et al. Crise da água na região metropolitana de São Paulo. GEOUSP: Espaço e Tempo, 19 (3). doi:10.11606/issn.2179-0892.geousp.2015.104114. Accessed 12 July 2016
Jacobi P et al. (2015) Crise hídrica na Macrometrópole Paulista e respostas da sociedade civil. Estudos Avançados, 29(84). http://dx.doi.org/10.1590/S0103-40142015000200003. Accessed 6 July 2016
Jacobi P (2016) Interview with Pedro Jacobi, Universidade de São Paulo, 29 March 2016
Martins E et al. (2015) Crise hídrica e direitos humanos – Relatório de violação de direitos humanos na gestão hídrica do estado de São Paulo. Aliança Pela Água, Coletivo de Luta pela Água, Greenpeace and IDEC, São Paulo. http://www.greenpeace.org/brasil/Global/brasil/documentos/2015/greenpeace_relatorio_hidrica_A4-ALTA.pdf. Accessed 17 May 2016
MMA (2016) Água. http://www.mma.gov.br/agua. Accessed 24 Jan 2016
PBMC (2012) Sumário Executivo do Volume 1 - Base Científica das Mudanças Climáticas. Contribuição do Grupo de Trabalho 1 para o 1° Relatório de Avaliação Nacional do Painel Brasileiro de Mudanças Climáticas. Volume Especial para a Rio+ 20. http://www.insa.gov.br/wp-content/themes/insa_theme/acervo/painelbrasileiro.pdf. Accessed 7 June 2016
Pio (2016) Interview with Anicia Pio, Federação de Indústrias do Estado de São Paulo (FIESP), 30 March 2016
Presidência da República (1997) Lei 9.433 de 8 de janeiro de 1997. http://www.planalto.gov.br/ccivil_03/leis/L9433.htm. Accessed 6 July 2016
Presidência da República (2007) Lei 11.445 de 5 de janeiro de 2007. http://www.planalto.gov.br/ccivil_03/_ato2007-2010/2007/lei/l11445.htm. Accessed 6 July 2016
RBA (2014) Alckmin encerra horário eleitoral gratuito culpando mudança climática por falta d'água. http://www.redebrasilatual.com.br/eleicoes-2014/na-tv-alckmin-defende-se-de-crise-da-agua-e-skaf-apela-para-junho-de-2013-1865.html. Accessed 20 June 2016
Sabesp (2014) CHESS—Crise Hídrica, Estratégia e Soluções da Sabesp Para a Região Metropolitana de São Paulo. http://site.sabesp.com.br/site/uploads/file/crisehidrica/chess_crise_hidrica.pdf. Accessed 20 June 2016
Sabesp (2016) Interview with company manager at Sabesp, 31 March 2016
SAE (2015) Brasil 2040 Resumo Executivo. Available at http://www.sae.gov.br/wp-content/uploads/BRASIL-2040-Resumo-Executivo.pdf. Accessed 19 Jan 2016
Silva R, Porto M (2003) Gestão urbana e gestão das águas: caminhos da integração. Estudos Avançados 9(47). http://dx.doi.org/10.1590/S0103-40142003000100007. Accessed 20 June 2016
Targa, M, Batista G (2015) Benefits and legacy of the water crisis in Brazil. Ambiente e Água. doi:10.4136/ambi-agua.1629. Accessed 19 Jan 2016
UN (1992) Vienna Declaration. UN RES/64/292. http://www.un.org/en/ga/search/view_doc.asp?symbol=A/RES/64/292. Accessed 20 June 2016
UN-Water (2013) Water security. http://www.unwater.org/topics/water-security/en Accessed 66 July 2016
Whately M (2016) Interview with Marussia Whately, Aliança Pela Água, 10 April 2016

Author Biography

Claudia de Andrade Melim-McLeod Guest lecturer the Oslo and Akershus University College of Applied Scienes in Norway and Principal Consultant at MMC Governance and Natural Resource Management. She is a former Visiting Senior Fellow at the London School of Economics and Political Science and Governance Advisor at the United Nations Development Programme.

Chapter 26
Evidences in Literature About Physical Rehabilitation After Natural Disasters

Mauren Lopes de Carvalho, C.M. Freitas and E. Miranda

Introduction

The World Health Organization (WHO 2015) reminds us of the negative impacts that climate changes have on food, air and water, the key factors for health. Such changes have contributed for the worsening of tempests, floods, droughts, which alter the environment, interfere in the biological cycle of vectors, and provoke the contamination of soil and waters. These occurrences often materialize themselves as natural disasters, affecting not only the environment, but also the local infrastructure (Freitas et al. 2012).

Natural disasters may cause injuries, amputations, traumatisms, death, and can trigger outbreaks and epidemics. Likewise, they increase the aggravation of chronic diseases. In this regard, bringing new needs in terms of health while at the same time compromising the treatment of chronic diseases and the ongoing processes of physical rehabilitation (Brazil/Ministry of Health 2011; Guha-Sapir et al. 2007). They cause the demand for immediate assistance and, afterwards, for physical rehabilitation measures.

The physical rehabilitation favors people with disabilities, or nearing the development of disabilities in the maintenance of an ideal functionality to interact with the environment (WHO/The World Bank 2011). It is necessary to reduce the impact of deficiencies in the pursuit of independence, social integration and improvement of life quality. Ideally, it starts just after the injury or disease and may extend throughout life. Many times it involves treatments in the hospital, community and at home (Bodstein et al. 2003).

M.L. de Carvalho (✉) · C.M. Freitas · E. Miranda
Center for Studies and Research in Emergency and Disaster on Health,
Oswaldo Cruz Foundation (Fiocruz), Av. Brasil 4036/916, Manguinhos,
Rio de Janeiro, RJ 21040-361, Brazil
e-mail: mauren.carvalho@ifrj.edu.br

W. Leal Filho and L. Esteves de Freitas (eds.), *Climate Change Adaptation in Latin America*, Climate Change Management,
https://doi.org/10.1007/978-3-319-56946-8_26

Soon after a disaster, all efforts and resources are mobilized to respond to the immediate assistance demands that are so evident to society. It is noteworthy however, that among those that save themselves there are some that will silently bear the marks of the disaster in their bodies for a long period, potentially becoming disabled persons. Seen in these terms, we highlight that people with disabilities, as well as those with limited access to health services, are especially vulnerable to the health impacts generated by climatic changes (WHO 2013).

The Convention on the Rights of Persons with Disabilities also acknowledged and approved in Brazil, points out that people with disabilities are those that have long-term handicaps of physical, mental or sensorial nature. These, in their interaction with the many barriers, may obstruct their full and effective participation in society in equal conditions to other persons (Brazil 2009).

Consequently, the World Health Organization (WHO 2015) establishes that health professionals working at the local, national or international level, possess the responsibility, political influence and the necessary capacities to perform for the public's protection from health threats related to the climate. Answering to this need, the subcommittee for rehabilitation in disasters of The International Society of Physical and Rehabilitation Medicine performed the first symposium about Rehabilitation Disaster Relief in the year of 2011. In this event, the need to develop better practices and to generate a baseline of evidences for rehabilitation in disasters was identified (Gosney et al. 2011).

Thus, to contribute to the generation of evidences concerning physical rehabilitation in disasters, the present article's purpose is to identify and systematize the main aspects of this process through an analysis of the scientific literature.

This analysis was designed to provide the theoretical support for a research project about the post-disaster physical rehabilitation process that took place at the Rio de Janeiro Mountain Region, at January 12th 2011. In this occasion, heavy rainfalls caused floods and landslides, striking directly at more than 32,000 people, among them 918 deceased according to the civil defense. This was considered the greatest climatic disaster ever occurred in Brazil so far (Freitas et al. 2012). This project was finalized in January 2017 and was executed as a doctorate research at Public Health National School/Oswaldo Cruz Foundation (Fiocruz), Brazil.

Analyzing the situation of natural disasters in Brazil showed that every region in the country suffer it differently. Climatologic events (mainly droughts and dry seasons) are the most common, corresponding to 57% of the events registered between the 90s and 2000, and its impacts reaching the Northeast Region above all others. On the other hand, between the years 1991–2000, 81.7% of occurrences of mass movement were registered in the Southeast Region. Its uneven terrain, especially in Rio de Janeiro and Espírito Santo, makes them particularly susceptible to landslides following heavy rainfalls, which are regular in the region. The main characteristic of this type of disaster are its high lethality, besides provoking injuries and traumatisms (Freitas et al. 2014).

Methods

To perform a wide survey in the bibliographical production and because it is a recent theme in the literature, the search mechanism did not define a time limit to start the query. The year that each database began its coverage was adopted as the lower threshold and as the upper threshold was used April 2016, when the survey was performed. The databases consulted were: MEDLINE, LILACS, BVS desastres, Web of Science, Scopus and ScienceDirect.

Initially, wide search mechanisms were used with the purpose of selecting a broad spectrum of publications that could be refined afterwards by reading the tittles and abstracts, thus avoiding the loss of relevant articles that had subthemes with subtitles that could not be foreseen before performing the search.

Three groups of descriptors or keywords were used for the tittle and abstract: (1) related to rehabilitation or physiotherapy (*rehabilitation, "rehabilitation services", "physical and rehabilitation medicine" and "physical therapy"*); (2) related to health, sickness, disabilities and injuries (*health, "disabled persons", "chronic disease", disability OR disabilities, injury*) and (3) related to disasters (*disaster$, "health effects of disasters", "disasters vulnerability", "natural disasters", "disaster recovery", "disaster relief"*).

Upon performing the initial surveys, it was possible to identify a feedback of many specific articles about mental health, post-traumatic stress, wars and terrorism. This resulted in the refinement of the search mechanism, requesting the removal of publications that contained the following words in their title: *"mental health", "post traumatic stress", psycho*, "PTSD", terrorism, war, refugee*. Besides that, according to the possibilities of each database, filters or restrains were used for the Portuguese, English and Spanish languages; type of document, article or review and works on humans.

All these steps lead to the following search mechanism: *(tw:(rehabilitation OR "rehabilitation services" OR "physical and rehabilitation medicine" OR "physical therapy")) AND (tw:((health OR "disabled persons" OR "chronic disease" OR disability OR disabilities OR injury) AND (disaster$ OR "health effects of disasters" OR "Disasters vulnerability" OR "natural disasters" OR "disaster recovery" OR "disaster relief"))) AND NOT (tw:("mental health" OR "post traumatic stress" OR psycho$ OR "PTSD" OR terrorism OR war OR refugee)).*

In this respect, the results of the six databases surveyed were gathered; however, there were repetitions among the references retrieved. To eliminate these repetitions, the open access databases (ScienceDirect, Medline and LILACS) were prioritized due to the convenience for obtaining the articles.

The following criteria of inclusion was adopted for the reading of tittles, abstracts or articles: those that approached specifically and simultaneously the aspects related to physical rehabilitation and situations of natural disasters. The criteria of exclusion applied was: publications that did not characterize full scientific articles, researches on animals and in languages that were not English, Portuguese or Spanish.

At last, we proceeded to the reading of the full articles to define categories of analysis and, from these categories, indicate the findings from the literature review.

Results

Bibliometrical Data

The survey of databases resulted in 398 references, 119 of which were recognized as repetitions. Without the repetitions, 279 references remained. To these, the criteria of inclusion and exclusion were applied. Two hundred and fifteen references were removed because they did not fulfill the approach requirements: physical rehabilitation and disaster situations, simultaneously. Then, another 18 references were removed for not characterizing full scientific articles, researches on animals or in a language that was not English, Portuguese or Spanish. After applying all the criteria of inclusion and exclusion, there were 46 articles left, most of them originated from the databases MEDLINE, Scopus and Web of Science (Fig. 26.1).

According to the description in the methods, the bibliographical survey did not adopt a lower threshold for the year of publication. Even so, no article previous to the 90s were found, only two articles from this decade, a single article in 2001, another one in 2004 and the remaining 42 articles from 2007 to 2014, with peaks in the years 2007, 2011 and 2012 (Fig. 26.2).

From the reading of the full articles, it was possible to establish three categories of analysis that encompass the central themes addressed by the current review. They are: main occurrences related to rehabilitations after natural disasters; services and cares directed to the rehabilitation after natural disasters; and training of human resources and effectiveness of rehabilitation actions after natural disasters.

Of the 46 articles selected, three of them consist of literature reviews, 15 are experience reports, another 15 articles are concerned with researches of quantitative character, eight of them present qualitative researches and five gather researches that use qualitative and quantitative methods jointly. We highlight that among the experience reports, one of them concerns the first International Conference of Rehabilitation in Disasters (Table 26.1).

No Brazilian article was found in the query. Most of the works published about rehabilitation in situations of natural disasters around the world were written based in the event of earthquakes. Not all articles address one specific disaster, so the table does not include all the 46 articles analyzed (Table 26.2).

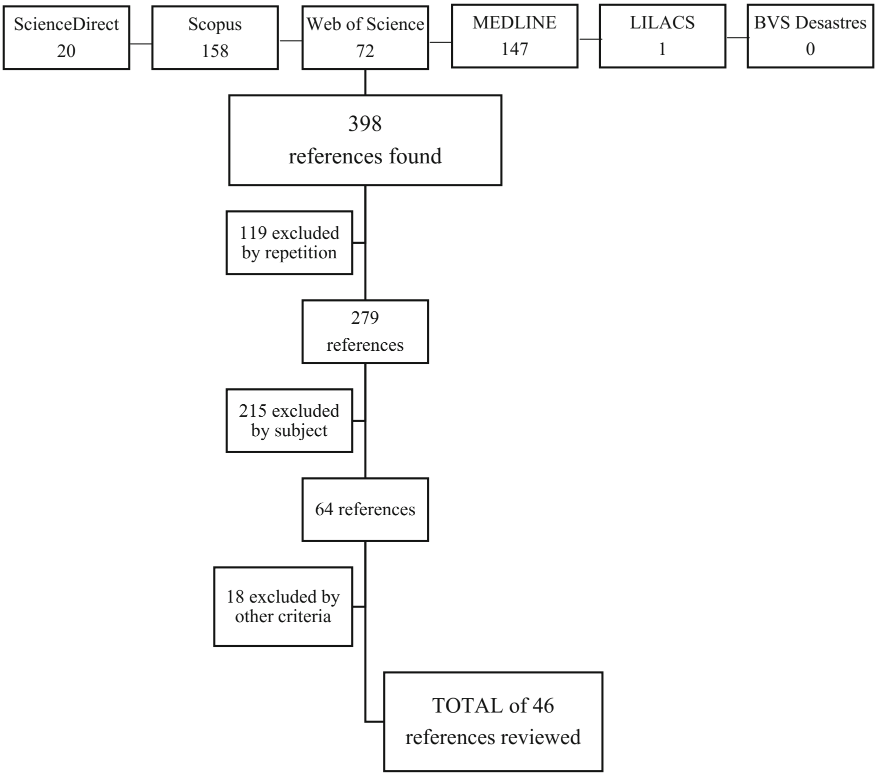


Fig. 26.1 Bibliographical query in six databases

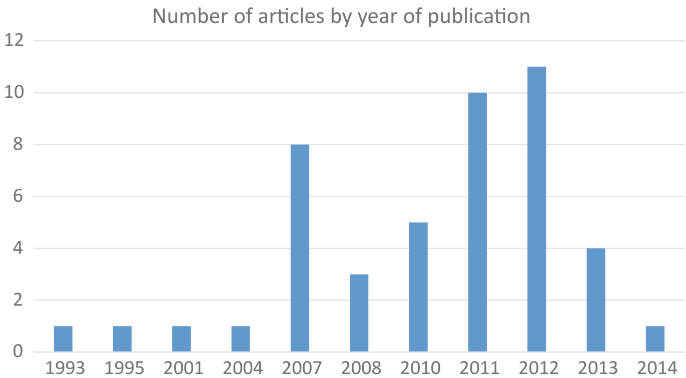


Fig. 26.2 Distribution of the 46 reviewed articles by year of publication

Table 26.1 Types of studies found in the literature review

Types of study	Number of articles
Literature reviews	03
Experience reports	15
Quantitative researches	15
Qualitative researches	08
Qualitative/quantitative researches	05
Total	46

Table 26.2 Main themes of the articles about disaster and physical rehabilitation

Type of disaster/article's theme	Location and date	Impacts	No. of publications	References
Earthquake	Port-au-Prince, Haiti January 12th, 2010	Deaths: 220,000 Injured: more than 300,000	10	Landry et al. (2010a, b), Rauch et al. (2011), Redmond et al. (2011), Campbell et al. (2012), Gorry (2010), O'Connell and Ingersoll (2012), Sarani et al. (2012), Iezzoni and Ronan (2010) and Clover et al. (2011)
Earthquake	Sumatra, Indonesia September 30th, 2009	Deaths: 1115 Severely injured: 1214 Slightly injured: 1688	1	Pang et al. (2011)
Earthquake	Sichuan, China May 12th, 2008	Deaths: 86,000 Injured: 350,000	8	Li et al. (2012), Zhang et al. (2011, 2012, 2013), Jiang et al. (2012), Xiao et al. (2011), Xu et al. (2011) and He et al. (2011)
	Sichuan, China April 20th, 2013	Deaths: 196 Injured: 11,470	1	Zhang et al. (2014)
Earthquake	Muzaffarabad, Pakistan October 8th, 2005	Deaths: 73,338 Severely Injured: 126,000–128,000 Spinal cord injury: about 650–750 people	7	Tauqir et al. (2007), Rathore et al. (2007, 2008), Gul et al. (2008), Bozkurt et al. (2007), Awais et al. (2012) and Awais and Saeed (2013)

(continued)

Table 26.2 (continued)

Type of disaster/article's theme	Location and date	Impacts	No. of publications	References
Earthquake	Bam, Iran December 26th, 2003	Deaths: 36,000 Injured: 23,000 Spinal cord injury: about 200 people	3	Raissi (2007), Raissi et al. (2007) and Khankeh et al. (2013)
Earthquake	Marmara, Turkey August 17th, 1999	Deaths: 17,480 Injured: 43,953	1	Kazancioglu et al. (2001)
Earthquake	Jiji, Taiwan September 30th, 1999	Deaths: 2321 Injured: 8679	1	Tsai et al. (2004)
Earthquake	Armenia, Soviet Union December 7th, 1988	Deaths: 25,000 Injured: 150,000	1	Burke et al. (1993)
Forest fire	Victoria, Australia February 7th, 2009	Deaths: 173 Injured: more than 400	1	Wasiak et al. (2013)
Hurricane Katrina	New Orleans, USA August 26th, 2005	Deaths: 1600	2	Bloodworth et al. (2007) and Kessler et al. (2007)
Flood	Bangkok, Thailand 2011	Deaths: 815 Affected: 2.9 million	1	Sihawong et al. (2012)

Main Occurrences Related to Rehabilitation After Natural Disasters

Of the 46 articles selected, 12 specifically address spinal cord injuries in earthquakes (Landry et al. 2010a; Rauch et al. 2011; Tauqir et al. 2007; Raissi 2007; Rathore et al. 2007, 2008; Li et al. 2012; Gosney et al. 2013; Burns et al. 2012; Gul et al. 2008; Raissi et al. 2007; Burke et al. 1993). The earthquake is the natural disaster that most frequently causes spinal cord injury. However, there are other disasters that may also lead to this outcome, as in the case of the Vietnam typhoon in 2009, when 29 people were pointed out in the literature as having suffered spinal cord injury (Burns et al. 2012).

The spinal cord injury happens mostly because of crushing by sudden falls when escaping or by the inadequate rescue or transportation (Rathore et al. 2007, 2008). The spine's lowest regions are the most frequently affected and the young are especially impacted (Tauqir et al. 2007; Rathore et al. 2007). The main damages associated to spinal cord injuries are brain injury, pelvic fractures, abdominal and chest injuries and fractures on long bones (Rathore et al. 2007).

Besides, according the Centers for Disease Control and Prevention (CDC 2011) spinal cord injuries, the crush syndrome, fractures and dislocations, infectious wounds and head, face and brain injuries are the most commonly related to earthquakes, in addition to burnings and multiple fractures (Landry et al. 2010a).

The main regions of the body affected by fractures and dislocations in case of an earthquake are the lower limbs and the lumbar spine. Then the upper limbs and, finally, the pelvis (Awais and Saeed 2013; Awais et al. 2012; Zhang et al.2014). Along with musculoskeletal injuries, the respiratory and gastrointestinal disorders are common (Bozkurt et al. 2007).

The most habitually performed surgeries are debridement, fixation of fractures, amputations and grafting of huge wounds (Sarani et al. 2012), moreover, hemi-arthroplasties, fusions, open and closed reductions and limb salvage (Awais et al. 2012). The most prevalent complications in the postsurgical recovery period include pressure ulcers, pulmonary embolisms, infected wounds (Tauqir et al. 2007), urinary tract infections, deep vein thrombosis and depressive disorder (Rathore et al. 2007).

The physical health is also impaired by other mechanisms besides traumatic injuries. Tsai et al. (2004) show an increase in hospitalizations because of acute myocardial infarction up to 6 weeks after the earthquake of 1999 at Jiji, Taiwan, a number significantly higher compared to the one registered in the same period of the previous year (Tsai et al. 2004). The difficulty to access doctors and medications, lack of financial resources, of health insurance, absence of transportation, or even lack of time may cause the treatments' interruption, as it happened to 20.6% of people in chronic health conditions after hurricane Katrina (Kessler et al. 2007). Thus, the effects of a natural disaster for the health may extend in time, compromising the quality of life, global physical performance and vitality, passing through persistent pain and psychological stress (Wasiak et al. 2013).

Services and Cares Directed to Rehabilitations After Natural Disasters

It was a consensus for different authors that the rehabilitation does is not limited to the biomedical intervention, reaching social, economic, behavioral and environmental aspects (Rauch et al. 2011; Iezzoni and Ronan 2010; Campbell et al. 2012; Li et al. 2012). Since the objective is to promote for the individual a maximum level of independence, functionality and reintegration in society, it is necessary to guide and stimulate the family too (Raissi et al. 2007; Khankeh et al. 2013; Burns et al. 2012; Raissi 2007).

Patients with severe injuries may have a productive life again, including the return to the labor market, however, it is paramount to go through a complex process of rehabilitation, which demands specialized health care, teamwork and the constant attention to health, in such a way as to avoid immediate and late complications (Rathore et al. 2008; Gul et al. 2008).

The organizations that provide relief often do not have the experience in rehabilitation, which is reflected in poor care, such as the offer of electrotherapy-based treatments when it would be more appropriate to focus in functional activities and prevention of complications (Raissi 2007; Raissi et al. 2007). An example demonstrated in the literature review investigated in this article is the case of spinal cord injury victims. In these cases, it becomes necessary to provide orientations concerning the cares related to the defecation and urination, maintenance of skin integrity, pain handling and adaptation to new assistive technologies.

In some cases the rehabilitation may extend throughout the entire life and is related to different aspects, including nutritional, psychological and cultural, hence the importance of the local professionals' participation (Raissi 2007).

A balanced nourishment is important for maintaining skin integrity and recovering from ulcers. Psychological factors such as depressive disorder and feelings of rage are associated to the increase of pain. Sexuality-related matters are usually ignored, such as the contraceptive measures that need to be addressed in a timely fashion (Raissi et al. 2007; Khankeh et al. 2013; Burns et al. 2012; Raissi 2007).

Various works highlight the importance of actively seeking the rehabilitation's needs (Bloodworth et al. 2007; Awais and Saeed 2013). The rehabilitation demands a long term investment and because of that it is commonly neglected in developing countries after natural disasters (Raissi et al. 2007). After the search, rescue and hospitalization periods, there is no monitoring for cases that need extended care, resulting in clinical complications and the establishment of impairments and incapacities, as demonstrated by Khankeh et al. (2013) after the 2003 earthquake in Iran.

Training of Human Resources and Effectiveness of Rehabilitation Actions After Natural Disasters

Especially in developing countries, the structural, material and human resources are too few to respond to the complexity of the rehabilitation process. Different works reveal the scarcity of experienced rehabilitation professionals in these countries (Rathore et al. 2007; Raissi 2007; Landry et al. 2010b; Raissi et al. 2007; Burke et al. 1993), raising awareness to the need for their education (Iezzoni and Ronan 2010; O'Connell and Ingersoll 2012).

International agencies offer educational programs that approach physical rehabilitation techniques for local health professionals in China, 2008 (He et al. 2011), in Pakistan, 2005 (Rathore et al. 2008) and in Armenia, 1988 (Burke et al. 1993). The last step in the rehabilitation may occur in the environment that the person lives, by means of the community's rehabilitation services. In these situations, local professionals develop sustainable practices, including the rehabilitation of functional and occupational skills, adaptation of assistive technologies for the difficulties in the local terrain and services related to prosthesis maintenance (Campbell et al. 2012; Iezzoni and Ronan 2010; Awais and Saeed 2013).

On the other hand, the fragmentary actions offered by different humanitarian organizations undermine the collection and the registration of epistemological data, (Raissi 2007) concerning the continuity of the care (Redmond et al. 2011). Besides that, the equipment donated by non-governmental organizations may not be well distributed or may end up being underutilized by lack of knowledge for its appropriate use and maintenance (Raissi et al. 2007).

Even worse is when the lack of basic health services affects a population since the normality period. This is Haiti's case (Landry et al. 2010b), where preexisting conditions, such as arterial hypertension, are aggravated after the disaster (Redmond et al. 2011) and entails in another barrier to the rehabilitation treatment, since the patient needs to be clinically stable so that activities that require physical effort are performed.

Nonetheless, rehabilitation actions in the community were positive in Haiti, but still need to be formalized as well as connected to clinical actions. Patients must leave the hospital with clear information about the proceedings performed, with the purpose to give adequate support to the treatment's continuity outside (Redmond et al. 2011).

Mistakes are common in clinical evaluations, especially in cases of spinal cord injury, in which the precision of such diagnostic is fundamental for the rehabilitation team's planning of subsequent interventions (Rathore et al. 2008; Raissi 2007). Nevertheless, groups of patients that received rehabilitation assistance after the earthquake in Sichuan, China (2008), obtained better results for independence in daily life activities (Zhang et al. 2012, 2013), life satisfaction and quality (Zhang et al. 2013) than similar groups without intervention. While rehabilitation interventions were positively associated with the functional recovery, the long periods of immobilization, advanced ages and depressive symptoms were negatively associated (Xiao et al. 2011).

Considering so many challenges, Burns et al. (2012) present propositions for solutions, such as keeping an international database of experienced voluntary professionals for emergency relocation, the dissemination of knowledge about rescue, early evaluation by specialized professionals, and active search for cases that need rehabilitation and guidance for the families. Concerning treatment barriers, wandering multiprofessional teams or the establishment of special transportation for people with disabilities to facilitate the access to regular health monitoring services, which may also occur by means of regular phone calls to resolve doubts at the same rate that the challenges present themselves (Burns et al. 2012). Redmond et al. (2011) also suggests the development of a simplified epistemological database that may be used by different agencies (national and international) of humanitarian response (Redmond et al. 2011).

Discussion

The bibliometrical data found in this research shows that the databases Scopus, MEDLINE and Web of Science provide the highest number of publications about physical rehabilitation and natural disasters. Curiously, no article from BVS desastres base was used. However, as shown by Rocha et al. (2014), it is about having a diverse database, that shelters a greater number of technical publications than of scientific articles. Two hundred and fifteen articles initially found were excluded because of the subject. Most of these were about disaster or rehabilitation, but not both simultaneously. Others used the word *disaster* in a figurative sense, or the term *rehabilitation* did not meant the physical aspects and those of human health.

The chronological analysis of reviewed articles in this work corroborates the information that the theme of post-disaster physical rehabilitation is recent in literature. Moreover, that its peaks in publication in 2007, 2011 and 2012 are related to specific occurrences, such as the 2005 earthquake in Pakistan, hurricane Katrina of 2005 in the USA and the 2010 earthquake in Haiti.

Concerning the methodological approaches found in the reviewed articles, a diversity of focus becomes noteworthy (quantitative, qualitative and mixed) and a significant number of experience reports.

The fact that not a single Brazilian article was found and most of the post-disaster rehabilitation articles address earthquakes specifically indicates the need of studies about physical rehabilitation in landslides situations, a type of natural disaster that occurs in Brazil that has huge potential to cause injuries.

Thus, the project "Physical rehabilitation and health recovery in the context of natural disasters: case study in Nova Friburgo" had the intention to contribute with the investigation of different paths traversed by the victims that needed rehabilitation services after the 2011 disaster, contrasting it with the vision and experience of the professionals involved, and with the point of view of the county's public rehabilitation services manager. The objective was to identify and analyze health needs and problems related to physical rehabilitation, also to identify the ways to recovery or preservation of the physical capacities of those that suffered the direct consequences of the disaster.

Despite the many occurrences of body injuries described in the present article, the demand for post-disaster physical rehabilitation did not arise only because of them, but also by complications that may manifest themselves in the hospitalization period, or even by the worsening of the chronic diseases and/or interruption of treatment. According to the World Report on Disability (2011) many health problems may be related to the appearance of a disability, such as contagious, chronic, genetic diseases, as well as traumatic injuries (WHO/World Bank 2011). After the disaster of 2011 in Japan, for instance, the rehabilitation teams were mostly occupied, not by the victims of traumatic injuries, but by the prevention of paralysis syndrome and handling of chronic patients, especially the elderly (Liu et al. 2012).

Therefore, those responsible for the services and cares towards post-disaster rehabilitation need to understand the disability in its diversity, because it is not always visible. The disabled person may be in a wheelchair with spinal cord injury, but it may also be someone that inhaled dust for several hours, damaging the pulmonary function or even a child that survived drowning, but as a consequence had a delay in motor development (WHO/World Bank 2011). These needs will not appear immediately after the disaster and because of that will not be resolved with punctual measures. A system of public health is necessary, one that has a compromise with the continuity of the care and is sensitive to the rehabilitation needs, those that are evident or hidden to the nonprofessional's eyes.

In this regard, the international literature indicates the importance of efforts to develop and implement good public, universal, decentralized systems that offer essential health services, including rehabilitation services (Gorry 2010; O'Connell and Ingersoll 2012), also considering that most people that are sick, disabled or that suffered accidents, do not possess the minimum resources to sustain health rehabilitation demands individually (Rauch et al. 2011). We display in the present article that even though the assistance actions for post-disaster rehabilitation still need to be unified, coordinated and consolidated, they have provided improvements in the quality of life, independence and prevention of disabilities for victims of natural disasters in different scenarios.

Despite the rehabilitation needs generated by the disasters and pointed out in this review, Rathore et al. (2012) observed that the response plans and acute care protocols in disaster situations usually do not include rehabilitation interventions, resulting in the negligence of acute needs and the establishment of medical complications and permanent incapacities that could be avoided.

The disabilities are related with some alteration, permanent or temporary, in the body's physiological function. When the disability makes the performance of some activity or task impossible, it is said that it provoked an incapacity, and these are susceptible of prevention (Perracini and Fló 2011). The incapacities are related with the body disabilities as much as with an environment that is not able to host the special necessities, being thus necessary to take disabled people's needs in consideration in the process of rebuilding the damaged territories.

This article's main limitation is that it handles an exploratory study, investigating a theme that is at the same time extensive and novel in literature, making it more suitable to expand the survey of questions than providing answers. As a theoretical support tool for the study of physical rehabilitation after natural disasters in Brazil, it lacks information about the type of disaster that causes most direct injuries and many deaths in this country, landslides associated to heavy rainfalls, while emphasizes the earthquake, which is extremely uncommon in Brazil.

Conclusion

Considering the health sector's need to adapt to climatic changes, the implication of these changes and the increase in the frequency and intensity of natural disasters in the world, the main lessons to be integrated from this work are that:

- The population's previous health conditions interfere in the capacity of recovery after a disaster. The population with highest chances of fully recovering is the one with better life conditions and that possess the highest level of basal health;
- Not only direct injuries, but the outbreaks of transmissible diseases, the worsening of chronic conditions and the extended immobilization periods interfere in the establishment of disabilities and handicaps after disasters;
- The rehabilitation processes are long and interdependent, demanding attention to the continuity of care;
- The disaster has the characteristic of disorganizing a community and its individuals, causing material and human losses, whilst disabilities also impose the establishment of a new reality. Therefore, if the rehabilitation usually goes beyond the physical aspects, after a disaster, an even greater effort is paramount in order to achieve the social, economic, behavioral and environmental aspects of rehabilitation;
- Physical rehabilitation needs are insidious and arise months after the disaster. This entails in difficulties to correlate the disability to the event, and in the risk of neglecting the care in face of these barriers, or even other demands imposed by events like these;
- There is a scarcity of rehabilitation professionals with training and experience in many countries. This scarcity is also reflected in the lack of services and the population's disregard concerning this possibility of care;
- It is the public health system's responsibility to perform the active search of rehabilitation needs after natural disasters, offering opportunities so that life can remake itself after a tragedy;
- The post-disaster rehabilitation actions are simultaneously necessary to achieve the maximum level of recovery of a population and so that this population does not become even more vulnerable due to the increase in the number of disabled persons;
- It is necessary to rethink contingency plans that ignore the needs of post-disaster rehabilitation.

