Received 19 December 2010
Revised 17 May 2011
Accepted 13 July 2011

Conceptual elements of climate change vulnerability assessments: a review

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Abstract

Purpose – The concept of vulnerability in climate change literature is underpinned by numerous theoretical contributions across different disciplines leading to disparate understandings of what climate change vulnerability entails, as well as different methodological frameworks for assessment. This multiplicity of contributions helped not only to frame and shape different understandings of vulnerability but also to define the conceptual and analytical elements considered as critical in any climate change vulnerability assessment. The purpose of this paper is to review the literature on climate change vulnerability and explore and synthesize those conceptual and analytical aspects considered fundamental in a vulnerability assessment in climate change.

Design/methodology/approach – Drawing on existing literature on climate change vulnerability and vulnerability assessment frameworks, the paper provides a review of the conceptual elements regarded as critical in integrated assessments of climate change vulnerability to date.

Findings – A review of the existing literature identified nine critical elements in vulnerability assessments: the coupled human-environment system and place-based analysis; key components of vulnerability; multiple perturbations; scales of analysis; causal structures of vulnerability; engaging stakeholders; differential vulnerability; historical and prospective analysis; and dealing with uncertainty. The paper concludes by highlighting some of the remaining challenges and limitations for the development of integrated vulnerability assessment in climate change research.

Originality/value – The paper presents a synthesis that draws on existing literature on climate change vulnerability theory, as well as vulnerability assessment frameworks that attempt to apply those concepts in the assessment of climate change vulnerability.

Keywords Climate change, Risk assessment, Integrated vulnerability assessment, Conceptual elements, Assessment frameworks

Paper type General review

1. Introduction

The study of vulnerability in climate change research is largely underpinned by the hazards literature (Cutter, 1996; Cutter *et al.*, 2000; Janssen *et al.*, 2006), but also influenced by other research strands such as human ecology, political economy,

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The authors would like to thank the Scottish Alliance for Geosciences, Environment and Society for funding this research, also the Editor of the journal and the two anonymous reviewers for their constructive comments and suggestions. The authors would also like to thank Dr Andy Inch for his comments on the paper.

International Journal of Climate Change Strategies and Management
Vol. 4 No. 1, 2012
pp. 6-35
© Emerald Group Publishing Limited
1756-8692
DOI 10.1108/17568691211200191

political ecology, food security, and development studies[1] (Adger, 2006; Füssel, 2007b; Mclaughlin and Dietz, 2008). Janssen *et al.* (2006) uncover the increasing interest by the scholarly community in the study of vulnerability which emerged from across a wide range of disciplines. Such multivariate contributions are clearly expressed by the array of vulnerability definitions which overall contribute to a certain confusion in the terminology and lexicon used in climate change vulnerability studies (Cutter, 1996; Adger, 2006; Füssel, 2007b). Smit *et al.* (2000) for example define vulnerability as the "degree to which a system is susceptible to injury, damage or harm" whilst Blaikie *et al.* (1994) describe vulnerability as "[...] the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard." A third definition by the Intergovernmental Panel on Climate Change (IPCC) conceives vulnerability as "the degree to which a system is susceptible to and unable to cope with, adverse effects of climate change, including climate variability and extremes" (Parry *et al.*, 2007). The first definition is quite generalised as it does not specify the subject of analysis or the hazardous event in question. Conversely, the definition by Blaikie *et al.* (1994) explicitly identifies social systems and their characteristics as the subject of analysis whilst recognising natural hazards as the source of harm to the system. The IPCC definition is broader in its scope regarding the subject of analysis which can either be an economic sector, a bioregion, the coupled human-environment system (CHES), etc.; but very specific regarding the hazard affecting the system which is climate change.

The dissimilarities between the three definitions presented above are associated with distinct perspectives on what vulnerability to climate change entails. In climate change research these conceptual perspectives on vulnerability can be broadly categorised as biophysical, social and integrated perspectives. These disparate views tend to apply particular methodologies to perform the analysis of vulnerability including climate impact assessments (CIAs), vulnerability assessments (VAs), and adaptation assessments. Despite conceptual and analytical differences all three perspectives offer ways of assessing vulnerability to climate change. The biophysical view focuses on the biophysical conditions and the exposure to hazards of a particular unit of analysis; the social perspective conceives vulnerability as a pre-existing condition of social systems prior to the hazardous event. The integrated perspective is an amalgamation of the other two perspectives as it aims to address and integrate both the biophysical and social dimensions of vulnerability in the analysis. This perspective is perceived as the current paradigm and analyses performed under this approach address particular conceptual and analytical elements in the assessment of vulnerability.

However, despite efforts in the development of conceptual and analytical knowledge of climate change vulnerability certain challenges prevail limiting the potential that integrated approaches can offer to the analysis of vulnerability.

The purpose of the paper is twofold. First, a synthesis of the main conceptual perspectives on vulnerability in climate change research is presented together with the types of assessment generally associated with those views. Second, the paper reviews the conceptual and analytical elements regarded as critical in any VA together with examples of conceptual frameworks used in the analysis of climate change vulnerability. In doing so, the authors aim to expose the main antecedents underpinning the conceptual elements in VAs and some of the remaining challenges to realise the potential that integrated approaches can offer to the analysis of vulnerability.

The paper is organised as follows. Section 2 presents the context of the vulnerability concept in the climate change literature. Section 3 reviews and synthesises the main conceptual elements perceived critical in any VA in light of the integrated perspective on vulnerability. Section 4 draws together some examples of conceptual VA frameworks from the literature; Section 5 presents some of the remaining challenges and limitations regarding VAs; and Section 6 concludes the paper.

2. Vulnerability in climate change research

In the climate change literature vulnerability can be generally categorized as biophysical vulnerability (also termed physical or natural) or social vulnerability (or socioeconomic) (Cutter, 1996; Klein and Nicholls, 1999; Brooks, 2003; Füssel, 2007b). This artificial dichotomy is broadly related to two disparate conceptual approaches to vulnerability: vulnerability as potential exposure to hazards or vulnerability as a state and/or propriety of a system (Dow, 1992; Brooks, 2003). A third perspective on vulnerability emerged as an alternative solution to the limitations posed by the two conventional approaches. It aims to integrate conceptual and analytical elements of the other two perspectives in order to provide a more complete insight into vulnerability. These three perspectives on vulnerability and some of their main conceptual and analytical differences are presented in Table I.

Vulnerability as a biophysical condition addresses the vulnerability and degradation of environmental conditions and extrapolates these in terms of potential impacts on humans (Liverman, 1990). This approach, largely based on the natural hazards tradition focuses on the distribution of hazardous conditions, the human occupancy within hazardous areas, and the degree of loss related to a specific hazardous event (Dow, 1992; Cutter, 1996). In this approach, vulnerability is regarded as an "end-point" (i.e. the outcome of climate change impacts minus adaptation) as its main purpose is generally to provide an understanding of climate change impacts and inform decision-making regarding the costs of adaptation versus the costs of mitigation (O'Brien *et al.*, 2007). The main focus is therefore upon the source of risk or hazard, which determines the level of vulnerability and issues such as magnitude, duration, and impact of the climatic event normally characterize this type of study. These approaches are also known as risk-hazard approaches (Turner *et al.*, 2003a; Eakin and Luers, 2006) or impact-driven

Table I.
Conceptual differences between biophysical, social and integrated perspectives of vulnerability

	Perspectives on vulnerability		
	Biophysical	Social	Integrated
Focal point of analysis	Biophysical conditions and the hazard	Social systems and social conditions	Both biophysical and social systems (i.e. the CHES)
Type of analytical questions	What are the hazards and impacts?	How are people affected? How are they capable to cope with climate change?	How and why do coupled systems change? What is their capacity to adapt?
System of analysis	Sectors, regions, activities, places	Social groups, e.g. communities, individuals	Coupled human-environment system, ecosystems
Time period of interest	Future climate change	Current climate variability	Current and future climate change

Source: Adapted from Eakin and Luers (2006) and O'Brien *et al.* (2007)

studies (Ford *et al.*, 2010). However, although capable of providing an overall understanding of the physical processes generating exposure, this perspective is limited as it excludes the social, economic, political and cultural factors that need to be addressed in the estimation of vulnerability (Ford, 2002; Cardona, 2004).

