Chapter 9
A Conceptual Framework for Understanding Vulnerabilities to Extreme Climate Events

Harry Polo Diaz

Abstract Many regions of the world are experiencing impacts of climate change of increasing variability, including drought and flood events. Proactive adaptation to climate change builds resiliency and reduces vulnerability to extreme events, lessening their impact and also their classification as "disasters." Adaptive strategies need to address the changing climate, other exposures (i.e. globalization and neo-liberalism), and sensitivities (i.e. unequal access to economic capital or lack of human capital).

This paper presents a research framework used by an international and interdisciplinary research project for assessing and building resiliency to climate change and extreme events of drought and flood in five countries of the Americas. The paper discusses how past, present, and future vulnerabilities are integrated into the research process, the complexities and nuances of dealing with local vulnerabilities to extreme climate events, and the incorporation of an adaptive governance assessment.

Keywords Climate change • Vulnerability • Extreme events • Americas

Introduction

We are living a time of major social, economic and environmental changes that are already affecting our lives in different ways, changes that emerge from the increasingly complex interrelationships between social and ecological systems. The period has been characterized as, "the Anthropocene", a historical moment where social systems have become increasingly dysfunctional in their relations with nature causing serious disruptions to environmental stability that pose "increasing threats to human security for both present and future generations" (O'Brien 2013: 72; Hackmann and Moser 2013; Wheeler 2012).

Climate change is one of the multiple expressions of this global environmental change. An unprecedented concentration of greenhouse gases in the atmosphere is

H.P. Diaz (✉)
University of Regina, Regina, SK, Canada, S4S 0A2
e-mail: harry.diaz@uregina.ca

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linked to an overall warming of the planet, which has been interfering and affecting climate and weather patterns and presenting one of the most prominent sources of increased human vulnerability. The World Meteorological Organization has estimated that from 2001 to 2010, more than 370,000 lives were lost as a result of extreme climate conditions, including heat waves, cold spells, drought, storms and floods, marking a 20 % increase in deaths compared to the previous decade (WMO 2013). The magnitude and frequency of extreme climate events are projected to increase under climate change, potentially increasing people's vulnerabilities and associated risks.

This paper deals with the conceptual approach used by an international, comparative, and interdisciplinary research project that focuses on the present and future vulnerabilities of rural people—farmers and residents of small towns—to the increasing number of extreme climate events. The Vulnerability and Adaptation to Climate Extremes in the Americas (VACEA) project takes place in five American countries: Argentina, Brazil, Canada, Chile, and Colombia. The goal of the project is the understanding of present and future extreme climate events, not just in terms of climatic hazard parameters such as timing, duration, intensity and geographic scope, but relative to human exposure-sensitivity. Disasters are a spatial interaction between hazards and a social system that is sensitive to the event and likely to suffer human and economic loss as a result of this interaction (Wisner et al. 2004; Paul 2011). Thus, VACEA focuses on the nature of hazards that emerge in the context of climate change and their impacts on rural people, who are characterized by different degrees of vulnerability due to unequal social conditions.

A systematic understanding of the relationships between extreme climate events and the socio-economic conditions that contribute to climate vulnerabilities is fundamental in order to grasp the implications of climate change. These relationships, however, are difficult to grasp using traditional scientific approaches. They are a "wicked" problem, which "is a complex issue that defies complete definition, for which there can be no final solution, since any resolution generates further issues, and where solutions are not true or false or good or bad, but the best that can be done at the time" (Brown et al. 2010: 4; see also Rittel and Webber 1973; Batie 2008; Conklin 2006). Part of the wickedness of these is related to our attempts to define and explain them using traditional disciplinary modes of inquiry, which tend to overemphasize some aspects of these problems and ignore others. In this perspective, the VACEA project has developed and strengthened an interdisciplinary approach to understanding these climate-social events, one that combines the efforts of both natural and social scientists.

