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Vulnerability assessment within climate change and natural hazard contexts: revealing gaps and synergies through coastal applications

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Abstract The climate change and natural hazard communities have developed the notion of vulnerability and associated methods for its assessment in parallel, with only limited interaction. What are the underlying reasons for this diversity; is there advantage in greater synergy? If yes, what are the pathways through which greater integration could be fostered? This paper discusses these issues using vulnerability studies in coastal areas to describe gaps between climate change and natural hazard approaches, and investigates scope for mutual learning and collaboration in the development of methodologies for vulnerability assessment. An overview of methods highlights the separation between climate change and natural hazard approaches. The main differences identified, beyond formal divergences in terminology, are linked to: process (stress vs shock), scale (temporal, functional and spatial), assessment approach (statistical vs prospective) and levels of uncertainty. We argue that the underlying source of divergence is the initial difference of purpose, one being identification of climate change adaptation pathways, the other being disaster risk reduction. In this context, the notion of vulnerability and its expression through assessment studies is the focal point connecting both domains. Indeed, the ongoing and active development of vulnerability concepts and methods have already produced some tools to help overcome common issues, such as acting in a context of high uncertainties, taking into account the dynamics and spatial scale of a social-ecological system, or gathering viewpoints from different sciences to combine human and impact-based approaches. Based on this assessment, this paper proposes concrete perspectives and possibilities to benefit from existing commonalities in the construction and application of assessment tools.

Keywords Vulnerability · Coastal zone · Climate change · Natural hazard · Adaptation · Disaster risk reduction

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Introduction

Since the 1970s, vulnerability assessment has been increasingly important for risk reduction (OEP-EOP 1972). Vulnerability, as developed by the natural hazard research community, was first defined as the degree of loss to a given element, or set of elements, at risk. This resulted from the occurrence of a natural phenomenon of a given magnitude. Vulnerability was often expressed in quantitative terms in a number of indexes on a scale from 0 (=no damage) to 1 (=total loss) (UNDRO 1984). The intention was to propose another perspective on disasters than a strict "exposure to hazard" measure that communicated to policy makers the likelihood of disaster. Understanding disaster risk, as opposed to hazard risk, required the inclusion of some assessment of the endangered asset: its exposure, susceptibility to harm and ability to manage or cope with any impacts and subsequent losses (Pelling 2001). Various frameworks, such as Turner et al. (2003), Cardona (2003) or Birkmann (2006), have built on this basic understanding. Each of these influential models are broadly similar in the categories they include and the relationships identified between elements in their construction. For example, each recognises that vulnerability includes exposure, susceptibility and response capacity components and that risk is generated at different and interlocking scales. There are, however, key differences: Cardona (2003) presents a model placing emphasis on the management of disaster risk, whereas Turner et al. (2003) draw out the interaction between social and ecological/environmental systems as both a context and driver for vulnerability. Birkmann (2006) attempts to combine these approaches in the BBC conceptual framework and aims to show vulnerability within a dynamic process. Most recently, and influenced by the use of vulnerability in the Intergovernmental Panel on Climate Change (IPCC), vulnerability is being refined and structured according to the IPCC definition as composed of three factors: (1) exposure, (2) susceptibility, and (3) coping or adaptive capacity. These terms cover the same range of input variables as had been used by existing vulnerability analyses, but are associated with different and more detailed concepts. This is in itself an important way in which climate change science has brought new perspectives to natural disaster risk reduction. In this formulation, exposure equates with the impact side of vulnerability, susceptibility with the fragility of the element exposed, and capacity with the ability of risk elements to face the adverse effects of a hazardous event (coping/adaptation). As this introduction indicates, the term vulnerability is now a central concept in a variety of other research disciplines and it is conceptualized in very different ways by scientists from different knowledge domains and even within the same domain (Füssel 2007).

From the 1990s, and often in parallel with only limited interaction, the climate change community (notably the IPCC) has developed its own understanding of vulnerability and an associated set of assessment methodologies (IPCC-CZMS 1991). The conceptual development of vulnerability assessment approaches is partly comparable to the evolution of risk determination methodologies within the disaster risk community: after a phase during which the emphasis was set on physical parameters (for example the direct impact of changes in temperature and precipitation on ecological systems, or technical measurements for adaptation to such changes), the incorporation of societal and economic aspects for describing sensitivity and adaptive capacity of the potentially affected populations gained importance. Natural as well as social scientists are keen to measure and assess vulnerability, with a special focus on different regions, sectors, ecosystems or social groups. Therefore, climate change vulnerability assessment has been presented as an essential step toward predicting the impacts of climate change and assessing adaptive capacity within social and social-ecological systems.

The engagement of the climate change community with vulnerability has given new momentum to the development of vulnerability studies but also has caused some confusion with the existence of two intellectual and policy communities sharing a common term and associated methodologies but with quite different applications.

