Chapter 8
Improving Regional Landscapes Management to Support Climate Change Adaptation

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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

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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

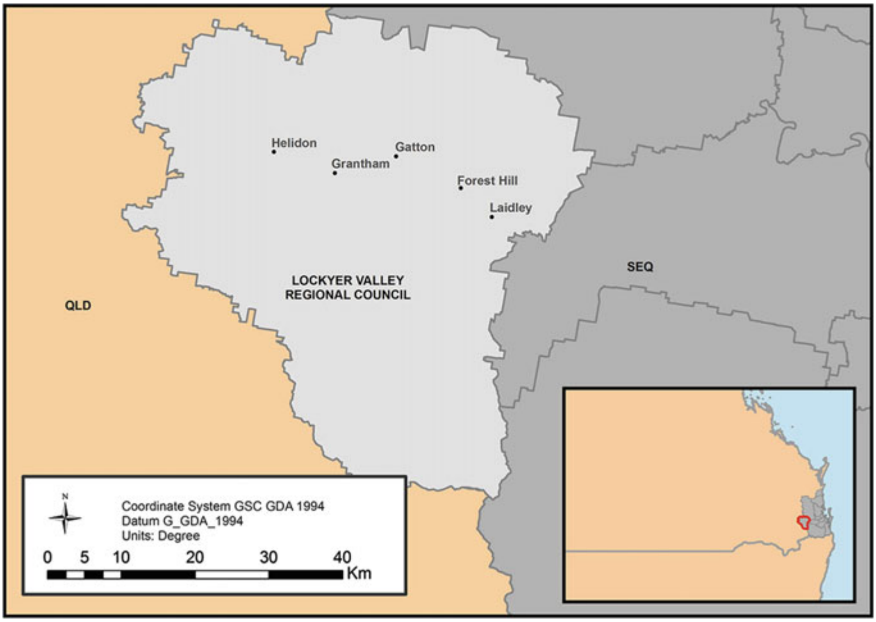

Fig. 8.1 Localization of the townships most affected by the 2011 floods in the Lockyer Valley, QLD—Australia

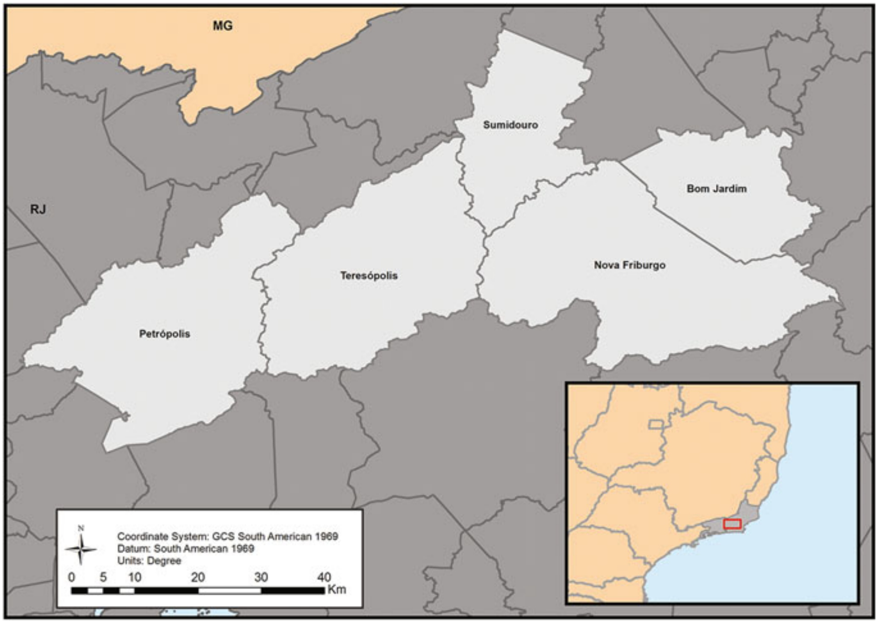

Fig. 8.2 Localization of the municipalities most affected by the 2011 landslides in the Região Serrana of Rio de Janeiro—Brazil

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.

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