In the social perspective, vulnerability is conceived as a socially constructed phenomenon resulting from particular social, political, historical and economic processes and structures impacting on individuals/groups which can lead them to vulnerable conditions (Liverman, 1990; Cutter, 1996; Adger, 1999; Brooks, 2003). Contrary to the biophysical view, in this perspective vulnerability is regarded as a property, an inherent condition of a social system (e.g. individuals, communities, social groups).

Largely based on political economy and political ecology research traditions (Eakin and Luers, 2006; Füssel, 2007b) this approach emerged as a reaction to the conventional modernization theory in geography in the 1960s and 1970s (Hewitt, 1983; Blaikie *et al.*, 1994; Greenberg and Park, 1994). Numerous conspicuous events and industrial accidents during the same period (e.g. The 1970 cyclone in Bangladesh; the 1986 Chernobyl nuclear disaster) (Tierney, 1999; Smith, 2001) also led to an increasing recognition of socio-economic conditions as the main causes of disasters and people's vulnerability (O'Keefe *et al.*, 1976).

Many studies on social vulnerability are therefore related to chronic hazards and disasters in developing countries where, as a result of the hazard, the most vulnerable are affected by, e.g. famine, hunger, and drought (Cutter, 1996; Adger, 1999). The focus is drawn to social systems and vulnerability is conceived as having two sides: an external side encompassing the perturbations and risks the system is subjected to, and an internal side which includes the system's own capacity to cope and respond to hazardous events (Chambers, 2006). As a result, issues such as resilience, sensitivity, resistance, and coping capacity are common elements in these type of studies (Dow, 1992; Ford, 2002). In this perspective, vulnerability is perceived as the "starting-point" of the analysis where it is considered as a dynamic state resulting from social, environmental, political, and economic processes (O'Brien *et al.*, 2007). This perspective is also known as contextual vulnerability (Ford *et al.*, 2010). However, by over emphasizing the social and political structures and processes generating vulnerability and by neglecting the hazard impact and physical damage from the analysis, some of the studies using this perspective have only provided a limited understanding of vulnerability (Cardona, 2004).

The limitations posed by the two conventional perspectives and the emergent notion that "any distinction between social and natural systems is arbitrary" (Adger, 2006) led to the appearance of new approaches to study climate change vulnerability. This conceptual shift was due to changes in the scientific knowledge of complex systems (e.g. interconnectedness of anthropogenic climate change at various scales; surprise and unpredictability in the day-to-day) and the appearance of new forms of social and political interactions (e.g. more participatory decision-making processes; wider acceptance of environmental issues, human rights). As a result, new ways of conceptualising and defining issues emerged (Gallopin *et al.*, 2001) together with an appreciation that the complexity of problems and situations required better integration of the various dimensions of reality in complex systems[2]. Complex systems such as the human-environment system are perceived as encompassing factors such as multiplicity of scales, irreducible uncertainty, non-linearity, and a range of legitimate perspectives (Gallopin *et al.*, 2001).

Integrated approaches to vulnerability (also known as synthetic or hybrid approaches) aim to address both the biophysical and social dimensions of vulnerability (Füssel and Klein, 2006; Eakin and Luers, 2006; Ford, 2002). As a result, this perspective is broadly perceived as an amalgamation of the other two perspectives of vulnerability (Table I). In this view, "nature-society relationships are conceptualized as a mutuality, rather than as a duality" and vulnerability is determined by both biophysical conditions as well as social, political, economic, and institutional processes (O'Brien *et al.*, 2007). The process of conceptual integration is pursued by merging concepts from disparate views on vulnerability (Newell *et al.*, 2005). By attempting to blend the two conventional perspectives on vulnerability, this approach is perceived as capable of providing a better and clearer understanding of the multiplicity of processes and dynamics affecting the vulnerability of the coupled system to climate change. This is particularly important in the context of policy-driven assessments aiming to provide measures to inform adaptation policy towards reducing vulnerability to climate change (Füssel and Klein, 2006).

The integrated view on vulnerability is regarded as the current paradigm in the analysis of climate change vulnerability. It provides a broad conceptual and analytical platform by allowing the integration and application of different conceptual backgrounds as well as a range of methods and tools which have the potential to complement each other and improve the information provided (Mastrandrea *et al.*, 2010). However, the integration of disparate conceptual backgrounds (i.e. biophysical and social perspectives) can be problematic as it requires working with and blending in different ways of framing and performing the analysis of vulnerability (Table I).

2.1 Different approaches, different methods

These different conceptual approaches to vulnerability together with a paradigm shift in the climate change fora in the 1990s led to the development of different assessment methodologies. Three main types of assessment and the differences and commonalities between them are described in Table II.

CIA, considered as the first type of assessment to emerge in climate change research, were largely developed in the light of the biophysical perspective on vulnerability. This type of assessment looks at the long-term impacts of climate change on natural and human systems (Füssel and Klein, 2006; Parry *et al.*, 2007; Carter *et al.*, 2007). The IPCC methodology is considered the conventional approach to CIA (UNFCCC, 2004) although other frameworks have been developed and proposed since (Feenstra *et al.*, 1998). The development of this type of study was driven by the need to understand the potential impacts of climate change and the level of urgency regarding stabilization of greenhouse gases (GHG) and respective mitigation agenda (UNFCCC, 2005). However, growing evidence of the unavoidable impacts of climate change allied to slow progress on the reduction of GHG emissions led to a shift in conceptual focus from a mitigation-based analysis to one focusing primarily on adaptation (Schipper, 2006). Concerns were now over the vulnerability of social systems and the way these may be affected by climate change. In this context, particular attention was drawn to the least developed countries (LDCs) as many have already experienced climate change impacts and related events (e.g. floods, drought) with serious consequences to people's livelihoods, production systems and the environment (Mertz *et al.*, 2009; Parry *et al.*, 2007). Many LDCs also lack the capacity to adapt and respond to climate change

Table II. Differences and commonalities between climate impacts assessment, vulnerability assessment, and adaptation assessment

	CIA	VA	AA
Main approach	Top-down/scenario-driven	Bottom-up/vulnerability-driven	
Spatial scale	National to global	Local to global	Local to national
Key methods and tools	Development of scenarios; downscaling techniques; sectoral impact models	Vulnerability indicators; past and present climate risks; stakeholder tools; case studies; risk assessment techniques; decision support tools; agent-based methods; narrative methods	
Account for climate variability, non-climatic factors, and adaptation	Little	Partial/full	Full
Degree of stakeholder involvement	Low (mainly research driven)	Medium (research/stakeholder-driven)	High (stakeholders/research-driven)
Examples of research questions	What are the potential biophysical impacts of climate change?	What is the vulnerability to climate change, considering feasible adaptations?	Which adaptations are recommended for reducing vulnerability to climate change and variability?

Source: Based on UNFCCC (2004), Füssel and Klein (2006) and Carter *et al.* (2007a)

due to general conditions such as fragile economies, low access to technology, generalised poverty, and high levels of inequality amongst populations (UNFCCC, 2011). As a result, an increasing interest by the international community emerged particularly regarding the analysis of vulnerability towards the development and implementation of adaptation policy in those countries (Mertz *et al.*, 2009).

This resulted in the appearance of new vulnerability driven methodologies characterized by "bottom-up" approaches more aligned with social and integrated perspectives on vulnerability. In analytical terms, a focus on current climate variability alongside adaptation and non-climatic factors marks the shift from CIA to VAs (Füssel and Klein, 2006). This shift is also associated with new approaches to stakeholder engagement, more sophisticated socio-economic scenarios, and the consideration of adaptation measures, decision-support tools and enhancement of adaptive capacity as ways of reducing vulnerability to climate change (UNFCCC, 2005). Some VA termed "second generation" further address relevant non-climatic drivers (e.g. economic, demographic), and the adaptive capacity of the system under analysis (Füssel and Klein, 2006). Adaptation Assessment (AA) is another type of methodology which focuses primarily on information requirements of stakeholders for policy development and facilitation of decision-making processes (Füssel and Klein, 2006). However, the distinction between VA and AA is artificial as they share many analytical components, methods and tools, and both use bottom-up approaches to localized vulnerability and adaptation. They are therefore more attuned to local contexts and more capable of identifying local options and limitations than top-down approaches (UNFCCC, 2004).