The central focus of the VACEA project is climate vulnerability. Vulnerability, in very general terms, "is the measure of an entity's inability to deal with a natural disaster" or any form of stress (Paul 2011: 68). There is a multiplicity of definitions of vulnerability (see Paul 2011; Birkmann 2006; Patt et al. 2009), although VACEA has emphasized the approach used by the IPCC, where vulnerability is a function of exposure, sensitivity and adaptive capacity to climate (a more systematic discussion of these terms is found in the next section of this paper).

The paper explains the conceptual and methodological framework that has provided direction to the work of the project. Initially, the paper explains the general perspective of the project to assessing both present and future vulnerabilities, an important aspect given that climate change is a temporal and spatial process without a clear end. The second section outlines the conceptual framework adopted by the project for an assessment of local vulnerabilities. This is followed by a section that provides a brief discussion on adaptive governance, an institutional capital that is important to rural people to reduce their vulnerabilities to climate. Finally the paper offers some insights learned in these assessments for future work in this area.

Dealing with Present and Future Vulnerabilities

Climate change, as a component of global environmental change, is expected to have a myriad of complex impacts upon our lives. Many of these of these impacts may be beneficial—such as an extension of the growing season in agriculture—but most of them will be problematic. As is argued by Feliciano and Berkhout, "contemporary analysis of the impacts of climate change and environmental change is concerned with the factors that underpin risk, vulnerability and human resilience, and how these are perceived, framed, and managed in different social contexts" (2013: 226).

In this context the project assumes climate change mainly as a risk issue. Following Smit and Pilisova, who argue that "the key adaptations are less of often those related to changes in longer-term average temperature and more often related to the frequency and magnitude of extremes such as droughts or floods" (2003: 11), the project emphasizes the point that at local and regional scales the major climate hazards are related more to variability and not to averages. Extreme forms of variability—such as drought and floods—are especially important because they escape the adaptive ranges that characterize local or regional systems. Based on a common experience, local people, communities and institutions learn to adapt to climate within a certain range of climatic conditions—the adaptive range—defined by the historical "ups and downs" of climate variability. Our studies in western Canada have demonstrated that farmers living in areas prone to drought are able to cope with this phenomenon for a period of 2 or 3 years, while those farming in areas that are not historically affected by water scarcities show a lower adaptive range that is usually restricted to a year (Warren and Diaz 2012). This plasticity of human response to the environment, based on experience and learning, is what allows people and systems to deal with different climatic conditions and with a range of historical variability (for an excellent discussion of human adaptation to environmental conditions see Moran 2008). Thus, climate hazards—or extreme climate events—are climate phenomena that escape what is considered to be the normal historical variability and are problematic to people due to their incapacity to deal with them. In this context, the main problem of climate change is an increasing

variability that escape the existing coping ranges of people, a new variability that lead to more frequent and more severe climate extremes and to an increase of existing vulnerabilities or the emergence of new ones.

The VACEA project addresses the consequences of global climate change for regional climate variability and extremes and the associated vulnerabilities and adaptive strategies of rural people, who are highly vulnerable because their livelihoods makes them highly exposed and sensitive to climate variability and extremes. The project seeks to analyze the current vulnerabilities in the context of projected shifts in climate variability, including the frequency and intensity of extreme events, an analysis that should produce important insights into rural people's future risks and opportunities, informing the adoption of more appropriate local practices and adjustments to governance policies.

With this perspective in mind, the project adopted a model for assessing vulnerability that highlights the need to understand it within the context of past and present, as well as future climate conditions (see Smit and Wandel 2006: 288), a model presented in brown at the center of Fig. 9.1. It makes use of three sets of interrelated activities to realize this present and future vulnerability assessment. The first set involves the development of an understanding of the past and current degree of vulnerability of rural systems, where the effort involves an identification of how climate-related factors influence individuals, communities or economic sectors, as well as specific ecosystems, and what ability exists to manage changes in these. The second set of activities involves constructing future climate projections for the area where the system occurs, with an emphasis on the frequency and magnitude of extreme climate events. Finally, bringing together the insights produced by the first two set of activities in order to assess future vulnerabilities based on how the current vulnerabilities will be affected by the expected future conditions. The approach, undoubtedly, is characterized by some degree of uncertainty regarding future climate and social conditions, but the first two sets of

