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# Analysis and selection of the best approach for vulnerability assessment in natural environments

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**Abstract**. Nowadays, despite the significant importance of ecosystems in providing services and numerous natural products, transformation and degradation of these natural systems is dramatically increasing due to different stresses caused by natural and anthropogenic factors. In order to avoid degradation and achieve the conservation goal of ecosystems, reducing the effects of different stresses is required through the application of appropriate planning. To do this, adequate and customizable information concerning natural environment's vulnerability in relation to a wide range of hazards is needed. Vulnerability assessment through the identification of potential stresses (natural and anthropogenic) as well as estimation of the degree of reduction or damage on ecosystems play an important role in creating a quantitative and qualitative picture of the processes and outcomes related to vulnerability. This paper aims to analyze the vulnerability assessment methodology in natural environments and select the best approach by comparing approaches and assessing the benefits of their applications. The results of this study revealed that among the main existing approaches for the study of vulnerability (Risk-Hazard, Pressure and Realize, Political Economy/Political Ecology, Resilience and Integrated approaches), Integrated approach can be considered the best one since it develops a rational and effective relationship between the results of vulnerability analysis and decision-making process and also presents suitable adapted options in order to adjust the devastating consequences on natural environment and meet the challenges in vulnerability assessment and provide a detailed theoretical conceptual model to identify the vulnerability of the natural environments.
**Key Words**: vulnerability, integrated approach, ecosystems, decision-making.

**Introduction**. Ecosystems have been supportive elements for the survival of human and other forms of biological life on the earth planet and also are the origin of services (provisioning services, regulating services, cultural services, and supporting services) and natural products because of their wide range of ecological functions (Costanza et al 1997; Duke et al 2007). Such functions play an important role in providing the welfare of human in different levels (locally, regionally and globally) (Freeman 1995; Hanley et al 2003; WHO 2005; Eggert & Olsson 2009).

Despite such importance, changes and degradations in ecosystems' structure and function have been increasing dramatically in recent decades (WHO 2005; UNEP 2006; MEA 2005; Barbier et al 2008). Change, transformation and degradation in natural ecosystems are arise by various stresses caused by natural and anthropogenic factors such as storm, landslide, movements of the earth's crust and release of its latent energy, fire, epidemics, deforestation, erosion and sedimentation, deformation of landscape, environmental pollutions, invasion of exotic species, drought and flood (Meyer 1996; Ong Che 1999; Schaffelke et al 2005; Kathiresan & Rajendran 2005; Binelli et al 2007; Castellanos Abella & Van Westen 2008). The direct impacts of such stresses on ecosystems are 60% drop in ecosystems' services, poverty growth and inequity in the society (WHO 2005). In fact, people change the structure and management of ecosystems in order to improve their health and welfare. Therefore, when people face health and welfare problems, people's dependence on ecosystems' services increases and so because of this pressure, the capacity of ecosystems' services to people decreases (WHO 2005; Danielsen et al 2005; Kathiresan & Rajendran 2005; Dahdouh-Guebas et al 2005a, b).

Considering the consequences of mentioned natural factors and anthropogenic impacts which are serious threats for ecosystems, mitigation of their impacts with the help of suitable planning and mitigation tools is inevitable (Mahendra et al 2011). To achieve this goal and provide a suitable situation for taking necessary actions in the place of event, adequate and programmable information is needed to determine vulnerability of natural environments toward a wide range of hazards (Cutter et al 2000). Hence, vulnerability assessment through the recognition of potential stresses (natural or anthropogenic) that natural systems are faced with and the estimation of reduction degree or degradation of biophysical structures, human societies and ecological processes caused by destructive events with specific intensity (Lahsen et al 2010; Mahendra et al 2011), plays an important role in creating a qualitative and quantitative image of processes and results of vulnerability (Adger 2006). In fact, vulnerability assessment of ecosystems is one the most important tools to achieve natural ecosystems conservation's goal and on the other hand, offer effective management and planning solutions to minimize destructive impacts of stresses (Luers et al 2003) and determine appropriate measures that can be taken to reduce vulnerability and cause sustainable use of land before the potential for damage is realized. This paper aims to analyze the vulnerability assessment methodology in natural environments and select the best approach by comparing approaches and assessing the benefits of their applications.

**Material and Method**. The main objective of this study is to review literatures in the field of vulnerability assessment and analyze its methodology by means of the study of analytical approaches and results of studies done in this field. To do this, 189 peer-reviews were investigated. Finally, after studying the weaknesses and strengths of existing approaches in vulnerability assessment, the most effective approach to determine vulnerability in natural environments was introduced.

***Natural environments***. Human presence on the land's nature has gradually changed many intact and untouched ecosystems and in some cases such ecosystems has become transformed. Consequently, changes in structure, process and function of ecosystems caused by human activities lead to, in addition to ecosystems, a new concept in the literature of resources management and environment arise. Gradually, besides forest ecosystem, forest environment was introduced. Forest environment is a forest ecosystem that a part of its structure and function has changed due to human presence and their management plans, but yet its general landscape is similar to forest ecosystem. In this way, Sea environment, Coastal environment, Grassland environment, Mountains environment, River environment, Desert environment and Wetland environment formed in a way that each of them represents ecosystems that are affected by human. This set that its structure has changed but has maintained the landscape of natural ecosystems and has been managed by human, is called the natural environment (WHO 2005; UNEP 2006).

In fact, the natural environment includes ecosystems that are subject to change (not transformation) due to human's interferences. Thus, transformed environments with new structures were born in a way that there are no equivalents in evolutionary nature as a result of increasing interference and influence by human. Some of such environments are urban environment, rural environment, agricultural environment and industrial environment. Such artificial and anthropogenic environments have anthropomorphic processes and functions and are distinguished by their own dominant function and structure. This evolution of human's behavior is like domestication of ecosystems after domestication of plants and animals. While such interference brings economic benefits, definitely causes vulnerability to ecosystems and land. It is clear that ecosystems' vulnerability change their structure and process in a way that there is no high efficiency for humans' economic goals. Therefore, identifying and providing adequate and accurate information about natural environments' vulnerability in relation to a wide range of hazards and also reducing impacts of these hazards with the help of appropriate planning are the most effective solutions for protection and conservation of transformed natural environments (Cutter et al 2000; Mahendra et al 2011).

***The concept of vulnerability****.* The most fundamental definition for vulnerability is derived from the Latin origin of “vulnerare” meaning “to wound”. Therefore, vulnerability means the capacity to be wounded (Kates 1985) and is degree to which a system is likely to experience harm due to exposure to a hazard (Turner et al 2003a). Vulnerability is a concept used in many different fields (Adger 2006; Smit & Wandel 2006) but there is no agreement on its definition. As a result, there are various definitions for it in different scientific literature (Cutter 1996; Kelly & Adger 2000; McCarthy et al 2001; Downing et al 2001; O’Brien et al 2004; Brooks 2003; Smit & Wandel 2006; Adger 2006; Gallopin 2006; Kaplan et al 2009).