However, one should avoid considering these different typologies of assessment[3] as mutually exclusive or competitive as they can complement each other and be integrated in the same assessment exercise (Mastrandrea *et al.*, 2010). The integrated perspective on vulnerability aims for that integration through the combination and articulation, whenever possible, of different methods and tools in the analysis. In the next section the paper goes on to consider the key elements required in such integrated analyses.

3. Conceptual elements of climate change VAs

Section 2 introduced the main conceptual perspectives on vulnerability in climate change research together with the typologies of assessment that are commonly used in the analysis of climate change vulnerability. This section aims to present the conceptual and analytical elements normally addressed and considered when performing vulnerability analysis studies under the integrated perspective (Section 2). The starting point for this review is the study by the Research and Assessment Systems for Sustainability Program (RASSP, 2001). Aiming to explore the conceptual and design challenges facing integrated VAs and decision-making support, the RASSP study uncovered the key elements regarded as critical in any vulnerability framework and assessment. These elements were: identify the CHES as the subject of analysis; assess vulnerability in terms of its place-based characteristics; include key system elements; incorporate multiple and interacting perturbations; profile differential vulnerability; recognize the potential importance of cross-scale dynamics; the role of endogenous perturbations; incorporate non-linear and stochastic characteristics and surprise; and identify causal structures. Recognizing the importance of such factors in integrated VAs) the present paper extends beyond the discussion in RASSP (2001) by expanding these ideas and concepts with new developments in climate change research and literature. The following sub-sections discuss those conceptual and analytical elements with a view to exploring their implications for the potential of the integrated perspective in vulnerability analysis (Figure 1).

3.1 The CHES

The core element of any VA is the subject of analysis, i.e. the focus of the VA. The subject of analysis will depend on the purpose of the assessment and the conceptual approach utilised to perform the analysis. For example, in the biophysical view of vulnerability

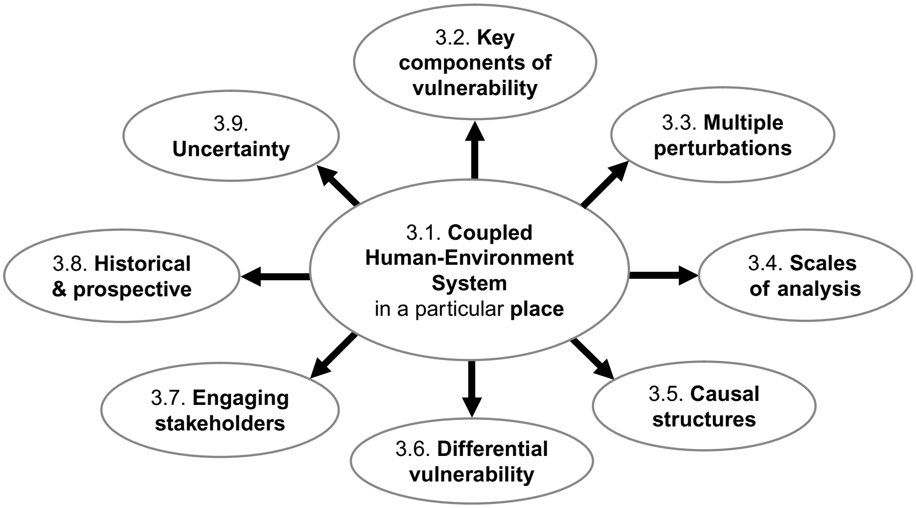


Figure 1.
Conceptual elements of integrated vulnerability assessments

the onus is on the hazard (i.e. climate change), the biophysical factors generating exposure, and the impacts on the exposure unit. Conversely, in the social vulnerability perspective the subject of study tends to be social systems, e.g. a community, a particular social group. In integrated approaches, the CHES is recognised as the main subject of analysis in VA (RASSP, 2001; Gallopin, 2006; Young *et al.*, 2006). Despite the various terms applied, e.g. CHES (RASSP, 2001; Turner *et al.*, 2003a); coupled human and natural system (Liu *et al.*, 2007); social-environment system (Eakin and Luers, 2006); and social-ecological system (Gallopin, 2006; Adger, 2006) this type of system is generally conceptualised as encompassing both environmental and social components and the interactions between them (Gallopin *et al.*, 1989 in Gallopin *et al.*, 2001). In CHES "people and nature interact reciprocally and form complex feedback loops" (Liu *et al.*, 2007) making it a synergetic and dynamic system that evolves through time and space.

In this context, it is crucial to identify the attribute(s) of concern within the coupled system which will be under scrutiny when performing the VA, e.g. human lives, environmental degradation, income and cultural identity of a community (Luers *et al.*, 2003; Füssel, 2007b). This allows the identification of those linkages most important to the analysis of vulnerability.

Another important aspect regarding the CHES is the notion of place. This idea, re-introduced by Cutter's model of hazard-of-place, focuses the assessment on a particular geographic area (Cutter, 1996). The central idea is that the CHES is intrinsically related to a particular geographical area and therefore establishing that delimitation helps to identify the dimensions and scales of interaction and influence relevant to the coupled system under analysis. Moreover, place represents a particular context where communication, processes and decision-making occur (Wilbanks, 2002).

Many existing VA frameworks consider the CHES as the subject of analysis (Carter *et al.*, 2007) and adopt the notion of place-based assessment (Cutter, 1996; Klein and Nicholls, 1999; Turner *et al.*, 2003a; Polsky *et al.*, 2003; Ford and Smit, 2004; Lim *et al.*, 2004).

However, a very limited understanding of how human and environmental systems are coupled and the ways in which they interact remains problematic in vulnerability analysis due to the lack of empirical studies (Birkmann and Wisner, 2006; Liu *et al.*, 2007). Liu *et al.* (2007) uncover some of the complexities and challenges in the analysis of CHES using six disparate case studies across the world. Their study reveals that the complexity of this type of system is still far from being understood and that there is a pressing need for more empirical analysis and more comprehensive portfolios to enhance knowledge regarding coupled systems (Liu *et al.*, 2007).

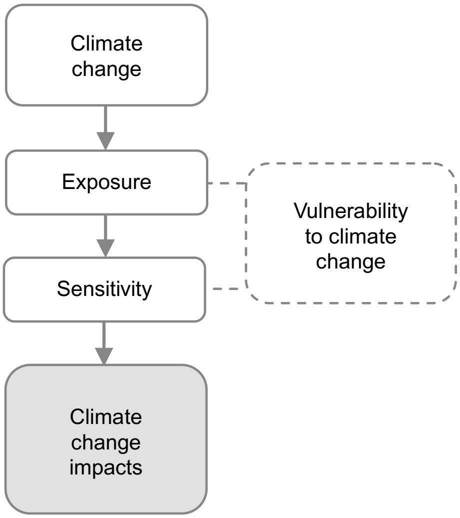
3.2 Key components of vulnerability

In climate change research the key components of vulnerability generally include elements of exposure, sensitivity and adaptive capacity (Carter *et al.*, 2007; Smit and Wandel, 2006). According to the IPCC, exposure is "the nature and degree to which a system is exposed to significant climatic variations" (McCarthy *et al.*, 2001). Sensitivity is generally conceived as "the degree to which a system is affected, either adversely or beneficially, by climate variability or change" (Parry *et al.*, 2007). Adaptive capacity, also termed coping capacity (Turner *et al.*, 2003a) or the capacity of response (Gallopin, 2006) is regarded as the "ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences" (Parry *et al.*, 2007)[4].