At the same time, an increasing number of scientists debate the influence of global warming on the frequency and intensity of natural hazards. Independent from the existence of a potential correlation (negative and positive), this debate forces researchers from the two communities of climate change and disaster risk to consider broadening their horizons to explore the potential conceptual and analytical benefits of closer integration between disaster risk and climate change community studies.

We argue there are strong advantages in moving towards integration. This paper sets forth these advantages using the shared notion of vulnerability as a focal point for discussion. The depth of work developed by both domains applied to coastal zones offers in particular a focussed opportunity to examine the meanings and methods attributed to these different frames for vulnerability assessment. They are at the interface between a dynamic environment (erosion processes, marine flooding) and highly concentrated assets (megacities, tourism development, environmental values), with disaster risk reduction—as part of natural hazards and climate change—being a major issue for coastal managers and communities. This is the empirical context we draw from and is one that provides a rich experience of vulnerability assessment for specific coastal hazards induced by tsunamis or storm surges, but also for the effects of climate change on coastal zones, particularly through accelerating sea level rise (IPCC-CZMS 1991).

This paper intends to add clarity to the fuzzy framings of these two applications of vulnerability. We highlight gaps and similarities between both schools of thought, using the example of coastal vulnerability studies. At this stage, it is worth noting that the authors use tsunami as one only of the examples of rapidly impacting hazards that has been investigated extensively by the disaster risk community. The aim is only to compare the vulnerability assessment to this kind of hazard with how the climate change community has assessed vulnerability to one of the major concerning issues of global warming, which is sea level rise and connected storm surges. However, the type of hazard considered—and any possible lack of connection to climate change—is not crucial for comparing both vulnerability assessment approaches.

First, a brief description of existing literature will provide a general overview of existing methods and indicators used in different contexts for coastal vulnerability assessment. These concrete examples will then be used to provide the empirical basis for the identification of similarities and differences. In the "Conclusion", we summarise our main findings and look for opportunities to learn from and for potential linkages between both perspectives.

Literature overview

This non-exhaustive overview intends to provide concrete material for further discussion by highlighting briefly major vulnerability studies related to coastal zones. The methods presented are drawn from major research initiatives and aim to represent the most influential applications of vulnerability within the two domains of interest, as well as drawing from the existing review literature (e.g., UNFCCC 2008; McFadden et al. 2006; Romieu and Vinchon 2009; Birkmann and Fernando 2008; Taubenböck et al. 2009; Post et al. 2009; Reese et al. 2007; Kaplan et al. 2009). This allows the analysis and subsequent discussion to focus on the core underlying assumptions that frame assessment methods rather than being distracted by infinite variations in the details of application of individual assessments. This is an important task but beyond the scope of the present paper. Relevant studies were included in this review based on three criteria: (1) vulnerability assessment applied in a coastal area; (2) providing a detailed definition and framework for the term "vulnerability"; (3) a representative method for one specific application (i.e., that the method is widely used or often cited).

Vulnerability to coastal hazards

Studies dealing with existing hazards in coastal areas, such as tsunamis or marine flooding during a storm, use vulnerability as a key step toward risk assessment and management. Depending on the focus of the authors, different concepts and dimensions of "vulnerability" are considered; however, all focus on the same general issue, which is risk assessment. Some studies use vulnerability to describe physical systems—a physical descriptor of a coastal system's sensitivity to pressures such as waves, currents, human action (e.g., Mendoza 2008). This notion, which is linked to our understanding of geomorphologic processes, has however proved to be limited for risk assessment (McLaughlin et al. 2002). Thus, natural sciences have developed a focus on damage to human assets induced by geomorphologic processes. This focus describes vulnerability as a way to link hazard characteristics (e.g., a specific velocity, depth or duration of inundation) and expected damage to human assets through explicit functions, such as damage functions for buildings of a particular design, and also for exposed populations (Fig. 1). This approach has become widely used in engineering and natural science, with many different functions considered.

However, factors other than the "physical" have proven essential for coastal risk assessment (Heinz Center 2002), for instance, social characteristics (e.g., poverty). Following this viewpoint, Boruff et al. (2005) used socio-economic data from the US-Census database in order to produce a socio-economic coastal vulnerability index, as developed by Cutter et al. (2003) for natural hazards. Birkmann and Fernando (2008) also focus on the social dimension of vulnerability and present a conceptual framework for capturing vulnerability by the selection of indicators and methods to measure revealed and emergent vulnerability of coastal communities at the local level in two selected tsunami-affected coastal cities in Sri Lanka. Accordingly, various interdisciplinary studies were conducted after the 2004 Tsunami interlinking data, selecting methods and results from engineering, remote sensing and social sciences to provide comprehensive information for disaster risk assessment, management and reduction (Taubenböck et al. 2009; Post et al. 2009; Garcin et al. 2008; Reese et al. 2007).