Generally, vulnerability is a developmental, multidimensional, cross-scale and interdisciplinary concept that is full of interactions and complicated relationships. According to the field of study, it is specifically used for social, ecological, natural, biophysical subsystems or coupled socio-ecological system (Turner et al 2003a; O’Brien et al 2004; Gallopin 2006; Cutter & Finch 2008; Kaplan et al 2009; Khan 2012; Menoni et al 2012). Its development is significant in Natural Hazard and Risk Assessment (Hewitt 1983), Food Security (Sen 1981; Dreze & Sen 1990), National Security (Homer-Dixon & Blitt 1998) and Environmental changes (Liverman 1990a; Kasperson et al 1995). According to the existing definitions, vulnerability of any system (on any scale) is a reflection of exposure, sensitivity to high risk situation, ability, capacity, resilience to cope and adaptation or recovery from impacts related to mentioned situations (Blaikie et al 1994; Bohle et al 1994; Timmerman 1981; Moser 1998; Downing et al 2001; Kasperson & Kasperson 2001; McCarthy et al 2001; Turner et al 2003a, b; Smit & Pilifosova 2003; Adger 2006; Füssel & Klein 2006).

According to Moser (1998), recognition of two parts of system: sensitivity and resilience is required for any definition of vulnerability in which sensitivity means the ability of system in response to stress impacts and also is a domain in which such ability can be affected by the changes of stress factor. Assessment report of Intergovernmental Panel on Climate Change (IPCC) includes the two mentioned parts of system and adds the third part called the ability of adaptation. This includes a degree that a system is sensitive to adverse impacts of stress factors such as variability and destructive events caused by stress factors or is unable to cope with them. Accordingly, vulnerability is a function of variability’s feature, size, and rate toward a system exposed to stress, sensitivity and adaptation ability (IPCC 2001). In accordance with this definition, vulnerability has an external dimension reflecting exposure to stress factor and a more complicated internal dimension including sensitivity and adaptation of systems to the stress factor (Figure 1) (Füssel & Klein 2006; IPCC 2007).

In describing of vulnerability space, Watts & Bohle (1993) use “risk of exposure to hazards” as the external dimension while the internal dimension includes capacity (risk of lack of enough capacity for preparing resources to cope with hazards) and potential ability (risk of the existence of destructive consequences). Downing et al (2001) determine three action areas of vulnerability including critical of the current situation, adaptive capacity, and danger of stress factor. In this regard, Luers et al (2003) suggest a method to measure vulnerability (for a specific system, output variable and the stress factor) based on exposure, sensitivity, and adaptive capacity. Turner et al (2003a) also expressed that in addition to exposure and sensitivity, resilience plays an important role in determination of vulnerability. These researchers prepared an integrated conceptual framework for vulnerability by means of three mentioned dimensions. Thus, vulnerability is known as a reflection of sensitivity, exposure, and adaptive capacity in a way that a range of biophysical and socio-economic factors influences these dimensions. Based on the mentioned framework by Turner et al (2003a), Adger (2006) also revealed that vulnerability is mostly a set of three parts of exposure to disturbances or external stresses (external dimension), sensitivity to disturbances and adaptive capacity (internal dimension) by investigating the source of change of vulnerability approach in natural and social sciences.

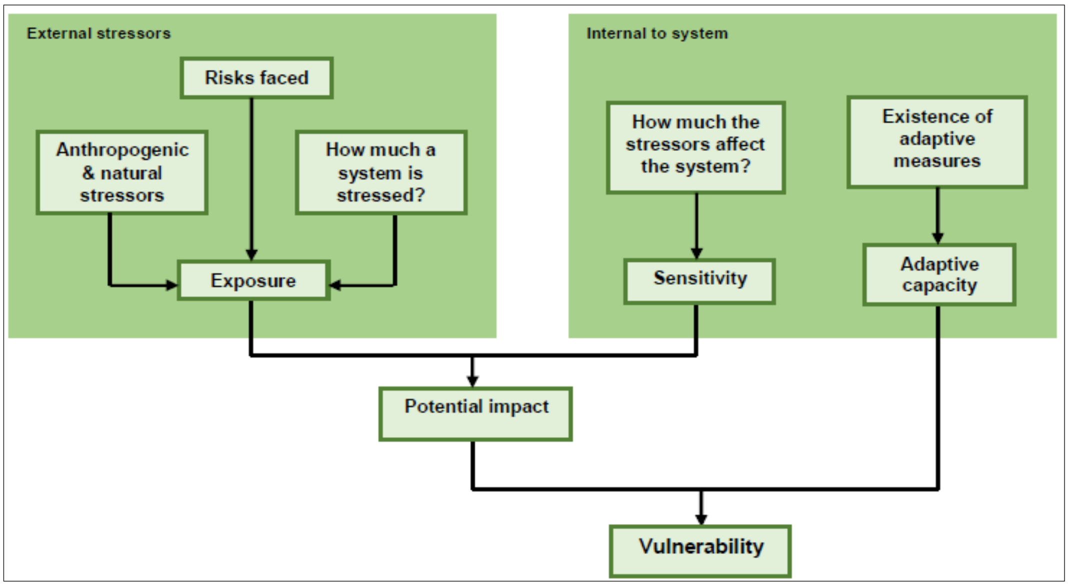


Figure 1. Relationship between vulnerability and its components (Australian Greenhouse Office, 2005).

Sensitivity is a concept with different meanings. Adger (2006) defines sensitivity as a range in which a natural or human system can absorb consequences without standing long-term damages and other noticeable changes. Smith & Wandel (2006) expressed that sensitivity concept is not apart from exposure concept and use these two concepts together (sensitivity-exposure). Luers (2005) also integrates these two concepts and defines sensitivity as a degree in which a system responds to external disturbances. In this approach, sensitivity also includes system's ability to resist and return to pre-stress conditions (resilience). In an overview of the concept of sensitivity, Gallopin (2003) defines it as a degree in which a system is affected by one or a set of internal or external disturbances. From this perspective, sensitivity is an innate feature of coupled socio-ecological systems and is apart from the ability to cope and exposure.

Generally, adaptive capacity of system with the help of thresholds and ranges of coping capacity are analyzed by situations that system is adapted to or recovered from (de Loe & Kreutzwiser 2000; Smit et al 2000). System's adaptive capacity (according to Adger 2006; Smit & Wandel 2006; IPCC 2001), that is called coping capacity by Turner et al (2003a, b) and response capacity by Gallopin (2003), includes the ability of system to regulate a disturbance, mitigate potential damage, take advantage of opportunities and overcome the consequences of changes happening in the system. According to the definitions by Adger (2006) and Kasperson et al (2005), exposure is considered a degree, duration and domain in which a system is exposed to or affected by disturbances. Bohle (2001) expressed that despite adaptive capacity and sensitivity, exposure is not a component of a system but a feature of the relationship between system and disturbances. If exposure concept is apart from vulnerability, exposure is a relative feature and vulnerability is a system's feature. Consequently, system's vulnerability is calculated based on sensitivity and adaptive capacity but exposure to a specific disturbance is determined separately (Gallopin 2003).