Therefore, the prevention of disasters requires collective organization and work. The answer involves concentrated efforts and even acts of heroism. Rehabilitation itself involves mainly the ethical compromise with the continuity and wholeness of actions.

Finally, the perspective for the future is to invest more in studies about physical rehabilitation after landslides, since the surveys about injuries and post-disaster rehabilitation are focused primarily in earthquake situations.

References

Awais SM, Dar UZ, Saeed A (2012) Amputations of limbs during the 2005 earthquake in Pakistan: a firsthand experience of the author. Int Orthop 36(11):2323–2326

Awais S, Saeed A (2013) Study of the severity of musculoskeletal injuries and triage during the 2005 Pakistan earthquake. Int Orthop 37(8):1443–1447

Bloodworth DM et al (2007) Impairment and disability in the astrodome after hurricane Katrina: lessons learned about the needs of the disabled after large population movements. Am J Phys Med Rehabil 86(9):770–775

Bodstein R, Ramos CL, Hortale VA (2003) Programa de Reabilitação Comunitária: experiência de inclusão social da pessoa portadora de deficiência FUNLAR-Rio de Janeiro. FIOCRUZ, Rio de Janeiro

Bozkurt M et al (2007) The evaluation of trauma patients in Turkish Red Crescent Field Hospital following the Pakistan earthquake in 2005. Injury 38(3):290–297

Brazil (2009) Decree no. 6.949, 25 August. Convenção Internacional sobre os Direitos das Pessoas com Deficiência. http://www.planalto.gov.br/ccivil_03/_ato2007-2010/2009/decreto/d6949.htm. Accessed 30 June 2016

Brazil/Ministry of Health (2011) Guia de preparação e resposta aos desastres associados às inundações para a gestão municipal do Sistema Único de Saúde. http://www.cve.saude.sp.gov.br/htm/zoo/pdf/lepto11_guia_sms_desastres.pdf. Accessed 18 Feb 2016

BRASIL, Envoronment Ministry (2011) Relatório de Inspeção Área atingida pela tragédia das chuvas Região Serrana do Rio de Janeiro. http://www.mma.gov.br/estruturas/182/_arquivos/relatoriotragediarj_182.pdf. Accessed 12 dez 2016

Burke D et al (1993) The development of a spinal injuries unit in Armenia. Paraplegia 31:168–171

Burns A, O'Connell C, Rathore F (2012) Meeting the challenges of spinal cord injury care following sudden onset disaster: lessons learned. J Rehabil Med 44(5):414–420

Campbell DJT, Coll N, Thurston WE (2012) Considerations for the provision of prosthetic services in post-disaster contexts: the Haiti Amputee Coalition. Disabil Soc 27(5):647–661

Centers for Disease Control and Prevention (2011) Post-earthquake injuries treated at a Field Hospital—Haiti, 2010. http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5951a1.htm. Accessed 19 Feb 2016

CLover AJ et al (2011) Experience of an orthoplastic limb salvage team after the Haiti Earthquake: analysis of caseload and early outcomes. Plast Reconstr Surg 127(6):2373–2380

Freitas CM et al (2012) Vulnerabilidade socioambiental, redução de riscos de desastres e construção da resiliência: lições do terremoto no Haiti e das chuvas fortes na Região Serrana, Brasil. Ciênc Saúde Colet 17(6):1577–1586

Freitas CM et al (2014) Desastres naturais e saúde: uma análise da situação do Brasil. Ciênc Saúde Colet 19(9):3645–3656

Gorry C (2010) Once the earth stood still (part I): Cuban rehabilitation services in Haiti. MEDICC Rev 12(2):44

Gosney J et al (2011) Developing post-disaster physical rehabilitation: role of the World Health Organization Liaison Sub-Committee on Rehabilitation Disaster Relief of the International Society of Physical and Rehabilitation Medicine. J Rehabil Med 43(11):965–968

Gosney JE et al (2013) Medical rehabilitation of spinal cord injury following earthquakes in rehabilitation resource-scarce settings: implications for disaster research. Spinal Cord 51:603–609

Guha-Sapir D, Van Panhuis WG, Lagoutte J (2007) Patterns of chronic and acute diseases after natural disasters—a study from the International Committee of the Red Cross field hospital in Banda Aceh after the 2004 Indian Ocean tsunami: patterns of chronic and acute diseases after natural disasters. Trop Med Int Health 12(11):1338–1341

Gul S et al (2008) Multitasking a telemedicine training unit in earthquake disaster response: paraplegic rehabilitation assessment. Telemed J e-Health 14(3):280–283

He HC et al (2011) The urgent rehabilitation technique education program for Wenchuan earthquake victims. Hong Kong J Emerg Med 18(5):324

Iezzoni LI, Ronan LJ (2010) Disability legacy of the Haitian earthquake. Ann Intern Med 152 (12):812–814

Jiang J et al (2012) Lessons learnt from the Wenchuan earthquake: performance evaluation of treatment of critical injuries in hardest-hit areas: lessons learnt from the Wenchuan earthquake. J Evid Based Med 5(3):114–123

Kazancioglu R et al (2001) The outcome of patients presenting with crush syndrome after the Marmara earthquake. Int J Artif Organs 24(1):17–21

Kessler RC et al (2007) Hurricane Katrina's impact on the care of survivors with chronic medical conditions. J Gen Intern Med 22(9):1225–1230

Khankeh H et al (2013) Life recovery after disasters: a qualitative study in the Iranian context. Prehosp Disaster Med 28(6):573–579

Landry MD, O'Connell C et al (2010a) Post-earthquake Haiti: the critical role for rehabilitation services following a humanitarian crisis. Disabil Rehabil 32(19):1616–1618

Landry MD, McGlynn M et al (2010b) Humanitarian response following the earthquake in Haiti: reflections on unprecedented need for rehabilitation. World Health Popul 12(1):18–22

Li Y et al (2012) Evaluation of functional outcomes of physical rehabilitation and medical complications in spinal cord injury victims of the Sichuan earthquake. J Rehabil Med 44 (7):534–540

Liu M et al (2012) How did rehabilitation professionals act when faced with the Great East Japan earthquake and disaster? Descriptive epidemiology of disability and an interim report of the relief activities of the ten rehabilitation-related organizations. J Rehabil Med 44(5):421–428

O'Connell C, Ingersoll A (2012) Upper limb prosthetic services post haiti earthquake: experiences and recommendations of haiti-based rehabilitation program. J Prosthet Orthot 24(2):77–79

Pang HN et al (2011) Management of musculoskeletal injuries after the 2009 western Sumatra earthquake. J Orthop Surg 19(1):3–7

Perracini MR, Fló CM (2011) Funcionalidade e envelhecimento. Guanabara Koogan, Rio de Janeiro

Raissi GR (2007) Earthquakes and rehabilitation needs: experiences from Bam, Iran. J Spinal Cord Med 30(4):369

Raissi GR, Mokhtari A, Mansouri K (2007) Reports from spinal cord injury patients: eight months after the 2003 earthquake in Bam. Iran. Am J Phys Med Rehabil 86(11):912–917

Rathore FA et al (2007) Epidemiology of spinal cord injuries in the 2005 Pakistan earthquake. Spinal Cord 45(10):658–663

Rathore FA et al (2008) Spinal cord injury management and rehabilitation: highlights and shortcomings from the 2005 earthquake in Pakistan. Arch Phys Med Rehabil 89(3):579–585

Rathore FA et al (2012) Medical rehabilitation after natural disasters: why, when, and how? Arch Phys Med Rehabil 93(10):1875–1881

Rauch A et al (2011) Rehabilitation needs assessment in persons with spinal cord injury following the 2010 earthquake in Haiti: a pilot study using an ICF-based tool. J Rehabil Med 43(11):969–975

Redmond AD et al (2011) A qualitative and quantitative study of the surgical and rehabilitation response to the earthquake in Haiti, January 2010. Prehosp Disaster Med 26(6):449–456

Rocha V et al (2014) O tema desastre na área da saúde: perfil da produção técnico-científica na base de dados especializada em desastres da Biblioteca Virtual em Saúde (BVS). Ciênc Saúde Colet 19(9):3775–3790

Sarani B et al (2012) The academic medical centre and nongovernmental organisation partnership following a natural disaster. Disasters 36(4):609–616

Sihawong R, Janwantanakul P, Pensri P (2012) Incidence of and risk factors for musculoskeletal symptoms in the neck and low-back during severe flooding in Bangkok in 2011. J Rehabil Med 44(8):624–628

Tauqir SF et al (2007) Complications in patients with spinal cord injuries sustained in an earthquake in Northern Pakistan. J Spinal Cord Med 30(4):373

Tsai CH, Lung FW, Wang SY (2004) The 1999 Ji-Ji (Taiwan) earthquake as a trigger for acute myocardial infarction. Psychosomatics 45(6):477–482

Wasiak J et al (2013) 12-Month generic health status and psychological distress outcomes following an Australian natural disaster experience: 2009 Black Saturday Wildfires. Injury 44 (11):1443–1447

World Health Organization (2013) Protecting health from climate change: vulnerability and adaptation assessment. http://www.who.int/globalchange/publications/vulnerability-adaptation/en/. Accessed 28 July 2016

World Health Organization (2015) Did you know: by taking action on climate change you can strengthen public health. http://www.who.int/globalchange/publications/didyouknow-health-professionals.pdf. Accessed 30 June 2016

World Health Organization/The World Bank (2011) Relatório mundial sobre deficiência. http://www.pessoacomdeficiencia.sp.gov.br/usr/share/documents/RELATORIO_MUNDIAL_COMPLETO.pdf. Accessed 28 July 2016

Xiao M et al (2011) Factors affecting functional outcome of Sichuan-earthquake survivors with tibial shaft fractures: a follow-up study. J Rehabil Med 43(6):515–520

Xu J et al (2011) Long-term results of patients with head injuries treated in different hospitals after the Wenchuan, China, Earthquake. World Neurosurg 75(3–4):390–396

Zhang JL et al (2011) The motor function and activities of daily living capacity of seismic wounded patients in intensive care unit ward in 5.12 Wenchuan Earthquake of China. Hong Kong J Emerg Med 18(2):86

Zhang X et al (2012) Functional outcomes and health-related quality of life in fracture victims 27 months after the Sichuan earthquake. J Rehabil Med 44(3):206–209

Zhang X et al (2013) The NHV rehabilitation services program improves long-term physical functioning in survivors of the 2008 Sichuan Earthquake: a longitudinal quasi experiment. PLoS ONE 8(1):e53995

Zhang L et al (2014) Epidemiological analysis of trauma patients following the Lushan Earthquake. PLoS ONE 9(5):e97416. http://journals.plos.org/plosone/article?id=10.1371%2Fjournal.pone.0097416. Accessed 30 July 2016

Chapter 27
Social Cartography and the Defense of the Traditional Caiçara Territory of Trindade (Paraty, RJ, Brazil)

Anna Cecília Cortines, Robson Dias Possidônio, Natália Cristina F. Bahia, João Crisóstomo H. Oswaldo Cruz, Leonardo Esteves de Freitas and Edmundo Gallo

Introduction

The currently hegemonic model of development, production and consumption has been contributing decisively to climate change, which has been affecting a large part of the global population, especially the most vulnerable ones, which are often exposed to climate-related risks (Magrin et al. 2014). The dislocation of such

A.C. Cortines (✉)
Observatory of Sustainable and Healthy Territories (OTSS), Oswaldo Cruz Foundation (Fiocruz) and the Forum of Traditional Communities of Angra dos Reis, Paraty and Ubatuba (FCT), Rua Araponga, 502, Caborê, 23970-000 Paraty, RJ, Brazil
e-mail: cortinesanna@gmail.com

R.D. Possidônio
Caiçara and President of Trindade Tourism Boat Drivers and Artisanal Fishermen Organization (Abat), Trindade, 23970-000 Paraty, RJ, Brazil
e-mail: robtrinda@gmail.com

N.C.F. Bahia · J.C.H. Oswaldo Cruz
OTSS/Fiocruz/FCT, Paraty 23970-000, RJ, Brazil
e-mail: natalia.fbahia@gmail.com

J.C.H. Oswaldo Cruz
e-mail: joaohoc@gmail.com

L. Esteves de Freitas
Laboratory of Geo-Hydroecology at Geography Department, Federal University of Rio de Janeiro and Fiocruz, CCMN, Avenida Athos da Silveira Ramos, 149, Sala H1-015, Ilha Do Fundão, 21941-909 Rio de Janeiro, RJ, Brazil
e-mail: leonardofreitas73@gmail.com

E. Gallo
Oswaldo Cruz Foundation (Fiocruz), Center for Functional Ecology of the University of Coimbra, Rua Araponga, 502, Caborê, 23970-000 Paraty, RJ, Brazil
e-mail: gallo@fiocruz.br

W. Leal Filho and L. Esteves de Freitas (eds.), *Climate Change Adaptation in Latin America*, Climate Change Management,
https://doi.org/10.1007/978-3-319-56946-8_27

populations is an important consequence of climate change, altering their livelihoods and social relations, as well as threatening the viability of entire social, economic and environmental structures of their territories (International Institute for Sustainable Development 2003).

According to the 2030 Agenda and its Sustainable Development Goals (SDGs), finding a sustainable mode of development that integrates three pillars—economic, social and environmental ones—is still a challenge (UN 2015). The need for sustainability is consensual, but how to attain a sustainable mode of production and consumption is disputed: “The most important point of contention is the organization of production and consumption. Some groups defend that the capitalist mode of production has to continue, confident that technological development, mainly, will be able to assure the sustainability of development. Others say that sustainable societies can only exist if production and consumption structures are changed and linked to values such as well-being, happiness, cooperation and solidarity. “This dispute materializes itself in the proposals of the two groups, from their epistemological views to their operations” (Freitas et al. 2016, p. 355). In this dispute, relying heavily on technology to solve sustainability and climate change-related problems is not reasonable. Technology and science play a fundamental role in maintaining the hegemonic levels of production and consumption and maximizing profits, but their capacity to promote social, economic and environmental sustainability is limited (Dagnino 2004).

In fact, “although the legitimacy of the capitalist mode of production and of post-industrial economic development is still based on technology and science, it was mainly legitimized by the forms of social organization it produced which, generally-speaking, promoted autonomy, worsened inequities, social asymmetries and exploration” (Gallo et al. 2012, p. 23).

Promoting sustainable production and consumption practices focused on well-being, cooperation and solidarity is essential for the development of sustainable modes of production and consumption that generate processes of adaptation to climate change. These three aspects of production/consumption modes can be observed in different traditional communities, such as the Caiçara, Quilombola and Indigenous communities of the municipalities of Angra dos Reis and Paraty—in the state of Rio de Janeiro—and Ubatuba—in the state of São Paulo, in Brazil.

However, since territories are living things—and impacted by both the dominant capitalist and counter-hegemonic rationales—, development models are under permanent dispute, and the asymmetry of power between them threatens the territory and the lifestyles of traditional communities, producing an unsustainable future and shortening the reach of the SDGs.

Such dispute must involve the strengthening of traditional livelihoods and the recognition of the importance of their practices for the sustainability of the territory, which in turn provides them with political visibility and support their empowerment in the social production of the territory.

The spatialization of such traditional practices through Social Cartography has been an alternative form of territorial representation for Traditional Peoples and Communities. The first recognized systematic study of participatory mapping took place in the 1970s, in Canada, during the development of the "Inuit Land Use and Occupancy Project." Hundreds of Inuit people participated on the project, and more than 200 maps of land use and occupancy were produced (Gorayeb and Meireles 2014).

In Brazil, Social Cartography has been developed since the 1990s through social mapping experiences in the Amazon, consolidated in the "New Social Cartography of the Amazon Project" since 2005 (NCS 2014). This methodology has been helping communities in the fight for their territories based on the representation of their practices in maps which document their spatial dimension, generate information, and empowers them to dialogue and establish agreements with other social actors on their territory.

Traditional Communities and Sustainable Territories

Each people or community builds their territories socially in their own manner, based on specific conflicts experienced or provoked by different actors, which implies different relationships with available natural resources. The way these groups use their natural resources, which includes a complex social network and assumes simple cooperation approaches in their productive processes and daily activities, defines a territory that is accompanied by the development of specific identities (Almeida 2008).

Therefore, territories represent individual and collective factors of identity, which strengthens bonds and the self-affirmation of the people or the community. Territories are "the spaces in which communities recognize themselves and find the means to experience and recreate lifestyles and reproduce their history, their knowledge and, most importantly, their values. "Territories are, ultimately, the physical-cultural space in which the life of that community finds ground to develop" (Cappucci 2016, p. 107).

Although traditional livelihoods are commonly in harmony with the environment, they have been threatened by excluding environmental policies, real estate speculation, uncontrolled tourism, megaprojects, urbanization, and climate change, among other factors. The territories of traditional communities include biodiversity hotspots—which, therefore, are important for nature conservation—and great scenic beauty. This context has caused various communities to be removed from their traditional territories, which led them to occupy hills and favelas under precarious living conditions (Toledo 2001; Diegues 2016).

The access to land and its natural resources are determining factors for the ability of these populations to deal with changes in their territories and livelihoods (Adger and Kelly 1999). Moreover, according to Arruda (1999), traditional communities developed extensive empirical knowledge on nature through observation and experimentation over time.

Maintaining the livelihoods of traditional communities depends therefore on fighting for the ownership of the land and on assuring their sovereignty over their traditional territories and the traditional use of natural resources, as well as promoting the value of such practices, of community-based tourism, their management capacity and their social representations.

The strengthening of these communities, the promotion of their knowledge values and the development of territorialized social practices are the goals of the Observatory of Sustainable and Healthy Territories (OTSS), a joint initiative of the Oswaldo Cruz Foundation (Fiocruz) with the Forum of Traditional Communities of the Municipalities of Angra dos Reis, Paraty and Ubatuba (FCT), where around 70 traditional communities live (caiçara, quilombola and indigenous populations) (OTSS 2016). The cartography of social practices is a representation of the collective daily life, of the struggles and actions of popular movements, as well as of their wishes and desires (Ribeiro et al. 2006).

Social Cartography, beyond being a cartographic product, is done by communities (although with the technical support of researchers). It maps threats, the traditional practices that constitute their collective identity and circumscribe the territory, all based on the perspective of those who really understand that reality (Almeida 2006). It is up to communities to choose which social and cultural practices they want to share with the world. It is an opportunity for traditional communities to discuss the historic uses and the occupation of their territories.

Beyond the production of maps, Social Cartography is a tool in the fight for the rights of traditional communities to promote their affirmation strategies. This methodology includes an evaluation of the current situation (Present Maps), the establishment of a future situation (Future Maps), of strategies to face conflicts, as well as the identification and coordination with other actors in a network of solidarity that can expand their ability to take actions.

Territory: The Traditional Caiçara Community of Trindade

Caiçara communities have been legally recognized as traditional communities by ILO's Convention 169 and Federal Decree 6040/2007. Grabner (2016) highlights that Decree 6040, which created the National Policy for the Sustainable Development of Traditional People and Communities, has been playing an increasingly important role in the fulfillment of the rights of traditional people and communities, especially the non indigenous and quilombola ones, which have their own legal framework.

The traditional caiçara community of Trindade is located in the municipality of Paraty, in the south coast of Rio de Janeiro, ranging from Ponta da Galeta to Ponta da Trindade (Plante and Breton 2005), as shown in Fig. 27.1. The history of Trindade includes many conflicts about land ownership and resources that its community requires to survive (Lhotte 1982).

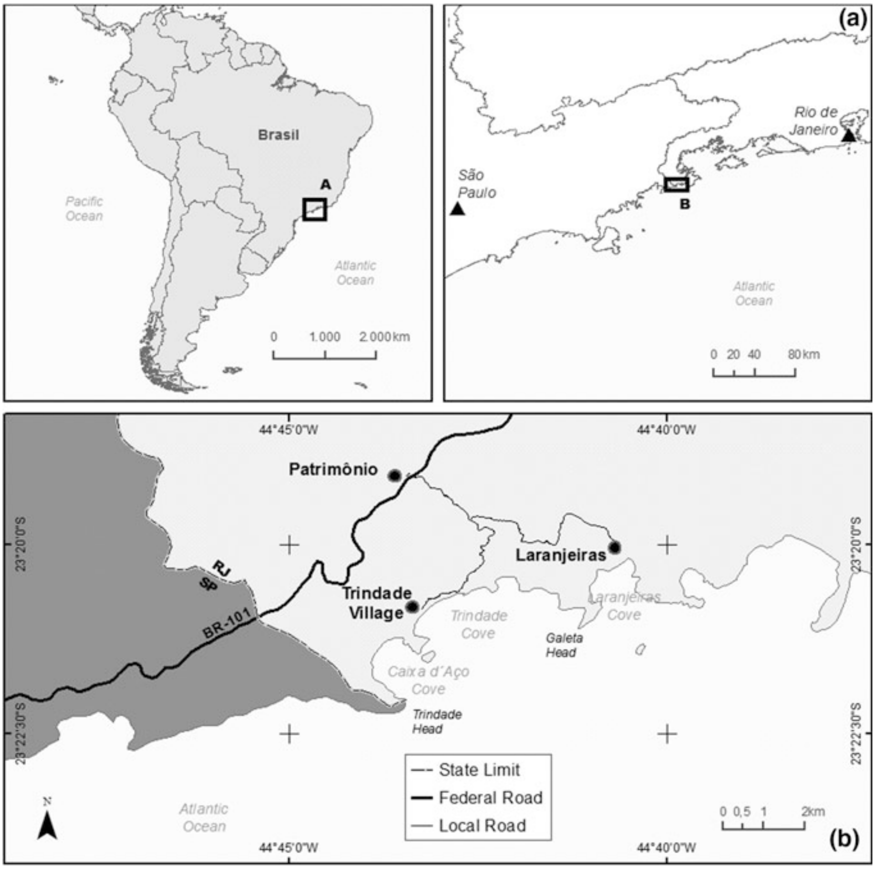


Fig. 27.1 Map of traditional caiçara community of Trindade

In the 1970s, the community went through a violent dispute with a private company—Paraty Desenvolvimento Territorial S/A (Brascan-Adela)—, which tried to seize their territory, first buying it and later trying to remove them (Lhotte 1982). With the help of the Society for the Defense of the Brazilian Coast, the community resisted and assured their right to part of the community's original lands after the signing of an agreement in 1982 (Lhotte 1982; Plante and Breton 2005).

In 1971, the Serra da Bocaina National Park (PNSB) was created, overlapping part of the area used by the community. In 1983, the Cairuçu Environmental Protection Area (APA Cairuçu) was created, including the entire area of the Trindade community (Brazil 2002; Conti and Antunes 2012). Although the goal of the conservation units created in Brazil at the time was often to restrain real-estate speculation, they also restricted the traditional use of areas and produced land tenure insecurity, which caused many conflicts and negatively influenced the quality of life of local populations.[1] The existence of both these conservation units brought about a series of environmental restrictions for the members of the village, especially regarding traditional agriculture and extractive activities (Plante and Breton 2005).

The implementation of the PNSB began in the 2000s, although there had been enforcement operations prior to that, with many actions related to the organization of tourism, as well as criminalization of community members because of the existence of constructions related to tourism, housing and artisanal fishing.

The Traditional Artisanal Fishing Territory of Trindade

Artisanal fishing uses terrestrial and marine areas resources and is crucial for the caiçara culture and identity. In Trindade, one of the most important artisanal fishing areas, the Caixa d'Aço Cove, is overlapped by the Serra da Bocaina National Park (PNSB).

Abirached (2011) observed that although the PSNB team has not been enforcing or prohibiting artisanal fishing at the Caixa d'Aço Cove, the caiçara feel insecure as to the continuation of their activities, despite the existence of an apparent tacit agreement between the Park managers and fishermen.

In 2012 and 2013, during a review of the management plan of the PNSB, the need of prohibition of fishing over time inside the Park was highlighted—as it is an integral protection unit that does not allow the direct use of natural resources (Bahia et al. 2012). At that moment, the management team of the Park recognized that artisanal fishing would have to be managed for a certain period, while the National Park and other government instances created alternative means of subsistence for the artisanal fishermen (PNSB's Consultative Council 2013).

This view weakens artisanal fishing at Trindade, an important activity for the culture and part of the community's traditional livelihoods. Despite the situation, Trindade fishermen continue to practice forms of artisanal fishing, especially at the Caixa d'Aço Cove. Maintaining the fishing activity assures that future generations will receive this traditional knowledge and preserves one of the most essential aspects of caiçara communities, which is working with different activities at the same time. In the case of Trindade, tourism and artisanal fishing are the main economic and subsistence activities (Freitas et al. 2016).

To develop alternatives, leaders of the Trindade Tourism Boat Drivers and Artisanal Fishermen Organization (Abat) and Forum of Traditional Communities of

---

[1]Most of the caiçara communities in the OTSS region live in a situation of land tenure insecurity because their traditional territory overlaps an integral protection conservation unit. These conservation units were created without prior consultation to the population and before the creation of the National System of Conservation Units (Law 9985/2000), except the expansion of the Ilha Grande State Park and the creation of the Cunhambebe State Park.

Angra, Paraty and Ubatuba started the Social Cartography of Artisanal Fishing at Trindade, with the technical support of the OTSS.

Methodology

OTSS's actions are based on research-action, which assumes an approximation between researchers and their objects, and the search for knowledge about realities that are being studied cannot be separated from the action over that same reality (Ketele and Roegiers 1993; Engel 2000; Thiollent 2006; Gallo and Setti 2012, 2014).

The use of research-action methodologies with traditional communities assumes a level of interaction between scientific and traditional knowledge, the latter playing a crucial role in the operation and interpretation of such reality. Therefore, research-action is based on an ecology of knowledge, a form of approaching reality through a plurality of knowledges and through the dialogue between such knowledges, which remain autonomous, and the generation of new knowledge which emerges from these interactions (Santos 2006, 2007).

The use of Social Cartography to think, spatialize and appropriate traditional territories promotes a form of community-led knowledge development that mirrors OTSS's approach, which seeks individual and collective empowerment.

So, in face of this situation which threatens the Caiçara traditional way of life in Trindade, leaders of the Trindade Tourism Boat Drivers and Artisanal Fishermen Organization (Abat) and Forum of Traditional Communities of Angra, Paraty and Ubatuba started the Social Cartography of Artisanal Fishing at Trindade, with the technical support of the OTSS.

The first step was the preparation of a map by a group of Abat's artisanal fishermen[2] to contextualize and produce awareness on the other council members regarding the situation of artisanal fishing at Trindade. This was introduced at the Meeting of PNSB's Consultative Council in November, 2013 (Fig. 27.2).

After that, planning of the Social Cartography, which would involve caiçaras from Abat, Caixa d'Aço Bocaina Mar NGO and OTSS's team, had as main goals to produce the social mapping to make their conflicts on the territory more visible, and to characterize Trindade as a traditional caiçara community.

The following aspects were established through workshops and interviews: (1) the most relevant information to be mapped and identified, especially the use of land and sea resources, since fishing materials (such as canoes, paddles, baskets, etc.) are made from resources taken from the Atlantic Forest and, without them, maintaining artisanal fishing practices would be harder; (2) the places where

[2]Maps are commonly used in Participatory Rural Appraisal. They are "drawings that represent the space or the territory that is being discussed […] As a tool, it allows various aspects of the reality to be discussed more broadly, thus being used as an exploratory mechanism, at the beginning of a diagnostic process" (Faria and Ferreira Neto 2006, p. 25).

Fig. 27.2 Map with the areas associated with artisanal fishing at Trindade

Fig. 27.3 Revision and validation of data

traditional practices were carried out and those which continue to be used today despite restrictions and changes imposed by tourism and the existence of conservation units; and (3) cultural practices and sacred areas.

After that, workshops on mapping using a GPS and marking the spots used by the community were carried out. The contents of the first maps were brought into a geodatabase, which also included other geographic information. As the map was being made, versions of it were introduced and discussed with the fishermen in four different workshops, in order to assure that the information included was adequate and that new information regarding fishing, agriculture, housing, handcrafts, among others, was also included. The final version of the map was validated by the group involved (Fig. 27.3). The icons representing different uses and areas on the map were drawn by the fishermen (Fig. 27.4).

Fig. 27.4 Icons representing traditional practices being drawn

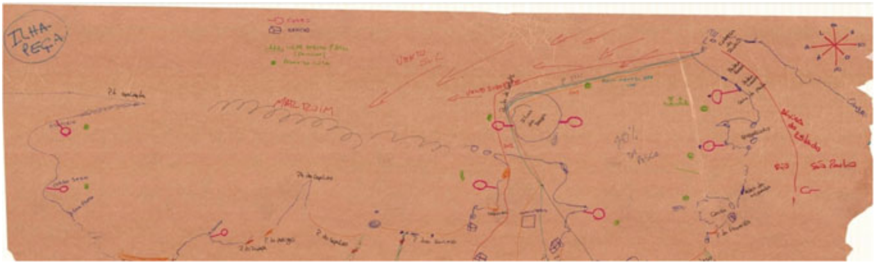


Fig. 27.5 Map made by Trindade fishermen for the Bocaina Socioenvironmental Justice Conference

The oldest artisanal fishermen reported information about the coastline of the entire region, which allowed a great level of detail concerning coastal toponymy (rocks, coves, fishing nets, coastal fishing spots) and the different tools and techniques used in each of those places.

Besides the maps, all other information obtained in the workshops and interviews were systematized by team of community members and technicians. The systematized local knowledge on the territory was linked to the geodatabase, allowing that important materials were produced and applied in current and future negotiations.

As the Social Cartography activities were being carried out, a negotiation with community-based organizations and government institutions was started to build the way to assure the right of artisanal fishermen and caiçara families to be able to maintain their activities and housing in Trindade, especially at the Caixa d'Aço Cove.

The workshop dedicated to the production of a map and for the preparation of the artisanal fishing case at the Bocaina Socioenvironmental Justice Conference

(April 2015) is an example of this phase (Fig. 27.5). The interchange experience with other leaders of the National Commission to Strengthen Extractive Marine Reserves and Coastal Marine Extractive People (Confrem) should also be highlighted.

Conclusion

Maintaining traditional livelihoods and practices positively influences sustainability, creating conditions for the implementation of the Sustainable Development Goals in their territory and for the prevention and adaptation to climate change.

However, the ones at the vectors of the hegemonic model of development and territorial management have benefited largely from real-estate projects and real-estate speculation as a whole, and have assumed a more preservational and intimidating attitude concerning the areas that overlap protected areas. That led traditional communities to lose empowerment and autonomy over their territories and practices, which threatens the maintenance of their livelihoods.

This work is coherent with the OTSS's approach to research with traditional communities, and sought to promote the autonomy of individuals and collective of Abat members through social cartography. The limits of the traditional territory of Trindade were identified, and the use and management of natural resources—which, with the variables and adaptations to be applied in the long term, not only will be key to developing and disseminating sustainable development models, but also is intimately related to the maintenance of traditional territories—were spatialized.

This helped raising the awareness of conservation units council members and the inclusion of demands of the traditional livelihoods of Trindade in PNSB's Management Plan, after the presentation of the map during the Meeting of PNSB's Consultative Council on November 2013. Moreover its use in the Bocaina Socioenvironmental Justice Conference produced a line of dialogue between traditional communities and environmental agencies, with the mediation of the Federal Prosecution Service.

Another important result was the increased level of awareness regarding the importance of social mapping as a tool to contrast traditional areas with the legislation that applies to the territory (boundaries of conservation units, municipal zoning, among others), placing such information at the center of the territorial planning of the region.

Such awareness was decisive for community members to have sufficient drive to be the agents of the social cartography process with OTSS. Since they fear new sanctions and restrictions, they are usually unwilling to share information on their territory.

The cultural dissemination generated by the presence of artisanal fishermen of different generations in the workshops and meetings—which promoted a rich exchange of information and knowledge among them—should also be highlighted.

Finally, the information and maps produced collectively can now be used in different spheres of negotiation to resolve conflicts. These maps can be adapted to specific demands and symbolic systems, thus expanding Abat's and FCT's management capacities, as well as their dialogue with solidarity networks and local managers, with the goal of assuring the maintenance of traditional livelihoods and the sustainability of the territory.