The approaches presented above use an explicit vulnerability assessment in order to present main factors contributing to risk at the level of communities. The NOAA (United States National Oceanic and Atmospheric Administration) proposes a tool directly oriented to coastal managers, which intends to present the main factors contributing to vulnerability (http://www.csc.noaa.gov/rvat/). This tool is integrated in GIS and gathers information for

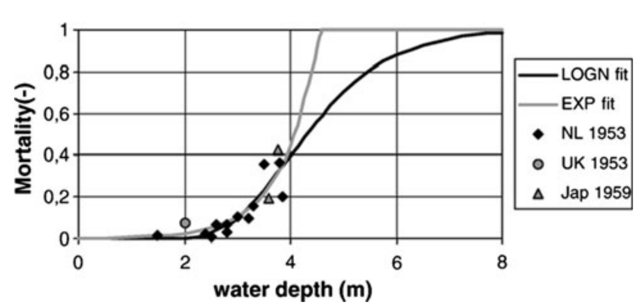

Fig. 1 Example of vulnerability curve for mortality and marine flooding (from Jonkman et al. 2008)

hazard understanding, critical infrastructure identification, social, economic and environmental analysis. A guideline helps managers to add local information and to structure it within the tool in order to identify concrete actions to reduce vulnerability.

The methods described so far use the notion of vulnerability as a means to link hazard risk to disaster risk through loss potential with some indirect measures being calibrated against past losses. This inductive or "impact-based" approach works well when hazard is constant—i.e. that the relationship between a vulnerability indicator—say a construction standard—and a hazard can be predicated based on past observation. However, in many cases, particularly while considering climate change, the uncertainty associated with the method makes this approach more problematic. Deductive approaches offer an alternative and draw from theory to identify indicators of vulnerability and measure their characteristics independent of past loss—for example by expert or local evaluation. This approach is also better suited for the appraisal of risk perception (Meur-Férec et al. 2008), the effectiveness of governance and other less tangible inputs, which are not readily available from coarse scale social data sources such as a population census. For instance, Adger et al. (2005) identified means for action in order to enhance resilience, based on social or ecological considerations (Fig. 2).

Alongside the development of tools (methods and indicators) to measure vulnerability for strategic policy input, there have been attempts to engage in local and, to varying degrees, participatory vulnerability assessments of disaster risk for coastal communities. These community risk assessment (CRA) methodologies have often been conducted in developing country contexts and many have been implemented by development and humanitarian agencies (http://www.proventionconsortium.org). CRA methods are built on rapid rural appraisal methodologies applied in more generic participatory development research. They emphasise local actor involvement in the identification of hazard types and from here the development of local indicators for vulnerability and capacity and the collection of data. These methods produce very local but contextually rich assessments of vulnerability and often also include assessment of hazard risk perception. Data produced can be quantitative and may be produced using participatory GIS, but the participatory nature of many studies means they serve the multiple purposes of providing a catalyst for social bonding, a mechanism for raising local awareness of vulnerability, to feed into local risk management plans (e.g. identifying evacuation roots), as well as producing a vulnerability assessment. The level of accuracy of the vulnerability assessment is not always the first priority. Just as important is the galvanisation of local community actors around the idea of disaster risk with the CRA process providing the focus (through specific local expressions of hazard and the location of vulnerable individuals and infrastructure, and also of capacities to respond and reduce risk). The local focus of these studies also makes comparison difficult. Still they have provided a mechanism for surfacing intangible values that shape risk perception and behaviour when faced with potentially disastrous hazard risk and of engaging directly with those at risk (Pelling 2007).

Coastal vulnerability to climate change

The climate change community first described coastal vulnerability as a major issue within a general aim pursued, which was to highlight the importance of adaptation in parallel of climate change mitigation (IPCC-CZMS 1991). Therefore, vulnerability had been described as a result of the long-term (e.g., 2100) impacts of climate change, including adaptation processes. Coastal vulnerability assessment was first proposed at national scales with a "common methodology" in order to give concrete proof of the relevance of adaptation strategies compared to future impacts of climate change (Nicholls 1995). A global

Fig. 2 Examples of local- and regional-scale actions to enhance resilience in social–ecological systems exposed to abrupt change (from Adger et al. 2005)

Elements of vulnerability	Local action	National and international action
Exposure and sensitivity to hazard	Maintenance and enhancement of ecosystem functions through sustainable use Maintenance of local memory of resource use, learning processes for responding to environmental feedback and social cohesion	Mitigation of human-induced causes of hazard Avoidance of perverse incentives for ecosystem degradation that increase sensitivity to hazards Promotion of early warning networks and structures Enhancement of disaster recovery through appropriate donor response
Adaptive capacity	Diversity in ecological systems Diversity in economic livelihood portfolio Legitimate and inclusive governance structures and social capital	Bridging organizations for integrative responses Horizontal networks in civil society for social learning

assessment based mainly on these studieshas been proposed (Hoozemans et al. 1993). As a matter of fact, the major phenomenon considered within these coastal studies is sea level rise impact, with storm or hurricane changes still being highly uncertain. Seven vulnerability indicators are proposed in order to represent climate change impacts and adaptation strategies results (Fig. 3).