***Vulnerability assessment***. As mentioned before, vulnerability is mostly considered as a function of exposure and sensitivity of system to stress and external hazardous situations, and also the capacity of system to absorb or cope the impacts of mentioned stresses in various scales (IPCC 2001, 2007; Turner et al 2003a; Adger 2006; Smit & Wandel 2006). Based on these characteristics, Smit & Wandel (2006) proposed a general framework for vulnerability assessment in natural environment (Figure 2). But there is a disagreement on concepts of vulnerability and their relationship. Such disagreements lead to differences in the analysis of vulnerability such as objective of vulnerability assessment, applied concept in the analysis of vulnerability, the target issue and spatial and temporal scales of decision making (Eakin & Luers 2006; Füssel 2007). In fact, it could be expressed that disagreement on determination of external stress factors (external factors) that system is exposed to and internal factors that determine the impacts of the stresses on system, lead to the creation of conceptual models and different vulnerability assessment methods in order to develop theoretical fundamental and practical applications (Adger 2006; Eakin & Luers 2006; Füssel 2007; Green & Penning-Rowsell 2007; Manuel-Navarrette et al 2007; McLaughlin & Dietz 2008; Polsky et al 2007; Gallopin 2006). Despite the existing differences, all these approaches have a number of common elements such as the examination of vulnerability from social-ecological perspective, the importance of place-based studies, the conceptualization of vulnerability as an equity or human rights issue and the use of vulnerability assessments to identify hazard zones, thereby forming the basis for pre-impact and hazard mitigation planning (Clark et al 2000; Cutter et al 2000; Ellis 2000; Sanchez-Rodriguez 2002; Sarewitz et al 2003; Turner et al 2003b; O'Brien et al 2004; Brooks et al 2005).

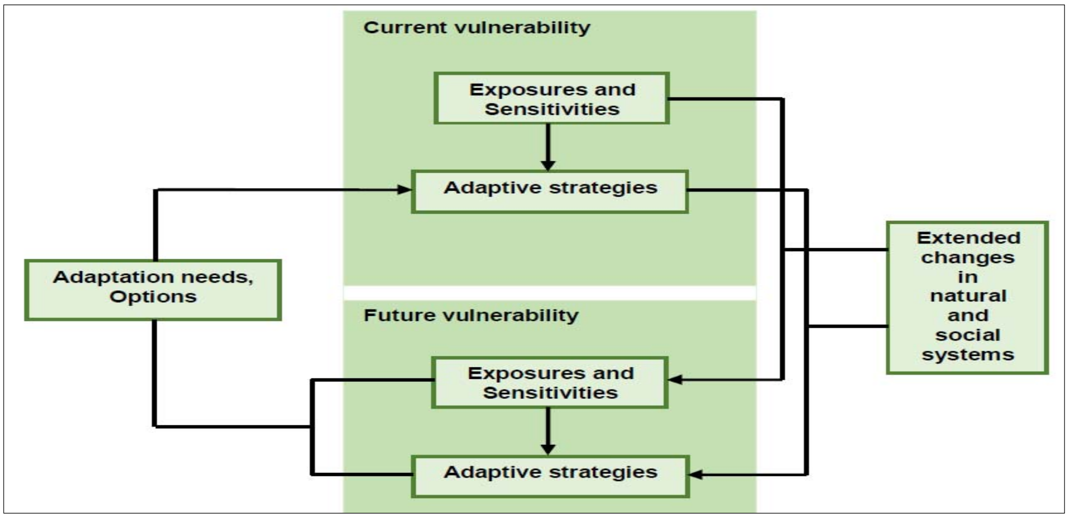


Figure 2. Conceptual framework for vulnerability assessment (Smit & Wandel 2006).

But in general, the whole researches done in this field (vulnerability assessment) have been carried out based on two main approaches: biophysical approach and social approach (Dow 1992; Kelly & Adger 2000; Cutter 2003; Adger 2006; Füssel & Klein 2006; Eakin & Luers 2006; Füssel 2007; McLaughlin & Dietz 2008). In biophysical approach, vulnerability is considered a set of physical events that a system is exposed to, likelihood or abundance of occurrence of event, range (domain) of exposure, and system's sensitivity to the impacts of a specific event. In this approach, the role of human system in mitigating an event is less considered and the main focus is on the features of event like its magnitude, frequency, occurrence pace and spatial spread. While, in social approach, the role of human factors and vulnerability derivers such as economic, social and political situations are considered. In this approach, hazards and diseases are caused not only by physical events but also by economic, social and political situations (Adger 2000; O'Brien & Leichenko 2000; Brooks 2003; Adger et al 2005; Pelling & High 2005). Finally, five approaches can be determined based on the classification of vulnerable factors as external and internal social, economic and biophysical factors (Table 1) (Füssel 2007).

In this study, dividing vulnerability factors into four categories including internal and external socio-economic and biophysical factors is according to the components of an integrated framework for assessment by Turner et al (2003a) in a way that internal socio-economic vulnerability equals to resilience, internal biophysical vulnerability equals to sensitivity, external socio-economic vulnerability equals to human situations and impacts and external biophysical vulnerability equals to environmental situations and impacts. "Cross-scale" phrase is used for the combination of internal and external factors and "integrated" phrase is used for the combination of socio-economic and biophysical factors. So, the combination of four mentioned groups can be called "cross-scale integrated".

Table 1

Approaches and main factors in vulnerability assessment

| *References* | *Existing experience* | *Approach's insight into vulnerability* | *Host system* | *The emphasis* | *Applied subject* | *Applied region* | *The main purpose* | *Vulnerability factors* | *Approach* |
|---|---|---|---|---|---|---|---|---|---|
| Wilhite (2000); Burton et al (1978); Kates (1985); Smith (1997); Anderson & Woodrow (1998); Downing et al (1999) | Climate change and its impact on societies | It is a physical risk and a social response within a geographical area | Human communities | Physical systems | Natural hazards | Geography | Risk assessment, identification of vulnerable groups and critical regions | Internal biophysical factors | Risk-hazard |
| MacMahon et al (1960); Blaikie et al (1994); Kjellstrom & Corvalan (1995); Wisner et al (2004) | Social vulnerability and the way it is created | The ability of individuals and societies to predict sustainability, overcome and recover from anthropogenic or natural hazards and its sensitivity and adaptive capacity | Human communities | Social systems | Biophysical risk of human societies | Risk-hazard | Development of a human ecology model linking risk with economic-political resources Description of ecological and physical hazards Management of disasters | Internal socio-economic and biophysical factors (internal integrated) | Pressure and realize |
| Blaikie et al (1994); Liverman (1990a, b); O'Brien & Leichenko (2000) | Analysis of poverty and degradation of natural resources | A function of biophysical risk factors and potential possibility of decreasing population exposed to hazards | Human communities | Social systems | Biophysical risk of human societies | Communities' development and poverty; human activity; environmental change | Detection social inequality and conflict between human societies | Internal and external socio-economic factors (cross-scale) | Political economy/ political ecology |
| Holling (1973); Carpenter et al (2001); Folke et al (2002); Walker et al (2004); Hudson (2010); Simmie & Martin (2010) | Land degradation, climate change and global environment | Capacity of an ecosystem resilience in the face of change | Human communities and natural environment | Coupled social and ecological systems | Biophysical stresses and disturbances | Ecological and social sciences | Determine thresholds and uncertainties; identify changes and transformation occurring in human and natural systems | A set of internal and external socio-economic and biophysical factors (cross-scale integrated) | Resilience |
| Cutter (1993, 1996, 2003); Cutter et al (2000); Fraser et al (2003); Turner et al (2003a, b); O'Brien & Leichenko (2000); O'Brien et al (2004) | Climate change and its impact on coupled systems | The probability that a person or group is exposed to a hazard and its destructive impacts | Human communities and natural environment | Coupled social and ecological systems | Physical stresses | Climate hazards | Development of an integrated framework for studying the interactions among the components of coupled socio-ecological systems | A set of internal and external socio-economic and biophysical factors (cross-scale integrated) | Integrated |