References

Abirached CFA (2011) Ordenamento Territorial e Áreas Protegidas: conflitos entre instrumentos e direitos de populações tradicionais de Ubatuba-Paraty. Brasília, UNB. Dissertação de mestrado

Adger WN, Kelly PM (1999) Social vulnerability to climate change and the architecture of entitlements. Mitig Adapt Strateg Glob Chang 4(3–4):253–266

Almeida AWB (2006) Quilombolas, Quebradeiras de Coco Babaçu, Indígenas, Ciganos, Faxinalenses e Ribeirinhos: movimentos sociais e a nova tradição. Rev Propos Rio de Janeiro 29(107/108):25–38

Almeida AWB (2008) Terra de quilombo, terras indígenas, "babaçuais livre", "castanhais do povo", faixinais e fundos de pasto: terras tradicionalmente ocupadas. PGSCA/UFAM, Manaus

Arruda R (1999) "Populações tradicionais" e a proteção dos recursos naturais em unidades de conservação. Ambient Soc Ano II, n. 5:79–93

Bahia NCF, Seixas CS, Araujo LG, Farinaci JS; Chamy P (2012) Implementation of a national park over traditional lands of the Trindade community in Paraty, Brazil. In: Magro TC, Rodrigues LM, Silva Filho DF, Polizel JL, Leahy J (eds) Protected areas and place making: How do we provide conservation, landscape management, tourism, human health and regional development? Protected areas and place making conference proceedings. Piracicaba: Esalq, pp 46–51

Brazil. Ministério do Meio Ambiente/Ibama/Direc (2002) Plano de manejo do Parque Nacional da Serra da Bocaina: encarte n. 5. Brasília: FEC/Unicamp

Cappucci M (2016) Aspectos fundiários das comunidades caiçaras. In: Neto PS (Org) Direito das comunidades tradicionais caiçaras. São Paulo: Ed. Café com Lei, pp 105–131

Conti BR, Antunes DC (2012) Conflitos na gestão do Parque Nacional da Serra da Bocaina: entraves ao desenvolvimento local na vila de Trindade (Paraty, RJ). Interações 13(2):213–223

Dagnino RA Tecnologia social e seus desafios (2004) In: Lassance Jr, AE et al Tecnologia Social—Uma estratégia para o desenvolvimento. Rio de Janeiro: Fundação Banco do Brasil, pp 187–209, 2004. http://www.oei.es/salactsi/Teconologiasocial.pdf. Accessed 25 Sep 2016

Diegues AC (2016) Prefácio. In: Neto PS (Org). Direito das comunidades tradicionais caiçaras. São Paulo: Ed. Café com Lei, pp 11–19

Engel GI (2000) Pesquisa-ação. Educar em Revista 16:181–191, Universidade Federal do Paraná, Brasil, pp 3–4

Faria AAC, Ferreira Neto PS (2006) Ferramentas do diálogo—qualificando o uso das écnicas do DRP: diagnóstico rural participativo. MMA e IIEB, Brasília

Freitas LE, Cruz JCHO, Cortines AC, Gallo E (2016) Observatory of Sustainable and Healthy Territories (OTSS) GIS: Geo-Information for the Sustainability of Traditional Communities in Southeastern Brazil. In: Leal Filho W, Azeiteiro UM, Alves F (eds). Climate change and health improving resilience and reducing risks. 1 edn. Springer International Publishing, Nova York, v. 1, pp 353–367

Gallo E, Setti AFF, Magalhães DP, Machado JMH, Buss DF, Netto FAF, Buss PM (2012) Saúde e economia verde: desafios para o desenvolvimento sustentável e erradicação da pobreza. Ciência e Saúde Coletiva 17:1457–1468

Gallo E, Setti AFF (2012) Abordagem ecossistêmica e comunicativa na implantação de agendas territorializadas de desenvolvimento sustentável e promoção da saúde. Rio de Janeiro: Ciência e Saúde Coletiva, n. 17, pp 1433–1446. doi:10.1590/S1413-81232012000600008. Accessed 3 June 2015

Gallo E, Setti AFF (2014) Efetividade em desenvolvimento sustentável: o caso do Projeto Bocaina. In: Anais do GeoSaude 2014: A geografia da saúde no cruzamento de saberes, Coimbra, pp 696–699

Gorayeb A, Meireles J Cartografia social vem se consolidando como instrumento de defesa de direitos. Rede Mobilizadores, 10 fev 2014. http://www.mobilizadores.org.br/entrevistas/cartografia-social-vem-se-consolidando-com-instrumento-de-defesa-de-direitos. Accessed 27 July 2016

Grabner ML (2016) Os caiçaras e as unidades de conservação de proteção integral: convergência entre os direitos fundamentais das comunidades tradicionais e a conservação ambiental. In: Neto PS (Org) Direito das comunidades tradicionais caiçaras. São Paulo: Ed. Café com Lei, pp 65–104

International Institute for Sustainable Development (2003) Livelihoods and Climate Change. IISD, International Union for Conservation of Nature and Natural Resources and Stockholm Environment Institute

Ketele J, Roegiers X (1993) Methologie du recueil d'informations: fondements de me´thodes d'observation de questionaires, d'interviews et d'e´tude de documents, 2nd edn. De Boeck Université, Bruxelles

Lhotte C (1982) Trindade para os trindadeiros. Campinas, Departamento de Antropologia/IFCH/Unicamp. Dissertação de mestrado

Magrin G, Marengo J, Boulanger JP, Buckeridge M, Castellanos E, Poveda G, Nobre C, Scarano F, Vicuna S (2014) Central and South America. In: Barros VR et al (eds) Climate Change 2014: impacts, adaptation and vulnerability. Part B: Regional aspects, Contribution of Working Group II to the fifth assessment report of the Intergovernmental Panel on Climate Change IPCC. Cambridge University Press, Cambridge, pp 1499–1566. http://ipcc-wg2.gov/AR5/report/citations/. Accessed 26 Sep 2016. ISBN 978-1-107-68386-0

NCS. Projeto Nova Cartografia Social: apresentação (2014). Manaus, UFAM. http://novacartografiasocial.com/apresentacao/. Accessed 26 Sep 2016

OTSS (2016) Mapa das Comunidades Tradicionais. Available at https://www.google.com/maps/d/viewer?mid=16gJwBTnxNw5E5XQHVicr07bNJ7I. Accessed 26 Sep 2016

Plante S, Breton Y (2005) Espaço, pesca e turismo em Trindade. In: Diegues AC (Org) Enciclopédia Caiçara. Vol. III. O Olhar Estrangeiro. Ed. Hucitec, pp 21–74

PNSB's Consultative Council (2013) Memória da Reunião Ordinária do Conselho Consultivo do Parque Nacional da Serra da Bocaina. São José do Barreiro, SP, 29 November 2013

Ribeiro ACT et al (2006) Relatório Técnico-Científico do Projeto: Cartografia da Ação e Análise de Conjuntura: reivindicações e protestos em contextos metropolitanos (quatro volumes). Programa Cientista do Nosso Estado, Rio de Janeiro, Faperj, pp 2005–2006

Santos BS (2006) A gramática do tempo: para uma nova cultura política. Cortez, São-Paulo

Santos BS (2007) Para além do pensamento abissal: das linhas globais a uma ecologia de saberes. Novos estudos—CEBRAP, São Paulo, n. 79. http://www.scielo.br/scielo.php?pid¼S0101-33002007000300004andscript¼sci_arttext. Accessed 29 Sep 2016

Thiollent M (2006) Metodologia da pesquisa-ação. Cortez, São Paulo. ISBN: 9788524911705

Toledo VM (2001) Povos comunidades tradicionais e a biodiversidade. In: Levin S et al (eds) Encyclopedia of Biodiversity, Instituto de Ecologia, Unam

UN (2015) Transforming our world: the Agenda 2030 for sustainable development. http://nacoesunidas.org/pos2015/agenda2030/. Accessed 30 Sep 2016

Chapter 28
Scenario Planning Toward Climate Adaptation: The Uruguayan Coast

Gustavo J. Nagy and Ofelia Gutiérrez

Introduction

Climate Threats, Adaptation, Adaptation Deficit and "Thinking of Futures"

> Climate change and variability are a threat to coastal socio-environmental systems of South America and their increase would trigger the current climate adaptation deficit (Villamizar et al. 2017).

Because of the changing climate on coastal areas of South America, and Uruguay in particular (Fig. 28.1), adapting to "climate threats" along with mis-management pressures will be an ongoing challenge into the future (Box 28.1). There are clearly benefits from acting now to adapt and provide for a more resilient

G.J. Nagy (✉)
Costal and Estuarine Environmental Change (CEEC) Team. Oceanografía y Ecología Marina, Instituto de Ciencias Ambientales y Ecología, Facultad de Ciencias, Universidad de la República (UdelaR), Iguá 4225, POB 11400, Montevideo, Uruguay
e-mail: gustavo.nagy56@gmail.com; gnagy@fcien.edu.uy
URL: http://clivianet.poliagile.com/

G.J. Nagy · O. Gutiérrez
Climate Vulnerability, Impact and Adaptation Network (CliVIA-Net), Montevideo, Uruguay
e-mail: gutierrez.ofelia@gmail.com; oguti@fcien.edu.uy
URL: http://clivianet.poliagile.com/

O. Gutiérrez
Costal and Estuarine Environmental Change (CEEC) Team. UNCIEP, Instituto de Ciencias Ambientales y Ecología, Facultad de Ciencias, Universidad de la República (UdelaR), Montevideo, Uruguay

G.J. Nagy · O. Gutiérrez
Facultad Politécnica, Universidad Nacional de Asunción (PF-UNA), San Lorenzo, Paraguay

W. Leal Filho and L. Esteves de Freitas (eds.), *Climate Change Adaptation in Latin America*, Climate Change Management,
https://doi.org/10.1007/978-3-319-56946-8_28

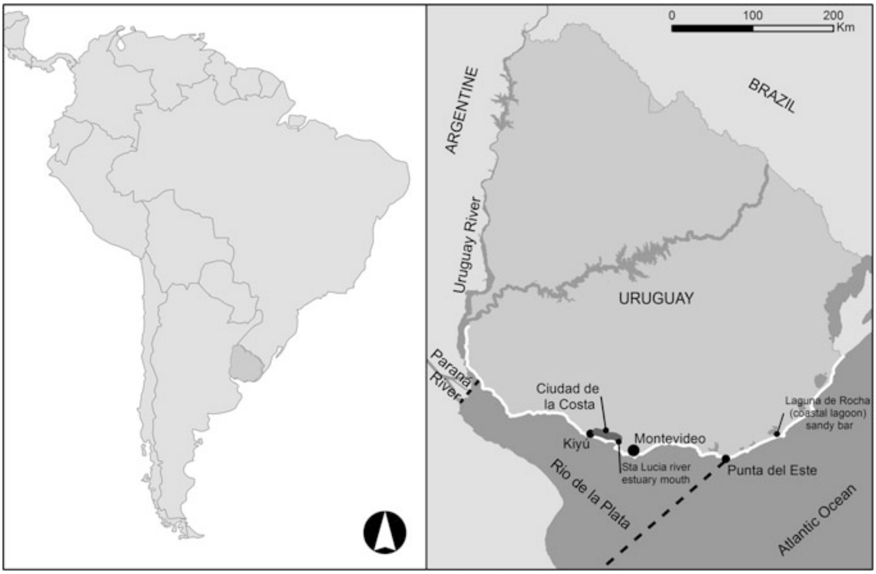


Fig. 28.1 *Left* South America. *Right* Uruguay. The *white line* indicates the Uruguayan coast corresponding to the Rio de la Plata estuary and the Atlantic Ocean. The studies sites are indicated

Box 28.1 Climate threats, adaptation, adaptation deficit, and "thinking of futures"

Climate threat Any *"climate-driven, continuous (climate change) or discrete (extreme weather or climate-related events) stressor on the environment and humans", and the ambient stressors, risk domain, and impacting processes associated with* (Reser and Swim 2011; Nagy et al. 2014b).

Climate Adaptation *"Monitoring change and undertaking deliberate and considered adjustment actions and reinforcement strategies in natural and human systems to avoid, cope, or reduce harms and losses of climate change and variability, and their effects"* (UNDP 2006; IPCC 2007; UKCIP 2014; VCCCAR 2014).

Adaptation deficit *"Many places and countries are underprepared for current climate conditions, much less for future changes"* (Burton 2004; Leary et al. 2008). *Adaptation deficit can be thought as "a persistent vulnerability, the inability to cope with current climate variability, and/or the lack of adaptive capacity to extreme events"* (Nagy et al. 2008; Preston et al. 2013; Villamizar et al. 2017).

Stakeholders' participation *Public participation encompasses a range of procedures and methods designed to consult, involve, and inform the public to allow those that would be potentially affected by a decision or policy to have input into the process. The latter are also known as Stakeholders* (IFC 2007). *The inclusion of stakeholders' perceptions of climate threats into participatory decision-making and action processes provides social legitimacy and community buy-in* (Tompkins 2005; Eisenack et al. 2007; Few et al. 2007; Nagy et al. 2014c).

Thinking of "futures" *A "What if?" learning exercise and a way to develop alternative scenarios which are tools to learn to adapt more than to foresee* (Moore et al. 2013).

community in the future (Leary et al. 2008; Britton et al. 2011; Villamizar et al. 2017).

The coastal management and climate adaptation model in Uruguay lies on participatory processes based on scientific research and capacity building of institutions and local stakeholders, so that knowledge can be integrated into the design and application of policies and collective action (Gómez-Erache et al. 2010; Nagy et al. 2014b, 2015).

The aim of this chapter is to explain the application of participatory scenario planning (PSP) for thinking of "futures"—a "what if" learning exercise and a way to adapt to climate threats (Moore et al. 2013). Planning for climate change is critical to minimize future risks to coastal communities and the coastal environment (Norman and Gurran 2016).

A hypothetical PSP case study is presented which is based on actual data and experiences from the Uruguayan coastal areas.

Scenarios and Storylines in Climate Adaptation Pathways

> Because of the extensive uncertainties that exist in the future drivers of and responses to climate change, future scenarios are necessary to explore the potential consequences of different management response options (Moss et al. 2010).

Scenarios in the area of climate and global change assessment are dominated by exploratory, top-down scenarios in forecasting mode. However, the research community is making a serious effort to develop participatory scenarios that cross the boundaries between knowledge and action and are salient, credible and legitimate (Cash et al. 2003). Scenarios (Box 28.2) are used widely in vulnerability and risk assessment exercises to inform impact models from which scientists, managers and/or resource-users identify adaptation strategies to minimize risk (Wilby and Dessai 2010). Therefore, scenarios do not give answers but a vision of consistent, logic and plausible futures. According to Chinvanno (2011) more than to choice a scenario it is important to think about the consequences of each one for each sector or system. What are the thresholds? Who are at risk? How can we manage the threats and potential impacts?

Box 28.2 Scenarios and storylines in climate adaptation. What if statements?

Scenarios are "A plausible and internally consistent story in which a description about the path (of possible events) from the present to a future horizon is made (storyline)" (IPCC 2007). "Plausible futures that allow to envision and evaluate the outcomes of potential decisions in the context of different sets of background conditions" (Dessai and van de Sluijs 2007). "Some uncertainties cannot be adequately depicted in terms of probabilities, but can be specified in terms of (a range of) "possible outcomes" often constructed in terms of "what-if" statements" (Dessai and van de Sluijs 2007; Nagy et al. 2014c).

Normative science-driven “Top-down” approaches

> A common misconception about climate scenario stated by is that for the fact that we can see precise result of simulation, it does not mean that it is accurate nor represents truth of the future. Furthermore, climate risk in the future may not be as it was any more; thus, the way to cope with risk as it is today may not be a viable option in the future Chinvanno (2011).

The Intergovernmental Panel on Climate Change (IPCC) works on climate scenarios and storylines (IPCC 2013; van Vuuren and Carter 2014). The IPCC Global Climate Representative Concentration Pathways (RCPs) describe four climate futures, all of which are considered possible depending on how much greenhouse gases are emitted in the years to come (Wyant et al. 2009). They relate global warming with atmospheric greenhouse gas concentration trajectories named RCP2.6, RCP4.5, RCP6, and RCP8.5 (Moss et al. 2010) used for climate modeling and research.

Scenario Planning (SP): methodological approach

> Strategic planning does not deal with future decisions but with the futurity of present decisions. The only relevant discussions about the future are where we succeed in shifting the question from whether something will happen to what we would do if it did happen (Drucker 1974).

Scenario Planning (SP) is a strategic planning method to make flexible long-term plans also called scenario analysis (Schoemaker 1995; National Park Service 2013); when stakeholders participate it becomes a participatory approach (PSP). Thinking of alternative futures through PSP is a “systematic way of bracketing uncertainty which supports the interaction of diverse stakeholders to develop a shared understanding of risks, trade-offs, and possible management actions” (Cobb and Thompson 2012; Moore et al. 2013).

The use of “what if” or “what future do you envision” in PSP increases awareness, buy-into the scenarios through considering scientific and local knowledge, communication and understanding of uncertainties and risks, and the adjustment of expectations to the institutional needs and implementation possibilities about adaptation options and needs (Chinvanno 2011; Evans et al. 2013; Noble et al. 2014; Nagy et al. 2014c). The approach to scenario planning can vary according to the coastal risk being assessed (storms, sea level rise) (Norman and Gurran 2016).

PSP mixes top-down and bottom-up approaches to build “alternative futures”. The former includes current climate and socio-economic baselines, time-series, prescriptive climate models, and RCPs (IPCC 2013) for future time-horizons (e.g. 2030–50) through the interaction between experts and stakeholders. In the latter experts and stakeholders assess acceptability, barriers, the plausible direction, magnitude and rate of change, impacts, thresholds, the interaction of climatic and non-climatic drivers, and options to planning adaptation futures. The participatory approach methodology usually includes semi-structured and in depth interviews, workshops and group discussions (Nagy et al. 2014b, 2016). The approach followed in PSP is the development of alternative contrasted scenarios or “futures” with two posed climatic trends which must be plausible and logic (Cobb and Thompson 2012; Moore et al. 2013).

Participatory Scenario Planning in climate adaptation

> Climate change adaptation requires us to continue to learn from the past, but be ‘forward looking’, anticipate plausible but unprecedented conditions, and expect surprises. In this context, we must revisit our management goals and ‘desired conditions,’ since frequently these describe our expectations based on historic conditions. To that end, scenario work explores and describes characteristics of several plausible futures, enabling managers to consider how to define and meet their goals (desired conditions) under changing, and new circumstances (National Park Service 2013).

The breaking dilemma of climate change adaptation planning is: What can we do if we do not know for sure what will happen? Scenario planning is an approach to develop the test conditions for plausible futures. The use of “what if?” implies a change of mindset from: What will happen to us? to “What will we do if this or that will happen?” (Chinvanno 2011) which simplifies the complexity by focusing on the key variables and links adaptation to risk-management (Moore et al. 2013; Nagy et al. 2013, 2014c). Therefore, climate adaptation evolves from an impact-based approach to a risk-based assessment (Chinvanno 2011) which implies main-streaming adaptation into (future) development taking into account climate and socioeconomic changes (Villamizar et al. 2017).

Development of a Participatory Scenario Planning

A key question before using scenario planning is: When/why/for what to use scenario planning? When critical drivers can’t be controlled (Peterson et al. 2003; Moore et al. 2013), which is the case regarding climate threats (Fig. 28.2).

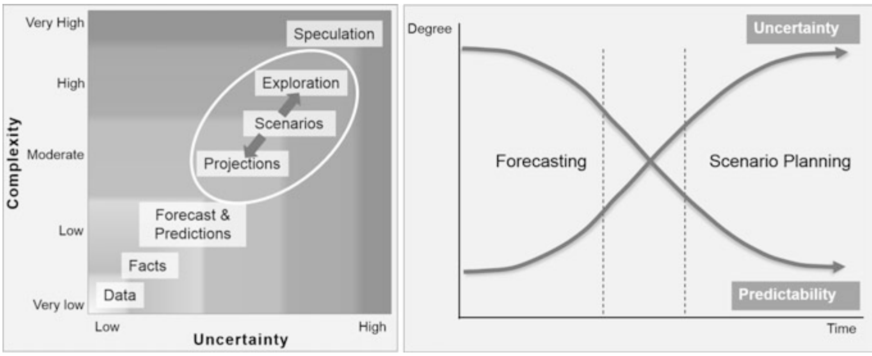


Fig. 28.2 Relationships uncertainty versus complexity (*left*), and predictability versus uncertainty (*right*). Modified from Harbottle (2013)

Scenario Planning Steps

The planning of participatory scenarios consists of four main phases usually developed through group discussion and brainstorming as follows (Fig. 28.3 and Box 28.3) (Harbottle 2013):

1. Problem analysis: Identification of issues, factors, driving forces and stakeholders.
2. Analysis of drivers: Identification of critical uncertainties (Scenario logics where the axe dimensions are based on uncertainties).

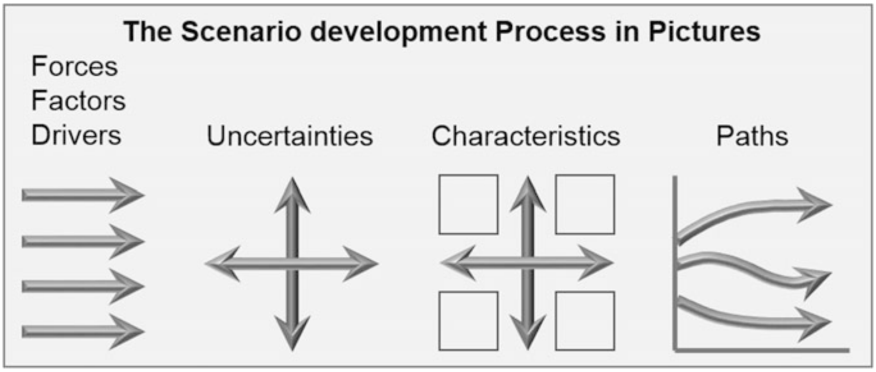


Fig. 28.3 The scenario development process and symbols. Modified from Harbottle (2013)

Box 28.3 Scenario planning steps from Schoemaker (1995), van der Heijden (1996), National Park Service (2013), and Meinert 2014)

Step 1 *Decide drivers for change/assumptions* Definition of the assumptions on which the scenarios will be based (e.g., purpose, strategic challenge, and desired outcomes), and the most important "drivers of/for change"). To identify and analyze the critical forces, variables, trends and uncertainties that may affect the strategic challenge and the focal question. Emphasis is given to those varying with time and less predictable "uncertainty".
Step 2 *Bring drivers together into a viable framework* Linking of the drivers into large groups "mini-scenarios".
Step 3 *Produce a small number of scenarios from the critical forces and impact identified* Placement of the factors and the connection between them in these groups. Definition of what each group of factors represents.
Step 4 *Reduce to two or three scenarios* Reduction to two or three larger scenarios into which all the topics can be sensibly fitted. What do these scenarios mean? What do they mean to the focal question and strategic challenge? What do we do about it?
Step 5 *Draft the scenarios* The scenarios are then 'written up' in the most suitable form for use by the managers who are going to base their strategy on them.
Step 6 *Identify issues arising* Critical outcomes of scenarios and the strategy to minimize risk are evaluated. To identify important indicators that can signal changes in the environment as the future unfolds.

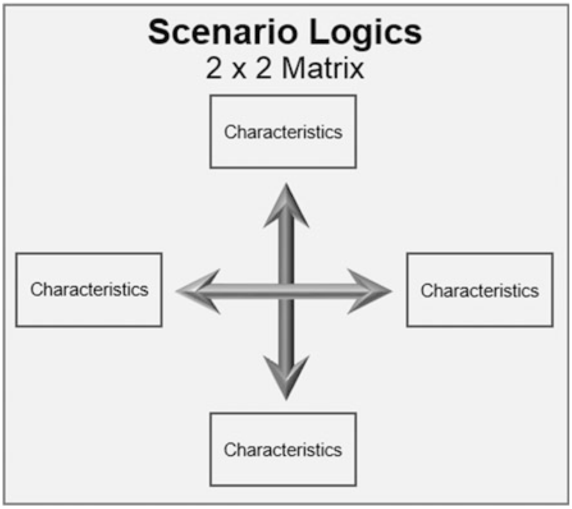


Fig. 28.4 Scenario logics "2 × 2 matrix framework" where uncertainties (driving forces) and characteristics are plotted and described. Modified from Harbottle (2013)

3. Development of plausible (credible, accepted and logic) scenarios: Characteristics and storylines.
4. Development of strategies and plans: Discussion of implications and paths.

Scenarios and systems thinking are organized on the basis of structures, patterns and events (Harbottle 2013). Systems are usually analyzed from events to structure (observations → trends → causal relationships), whereas scenarios are analyzed inversely, from structure to events (scenario logic → characteristics and storylines → story). Scenario logics can be thought as the organizing principle of the key drivers of change (Fig. 28.4).

Experts inform stakeholders about the direction and magnitude of change, whereas the thresholds, management implications, the desired situation, and time horizons are defined through discussions with stakeholders. The use of trends and of comparisons instead of a wide numerical range numbers allows reducing stakeholders' perception of uncertainty (Seijo et al. 2013; Nagy et al. 2014b) as follows:

- Similar to current: =
- Increase/decrease within typical observed variability: ±
- Increase beyond observed typical variability: ++/−−

Case Study: Scenario Planning of Coastal SES in Uruguay

Background

A case study of stakeholders' perception of climate threats and impacts, citizen participation, and scenario planning in climate adaptation in coastal areas of Uruguay (Fig. 28.1) is presented which is based on:

1. Several recent articles, book chapters and reports (Table 28.1).
2. An invited presentation made at the Brown International Advanced Research Institutes (BIARI) Climate 2016 (http://www.watson.brown.edu/biari/).

All these experiences share similar approaches aimed at analyzing current and projected trends, stakeholders' expectations and climate scenarios for 2030–2050.

Table 28.1 Experiences in coastal areas of Uruguay referred to in this article

Article	Key-words	Reference
El papel de los grupos de interés en los procesos de adaptación a las amenazas climáticas en áreas costeras del Uruguay: El caso de la Laguna de Rocha	Climate threats. Climate adaptation. Participation. VRA. Risk management	Seijo et al. (2013)
Enfoque, Conocimiento y Medidas Para enfrentar las Amenazas del clima Presente en la Zona frontal del Río de la Plata, Uruguay	Climate threats	Nagy et al. (2013)
Adjusting to current climate threats and planning adaptation: the case of the Uruguayan Coastal Zone within the Rio de la Plata river estuary	Climate threats, trends and scenarios. "What if". Scenario Planning	Nagy et al. (2014b)
Integrating Climate Science, Monitoring, and Management in the Rio de la Plata Estuarine Front (Uruguay)	Climate adaptation. Participation. VRA. Scenario Planning	Nagy et al. (2014a)
Stakeholders' climate perception and adaptation in coastal Uruguay	Climate threats. Climate adaptation. Participation. VRA. Risk management. Climate scenarios. Socioeconomic baselines	Nagy et al. (2014c)
A risk based and participatory approach to assessing climate vulnerability and improving governance in coastal Uruguay	Climate adaptation. Climate scenarios. VRA. Risk management	Nagy et al. (2015)
Addressing climate extremes in Coastal Management": The case of the Uruguayan coast of the Rio de la Plata System from 1983–2013	Climate threats. Climate adaptation	Verocai et al. (2015)
Sea-level trends along freshwater and seawater mixing in the Uruguayan Rio de la Plata estuary and Atlantic Ocean coast	Climate threats. SLR	Verocai et al. (2016)
Climate teleconnections and indicators of coastal systems response	Climate threats. ENSO. SLR. Beach erosion	Gutiérrez et al. (2016)
A successful integrated coastal management experience through socio-institutional capacity building and ecosystem-based adaptation	Climate threats. SLR. VRA. Beach erosion Participation. Climate adaptation. Social and institutional strengthening	Carro et al. (2016)

Vulnerability Reduction Assessment (VRA)

Experts, managers and stakeholders participated in vulnerability perception assessments (VRA, Crane Droesch et al. 2008) of threats, impacts, vulnerability and uncertainties focused on the development of adaptation actions and scenario planning (Box 28.4). The panel of experts was integrated by natural and social scientists. Typical questions regarding climate threats were: “Which climate threats do you perceive”? “Are you worried by them? “What future do you envision: similar or worse?” “What if perceived threats and impacts increase?

Data and experiences from Table 28.1 and global RCP outcomes (Table 28.2) were used to assess the perception of managers and stakeholders about expected future changes in relation to baselines. Participants ranked climate threats, uncertainty and impacts based on past and current changes compared with the expected future from RCP outcomes through a 5-scale Likert scale (1: very low; 3: moderate; 5: very high), and ranked each perceived climate threat and impact.

Box 28.4 Vulnerability reduction assessment (VRA)

The vulnerability reduction assessment (VRA, Crane Droesch et al. 2008) forms a cornerstone of the UNDP-GEF Community Based Adaptation (CBA) programme’s monitoring and evaluation activities. It is designed to measure community-level adaptive capacity to climate change and variability. VRA measures the change in the adaptive capacity of a community participating in a CBA project. It is a relative measure, and is designed to measure change against a pre-project baseline. The key quantitative output of the VRA is the relative change from the baseline score (before-after implementing measures and developing scenarios). Participatory VRA were conducted following GEF criteria (as modified by Seijo et al. 2013; Nagy et al. 2014b) at several coastal sites in Uruguay from 2010–14 to assess decision-makers and stakeholders’ vulnerability and risk perception, as well as barriers and opportunities to implement adaptation. The VRAs consisted of four stages (Nagy et al. 2015) as follows.
1. Several meetings, semi structured and in depth interviews with different groups of stakeholders, managers and NGO members were held.
2. Focus group discussions and brainstorming were conducted. A multiple question matrix was filled with qualitative comments and a numerical assessment measured through corresponding open-ended, perception-based questions, which in turn aggregate to serve as indicators of adaptive capacity. A Likert 1–5 scale was used where 1 is low vulnerability/capacity, or high barrier, and 5 is high vulnerability/capacity, or low barrier perception of climate threats, obstacles, and supportive factors to implementing adaptation.
3. A dialogue between participants and experts was held in order to achieve a collective agreed value for each question and oral comments.

Table 28.2 Temperature (°C) and SLR (m) projections for the Uruguayan coast. Based on IPCC AR-5 RCP 4.5 and 8.5 mid-term projections (IPCC 2013)

2046–2065			
Scenario	Global temperature mean and likely range projections (°C)	Global mean sea level rise and likely range projections (m)	
RCP4.5	1.4 (0.9–2.0)	RCP4.5	0.26 (0.19–0.33)
RCP8.5	2.0 (1.4–2.6)	RCP8.5	0.30 (0.22–0.38)

The erosion and loss of sandy beaches, dunes, bars and cliffs was perceived as a climate threat and/or impact by most participants who mixed sea level rise (SLR), wind-induced flooding, beach erosion and mismanagement issues. The results of VRAs were expressed as the average (e.g., 3.1) or as the two topmost discrete Likert-scale values (e.g., 3, 4). Because warming and SLR trends along the Uruguayan coast were 0.8–1.0 °C and 0.1–0.2 m respectively (Nagy et al. 2007; Verocai et al. 2016), most participants of workshops (≈90%) did not perceive them as a risk or impact but as a threat (Nagy et al. 2014b). Therefore, a warming of 0.5 °C or a SLR of 0.1 m is perceived as a baseline ranked as very low (1), the actual warming of $\leq$ 1.0 °C and a SLR $\leq$ 0.2 m as low (2), whereas +1.5–2 °C and 0.3–0.4 m are ranked as moderate (3) and high (4) respectively. Storm surges (an increase in coastal water level caused by the action of wind blowing over the sea surface) were placed as the main threat or driver of change by most participants (>90%); SLR > 0.3 m, extreme rainfall, and southern wind changes (SE or SW), were placed as the second, third and fourth (>70, 60 and 50% respectively) (Nagy et al. 2014b), whereas SLR < 0.2 m was considered as low impact and/or a low uncertainty threat. Beach erosion or loss, river/sea flooding, and damages to infrastructure were placed as the main three impacts.

According to Verocai et al. (2015) the most common impacts due to storm surges in Uruguay are damages to the population (i.e., evacuated, temporal loss of electricity), real estate, infrastructure, sandy beaches and dunes erosion.

Scenario Planning of Adaptation of Coastal Areas

The steps followed in the case study of coastal areas of Uruguay (Table 28.3) are based on the processes presented in Boxes 28.1–28.5 and other sources (e.g. Kleiner 1999; Meinert 2014).

Table 28.4 summarizes the climate variables "Drivers Matrix" of the coastal areas of Uruguay based on observed trends, and RCP 4.5 and 8.5 scenarios.

These data (or similar ones) were communicated by experts to managers and stakeholders. The scenario logics organize the climatic drivers of change, threats and impacts, and human drivers (e.g., coastal management, gross domestic product-GDP, and population density). The former were assumed as being not controllable and uncertain, whereas the latter were perceived as being uncertain and

Table 28.3 Steps to develop scenario planning. Modified from Kleiner (1999), Polczinki (2009), and Meinert (2014)

Approach: expert judgment, group discussion and brainstorming of data, current situation, plausible trajectories and desired situations	
Step	Main questions
1. Definition of the focal issue and key question	What problem are you trying to solve? How quickly changes have happened in the past? Are there common trends?
2. Definition of key factors	Climate; development; economy; land use; management; weather
3. Information gathering, identification and listing: of key factors, trends, people at risk, and stakeholders	What information is relevant to the topic? Who will be affected? Who are the stakeholders? Which are the relevant climate and non-climate trends and driving forces at the/for the studied site/sector-system?
4. Identification and ranking of critical uncertainties	How certain are the driving forces? How predictable are the driving forces? Which are the topmost uncertainties?
5. Definition of scenario logics	Which axes better contain the topmost and uncertain driving forces? In what way will the key drivers of change develop and change the management actions?
6. Creation of scenarios (and writing of narrative stories)	Are the trends compatible within the time horizon? Are the forces and their uncertainties appropriate to construct plausible scenarios? Are stakeholders' expectations included in the desired state? Is it possible to reduce the vision of the future to a few scenarios? Which are the reasons to define the proposed situations? Are they relevant for the goal?
7. Implications and assessment of scenarios	Are the most relevant issues contemplated? Which are pros and cons of the alternative scenarios?
8. Identification and listing of key indicators	Are enough quantitative relationships and indicators available to describe and understand the consequences of each scenario?
Post development	
9. Monitoring of key indicators	Are the changes in driving forces and the impacts captured by the indicators? Are more data needed?
10. Updating scenarios	Are scenarios flexible enough to accept modifications as needed in adaptive co-management?

somewhat controllable. The scenarios are chosen according to their perceived uncertainty, observed impact and potential threat. The uncertainties are perceived as a continuum of possibilities ranging between two extremes (e.g., two values for SLR, and historical or significant increase for storm surges) (Scearce et al. 2004).