Perhaps more important than establishing definitional differences is to understand how these components relate to each other in the various conceptualisations of vulnerability. In the biophysical view the analytical focus is on the exposure to climate change and the sensitivity of the subject of analysis to that exposure. Vulnerability is therefore conceptualised and analysed based on these two components and adaptive capacity is normally not accounted for in the analysis. In the social perspective, vulnerability is conceptualised as a pre-existing condition of the unit of analysis and, as a result, exposure (to climate change) is considered as an external element in the analysis of vulnerability (Gallopin, 2006). Looking at the social vulnerability of farmers in Mexico and Argentina, Eakin *et al.* (2008) analyse their vulnerability to climatic events by determining the differential sensitivities and capacity to adapt across the various farm households. Exposure is regarded as an external element as vulnerability is conceptualised as a characteristic (and not as a predisposition to damage) of farm households as the result of susceptibilities and/or lack of capacity to adapt (Cardona, 2004). In integrated approaches vulnerability is perceived as a property of the CHES encompassing the dynamics between its social and natural components. As a result, in this approach exposure to climate change is addressed as an internal component of the vulnerability of the coupled system (Gallopin, 2006).

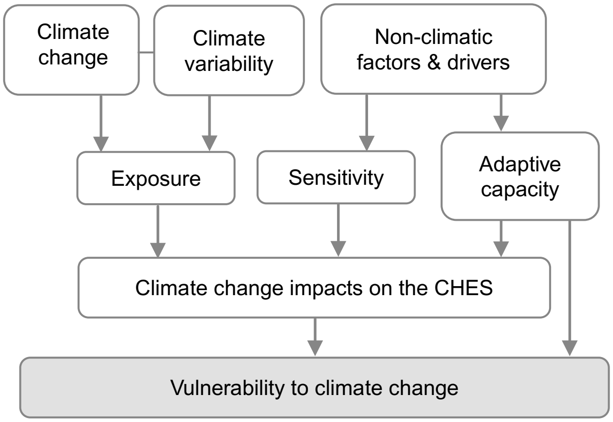
The analysis of the key components of vulnerability under different typologies of assessment also differs. In the CIA model vulnerability is determined by the relationship between sensitivity and exposure of the subject of analysis to climate change (Figure 2); whilst in the VA model (Figure 3), other factors are accounted for in the analysis of vulnerability including climate variability, non-climatic factors and drivers, and the CHES' capacity to adapt.

Accounting for adaptive capacity in a VA is fundamental as it translates the existing and/or potential capacity to perform adjustments in response to climate change. In fact, vulnerability and adaptive capacity are broadly perceived as being negatively correlated as the higher the adaptive capacity the lower the system's



Source: Based on Turner II *et al*. (2003a, b)

Figure 2.
Basic climate impact assessment model



Source: Based on Füssel and Klein (2006)

Figure 3.
Basic vulnerability assessment model

vulnerability and vice versa (Smit and Pilifosova, 2003; Brooks and Adger, 2004; Füssel and Klein, 2006). Adaptive capacity is determined by a range of conditions and resources termed as the determinants of adaptive capacity which normally include economic wealth, information and skills, technology institutions, social capital, natural resources, and equity (Burton *et al.*, 2001; Smit *et al.*, 2001; Yohe and Tol, 2002; Brooks and Adger, 2004; Smit and Wandel, 2006). However, many VA frameworks lack the analytical detail required to understand the system's adaptive capacity and as a result adaptive capacity frameworks have been developed (Wall and Marzall, 2006; Marlin *et al.*, 2007; Walker *et al.*, 2007).

The analysis of the key components of vulnerability often relies on the use and integration of indicators. However, the relationship between the components regarding their relative importance and influence on the vulnerability of the coupled system is generally unknown. To overcome this limitation some studies involve stakeholders and/or use expert knowledge to determine the relative importance of each of the key components in the analysis of vulnerability (Preston *et al.*, 2009).

The three key components of vulnerability: exposure, sensitivity, and adaptive capacity are addressed in most VA frameworks. However, the relationship and dynamics between key components and their relative importance in generating/reducing vulnerability remain unclear in many existing frameworks.

3.3 Multiple perturbations

The CHES is constantly changing due to numerous pressures and factors influencing it (e.g. political and economic systems, demographic changes) and as it changes, so does its vulnerability to climate change (RASSP, 2001). A perturbation is an influence that may affect (negatively or positively) an attribute of the coupled system and is interchangeably used with terms such as stresses, hazards, stimulus and events (Smit *et al.*, 2000). However, some distinguish between these concepts, e.g. hazards which can be either perturbations (discrete hazards) or stressors (continuous hazards) (Füssel, 2007b; Turner *et al.*, 2003a). The idea of hazard is normally related to an external perturbation, i.e. external to the subject of analysis (Cardona, 2004).

Perturbations can vary in nature, magnitude, timing, and how the subject will be exposed and respond (Turner *et al.*, 2003a; Schröter *et al.*, 2005). Studies using a risk-hazard/impact approach (i.e. biophysical perspective) tend to focus their analysis on a single stressor or perturbation and its multiple effects on the unit of analysis (Kasperson and Kasperson, 2001). Conversely, in VA the notion of multiple perturbations (largely based on food security studies) is used where multiple causes can lead to critical outcomes (Polsky *et al.*, 2003; Schröter *et al.*, 2005).

In broad terms, one can distinguish between internal and external perturbations (Gallopin, 2006) where the former encompass those occurring within and between the human and environmental components of the system (e.g. unsuitable land management practices in a farming community) (Füssel, 2007a) and the latter include the exogenous factors and conditions exerting pressure and influencing the coupled system (e.g. national policy on local land management practices). It is therefore fundamental to understand the structures, forces, and dynamics affecting the coupled system (exogenous perturbations) as well as the interactions within and between its elements (endogenous perturbations) (Gallopin *et al.*, 2001). In addition, other threats can be posed by factors other than climate change (e.g. economic crisis; unemployment) or exacerbated by the confluence of multiple perturbations subjecting the coupled system to different exposures and vulnerabilities (O'Brien *et al.*, 2004b).

To overcome the challenge of identifying those perturbations relevant to the subject of analysis, Kasperson and Kasperson (2001) suggest using past experiences of vulnerable situations and working backwards towards identifying the perturbations that led to those instances. Another approach focus on particular unwanted outcomes and works backwards through the causal structures in order to identify the stresses most likely to generate those unwanted outcomes (RASSP, 2001). However, many vulnerability studies focus on external perturbations and, as a result, there is a lack of understanding regarding the role of internal perturbations and the interactions within the coupled system (RASSP, 2001; Gallopin, 2006).

3.4 Scales of analysis

In the context of VA, scale is understood as the "spatial, temporal, quantitative, or analytical dimensions used by scientists to measure and study objects and processes" and relates to terms such as, levels, extent and resolution (Gibson *et al.*, 2000). Levels represent the various locations on a particular scale (in a temporal scale for example the levels could refer to short, medium and long duration); extent refers to the size of the scale (i.e. the outer boundary of what's being measured); and resolution relates to the precision (i.e. the smallest unit used in the analysis) (Evans *et al.*, 2002; Gibson *et al.*, 2000).

Scale issues are intrinsically linked to the way in which data are collected and represented (Evans *et al.*, 2002). In data collection scale refers to the way in which reality is portrayed (e.g. representation of objects – roads, villages, etc. – in a map) so it can then be used as data. The representation of those objects will be affected by the map scale utilised (e.g. the representation of a stream at a particular scale may not be relevant at a larger scale[5]).

The analysis of the CHES poses numerous challenges regarding scales of analysis. First of all, the human and environmental components of the coupled system may operate at disparate spatial, temporal or even functional scales (Cumming *et al.*, 2006). According to Cumming *et al.* (2006) these scale mismatches between the system's components – environmental and social – can occur whenever the scale at which these operate do not align properly potentially limiting the analysis. This problematic is further exacerbated by the fact that different disciplines tend to use different scales to represent and analyse particular phenomena (Cash and Moser, 2000). In social sciences for example, scale can be defined by applying organisational or functional levels (i.e. city; neighbourhood; household) (Stephen and Downing, 2001); whilst in natural sciences it can relate to particular biophysical conditions (e.g. river catchments area; bioregions) (Cash and Moser, 2000).