The most developed indicators amongst those are possibly applications of vulnerability that focus on non-human systems: biophysical impacts of climate change on the coasts have been a whole scientific topic (e.g., sea level rise flood maps online http://flood.firetree.net/), motivating many studies and using the term "vulnerability" as a central focus (e.g., Idier et al. 2009). For instance, many different studies have been developed in Australia in order to take into account local biophysical specificities (e.g., coral reefs). This has been the basis for a national harmonization of methods and a refinement of this notion of coastal vulnerability (Harvey and Woodroffe 2008). Focusing as well on biophysical impacts, effects of sea level rise on erosion and flooding processes have been qualified through vulnerability indicators, in order to describe the fragility or sensitivity of coasts facing sea level rise (Thieler and Hammar-Klose 1999).

This first basic approach can be described roughly by the equation "Vulnerability = Impacts − Adaptation" (McFadden et al. 2006). Based on that vision, more detailed frameworks have been proposed in order to describe precise interactions between impacts and adaptation strategies, including social, biophysical and a combination of social-ecological systems functions (Klein and Nicholls 1999). For example, the specific issues associated with small island developing states imposed the consideration of local communities' characteristics in order to understand adaptation strategies (Yamada et al. 1995). This contrasts with work on natural hazards vulnerability that has used macro-indicators to measure island-wide vulnerability, but has been able to measure adaptive capacity only very indirectly (Pelling and Uitto 2001).

National scale vulnerability assessments using this common methodology have been gathered, and a recent coastal database was developed as part of the DINAS-COAST (dynamic and interactive assessment of national, regional and global vulnerability of coastal zones to climate change and sea-level rise) project, which represents the world's coasts with natural, ecological, and social parameters, including population and GDP (gross domestic product) scenarios based on IPCC projections. An associated GIS tool—DIVA (dynamic interactive vulnerability assessment)—calculates vulnerability indicators, as described within the common methodology, associated with the user's choice of climatic and socio-economic scenarios (Vafeidis et al. 2008). This use of GIS as an interactive tool very easily allows up- and down-scaling, and provides the opportunity to cover a wide range of socio-economic and climatic scenarios. Such a tool is, however, based on many assumptions that limit its relevance for local scales and restrain its applicability for local or regional prospective scenarios, which could differ from IPCC scenarios by proposing land use changes or identification of thresholds.

Climate change work has also intended to measure vulnerability and to tie this to adaptation through local assessments. Local assessments provide a more bottom-up and locally contextualized view of vulnerability formation. This adds richness but is difficult to connect to climate change projections, which are not yet available with sufficient resolution for local assessment. They are, in contrast with larger, more top-down vulnerability assessments, for example of national economic sectors that are built on top of global climate change assessment projections. Adger et al. (2005) describe the more bottom-up view as the human-based approach. Here, studies aim to identify human and social characteristics that determine the capacity of communities to face a stress or a shock drawing on local variables (i.e. at a community's scale). This differs from the widely used climate change vulnerability assessment described above, where the starting point is a specific climate change scenario and where vulnerability is identified through data at a coarse spatial scale. The human-based approach is driven more by

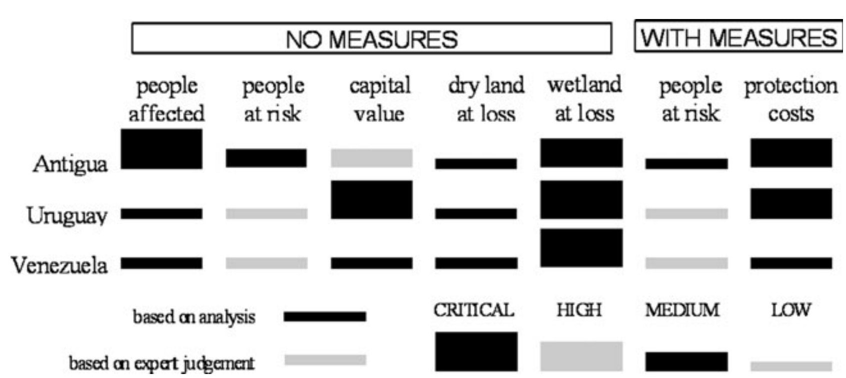

Fig. 3 Synthesis of national vulnerability assessment to climate change, using the "common methodology" (extract from Nicholls 1995)

the objective to describe adaptation than vulnerability. The underlying argument is that, at more local levels (e.g., community level), uncertainty from climate change increases as more and more intervening factors and processes influence the ways that climate change is felt and can be responded to. This increases the relative importance of revealing adaptive capacity, as part of the overall vulnerability assessment, which still remains the core objective. The most recent work has drawn on thinking from social-ecological systems resilience theory to help build a common core set of attributes for adaptation, which, for most studies, incorporate some element of social learning and self-organization, often through indicators of social networks that determine access to and quality of information (Tompkins and Adger 2004).