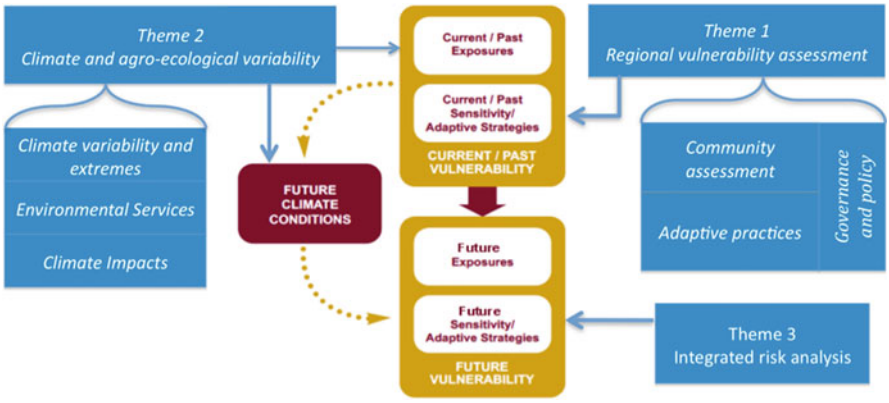

Fig. 9.1 Vulnerability assessment model and research themes

activities provide at least some degree of relatively secure knowledge that should satisfy the need for action in relation to the future climate risks (see Murphy 2014).

Figure 9.1 also illustrates in blue the sets of interrelated research activities used in the project. These activities fall under three major research themes: Regional Vulnerability Assessment (Theme 1), Climate and Agro-Ecological Variability (Theme 2), and Integrated Risk Analysis (Theme 3). The themes appear in Fig. 9.1 in relation to the vulnerability assessment model and the investigation of past, current and future exposure, sensitivity and adaptive capacity. As indicated before, the project integrates the work of both natural and social scientists in order to grasp the complexities of vulnerabilities n the context of the continuous interaction between climate and rural society. Social scientists are fundamentally involved in Theme 1, assessing the vulnerabilities of rural communities, the capacity of regional and national governance systems to reduce rural vulnerabilities, and the robustness of specific adaptive practices. Natural scientists' work is focused on Theme 2, dealing with existing climate variability and their impacts on ecosystems, as well as with future climate scenarios. Theme 3 is expected to integrate the insights from the natural and social disciplines produced in the contexts of the first two themes in order to construct an interdisciplinary understanding of the complexity of future extreme climate events and their impacts (Repko 2012).

Dealing with Local Vulnerabilities

Given the interest of the VACEA project on the consequences of climate change on regional climate variability and extremes and their associated risks for rural people, a central research component of the VACEA project has been a vulnerability assessment of rural social conditions (presented in the previous section as Theme 1, "Regional Vulnerability Assessment"), which is an internationally recognized approach for assessing and understanding the social dimensions of climate hazards (for a discussion of the approach see Smit and Wandel 2006). This assessment facilitates a comprehensive understanding of vulnerability in terms of (a) the magnitude of the threats that extreme climate events present, (b) determine priorities for adaptation, and (c) contribute to policy development.

This research component has been organized around a group of rural community vulnerability assessments, and the role that some other entities—governments and policy and adaptive practices—play in the reduction of rural vulnerability. This section discusses the conceptual framework that informs the community vulnerability assessment, which constitute the core of Theme 1.