Moreover, the choice of analytical and methodological approaches (e.g. top-down/bottom-up approaches) can lead to fundamentally different interpretations of the same phenomenon. For example, analyses based on the biophysical perspective and using a CIA approach tend to focus on larger scales (e.g. national/global) whilst those employing the social perspective using a VA/AA approach normally apply smaller scales (e.g. local/regional).

In VA it is fundamental that the scale considered is congruent with the purpose of the analysis. By focusing the analysis solely at the local level for example, certain interactions and dynamics across scales can be omitted and consequently important determinants at larger scales will be excluded in the explanation of local issues (Wilbanks and Kates, 1999; Wilbanks, 2002). Moreover, as the scale of analysis changes so the variables explaining a particular phenomenon change (Evans *et al.*, 2002). Looking at the vulnerability of Norway to climate impacts, O'Brien *et al.* (2004a) ascertain the different outcomes when performing the analysis of vulnerability at a larger scale (national) and then at smaller scales (regional/local). By doing so, the authors unravel the disparate nuances of vulnerability that emerge when using different scales in the analysis of Norway's vulnerability to climate change. Hence, determining the scales of analysis to be used in the VA frames the analysis (and consequently the outcomes) in particular ways which, in certain cases, can raise issues of equity, justice and differential vulnerability (Schneider *et al.*, 2007).

The scale of agency is also critical particularly in the context of policy-driven assessments towards policy to reduce vulnerability. This implies matching the scale of analysis used in the VA with institutional and managerial powers to act upon the outcomes of the analysis (Cash and Moser, 2000).

Understanding cross-scalar dynamics, i.e. between the level at which the CHES operates and other levels is fundamental to understand the dynamics surrounding the coupled system and the plurality of legitimate perspectives (Gallopin *et al.*, 2001). The notion of hierarchy is commonly used to address cross-scalar dynamics and relates to the idea of grouping together objects along an analytical scale (Gibson *et al.*, 2000). Nested hierarchies (such as constitutive hierarchies) are characteristic of complex systems where the lower levels can be aggregated into new units with emergent properties and organisation (Gibson *et al.*, 2000). Hierarchy theory can be used to the scaling of both biophysical and social data as it allows the consideration of the various levels of spatial and temporal resolution from both dimensions of the coupled system (Evans *et al.*, 2002; Wilbanks, 2002). By addressing the levels above and below the level of reference (i.e. the level at which the coupled system operates), this theory allows integration and analysis of data at multiple levels (Evans *et al.*, 2002). Alternative solutions for dealing with scale in VA include converging the assessment to a single intermediate scale of analysis (e.g. regional) or adopting a multi- or meta-scale synthesis using information at multiple scales and seeking a greater level of understanding from all the information provided (Wilbanks, 2002). Many tools have been developed and used to help deal with transitions between scales, such as geographical information systems, statistical downscaling, and nested economic models. However, these are often limited by the absence of integrating frameworks, lack of multiple-scale data, and integrated modelling capacity (Wilbanks, 2002; Eakin and Luers, 2006).

Turner *et al.* (2003a) propose a conceptual framework to assess the vulnerability of CHES to hazards which addresses the cross-scalar dynamics influencing the coupled system by applying a conceptual scale: local, regional, and global. However, methodological and operational challenges in assessing the myriad of interactions between scales and the numerous linkages between the system's components have been noted by Eakin and Luers (2006). Hence, the integration of information from disparate scales of analysis as well as our limited understanding of cross-scale dynamics and interactions can pose serious challenges to the analysis of the vulnerability of coupled systems to climate change (Cash and Moser, 2000).

3.5 Causal structures of vulnerability

The notion of causality in vulnerability studies is largely underpinned by political economy and political ecology research traditions which emphasise the role of socio-economic and political factors in generating people's vulnerabilities. In his analysis of the Katrina event in New Orleans, Oliver-Smith looks at the spatial correlation between socio-economically deprived areas and those areas more exposed to the event (i.e. below sea level). In doing so, the links between unsafe conditions and the most socio-economically vulnerable groups become clear. The lack of institutional and social support to the most vulnerable also exacerbated the impacts of the Katrina event (Oliver-Smith in Birkmann and Wisner, 2006).

Some authors have been critical in the development of our understanding of causality in vulnerability analysis such as Sen (1981) and Watts and Bohle (1993). In a disaster risk context, the pressure-and-release (PAR) model by Blaikie *et al.* (1994) has also contributed greatly to the understanding of causal structures of vulnerability by attempting to explain the processes and mechanisms leading to people's vulnerability. In this model vulnerability is generated through three interconnected levels: from the root causes of vulnerability, to dynamic pressures, finally leading to unsafe conditions (Figure 4).

In their conceptualisation, risk is formulated by two concomitant factors: the occurrence of hazards and vulnerable people. The onus of the analysis is therefore on the underlying causes of vulnerability and the capacity of social groups to anticipate, cope, and recover from the occurrence of natural hazards (Blaikie *et al.*, 1994).

Both the PAR and VA models offer ways of analysing vulnerability despite using different conceptualisations and formulations, focusing on different hazards and looking at different subjects of analysis. Nonetheless, the underlying notion of multiple and intersecting processes and structures generating vulnerability from the PAR model has permeated into the VA model. By analysing the non-climatic factors and drivers influencing the system, the VA allows the examination of the multiple causes leading to vulnerability (Ribot, 1995).

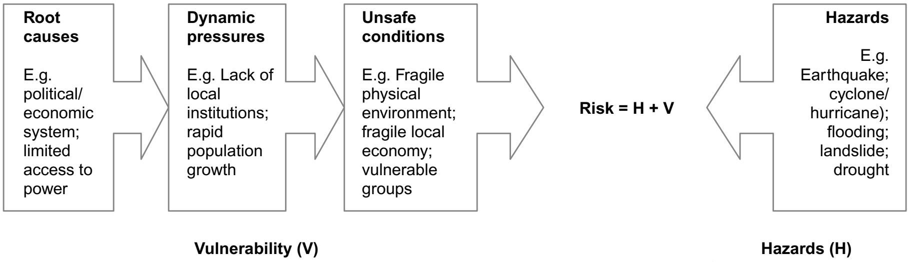
However, despite efforts to address the causal structures of vulnerability in climate change research, establishing the empirical relations between underlying processes and impacts on the subject of analysis can be challenging (Eakin and Luers, 2006; Young *et al.*, 2006).

3.6 Differential vulnerability

Vulnerability is perceived as a differential concept as it is unequally distributed across the coupled system (Downing and Patwardhan, 2004; Smit and Wandel, 2006; Adger *et al.*, 2007). The pursuit of better understanding of the nuances of vulnerability was promoted by feminist studies where vulnerability (often linked to poverty) is exacerbated by cultural and social norms which place women in more vulnerable positions (e.g. dependency for subsistence, reduced educational opportunities, less political power) (Cannon, 2002; Fordham, 2004). Other dimensions commonly associated with conditions of vulnerability are poverty (Chambers, 2006), class (Susman *et al.*, 1983), and also age, religion and ethnicity (Blaikie *et al.*, 1994; Morrow, 1999). Factors such as health and access to education and services (e.g. transport, housing) have also been identified as contributing towards people's adaptive capacity therefore potentially reducing their vulnerability (SNIFFER, 2009). As a result, accounting for differential adaptive capacity in VA is important as it varies amongst groups and can be limited by particular barriers (e.g. political, institutional) or even access to resources (Polsky *et al.*, 2003; Adger *et al.*, 2007). These manifestations of vulnerability are not however mutually exclusive as they can coexist and therefore express different nuances of vulnerability (Morrow, 1999). For example, Pradhan *et al.* (2007) found that in the flooding events of 1993 in Nepal fatality was highest among young children and women and also the poor living close to flooding waterways in poor quality housing.