Table 28.4 Climate variables "Drivers' Matrix" of the coastal areas of Uruguay based on observed trends and RCP 4.5 and 8.5 scenarios. *Sources* Nagy et al. (2016) and Verocai et al. (2016)

Climate variable	General change expected	Specified change expected and reference period	Size of expected change compared to recent changes	Confidence
Temperature	Increase	2030 +2 °C ±1	Large	Very likely
		2050 +3 °C ±2		
Precipitation and runoff	Increase	2030 +1–3% ±2 2050 +2–5% ±3	Weak (regarding 1971–2002)	Likely
	Increase	+0–10% ±5	Very weak	Uncertain
Wind speed and storm surges	Increase	Increase in frequency and intensity of eastern (E) and southeastern (SE) winds	Any increases exacerbated by sea level rise	Increased in frequency and intensity. Observed and modeled. Uncertain/likely
Sea level	Increase	Increase in frequency and intensity of southeastern (SE) winds	Moderate to large	Likely to very likely

Table 28.5 Combined matrix of climate and human variables (drivers). The two topmost common Likert-scale (1–5) experts and stakeholders' perceptions of uncertainties, threats and impacts are shown. (i.e., very high and high: 5, 4)

Variable	Uncertainty	Observed impact	Potential threat
Biophysical/climate	Two topmost choices		
River flow change (increase/decrease in river inflow to the Rio de la Plata estuary)	5, 4	2, 1	2, 3
Sea level rise (m)	4, 5	2, 1	4, 5
Wind regime change (increase/decrease in SE and SW winds)	4, 3	2, 3	3, 2
Storminess (frequency and/or magnitude of extreme winds and storm surges)	4, 3	4, 5	5, 4
Extreme rainfall change (increase/decrease in extreme rainfall events)	4, 3	2, 3	4, 3
Warming (°C)	3, 4	1, 2	3, 4
Social	Two topmost choices		
Management policy	5, 3	4, 3	4, 5
Management actions	4, 5	4, 5	5, 4
Population density	2, 3	4, 3	3, 2

The 2 × 2 scenario logics matrix was built by choosing the three topmost critical uncertainties and threats. To explore local human drivers the climate variables matrix was combined with a human drivers (management) matrix created by the experts (Table 28.5).

Box 28.5 Meaning of each alternative and example of a brief narrative

• *"Storminess": Very strong winds + storm surge, flooding and beach/dune/cliff erosion* • *"SLR": Permanent water/sea level increase + inundation and beach loss.* • *"Wind change SE": More SE and less SW winds (+/-), temporary flooding and beach recovery (Spring-Summer/El Niño) pattern.* • *"Human (mis)management": "Wind change SW": More SW and less SE winds (+/), temporary flooding and beach erosion (Late winter/La Niña) pattern.* • *Coastal Management/Climate Adaptation Policy and Actions: Historical or significant increase in the application of good policy practices (e.g., integrated community, sub-national and national law enforcement, policy and monitoring). Ineffective hard structures; lack of eco-soft works to retain sand (e.g., dune revegetation, sand captor fences).*
Example of a brief narrative: Storminess (+/−) and wind change (SE) (+/−)
"Many managers and stakeholders perceive an increase in extreme southern wind induced storm surges and flooding, often associated with sand loss and coastal erosion. Most perceive this as one of the three topmost threats to coastal ecosystems, populations and infrastructure. Experts report an observed increased trend in the frequency of southeastern winds and their likely further increase in the mid-future as suggested by climate models. These winds —if are not extreme ones—, favors the recovery of sand, as usually occurs during spring and summer when SE winds prevail, as well as during El Niño years. Therefore, the desired situation of beach conservation will very likely depend under a scenario without further management actions (named historical), on the balance of erosive storms surges events and recovering SE winds and El Niño events".

The vision of the future was represented by 4 climate scenarios and 1 management scenario which include the combination of the three topmost perceived uncertainties, threats and impacts. For instance GDP and population density were not retained due to their low relative impact the former, and to low relative uncertainty the latter. The opposed alternative futures (Box 28.5) expressed in x-y dimensions are as follows:

Climate drivers' matrix (4 scenarios)

1. Storminess (±) and SLR (±)
2. Storminess (±) and wind change (SE) (±)
2. SLR (±) and Storminess (±)
4. Storminess (±) and wind change (SW) (±)

Management drivers' matrix

5a, b. Human (mis)management (policy and interventions) of coastal areas (±).

A climate 2 × 2 scenario logics matrix is shown in Fig. 28.4, whereas Table 28.6 summarizes the development of the hypothetical case study of the coastal areas of Uruguay.

The use of climate trends and models is accepted by most stakeholders and managers because they perceive the former as a good descriptor of the recent past, present and of the plausible near-term future pathways. Regarding models, they are understood as a useful planning tool for the mid-term future if the outputs are a continuity—more or less accelerated—of current trends.

Table 28.6 Summary of the development of scenario planning for coastal areas of Uruguay

Scenario development steps	Main threat/impact perceived by participants	Desired outcomes and state
1. Focal issue and question	How to prepare to and how to reduce the impacts (e.g. beach erosion/loss) due to increased storm surges + SLR and flooding?	Increased coastal resilience for 2020–2040
2. Identification of key factors	Climate threats and management	Reduced human (mis) management-related impacts
3. Identification of drivers, trends and stakeholders	Wind storm-surges, extreme rainfall, SLR. ENSO-related variability. Community neighbors, local, sub-national and national-level managers.	1. Increased forecasting, early warning and modeling capacities 2. Increased participation
4. Identification and ranking of critical uncertainties	1. Will the frequency and/or magnitude of storm surges increase? 2. Will SLR be greater than the observed one (≥ 0.2 m)? 3. Will the most exposed beaches disappear by 2040?	Better assessment and management of vulnerable areas
5. Scenario logics	Main axes: More-Less wind storm-surges More-Less 0.2 m SLR	1. Science-based early forecasting and early warning 2. Participatory management including soft measures 3. Relative less erosion and loss of sandy beaches, dunes and cliffs due to flooding and inundation
6. Creation of scenarios	Is it possible to reduce the vision of the future to a few scenarios? The trends, projections, forces, uncertainties, and stakeholders' expectations are reflected in the plausible desired state?	
7. Implications and assessment of scenarios	Which are the consequences of each scenario on coastal ecosystems, roads and infrastructure, ecosystem services, and human population?	
8. Development of early indicators	Which are the early indicators of threat, impact and change to be monitored?	1. Real time forecasting and early warning 2. Local watching of threats, impacts and change
Post development monitoring and evaluation, and update		

Nesting the four selected climate matrix within the management policy and actions matrix allow the participants to consider several different, but plausible climate and management environments (Fig. 28.5). Thus, stakeholders, managers and experts are able to discuss the combination of management scenarios with the selected climate scenarios and their importance to the focal question before selecting two or three scenarios (Fig. 28.6).

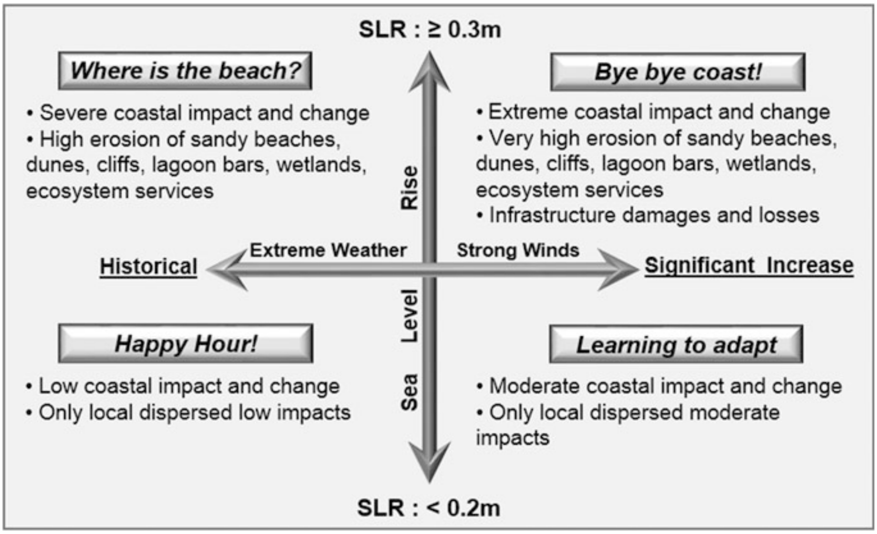
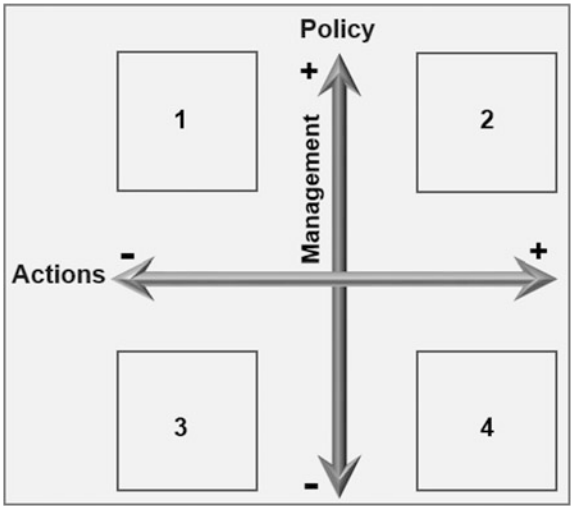


Fig. 28.5 Hypothetical scenario logic framework for storminess and sea level rise (SLR) in coastal areas of Uruguay for ≈2050 (climatic scenario 1e)

Fig. 28.6 Nested climatic (4 scenarios) and management scenarios logics



The selected scenarios must be monitored and the management options reevaluated periodically so that they evolve along with the climate, stakeholders' perceptions, and institutional needs.

Concluding Remarks

Scenario planning is used to explore plausible and logic future scenarios, particularly when the drivers of change are not controlled (or are poorly controlled) which is the case of climate threats.

These scenarios are based on: (i) normative top-down climate trends and modeling, and (ii) bottom-up perceived uncertainty, vulnerability, impacts and threats.

Scenario planning is being used in climate adaptation because of the high level of uncertainty and impacts associated with climate drivers of change. This approach is friendly to many stakeholders and managers because of their participation and the fact that "building plausible pathways" facilitates defining adaptation policies and actions under a "perceived more controllable uncertainty".

The case study is based on a hypothetical and flexible scenario built with actual data and experiences depicting coastal areas of Uruguay. This case study is used to show the application of scenario planning as a by-product of vulnerability reduction assessments.

The participation of managers and stakeholders together with natural and social science experts provides social legitimacy, "buy-into the scenarios" and the adjustment of expectations to the institutional needs. The process itself creates capacity to move forward and must be reviewed periodically through post-development monitoring and evaluation.

References

Britton R, Dahm J, Rouse H, Hume T, Bell R, Blackett P (2011) Coastal adaptation to climate change: pathways to change. A report prepared as part of the coastal adaptation to climate change project. NIWA, FRST funded Coastal Adaptation to Climate Change project (C01X0802), New Zealand. https://www.niwa.co.nz/sites/niwa.co.nz/files/pathways_to_change_nov2011.pdf. Accessed 4 June 2016

Burton I (2004) Climate change and the adaptation deficit. Occasional paper 3. In: Fenech A, Bing Rong R, MacIver D, Auld H (eds) Climate change: building the adaptive capacity. International conference on adaptation science, management and policy options. Meteorological Service of Canada, Downsview, Ontario, pp 25–33. http://projects.upei.ca/climate/files/2012/10/Book-5_Paper-3.pdf. Accessed 4 June 2016

Carro I, Seijo L, Lagos X, Gutiérrez O, Nagy GJ (2016) A successful integrated coastal management experience through socioinstitutional capacity building and ecosystem-based adaptation. Working Paper, Version 1. Coastal and Estuarine Environmental Change Group, IECA, Facultad de Ciencias, Universidad de la República, Montevideo. doi:10.13140/RG.2.2.11231.66727

Cash DW, Clark WC, Alcock F, Dickson NM, Eckley N, Guston DH, Jäger J, Mitchell RB (2003) Knowledge systems for sustainable development. Proc Natl Acad Sci USA (PNAS) 100:8086–8091. doi:10.1073/pnas.1231332100

Chinvanno S (2011) Mainstreaming climate change into community development strategy: a critical opinion on climate change adaptation planning and case study in Thailand, Bangkok. http://www.thailandadaptation.net/pdf/pdf3/14.pdf. Accessed 1 June 2016

Cobb AN, Thompson JL (2012) Climate change scenario planning: a model for the integration of science and management in environmental decision-making. Environ Model Softw 38:296–305. doi:10.1016/j.envsoft.2012.06.012

Crane Droesch A, Gaseb N, Kurukulasuriya P, Mershon A, Moussa KM, Rankine D, Santos A (2008) A guide to the vulnerability reduction assessment. Community-based adaptation programme, United Nations Development Programme (UNDP), New York (UNDP Working Paper). http://www.seachangecop.org/files/documents/2008_12_CBA_Vulnerability_Reducation_Assessment_Guide.pdf. Accessed 11 July 2016

Dessai S, van de Sluijs J (2007) Uncertainty and climate change adaptation—a scoping study. Utrecht. http://www.nusap.net/downloads/reports/ucca_scoping_study.pdf. Accessed 23 June 2016

Drucker PF (1974) Management: tasks, responsibilities, practices, revised. Harper & Row, New York. http://www.icmbpl.com/Management-Tasks,Responsibilities,PracticesbyPeterDruckerebook.pdf. Accessed 28 June 2016

Eisenack K, Tekken V, Kropp JP (2007) Stakeholder perceptions of climate change in the Baltic Sea Region. Coastline reports (8). In: Schernewski G, Glaeser B, Scheibe R, Sekścińska A, Thamm R (eds) Coastal development: the Oder estuary and beyond. EUCC—the Coastal Union, Warnemuende, pp 245–255. http://databases.eucc-d.de/files/documents/00000816_Eisenack_Tekken_Kropp.pdf. Accessed 10 June 2016

Evans LS, Hicks CC, Fidelman P, Tobin RC, Perry AL (2013) Future scenarios as a research tool: Investigating climate change impacts, adaptation options and outcomes for the Great Barrier Reef, Australia. Hum Ecol 41:841–857. doi:10.1007/s10745-013-9601-0

Few R, Brown K, Tompkins EL (2007) Public participation and climate change adaptation: avoiding the illusion of inclusion. Clim Policy 7:46–59. doi:10.1080/14693062.2007.9685637

Gómez-Erache M, Conde D, Villarmarzo R (eds) (2010) Sustainability of integrated management in the coastal zone of Uruguay: connecting knowledge to action. EcoPlata Program/IDRC, Montevideo. http://www.ecoplata.org/wp-content/files_mf/2010ecoplata_thesustainabilityofimczingles.pdf. Accessed 2 June 2016

Gutiérrez O, Panario D, Nagy GJ, Bidegain M, Montes C (2016) Climate teleconnections and indicators of coastal systems response. Ocean Coast Manag 122:64–76. doi:10.1016/j.ocecoaman.2016.01.009

Harbottle T (2013) Effective planning and risk management in an uncertain business environment. Risk management and scenario planning. In: University of Lethbridge. http://classes.uleth.ca/200603/mgt4451y/U%20of%20L%20Mgt%204451%20Risk%20and%20ScenariosPresentation.ppt. Accessed 18 June 2016

IFC (2007) Stakeholder engagement: a good practice handbook for companies doing business in emerging markets. International Finance Corporation, World Bank Group, Washington, DC. http://www.ifc.org/wps/wcm/connect/938f1a0048855805beacfe6a6515bb18/Ifc_StakeholderEngagement.pdf?MOD=AJPERES. Accessed 2 June 2016

IPCC (2007) Climate change 2007: impacts, adaptation and vulnerability. Contribution of working group II to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge. https://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4_wg2_full_report.pdf. Accessed 20 June 2016

IPCC (2013) Summary for policymakers. In: Climate change 2013: the physical science basis. Contribution of working group I to the fifth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge. http://www.ipcc.ch/report/ar5/wg1/. Accessed 4 June 2016

Kleiner A (1999) Doing scenarios. In: Whole earth catalog. Access to tools and ideas. http://wholeearth.com/issue/2096/article/74/doing.scenarios. Accessed 25 June 2016

Leary N, Adejuwon J, Barros V, Batimaa P, Biagini B, Burton I, Chinvanno S, Cruz R, Dabi D, Comarmond A de, Dougherty B, Dube P, Githeko A, Hadid AA, Hellmuth M, Kangalawe R, Kulkarni J, Kumar M, Lasco R, Mataki M, Medany M, Mohsen M, Nagy GJ, Njie M, Nkomo J, Nyong A, Osman-Elasha B, Sanjak E-A, Seiler R, Taylor M, Travasso M, von Maltitz G, Wandiga S, Wehbe M (2008) A stitch in time: general lessons from specific cases. In: Leary N, Conde C, Kulkarni J, Nyong A, Pulhin J (eds) Climate change and adaptation. Earthscan, London, pp 1–27. http://sei-us.org/publications/id/96. Accessed 2 June 2016

Meinert S (2014) Field manual-Scenario building. European Trade Union Institute (ETUI), Brussels. http://www.etui.org/Publications2/Guides/Field-manual-Scenario-building. Accessed 2 June 2016

Moore SS, Seavy NE, Gerhart M (2013) Scenario planning for climate change adaptation. A guidance for resource managers. Point Blue Conservation Science and the California Coastal Conservancy, Oakland. http://www.prbo.org/refs/files/12263_Moore2013.pdf. Accessed 2 June 2016

Moss RH, Edmonds JA, Hibbard KA, Manning MR, Rose SK, van Vuuren DP, Carter TR, Emori S, Kainuma M, Kram T, Meehl GA, Mitchell JFB, Nakicenovic N, Riahi K, Smith SJ, Stouffer RJ, Thomson AM, Weyant JP, Wilbanks TJ (2010) The next generation of scenarios for climate change research and assessment. Nature 463:747–756. doi:10.1038/nature08823

Nagy GJ, Bidegain M, Caffera RM, Norbis W, Ponce A, Pshennikov VA, Severov DN (2008) Fishing strategies for managing climate variability and change in the estuarine front of the Río de la Plata. In: Leary N, Adejuwon J, Barros V, Burton I, Kulkarni J, Lasco R (eds) Climate change and adaptation. Earthscan, London, pp 353–370

Nagy GJ, Bidegain M, de los Santos B, Verocai JE (2016) Climate and sea level baselines for the coastal areas of Uruguay from 1979–2014. Technical report. December 2015. Montevideo. http://dx.doi.org/10.13140/RG.2.1.3632.9040. Accessed 2 June 2016

Nagy GJ, Gómez-Erache M, Fernández V (2007) El aumento del nivel del mar en la costa uruguaya del Río de la Plata. Tendencias, vulnerabilidades y medidas para la adaptación. Medio Ambiente y Urbanización (ISSN 0326-7857) 67:77–93. http://www.ingentaconnect.com/content/iieal/meda/2007/00000067/00000001/art00006. Accessed 2 June 2016

Nagy GJ, Gómez-Erache M, Kay R (2015) A risk-based and participatory approach to assessing climate vulnerability and improving governance in coastal Uruguay. In: Glavovic B, Kelly M, Kay R, Travers A (eds) Climate Change and the Coast Building Resilient Communities. CRC Press, Boca Raton, Florida, pp 357–378. doi:10.1201/b18053-23

Nagy GJ, Muñoz N, Verocai JE, Bidegain M, de los Santos B, Seijo L, García JM, Feola G, Brena B, Risso J (2014a) Integrating climate science, monitoring, and management in the Rio de la Plata estuarine front (Uruguay). In: Filho WL, Alves F, Caeiro S, Azeiteiro UM (eds) International perspectives on climate change: Latin America and beyond, pp 79–91. Springer International Publishing, Cham. doi:10.1007/978-3-319-04489-7_6

Nagy GJ, Muñoz N, Verocai JE, Bidegain M, Seijo L (2014b) Adjusting to current climate threats and building alternative future scenarios for the Rio de la Plata coast and estuarine front, Uruguay. J Integr Coast Zone Manag 14:553–568. doi:10.5894/rgci472

Nagy GJ, Seijo L, Verocai JE, Bidegain M (2014c) Stakeholders' climate perception and adaptation in coastal Uruguay. Int J Clim Change Strateg Manag 6:63–84. doi:10.1108/IJCCSM-03-2013-0035

Nagy GJ, Seijo L, Verocai JE, Brugnoli E, Bidegain M (2013) Enfoque, conocimiento y medidas para enfrentar las amenazas del clima presente en la zona frontal del Río de la Plata, Uruguay. Costas: Revista Iberoamericana de Manejo Costero Integrado (ISSN 2304-0963) 2:67–87. http://unesdoc.unesco.org/images/0022/002270/227017m.pdf#227739. Accessed 25 July 2016

National Park Service (2013) Using scenarios to explore climate change: a handbook for practitioners. National Park Service Climate Change Response Program, Fort Collins, Colorado. https://www.nps.gov/subjects/climatechange/upload/CCScenariosHandbookJuly2013.pdf. Accessed 6 July 2016

Noble IR, Huq S, Anokhin YA, Carmin J, Goudou D, Lansigan FP, Osman-Elasha B, Villamizar A (2014) Adaptation needs and options. In: Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR, White LL (eds) Climate change 2014: impacts, adaptation, and vulnerability. Part A: global and sectoral aspects. Contribution of working group II to the fifth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, pp 833–868. http://www.ipcc.ch/pdf/assessment-report/ar5/wg2/WGIIAR5-Chap14_FINAL.pdf. Accessed 10 July 2016

Norman B, Gurran N (2016) Adapting to long term coastal climate risk through planning approaches and instruments. Coast adapt information manual 5. National climate change adaptation research facility, Gold Coast. https://www.nccarf.edu.au/sites/default/files/tool_downloads/IM_5_planning_instruments_uploaded.pdf. Accessed 6 July 2016

Peterson GD, Cumming GS, Carpenter SR (2003) Scenario planning: a tool for conservation in an uncertain world. Conserv Biol 17:358–366. doi:10.1046/j.1523-1739.2003.01491.x

Polczinki M (2009) Scenario planning: 'Thinking the Unthinkable'. http://www.flca.net/images/ScenarioPlanning.pdf. Accessed 6 July 2016

Preston B, Dow K, Berkhout F (2013) The climate adaptation frontier. Sustainability 5:1011–1035. doi:10.3390/su5031011

Reser JP, Swim JK (2011) Adapting to and coping with the threat and impacts of climate change. Am Psychol 66:277–290. doi:10.1037/a0023412

Scearce D, Fulton K, Global Business Network community (2004) What If? The art of scenario thinking for nonprofits. Global Business Network, Emeryville, California. http://monitorinstitute.com/downloads/what-we-think/what-if/What_If.pdf. Accessed 3 June 2016

Schoemaker PJH (1995) Scenario planning: a tool for strategic thinking. Sloan management review 36:25–40. http://sloanreview.mit.edu/article/scenario-planning-a-tool-for-strategic-thinking/. Accessed 3 June 2016

Seijo L, Nagy GJ, Verocai JE, Bidegain M (2013) El papel de los grupos de interés en los procesos de adaptación a las amenazas climáticas en áreas costeras del Uruguay: El caso de la Laguna de Rocha. Costas: Revista Iberoamericana de Manejo Costero Integrado (ISSN 2304-0963) 2:97–113. http://unesdoc.unesco.org/images/0022/0. Accessed 3 June 2016

Tompkins EL (2005) Planning for climate change in small islands: insights from national hurricane preparedness in the Cayman Islands. Glob Environ Change 15:139–149. doi:10.1016/j.gloenvcha.2004.11.002

UKCIP (2014) Glossary. In: United Kingdom climate impacts programme. http://www.ukcip.org.uk/glossary/. Accessed 9 June 2016

UNDP (2006) United Nations Development Programme—Adaptation. http://www.wamis.org/agm/meetings/wocald06/S4-Muthui.pdf. Accessed 9 June 2016

van der Heijden K (1996) Scenarios: the art of strategic conversation. Wiley, Cape Town. http://www.untag-smd.ac.id/files/Perpustakaan_Digital_1/CREATIVETHINKINGScenarios, Theartofstrategicconversation.pdf. Accessed 10 July 2016

van Vuuren DP, Carter TR (2014) Climate and socio-economic scenarios for climate change research and assessment: reconciling the new with the old. Clim Change 122:415–429. doi:10.1007/s10584-013-0974-2

VCCCAR (2014) What is adaptation? In: The Victorian centre for climate change adaptation research (VCCCAR). http://www.vcccar.org.au/what-is-adaptation. Accessed 6 July 2016

Verocai JE, Gómez-Erache M, Nagy GJ, Bidegain M (2015) Addressing climate extremes in coastal management: the case of the Uruguayan coast of the Rio de la Plata System. J Integr Coast Zone Manag 15:91–107. doi:10.5894/rgci555

Verocai JE, Nagy GJ, Bidegain M (2016) Sea-level trends along freshwater and seawater mixing in the Uruguayan Rio de la Plata estuary and Atlantic Ocean coast. Int J Mar Sci 6:1–18. doi:10.5376/ijms.2016.06.0007

Villamizar A, Gutiérrez ME, Nagy GJ, Caffera RM, Leal Filho W (2017) Climate adaptation in South America with emphasis in coastal areas: the state-of-the-art and case studies from Venezuela and Uruguay. Clim Dev 9:364–382. doi:10.1080/17565529.2016.1146120

Wilby RL, Dessai S (2010) Robust adaptation to climate change. Weather 65:180–185. doi:10.1002/wea.543

Wyant MC, Bretherton CS, Blossey PN (2009) Low cloud response to a warmer climate in a superparameterized climate model. Part I: regime sorting and physical mechanisms. J Adv Model Earth Syst. doi:10.3894/JAMES.2009.1.7

Author Biographies

Gustavo J. Nagy Ph.D. in Oceanography, University of Bordeaux, France. Expert and researcher in Estuaries; Hydroclimatology/ENSO; Vulnerability, Impacts and adaptation (VIA); Climate scenarios in VIA and Risks Assessments in Coastal, Water resources and Well-Being sectors. Professor of Environmental Sciences; Oceanography; Estuaries; Climate Adaptation and Risks; Earth System Science and Global Change: Universidad de la República (Uruguay) and Universidad Nacional de Asunción (UNA), Paraguay. Member of IPCC (2003–2007); National Research System (2009–2011 and since 2016), Basic Geosciences Research Programme (since 2014). Editorial Board of J of Climate Change Strategies and Management. Reviewer of several International Journals. Coordinator of CliVIA-Network.

Ofelia Gutiérrez Ph.D. in Environmental Technology and Water Management, International University of Andalucía, Spain. Expert and researcher in Physical Geography, Geomorphology, GIS, and Cultural and Natural interactions in Coastal Areas. Assistant Professor of Environmental Sciences; Geomorphology. GIS and Landscape Ecology: Universidad de la República (Uruguay). Candidate of Uruguay National Research System (since 2016), member of Basic Geosciences Research Programme (since 2016), and CliVIA-Network (since 2016). Reviewer of several International Journals.

Chapter 29
Altos de la Estancia: An Applied Project of Risk Governance in Colombia

Duván Hernán López Meneses and Sonia Hita Cañadas

Introduction

Disaster risk governance is considered an important component of risk management and adaptation. Strong collaborative frameworks for disaster risk governance in zones threatened or impacted by risk have been identified as a priority for the effective and sustainable implementation of disaster management measures in the global agenda. They can be easily correlated and extended to the general roadmap of adaptation to climate change.[1]

Many authoritative voices argue that risk governance, at least at the local level, is not just desirable but also part of the process of guaranteeing the social conditions required to cope with the threats and challenges of a changing climate.

Fraser (2014), presented a Ph.D. research that questions the capacity of existing approaches to allow us understand the role of urban politics and governance in shaping vulnerabilities to climate-related risks (Fraser 2014, p. 22). She argues for a re-politicization of approaches to understanding urban risk and adaptation, and for transformations in policy to reflect this approach (Fraser 2014, p. 22).

[1]According with the recently approved global platform for disaster risk management one of the four global priorities highlighted is the strengthening of disaster risk governance to manage disaster risk (UNISDR 2015).

D.H. López Meneses (✉)
RECNET—Recycling Cities Network International, Av. Jiménez 4-49, Suite 219,
Bogotá 111711, Colombia
e-mail: duvanhernan@gmail.com

D.H. López Meneses · S. Hita Cañadas
UNESCO Chair on Sustainability - Universitat Politècnica de Catalunya, c/o EUTEIT /
UNESCO Chair of Sustainability, UPC, Calle Colon 1, 08222 Terrassa, Barcelona, Spain
e-mail: soniahitac@gmail.com

W. Leal Filho and L. Esteves de Freitas (eds.), *Climate Change Adaptation in Latin America*, Climate Change Management,
https://doi.org/10.1007/978-3-319-56946-8_29

In a case study, she analyzes Bogota's program of risk management and in particular the impact of public policy on four study sites, including Altos de la Estancia. She demonstrates how risk assessment and management practices create new inclusions and exclusions, how the understanding and response to risk differs from one community to another depending on the social context and how risk is impacted through the agency of people forged in socio-economic and political networks of power.

Various disciplines have addressed disaster risk in recent years. Since 1971, the General Assembly of the United Nations established a "Disaster Relief Coordination" which released the first manuals and guides that covered the basic conceptual framework an institutional framework around the issued began to be shaped (UNDRO 1979).

Many scholars agree that such conceptualization and analysis of the subject of risk assessment and disaster prevention was initially the domain of specialists in the natural sciences, with an emphasis on the knowledge about "hazards", understood as physical phenomena of natural or technological origin, which may occur at a specific site and at a given time and produce adverse effects on people, goods and/or the environment (Cardona 1993).

The study of "physical vulnerability" was a step forward, initially related specifically to the degree of exposure and the fragility or capacity of the elements exposed to the phenomena. In this way, the disaster's risk field of study extended but still very dependent on the hazard, not to the social conditions beyond physical vulnerability (Cardona 1993).

From the decade of 90s disaster management included a social discourse that promoted new theoretical, academic and institutional developments at the continental level with a global leadership (Maskrey 1993).

The introduction of the social sciences into risk management problematized the issue of disasters as a phenomenon of a social nature (Lavell 1993, p. 111), linked to development (Wijkman and Timberlake 1985, p. 31; Wilches 1993; Cardona 1993; Maskrey 1993, p. 96; Lavell 1993). A complex approach to the social factor of vulnerability was explored as a fundamental aspect, linked to the cultural aspects of the communities at the local level (Maskrey 1989; Medina and Romero 1992). Such conceptualization and management affected work in the field, especially in developing countries (Cardona 1993). From there, the need for a social conceptualization of disasters was proposed and promoted (Lavell 1993, p. 118). This conceptualization which has been formulated essentially around the theory of systems, understand disasters as crisis events in the interaction between the natural system and the Social system (Lavell 1993; Wilches 1993).

In 1988, with the creation of the National System for Prevention and Attention to Disasters, Colombia was considered a Latin America pioneer in terms of public policies for disaster risk management. But today, more than 20 years later, the system has undergone very few adjustments or transformations to adapt it to the changes and challenges of Colombian society and the global context (World Bank 2012).

For the case of Bogota the public policy of risk management has a similar tradition. More than 20 years of experience, a recognized trajectory and huge amounts of resources from municipal's public funds and furthermore from funds disposed by the national government and several cooperation agencies and financial entities at global scale.

Fraser (2014, p. 15) describes how Bogotá counts with a "sophisticated and globally renowned system of risk management" producing "some of the most detailed records of risk and vulnerability in the world, on the basis of which the city government has implemented a host of resettlement programs, structural mitigation works and education campaigns". In her opinion Bogota "stands out as an appropriate site in which to investigate the politics and governance of risk and expertise in informal urban settlements".

Is undeniable the valuable experience of Colombia and Bogota in particular, regarding disasters risk management in public policy as an adaptive trend thinking in climate change, but the distance between the conceptual evolution on the matter and the practical application is still so long.

Fraser (2014, p. 15) confirmed that "The risk management paradigm in Bogota reflects an 'impacts-based' approach, aiming primarily to protect against the 'natural', but has little engaged with the social vulnerability of affected communities."

In a different theoretical vein, interrogating for urban risk governance considering the case of Bogotá, Zeiderman (2012, 2013), exemplifies how the creation of disaster risk 'zones' in informal urban areas reflects a form of 'biopolitical' rule, echoing Foucault's notion of 'biopower', as a modern technology of power concerned with the care and growth of populations.