As indicated before, vulnerability is defined in the VACEA project as the degree to which a system, such as a rural community or a farm, is susceptible to the adverse effects of stressors and change (Smit and Wandel 2006; Wisner et al. 2004). Following the definition of the IPCC (2001: 995), the project emphasizes the roles of climate variability and climate change as stressors that create risks (and opportunities) for rural people. In more precise terms, we define vulnerability as a

function of two dimensions: first, exposure to climate hazards and their impacts; and, second, the social conditions that determine sensitivity—the degree to which a system is affected by its exposure to a climate-related stimuli—and adaptive capacity, the ability of a system to adjust to climate risks and opportunities by increasing its coping range. Figure 9.2 represents these two dimensions of vulnerability. Exposure is a characteristic of a climate system and it refers to the frequency of climate hazards—i.e. droughts, storms, and others—and their attributes—such as intensity, duration, and coverage—that define the magnitude of their impact on social systems. Sensitivity and adaptive capacity, on the other side, are characteristics of the social system and are mainly determined by people's access and control of essential resources (they are also called determinants as we could see in Fig. 9.2) that support their livelihoods. It is the existence of these resources that define, to a large extent, the coping range of individuals or local systems, such as a farm or a community. In this perspective, vulnerability emerges from the interactions between the human and the natural systems.

In very simple terms, a social system that is characterized by limited resources is more vulnerable and, consequently, more conditioned to be impacted by climate hazards. Figure 9.2 lists these resources based on what the IPCC calls "the determinants of adaptive capacity" (IPCC 2001: 893; for a similar list of resources see Department for International Development 2000). Access and control of these resources are important to reduce vulnerabilities, but it is the capabilities of actors to organize them into adaptive activities what defines the balance between

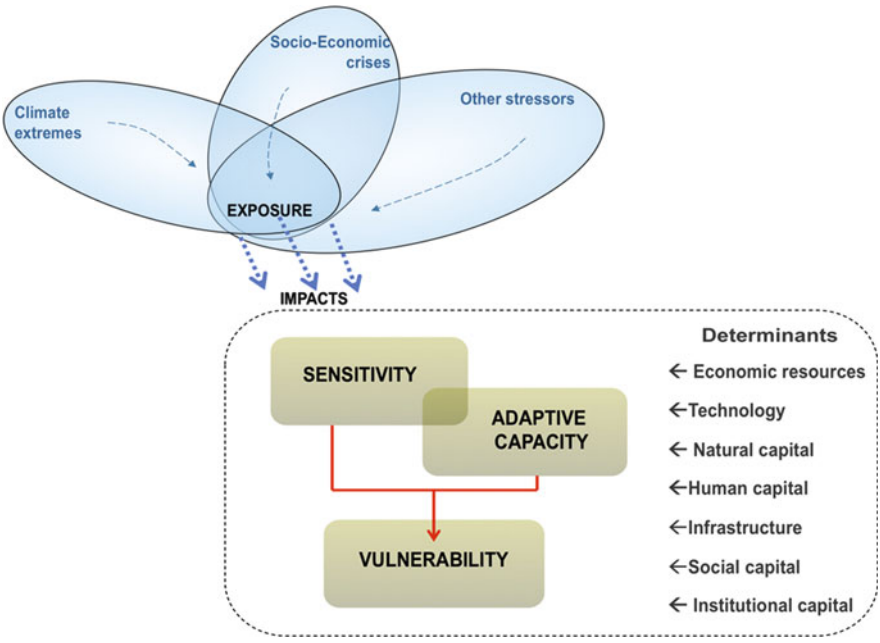

Fig. 9.2 The dimensions of vulnerability. *Source*: Wandel et al. (2016)

sensitivity (determined by lack of or limited resources), and adaptation (defined by the existence of resources that could be mobilized to reduce sensitivity).

These determinants of adaptive capacity, which are also called resources, are:

- **Economic resources**. The existence of monetary capital, financial means, wealth, productive resources, and others forms, which could contribute to the development of an adaptive capacity.
- **Technology**. The availability and access to technology—such as irrigation systems, flood control measures, warning systems, and others—as well the existence of a capacity to develop new technologies that could contribute to a more robust adaptive capacity.
- **Natural capital**. The availability and access to basic environmental services (water, soil, seeds), which are fundamental to the viability of rural livelihoods.
- **Human capital**. The educational and knowledge levels, as well as expertise, we find in a system. It includes traditional knowledges about nature, and especially climate and weather, and their relationships with agricultural practices. Systems with the capacity to produce, disseminate and store information (high educational levels or efficient communication among producers to disseminate successful practices) have a better ability to understand and predict climate hazards, reducing their vulnerability to climate and climate-related events.
- **Infrastructure**. The existing of proper housing conditions, drainage systems, weather-resistant roads, coastal defense, and others forms of allows regions and populations not only to cope with extreme weather events but also to recuperate faster from their impacts.
- **Social capital**. The existence of social networks characterized by trust and reciprocity that integrate individual resources to facilitate collective tasks (Putnam 1995; Coleman 1988).
- **Institutional capital**. Established institutions facilitate the management of climate-related risks—such as the existence and availability of insurance services, water conservation programs, and others—reinforcing (or debilitating) the adaptive capacity of the population.

This last form of capital is found both at the local and the provincial and national levels. The VACEA project, following findings from previous projects that indicate that the adaptive capacity of communities is always nested in larger institutional contexts (see Hurlbert et al. 2009), has included a governance assessment as part of its research activities, as it is indicated in the next section of the paper. No less relevant is gathering information about the role that social capital plays in the reduction of the vulnerability of communities. We have evidence from previous related projects that social capital—a local and informal institution that emerges around local institutions such as kinship, friendship—is an important resource in dealing with the impacts of disasters or having access to a larger number of other resources (Diaz et al. 2003).

In the process of carrying out the assessment we have given especial attention to the fact that vulnerability is not an unalterable condition but rather it is subjected to changes depending on the intensity of the stressor, the quality and quantity of resources that are available to rural people and the capacity of the rural people to manage the resources. As an example, resources could be limited and if they are used unwisely in a situation of vulnerability it could leave a family with the necessary resources to face future risks. Also important to consider in the community vulnerability assessment is the process of differentiation that characterizes the integration of rural people to economic and social processes in the five countries, a process where some actors are able to be better integrated than others. This difference in the process of integration is due both to a historical process of economic marginalization and to institutional failures, which result on an unequal distribution of resources essential to adaptive capacity. A clear example is that some rural actors have a better adaptive capacity than others due to a better economic situation. Landless peasants, small producers, and women are normally more vulnerable, a condition that could become worse with extreme climate events (Wisner et al. 2004).

It is also important to emphasize the point that vulnerabilities are not only related to access and control of the listed resources or determinants, but also to other conditions. The nature of productive systems creates specific conditions of vulnerability for different type of agricultural producers. As an example, the water demands vary between farmers and ranchers, as well as among different type of producers, during the year. No less relevant is the localization of the productive units within the basin. Non-existent or limited access to irrigation is a fundamental issue for agricultural producers in the context of increasing water scarcities (Warren 2016).

A final point of discussion in relation Fig. 9.2 are the sources of stress that affect local vulnerabilities (presented at the top left corner of the figure). We have identified "climate extremes" and "socio economic crises", but there are a variety of other non-climate stressors that could affect local people in rural localities, such as government policies or animal diseases. Thus, vulnerability to extreme climate events could be strongly interlocked to other types of vulnerability. Climate is not the single determinant of the communities' vulnerability. Rather, climate and water stresses are part of a suite of stresses that individuals and communities must manage on their everyday life. Our studies in Canada and Latin America indicate that rural people are exposed to several non-climatic stressors—such as market conditions, political processes, domestic catastrophes, and others—which are normally more relevant to them than climate (Wandel et al. 2010; Montana 2012). Particularly problematic for them is the interlocking of climatic and non-climatic vulnerabilities at a single moment in time, such as the case of a drought at a moment in which market crop prices are low. It is this interlocking of stressors that multiply the negative impacts of risks leading to double exposures (Leichenko and O'Brien 2008).