3.7 Engaging stakeholders

In bottom-up approaches, i.e. VA and AA, there is a general perception that local actors hold information and possess local knowledge regarding past (climatic) events. As a result, their experience and knowledge are seen as valuable contributions to understand the context-specific conditions and existing local capacity to adapt to such events (Ford, 2002; Swart *et al.*, 2004; Carter *et al.*, 2007). Moreover, engaging local actors in a VA is perceived as a valuable process as it allows for a more legitimate and transparent production of information, salient policy (particularly regarding the development of adaptation policy) and greater credibility regarding the outcomes and feasibility of the analysis (Conde and Lonsdale, 2005; Schröter *et al.*, 2005; Meinke *et al.*, 2006; Eakin and Luers, 2006). The framework by Polsky *et al.* (2003) highlights



Source: Adapted from Blaikie *et al.* (1994)

Figure 4. The pressure and release model

the importance of involving stakeholders from the outset of the project arguing that ultimately they will be the ones responsible to act upon the outcomes of the VA.

A stakeholder can be understood as "a person or an organisation that has a legitimate interest in a project or entity, or would be affected by a particular action or policy"[6] (Parry *et al.*, 2007). Common stakeholders' categories include the scientific community, policy makers, the public, the media, NGOs, and industry (Keskitalo, 2004). The type of engagement will vary depending on the role stakeholders are expected to play (e.g. informants, reviewers) (Carney *et al.*, 2009) which in turn will determine their level of involvement (e.g. participation by consultation, self-mobilization) (Conde and Lonsdale, 2005) at particular stages of the assessment (e.g. at the beginning/end of the project) (Welp *et al.*, 2006). An array of participatory methods and techniques exist to facilitate engagement at various levels, e.g. focus groups, workshops, mapping, development of scenarios (Elliot *et al.*, 2005).

In this context, the co-production of knowledge through the interaction of scientists, policy-makers and the public is regarded as the alternative approach to integrate "local" and "everyday" knowledge with scientific knowledge. Such model requires a considerable commitment towards stakeholder participation and interaction in the research process, interdisciplinarity (i.e. capacity and effort by scientists from disparate backgrounds to work together), and production of knowledge that is usable (Lemos and Morehouse, 2005). However, a number of factors can potentially jeopardise the implementation of this type of model including lack of resources, political constraints, and the level of suitability between science and stakeholders' needs and expectations (Lemos and Morehouse, 2005). Moreover, critiques of public and stakeholder participation have been noted by Few *et al.* (2006). These include issues regarding the methods of engagement and the ways in which those represent a meaningful inclusion in the assessment process, as well as, the more conceptual and operational difficulties in achieving a broad public/stakeholder engagement, i.e. "who participates and on what basis" (Few *et al.*, 2006).

3.8 Historical and prospective analysis

Performing both historical and prospective analysis is another important dimension of VA (Polsky *et al.*, 2003; Schröter *et al.*, 2005). In VA, the starting point of the analysis is to understand the current vulnerability of the coupled system to climate change, i.e. is the CHES presently affected by climate change? And; what are the impacts on climate change on the coupled system? Assessing the current vulnerability of the CHES allows understanding of the main issues and conditions affecting the coupled system's vulnerability to climate change, e.g. its exposure to particular climate risks, existing adaptation measures already in place (Lim *et al.*, 2004). In certain cases however climate change impacts may still be unknown (or fully understood) and, as a result, the analysis of current vulnerability is not performed and only prospective analysis is applied (these studies normally employ the biophysical perspective).

Workshops, interviews, focus groups, mapping, and vulnerability profiles are some of the methods and tools used to collate information on current vulnerability (Downing and Patwardhan, 2004). The use of indicators has been common practice in vulnerability studies (Cutter *et al.*, 2000; Moss *et al.*, 2001; Yohe and Tol, 2002; Adger *et al.*, 2004; Benkert and Malone, 2005; Aall and Norland, 2005; Vincent, 2007; Eriksen and Kelly, 2007), although this is a contested area amongst scholars (Vincent, 2007; Adger *et al.*, 2007). Understanding the system's current vulnerability helps to identify and establish the main issues and priorities in terms of analysis (Ford *et al.*, 2006) as well as providing "a roadmap from known territory into uncertain futures" (i.e. a system's future vulnerability) (Dessai and Sluijs, 2007b).

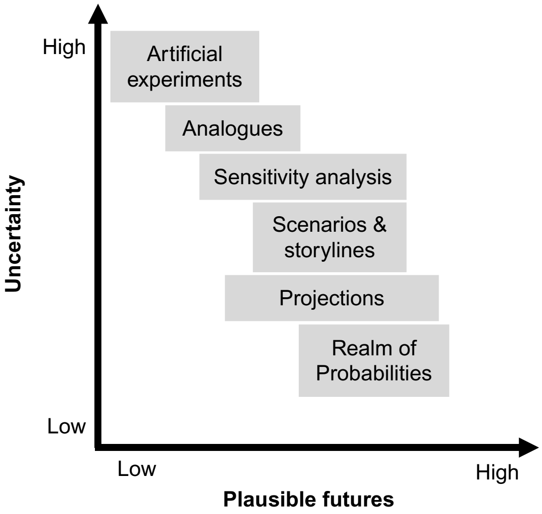
Some of the methods used for characterising future conditions in climate change research are shown in Figure 5.

In VA the analysis of future vulnerability is normally pursued through the use of projections and scenarios of the future. A projection is perceived as "any description of the future and the pathway leading to it" (Carter, 2007) and can be deterministic or probabilistic (Dessai *et al.*, 2009).

A scenario is a "consistent and plausible picture of a possible future" (EEA, 2009) and it can represent a range of alternative futures outlining how the world might look under different conditions (Lorenzoni *et al.*, 2000; Carter, 2007). Projections may be used as raw data for developing a scenario although these normally require other information sources (e.g. data on baseline conditions) (Carter, 2007).

In general terms, scenarios can be extrapolatory or forecasting (use past trends and iterate these into the future); normative or backcasting (built on visions of the future and the pathways leading to them); or exploratory (a mix of the two former approaches using different social and economic conditions to create different ideas of possible futures) (Berkhout *et al.*, 2002; Rounsevell and Metzger, 2010).

There are two broad categories of scenarios that can be used to characterise the future in climate change research: climate scenarios which provide information on potential future climate change; and socio-economic scenarios which provide possible trajectories of future social and economic conditions and change (Carter, 2007; Lorenzoni *et al.*, 2000). It is important to stress that socio-economic scenarios are used to characterise not only the multiple drivers of anthropogenic greenhouse gas emissions in climate scenarios (e.g. IPCC Special Report on Emission Scenarios), but also the vulnerability,



Source: Adapted from Carter (2007) and Zurek and Henrichs (2007)

Figure 5.
Categories of future characterisations

sensitivity and adaptive capacity of social systems to that change (UKCIP, 2001; Dahlström and Salmons, 2005; Carter, 2007). As future climate change will be experienced in different social and economic conditions than current ones, using socio-economic scenarios (in combination with climate scenarios) accounts for the system's particular conditions and characteristics and therefore develop ideas of possible socio-economic futures, providing "a more dynamic image of the future" (Lorenzoni *et al.*, 2000). Examples of studies combining climate scenarios with socio-economic scenarios include Holman and Loveland (2001), Lorenzoni *et al.* (2000) and Wade *et al.* (2006). Scenario-based approaches can be extremely helpful when considering uncertainty in future pathways in CHES (Zurek and Henrichs, 2007), as well as a powerful tool to communicate that uncertainty and explore potential futures with stakeholders (Conde and Lonsdale, 2005). However, the uncertainty surrounding prospective analysis particularly regarding complex systems such as the CHES adds to the overall complexity in the analysis of vulnerability (Section 3.9).

3.9 Dealing with uncertainty

Climate change uncertainty can be understood as an "expression of the degree to which a value (e.g. the future state of the climate system) is unknown" (Parry *et al.*, 2007).