Learning from this comparative review

Separating the literature review into two classes—climate change and natural risk oriented studies—may imply a bias in the objective analysis of vulnerability. However, this overview can be used to highlight what common issues and what major differences can be identified within both frames.

Gaps and differences

Obviously, in light of this overview of existing approaches, the way vulnerability is treated and assessed appears to be highly variable within the contexts of climate change and natural hazard. These differences are expressed by formal divergences such as the fact that both communities use different terms and concepts within their vulnerability assessments: for example, the term hazard is seen as a more gradual and creeping change (e.g., sea level rise, changes in frequency and intensity of storms and hurricanes) within the climate change community, whereas the natural hazard community focuses more on sudden-onset hazards. An exhaustive and comparative description of exiting terminology within each domain is not the topic of this paper and we refer to the existing literature to provide a wider understanding of possible biases and misunderstanding (see, for example, Smit and Wandel 2006).

It is worth noting that, within the disaster risk reduction community, there exist a large number of different concepts for measuring vulnerability, offering a great variety of definitions of key terms (see for example Thywissen 2006). In contrast, the strong influence of the IPCC within the climate change community has resulted in a rather homogenous adoption of the vulnerability concepts most valued by the scientific community reflected by the intergovernmental panel. Beyond the formal divergences, it is worth trying to extract and describe the underlying reasons for the variety of vulnerability assessment approaches in disaster risk reduction and climate change adaptation.

First of all, the major difference observed between those two groups of studies is the objective pursued. Within the natural hazard community, vulnerability has been developed in order to highlight means for risk reduction without focusing on hazard reduction only (Heinz Center 2002). Within the climate change community, vulnerability is used in order to understand pathways of adaptation (in relationship with mitigation) while facing a progressive climate change, and having progressive or threshold-type biophysical impacts (e.g. Yamada et al. 1995). This reveals a distinction between vulnerability viewed as a failure of capacity (natural hazard vulnerability and coping) and a failure of a long-term learning processes (climate change vulnerability and adaptation).

Therefore, this implies consideration of damage processes or communities' behavior with two very different perspectives. Vulnerability being, in both cases, a key concept concerning damages and society, the way of assessing it—as a dynamic or static object—inevitably differs. Whereas climate change impacts are progressive over time, with crisis events as well as progressive long-term processes (e.g., sea-level rise), natural hazards occur as an episodic and intense event in time, although they can be recursive and have impacts long after the event. Climate change is a "stress", whereas natural hazards might be considered as a "shock". Individual or societal behavior while facing these different processes is associated with different institutional, social and psychological mechanisms (Turner et al. 2003).

Besides this crucial dynamic time scale difference, the spatial scale also contributes to major divergences between both frameworks. The potential impacts of climate change (e.g. sea-level rise) could be spatially and globally heterogeneous, though they are often identified as "global" change. The awareness has come from a global scale, but the need for concrete impact assessment and adaptation strategies is local (Harvey and Woodroffe 2008). This need is also strengthened due to the lack of information/data on concrete effects of climate change at the local level. On the contrary, the consideration of natural risks comes from a very local consideration, which has been extended to a global level in order to find common practices (e.g. tool from the NOAA).

Scale dependence is also manifest through the interplay of different levels of organization management for climate change and disaster risk management (Birkmann et al. 2009). Within government structures climate change still frequently remains outward looking, associated with international climate policy negotiations. Disaster risk is more inward looking, with a focus on sub-national risk management and a trend toward local government leadership. This reflects a science of climate change that operates at a lower resolution than the grounded work of disaster risk management. The institutional separation of climate change and disaster risk management can lead to functional mismatches, and certainly represents a barrier for climate change policy and practice to learn from, and also influences disaster risk management (Schipper and Pelling 2006). Recent initiatives from the IPCC and ISDR (United Nations International Strategy for Disaster Reduction 2009), for example in the production of an IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation have explicitly aimed at overcoming these barriers to joint communication and learning.

A direct effect of previous differences is that the statistical definition of risk (e.g., the notion of return period of an event, or experienced economic losses from past disasters) is no longer appropriate in studying climate change impacts and adaptation (ISDR 2009). Whereas risk can be considered as a probability of loss, and is defined so in many different contexts (economics, finance), climate change is associated with a prospective evaluation of future damage or loss until a given timescale (2100 being the most frequent term). This "statistical" gap inevitably induces a gap between the means and tools needed by decision makers for risk management and for climate change adaptation measures. As a matter of fact, ways of assessing vulnerability to help risk reduction and vulnerability to help climate change impacts reduction are not directly comparable. However, the two viewpoints (statistics vs prospective scenarios) are highly related, since climate change, which is an ongoing process, might have a significant influence on the return period of sudden events, such as storms on the coastal zone, and thus on risk calculation, even for past events. Basically, this means that considering statistics and prospective scenarios has a strong impact on risk calculation for sudden hazards as well.