Vanegas (2015) examines for the eastern hills of the city of Bogota, the role played by categories as "environmental preservation zones" and "high risk zones" imposed by the state and the emergent experiences of political creativity for occupy and resistance.

Disconformity with risk management procedures and worsening of social conflicts could be easily found on many territories historically impacted by these public policies across the city of Bogota. According with the World Bank (2012, p. 5), "the conceptual advances about the risk management have not been taken to the level of State policies in Colombia, thus contributing to increase of risk".

From our perspective, initially as part of the recovery process at Altos de la Estancia between the years 2012 and 2015 and since then, as academic partners and researchers of the process (as part of doctoral studies in sustainability at Universitat Politecnica de Catalunya—UPC,[2] the UNESCO Chair on Sustainability of UPC and the Recycling the City Network—RECNET),[3] the intervention in Altos de la

[2]UPC is the official acronym used along the present paper to designate the Polytechnic University of Catalonia).

[3]Recycling the City Network—RECNET, is an initiative originated under the objectives and actions issued by the UNESCO Chair on Sustainability of the UPC, founded with the primary focus on promoting the participatory community development through the transfer of experiences and the collaboration of key stakeholders in re-thinking the transformation of cities for a

Estancia is emblematic because it had an enormous community drive, an innovative strategy of institutional positioning, an enhanced consolidated common vision that aimed to involve stakeholders to transform the 73 ha high risk zone (also known as "the polygon"[4]) into a metropolitan park, and a complex organizational structure that in its operation not only guaranteed the execution of the project but also constituted a specific arrangement, for the exercise of local governance, in the target territory.

Such a structure constitutes an organic fabric installed that explains the positive territorial and cultural transformations that characterized the project, but beyond it constitutes an enduring achievement for the society, capable to continue producing positive transformations in the zone. This aspect reveals one of the project's most important innovations that concern us: the practical exercise of a governance approach as a risk management mechanism.

The theoretical conceptions that conceive an alternative to present and future climate crisis by intermediate of risk governance, community governance, collaborative creation of the space, social adaptation to climate challenges or cultural resilience, have many lessons learned to review in the recovery project implemented in Altos de la Estancia (between the years 2012 and 2016), probably one of the few cases developing such conceptions in a concrete site. That is what pretends to illustrate the present document.

Therefore, it is understandable the interest awakened around the project and in particular the recognition granted by the Risk Award 2015, as one of the top 20 disaster risk reduction, people—centered, sustainable and innovative initiatives.[5]

Risk governance is illustrated as an appropriate approach to reduce the conditions of risk. That implies one theoretical conception to be highlighted as well, what is the understanding of the risk conditions beyond their physical expression as a social construction (made of degradation, disconnection and dysfunction on socio environmental structures) that affected governance in a broader sense of this concept.[6]

(Footnote 3 continued)

sustainable transition to a more resilient socio-ecological systems. For further information remit to http://www.recitynet.org/.

[4]The term "polygon" is used as it was regularly done during the project and among the communities around, to denominate the 73 ha zone directly affected by the landslide and declared as a high-risk zone (with special treatment in the land use dispositions of the city). This polygon is the same zone projected as the area of service of a future metropolitan park (Alcaldía Mayor de Bogotá 2012b).

[5]The Risk Award 2015 was conceded to the proposal postulated with the title "Altos de la estancia, Ciudad Bolivar, Bogota: a case of community resilience to build up a metropolitan park". For more information see IDIGER & RECNET (2015).

[6]Governance is conceived in a way that involves a wide range of stakeholders as decision makers at the local level as opposed to that governance that is circumscribed as the response from the political system to social demands. This approach has a brief elaboration based on multiple authors by López et al. (2016b).

In such perspective risk conditions would raise reflecting the existence of deep social failures and inabilities to adequate governance structures in front to the challenging conditions of reality. Global triggers like climate change and many other conflicts, proper from the particular situations at country and local level, exacerbated the challenging complexity and dynamicity.

For the case of Colombia, a political armed conflict spanning over more than 50 years has deeply impacted both, the entire structure of the society and the spatial construction of the territories. The impact of Colombia's political conflicts on the constitution of risk zones, around the main urban centers and their peripheries is undeniable.

The entire cycle of exclusion, poverty, violence and degradation of the social space in urban centers must be considered into the analysis of the territories when is pretended to assist them with territorial interventions. Risk management is demanded to extend his perspective beyond hazards, to contribute in equitable, effective, inclusive, sustainable, resilient and adaptive responses to dignify the nature and the human beings.

Methodology

The data collection that supports the present paper became available for the researchers during their personal experiences. Duván López is geologist graduated in 2004 with emphasis on environmental geosciences, enrolled as technical assistant of the municipal institution for disaster's management of Bogota during the years 2005 and 2007; then became part of activism movements to articulate social demands on high risk zones among community representatives, nongovernmental organizations, academy and decisions makers of the public sector from 2007 to 2012 and occupied a place as former deputy of risk management in Bogota during the years 2012–2015.

Sonia Hita is photographer and social communicator, enrolled as part of RECNET as volunteer on projects of urban transformation in Bogota since the year 2013 up to the present and particularly offered a support and company during the initial stage and evolution of the community communication network of Altos de la Estancia—REDESTANCIA.[7]

Those roles allowed to the authors the easy access to a huge amount of data and information, including technical informs, reports and diagnosis, documents of public policy with their respective technical supports, historical reports, aerial photographs, interviews and testimonies from community representatives, former

[7]REDESTANCIA—Is translated into English in the present paper as The Network of Communications of Altos de la Estancia. Was conceived as a plural initiative of popular communicativeness in response to the institutional support during the development of the Altos de la Estancia recovery project between the years 2013 and 2015. More information regarding this initiative on http://www.redestancia.blogspot.com.es.

staff or current officers from institutions; personal stories and relates from people of the zone and community leaderships, among others.

Is important here to mention that Duván López participated as research assistant during the years 2009 and 2010, for the surveying of the research reported by Fraser (2014). In fact many inspiring information and reflections come from such personal and professional experience, as long as the author accompanied to Fraser on implementing a systematic surveying in different sites of study across Bogota, being one of them the zone of Altos de la Estancia.

The methods used by Fraser included participant observation, field visits, oral histories, semi-structured households surveys, semi-structured interviews with community leaders and key informants, Semi-structured interviews with district officials and document analysis (Fraser 2014, pp. 81–85).

At the other hand, some of the contains presented are influenced by the community claims to reconfigure the categories and policies to manage climate risk in Bogota, grouped by the initiative called Arraigo (a platform of people affected by risk and resettlement) and studied by López (2016b) as part of his master degree in contemporaneous philosophy, where was pretended to analyze the philosophical clues of risk's resettlement and their resistance in Bogotá, by using an hermeneutic method, developed through the interpretation of a theoretical system, in order to give reason for the manifestation of such political conflicts.

At the end the lines following are made of travel notes, reflections on the road and correlations among the evidences acquired along the experience and testimony of the evolution of the problematic in Altos de la Estancia since the beginning of 2006 and during the reshaping and implementation of the recovery process between the years 2012 and 2016. In this order of ideas, they constitute an empirical framework arranged to suggest the methodological and theoretical aspects of risk management, what is being developed in a certain way by Lopez, as part of his plan research presented to the program of Doctoral Studies on Sustainability at the Polytechnic University of Catalonia, under the supervision of Jordi Morato Farreras and co-supervision of Arabella Fraser, with the title: "Risk beyond hazard: a theoretical analysis for understand the constitution of climate risk".

The Context of the Study Zone: Social Constitution of the Risk

The city of Bogotá is located at 2600 m above the sea level, on the Colombian Eastern Andean Mountain Range, over the southeast border of an extensive plain that is called the "Cundiboyacence Plateau".

Towards the Eastern and Southern flanks of the city the edges of the plateau are well defined by mountainous strips known as "Eastern Hills of Bogotá" and "Hills of Ciudad Bolivar" (see Fig. 29.1). These hills display a variable topography,

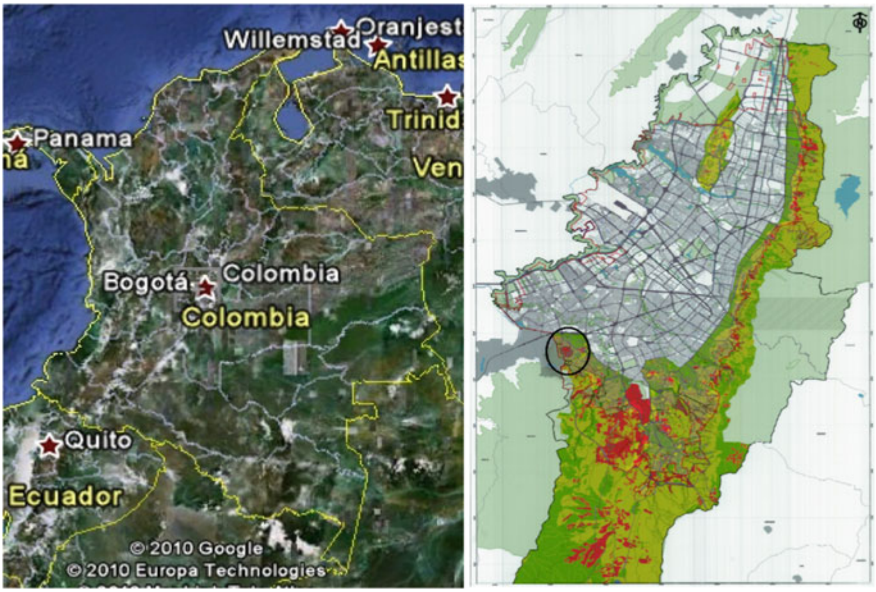


Fig. 29.1 Localization of Colombia and the city of Bogotá (*left*). On the *right* the mapping of landslide hazard for the urban zone of Bogota (taken and modified from Ingeocim 1998). It is appreciated a peripheral surrounding belt with a three colors scale: *red* the highest hazard level, *yellow* intermediate and *green* a low hazard level. In the inner central flat zones of the city not hazard of this type is recognized, the mesh of street and roads is plot. The zones with a soft *green* are rural areas (not assessed with hazard). The figure reflects how the most of the urban zone of the city is predominantly flat without landslide hazards. The hazard concentrates on the peripheral mountainous zone. The 73 ha, high risk zone or “the polygon”, has been marked with a *circle* in the map of Bogota

predominantly steeply; product of complex processes of tectonic folding affecting predominantly sandstone rocks with a high competence against erosion.

Over these competent levels of sandstones there are resting indifferently, argillaceous levels and recent deposits of different origin; some of these materials also have undergone through phases of tectonic folding; in other cases they are superposed on the topography product of recent actions of depositional or erosive morphodinamyc processes that have modeled the landscape (López 2007).

Surrounding the great buildings and avenues, predominantly settled on the flat Bogotá, vibrates a reality little recognized and understood in its complexity: the informal city, built with the alone effort of its inhabitants, without planning or major presence of the State and in the middle of scarcity of resources and waves of displacement from the rural areas affected by violence. Altos de la Estancia, in Ciudad Bolivar, is a good example of this “another reality in Bogota”.

Fig. 29.2 The devastating effect of landslides in Altos de la Estancia (*main frame*). At the *left*, historical aerial photographs that reflect the intensive spreading of industrial mining (1995), the top level of occupation by informal settlements (1998) and the state of the polygon on 2007 when the maximum movement of population by resettlements had been reached. Taken and modified from López (2014a, b)

Altos de la Estancia expresses a history of multiple impacts that date back from the colony in the century XV. The place preserves the footprints stamped by industrial mining activities beginning on the 50s and by an intensive occupation by thousands of Colombians who found there a place to settle a house and make a live (Fig. 29.2).

In most of the cases the welcomed families did not found the most acceptable conditions. Usually they were large families with an important proportion of children, fragile familiar structures and low insertion capacities to city markets as they lack of technical elements or basic knowledge to solve the needs imposed by the urban scope. A high percentage of these populations arrived illiterate or they had not surpassed the primary levels of education, therefore this segment of the population were forced to vacancy or enrolled under the lowest rank of the labor market or what is called the informal jobs (Alcaldía Mayor de Bogotá 2004).

Such social and environmental liabilities, combined with the geological complexity of the area and the great abundance of water, characteristic of our equatorial climate, resulted in the configuration of risks manifested in the late 1990s, giving rise in Altos de la Estancia to one of the largest landslides that exists worldwide, with a total of 73 ha of affectation (Fig. 29.2).

Figure 29.3 illustrates for the territory of Altos de la Estancia the chronological constitution of the risk for that specific local context based on variables of urban

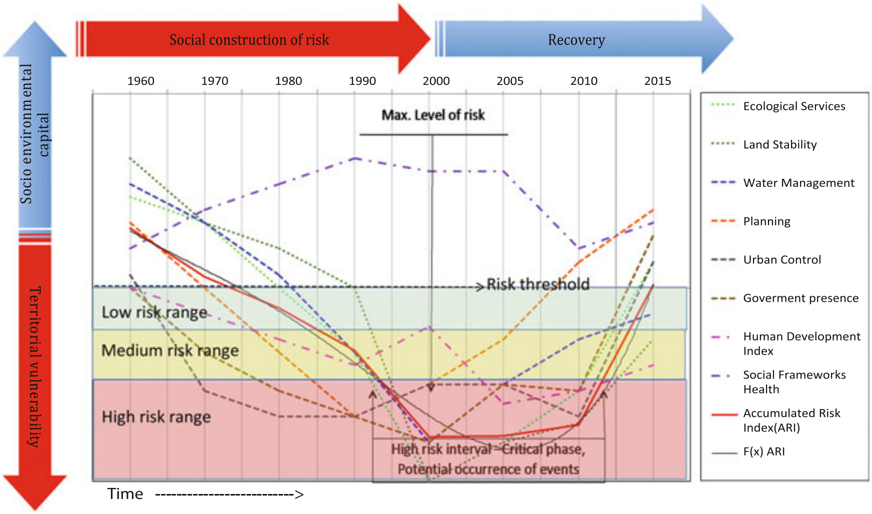


Fig. 29.3 Illustrative scheme for territorial concentration and social construction of risk, for the specific local context of Altos de la Estancia, Bogotá Colombia, in terms of an hypothetical Accumulated Risk Index (ARI)

resilience (Alliance 2007) and several researches, sources of information, practical experiences and reflections about that zone; some of them well documented (López 2007, 2013, 2016a; IDIGER 2014; IDIGER, TdeA and JBB 2014; IDIGER & RECNET 2015; Fraser 2014; López et al. 2016a, b).

Several components of urban resilience became degraded progressively above the territory until configure an increasing condition of risk. When the trend for degradation trespassed certain “risk thresholds” the territory became into an unacceptable level of risk, a critical phase where occurrence of undesirable events became feasible.

The Fig. 29.3 reflects the understanding of “the problem of risk in Altos de la Estancia as a sum of tragedies that were concentrated in this territory throughout its history”.[8] That diagnosis provides the perspective of the challenge assumed by the recovery process. Such understanding encouraged a tactical crusade, to convene the maximum support into the institutional scheme of the public administration in the city of Bogota and deeply justified the fundraising and involving of stakeholders, as the UNESCO Chair on Sustainability of the UPC; through the Tecnológico de Antioquia—TdeA, an academic partner of departmental order based in the city of Medellín, Colombia.[9]

[8]The phrase inside quotation marks is the introductory verse of the audiovisual documentary titled: Altos de la Estancia—Caminos de Vida Digna (IDIGER et al. 2014).

[9]For the year 2012 the city of Medellin in Colombia was leading a very visible experience of urban transformation including a project led by the UNESCO Chair on Sustainability at the UPC to recover the Moravia Hill (former landfill) (Aguirre 2014). In this sense, the project “Altos de la Estancia” constituted a remarkable experience of south-south, city to city exchange of knowledge.

In correspondence with the above, the intervention to manage the risk conditions in Altos de la Estancia between the years 2012 and 2016 was design and implemented not as a physical intervention to control the risk but furthermore, a comprehensive approach to impact each of the several components of the risk in that particular historical, territorial perspective. The risk management approach applied intended to attend the territorial liabilities and deficits at physical/environmental, institutional and communitarian level, by creating or restoring the socio-environmental capital as a framework of resilient risk governance.

The Recovery Project: A Methodology to Promote Risk Governance

Table 29.1 illustrates a strategy operated, that explains the resulting dynamism and intense social activity displayed over the territory of Altos de la Estancia, especially at institutional and communitarian levels. The intervention scheme starts from the recognition of the problem that occurs as a process of consciousness that demanded a committed implication of stakeholders, involving those responsible to take the recovery actions at political, technical, and administrative levels in the central administration, but also those local authorities distributed on decentralized levels of the city.

These last ones use to be directly linked to the territorial problems and usually better informed and conscious on the conflicts, but are also victimized by them, requiring part of the assistance during the process of intervention, because their capacities of response have been exceeded reiteratively. In a context of failed governance, the highest social pressure rests on such several intermediate and low-level agencies or even on individual officers without sufficient resources to provide solutions.

The communities of course are conscious of the territorial conflicts but suffer those in many different ways and invoke the state or not with different approaches and multiple mechanism of agency, with more or less efficiency. In a context of low governance, the requirements and claims from the communities never found a sufficient response.

Dissatisfaction, deception, resentment, distrust or reticence, are some of the common attitudes and drivers of the community actors in the agency of territorial conflicts and in the establishment of relationships with the State (Fraser 2014).

For the case of the Altos de la Estancia recovery project, the political establishment was not certainly aware at all of the dimension and complexity of the territorial conflict in Altos de la Estancia, but on the year 2012, into the inaugural moment of the government period, the political willingness was very receptive to

Table 29.1 Methodology of for institutional and communitarian articulation into the recovery process

Before	Meanwhile	After
Identification and upscaling of the recovery project	Integral intervention	Gobernability and appropriation
Focus and prioritization Technical diagnosis Technical studies Regional studies Characterization of population Citizen requirements Planning tools (land use plans, development plans)	Design of intervention Plan for immediate actions Thematic tables Control and follow up matrix Normative adjustment Land use prospective and setting up	Follow up and assessment IAP Committees Citizen's review boards
Coordination of stakeholders (institutional, social, political and communitarian) Think tanks Round/solution tables Citizen's assemblies Citizen's hearings Local's authorities	Fund raising Local funding—Inversion's Annual Plans (IAP) Regional/national funding Loans Private funding Cooperation funding	Social and institutional appropriation Lines of action, programs, projects Coadministration Installed capacities Community initiatives Entrepreneurship Cultural networking Community markets Local products and services offer
Up scaling at district level Advisory boards Mayor's cabinet City council Development plan	Organization of operations Agreements of operation Contracting and recruitment Bank of projects Public private partnerships Implementation Civil Works Geotechnical bioengineering Landscape beautification Spaces for people	Governance Local economies Cultural activities Improvement of livelihoods

Taken and modified from López (2013)

targeting key processes where to foster local development and impact the peripheral, informal, segregated territories and communities in the city of Bogota (Alcaldía Mayor de Bogotá 2012a).

That attitude was then well assisted based on the strategy (Table 29.1), to take advantage of the social forces demanding for solutions in Altos de la Estancia and scale up the situation rapidly at the highest political levels.

Regarding this particular issue is fundamental to recognize the role played by the denominated Mesa Technical de Altos de la Estancia—MTA (technical roundtable advisory board) an organizational initiative, community based, product of a prolonged process of social qualification to confront the risk conditions in the zone.

Burgos (2015, p. 44) describes MTA as "an alternative participatory channel, which aimed to gather community, institutional and political leaders to discuss and implement disaster risk management strategies in the aftermath of the landslide". That "allowed new forms of interaction between actors as well as facilitating new leaderships" (Burgos 2015, p. 41).

The preexistence of MTA signified the availability on an unified body of pressure, that uses to maintain tense and confrontational relationships with the institutional framework, but once the channels were opened to release that social force and capital, in front to the decision makers at a high level, was possible the identification of competencies and possibilities at the institutional level, the constitution of a regulatory framework and formal disposition of goals, responsibilities, funding and chronological deadlines to develop the project.

As was planned, projected and required by the innovative strategy displayed, a political mandate was established formalizing a common agenda for the local development of the zone, under the figure of an action plan for the integral recovery of the sector Altos de la Estancia and its area of influence, with the "purpose of concretize the integral recovery of the zone declared as high risk and revitalize it to integrate it as a functional area into the urban context" (Alcaldía Mayor de Bogotá 2012b, 2013).

Thanks to the project Altos de la Estancia, a process of institutional qualification for risk governance resulted in Bogotá in a variety of ways, among the many agencies of the city's public administration. The strengthening of institutional capacities included organizational aspects (like the setting of formal spaces, channels, roles, schedules and times for goals reaching, coordination and operation of the actions) and other pedagogic, formative and technological aspects, for example the learning of new techniques or the innovation and experimentation, everything was accompanied by a disposal of physical and economical resources and not least important, by the improvement of legal, administrative and logistic mechanisms for operation and the establishment of channels for interaction of institutions with each other and with communities and representatives.

Culture and Territory: Fields for Expression and Enhancement of the Risk Governance

The measures of risk management for mass movements or landslides are commonly evaluated according to the physical stabilization of the landscapes or the geotechnical properties of the soil. But in our case in Altos de la Estancia, between the years 2012 and 2015, the interesting component of the recovery process was the inducement of organizational arrangements at institutional and communitarian level. The social systems constituted the target of the project, where the adaptive and resilient structures were promoted and emerged capable to operate the governance of risk. Such effort was the fertile soil for progressive growing of cultural and territorial transformations.

But culture and territory are much more than the mere fields for expression of the recovery processes; they are also the entrance to the inducement of the social changes in a cycling recovery process (López 2013). The personal, family and communitarian human dimensions of the inhabitants on Altos de la Estancia were the domains for a cultural incidence to the appropriation of a collective imaginary and to the resolution of it, over the geographical space (as a planned metropolitan park taking shape).

The above is valid as well for the case of public officers and delegates. The collective projection encouraged the reconstitution of the social fabric in function or under the excuse of the recovery process. The possibility of a common expectation played a role in activates the commitment required to dispose the willingness and generate the context to intervene the space and its surroundings. Then came the whole process of capacity building, on institutions and community organizations, in terms of techniques and skills for recovery, as well as the implementation of initiatives.

Appropriation intercedes and moves from culture to the territory as a spontaneous driver to concretize the social creation of the space. Jiménez (2016) based on the thinking of Henri Lefebvre (1901–1991), proposes the right to the appropriation in the construction of a human radical space to guarantee the right to the city. Lefebvre in fact, provides in his extensive work a theoretical approach to the concept of appropriation, very susceptible to be linked at all with what has been mentioned here as governance, adaptation and social creation of the space (Lefebvre 1947, 1967, 1970; López 2016b).

Testimonies from neighbors of the zone give reason about different manners for the cultural process of appropriation mentioned. On Fig. 29.4, Libardo Rodriguez illustrates the emotive sense of ownership and commitment with the Altos de la Estancia recovery project, but even more, with the collective imaginary of the pretended transformation of the high-risk zone into a metropolitan park.

We are the "Corporation of Environmental Guards for the Management and Recovery of Risk - COR-PAMGER". We are in the polygon of Altos de la Estancia where we are making a farm or an agroecological garden, which is going to beautify the sector and we are doing some fields of aromatic and medicinal plants […] Here is going to be located a Park for the entire district and for all the country, is going to be called "Parque Altos de la Estancia".
We are inviting all of Colombia and Bogota to be present in this Park to look at us; support us and see what the Colombian State is really doing today for this beautiful land we have here. The viewpoint that we have does not have any comparative in the world; we are proud to be from Ciudad Bolivar and have the lookout that we have today here in the Park of "Altos de la Estancia"

Libardo Rodríguez, Legal Representative, CORPAMGER

"La Liga (League of Consumers of UPZ 69 (see Picture) is an organization formed in Altos de la Estancia by people living around this park of Altos de la Estancia. As you can see here are the live filters that are being built (for us) in the park for the conduction of the runoff water and rainwater that has been one of the phenomena that has affected the landslides on Altos de la Estancia.
These filters and live "trinchos" are made in bamboo, the filters are made and after the filter is made, it is forested so that these trees with the pivoting roots and the fasciculated roots go tethering the terrain. The pivotal root is absorbing the groundwater to try to mitigate the runoff and reduce the risk.

Humberto Oviedo, Legal Representative, League of Consumers UPZ 69

Fig. 29.4 Testimonies from community representatives in Altos de la Estancia. Libardo Rodriguez (*above*) demonstrates his emotive sense of ownership and commitment with the Altos de la Estancia recovery project but furthermore, with the collective imaginary of the pretended transformation of the high-risk zone into a metropolitan park. Humberto Oviedo (*below*) illustrates how the information and knowledge were deep installed and projected to the serve of the social creation of the space and the recovery process. For this particular case, Humberto refers to the function provided by the using of "geotechnical bioengineering measures" (The geotechnical bioengineering makes reference to an innovative technique to stabilize mass movements and

Many expressions from a variety of stakeholders started to reflect how the conviction of the possibility of a park was taking place. That generates a social context adequate to implement the recovery project but furthermore it started feeding a social vindication for such park, that pushes an accelerates the rhythm of recovery at all.

Humberto Oviedo gives account for another perspective of appropriation highly qualified, in terms of what could be designated as risk governance in a very detailed level. This citizen, regarding the conditions of risk, provides very detailed explanations. He internalized many technical elements to understand and manage such conditions. But the most extraordinary result, that illustrates this case, is the fact of having community representatives, not just as passive observers or indirect supporters of risk management, but taking part as entrepreneurships initiatives, capable to offer a public service to implement innovative physical measures to control risk. Some of these aspects are analyzed for the case of Altos de la Estancia and revealed as strategies of population's empowerment for disaster risk management and climate change adaptation (Burgos 2015).

Into the many aspects of culture, social communication is considered fundamental to explain the development of the project. Social communication was conceived to induce, expand and consolidate the territorial transformations, by creation and transmission of information and knowledge, from the bottom of the local context, out to the entire society across the surroundings, the city of Bogota and beyond; linking and extending the project globally to gain support on the long term.

From the very beginning was formulated a strategy conferring to the members of the community their own place as potential nodes into a network. The slogan appropriated was "Network of Communications Altos de la Estancia, a collective construction".

Not only the local cultural expressions were involved into the project. The facilities disposed by institutions and community to celebrate cultural acts were frequently used to celebrate special journeys, like the district week of Altos de la Estancia, the festival called "ojo al sancocho", the Wind Festival of Altos de la Estancia and many others. On such instances were welcomed cultural expressions from different territories and backgrounds. Part of this process is portrayed in many documents. Merely to be mentioned the documentary "Altos de la Estancia—routes of a dignified life", produced with the assistance of the work team of the project as a closure testimony, that describes precisely the role of culture in that route, that circulates from risk to the recovery and appropriation of the territory (IDIGER 2014).

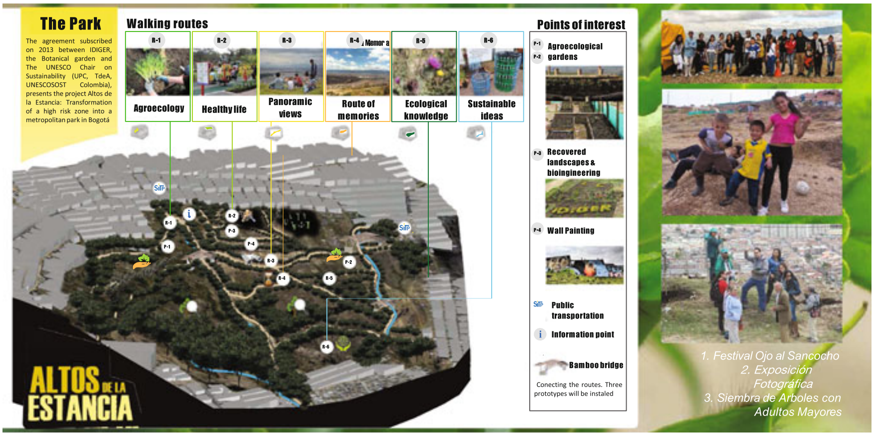
Many efforts were centered in the technical formation in means of communication and communicative tools, but the proposals of each communicative act, in a project with such expectations, were not just the mere use of communications with entertainment function. Each communicative act was addressing the achievement for one or more of the several goals marked into the common agenda.

The use of communicational campaigns may explain for example, how were indirectly convened and enrolled neighbors qualified or proud to execute physical interventions, like vegetable gardens or facilities for routes and walk accessibility to the park using bamboo, wood and available local materials (Fig. 29.5).

From oral histories in interviews were taken back to memory the "left behind" capacities acquired by inhabitants on their own origins from the rural zones.

Fig. 29.5 In the *upper left corner* Humberto Oviedo (original from the country side at one of the territories more affected by the violence in Colombia). Humberto has been showed as one of the most involved leaders to serve the recovery process. He accepted as many others the challenge to participate with his constituted association (Liga de Consumidores de la UPZ 69—league of consumers of the UPZ 69) into a entrepreneurship initiative to take advantage of their "installed attitudes", as former peasants, to develop for this case some exceptional measures of "geotechnical bioengineering". In the right intermediate case is shown a vegetable garden, designed, grew and operated by CORPAMGER, another non profit association leaded by Libardo Rodríguez, involved to the project in a similar way as Liga de Consumidores. The *upper* and *lower right corners* are institutional locations operated by Jardín Botánico de Bogotá (Botanical Garden of Bogota), where some inhabitants of the surroundings used to assist to pedagogical workshops on urban agriculture and to have practice and contribute to the recovery process. The *lower left corner* shows a gardening arrangement done by Liga de Consumidores with the name of a governmental institution, that constituted a very sympathetic wink that gratifies the governmental presence and proof trust and cordiality (images courtesy of REDESTANCIA)

Identity attachments and reminiscences, invoked from that past, pushed in many cases the commitment to recognize, valorate and contribute, disposing such disused skills and practices to the works required.



R-1 Vegetable gardens, plant of composting, Agroecological Market and environmental openroom. Furthermore the route will transit along a vegetal arrangement with native species propitiated by the project.

R-2 Round circuit for running with biohealthy points, children playgrounds and a fresh water station. Furthermore, the route will transit along a vegetal arrangement with species propitiated by the project.

R-3 A walk along contemplative viewpoints with furnishing to have rest, picnic stations and a particular vegetal arrangement with native species propitiated by the project.

R-4 Open space for theater or convention, remainders of last inhabitants and geological illustrative points. Furnishing and vegetal arrangements propiciated by the project.

R-5 Oriented to visitants with academic interest and researchers. Included experimental modules and vegetal arrangements.

R-6 Locations with experimental innitiatives of soil bioingenieering, risk mitigation, community alternative productions. Furnishing and particular vegetal arrangement with native species propitiated by the project.

Fig. 29.6 Part of some published material pretended to be an illustrative map revealing the utilities and services offered or expected for visitors and tourist, as the result of the projected park of Altos de la Estancia. It would include the location and description of the main thematic routes traced, the existing points of interest and brief instructions to access to the polygon using the public transportation. Image taken and modified from López (2014b, November)

The proper reflections of inhabitants resulted turning the perspective of the polygon from a risky dangerous and isolated zone to a source of opportunities, as source for food self-production, healthy consume on their homes and extra incomes. Also by touch and work they memory their past, reencounter identity traces and satisfy their time (Fig. 29.5).

The territorial expressions of the recovery project, outlined in Fig. 29.5, are considered the probably more palpable manifestation of the approach proposed by the Altos de la Estancia recovery project, between the years 2012 and 2015. They manifest spatial transformations addressed by organizational arrangements, on social structures dynamized by cultural drivers as identity, collective imagines, trust and appropriation.

Finally, to continue illustrating the role played by the cultural drivers to stimulate and orientate the social creation of the space, particularly for the case of the "shared vision" as one of them, is useful to caricature an anecdotic story of the project: the designing and releasing of a guiding map for visitors to the projected park (Fig. 29.6).

The requirement to produce such a map arose from the beginning of the project, as an idealistic initiative to display a marketing campaign of the recovery process, inspired on similar cartographic products available for urban public spaces relatively comparable, because of their extensive and mountainous landscape, like Park Guell on Barcelona (Spain) or Golden Gate Park on San Francisco, California.

Is not usual to encounter in Colombia such cartographic products for guiding visitors into public spaces, like parks or other points of interest. But the difficulties to obtain that map for Altos de la Estancia were more than just operative. Even being required since the very beginning of the project, the product was only delivered as one of the final outcomes released.

The fact was that many items to be plot into the map were certainly conceived from the beginning, but only as fragmented intentions, expectations, claims or simply ideas inside each of the stakeholders. The questions about what to plot or where to do it only were having responses in parallel with the evolution from conflict to agreement, by intensive trades that took place among the stakeholders, at political but even at personal levels. For example the steering committee of the project once realized that, for the case of the location of thematic routes, almost every governmental institution involved and furthermore, almost every officer and community representative wanted to trace their proper, particular thematic route, without consensus with the others, neither about the initial or the final points.