In this context climate change uncertainty includes, for example, natural internal variability of the physical system and its sensitivity to future climate change as well as uncertainty surrounding the social dimensions of the CHES namely its capacity to adapt to climate change and the success of a particular adaptation strategy (Mearns, 2010). There is also uncertainty associated with our limited knowledge of the climate system and the ways in which uncertainty is modelled in studies (Hallegatte, 2009; Foley, 2010). Uncertainty related to our understanding of the climate system includes, for example, trajectories of future GHG emissions and the climate's sensitivity to future changes (Hallegatte, 2009; Foley, 2010); whilst uncertainty with models and data includes unknown errors in models' structure and data (Schneider and Kuntz-Duriseti, 2002; Foley, 2010) and uncertainty in modelling the impacts of climate change and their distribution in the coupled system (Dessai *et al.*, 2009).

The problem of uncertainty is further exacerbated by spatial and temporal mismatches, e.g. climate change caused by global changes but with local impacts (Schneider and Kuntz-Duriseti, 2002) and by non-linear processes and self-organisation within the coupled system (Gallopin *et al.*, 2001). Although unexpected events, i.e. surprise, are still poorly understood due to the complexity surrounding processes and linkages in coupled systems, it is crucial that assessments of vulnerability are able to address this type of event (RASSP, 2001; Schneider and Kuntz-Duriseti, 2002).

The conventional approach, underpinned by an evidence-based policy making paradigm argues that uncertainty "needs to be characterised, reduced, managed and communicated" (Dessai and Sluijs, 2007b). It defends the use of sophisticated and integrated models and techniques to reduce uncertainty and inform policy and strategies (Morgan *et al.*, 2009; Dessai *et al.*, 2009).

An alternative approach places less importance in reducing the uncertainty arguing instead for new and flexible ways of characterizing that uncertainty in a policy-setting context (Mearns, 2010). Lempert *et al.* (2004) for example suggest an "assess-risk-of-policy" framework to support robust decision-making against currently known uncertainties (Mearns, 2010) whilst Hallegatte (2009) defends the need for more flexible decision-making frameworks and proposes different types of strategies to achieve this (e.g. no-regret strategies, reversible strategies, etc.). In the face of a certain irreducible uncertainty there is an underlying argument for more iterative, strategic and flexible mechanisms for the implementation and monitoring of adaptation measures and strategies against new knowledge to allow the necessary flexibility to adapt to new situations and knowledge (Lim *et al.*, 2004; Mearns, 2010). The framework by Lim *et al.* (2004) defends this position suggesting a need to continuously monitor and evaluate the implementation of the adaptation strategy (following the VA) in order to assess success against its objectives and if necessary review and correct the strategy accordingly.

Another crucial aspect regarding climate change uncertainty is how to convey it to stakeholders and the general public. The responsibility of science to provide information on the rate and magnitude of change and potential damaging events presents serious issues regarding the use of language (Manning, 2003). The IPCC advises full consideration of the various sources of uncertainty in climate change research and careful use of language to convey such findings (e.g. probabilistic estimates of future climate change) as different recipients will have different understandings of findings (IPCC, 2005).

Although climate change uncertainty has been receiving growing attention by scholars much of it focuses on the uncertainties surrounding the climate system (Dessai *et al.*, 2007a). Fewer efforts have been made regarding uncertainties in the analysis of climate change vulnerability and impacts of actions taken (Dessai *et al.*, 2007a). Looking at seven national adaptation strategies, Biesbroek *et al.* (2010) review the main factors conditioning the development and implementation of adaptation policy and existing knowledge gaps in the formulation of this type of policy. Based on the study their recommendations included the need to further develop effective ways of assessing, managing and communicating uncertainty in a policy context.

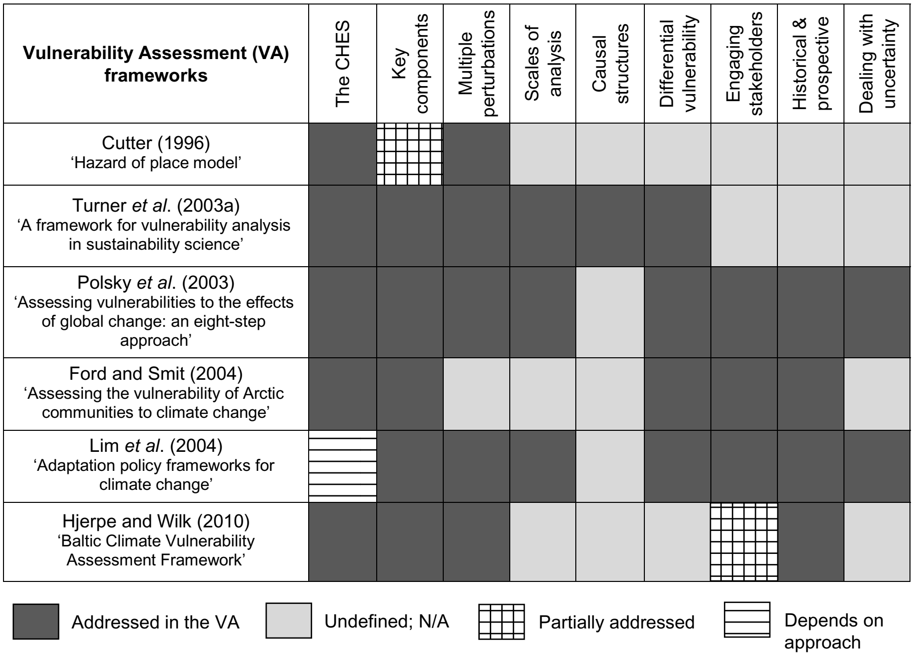
4. Examples of VA frameworks

Several conceptual and analytical frameworks to assess climate change vulnerability exist in the literature. However, some of these frameworks have been developed in different conceptual contexts (although with clear linkages) to that of climate change research (e.g. sustainability, global environmental change, environmental hazards). Nonetheless, these frameworks are important contributions to the field, as they have helped to shape and inform our conceptual and analytical understanding of integrated VAs in climate change. Table III shows some examples of VA frameworks against the various conceptual elements reviewed in Section 3.

Of all the VA frameworks listed in Table III, the Adaptation Policy Framework by the United Nations Development Programme (Lim *et al.*, 2004) is the most comprehensive regarding the nine conceptual elements discussed. Owing to its non-prescriptive nature, this framework allows the selection of the most appropriate approach and methods to perform VA given the particularities of the study being performed (Downing and Patwardhan, 2004).

The CHES and the key components of vulnerability are the conceptual elements most common to the frameworks in Table III. The only exception regarding the analysis of the CHES is the framework by Lim *et al.* (2004). This framework allows the use of different analytical and conceptual approaches (e.g. risk/hazard based; vulnerability based) and, as a result, the unit of analysis can differ (e.g. CHES, a community, a bioregion) depending on the analysis. All frameworks in Table III

Table III.
Examples of vulnerability assessment frameworks



Vulnerability Assessment (VA) frameworks	The CHES	Key components	Multiple perturbations	Scales of analysis	Causal structures	Differential vulnerability	Engaging stakeholders	Historical & prospective	Dealing with uncertainty
Cutter (1996) 'Hazard of place model'	■	▦	■	□	□	□	□	□	□
Turner *et al*. (2003a) 'A framework for vulnerability analysis in sustainability science'	■	■	■	■	■	■	□	□	□
Polsky *et al*. (2003) 'Assessing vulnerabilities to the effects of global change: an eight-step approach'	■	■	■	■	□	■	■	■	■
Ford and Smit (2004) 'Assessing the vulnerability of Arctic communities to climate change'	■	■	□	□	□	■	■	■	□
Lim *et al*. (2004) 'Adaptation policy frameworks for climate change'	▤	■	■	■	□	■	■	■	■
Hjerpe and Wilk (2010) 'Baltic Climate Vulnerability Assessment Framework'	■	■	■	□	□	□	▦	■	□

■ Addressed in the VA
□ Undefined; N/A
▦ Partially addressed
▤ Depends on approach

address the key components of vulnerability except for Cutter (1996) since this framework does not account for adaptive capacity in the analysis of vulnerability. The causal structures of vulnerability are the least regarded element in the various frameworks being only considered in the framework by Turner *et al.* (2003a). Applying this framework to three case studies, Turner *et al.* (2003b) unravel the complexity in capturing and analysing such processes and dynamics in empirical studies. This complexity in capturing structural processes and linking them to impacts on the coupled system may be the reason why this conceptual element is not addressed in the majority of VA frameworks.