Moreover, from a formal viewpoint, it is worth noting that, within the climate change domain, the expected outcomes of vulnerability studies are the vulnerability assessments themselves. This final result of the studies gathers the assessment of impacts induced and the results of adaptation processes (e.g., Nicholls 1995; O'Brian et al. 2004). On the contrary, natural risk studies use vulnerability as a step toward risk assessment, in parallel and in interaction with hazard exposure evaluation (e.g., Jonkman et al. 2008). The final result expected for decision making is risk assessment, seen as a probability of damages and losses.

Considering all these identified differences, it appears that they are all linked directly to the initial source of divergence, which is the gap between the two objectives pursued, in other words the difference between the questions "how to adapt to progressive climate change?" and "how to reduce an existing risk?"

Similarities and common issues

Despite this distinction between climate change and natural hazard studies, the general overview reveals some common characteristics or key issues.

A first general observation is that, while studying coastal vulnerability (either to climate change or to natural hazards), the focus is on different aspects or systems, from geomorphology to social conditions or ecosystems to social systems. Some studies consider coastal vulnerability as the sensitivity of the physical environment, i.e., the coast itself (e.g., beach vulnerability in Mendoza 2008, coastal vulnerability index in Thieler and Hammar-Klose 1999). However, this physical focus does not contribute to our general understanding of how to reduce risk or how to adapt, but rather to the understanding of hazard processes, such physical processes inducing erosion. Therefore, for the climate change and natural hazard communities, this geomorphology-based vision has been neither completed (e.g. Boruff et al. 2005) nor used directly for management purposes.

Furthermore, both domains face the difficulty of integrating knowledge and methods from two disciplines: social and natural sciences. Scientists from these disciplines nowadays have a great opportunity to overcome this issue through interdisciplinary works, such as those promoted by the European Commission (e.g., FP7 projects MOVE, ENSURE, CAPHAZNET). As a concrete illustration of this, following the tsunami in 2004, various studies brought great insight into existing gaps between these disciplines, while focusing also on the social system within coastal vulnerabilities (Birkmann and Fernando 2008; Taubenböck et al. 2009; Post et al. 2009; Reese et al. 2007; Kaplan et al. 2009). In order to ensure human security, adequate adaption strategies that take into account the natural and social processes are needed; hence, communication and cooperation between natural and social scientists is essential. Thus, common problems of complexity that could be identified have common characteristics such as:

- Scale dependence: spatial (local–global), temporal (static–dynamic) and functional (different institutions) scales (Birkmann et al. 2009)
- Integrative assessment methods (quantifiable physical phenomena–quantitative descriptive criteria).

Finally, both approaches have to deal with the same general topic of a coupled and dynamic system composed of both environment and society (Turner et al. 2003). On

Table 1 Synthesis of gaps and common issues between vulnerability in the contexts of climate change and natural hazard

School of thought	Natural hazard	Climate change
Differences		
Objective pursued	Identify risk reduction measures: reduce probability of damage	How to face a progressive climate change: adaptation relevance and strategies
Kind of process	Natural hazards—"shock"	Progressive and irreversible—"stress"
Timescale	Event-scale (before/during/after), discrete events, static processes	Long-term and progressive viewpoint (e.g. 2100) discrete and continuous, dynamic processes
Spatial scale	From a local consideration to a global one	From a global awareness to a local need
Functional scale	Often lies within the responsibility of the Ministry of the Interior, Defence or Development	Mainly environment ministries and meteorological services
Simplified formulation	Risk = Hazard × Exposure × Vulnerability	Vulnerability = Impacts − Adaptation
Vulnerability assessment	Step within risk assessment	End in itself
	Risk is associated with a notion of probability of occurrence at any time	Prospective scenarios until a given term
Level of uncertainty	Low to medium	Medium to very high
Common issues	Define a focus, wider than physical environment itself	
	Find a convergence between "impact based" and "human based" approaches	
	Take into account dynamics and interactions of the socio-environmental system	

the one hand, because of the high interaction between these factors, natural hazards can no longer be considered as an endogenous and absolute pressure on society. For instance, human construction on the coast may modify physical processes and hazards (Jonkman et al. 2008). Moreover, the dynamics of the whole complex system obliges one to consider hazards and risk as dynamic notions over time (Vinchon et al. 2009). On the other hand, climate change science places its scientific basis on the development of the understanding of these dynamics and interactions, by developing powerful concepts, frameworks and tools in order to understand and model this issue (Vafeidis et al. 2008).