*Risk-Hazard approach.* Generally, researches done on natural hazards (in a geographical area) and theories on determination of hazard features, risk threshold range, human behavior and coordination with environmental risk are the source Risk-Hazard approaches in vulnerability assessment (White & Haas 1975; Burton et al 1978).

This approach has been dramatically applied by engineers and economists to study hazards and also is like a similar concept in epidemiology (Downing & Patwardhan 2004). This approach also tries to integrate physics with engineering principles and social techniques in order to describe the relationship among system's elements. It is based on exposure, likelihood of stress occurrence, and the impacts of natural and unnatural hazards (Downing et al 2001; Brooks 2003). The key point of risk-hazard approach is the clear distinction between hazard and vulnerability that are considered two determining factors of risk.

In this approach, risk consists of a physical event, phenomenon or human activities that are potentially damaging and is recognized by spatial distribution, intensity, abundance and likelihood of occurrence. Vulnerability also shows the relationship between hazard intensity and the degree of degradation (Brooks 2003; Jones & Boer 2003; Schilling et al 2012; Wilhelmi & Morss 2013). In risk-hazard approach, vulnerability is more descriptive and is mainly based on physical systems and hazard is assumed a known and static phenomenon (Figure 3) (Downing et al 1999).

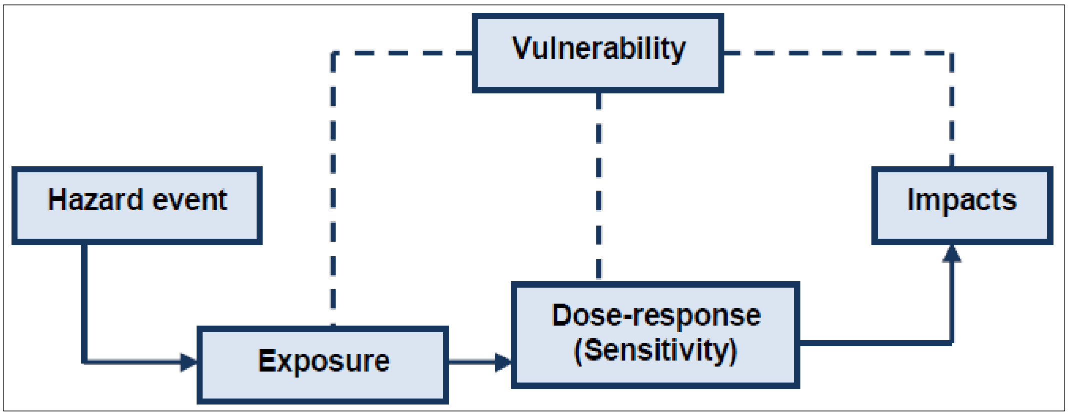


Figure 3. Framework of Risk-Hazard approach.

In risk-hazard approach, integration of physical event and main characteristics of populations exposed to risk that this makes its capacity limited for responding, can be seen. In fact, the vulnerability of populations is considered a function of biophysical risk factors and also the potential possibility of decreasing the population exposed to hazards (a kind of social response) (Hewitt & Burton 1971; Cutter 1996; Brooks 2003). Therefore, vulnerability is a physical risk and a social response in a geographical area and is known as internal biophysical vulnerability (Table 1).

According to the implementation of this approach, natural hazards and different social and political changes have various impacts on different groups of society. Human populations' vulnerability for many natural hazards depends on different levels of exposure and adaptive capacity (Burton et al 1978, 1993; Smith et al 2001; Smit & Pilifosova 2001; Burton et al 2002; Polsky et al 2007).

Considering the main objective of this approach, risk assessment is recognition and prediction of vulnerable groups and critical regions through determination of the likelihood of occurrence and hazards consequences and it is mainly used in studying repetitive physical events such as climate change and its consequences on human societies (Klein & Nicholls 1999; Burton et al 2002; Schilling et al 2012; Wilhelmi & Morss 2013). Although conducted surveys mainly focuses on the presentation of solutions for reduction of climate change impacts, a need to increase the adaptive capacity has been considered a way of understanding, regulation and management of environmental hazards and the ability to overcome. These indicate options enjoying resources and risk management strategies for preparation, avoidance, regulation and recovering from impacts caused by exposure (Nelson et al 2010; Schilling et al 2012; Huq et al 2003; Smith et al 2003; Smit & Pilifosova 2003). In this approach, adaptive capacity is related to resilience, sustainability and flexibility of communities (Smithers & Smit 1997) and determined by economic welfare, social networks, infra structures, social institutions, the experience gained by previous risks and equality of access to resources within the community (Smit & Pilifosova 2001; Smith et al 2003).

Risk-hazard approach has its own weaknesses in dealing with systems' vulnerability. Some of them are as follows (Turner et al 2003a): inability to demonstrate the ways that systems increase or decrease the effects of hazards occurrence; lack of distinction between subsystems and components that make a difference in the consequences of risks; lack of attention to the political and economic roles particularly the institutions and social structures that have a significant effect on creating variations in exposure and its consequences.

*Pressure and Realize Approach.* The origin of the Pressure and Realize approach (PAR) is the framework of Risk-Hazard and describes risk as the product of hazard and vulnerability (Blaikie et al 1994; Wisner et al 2004). The ultimate goal of this approach on the one hand, is developing a model of human ecology to identify the causes of vulnerability and link risk with political economy of resources and on the other hand, describing physical, biological hazards and also actions and principal management of natural disasters (Blaikie et al 1994; Winchester 1992; Pelling 2003). So, Adger (2006) considers Pressure and Realize model, a development factor of conducted surveys in hazards and ecology region and evolution of socio-ecological systems approach.