The map on Fig. 29.6, that pretended, at the beginning, just to illustrate an attractive offer for visitors, finally resulted reflecting deep inside the entire process of dispute and cultural creation of a shared vision of the space.

Conclusions

Altos de la Estancia is an urban territory that comprises an extended area of 73 ha, directly affected by landslide risks, that is planned to become a public park. One the most interesting components of the recovery project implemented, between the years 2012 and 2015, was the inducement of an organizational arrangement at institutional and communitarian level. Such effort was the fertile soil for quick growing of cultural and territorial transformations in the zone. Those concrete and visible transformations are shown and explained in the present paper as mere expressions of a recovery focused on social and cultural domains.

The Altos de la estancia recovery project illustrated in the present paper addressed not only the visible improvement of the landscape, but also the non-visible qualification of the connectivity and functionality on social structures and relationships. Those strengthened social arrangements, with renovated channels of linkage, are shown with many advantages as long-term risk governance mechanisms, beyond the limited political and institutional periods and beyond the functionality and temporality of solely physical interventions.

An effective strategy was applied to aim the insertion of the project as a driver to create risk governance, influencing the programmatic structure of the city government, to configure an inter-institutional scheme of responsibilities on the multiple agencies of the public administration, under a figure that was called an action plan for the integral recovery of the sector Altos de la Estancia and its area of influence.

The whole intervention of the institutions, the injection of public investments, the reconstitution of the social fabric and the crystallization of cultural and territorial transformations, could be seen as responses to the strategy applied, that constitutes a valuable methodological contribution of the project.

The implementation of measures for risk management, adaptation and resilience, occurred in Altos de la Estancia, not only at physical level but also at the cultural level, with organizational implications for the society on institutional and community domains. In this sense the present empirical research offers a valuable framework, with conceptual contributions in notions like risk governance, social adaptation and cultural resilience.

Culture is seen as a unique social mechanism capable of bring together the multiple and unpaired interests into a common resolution and provide the conditions for the recovery project with the approach proposed. Cultural mechanisms are presented as essential drivers of the recovery process for cultural resilience and risk governance. Collective imagines or shared visions, common agendas, social communication, identity, social creation of the space and appropriation; those were some of the cultural mechanisms playing this role according to the present research.

Social creation of the space is presented as a very convenient approach to implement processes of recovery like that on Altos de la Estancia, with a perspective of risk governance. The concept of appropriation plays a fundamental role, because it bridges the culture and the territory to concretize such social creation of the space. More conceptual fundaments on these aspects are required to develop a risk governance model or methodology.

The Altos de la Estancia recovery project developed between the years 2012 and 2015 constitutes an exceptional experience with lessons learned and methodological and conceptual outcomes, for addressing similar territorial conflicts from and in the Global South. This is worth to be emphasizing, because it implies a need for dialogue between this initiative and others implemented on similar contexts, which is one motivation for the present publication.

Risk governance, as an appropriate approach to reduce risk, underlies a theoretical conception that promises the understanding of the risk conditions, beyond their physical expressions, as a social construction constituted by failures of governance. The question for the governance mechanisms that can deconstruct the problematic of the risk has an equivalent question for the failures of governance capable to constitute the problematic of risk. This interrogation has a capital importance for processes confronting the traditional perspectives to analyze and manage risk, for example the mentioned platform called Arraigo, for people affected by risk and resettlement.

Acknowledgements We want to recognize the collaboration and support provided by the team Unescosost Colombia and Unesco Chair on Sustainability at UPC: Jordi Morató, Jorge Montoya, Yesica Ardila and Brent Villanueva. To the former coordinator of the Agreement 587 of 2013: Ana María Buriticá; to Arabella Fraser, David Reyes, Alirio Duque and Luis Sáez Rueda for the advising and assistance. To Nicola Tollin and Margarita Pacheco from RECNET, to the Community leaders in Ciudad Bolivar, Bogotá, Colombia: Humberto Oviedo, Libardo Rodríguez, Agustín Nieto, Inocencio Cepeda, Bertilda Salas, Ciro Ortega and Heriberto Flor and on behalf of many of them to the Mesa Técnica Altos de la Estancia. To the Network of Communications Altos de la Estancia—REDESTANCIA. To Elkin González, community delegate on the Municipality Council of Planing and on the Local Council of Risk Management of Ciudad Bolivar. To the people of the Institute for Risk Management and Climate Change of Bogota—IDIGER and other public institutions that lead and support the implementation of the action plan for the recovery of altos de la Estancia. To Jorge Aguaza and Kristen Blue who dedicate their time reviewing or supporting the translation into English. To Colfuturo that currently supports by funding part of the research presented.[10] To our parents and relatives that stand up for us during the long journeys of the project implementation and the current research and in particular to little Eloi and Xué. To all of them so many thanks.

References

Aguirre L (2014) Moravia Florece en medio de disputas por el terreno [Moravia: Flourish on the middle of disputes for the terrain]. El Mundo. http://www.elmundo.com. Accessed 22 May 2015

Alcaldía Mayor de Bogotá (2012a) Acuerdo 489 de 2012, Plan de desarrollo económico, social, ambiental y de obras públicas para Bogotá DC 2012–2016 [Agreement 489 of 2012, plan of economic, social and environmental development and for public works in Bogota DC 2012–2016]. Oficina de Comunicaciones, Alcaldía Mayor de Bogotá, Bogotá

Alcaldía Mayor de Bogotá (2012b) Decreto 489 de 2012. Por medio del cual se determinan y articulan funciones en relación con la adquisición predial, administración, manejo y custodia de los inmuebles ubicados en suelos de protección por riesgos en Altos de la Estancia, en la localidad de Ciudad Bolívar y se dictan otras disposiciones [Decree 489 of 2012. By means of which are determined and articulated the functions in relation to the property, acquisition, administration, management and custody of the properties located in soils of protection by risks in Altos de la Estancia, in the locality of Ciudad Bolivar and Other provisions]. In: Régimen Legal de Bogotá DC (October 30 of 2012). http://www.alcaldiabogota.gov.co/sisjur/normas/Norma1.jsp?i=50070. Accessed 22 May 2015

Alcaldía Mayor de Bogotá (2013). Altos de la Estancia. Plan de Acción para la recuperación integral del sector de Altos de la Estancia y su área de influencia [Altos de la Estancia. Plan of action for the integral recovery of the sector of Altos de la Estancia and its area of influence], Bogotá (unpublished document)

Alcaldía Mayor de Bogotá, Departamento de Administración y Planeación Distrital (DAPD) (2004) Recorriendo Ciudad Bolivar, diagnostic físico y socioeconomico de las localidades de Bogotá [Running by Ciudad Bolivar, Physical and Socio economical diagnostic of the localities in Bogotá], Bogotá. http://www.dapd.gov.co/www/section-1996.jsp. Accessed 22 May 2015

[10]Colfuturo currently provides financial support to D. López as beneficiary of the program of loans/scholarships 2016 to finance Ph.D. Studies on Sustainability at the UPC.

Alliance R (2007) A research prospectus for urban resilience: a resilience alliance initiative for transitioning urban systems towards sustainable futures, Stockholm. http://www.resalliance.org/files/1172764197_urbanresilienceresearchprospectusv7feb07.pdf. Accessed 22 May 2015
Bojacá M (2006) Experiencia y resultados en el programa de reasentamientos humanos de la caja de vivienda popular, Proyecto La Colombianita [Experience and results in the human resettlement program of the popular housing fund, Project La Colombianita]. Bachellor's final inform on Public Administration. Escuela Superior de Administración Pública de Bogotá—ESAP, Bogota
Burgos N (2015) An analysis of risk governance systems in urban settlements, a case study of community participation in Altos de la Estancia, Bogota. Master's Thesis on disasters, adaptation and development. King's Colleague of London, London
Cardona O (1993) Evaluación de la amenaza, la vulnerabilidad y el riesgo: Elementos para el Ordenamiento y la Planeación del Desarrollo [Assessment of hazard, vulnerability and risk: Elements for landuse and development planning]. In: Maskrey A (comp) 1993. Los Desastres no son Naturales [Disasters are not natural]. La Red, Tercer Mundo Editores, Bogotá, pp 45–65
Fraser A (2014) Rethinking urban risk and adaptation: the politics of vulnerability in informal urban settlements. PhD Thesis (Doctor in Philosophy). London School of Economics and Political Science (LSE), London, United Kingdom
IDIGER—Institute Distrital de Gestión de Riesgos y Cambio Climático (2014). Lo que la tierra se llevó. Altos de la Estancia: Sueños de vida digna [What the land took. Altos de la Estancia: Dreams of a dignified life], Bogotá. Available at: http://issuu.com/fopae/docs/lo_que_la_tierra_se_llev_bw. Accessed 21 Jan 2017
IDIGER, TdeA—Tecnológico de Antioquia Cátedra UNESCO de Sostenibilidad Universitat Politècnica de Catalunya, JBB—Jardin Botánico de Bogotá (2014) Altos de la Estancia, caminos de vida digna [Altos de la Estancia, routes of dignified life] (video file). https://www.youtube.com/watch?v=qosR9RUG7CQ/. Accessed 21 Nov 2016
IDIGER & RECNET—Recycling the City Network (2015) Altos de la estancia, Ciudad Bolivar, Bogota: a case of community resilience to build up a metropolitan park. GRF—Global Risk Forum Davos, ISDR—International Strategy for Disaster Risk Management, Munich Re Foundation (Comp). Risk award first-hand news best Project proposals 2015, 20–21, Munich, Switzerland. http://www.munichre-foundation.org/de/dms/MRS/Documents/RISK-Award/2015_RISK_Award_Firsthand_news_high.pdf. Accessed 21 Jan 2017
Ingeocim Ltda (1998) Zonificación por inestabilidad del terreno para diferentes localidades de Bogotá [Terrain instability zoning for different localities in Bogotá]. Found for the Prevention and Attention of Emergencies of Bogotá, Bogotá
Jiménez P (2016) Claves epistemológicas para descifrar el derecho a la ciudad de Henri Lefebvre [Epistemological clues to figure out the right to the city of Henri Lefebvre]. ESTOA. Revista de la Facultad de Arquitectura y Urbanismo de la Universidad de Cuenca 8:5–13
Lavell A (1993) Ciencias sociales y desastres en América Latina: estrategias de intervención [Social sciences and disasters in Latin America: intervention strategies]. In: Maskrey A (comp), Los desastres no son naturales, Red de Estudios sociales en Prevención de Desastres en América Latina, Tercer Mundo Editores, Bogotá, pp 31–58
Lefebvre H (1947) Critique de la vie quotidienne I: Introduction, Paris: Grasset. [te: Moore J (1991) Critique of everyday life. Volume I: introduction]. Verso, London
Lefebvre H (1967) Le droit à la ville. [ts: JJ González-Pueyo (1969). El derecho a la ciudad], Barcelona
Lefebvre H (1970) La Révolution urbaine, Paris. [ts: Gallimard (1972). La revolución urbana]. Alianza, Madrid
López D (2007) Landslide risk assessment tools for make decisions quickly in critical situations. In: Annual Conference of the Canadian Institute of Geomatics: Geomatics for Disaster and Risk Management. Toronto, Canada (May 23 to 25 of 2007)

López D (2013) Construcción de resiliencia para la gobernanza y la recuperación de zonas de alto riesgo [Building Resilience for Governance and Recovery of High-Risk Areas]. In EAPDF—Escuela de Administración Pública del Servicio Federal (ed) 2013. Memorias Seminario Internacional Gestión de Riesgo de Desastres. México DF

López D (2014a) Proyectos de transformación participative: El caso de Altos de la Estancia en Bogotá [Participatory transformation projects: The case of Altos de la Estancia in Bogotá]. Power point presentation. In UN Habitat (Executive secretariat). Resilience Strategy for Urban Local and Regional Sustainable Development, networking event No. NE 154, VII World Urban Forum, Urban equity in development—Cities for life, Medellín

López (2014b) Altos de la Estancia: Transformacion de una zona de alto riesgo con vision de gobernanza, resiliencia y adaptacion al cambio global. [Altos de la Estancia: Transformation of a high risk area with a vision of governance, resilience and adaptation to global change]. Oral presentation in J. Morato (Chair) RESURBE: Nuevos desafios para la transicion hacia la resiliencia y la adaptacion a traves del desarrollo comunitario. Workshop conducted by the UNESCO Chair on Sustainability of the Universitat Politecnica de Catalunya, Barcelona, Spain. http://www.unescosost.org/project/resurbe/. Accessed 22 Jan 2017

López D (2016a) Arraigo: Luchas y perspectivas de la población desplazada por riesgo y reasentamiento de Bogotá [Arraigo: Fights and perspectives of the population displaced by risk and resettlement of Bogota]. In García E (ed). Working paper series Contested Cities No. 4. Madrid, Spain, Contested Cities International Congress 2016: pp 1–13. http://contested-cities.net/working-papers/2016/arraigo-luchas-y-perspectivas-de-la-poblacion-desplazada-por-riesgo-y-reasentamientos-en-bogota/. Accessed 22 Jan 2017

López D (2016b) Desgarre y arraigo: Claves filosóficas del reasentamiento por riesgos y sus resistencias en Bogotá [Tear and rooting: Philosophical clues of resettlement by risks and their resistance in Bogotá]. Master's thesis on Contemporaneous Philosophy, Universidad de Granada, UGR, Granada, Spain. https://arraigo.co/2016/11/11/lecturas-del-arraigo/. Accessed 22 Jan 2017

López D, Buriticá A, Ardila Y, Montoya J, Morató J (2016a) Altos de la Estancia: Transformación de una zona de alto riesgo en un Parque Especial para todos [Transformation of a high risk area into a special park for all]. In: Morató J, Salas H, Tollin N, Montoya J (eds) Reciclar ciudad. Repensar la transformación de las ciudades, 2nd edn, pp 140–150. Mexico DF, RECNET, UNESCO Chair on Sustainability, Universitat Politècnica de Catalunya—UPC & Universidad Nacional Autónoma de Mexico

López D, Buriticá A, Vanegas E (2016b) Arraigo: a platform of people affected by risk and resettlement of Bogota that demands new approaches to understand and manage risk. In: International Conference on Urban Risks 2016. Lisbon, Portugal, European Centre on Urban Risks, pp 965–972

Maskrey A (1989) El manejo popular de los desastres naturales: estudios de vulnerabilidad y mitigación [Popular management of natural disasters: Studies of vulnerability and mitigation]. Lima, Tecnología Intermedia (ITDG)

Maskrey A (comp) (1993) Los Desastres no son Naturales [The disasters are not natural]. Bogotá, La Red, Tercer Mundo Editores

Medina J, Romero R (eds) (1992) Los Desastres Sí Avisan. Estudios de Vulnerabilidad y Mitigación II [Disasters do advise. Studies of vulnerability and mitigation II]. Tecnología Intermedia (ITDG), Lima

Poveda N (2011) Colombia: Nueva Esperanza. Una Experiencia de Reasentamiento Con Enfoque de Gestión de Riesgo Y Ordenamiento Territorial [Colombia: Nueva Esperanza. A experience of resettlement with a risk management and territorial management approach]. In: Correa E (ed). Preventative resettlement for populations at risk of disaster: experiences from Latin America. World Bank and GFDRR, Washington, DC

Rivera H (1999) Susceptibilidad y predicción de la erosión en suelos de ladera de la zona cafetera central colombiana [Susceptibility and prediction of erosion in slope soils of the Colombian central coffee zone]. PhD Thesis on Soil Sciences, Universidad Nacional de Colombia, Facultad de Minas, Medellín (Colombia)

Rivera H (2001) Manejo y Estabilización de Taludes en Zonas de Ladera mediante Tratamientos Bioingenieriles [Management and stabilization of slopes in hillside areas by bioengineering treatments]. In Avances Técnicos CENICAFE 2001, Chinchiná, Colombia, Cenicafé

Rivera H, Sinisterra J (2006) Uso Social de la Bioingeniería para el control de la Erosión Severa [Social use of bioengineering for the control of severe erosion]. Corporación Autónoma Regional del Valle del Cauca (CVC), Cali

Robles S (2008) Impactos del reasentamiento por vulnerabilidad en áreas de alto riesgo en Bogotá 1991–2005 [Impacts of vulnerability resettlement in high-risk areas of Bogota 1991–2005]. Master's thesis on Habitat, Universidad Nacional de Colombia, sede Bogotá, Bogotá

United Nations Office for Disaster Reduction (UNDRO) (1979) Natural disasters and vulnerability analysis. Report of Experts Group Meeting, Geneva

United Nations International Strategy for Disaster Reduction (UNISDR) (2015) Sendai framework for disaster risk reduction 2015–2030. UNISDR, Geneva

Vanegas E (2015) Vivir y luchar por los Cerros. Formas y experiencias de la política [Live and fight for the hills. Forms and experiences of politics]. Master's thesis on social anthropology. UNSAM. IDAES.IDES, Buenos Aires

Wijkman A, Timberlake L (1985) Desastres Naturales: ¿fuerza mayor u obra del hombre? [Natural disasters: mayor force or man's work?], Earthscan, London. http://www.cridlac.org/digitalizacion/pdf/spa/doc716/doc716.htm. Accessed 22 Jan 2017

Wilches G (1993) La Vulnerabilidad Global. In: Maskrey A (comp) Los Desastres no son Naturales. La Red, Tercer Mundo Editores. Bogotá, pp 11–44

World Bank (2012) Análisis de la gestión del riesgo de desastres en Colombia: un aporte para la construcción de políticas públicas [Analysis of disaster risk management in Colombia: a contribution to the construction of public policies], Bogotá

Zeiderman A (2012) On shaky ground: the making of risk in Bogota. Environ Plan A 44(7):1570–1588

Zeiderman A (2013) Vital politics and urban citizenship in Bogota, Colombia: living dangerously. Am Ethnol 40(1):71–87

Chapter 30
Challenges and Potential Sustainable Solutions of Environmental Threats and Climate Change in Guatemala

Nelson Amaro

Introduction: The Need to Cope with Environmental and Climate Change Threats

The recent approval of the Sustainable Development Goals (SDGs), at the end of the year 2015 in the General Assembly of the United Nations, culminates a process of understanding the goals sought throughout the world, regarding economic growth, quality of life and the environment, including climate change. These three axes, in a joint and balanced way as well as the approach towards future generations, are the dimensions that precisely define the United Nations World Commission on Environment and Development in the Brundtland Report (1987). These SDGs replaced the Millennium Development Goals (MDG) changing the horizon for achievements from the year 2015–2030. However, over time, since the United Nations called these global efforts the "First Decade of Development" in 1960, its approaches and integration of its various components has not been an easy task.

Towards a New Consensus at the World Level

This consensus is equivalent to the acceptance of a new paradigm that included more than 190 countries. They are practically the territories that make up planet Earth itself. These agreements reached consensus by September 2015, and almost immediately, a similar event took place in the meeting of the Conference of the Parties, COP 21 in Paris at the end of December 2015. The willingness of atten-

N. Amaro (✉)
Sustainable Development Institute, Universidad Galileo, 7a. Avenida, calle Dr. Eduardo Suger Cofiño, Zona 10, Ciudad Guatemala, USA
e-mail: nelsonamaro@galileo.edu

W. Leal Filho and L. Esteves de Freitas (eds.), *Climate Change Adaptation in Latin America*, Climate Change Management,
https://doi.org/10.1007/978-3-319-56946-8_30

dance was significant despite possible cancellation of the event, due to terrorist attacks that blighted Paris, a few days before that date.

These same dimensions fought each other for their integration and supremacy in over the past 50 years. At the beginning, the economic aspect was privileged, while the social, environmental and climate change aspects remained less relevant in the approaches, policies and realities (Amaro 2012). It was not until the late 80s that talk about the "human face of development" began and this concern arose in the 90s. Finally, the United Nations Framework Convention on Climate Change (UNFCC) was accepted in 1992 and finally approved definitely in March 1994. After this meeting, 20 more encounters had to take place in order to reach the consensus achieved during the COP21 in Paris in 2015. In the final declaration, a petition was made to the Adaptation Committee and Least Developed Countries (LDC) Expert Group, under section (b) of "Adaptation", where the following recommendation may be read: "Study methodologies to evaluate the needs of adaptation in order to provide assistance to developing countries without placing undue burdens on them" (Naciones Unidas 2015).

This paragraph aims to an openness of minds. Continuous discussions took place for over those 20 years before, on the responsibility of mitigating climate change and the cost to be borne by each party. By the time the COP21 Agreements were reached, the argument for placing said burden on developed countries was often the axis where the consensus faltered. At the COP21, the discussions on funding became concentrated mainly on developed countries. At present, and in the declarations issued because of the COP22, the following year, a preponderant participation of developed countries is recognized. The target for all activities reaches a minimum investment of US$100 billion (Naciones Unidas 2015, Agreement 54). These sums will be contributions to the Green Climate Fund (GCF) and the Global Environment Facility (GEF), which are responsible for the financial functioning of the Convention. These instruments will be the guiding principle for these contributions, along with the support of the Least Developed Countries Fund (LDCF), Special Climate Change Fund (SCCF) and the Adaptation Fund (AF) (Naciones Unidas 2015, Agreements 59 and 60). Future meetings will have to rule the contributions, access to and distribution of these funds. The recent US Government withdrawal of these agreements reached in Paris and Morocco will surely intensify these discussions. Nevertheless, it may also strengthen more the participation and determination of other developed as well as developing countries' actors.

This evolution towards greater consensus points to the gradual awareness of the ecological dimension of development, which has resulted in numerous conferences, international meetings, accords and framework agreements in recent times. At first, social aspects were largely considered as a consumption and budget expenditure, not as a requirement for development, while the environment and its advocates appeared as lovers of nature and wildlife. Both approaches were marginal and often contradictory to the transformations and economic goals put as main objectives in the past (Amaro 2012).

Although important consensuses have been reached in achieving the compatibility of these objectives, still the necessary awareness of the need to make a reality of these dimensions, was far from becoming a basic premise for the activities carried out by universities, the market, the government and civil society. Lack of consensus affects the promotion of investment, policies and preventions. It is necessary to reflect on which challenges deserve special attention that could lead to methodologies that make needs visible, considering the set of vulnerabilities, threats and priorities, as outlined in the COP21 Agreements.

The present elaboration highlights three challenges, which should constitute central concerns if progress is a goal in these dimensions. The first one is about poverty and food security, demonstrating that the latter is the most direct relation of the possible impacts of climate change that affects populations. At least such is the case for Guatemalans. The second challenge relates to the inadequate coordination of key actors and decision-makers when addressing the aforementioned problems. The last and third challenge focuses on the need to channel these efforts towards regional and local levels, creating links between sustainable development, care of the environment and climate change in the most remote places where there are often major contradictions and deficiencies in economic growth, quality of life and environmental impacts.

Sustainable development is the prevailing paradigm in the world today and it is therefore necessary to face social conflicts that paralyze investment, influence economic growth and contribute to perpetuate and increase poverty and environmental pollution. The concept of paradigm, as Kuhn (1962) argues, may perhaps be synthesized simply as a "puzzle", which is shared by a community of scientists, after being found that other approaches that guide research and its applications, have limits to the advancement of knowledge.

Then, each one contributes to constructing knowledge from each perspective around the premises accepted in the paradigm, which equally has consequences for researchers as well as for decision-makers in these areas. The consensus reached at the United Nations General Assembly in New York in September 2015 and then in December 2015 at the COP21 in Paris, amounts to the acceptance of a paradigm, even though there were some stakeholders that may not yet share some of the premises of these contents. This is evidenced by the mentioned uncertainty created after the elections held in the United States of America in November 2016, despite previous ratifications of these agreements.

This elaboration wants to highlight which challenges are the most urgent to face at present in Guatemala. In doing so, it will establish the link between these priorities to be formulated and the needed measures to cope with threats coming from the lack of economic growth, its impact on poverty, the extension of this absence in food security and the way this weakness should be face through coordination and decentralization at the local level.

The Context of Sustainable Development, Poverty, Food Security and Climate Change to Highlight Challenges and Priorities in Guatemala

Modality 1 contains the 17 paradigmatic goals that substitute the Millennium Development Goals (MDGs), by the consensus reached. These same goals give an account of the environmental and climate change issues that are in the MDGs. On the other hand, recent studies give an account of the impact of climate change in Latin America, the Caribbean and Guatemala and the legislation efforts made to address these threats. A study by specialists of the United Nations Environment Program (UNEP) and the Latin American Parliament (2015) states:

> Virtually the entire land area of LAC (Latin America and the Caribbean) will be subject to caloric events that now occur every 700 years; the Amazon basin and many densely populated areas are expected to experience extreme drought; the Andean glaciers will have disappeared by the end of this century. Glacial melting will initially increase the risk of flooding, to later end in a drought that will affect the communities that depend on it; category 4 or 5 hurricanes could be more frequent and powerful. This, along with a one-meter increase of the current sea level, will have devastating effects, especially in the Caribbean. Events such as the gigantic Amazon droughts of 2005 and 2010, the increase in frequency of hurricanes in the Atlantic, and the loss of 90% of tropical glaciers are clear evidence of this. (p. 13, translation made by the author)

This situation has a closer impact on Guatemala whose coasts are bathed by the Caribbean, the dangers of which have been pointed out as well as the increased presence of cyclones. In addition, the United Nations University in Tokyo (2013) recognized these shortcomings. Researchers elaborated a World Risk Index here that ranked 173 countries according to their degree of vulnerability regarding natural hazards and institutional capacity to face these threats. Guatemala ranked fourth, only behind Vanuatu, Tonga and Philippines. This situation has also been noted by other authors, who have demonstrated the recurrence of disasters due to floods and storms, highlighting its frequency mainly from 1998 with Hurricane Mitch and repeated at great costs to the country in 2005, 2010 and 2011 (Amaro et al. 2014).

The first goal depicted in Graphic 30.1 focuses precisely on the eradication of poverty and the second, which has the same title, was one of the main programs called “Zero Hunger Pact”. The Food Security and Nutrition Secretariat (SESAN by its initials in Spanish) implemented this program in Guatemala since 2011 in alliance with other government branches and different municipalities of the country. This program aimed to reduce by 10% the undernourished population under 3 years old and diminish child mortality in children under 5 years in 166 municipalities prioritized according to their poverty conditions, in 4 years culminating in 2015 (SEGEPLAN, Circa 2012).

This program was launched with great publicity during the previous administration presided by General Otto Pérez Molina (2012–2015), who is now facing corruption charges and preventive detention in Guatemala since his final year in

Graphic 30.1 *Source* UN News Centre (2015), Sustainable development goals kick off with start of new year. http://www.un.org/sustainabledevelopment/blog/2015/12/sustainable-development-goals-kick-off-with-start-of-new-year/. Accessed 28 Jan 2017

office (2015) which he was unable to conclude due to the aforementioned reasons. The press recently voiced concerns in the dissemination of the results obtained during this program according to evaluations held during the period 2012–2015. It is necessary to take into consideration that, although there is a decrease in Guatemalan poverty levels from 59.9% in 2012 to 58.2% in 2013, chronic malnutrition rises to 60.6% in the year 2014 when evaluating children under 5 years of age. However, the current leader of the SESAN recognizes that the program reached only 30% of the residents of the prioritized municipalities (Muñoz Palala 2016). These actions are an example of the implementation difficulties following international agreements.

What Can Be Done? Sustainable Development, Mitigation and Adaptation as Responses

The subject of natural resources and disasters is crucial in the sustainable development and climate change issues. The plea of the COP21 Agreements aims to the formulation of methodologies capable of detecting the needs, legal backgrounds (PNUMA/PARLATINO 2015) and economic, environmental and social implications in order to resolve its consequences. Altamonte and Sánchez (2016) advance an elaboration close to the study presented here. These authors state:

> In other words, governance may be seen as the collection of processes of both decision-making as well as the implementation of resulting decisions, in which institution act through mechanisms, procedures and rules formally or informally established. An adequate governance must be capable of managing the multiple fiscal, regulatory, macroeconomic, social, environmental and long-term public investment (among other) challenges that are implicit in the path of natural resource-based development that in fact represents absolute development. (pp. 16 and 17. Translation made by the author.).

Faced with this situation, the possible answers should concentrate on focusing the dimensions that might attenuate the mentioned factors. This call should consider the goals enunciated by the consensus around the SDGs that make an appeal to the eradication of poverty and hunger in conjunction with the environment and climate change threats that are largely responsible for this situation. An improvement in these dimensions will necessarily have an impact on the effects of the detected vulnerabilities. Simultaneously, to reduce the emission of greenhouse gases (GHG) and the adverse conditions of climate change, efforts must be made. Guatemala has promised during the Conference of the Parties in Paris that it will reduce 11.2% of GHG emissions by its own means and with external aid, that amount can be doubled in order to achieve a 22.6% reduction by 2030 (MARN 2015, Sect. 3.2). This leads us to face in short, medium and long term, essential elements in the process of adaptation and for this, three challenges that must be faced in this field are highlighted next.

At present only Mexico and Guatemala have specific legislation on climate change enacted in Latin America (PNUMA y Parlamento Latinoamericano y Caribe 2015). As a result, the Guatemalan Government is engaged in a series of plans, following the approval by Congress of the Climate Change Law (2013). These operational plans cover 4 instruments: the National Action Plan for Climate Change Adaptation and Mitigation, that calls for the coordination of all related government bodies, the private sectors, civil society and universities. These bodies sit in the Climate Change Council headed by the President of the Republic. The Law specifies that this body should meet each 2 months. The goal is to implement the articles specified in the Law completely. The second operational plan refers to energy for production and consumption; the third, elaborates on a program for the reduction of Greenhouse Gases; and the fourth, aims to cope with the environmental problems created by private and public transportation (MARN 2016). There is no doubt that the government with regard to climate change is in a design stage, although it has a legislation in place that still is missing in most of the rest of Latin America.

Therefore, there are still possibilities for further actions in the climate change area. A general diagnostics on climate change in Guatemala (Castellanos and Guerra 2009) concludes with a call to intensify the activities related to woods and reforestation; the integrated management of basins; increase the provision of food; the need for an adequate handling of garbage; and a greater emphasis on the prevention of disasters. Complaints also abound regarding the lack of general awareness and government coordination with regard to climate change threats and dangers.

According with other studies made, the most dramatic situation of the impact of environmental factors and climate change on poor populations, are the so-called "Dry Corridors" that are defined as "a region characterized by semiarid soils and risk of droughts" (MAGA 2010). A last study on the subject says that "Climate change and the advance of the agricultural frontier will impinge upon the forest coverage, the increment of soil erosion and the reduction of water volumes….where the provision and supply of water represents 86% of the damages" (PNUD and PNUMA 2013). This situation affects crops, subsistence food and malnutrition, particularly on poor children with less than 5 years. This paper will concentrate on this interrelation, looking for further coordination to cope with this situation and suggesting measures to improve the quality of life of the poorest population in these territories.

Main Sustainable Development, Environment and Climate Change Challenges Faced by Guatemala

First Challenge

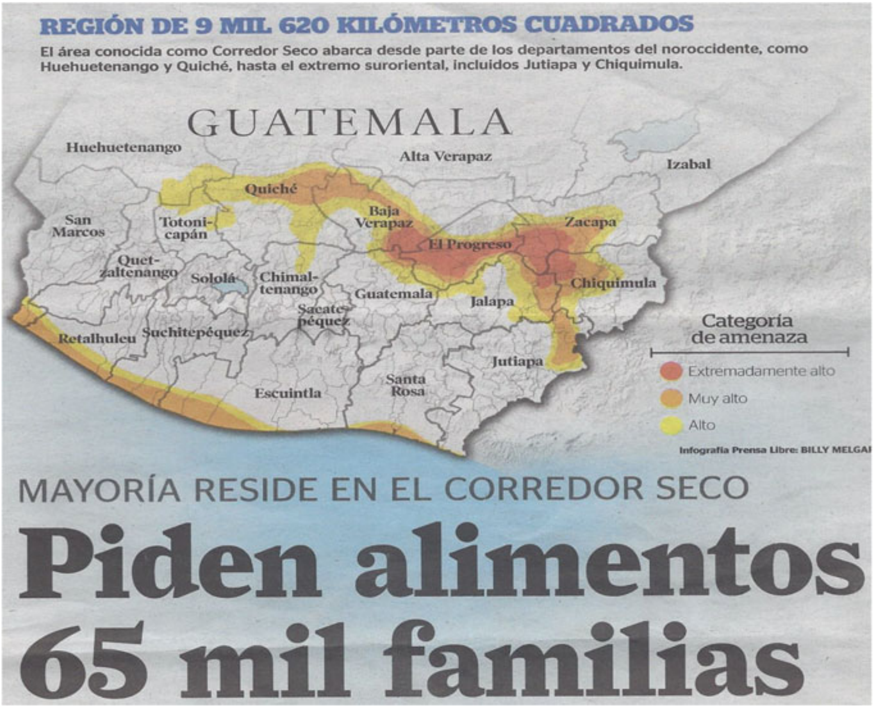
Economic, social, environmental and climate change are closely related. Economic growth must be a basic goal in order to achieve a reduction of poverty in the country and thus lessen the effects of climate change. The comparison between the previous global situation of the SDGs that have specific objectives to be met by the year 2030 and the reality of Guatemala, raise the eradication of poverty to a priority in the country. There can be no distribution of wealth without economic growth. Poverty perpetuates despite the comparative advantages of Guatemala as a frontier to the largest global market in the world: USA, Canada and Mexico. This vulnerability makes the effects of climate change more pronounced with regard to hunger and malnutrition. This is reflected in the information that follows.