Adaptive Governance

One important resource or determinant of adaptive capacity is formal institutional capital. In a previous study we learned that local adaptive capacity is always nested in larger institutional frameworks that contribute either to make this capacity more robust or to debilitate it. A variety of practices, processes, systems, and infrastructure, are attempted and taken by rural people to reduce climate-related risk and to create new opportunities. Accumulating assets, relocating human resources, diversifying income sources and crops, redefining land use, adopting new technologies are some of the indicators of the existence of an adaptive capacity. This local adaptive capacity has been shaped to a large degree by a wider decision-making networks at different levels (IACC 2009). In this context we considered relevant to assess the capacity of governance to reduce local vulnerabilities through different programs and policies.

According to Mosser, governance can be "conceived as the set of decisions, actors, processes, institutional structures, and mechanisms, including the division of authority and underlying norms, involved in determining a course of action" (2009: 315). It is a term to be contrasted from the similar, but differentiated, terms of "government" and "management." "Management" refers to the processes of decision-making, coordination and resource deployment that occur within a given institutional setting (Hatfield-Dodds et al. 2007: 3) while "government" centers on the institutions and actions of the state. Governance is wider than both of these terms, encompassing non-state actors such as businesses and civil society, which are brought into the societal steering of natural resources and social actors. Governance involves the range of institutions through which government agencies, citizens and groups articulate their interests and mediate their differences, participating in some of the decision-making processes of governments (Armitage et al. 2009; Kooiman 1993). Thus governance, in relation to extreme events, refers to the range of political, social, economic, and administrative systems that respond to, manage, and anticipate extreme events. A systematic community vulnerability assessment requires not only an evaluation of the local adaptive capacity but also of the capacity of external institutional systems to contribute to a reduction of local vulnerabilities to a variety of stressors, including extreme climate events. Of particular importance in the community vulnerability assessment is the identification of the key organizations interconnecting with community members and, specifically, the community members' relationships with local governments. In these terms, we are referring to what Adger refers as synergistic social capital, where "local management and government intervention work together to reduce risks" (2003: 43).

Governments could have a limited or even negative role in reducing the vulnerability of rural communities, either because of a policy deficit (absence of specific policies, policy perspective, or just a simple urban bias) and/or a style of governance that limit the capacity of government agencies to provide the necessary resources to rural people (different agency priorities, lack of inter-agency

integration and coordination, etc.) (Hulbert and Diaz 2013). Building on information obtained in the community vulnerability assessments, the VACEA's governance assessment has then as its purpose to provide information on the inter-linkage of government programs and policies and their contribution to governance and ultimately, community vulnerability.

Rural people mediate stressors and assets through local institutions, such as bonding and bridging social capital (Adger 2003), which are based on cultural practices, deep rooted lifestyles and ideological premises. This mediation may give rise to institutional capital or adaptive mechanisms, which relate in part to first, the assets which a community has at its disposal; and second, the interplay of government (federal, provincial and local governments) and civic institutions and the bridges and barriers to adaptation provided by these entities. Governance, thus, includes the local processes of decision making in relation to climatic events which is exercised by local institutions at the community level. Thus, an important research focus of VACEA's assessment is, accordingly, the local government which is mediating these community decisions through a combination of policy tools and policy processes as set by the federal and provincial governments.

In the context of the VACEA project we have oriented our effort to understand the extent to which multiple forms of governance could be understood as adaptive governance, which spans a range of political, social, economic, and administrative systems and develops, manages, and distributes a resource in a manner that promotes adaptive capacity through collaborative, flexible, and learning-based issue management across different scales. It is important to note that the governance assessment is not only an assessment of government or governance agencies. Rather, it is an exploration and assessment of the entire network of actors, institutions, relationships, organizations, and entities involved in managing and responding to climate variability, hazards, and extreme events.