This model has some similarities with the hierarchical models used in the science of epidemiology such as hierarchy of evidence (MacMahon et al 1960), Pressure-State-Response (PSR) model (OECD 1993), Driving force-Pressure-State-Effect-Action (DPSEA) framework (Kjellstrom & Corvalan 1995). This model was firstly used by Davis in 1978 to show the impacts of a disaster in creating human vulnerability and physical hazards (Davis 1978). This approach presents a descriptive model of vulnerability that consists of the main reasons of its creation, also vulnerability is defined as the ability of people or community to predict, sustainability, overcome and recover from anthropogenic or natural hazards and also their sensitivity and adaptive capacity (Blaikie et al 1994). In fact, the purpose of this approach is to identify the individuals or groups of the population that their lives and in general their well-being experience the greatest threat from natural hazards and adverse social, economic or political results (Figure 4) (Blaikie et al 1994).

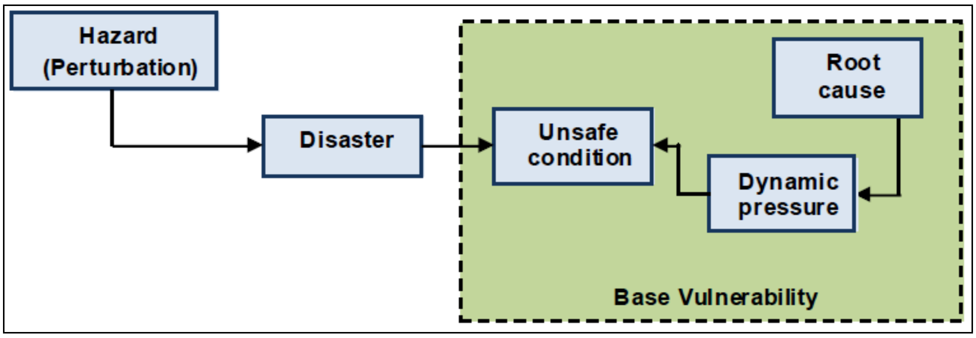

Figure 4. Framework of Pressure and Realize model in vulnerability assessment.

Pressure-Realize approach focuses on social vulnerability and the way of its creation. In other words, vulnerability is socially determined by a physical event and is a function of social situation and last changes that put people in a wide range of climate, political, or economic stresses and limit access to resources (such as poverty, development in sensitive and marginal regions) (Watts & Bohle 1993; Blaikie et al 1994; Kjellstrom & Corvalan 1995). Therefore, from the perspective of this approach protecting people from social events that are at risk of being unbalanced is more important than protection against natural hazards (Blaikie et al 1994; Wisner et al 2004; Sonwa et al 2012).

Although this approach is useful to describe human vulnerability, provides simple indices that only a specific human-environmental system exposed to single stress or disturbance consider (Cutter et al 2008; Sonwa et al 2012). In other words, this approach is unable to study coupled human-environmental systems exposed to a hazard (failure to identify the characteristics of exposure) (Dolan & Walker 2004) and definition of vulnerability has focused exclusively on human aspect and biophysical aspect of exposure and hazard size are considered the given definition to the concept of vulnerability separately (Kelly & Adger 2000). Also, this approach presents few details about a series of consequences of hazard occurrence and offers very little attention to the feedbacks of systems (Turner et al 2003a).

*Political economy or Political ecology approach.* Studies done in Risk-Hazard assessment and climate effects are the origin of political economy approach (Blaikie et al 1994). Political economy approach is common in the area of development and poverty of community (Adger & Kelly 1999; Pritchett et al 2000; Adger 2000; Alwang et al 2001) and is based on political, social and cultural factors that together make differences in the impacts of stresses, exposure and also the ability of recovering from previous impacts or adaptation and overcoming future threats (Sheridan 2001; Vasquez-Leon et al 2003; Füssel & Klein 2006; Adams & Hutton 2007; Bryant et al 2011). While this approach limits the analysis process of individuals and economic and social processes within human societies, focuses on a specific area of the historical and political conditions and is based on a descriptive model of socio-economic vulnerability to multiple stresses (Kelly & Adger 2000; Füssel 2004; Walker 2005). But in general, Political economy approach pays little attention to biophysical processes and their description for providing management and decision-making guidelines (Liverman 1990a; Adger et al 2001; Zimmerer & Bassett 2003).

The new form of Political economy approach is Political ecology approach that is rooted in the science of ecology and social sciences and affected by conducted surveys on hazards (Burton et al 1978; Paulson et al 2003) and its purpose is to describe necessary environmental actions on land management (Blaikie & Brookfield 1987). In this approach, the processes creating changes in environment and social institutions for vulnerability are the center of attention and such process are used to describe human-environment interactions and their consequences from the perspective of Political economy approach concerning the importance of scale, policy, economy and social processes (Bryant & Jarosz 2004; Neumann 2009).

Political ecology approach has been applied as a framework to recognize the complicated relationships between local people and global and national political economy and ecosystems (Schmink & Wood 1987; Neumann 2005; Walker 2005) and the main subjects of this approach is the analysis of poverty and natural resources degradation, unequal ownership of the resources, the availability and distribution of resources and efforts made in order to control the distribution of resources (Williams 1995; McCarthy 2002; Jarosz 2004).

Generally, Political ecology approach tends to study ecological processes and concentrate on human systems structures (Zimmerer & Bassett 2003; Neumann 2009) and causes fundamental issues about policies, ethics and social justice in relation to human activity and environmental change to be raised (Lipietz 1996).

Finally, it can be expressed that Political economy (recently political ecology) approach focuses on the political aspects of vulnerability, detection of social inequality and conflict within human societies.

*Resilience approach.* The concept of resilience was firstly used in the early 1970s in the science of ecology and the study of the interactions and functional response of populations (Holling 1961; Lewontin 1969; Rosenzweig 1971; May 1972). While an ecologist named Holling was studying on the resilience and sustainability of ecosystems as well as expressing multiple domains of sustainability or multiple domains of uptake in natural systems, he introduced resilience as the sustainability capacity of ecosystems in the face of change, the scale of sustainability and the ability of systems to accept changes and disturbances and also the ability to maintain relationships among populations (Holling 1973). Indeed, ecological resilience leads to identify processes causing change, detect thresholds and major factors that enable natural systems to absorb disturbances (Turner 2010).

The application of resilience approach in ecological studies influenced other fields of study such as anthropology (Hughes et al 2005; Davidson-Hunt & Berkes 2003; Colding 2007; Yan et al 2011; Sterk et al 2013) resulting in a theoretical basis for implementation of adaptive management and development of descriptive models and guidelines for ecosystems' management. After its application in the science of ecology and its effects on human sciences, resilience concept was used to study coupled socio-ecological systems (Walker et al 2006; Ruiz-Ballesteros 2011; Derissen et al 2011; Tidball & Stedman 2013) and also natural hazards in social sciences (Nelson et al 2007a, b; Berkes 2007; Renaud et al 2010; Zhou et al 2010).