These news and the following Figure appeared in the journal of greater circulation in Guatemala. Translation by the author in order of appearance from top to down: "Region of 9 thousand 620 km^2. Majority of population live in the "Dry Corridor". Below this title, it says:

"The area known as "Dry Corridor" extends from part of the northwestern Departments (provinces), like Huehuetenango and Quiché, to the southeastern end, including Jutiapa and Chiquimula". Then, the map of Guatemala is seen where the name of main departments or provinces appear. The color means: red light: extremely high; orange: very high; and yellow, high threat. The bigger headings refer to "Majority of the population lives in the Dry Corridor (small letters). "65 thousand families ask for food" (capital letters).

Source: Contreras, G. (9 August 2016). Piden alimentos 65 mil familias. *Prensa libre*, p. 6.

The content of the Graphic 30.2 shows territories of the so-called "Dry Corridors" in Guatemala. This information was selected as an example of how the



Graphic 30.2 Guatemala: a map of "Dry Corridors and Poor families Affected by Food Security"

extent of these phenomena reaches the general public in the country. The most evident alterations of climatic and environmental factors that mainly affect the population living in poverty and have an impact on nutritional levels in these areas are the following:

- Changes in temperature.
- Changes in precipitation.
- Flooding and drought cycles that affect water and hydro biological resources.
- Natural disasters often causing displacement and search for refuge.
- Agricultural crops either affected by droughts or flooding with direct impact in food security for the population living in poverty.
- Deterioration of soil already affected by the use of pesticides.
- Contamination of water, air, and appearance of related diseases.

Table 30.1 examines the economic growth in a short, medium and long term of Guatemala since the year 2001–2016. As can be seen, the modalities vary from 0.5% in 2009, which is the lowest and reaches the highest, 6.3% in 2008. In fact, in 16 years, this indicator only exceeded 4% in 5 years. Only 1 year, the figure reached 5% and another one 6%. In all other periods and years, rates have not exceeded 4% for a total of 9 years below 4%.

Table 30.1 Economic growth rates in percentages, as measured by Guatemala's Gross Domestic Product (GDP), 2001–2016

Year	GDP	
	At prices of 2001	
	Values	Var. %
2001	146,977.8	2.4
2002	152,660.9	3.9
2003	156,524.5	2.5
2004	161,458.2	3.2
2005	166,722.0	3.3
2006	175,691.2	5.4
2007	186,766.9	6.3
2008	192,894.9	**3.3**
2009	193,909.6	0.5
2010	199,473.8	2.9
2011	207,776.0	4.2
2012	213,946.6	3.0
2013	221,857.5	3.7
2014[p/]	231,118.2	4.2
2015[p/]	240,706.8	4.1
2016[py/(low)]	248,079.6	3.1
2016[py/(low)]	250,005.2	3.9

p/ Preliminary figures, py/ projected figures
Source Banco de Guatemala, Producto Interno Bruto, Base: 2001. http://www.banguat.gob.gt/inc/main.asp?id=51803&aud=1&lang=1. Accessed 10 January 2017

These economic growth rates in Guatemala are insufficient to achieve an effective distribution that can significantly lower the poverty rates that prevail in the country. It is enough to make a comparison of that same indicator with China. For example, between 2000 and 2016, China's lowest rate reached 6.7% (2016) and the highest achieved more than 14% (2007). From 2000 to 2016, China achieved a GDP growth of over 10% from 2003 to 2008 and then again in 2010, 9 in a total of 16 years (National Bureau of Statistics of China 2016).

Guatemala, in the past, has suffered violent political conflicts that had their greatest rise between the 50s and 90s. Finally, in 1996, the government an violent opposing forces sign the Peace Accords. These efforts were similar to the ones made in Latin America, now by Colombia. What has remained behind is that in the Peace Accords signed on that date, an economic growth rate goal of 6% is set, a figure that has rarely been achieved in all these years and there is not even any public discussion about it. The international experience represented by China proves that it is impossible to achieve significant accomplishments in this field, if systematic and continuous economic growth is not present. However, observers indicate that this is a "necessary but not sufficient" condition (United Nations Development Program 2015, p. 2). Actions in physical infrastructure, human capital formation and quality of life should also be added as an ingredient. Nevertheless, there would be agreement that without economic growth, the advances in distribution becomes impossible.

In comparison to the observations made for the case of Guatemala, the quoted report (United Nations Development Program 2015) states:

> …China has increased its per capita 5 times between 1990 and 2000, from US$200 to US $1000 and from US$1000 to US$5000 again in the year 2010, moving into the middle-income countries of the world category. Also during the period 1990–2005, it has eliminated 470 million people from the extreme poverty category, contributing to the 76.09% poverty reduction experienced worldwide during the same time period. (p. 5)

A review of current poverty trends in Guatemala based on the latest surveys (INE 2015) in the country yields the following results (1US$ = 7.43918, 7 February 2017 according to Banco de Guatemala):

- For the year 2000, the value of the total poverty line was Q4,319 per year. However, for 2014, the cost of food plus goods and services, reached Q10,218 that is equivalent to a 137% increase in the cost of living.
- By 2014, 59.3% of the population was living in poverty, that is, more than half the population had a consumption below Q10,218 per year.
- Between 2000 and 2014, total poverty increased by 2.9%, from 56.4% in 2000 to 59.3% in 2014.

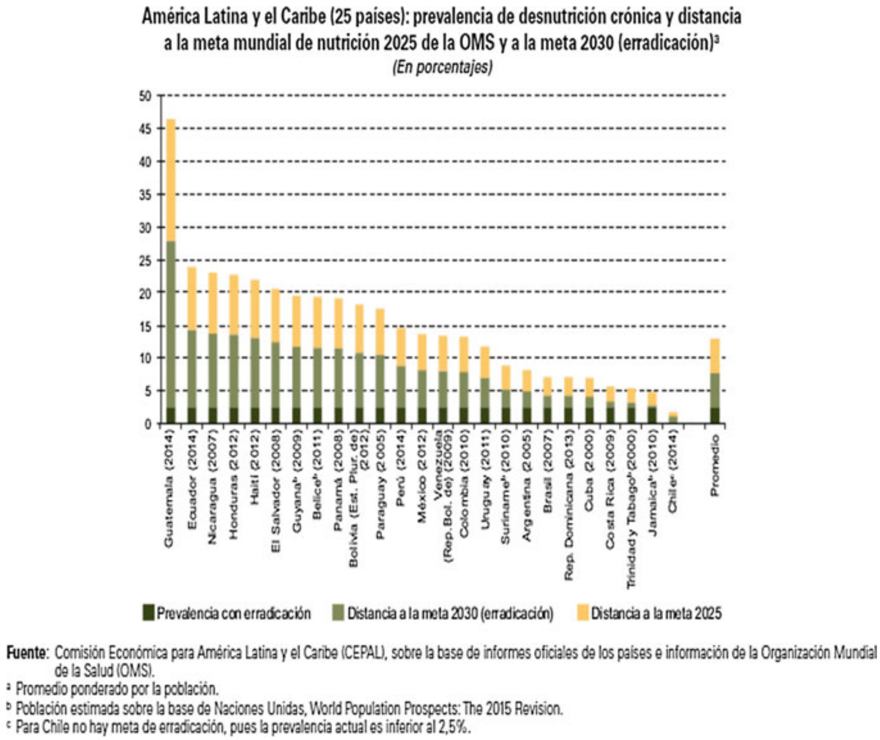
This, in turn, has causes and consequences related to the environment and climate change since it is the population living in poverty that lacks the instruments needed for adaptation. The poor population also largely suffers the vulnerabilities referring to the existing deficits in Guatemala and the necessary instruments to face this situation. Graphic 30.3 displays a dimension of malnutrition that explains largely the existing gaps in Guatemala. This factor tends to make the situation of living in poverty more vulnerable in relation to the natural and climatological factors. The relationship between abundance or scarcity of water with the nutritional levels is evident, as shown clearly in these figures in the case of Guatemala as compared to the rest of Latin America and the Caribbean.

Second Challenge

There are voids and opposing attitudes in the coordination of top decision-makers. It is necessary for universities, the private sector, civil society, the government and a shared and transversal ecological approach, to coordinate and make a difference regarding the effects of the environment and climate change in the context of a sustainable development. Deficits in these alliances are a missing characteristic of networks that have appeared in the current digital era.

These mentioned actors, sectors and dimensions are five protagonists that will be found by adding the mentioned stakeholders with the environmental and climate change approach. However, these concepts first began being three, called “the Triple Helix”, constituted by the academy, private sector and government, this concept has evolved to become later a “Quintuple Helix”.

To explain this challenge, it is necessary to delve into the explanation of the meaning of the so-called “helixes”. This trend emerged in the sixties, during the



Graphic 30.3 Latin America and the Caribbean (25 countries): Prevalence of cronic malnutrition and distance to the WHO world target of nutrition 2025 and the 2030 target (eradication). Translated by the author. It is warned in the notes below the Graphic that all figures for populations were drawn from United Nations sources and that they were used for deriving means affecting the countries shown. In addition, they mention that that for the case of Chile there is not target of eradication because, the target of prevalence is below 2.5%. As it is shown the worst situation prevails in Guatemala by a far distance.

Kennedy administration. His term that also were "Cold War" times, arose a troubling question: if enemies attack us-members of his cabinet asked themselves-with intercontinental rockets, how could we communicate in order to face that threat in a coordinated way? This is where the Defense Advanced Research Project Agency (DARPA) originates. The high military leadership, its headquarters being the Pentagon, soon saw the need to seek collaboration with universities and the private sector to materialize these innovations (González de la Fe 2009). The internet and its derived electronic innovations arises from this endeavor. Since 1997, an international research network on the Triple Helix (TH) model began to make international calls and meetings. They still meet every 2 years and even though they cover mainly developed countries, the "Four Asian Tigers" (Hong Kong, Singapore, South Korea and Taiwan) as well as Brazil have joined. These activities influence the emergence of entrepreneurial universities. There is no doubt that the

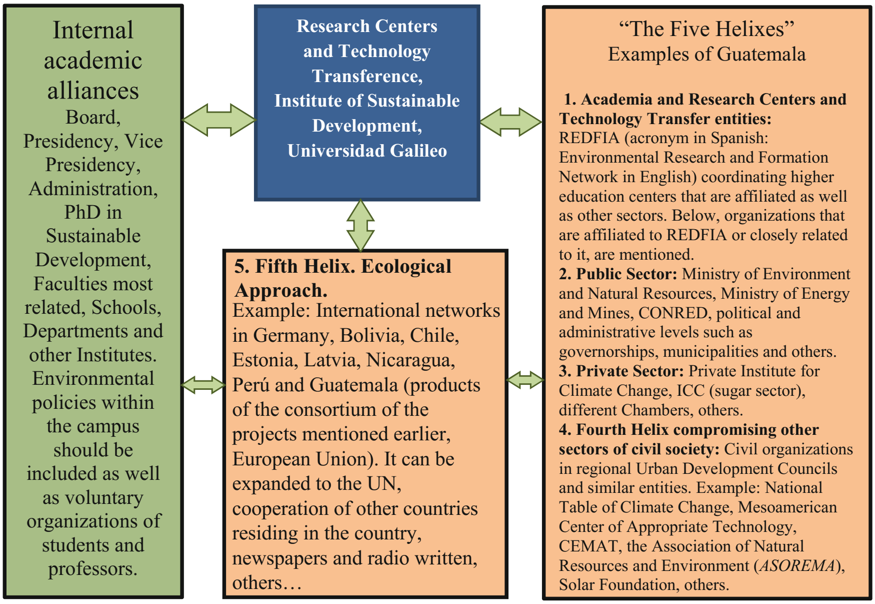
USA has a greater tradition of collaboration between the three sectors of the Triple Helix. The so-called "Silicon Valley", greatest source of innovation for the industries that make up the emerging "knowledge society", would not have been possible without TH alliances.

Henry Etzkowitz (2003) describes this movement in ten statements that synthesize this initial proposal of the TH and that then constitute the base for other extensions of it: 1. The source of innovation rests in triad networks, not independent work. 2. The social construction becomes as important as the physical devices. Examples found are business incubators, science and technology parks and their projection. 3. The model is interactive in the transfer of knowledge. Innovation arises when another sphere somehow originates, participates or assists. 4. "The capitalization of knowledge" happens in parallel with the "adoption of knowledge of capital". The first one invents new measures of research funding. Companies apply this knowledge. 5. The formation of capital is recycled in different ways: financial, social, cultural and intellectual. Who do you know?, and what do you know?, are essential and also interchangeable. Financial capital arises from this. It accumulates and intensifies accordingly to amount of triad collaboration. 6. Functional and territorial globalization contributes. 7. This makes achieving goals easier for sectors and territories that are lagging behind. 8. Reorganizations revolve around new opportunities in new technologies. 9. Universities become a source of horizontal and vertical development and according to this experience are reoriented. 10. Transformations become easy when technology renews and new networks arise.

However, missing in the previous description of the TH is the one using the innovation, who at the same time is the citizen and whose collective is Civil Society. This gives rise to another helix, in addition to the ones of the triad. In fact, having had experiences in national (Guatemala) and international networks, a fourth helix came to the fore for the developing countries case. Originally, it was unknown that there were already made efforts in such direction (CLIQ 2008–2011). Notwithstanding, these contributions were accepted and are an integral part of some efforts in Guatemala.

On the other hand, it is necessary to point out that there has been continuity in this approach within the environmental and sustainable development concerns (Leal et al. 2012; Amaro et al. 2012, 2014; see also http://www.galileo.edu in the Research section and in Publications of the Sustainable Development Institute within the same address). This expansion is accentuated with the recent proposal of an ecological helix, whose crosscutting insertion will give meaning to alliances between universities, the private sector, the government and civil society (Carayannis et al. 2012). Thus, this development is complete.

Graphic 30.4 exemplifies a real practice of this approach for the case experiences in Galileo University of Guatemala. The five helixes tend to incline towards the right of this graphic, placing existing related research centers towards the middle, specifically the Sustainable Development Institute that directly delves into the coordinated actions being undertaken. In addition, towards the left, the hierarchical structure of the university has their place, vertically, from its senior managers to the different faculties, administrations, institutes and other dependencies that compose



Graphic 30.4 An specific example of the "Five Helixes" approach at the Galileo University in Guatemala. *Source* Own design of the author

it. This formation must support in its group the approach of the "Quintuple Helix", which is integrated by other universities, the private sector, government, and civil society (NGOs, lobbies, and trade unions, among others). International aid is also another factor. This outward vision facilitates action within the University itself. In fact, the Board of Directors has already approved an Environmental Policy that directs sustainable development actions towards the campus itself.

The question that arises after describing the alliances comprised by a network containing each component of the "Quintuple Helix" is what could be the main problems that decision-makers can encounter, in order to reach the proposed goals. This approach draws from the nature of each entity belonging to each one of the helixes.

Universities often receive criticism for creating "ivory towers", to isolate themselves from the surrounding society. These attitudes largely stem from fear of interferences in research and teaching practices at the university of specific interests, whether of ideologies, power organs or external value systems. This may stem from governments jealous of their influence or from certain guilds pursuing immediate interests. In this sense, high education activity portrays a defending attitude towards the freedom of professorship and research, and convenient to step aside from this kind of contradictions and biases in order to have a broader and neutral view of society. It cannot be forgotten that it was in higher education institutions where the words "Faculty cloister", meaning confinement, originated.

That was the name used to refer to main researchers and professors belonging to a certain area of knowledge.

The theory of the "Helixes" goes a step beyond this dilemma. It calls for the innovation of behaviors. The approach prior to this one sees academia, industry and government as separate entities. There is a lack of sufficient evaluation and feedback of the knowledge created in the academic environment, while the learning needs for solving society's problems, which no citizen can forgo, are being lost. Therefore, a separation between basic and applied research emerges, and Education Ministries become isolated from the rest of the government and agents of change. This also has an impact in funds that fail to address urgent and problematic needs of the broader society.

The new approach stems from historical crises that separate societies into "developed and developing countries". Authors like Schumpeter (1966, 1978) call innovation in the industry as a fundamental engine to achieving this goal. The separation between basic and applied research calls for a collaboration between the academy and the industry to close this gap. On the other hand, the relationship between the energetic problem and its crisis since the 70s, create the need to search for new horizons. For this reason, starting in the nineties, the concept of "corporate social responsibility (CSR)" emerges, which was an absent value in the first stages of development.

However, attitudes in the private sector stem from different premises. Here there is also a fear of alterations to the "free supply and demand law" in a market that needs to be seen as free from pressure. The government and other forces alter prices. At the end, there is a conviction that these interventions thwart economic development and welfare of the masses. The important thing is therefore the return on investment and perceived rent, which must be free from any influence that might limit it. Notwithstanding that there are corporations that are oriented to the practice of social responsibility, many others prefer the inherent attitudes of a free market and the search of profit as supreme value. This may hinder alliances and networks in fields sensitive to sustainable development.

Civil society is also not free of thought currents that conspire to approach and consolidate alliances with other sectors. Specific sectors of them defend particular interests that have incidence in lobby practices, as would be the case of certain pressure groups. This situation is so varied that it makes these efforts appear as dispersed and often contradictory and short-term. These actions stem from diverse funding as a response to interests that are often disparate. In the end, many of these investments appear as a cost that does not fulfill the objectives sought. The tensions resulting from hydroelectric investments in Guatemala, mainly because of their water operations, are an example of this. Here national and local governments, private sector and neighborhood associations often assisted by NGOs, are seeking multiple and diverse ends that require a greater coherence. This dispersion is a weakness that is necessary to combat.

The government also suffers from tendencies that could hinder possibilities of alliances and broader networks. The new trends of the digital era and the access to knowledge and new practices induce horizontal relationships while the strength of alliances depends less on hierarchical and vertical structures. The latter are precisely the characteristics of organized state entities. The officers that comprise these public organisms tend to consider themselves as "rulers" of areas of their concern. Often they behave with citizens as if they are entitled to be obeyed without discussion or dissent. Therefore, the government places itself in a position of command that often drives away possible collaborators. The service attitude that leads to more horizontal relationships and broader alliances is less cultivated. This call does not mean that the state restraint of attending specific benefits addressed to specific territories related to citizen's common welfare. The state should continue to be responsible for these actions but in a more democratic way and less authoritarian manner. This vertical conduct can thwart any attempt to vertebrate helixes as an effective strategy.

Third Challenge

This dimension entails the need to create a decentralizing strategy to separate service providing functions that will eliminate gaps towards the local population downstream, which can be applied to the necessary adaptation measures to address sustainable development, environmental and climate change threats.

Before delving into the possible alternatives that could achieve a constructive relationship in this field, an opening is necessary to introduce arrangements with all the factors involved in investment decisions in the chosen territories. Here, some of the alternatives needed to make this a reality, based on the legal framework or making use of it respecting its premises. The modalities of Guatemalan reality that can intervene in the eradication of social unrest at local levels related to the extractive industry and other related industries as well, are the following (10) are illustrated below and then Table 30.2 summarizes another nine preceding those 9, for a total of 19 modalities):

(1) *A precondition: The Agreements of alliances within a decentralizing strategy*. This modality is the first in a series of conditions that should accompany decentralizing efforts depicted above. There should be a greements between all network stakeholders. It is the way to revert the centralist and vertical tendencies. Then the municipality and local institutions become an axis for the immediate expression of the community. The municipal government and universities may lead the organizing role of many of the needed functions and activities. Universities may act as advisors of official public institutions, while private entities and civil society may assume other responsibilities. One such agreement might be the creation of new administrative structures, beyond national, regional, departmental and municipal boundaries such as basins. The territories influenced by basins, whose boundaries and legal limits do not coincide with the existent ones, are those that interact with "Dry Corridors". They do not have a legal status in the country as a whole. Basins run across many political administrative structures and hierarchies, regardless of the unique climate change threats they represent.

In this manner, certain modalities involving community participation and its rationality can find a clear expression at a municipal or local level. Alternatives to strengthen alliances and networks become operational. Table 30.2 lists

Table 30.2 Separation of the functions of organizing, producing and funding of municipalities and organized neighbors granting access to civil society, private enterprises and universities

Modality	Coordinator	Producer	Payer
(1) Direct sale through improvements contribution	Municipal Government or University or both	Municipal government	Civil Society (consumer) or Private Company. Both focused on target population
(2) Contract	Municipal Government or Universities or both	Civil Society, Private Company or University or all	Municipal Government or Private Company or both
(3) Franchise (exclusive)	Municipal Government or Universities or both	Civil Society or Private Company or both	Consumer Civil Society or Private Company or both
(4) Franchise (multiple)	Municipal Government or Universities or both	Civil Society or Municipal Government or Private Company or all	Consumer Civil Society or Private Company or both
(5) Grant	Municipal Government or Universities or Civil Society or all	Civil Society or Municipal Government or Private Company or Universities or all	Municipal or Central Government through the former, Companies or Civil Society (supplier or consumer) or International cooperation
(6) Bonds or cash or exchange instruments given directly to the population	Municipal Government or Universities or Civil Society or all	Civil Society or Municipal Government or Private Company or Universities or all	Municipal or Central Government, Companies or Civil Society (supplier or consumer)
(7) Market	Civil Society	Civil Society	Civil society (consumer)
(8) Social investment funds	Municipal Government or Universities or both	Civil Society or Central Government or Municipal Government	Central Government or Municipality or international sources or Civil Society
(9) Self-service	Civil Society (NGOs), Universities or both	Civil Society (NGOs) or the affected population	There isn't. They are self-help programs. Ex. Construction of own housing

modalities with which the company that makes investments in any local territory can coordinate actions with the municipality, private enterprises, civil society and if appropriate with universities to implement actions leading to the sustainable development of communities. These agreements include paying attention to environmental and climate change threats. This condition would lead to the following articulations in discernible modalities:

(2) *The National System of Urban and Rural Development Councils*. The present Constitution of the Republic of Guatemala became legal in 1985 and the law on these mentioned councils got this same status since 1987. The structure covers the national, regional, departmental and municipal levels, and reaches villages and communities, in the recent changes approved in the year 2002. This legislation had approval together with a new Municipal Code and Decentralization Law. More local modalities are available here for actions to bring sustainable development to local territories. In these Councils, by law, the "Quintuple Helix" might be represented at all levels as well as this modality is represented in the Climate Change Council, which is headed by the President of the Republic of Guatemala, thanks to a law approved at the end of 2013.

(3) *The municipal or local development advisory commissions*. This modality is legislated in many countries on all continents, including Africa and Guatemala. It is about creating platforms where Mayors can share responsibilities with the Corporation and the most decisive forces of the community. For example, article 17 of the Municipal Code grants neighbors the right to integrate a municipal social audit commission (Curruchiche and Linares 2012).[1] Other representations might be incorporated if needed.

(4) *Open meetings to call the entire community such as Public Hearings and Open Town Hall Meetings*. These encounters are of an advisory nature. They might call "representatives of local organizations", such as communal groups, civil society organizations, trade unions, ecological lobbies and others. Public Hearings could stimulate a more open presence than the Open Town Hall Meetings. Today, this modality could become a prelude to appeal to the parties regarding problems concerning the environment and climate change, in such a way to ensure a reconciliation, before making use of the courts of justice. Another more modern goal of Public Hearings is to debate and clarify issues or alternatives that require decisions on behalf of the municipal authorities. This way, the Corporation can invite representatives of the "Quintuple Helix" such as central and municipal government authorities, technicians, stakeholders and neighbors, to provide information and points of view for common benefit.

The objective of this modality then points towards the implementation of a formal modality in which the Municipality acts as arbiter and manager in the task of said community through the handling of issues of common benefit. Like the Open Town Hall Meetings, this mechanism, must be cautious when the municipality itself is part of the case and there are questions for inaction on this matter. The most modern conception implies identifying subjects, inviting the people most related to important decision-making of the municipality, holding the audiences with the greatest possible amount of publicity and eventually taking a stand on the issue.

[1] All specific references to the legislation quoted belongs to the aforementioned document that is listed at the end of the text in the section of "References".

In almost all Latin America, including Guatemala, there is the modality of Open Town Hall Meetings and has a tradition that had its greatest surge in Latin America during the Wars for Independence at the beginning of the 19th century. Municipal or local corporations responds this way to the requests made by participants about their management system. This modality is The Municipal Code of Guatemala in Article 38 contemplates this modality. The meeting will link municipal authorities and community leaders in the solution of specific problems like garbage management; the creation of joint ventures to manage markets, the consequences on social services due to the presence of free zones or new industries, etc.

The tensions that these meetings face are conducive to the creation of the commissions described previously that provide solutions to potential or actual tensions. The objective in this modality points to the usefulness of the commissions in case of concrete problems that have possible short, medium and long term solutions. Technical assistance often supports the commission with a specialized report that is usually required in the deliberations for decision-making. This technical report should also contribute to the deliberations made in the so-called Public Hearings and Open Town Hall Meetings. This is a role that universities can fill with professors as well as students.

(5) *Stakeholder consultation*. This action aims to consult the affected population on crucial aspects of their work. This modality aids the Mayor when he is in the dilemma of making decisions that may seem unpopular. Article 38 of the Municipal Code of Guatemala contemplates this possibility. This is particularly helpful in the case of the Mayan population that constitutes a high percentage of Guatemala citizenship, international agreements supports this alternative.
(6) *Municipal and Governor Elections*. This is a decisive channel for the relationships between the community and municipal authorities. Probably the most decisive. It is a kind of final evaluation of local public management. The possibility of allowing the presentation of independent candidates from local levels, independent of national political parties, is already a reality in Guatemala. There are Civic Committees. However, in Guatemala the election by popular vote of governors is missing. His appointment is an attribution of the Executive Branch (the Presidente of the Republic) but according to a list of candidates submitted by bodies where Civil Society organizations are represented.
(7) *Local auxiliary authorities in territorial levels smaller than the municipality*. Decentralization does not end in the place where the municipality is located. There are auxiliary Mayors or equivalent modalities in smaller constituencies in Guatemala such as administrative posts, towns, neighborhoods, settlements, villages and hamlets.
(8) *Traditional forms of civic organization of the community*. In Guatemala, with a high percent of its population being of Mayan descent with pre-Hispanic influences, there is concern over traditional leadership conveyed by the presence of so-called “indigenous Mayors” along with Mayors elected in the same

circumscription without this cultural component. Article 23 of the Law on Urban and Rural Development Councils, establishes an Indigenous Advisory Council that will provide its services to both the Municipal Council of Urban and Rural Development (COMUDE, Consejo Municipal de Desarrollo in Spanish) and the Community Development Council (COCODE, Consejo Comunitario de Desarrollo in Spanish). The forces of modernity have often forgotten these structures and have preferred to establish in the communities new leaderships that compete with traditional leaderships. Lessons learned have favored the incorporation of these forms to the national development goals.

(9) *An administration for the people: house-to-house visits, government days in the neighborhoods and villages, audiences with the Mayor, direct telephone line, radio audiences, annual management accountability*. Their common denominator is a Mayor or Administrator "facing the people" through different means without a need for meetings. The various modalities are self-evident and require no further explanation. Their goal is to create a transparent government that is held accountable by the citizens and is responsive to their demands.

Specific modalities could be created by decentralizing functions at all levels and sharing responsibilities and benefits among the participating helixes. Table 30.2, makes a list of these distinctions that cover the activities that might be carried out and distributes them among the members of the helixes in a conjoined manner. The following alternatives that depend on the different situations presented for their implementation are enumerated next. The idea is to strengthen the objectives of sustainable development taking into consideration a "give and take" that leads to a win–win situation for all stakeholders. Local conflictive situations are conducive for the application of these modalities.

(10) *Integral approaches to people's participation*. Here the experience of the city of Porto Alegre in Brasil must be emphasized, because it does not fit into any of the modalities formerly described and can only be implemented if there is a high political will and integral outreach to incorporation of neighbors to the municipal management system. This experience is relevant because it has already been implemented for over 20 years and has managed to survive over time overcoming one of the problems of participation that once the external impulse ceases or discouragement begins, activities tend to decrease.

This experience is well documented (Genro and de Souza 1999; Harnecker 2000a; Lenin 1920). To carry out this activity, the municipality has been zoned and the population has organized around Popular Councils that in turn appoint representatives called "delegates" that participate in a Participatory Budget Council. There is a timetable and regulations for the entire annual budget discussion.

This process includes two plenary sessions, intermediary meetings between the neighbors and the administrative structures of the municipality and the selection of topics among which the neighbors will select priorities. For them "service forums" and "delegate forums" are also held. Priorities are decided on four main problems of their region or thematic priorities that are chosen among eight subjects: basic sanitation, housing policy, paving (asphalt, water and sewage systems), education, social care, health, transportation and circulation, and organization of the city. This is a collective decision. All of the above is collected in written documents for each region and there are indicators used to create the regional budget matrix. This way, a priority in one region may be the last one in another. From a technical standpoint, the Municipality has created a Regional Coordinator of the Participatory Budget (CROP) dedicated to this instrument and the need for a Forum of Community Counselors (FASCOM) that has emerged during the discussion process.

The alliances of the "Quintuple Helix" might be observed in Table 30.2. The organizing function refers to the design, regulation and evaluation of this decentralization. The productive function to those responsible for generating benefits for the population and paying function to those called on to finance this operation. The modalities can be combined and the representations of the networks could vary according to the nature of the good, service or benefit to which it pertains. In this sense, Table 30.2 offers s theoretical example to applicable global aspects such as citizen organization, training and any of the phases of planning and evaluation. Modalities depicted in Table 30.2 are explained in the next sections.

(11) *The direct municipal sale of a good or service and the contribution modality for improvements*. As the government authorizations and investments of the corporations materialize, the Municipality can take on services or examine those it already manages. A first approach is to examine the demands generated because of these changes. In light of scarce resources and considering new sources of income for the municipality and the generation of employment opportunities among the citizens, a possible approach is to share the costs with the consumers of said services and the community, involving the representations of the "Quintuple Helix" in the formulation, funding and delivery of such services. Regarding its funding, it is necessary to remember that in addition to consumers, private companies can also be held accountable in reducing the impacts of their local investments, under the premise that "whoever pollutes pays".

This way the local government becomes more solvent. The participation not only implies rights, but also responsibilities. An example of this is the "contribution to improvements". This seems to work best when the population directly participates as salaried local labor. The participation of universities in this modality appears in their character of advising based on placing specialized support personnel with the authorities in order to regulate and asses the progress of the operations undertaken. Many universities in Guatemala already have such mandate through the Supervised Professional Exercise (EPS), by which professors and students, share responsibilities in activities required to complete their undergraduate studies. These requirements could easily be channeled towards activities that address environmental and climate change threats.

(12) *Contract*. This modality would preferably be applied to technical assistance and service needs. In fact, for sewer and sewage treatment, municipal private companies could be hired. Construction is also susceptible of being ordered by contract. Operations that do not match those of the Municipality, like maintenance and transport repair, might be hired elsewhere. This could be extended to airport operations, garbage collection, cemetery management, food programs, etc. Labor for the construction of sewers can also be hired with community organizations. In this sense, the modalities above can be combined in order to achieve a better option. The corporation itself can be subject to contract by producing goods that fulfill the needs of neighbors. For example, extending electricity to neighbors who lack it could be one of those benefits.

(13) *Franchise (exclusive)*. The Municipal Government acts as organizer, granting a monopoly of production of a service to a firm, whether for profit or not. The difference with the contract is that the payer is no longer the government, but the citizen who consume the good or service, or the investing company. If there are agreements to do so, civil society organizations or the investing corporation can make the payment to the hired firm.

The Municipality usually maintains total or partial control over prices, and it can negotiate them even when this function is beyond their sphere of competence. This modality is best applied to public services like water, electricity, slaughterhouses and transport. For example, granting the municipal trail to livestock associations has these characteristics.

(14) *Multiple franchise*. Table 30.2 shows a similarity between the previous modality and this one. The difference is that in this modality the concessions are given to several producers. This creates a market with certain competition that can benefit consumers. Certain systems can be used to make the public sector compete with the private sector, allowing the consumer to choose. In this modality, the producer can also be the community in any of its forms, but both the organization as well as the payment are made by a private company or the consumer civil society or both.

(15) *Subsidy*. This modality is self-explanatory. An inherent problem in this arrangement is the creation of dependencies, in cases where there is not an alternative. This is important to bear it in mind. These situations refer to natural disasters, support for disabled people, situations of the population or people who are incapable of fending for themselves, etc.

(16) *Bonds*. This modality is also used to promote access to certain goods and services. Unlike subsidies, where the support goes to the producer and consumer options are restricted, this modality supports the consuming citizen who is able to see their preferences multiplied at a lower cost to the state. Modalities like this have been tried in Guatemala regarding food security, health and education.

The bond is distributed through regional and local state agencies. With that bond, the beneficiary can go to any business and trade it for food products and services of their preference. The merchant can then exchange said bond for cash. The result is to expand the net coverage of education and health and to increase business income without the need to create an additional bureaucratic structure.