Synthesis table

This comparative study of the climate change and natural hazard viewpoints on vulnerability has highlighted major differences, as well as important common issues. All of these points seem to be synthesized in the original difference between the two concepts, which has determined their use and applicability: one is used as a step toward risk assessment, in order to propose means for risk reduction (short term events, shock); the other has been developed in order to prove and evaluate adaptation while facing a progressive process, climate change (long term process, stress).

Table 1 proposes a synthesis of existing gaps and common issues, in light of this initial difference that comes from the objective pursued while using the notion of vulnerability.

Discussion

The major conclusion of this comparative review is that the gaps identified between coastal vulnerability in natural hazards and climate change communities are highly related to the major objectives of both concepts. In short, the gaps identified are related to the gaps between two kinds of objectives: (1) identify factors for risk reduction and evaluate their efficiency, in real contexts; (2) prove the need for adaptation to climate change and evaluate its efficiency, focusing on future conditions (e.g., 2100). However, both topics have common issues that appear to be essential and need to be addressed in future conceptual and methodological development: (1) harmonization of human-based and impact-based perspectives of a given problem (strengthen communication and cooperation); (2) description and consideration of different scales (time and space) within a given social-ecological system.

Studies in coastal areas attempting to accommodate both perspectives

Some existing studies provide insights into the possibility of reconciling both approaches. This is being achieved by presenting coastal risks as a dynamic process, taking into account socio-economic and climatic evolution, and defining risk evolution at different time-steps (e.g., the MISEEVA research project, Vinchon et al. 2009). This approach is based on the awareness that a dynamic assessment framework is required in order to capture future risks, accounting for changes in all vulnerability factors and dimensions over time (Füssel 2007). Another way of defining vulnerability to climate change in interaction with natural hazard knowledge would be to identify tipping points, defined as physical conditions at which technical, economic or social limits would be exceeded (Haasnoot et al. 2009). These tipping points, or key vulnerabilities, would present how much climate change a community could cope with, and the eventual need for—and strategy of—adaptation. Theoretical debate is making progress, with major contributions on concepts (Adger 2006) and frameworks (Turner et al. 2003).

In light of these examples, a first recommendation for a linkage could be the implementation of cross-sector, multi-scale and integrative approaches to merge both perspectives and to mainstream both into sustainable development in rural as well as in urban areas. This could be realized through the development of standardized methods, databases and quality criteria for moving from impact and needs assessment after disasters to a more anticipatory vulnerability assessment (Birkmann et al. 2009).

Adaptation and disaster risk reduction as the core debate

Actually, the need for bridging these conceptual and terminological gaps seems to be important primarily in understanding all the interactions between adaptation and risk management. Therefore, the constructive debate should not rest on the definition and methodological articulation of vulnerability alone—including the different terminologies of the factors of vulnerability. This notion is embedded in methodologies developed to address defined needs (of shock or stress types). The debate is rather on risk management and adaptation strategies, and how they might benefit from existing synergies.

One of the major outputs from existing knowledge on adaptation is that practical adaptation initiatives tend to focus on risks that are already problematic, thus adaptation has to be included in disaster preparedness programs (Smit and Wandel 2006).

Moreover, from an international management viewpoint, new perspectives and connections, emerging from both climate change adaptation institutions (UNFCCC, 2008) and natural disasters platforms (UN-ISDR 2009), seem to have been developed recently. Both institutions recognize that adaptation passes through disaster risk reduction.

So, on the one hand practical adaption initiatives focus on existing risks, so that adaptation measures can be inserted into risk management. On the other hand, risk reduction is presented as an essential adaption measure. These two outcomes highlight the need for concrete interactions of vulnerability assessment.

Mitchell and Van Aalst (2008) presented a constructive review of existing convergence between disaster risk reduction and climate change adaptation, highlighting incentives and obstacles in order to propose concrete recommendations and associated actions and agenda.

How vulnerability supports practical adaptation and risk reduction measures

These new perspectives on adaptation and natural risks face a major common issue, which is the identification of action possibilities in a context of high uncertainty. On the one hand, some existing risk frameworks would recommend dealing with this kind of highly uncertain risk assessment within a precautionary-based management approach, more or less based on the idea of vulnerability reduction (Klinke and Renn 2002). On the other hand, adaptation strategies to an uncertain climate change imply a development of new tools for decision making (Hallegate 2009). Therefore, the debate on uncertainty and vulnerability assessment should be a core discussion to bridge the gap, keeping in mind the final objective of providing useful tools for risk reduction and adaptation together, despite a high level of uncertainty in technical assessment.