Timmerman (1981) was the first person who entered resilience theory into social sciences. He describes resilience as a tool of a system or part of a system's capacity to absorb and recover from occurrence of hazardous events and states that society's vulnerability towards hazards is due to changes in science, technology and social organization. Using this approach the researchers suggested adaptive management strategies in order to increase the resilience of natural systems towards sudden events and shocks (Walker et al 2002; Folke et al 2003; Colding et al 2003; Olsson et al 2004). In this regard, Adger (1997, 2000), according to the definition by Timmerman (1981), studied the relationship between social and ecological resilience and described social resilience in relation to the concept of ecological resilience as the ability of groups or communities to overcome external stresses and disturbances caused by political, social, and environmental changes. Considering the fact that social and ecological systems have co-evolutionary relationships and two-way feedbacks (Gunderson & Holling 2002; Folke et al 2003; Janssen et al 2003; Chapin et al 2004), resilience of social systems in different ways is related to resilience of ecological systems that social systems are dependent on. So, the two-way relationships between ecosystems' resilience and social resilience have been studied in various scientific fields such as human geography, human ecology and ecological economics (Zimmerer 1994; Gunderson et al 1997; Levin et al 1998; Nelson et al 2007b; Zhou et al 2010). This approach has been empirically used in the context of land degradation (Goodman-Elgar 2008; Abdel Kawy & Ali 2012), agricultural systems (Cuc & Rambo 1993; Goodman-Elgar 2008; Altaweel & Watanabe 2012), coastal livelihood systems (Peluso et al 1994; Klein et al 1998) and climate change and the global environment (Kasperson et al 2005).

Applying the concept of resilience in the area of coupled socio-ecological systems is described as the ability to respond to disturbance, the capacity for self organizing and learning and adaptation (Folke et al 2002; Ruiz-Ballesteros 2011; Derissen et al 2011; Wilson 2012;). Among them, description of resilience as a degree of disturbance that a system can absorb and yet remain in the same situation or attraction domain has the most usage (Folke et al 2002; Folke et al 2003; Folke 2006). In fact, the purpose of resilience approach is to determine thresholds and uncertainties, as well as identify changes and transformations occurring in human and natural systems and the dynamics of socio-ecological systems (constant interactions between human and biophysical environment on different spatial and temporal scales) (Ludwig et al 2001; Gunderson & Holling 2002; Folke et al 2005; Hudson 2010; Simmie & Martin 2010).

The emphasis of resilience approach is to achieve a set of general principles of coupled socio-ecological systems in order to attain solutions (guidelines) for sustainable development of resources and maintaining the health of ecosystems (Walker et al 2004; Adger et al 2005; Anderies et al 2006; Reynolds et al 2007; Nelson et al 2009). However, most hypothesis and main features of resilience approach in relation to coupled socio-ecological systems are firstly extracted from studying ecological subsystems and then human subsystems and finally coupled human-environment subsystems on a larger scale (Alberti & Marzluff 2004; Folke et al 2005; Hudson 2010; Simmie & Martin 2010). But one of the problems existing in applying resilience approach for natural systems is a difference of resilience features of various systems. This difference results in failure to combine systems' resilience, and this is one of the main problems existing in resilience approach for the analysis of coupled human-environment systems (Turner et al 2003a).

Generally, the vulnerability factors in resilience approach include a set of internal and external socio-economic and biophysical factors (cross-scale integrated) (Table 1).

*Integrated approach.* Generally, the main part of studies about vulnerability of systems is related to the development of integrated frameworks for studying the interactions among the constituent parts of coupled socio-ecologic systems (Adger 2006). There are different definitions of vulnerability in integrated approaches of vulnerability assessment. In the integrated approach offered by Cutter (1993), vulnerability is defined as a possibility that a person or group is exposed to a hazard and affected by its impacts. In this regard, Turner et al (2003a) suggested conceptualizing vulnerability based on place that includes the stages of exposure, sensitivity and resilience and lacks a comprehensive definition of vulnerability. In addition to two mentioned definitions, integrated definitions of vulnerability have been used in different ways in the area of changes in the global environment and climate, and in reference to the regions, communities and other social units (O'Brien & Leichenko 2000; O'Brien et al 2004). One of the most important applications of integrated definitions of vulnerability is in mapping vulnerability (or risk) that is an interdisciplinary approach to identify specific (or critical) areas of vulnerability (O'Brien et al 2004; Metzger et al 2005).

Integrated assessments of vulnerability conventionally focus on physical stress factors such as natural hazards and climate change. Among studies done in this area, we can mention the studies by O'Brien et al (2004) and O'Brien & Leichenko (2000) that assessed the impacts of simultaneous combination of biophysical and socio-economic stress factors (twofold exposure).

Previous studies indicate that the development and milestone of integrated frameworks of vulnerability assessment is based on the study by Liverman (1990b) that presents useful methods for vulnerability assessment of systems. Various integrated approaches have been created such as hazard-place model and coupled framework for vulnerability in order to integrate risk-hazard approach with economic-political approaches (Cutter 1993, 1996, 2003; Cutter et al 2000; Turner et al 2003b). In this approach, the internal factors of vulnerable systems are integrated with external hazards of exposed system and vulnerability analysis, while focusing on a coupled socio-ecological systems, provides integrated and multidimensional assessment framework for vulnerability of coupled socio-ecological systems in order to achieve sustainable development of systems (Turner et al 2003a, b; Folke et al 2002; O'Brien et al 2004).

In integrated approach, the vulnerability of communities, regions and countries to climate hazards is characterized in cases of existing physical events and socio-economic capacities of adaptation to mentioned events. In these approaches, vulnerability is described as a product of the simultaneous interactions between biophysical and human processes and multiple stresses and shocks affecting coupled systems that can hold dynamic response with multiple feedbacks on different scales (Cutter 2003; Fraser et al 2003; Turner et al 2003a; O'Brien et al 2004).

One of the most comprehensive multidimensional frameworks for vulnerabilities assessment is offered by Turner et al (2003a) that is actually a part of extensive study by Kates et al (2001) in which identifying sustainability and achieving sustainable development goals have been considered. The multidimensional framework of Turner et al (2003a) is of a special importance because of a particular focus on relationships and feedbacks among coupled socio-ecological systems and analysis of the constituent elements of vulnerability (exposure, sensitivity and adaptive capacity) in a specific system on particular spatial scale (Figure 5).

This framework seeks to identify the relationship between vulnerability factors of system and assess the effects of cope and response of system's components (such as the degree of exposure of societies or the ecological parts of system). This is used as the basis of studies in the field of vulnerability assessment of systems to the effects of climate because of its comprehensiveness and integrity (O'Brien et al 2004; Schroter et al 2005; Ionescu et al 2005; Kaplan et al 2009). The results of final analysis done by multidimensional frameworks of Turner et al (2003a) include not only identification of current and future effects of stresses on system or identification of specific vulnerable populations but also description of feedbacks and major processes that create vulnerable situations.