Based on an increasing literature on governance and its specific dimension as adaptive governance (see among others, Berkes and Folke 1998; Folke et al. 2005; Olsson et al. 2006; Hatfield-Dodds et al. 2007; Burris et al. 2005; Lebel et al. 2006; Scholz 2005; Knieling and Leal 2013; Hill 2013; and Hulbert and Diaz 2013), the VACEA project has focused its governance evaluation on the following characteristics that exemplify adaptive governance:

- Responsiveness—the ability of governance networks, organizations and actors to respond in a timely manner to climate variability, hazards and extreme events, involving issues such as the capacity of the agency to respond to or account for ecosystem dynamics, climate variability, hazards, and extreme climate events and the existence of early warning systems.
- Reflexivity—the social learning aptitude of extreme climate events governance institutions, which include issues such as the capacity of the governance regime to assess or reassess practices for assisting adaptation to climate variability, hazards, and extreme climate events, its openness towards uncertainties, and the existence of constant monitoring and evaluation processes.

- Flexibility—the ability of the water and extreme climate events governance institutions to respond in a variety of manners as appropriate to the situation, context and particular needs of the community, dealing with issues such as the capacity to modify adaptation practices in response to unanticipated events or the adjustments of practices to take into account different needs and requirements.
- Capacity—the informational, human, and social capital in existence necessary to respond appropriately to climate variability, hazards, and extreme events, including the existence of leaders (government or significant social actors or networks in communities) that are capable of responding to climate variability, hazards, and extreme events, the availability and access to necessary and appropriate information, and
- Equity—the fairness of the extreme climate events governance regime in dealing with processes and impacts, including issues such as the existence of opportunities for multiple frames of reference, opinions, and problem definitions as well as the involvement of different actors, levels and sectors in the governance process, the implementation of responses to climate variability, hazards, and extreme events equitable to all community members.

Based on institutional profiles and data collected in the in-depth interviews and focus groups of the CVA these themes have been explored in the governance assessment. An assessment of local governance took place at the same time than the community assessments but the assessments of regional and national governance bodies was done post facto the community assessments.

Some Challenges

Conceptual frameworks are social constructions—a product of scientific deliberations—that help us to organize our approach to the understanding of reality. In these terms, they are not definitive. Rather they are subject to changes and modifications based on their confrontation with the empirical reality. Our conceptual framework, which we applied in the field research carried out in the five countries, was able to provide direction and develop a better understanding of the issue under consideration. Based on this experience and some new developments in the field of adaptive capacity, we think it is necessary to integrate new issues that could improve our understanding of the impacts of extreme climate events and people's capacity to reduce the risks associated to these impacts. Two aspects could be important here.

The first one is a very relevant issue that is necessary to consider in terms of the purpose of adaptation. Pelling (2012) identifies the need to frame the process of adaptation in the context of sustainable development, an argument that is also emphasized in the last IPCC report (Denton et al. 2014). Pelling advances the argument that adaptation should go beyond simple resiliency, which he defines as "a refinement of actions to improve performance without changing guiding

assumptions or the questioning of established routines (2012: 53). In other words, he argues against adaptive strategies oriented to maintain what we have been doing in the past, an approach that takes us into "the sustainability of the unsustainable". In these terms he argues the need to redefine adaptation as a process of transformation in the context of sustainability. This is an important aspect to be considered in our analysis of the existing adaptive strategies and of their capacity to secure sustainability.

A second aspect, no less important, is the need to establish a difference between community vulnerability, which involves individuals, households, and local groups, from the vulnerability of larger systems (see Paul 2011: 76–83). As indicated before, community vulnerability is nested in larger social frameworks such as those imposed by governance. However, there is a need to move beyond an assessment of policies and programs. There is also the need to assess the existence and resilience of a variety of services that are fundamental to everyday life and which are normally provided by governance. Availability of potable water, electricity, and health services, among others, are essential to local people. Murphy (2009), provides an interesting example based on the case of the ice storm that affected eastern Canada in 2008, when most of the infrastructure that supported the distribution of electricity was destroyed by the weight of ice, leaving a large number of rural people, farms, and rural business without defense against the cold weather.

These aspects, among others, force us to assume the complexity of climate change. All social groups and societies are vulnerable in different degrees to disaster, and are likely to become even more vulnerable in the coming future. In this way we need to intensify our efforts to develop more comprehensive understanding of the different manifestations of global environmental change and its associated risks in order to reduce its wickedness.

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