The purpose and context in which the various VA frameworks were developed also influences the conceptual elements that are addressed. For example, the frameworks by Polsky *et al.* (2003) and Lim *et al.* (2004) aim to provide general guidance on the process of assessing vulnerability and as a result, are more comprehensive in nature and therefore encompass a larger number of the conceptual elements. Conversely, the frameworks by Ford and Smit (2004) and Hjerpe and Wilk (2010) were developed for assessing the vulnerability of specific communities (Arctic and Baltic communities, respectively). As a result, both frameworks address particular conceptual elements which reflect the specific purpose for which each of these frameworks were developed in the first place.

The VA frameworks in Table III propose (to different extents) ways of analysing vulnerability based on the integrated perspective on vulnerability. However, the complexity in addressing the various conceptual elements in integrated assessments (Section 3) is clear as none of these frameworks fully considers all elements to perform the analysis of vulnerability.

5. Discussion

Section 3 has outlined the main conceptual elements in VA and Section 4 presented some examples of conceptual and analytical frameworks developed to assess vulnerability. This section aims to draw together some of the remaining challenges and prevailing limitations in performing integrated VA. The majority of these challenges relate to the lack of praxis which perpetuates our limited understanding of a number of critical issues regarding the assessment of climate change vulnerability. This deficiency is further exacerbated when the aim of VA is to provide meaningful and useful information to decision-makers towards developing adaptation policy (Patt and Dessai, 2005).

Overall, the need to continue developing empirical studies as well as applying and testing VA frameworks is associated to two underlying propositions. The first idea relates to the need to continue exploring and developing new ways of integrating disparate conceptualizations of vulnerability together with the multiplicity of methods to assess vulnerability. As the integrated perspective on vulnerability attempts to amalgamate concepts, ideas and methodologies from both the biophysical and the social perspectives (Section 2) the need to explore new bridges between conceptual perspectives is therefore critical in this context. This effort needs to be developed by recognizing the disparate conceptualizations, framings and interpretations of vulnerability in order to avoid misunderstandings across disciplines (O'Brien *et al.*, 2007) and therefore work towards identifying common points of contact between the different worldviews and framings of vulnerability (Newell *et al.*, 2005). This requires a commitment to explore and develop a shared language towards a common conceptual framework (Newell *et al.*, 2005). This blending process needs to be continuously applied and tested in order to "demonstrate the value of integrative research and [...] promote the trust and understanding across disparate disciplines" (Newell *et al.*, 2005). Moreover, VA frameworks need to be applied to real case studies so as to better understand the practical and operational implications of employing integrated approaches on the ground.

The second issue relates to those prevailing challenges and limitations regarding the study and application of the various conceptual elements of VA. For example, the interactions and dynamics between the components of the coupled system and the ways in which these relationships affect and influence the CHES' overall vulnerability to climate change are still poorly understood. This includes not only the interactions between the two components of the system – human and environmental – but also how internal perturbations affect and interact within the coupled system. Moreover, processes of causality between the underlying causes of vulnerability and the impacts on the coupled system also need to be further explored as these remain largely speculative in this type of study. Another example of such limitations is the need to continue exploring and developing new ways of analysing and integrating uncertainty in VA as there are clear limitations in many of the assessments being performed (Schneider and Kuntz-Duriseti, 2002). It is also fundamental to improve the ways in which that uncertainty is managed and addressed in the development and implementation of policy to reduce vulnerability. Table IV lists some of the critical challenges and limitations that prevail regarding the conceptual and analytical elements in VA.

These challenges and limitations can only be overcome with more empirical studies to further explore and test the integration and analysis of the various conceptual elements in VA. Moreover, without this empirical knowledge it is extremely difficult to produce relevant information particularly in policy-setting contexts. Only through

Table IV.
Challenges and limitations in the analysis of conceptual elements in integrated vulnerability assessments

Conceptual elements of VA	Challenges and limitations to analysis
The CHES	Limited understanding of how human and environmental systems are coupled and the ways in which the two components of the coupled system interact and influence each other
Key components of vulnerability	Limited knowledge regarding the relationship and dynamics between key components; lack of clarity in majority of VA frameworks on how to analyse these components
Multiple perturbations	Limited understanding on the influence of internal perturbations in the CHES, i.e. interaction between the human-environment dimensions and how these are affected by internal perturbations
Scales of analysis	Methodological and operational challenges including difficulty in articulating different spatial and temporal scales operating in the CHES; limited understanding of cross-scale dynamics and how to address such dynamics in the analysis
Causal structures of vulnerability	Empirical challenge regarding the difficulty in establishing the relations between underlying causal structures and processes and impacts on the CHES
Engaging stakeholders	Challenges surrounding co-production of knowledge between researchers and stakeholders; conceptual and operational challenges in achieving a broad public/stakeholder engagement that is significant and representative to the analysis
Historical and prospective analysis	The uncertainty surrounding prospective analysis adds to the complexity in the analysis of climate change vulnerability
Dealing with uncertainty	Lack of practical application and empirical studies exploring new ways of dealing and managing uncertainty particularly in policy-setting contexts

praxis can we further our understanding and knowledge regarding the vulnerability of coupled systems to climate change.

6. Conclusions

In climate change research vulnerability theory is underpinned by a plurality of epistemological and research traditions which has led to a multiplicity of perspectives and conceptualisations of what vulnerability to climate change entails. In light of this, three broad conceptual perspectives of vulnerability can be drawn from the literature: biophysical, social and integrated perspectives. The biophysical view relates to the potential exposure to hazards and the analytical focus is on source of risk or hazard which determines the overall vulnerability of the unit of analysis. The social viewpoint conceives vulnerability as an inherent property or state of social systems (i.e. internal to the system) and its onus is on the sensitivity and adaptive capacity of social systems to recover and adapt from exposure to climate change. The integrated perspective attempts to combine the two former perspectives. It addresses both the human and environmental components of coupled systems where vulnerability is defined by both the exposure to climate change, the susceptibility of the coupled system to suffer (or benefit) from such exposure and its capacity to adapt to those changes.

The majority of VA frameworks in climate change research already address and apply (to different extents) the integrated perspective of vulnerability in their analytical frames. However, despite conceptual efforts towards more integrated analyses of vulnerability a shortage of empirical studies in practice remains and, as a result, numerous challenges regarding the integration of different conceptual and methodological approaches persist in this type of analysis.

The need to bring conceptual development closer to empirical studies in the assessment of climate change vulnerability is therefore imperative to improve and enhance our understanding of complex systems such as the CHES in the face of climate change. Moreover, developing praxis to systematically test and evaluate the consistency, applicability and performance of integrated VA can and should advance and promote their use and application in real case studies.

The future of integrated analysis of climate change vulnerability is largely dependent on advances being made in the empirical testing of frameworks without which our overall knowledge and understanding of coupled systems and their vulnerability to climate change will remain limited.

Notes

1. For more on different disciplines' perspectives on vulnerability the reader is directed to Alwang *et al.* (2001) and Villagran (2006).
2. A system is defined as "a conceptualisation of a portion of reality in terms of a set of interrelated elements". Complex systems can only be characterised through "two or more irreducible perspectives or descriptions" (Gallopin *et al.*, 2001).
3. It should be noted that other types of assessment methodologies exist in the literature including risk-based approaches (Carter *et al.*, 2007).
4. Other adaptive capacity definitions can be found in the literature see for example McCarthy *et al.* (2001), Brooks (2003), Turner *et al.* (2003a, b), Brooks and Adger (2004), Gallopin (2006) and Adger *et al.* (2007).
5. In this paper the term larger scale will be used to refer to phenomena that are big in quantities or space and small scale to refer to those limited in their numerical, spatial or temporal extent (Evans *et al.*, 2002). It should be noted that although these terms are normally used in the day-to-day terminology, they are opposite to those utilised by cartographers (i.e. where larger scale stands for cartographic representation at greater detail).
6. For other definitions see for example Carney *et al.* (2009).

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