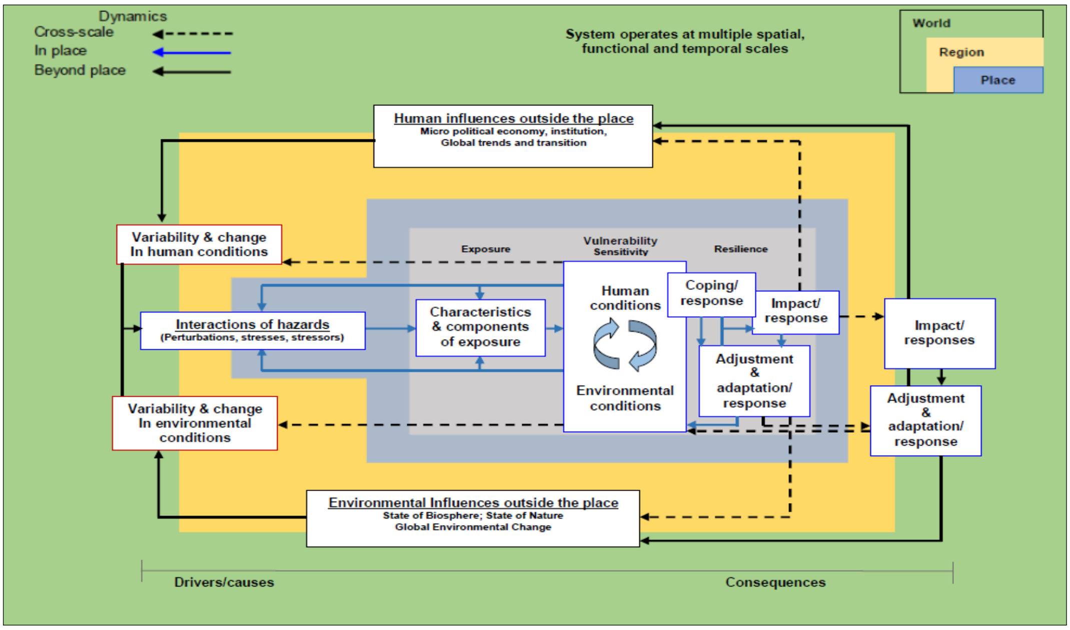


Figure 5. Framework of integrated vulnerability assessment (Turner et al 2003a).

## Results and Discussion

***Choosing the best approach for vulnerability assessment of natural environment***. Considering the fact that changes and degradations occurring in ecosystems is caused by natural and anthropogenic multiple stresses on them, approaches based on single stress-single consequence are unable to determine real vulnerability. So, application of suitable approach in order to identify multiple stresses and describe the mechanisms causing vulnerability in detail, as a feature of internal interactions of ecosystems, can be significantly useful to achieve conservation goal of natural ecosystems and present management solutions and effective planning in order to minimize destructive effects of multiple stresses (Turner et al 2003a). Despite the importance of the mentioned purpose, existing approaches for vulnerability assessment of ecosystems encounter problems; some of these problems are as follows: multiple stresses with interactive effects, integrating the dynamic nature of vulnerability in terms of time and space, considering perception of vulnerable populations and biophysical and socio-economic uncertainties, impacts and the consequences of scale (the impacts of dynamical cross-scale processes on vulnerability of a place) and inability to pay full attention to equity and social justice (Eakin & Luers 2006; Cutter et al 2008). However, studying the effects of multiple stresses on natural systems, in the context of global environmental change is of considerable importance (O' Brien & Leichenko 2000; O'Brien et al 2004; Schroter et al 2005). In general, a set of quantitative and qualitative data, financial resources and experts with different expertise are needed for the performance of each of the main approaches of ecosystems' vulnerability assessment. So, considering the requirements of situations and resources listed above as well as the strengths and weaknesses of each approach, we can compare their suitability and finally choose the most appropriate approach for vulnerability assessment of natural environment (Table 2). Some of criteria are as follows:

- simplicity of implementation;
- the level of need for a variety of qualitative and quantitative data;
- the level of coordination between the structure and approach's framework;
- processes and natural ecosystems functions;

- consider the human aspects in conclusions;
- development of institutional structures for linking the results of vulnerability analysis with decision-making process.

The level of attention to the role of institutions that could serve as stressors or structures affecting sensitivity and resilience of systems.

Table 2

Competence assessment of application of vulnerability assessment approaches in natural environment

| *Weaknesses in vulnerability assessment of natural environment* | *Strengths in vulnerability assessment of natural environment* | *Approach* |
|---|---|---|
| • Inability to study natural ecosystems in an integrated way; • Failure to study the effects of multiple stresses on natural ecosystems; • Failure to consider socio-economic factors for studying vulnerability; • Lack of development of institutional structures for linking the results of vulnerability analysis with decision-making processes; • Lack of attention to the role of institutions that could serve as stressors or structures affecting sensitivity and resilience of systems | • Easy to implement; • Require fewer experts to run | Risk-Hazard |
| • Inability to study natural ecosystems in an integrated way (failure to consider external socio-economic and biophysical factors for studying vulnerability); • Failure to study the effects of multiple stresses on natural ecosystems; • Failure to consider biophysical factors for studying vulnerability; • Lack of development of institutional structures for linking the results of vulnerability analysis with decision-making processes; • Lack of attention to the role of institutions that could serve as stressors or structures affecting sensitivity and resilience of systems | • Easy to implement; • Require fewer experts to run; • Consider the human aspects in conclusions | Pressure and Realize |
| • Inability to study natural ecosystems in an integrated way; • Failure to study the effects of multiple stresses on natural ecosystems; • Lack of development of institutional structures for linking the results of vulnerability analysis with decision-making processes; • Lack of attention to the role of institutions that could serve as stressors or structures affecting sensitivity and resilience of systems | • Easy to implement; • Require fewer experts to run; • Consider the human aspects in conclusions | Political Economy/ political ecology |
| • Complicated implementation; • The need for experts from various disciplines; • The need for a variety of qualitative and quantitative data; • The need for a substantial amount of financial resources; • Lack of development of institutional structures for linking the results of vulnerability analysis with decision-making processes; • Lack of attention to the role of institutions that could serve as stressors or structures affecting sensitivity and resilience of systems | • Coordination between the approach's framework and structure, processes and functions of natural ecosystems; • Consider the human aspects in conclusions; • Study the effects of multiple stresses (natural and anthropogenic) on natural systems; integrated and cross-scale | Resilience |
| • Complicated implementation; • The need for experts from various disciplines; • The need for a variety of qualitative and quantitative data; • The need for a substantial amount of financial resources | • Coordination between the approach's framework and structure, processes and functions of natural ecosystems; • Consider the human aspects in conclusions; • Study the effects of multiple stresses (natural and anthropogenic) on natural systems; • Integrated and cross-scale; • Development of institutional structures for linking the results of vulnerability analysis with decision-making process; • Pay attention to the role of institutions that could serve as stressors or structures affecting sensitivity and resilience of systems | Integrated |

**Conclusions**. Vulnerability is an implication used in various research fields as risk, natural hazards, food security, national security, poverty, development and environmental changes, but there is no consensus on its meanings. This disagreements cause to differences in aim of the vulnerability assessment, and difference on the concepts used in the analysis of vulnerability, the main issue and temporal and spatial scales of decision in the analyses of vulnerability. Appearing the conceptual models, and various methods of vulnerability assessment due to progress in theoretical foundations and practical applications of vulnerability like risk-hazard, political economy or political ecology, pressure and realize, resilience and integrated approaches are the result of this differences. The results showed that among these approaches, the integrated approach has more strengths compared to other approaches (like coordination between approach and structure, process and performance of the natural ecosystems, examine the effects of multiple stresses (natural and anthropogenic) on natural systems, integrated and cross-scale of approach etc.) it can be more efficient in use to identify processes and interactions that lead to vulnerability in natural environments. Thus, by the implementation of the integrated approach with providing a detailed theoretical conceptual model in order to identifying the vulnerability can propose adaptive options to moderate the destructive consequences at natural environments and through prioritization of managerial actions and by providing appropriate infrastructure achieve the ways that are needed to sustainability. In fact, by making a rational and effective connection between the results of vulnerability analysis and decision processes, integrated approach can be overcome the challenges in vulnerability assessment of natural environments.