Community oriented assessments of vulnerability have already provided some ways past this impasse. Their focus, if different from the management level lens, is more concerned with livelihood and human wellbeing than strategic physical or social infrastructure investment. There are multitudes of approaches and studies with no intentional common methodology but many points of commonality. The particular point of interest for this debate is the recognition that assessing the vulnerability or adaptive capacity of local actions at the community scale to future threats can incorporate pressures from both stress and shock. These methods require the construction of generic social attributes alongside hazard-specific ones to identify both exposure and susceptibility to specific and undefined hazards.

The distinction between climate change and natural hazards visions, methods for analyzing vulnerability and coping-adaptation, and the notion of stressor that combines stress and shock, is less of a problem, when studying (with) those at risk, and more of a problem when seeking to abstract risk for broad policy purposes. It is perhaps a product of the needs and data availability of these two levels of analysis. At the local level, those at risk have to deal with many sources of uncertainty that threaten livelihood and wellbeing—from economic, social and political as well as multiple environmental sources.

Finally, in light of this discussion, all the gaps and common challenges revealed by the coastal applications of vulnerability assessment represent a great opportunity to propose concrete interactions and to benefit from synergies between disaster risk reduction and climate change adaptation (Table 2).

Conclusions

The disaster risk reduction community and the climate change community have developed concepts for

Table 2 Synthesis of identified synergies for bridging gaps and dealing with common issues within climate change and natural hazard contexts

	How to benefit from synergies—proposal for interactions	Supporting literature
Gaps between climate change and natural hazard perspectives		
Objective pursued	Final aim of both: reduce adverse effects of external impacts, natural hazard risk and climate change are increasingly correlated, adaptation strategies and risk reduction measures are often overlapping	Smit and Wandel (2006), UNFCCC (2008), UN-ISDR (2009), Mitchell and Van Aalst (2008)
Kind of process	Describe a progressive climate change but irregular and including extreme events—the processes themselves might be different but the tools to analyze them similar	See Vinchon et al. (2009)
Timescale	A combination of the long view perspective of climate change with the snapshot view perspective of natural hazards could lead to an overall integrated risk assessment This should help to arrive at a common understanding of ongoing development processes	
Spatial scale	Learn from adaptation measures (e.g. at local scale) that could lead to secondary negative effects	
Functional scale	Strengthen cooperation and communication between the different institutions—international connections (e.g. UN-ISDR and UNFCCC), as well as national to local actions. Linking functional scales is a support toward integrated action at different spatial scales	
Simplified formulation	Risk reduction should be a visible part within adaptation and whenever possible adaptation to climate change should be part of risk reduction strategies—look beyond the differences in the definition of terms	
Vulnerability assessment	Vulnerability assessment should cross examine and integrate physical, social and economical future evolution—identification and usage of common methods or indicators, where appropriate	Adger (2006)
Level of uncertainty	Look for convergence on the choice of methods for the treatment of uncertainty; identify tools to help decision making in a context of high uncertainty	Hallegate (2009)
Common challenges faced by both domains		
From physical to socio-ecological focus	Using vulnerability assessment and the methods to assess the different dimensions of vulnerability	See Birkmann (2006)
Impact based versus human based	Vulnerability framework: develop holistic assessments of risk that can combine top-down and bottom-up viewpoints—look for ways of linking qualitative and quantitative risk assessment methodologies	
Dynamics and scale	Dynamic framework describing a coupled system	See Turner et al. (2003)

vulnerability assessments in recent years largely independently from one another. In both communities, the initial focus on a physical, natural science-based approach has been widened to incorporate more human-related social-science based phenomena. Coastal applications underline the opportunity to approximate both schools of thought in order to combine the experience that has been gained through various studies. The main differences between the two approaches stem from the discrepancy of their objectives; on the one hand the final goal is risk reduction of shocks (short-term process), on the other hand the overall objective is the most efficient adaptation to climate change (long-term process). The common challenges of both concepts are the adequate allowance for the complexity of the relationships and processes within the social–ecological coupled system to be observed. Specifically, this requires the consideration of various scales (time, space and function) and the integration of quantitative and qualitative appraisals. Whilst risk quantification in disaster research relies heavily on statistics of past events, climate change studies need to deal with prospective scenarios, entailing a high degree of uncertainty. The need for concrete decision tools in the context of such uncertainties seems to find an opportunity with community oriented assessments of vulnerability.

Though many formal and methodological differences have been identified thanks to the comparative review of existing vulnerability assessment methods in coastal areas, reasons that both communities should interact are predominant. Indeed, both domains have to face common challenges. Furthermore, the core debate behind existing gaps is the way disaster risk reduction and climate change adaptation may interact and benefit from synergies. Recent developments and future perspectives increasingly demand for a coalescence of both approaches, since global warming may alter return periods of disastrous events, which is the base for risk calculation, and risk reduction is progressively integrated in climate change adaptation strategies. The common notion of vulnerability, despite the identified—but constructive—gaps, seems to be the ideal tool for such connection. This reflection should help in the understanding of how to build from a capacity (vulnerability and coping) to a learning process (vulnerability and adaptation).

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