This modality as described previously can be extended to education and health if desired. This way the citizen will select those services that fulfill their basic needs. The organizer of the bond modality is the consumer, who can freely follow their preferences without any imposition. The producer is the existing private sector, operating within the market, which are available to the consumer. Finally, who pays is the Central or Municipal Government and ultimately the food donor that could even be the investing private company in this territory.

(17) *Market*. This modality is created to balance the excess of management of the municipality in activities that should be carried out by the private sector or other civil society organizations with the pursuit of service or profit. In this case the consumer orders and pays for the good or service. The civil community, created for profit or not, is in charge of offering the good or service in accordance to the laws of supply and demand.

In many cases this formula allows certain criteria on behalf of the Municipality. For example, the Municipality can be a promotor of certain goods and services that can create job opportunities within their jurisdiction. Neighbors can go to a Bank in order to carry out public works in benefit of a neighborhood, such as the paving of a street. The municipality or local administration can in this case endorse neighbors so they are able to obtain a loan from the banking system at the existing rates. The payment is distributed among the beneficiaries. In this case, the municipality played a facilitating role allowing the market to operate for the benefit of everyone.

(18) *Social Investment Funds created from the own funds of local levels*. The so-called “Social Investment Funds” have accompanied structural adjustment policies for some time in most of the world. As the economies of these countries are reactivated, there is less justification for the emergency and short-term orientation of this instrument. For this reason, they have transitioned from Social Emergency Funds to Social Investment Funds. They are mainly destined to infrastructure although a percentage has been destined to social programs and loans to small-scale entrepreneurs, depending on priorities.

NGOs and civil society in general, including neighborhood organizations, can play a major role. They can participate in the organization of the type of product or service they wish to deliver to the population. Production can be hired from either lucrative or non-lucrative private sector or with any other formula derived from the community. Finally, the payment is made by the contracting entity that might come from central or municipal government or even from international sources.

(19) *Self-service*. This is the simplest way to meet local needs for goods and services. The difference from committees is that the contribution is individual. All actions related to prevention, are placed under this area. Some of the individual activities that can contribute to a better municipality are garbage-recycling, precautions taken when disposing cigarettes, vigilance and security regarding crime. Savas (1987, p. 128) states that "Family as a self-service unit, is the original and most efficient department of housing, education, welfare and human assistance, and it provides a wide range of vital services to its members."

While these modalities can be abstracted in reality, in practice the same service can be provided with a combination of the actors outlined above. The common theme that underlies the presented arrangement is that these activities will not be carried out while the population remains absent from municipal management or with such tensions that it does not allow an orderly participation.

Conclusions and Recommendations

The main purpose of this elaboration has been to draw attention to the different dimensions of sustainable development, which are crucial to combat environmental pollution and the threats caused by climate change. To this end, the following conclusions and recommendations might be drawn from the former discussion:

1. These statements and the paper has its limitations. The statements made reflect a preference of the author with regard to many other alternatives and courses of action that might be taken on the basis of the findings presented. Particularly, one has to realize that the exercise of linking sustainable development with a multidisciplinary perspective and its ecological dimensions is relatively new. There are still gaps that have to be filled. Many years have elapsed since development as such found a niche in research and policies. A multidisciplinary perspective was absent for many years. A sectorial division of knowledge and practice prevailed for a long time. In a way, these discussions about priorities in sustainable development is a starting point and as such as all beginnings is an initial outlook that has limitations and calls for further clarifications. The risk of not doing so, will be the prevalence of former views already superseded.
2. Relations have been established among the different Sustainable Development Goals, approved by more than 190 countries at the United Nations General Assembly at the end of 2015. Global experiences indicate that there would be an intimate relationship between the final goal of eradication of poverty and the populations most affected by climate change whose effects lead to serious nutritional deficiencies.
3. On the other hand, this confrontation also calls for an alliance between different social sectors that could jointly and simultaneously articulate actions in order to achieve the desired goals by the year 2030.

4. The complexities of each country and the effects of these situations lead to the examination of these situations for Guatemala. In order to carry out this verification of the Guatemalan reality, three primary challenges were selected, without which hardly a difference could be made in the future.
5. The actions designed in the past are not truly sufficient to make a difference. Economic growth does not reach levels that actually reduce poverty significantly and it is a known fact that there cannot be distribution of wealth without an outstanding economic growth, which should at least reach the level fixed in the Peace Accords that mention the need to achieve 6% rate of economic growth.
6. Populations living in poverty, exemplified today by those suffering in Guatemala's "Dry corridor", reach hundreds of thousands, displaying nutritional levels that place Guatemala among the most desolate countries in terms of nutrition and hunger levels.
7. Actions carried out by the government alone do not appear to deliver the desired results. Only 30% of the population has been benefited by the program especially designed for this purpose last years.
8. This situation leads us to the realization that the government alone is not enough and that greater alliances are needed, in addition to significant economic growth and an effective distribution. This distribution requires also effective actions, which are decisive in physical infrastructure, human capital formation and quality of life. This leads us to the second challenge that targets the lack of effective coordination of all relevant sectors in this field.
9. These alliances support results achieved in other countries regarding the "Quintuple Helix", around which networks are built and the government establishes systematic and continuous alliances with the private sector, civil society and academia in order to make a difference in the challenges found when facing climate change and hunger, based on effective national partnerships.
10. However, the challenges do not end there. The tendency of action dispersion by each sector received a special attention. Particularly, civil society organizations that revolve around a myriad of objectives should put emphasis in collective priorities to make viable the activities of the networks.
11. This way, universities must turn more towards a broader society. The private sector, for its part, must display greater openness to corporate social responsibility. Civil society, constituted by myriads of public interest including lobby institutions, should avoid dispersion and multiplicity of goals and purposes, in order to make actions more effective. Finally, the government should avoid the tendency to see society in a vertical way and, following the digital era, propose more horizontal cooperation relationships, that emphasize relations based on solidarity rather than those based on authority,
12. To seal a third challenge, it is necessary to bring efforts to local levels including the most remote territories. This effort requires a decentralizing orientation that is innovative as well, because historically centralized decisions tend to dismiss the most vulnerable populations in rural and remote areas. In this sense, this

challenge requires different modalities or approaches in which alliances among the different stakeholders of the "Quintuple Helix" make joint efforts. This elaboration suggests 19 modalities that give rise to different courses of action in order to solve this dilemma.

13. The modalities suggested have a solid basis thanks to citizens' representations and agreements or conventions, made by municipal and local development councils, advisory commissions, public audiences and/or open councils.
14. Also, there is a need of direct citizen consultations, municipal and governor elections, local auxiliary authorities, openness to traditional organization structures. There is a need of administrations that "face the people" within an integral approach to community involvement, sale of services to citizens, contracts to satisfy population needs, exclusive and multiple franchises capable of generating specific benefits.
15. In addition, other modalities discussed were subsidies when there are no other alternatives, bonds that grant access to specific services, appeals to the market when necessary, social investment funds that are already practiced in Guatemala and many countries, and finally, appeals to the citizens to provide labor free of charge, for their own benefit.
16. All these modalities can combine according to the nature of the selected benefit. What is common is the presence of stakeholders oriented towards public citizen goods. These actions along with an effective representation on behalf of the academia, private sector, civil society and government, accompanied by a battle against poverty stimulated by significant economic growth, will be the courses of action that can make a difference regarding the Sustainable Development, environmental and climate change objectives of the future.

References

Altamonte H, Sánchez RJ (2016) Hacia una nueva gobernanza de los recursos naturales en América Latina y el Caribe. Santiago de Chile: CEPAL, Cooperación Alemana y Española y Ministerio de Asuntos Exteriores de Noruega

Amaro N (2012) The role of renewable energies and universities toward climate change in the light of past development experiences, 1960–2010. In: Leal Filho W, Gottwald J (eds) Educational and technological approaches to renewable energy. Peter Lang, Frankfurt, pp 11–40

Amaro N, Ruiz C, Fuentes JL, Miranda J, Tuquer E (2014) Strategic contributions to extreme climate change: the innovation helixes as a link among the short, medium and long-terms. In: Leal Filho W, Alves F, Caeiro S, Azeitero UM (eds) International perspectives on climate change. Latin American and beyond. Springer, Switzerland

Carayannis EG, Barth TD, Campbell DFJ (2012) The quintuple helix innovation model: global warming as a challenge and driver for innovation. J Innov Entrep. doi:10.1186/2192-5372-1-2. http://innovation-entrepreneurship.springeropen.com/%20articles/10.1186/2192-5372-1-2

Castellanos E, Guerra A (2009) El cambio climático y sus efectos sobre el desarrollo humano. Cuaderno de Desarrollo Humano 2007–2008 1. Guatemala: United Nations Development Program

Cliq (2008–2011) Creating local innovation through a quadruple hélix. Aunque este esfuerzo se basó en un proyecto que terminó en el año 2011, sus contenidos pueden recuperarse en: http://www.cliqproject.eu/en/cliq_project/?id=2

Contreras G (2016) Piden alimentos 65 mil familias. Prensa libre, (9 August 2016) p 6

Curruchiche J, Linares L (2012) Manual para un municipio participativo. Guatemala: Fundación Konrad Adenauer-Serviprensa

Etzkowitz H (2003) Innovation in innovation: the triple helix of university-industry-government relations. Social Sci Inf 42(3):293–337

Genro T, de Souza U (1999) Presupuesto Participativo: la Experiencia de Porto Alegre. Editora Fundación Perseu Abramo, San Pablo

González de la Fe, T (2009). Modelo de la Triple Helice en relaciones universidad, industria y gobierno: Un análisis escrito. AMBOR, Ciencia. Pensamiento y Cultura, CLXXXV 738, 739–755. doi:10.3989/arbor.2009.738n1040. http://arbor.revistas.csic.es/index.php/arbor/article/view/327/328

Harnecker M (2000a) Delegando Poder enla Gente. El Presupuesto Participativo en Porto Alegre. Habana, Cuba: MEPLA. http://www.rebelion.org/docs/95167.pdf

Harnecker M (2000b) Cómo vio Lenin el socialismo en la URSS. América Libre, 18. http://www.nodo50.org/americalibre/anteriores/18/harnecker18.htm

Instituto Nacional de Estadísticas (INE) (2015) Republica de Guatemala, Encuesta de condiciones de vida 2014, principales resultados, ENCOVI. https://www.ine.gob.gt/sistema/uploads/2015/12/11/vjNVdb4IZswOj0ZtuivPIcaAXet8LZqZ.pdf

Kuhn T (1962) The structure of scientific revolutions. University of Chicago Press, Chicago

Leal Filho W, Gottwald J (2012) (eds) Educational and technological approaches to renewable energy. Peter Lang, Frankfurt

Lenin WIU (1920) Conferencia del PC(b)R de la Provincia de Moscú. Moscú: O.C. (20–22 noviembre). Citado por Marta Harnecker

Ministerio de Agricultura y Ganadería, MAGA (2010) Diagnóstico a nivel macro y micro del corredor seco y definición de las líneas estratégicas del MAGA. Guatemala: MAGA

Ministerio de Ambiente y Recursos Naturales, MARN, Gobierno de Guatemala (2015) Contribución prevista y determinada a nivel nacional. Ciudad Guatemala, MARN

Ministerio de Ambiente y Recursos Naturales, MARN, Gobierno de Guatemala (2016) Documento descriptivo. Plan operativo anual 2016. http://www.marn.gob.gt

Muñoz Palala G (2016) SESAN no publica que desnutrición crónica en el país aumentó. Prensa Libre. http://www.prensalibre.com/guatemala/comunitario/piden-que-se-evaluen-estrategias-para-reducir-la-desnutricion-cronica. Accessed 29 Jan 2016

Naciones Unidas (2015) Convención Marco sobre el cambio climático. París: FCCC/CP/2015/L.9, (diciembre)

National Bureau of Statistics of China (NBS) (2016) China's Economic Indicators' List. http://chinaindicators.yukihotaru.com/gdp.html

Programa de Naciones Unidas para el Medio Ambiente, PNUMA y Parlamento Latinoamericano y Caribeño. PARLATINO (2015) Aportes legislativos de América Latina y el Caribe en materia de cambio climático. Panamá: PNUMA/PARLATINO

Programa de Naciones Unidas para el Desarrollo, PNUD y Programa de Naciones Unidas para el Medio Ambiente, PNUMA (2013) Evaluación del bienestar humano y ambiente en el corredor seco oriental de Guatemala. Guatemala: PNUD-PNUMA

Savas ES (1987) Privatization: the key to better government. Chatham House Publishers, New York, p 128

Schumpeter J (1966) Capitalism, Socialism and Democracy. Unwin University Books, London

Schumpeter J (1978) Teoría del desenvolvimiento económico. FCE, México

Secretaría de Planificación y Programación de la Presidencia, República de Guatemala, SEGEPLAN (2012) Pacto Hambre Cero: Retos para Guatemala. http://www.mineduc.gob.gt/PORTAL/contenido/menu_lateral/programas/seminario/docs13/PACTO%20HAMBRE%20CERO.pdf

United Nations Development Program China (2015) China, the millenium development goals, and the post-2015 development agenda. http://www.cn.undp.org/content/dam/china/docs/Publications/UNDP-CH_discussionpaper-MDGPost2015.pdf

United Nations World Commission on Environment and Development (1987) Our Common Future. Oxford University Press, Oxford

UN News Centre (2015) Sustainable development goals kick off with start of new year. http://www.un.org/sustainabledevelopment/blog/2015/12/sustainable-development-goals-kick-off-with-start-of-new-year/. Accessed 28 Jan 2017

Author Biography

Nelson Amaro Guatemalan Sociologist born in Havana, Cuba. Currently, he is the Director of the Institute of Sustainable Development at the Universidad Galileo in Guatemala City, where he has led the development and successful launch of a Doctorate in Sustainable Development and a Masters in Sustainable Development with a focus on both the Private and Public sector. He holds a Bachelors from Universidad Católica de Santiago de Chile, master's level studies from Harvard University and MIT in Boston, and a Ph.D. in Sociology from the University of Wisconsin, Madison. He has dedicated more than 20 years of his professional life to multiple international missions such as the United Nations, USAID, the World Bank and others. In Guatemala he has also held the positions of Dean of Social Sciences at the Universidad del Valle of Guatemala, UVG (1995–2000) and Vice Minister of Urban and Rural Development (1987–1989). The author wants to thank Daniella Suger, Janna Dettmer and Marco Amaro, who helped in this article's translation.

Chapter 31
Climate Change in Latin America: An Overview of Current and Future Trends

Walter Leal Filho

Introduction

With an area of approximately 21,069,500 km^2, Latin America accounts for almost 3.9% of the Earth's surface. This is more or less the equivalent of 14% of the total land surface area. The population of the region exceeds 590 million, whereas its combined GDP of around US$5.16 trillion, attests its economic relevance (Leal Filho and Wolf 2014).

Similar to what is seen in other parts of the world, there are clear signs of the impacts of climate change to Latin American countries. The region, where a substantial portion of the world's biological diversity can be found, hosts a wide range of ecosystems including rainforests and semi-arid zones. The disruption of natural ecosystems is one of the main causes of biodiversity and ecosystem losses in Latin America, a proportion of which is due to human-induced climate change.

According to the Fifth Assessment Report (AR5) produced by the Intergovernmental Panel on Climate Change (IPCC 2014), climate change in Latin America is likely to contribute towards altering coastal and marine ecosystems, with mangrove degradation being observed along the coast of South America, for instance.

In addition, AR5 mentions the fact that significant trends in precipitation and temperature have been observed in Central America (CA) and South America (SA). Whereas precipitation levels have increased in some parts of the region (e.g., southern Brazil, Paraguay, Argentina), in other areas it has been visibly reduced (e.g. north east Brazil, Peru). In addition, there across the region evidences of prominent increases in the both the intensity and the frequency of a variety of extreme events such as:

W. Leal Filho (✉)
School of the Science and the Environment, Manchester Metropolitan University, Chester Street, Manchester, UK
e-mail: w.leal@mmu.ac.uk

W. Leal Filho and L. Esteves de Freitas (eds.), *Climate Change Adaptation in Latin America*, Climate Change Management,
https://doi.org/10.1007/978-3-319-56946-8_31

- droughts in Bolivia and Brazil
- heat waves in major cities in Brazil, Chile and Venezuela
- tropical cyclones in the northern part of the region bordering the Caribbean

Coastal areas are also very vulnerable (Villamizar et al. 2016) as a result of the El Niño Southern Oscillation (ENSO) events, which threaten its economy and sustainable development.

IPCC reports that around 600 extreme climate and hydro-meteorological events have occurred in Latin America between 2000 and 2013, including thunderstorms, hailstorms, blizzards, avalanches, coastal storm surges, floods including flash floods, drought, heatwaves and cold spells.

Furthermore, the region is subject to long-term damages due to the continuous and rather intensive exacerbation of the problems caused by or led by climate change.

One example can be taken from the progressive melting of the glaciers in the Andes, a trend seen in the 1980s (Clapperton 1983), whose rates in 2015 were among their fastest for 12 years, thanks to the record-breaking El Niño that is warming up the area. The countries most severly affected have been Bolivia and Peru, whereas in Chile this trend has also been observed. There are estimates showing that the lower-level glaciers in the Andes, below 5500 m, are really endangered now, whereas Rabatel et al. (2013) identified the variability of the surface temperature of the Pacific Ocean as the main factor governing variability of the mass balance at the decadal timescale.

Moreover, various natural hazards are becoming more frequent. For instance, hurricane vulnerability in Latin America and in the neighboring Caribbean region is a matter of concern, due to the substantial loss potentials they are associated with. In addition, severe droughts in Bolivia in mid-2013 ignited more than 47,000 isolated fires, damaging agriculture (which provides the livelihood for over 70% of the population of the region), destroying large portions of forests and creating health problems among the population, as well as affecting the country's air traffic. This was followed by a long drought as recently as in 2016, believed to be the worst in 25 years, in the context of which the Bolivian government declared a state of emergency making funds available to alleviate a crisis that affected thousands of families. It has greatly weakened the agricultural sector, which is yet to recover. Both reduced yields, and in severe cases, complete crop failure negatively affect the profitability and viability of farms, or even endanger the livelihood of small landowners who depend on basic crops to generate their income.

Elsewhere, droughts are still a major problem. According to the World Wildlife Fund (WWF) notable recent droughts are those that afflicted the Amazon in 2005 and 2010 and a drought in Southeastern Brazil that lasted from 2012 to late 2015 (WWF 2017).

One of the Latin America's largest cities, São Paulo, experienced its worst drought in over 80 years by mid-2015. The city's main water system, the Cantareira reservoir, supports the water needs of 5.3 million people, but by August 2015 it was at record low levels with less than 17% of its normal water capacitydown from the 9 million before the drought (WWF 2017).

It is clear that climate change poses a serious and additional threat to urban areas, but also to poor farmers and rural communities in the region, some of whom live in remote areas with limited natural resources, communication and transportation networks, and which have to cope with weak governance systems. A recent book provided a wide overview of climate change in the region (Leal Filho et al. 2014), and identified some of the on-going activities taking place across Latin America.

But despite the fact that some literature exists, there is a need for a better understanding of how climate change affects the Latin American region, and for the identification of processes, methods and tools which may help the countries and the communities in the region to adapt. There is also a perceived need to showcase successful examples of how to cope with the social, economic and political problems posed by climate change in Latin America, especially the vulnerable communities and traditional—especially native indian—populations.

Socio-economics and Climate Vulnerability in Latin America

As mentioned in AR5 (IPCC 2014) the nature and scope of climate change means that it should be considered not in isolation but in close interaction with other important factors for development. These include land-use practices and land-use change, population growth, economic situations, and community behavior, among many others.

In addition, part of the problems seen in coping with climate change in Latin America is due to the economics of the region. A significant proportion of the populations in Latin American countries is very poor. Recent estimates indicate that the proportion of the population living below the poverty line has overall slightly decreased, but the poorest 20% still live in countries such as the Dominican Republic, Nicaragua and Honduras http://povertydata.worldbank.org/poverty/region/LAC). But even in wealthier countries such as Brazil, Chile or Argentina, poverty levels are still significant, and their governments need to undertake many efforts in order to handle the consequences of poverty within their national borders. This means that their vulnerability is even greater and so is the likelihood of them being negative affected by climate change and its ramifications.

Cities such as Buenos Aires, Santiago and Mexico City for instance, have experienced intensive urban expansion and the intensity of buildings in the their city centres make them quite vulnerable to the setting of urban heat islands, causing discomfort and health problems to many of their inhabitants.

Across Latin America, weak governance systems means that national governments have not succeeded to address the fundamentals of poverty or to reduce poverty levels, hence perpetuating the social divisions found in society and, inter alia, have increased the vulnerability of the poor to the impacts of climate change even further. As indicated by Leal Filho and Wolf (2014), there are many problems and deficiencies which have been contributing to the high degree of vulnerability of Latin American countries to climate change. Among others, the following were listed:

- poor or non-existing climate change governance systems,
- limited awareness on the causes and consequences of climate change,
- endemic poverty,
- limited access to capital and global markets,
- continuous ecosystem degradation,
- complex disasters and conflicts,
- unplanned urbanization,
- limited capacity (personal and institutional) to address the problem and its many ramifications (Leal Filho and Wolf 2014).

As indicated by Hardoy and Pandiella (2009), much of the urban expansion in Latin America has taken place over floodplains, mountain slopes, or areas prone to flooding or affected by seasonal storms, sea surges or other weather-related risks (Hardoy and Pandiella 2009). Ironically, these vulnerable sites are usually occupied by the poorest sectors of the population, which seem to trade the risks posed to their properties and to their lives by living in these areas, in exchange for cheap housing.

Table 31.1 outlines some of the socio-economic factors which contribute to the vulnerability of the Latin American region to climate change.

It has to be said that the vulnerability of specific countries is also affected by their individual sensitivity to different problems hazards, when they occur. For instance, in the years 2015 and 2016, a surge of Dengue, Zika Virus and Chikungunya in Rio de Janeiro, Brazil, was deemed as associated with climate change, whose links with health were documented by Costello et al. (2009) earlier one. Recent works performed by various authors have shown that there are real evidences of the connections, which suggest that on top of all current pressures

Table 31.1 Some of the socio-economic factors contributing to the vulnerability of the Latin American region to climate change

Factor	Impacts
Weak governance	Lack of legislation to prevent land occupation/use in vulnerable areas
Lack of awareness of climate risks	Higher exposure to hazards and extreme events
Poor land use planning	Greater vulnerability in drought and flood prone areas
Economic hardships	Force the poor to build settlements in risky areas
Lack of stakeholder engagement	The poor are alienated and their needs are not brought to the political agenda
Existence of harmful hazards	Susceptibility to adverse health problems, injury or death depending on the nature of the hazards and degree of exposure
Depletion of natural resources and ecosystems	Reduction in the levels of protection against hazards or extreme events

posed by climate change to the region, health problems are likely to become even more intensive, draining further human and material resources.

There is therefore a perceived need to identify how each country´s vulnerabilities are structured, their extent and the many factors which influence them. Unfortunately, despite the need for research in this field, there is a paucity of studies on the impacts of climate change on those with natural (non-managed) ecosystem-based livelihoods. In addition, further research is also needed to identify those populations most likely to be impacted by climate change, and the means to mitigate these impacts. This will form a sound basis upon which adaptation measures may be duly identified, and successfully implemented.

Looking at the Future: Towards a Pro-active Adaptation Framework

The examples from the past 20 years show that Latin American countries have largely failed to fully address the causes of climate change, and to properly handle the many consequences of climate change to their economic systems and the well being of their populations. However, recent progresses seen in association with the Paris Agreement indicate that positive changes may be expected in the coming years. For instance, most countries in the region have prepared and are busy implementing national climate change mitigation and adaptation plans, many being busy trying to identify ways to reduce their CO^2 emissions. More importantly, climate change adaptation is becoming more prominent in the discourse of governments, partly as a reaction to the recent extreme events seen in Brazil and Bolivia, which have placed the theme more prominently in the political agenda.

Whereas in the past a wibe characterized by intensive discussions after specific disasters and extreme events took place, but subsequently followed by inertia, it seems now that a new way of thinking is becoming mainstream, whereas climate change is becoming a more permanent topic of discussions. As a result of the many casualties related to dengue and the Zika Virus, for instance, cities such as Rio de Janeiro and Salvador in Brazil are pursuing campaigns in the summer months to alert people about the greater risks a warming climate poses to the spread of the mosquitoes and, *inter alia*, to the increase in the levels of the diseases.

Whereas little can be made by normal citizens to mitigate climate change, and they have little or no control over the emissions of green house gases or on the variations of atmospheric conditions, governments across the region can play a key role in reducing vulnerability. In the long-term, Latin American countries need to set-up solid **climate change adaptation framework**, ideally to be composed by the definition of a long-term climate mitigation and adaptation plan for the region, with concrete sets of activities, along with a time-table as to when they are expected to be achieved, and with indicators of progresses at specific periods of time. This may help to address the many ad hoc and non-binding measures which are listed in many of the region's national climate change plans.

As part of a possible **climate change adaptation framework**, there are some key areas where Latin American governments could become more involved. By doing so, they could assist in fostering the adaptation capabilities in their own countries in a more sustainable way. Some of these key areas are:

1. Identifying the existing technology needs seen in their most vulnerable areas, so that these may be met. According to UNFCCC (2016), there is a potential across the Latin American and Caribbean region, for more market participation, especially with regard to agriculture and forestry-based instruments. If duly used, these may lead to a greater degree of resilience, and paralleled reduction in the levels of vulnerability.
2. Facilitating the technology transfer required for the implementation of adaptation and mitigation efforts. It is a fact that, within Latin America, there are successful examples and a variety of studies on adaptation, which show how it could be pursed in context as varied as agriculture, land use, urban planning and coastal zone management. Much could be gained if a system to facilitate such a transfer of technologies and the dissemination of good practices could be systematically and continuously pursued. The set-up of a dedicated networking infrastructure of Climate Change Technology Transfer Centres (CTTCs) performed in the context of the project CELA (http://www.cela.net) led to a better use of the science and technology knowledge existing in the partnering countries Bolivia, Guatemala, Nicaragua, Peru, Estonia and Germany. The Centres have also set-up local networks linking universities with further industry and government actors, and also with the civil society. More such initiatives are needed.
3. A greater and closer integration of climate change issues, especially risks and hazards, into national and sectoral policies and plans, so as to handle them in a more systematic basis and not only after extreme events occur. Climate risk management is a metter of centreal relevance (Leal Filho 2013). Unfortunately, even in countries which have national action plans on climate change, the implementation of risk management as it relates to mitigation and adaptation measures is often detached from mainstream planning. This has the disadvantage of isolating climate change action, when the right thing to do would be to integrate them better in sectorial policies and plans. It is often the case that agencies in charge of handling risks and/or hazards (e.g. the emergency services such as fire departments, costal guard, etc.) or relevant professionals such as doctors, engineers, or architects –among others- are not directly involved in climate change mitigation and adaptation programmes. As a result, the handling of climate hazards and extreme events is rather erractic, as opposed to being well organized.
4. Seek a dialogue with partner governments in industrialised countries and international financial institutions, so as to secure the funding needed to implement mitigation and adaptation projects. Lack of funding is a major barrier to the implementation of climate change initiatives, especially in the poorest

countries in Latin America such as Honduras, Nicaragua, El Salvador or Guatemala. However, there are various international donors keen to support them in their efforts, as long as concrete and plausible plans and projects are submitted. Here, it should be pointed out that the emphasis should be on long-term initiatives, and less on short projects lasting a couple of years, which are indeed useful, but seldom lead to long-term and sustainable improvements and changes.

In addition, funding bodies such as the World Bank or the Inter-American Development Bank (IDB) are able—and willing—to consider requests for supports with loans which may be negotiated for the purpose of reducing vulnerability and increasing resilience, especially in key areas such as water resources management or agriculture. As a sign that this may work well, mention can be made to a recent document produced by the IDB, the Economic Commission of Latin America and the Caribbean (ECLAC) and the World Wildlife Fund (WWF, concerned with climate and development in Latin America and the Caribbean, where options for climate resilient low carbon development were outlined (Inter-American Development Bank, Economic Commission of Latin America, World Wildlife Fund 2013).

5. An improvement in respect of the understanding of the problems caused by climate change and the risks associated with it. Many of the risks and vulnerability to hazards seen today are a result of lack of knowledge or pure ignorance. Farmers do not need to be caught by surprise when a drought damages their crops. By means of better and timely information, they can develop a better understanding of the influences of climate change to their activities, and hence be in a better position to adjust their agriculture practices (e.g. time of seeding or time of harvest).

This is list of items is by no means comprehensive, but the serves the purpose of illustrating how much may be achieved by using an adaptive framework. It is certainly so that countries are well advised to address their specific needs and problems in the context of national climate change action plans and strategies, but unless the countries of the region work together, and mutually benefit from the exchanges of experiences and dissemination of good practice, progress is likely to be slow.

In order to prevent this from happening, some priorities should be established. A number of possible ones are listed in Table 31.2.

There are some encouraging signs that progress may be expected. Countries in the Latin American and the Caribbean region were for instance among the first ones to ratify the Paris Agreement. They are also among the most ambitious in terms of combating climate change and in respect of making use of markets in order to reduce greenhouse gas emissions and to green their economies.

According to the UNFCCC (2016) Panama, for instance, plans to become a carbon hub for the region, facilitating collaboration between public and private actors in the fight against deforestation, whilst promoting a culture of sustainable forest management and trade in international emission reductions.

Table 31.2 Some priorities to climate change adaptation in the Latin America

Priority	Relevance	Degree of complexity in implementation
Greater availability of climate data	Put the climate data at use in the areas they are is greatly needed such as in agriculture, coastal zone management or urban planning	Low, since a substantial amount of climate data is already available
Better information on funds (grants and loans) to support adaptation efforts	Increase access to the funding needed to implement adaptation projects	Low, since many funding streams are already available, albeit little known
Capacity-building	Increased capacity to prevent and handle hazards and extreme events	Medium, since it may require some investments in educational infra-structure
Coping with damages from extreme events to infra-structure	Making public buildings and public services less vulnerable to storms and cyclones	High, since if may require substantials investments and improvements in existing infra-structure
More engagement from women	Stronger engagement of women in climate change adaptation efforts	Low, since women´s potential for participation in climate change adaptation efforts is high

Conclusions

As this chapter has tried to illustrate, the many challenges that climate change poses to the Latin American region, and the diversity of impacts climate change brings about to individual countries, means that integrated approaches to tackle it as greatly needed. But in order to yield the expected benefits, it is important that a holistic view of the problem is promoted. It is not sufficient to only look at the atmospheric or geo-engineering reasons of the problem. Instead, it is important to investigate and ascertain the economic, social, and political elements of climate change, and make it a central part of decision-making, and not regard it as an important issues, as it is largely seen today.

In this context, it is not wise to wait until ecological changes endanger crop production or even lead to crop failures. or to leave the bleaching of coral reefs to increase, and only act after drops in fish catch volume have taken place. Concerned adaptive action is important here and now, so as to enable Latin American countries to cope with the many threats climate changes poses to their economic development and the well being of their populations.

References

Clapperton CM (1983) The glaciation of the Andes. Quat Sci Rev 2(2–3):83–84

Costello A et al (2009) Managing the health effects of climate change. Lancet 373:1693–1733

Hardoy J, Pandiella G (2009) Urban poverty and vulnerability to climate change in Latin America. Environ Urban 21(1):203–224. doi:10.1177/0956247809103019

Inter-American Development Bank (IDB), Economic Commission of Latin America and the Caribbean (ECLAC) and the World Wildlife Fund (WWF) (2013) The climate and development challenge for Latin America and the Caribbean: options for climate resilient low carbon development. IDB, Washington DC

IPCC (2014) Climate Change 2014: Impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects. Contribution of working group II to the fifth assessment report of the intergovernmental panel on climate change. In: Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR, White LL (eds) Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

Leal Filho W (ed) (2013) Climate change and disasters risk management. Springer, Berlin

Leal Filho W, Wolf F (2014) Managing the impacts of climate change in Latin America: the need for technology transfer. In: Leal Filho W, Alves F, Caeiro S, Azeiteiro U (eds) International perspectives on climate change: Latin America and beyond. Springer, Berlin

Leal Filho W, Alves F, Caeiro S, Azeiteiro U (eds) (2014) International Perspectives on Climate Change: Latin America and Beyond. Springer, Berlin

Rabatel A et al (2013) Current state of glaciers in the tropical Andes: a multi-century perspective on glacier evolution and climate change. Cryosphere 7:81–102

UNFCCC (2016) Countries in Latin American and Caribbean Region Leading Climate Action. UNFCC New Report, Bonn. http://newsroom.unfccc.int/unfccc-newsroom/countries-in-latin-american-and-the-caribbean-region-leading-climate-action/

Villamizar A, Gutiérrez ME, Nagy GJ, Caffera RM, Leal Filho W (2016) Climate adaptation in South America with emphasis in coastal areas: the state-of-the-art and case studies from Venezuela and Uruguay. Climate Dev. doi:10.1080/17565529.2016.1146120

World Wildlife Fund (WWF) (2017) Climate change impacts in Latin America. WWF, Washington DC