The results of this study could be as useful tool available to managers and decision-makers and than through which they can to choose appropriate approach to vulnerability assessment of natural environments. Undoubtedly a correct choice in vulnerability assessment approaches will lead to offer effective management and planning solutions to minimize destructive impacts of stresses and determine appropriate measures that could be taken to reduce vulnerability of natural resources and cause sustainable use of land by human before degradations happen.

## References


Abdel Kawy W. A. M., Ali R. R., 2012 Assessment of soil degradation and resilience at northeast Nile Delta, Egypt: the impact on soil productivity. The Egyptian Journal of Remote Sensing and Space Sciences 15:19-30.

Adams W. M., Hutton J., 2007 People, parks and poverty: political ecology and biodiversity conservation. Conservation and Society 5:147-183.

Adger W. N., 1997 Sustainability and social resilience in coastal resource use. CSERGE Working Paper Series, Centre for Social and Economic Research on the Global Environment, University of East Anglia, Norwich and University College London, UK, 39 pp.

Adger W. N., 2000 Social and ecological resilience: are they related? Progress in Human Geography 24:347-364.

Adger W. N., 2006 Vulnerability. Global Environmental Change 16(3):268-281.

Adger W. N., Kelly P. M., 1999 Social vulnerabililty to climate change and the architecture of entitlements. Mitigation and Adaptation Strategies for Global Change 4:253-266.

Adger W. N., Benjaminsen T. A., Brown K., Svarstad H., 2001 Advancing a political ecology of global environmental discourses. Development and Change 32:681-715.

Adger W. N., Arnell N. W., Tompkins E. L., 2005 Successful adaptation to climate change across scales. Global Environmental Change 15:77-86.

Alberti M., Marzluff J. M., 2004 Ecological resilience in urban ecosystems: linking urban patterns to human and ecological functions. Urban Ecosystem 7:241-265.

Altaweel M., Watanabe C. E., 2012 Assessing the resilience of irrigation agriculture: applying a social-ecological model for understanding the mitigation of salinization. Journal of Archaeological Science 39:1160-1171.

Alwang J., Siegel P. B., Jorgensen S. L., 2001 Vulnerability: a view from different disciplines. Discussion Paper Series No. 0115, Social Protection Unit, World Bank, Washington DC., 42 pp.

Anderies J. M., Walker B. H., Kinzig A. P. 2006 Fifteen weddings and a funeral: case studies and resilience-based management. Ecology and Society 11(1):21.

Anderson M. B., Woodrow P. J., 1998 Rising from the ashes: development strategies in times of disaster. Lynne Rienner Publishers, London, 338 pp.

Australian Greenhouse Office (2005), Climate change risk and vulnerability, promoting an efficient adaptation response in Australia. Report to the Australian Greenhouse Office, Department of the Environment and Heritage, 159 pp.

Barbier E. B., Koch E. W., Silliman B. R., Hacker S. D., Wolanski E., Primavera J., Granek E. F., Polasky S., Aswani S., Cramer L. A., Stoms D. M., Kennedy C. J., Bael D., Kappel C. V., Perillo G. M. E., Reed D. J., 2008 Coastal ecosystem–based management with nonlinear ecological functions and values. Science 319:321-323.

Berkes F., 2007 Understanding uncertainty and reducing vulnerability: lessons from resilience thinking. Natural Hazards 41:285-295.

Binelli A., Sarkar S. K., Chatterjee M., Riva C., Parolini M., Bhattacharya B., Bhattacharya A. K., Satpathy K. K., 2007 Concentration of polybrominated diphenyl ethers (PBDEs) in sediment cores of Sundarban mangrove wetland, northeastern part of Bay of Bengal (India). Marine Pollution Bulletin 54:1220-1229.

Blaikie P. M., Brookfield H. C., 1987 Land degradation and society. USA: Methuen & Co in Association with Methuen Inc, 130 pp.

Blaikie P., Cannon T., Davis I., Wisner B., 1994 At risk: natural hazards, people's vulnerability and disasters. Routledge, London, 221 pp.

Bohle H. G., 2001 Vulnerability and criticality: perspectives from social geography. IHDP 2:1-6.

Bohle H. G., Downing T. E., Watts M. J., 1994 Climate change and social vulnerability: toward a sociology and geography of food insecurity. Global Environmental Change 4:37-48.

Brooks N., 2003 Vulnerability, risk and adaptation: a conceptual framework. Tyndall Centre for Climate Change Research, Working Paper no. 38, pp. 1-16.

Brooks N., Adger W. N., Kelly P. M., 2005 The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. Global Environmental Change 15:151-163.

Bryant R. L., Jarosz L., 2004 Ethics in political ecology: a special issue of political geography introduction: thinking about ethics in political ecology. Political Geography 23:807-812.

Bryant R. L., Paniagua A., Kizos T., 2011 Conceptualizing 'shadow landscape' in political ecology and rural studies. Land Use Policy 28:460-471.

Burton I., Kates R., White G., 1978 Environment as hazard. New York, Oxford University Press, pp. 62-83.

Burton I., Huq S., Lim B., Pilifosova O., Schipper E. L., 2002 From impacts assessment to adaptation priorities: the shaping of adaptation policy. Climate Policy 2(2-3):145-159.

Carpenter S. R., Walker B. H., Anderies J. M., Abel N., 2001 From metaphor to measurement: resilience of what to what? Ecosystems 4:765-781.

Castellanos Abella E. A., Van Westen C. J., 2008 Qualitative landslide susceptibility assessment by multicriteria analysis: a case study from San Antonio del Sur, Guantánamo, Cuba. Geomorphology 94(3-4):453-466.

Chapin III F. S., Peterson G. D., Berkes F., Callaghan T. V., Angelstam P., Apps M., Beier C., Bergeron Y., Crepin A. S., Elmqvist T., Folke C., Forbes B., Fresco N., Juday G., Niemela J., Shvidenko A., Whiteman G., 2004 Resilience and vulnerability of northern regions to social and environmental change. Ambio 33:344-349.

Clark W. C., Jager J., Correll R., Kasperson R., McCarthy J. J., Cash D., Cohen S. J., Desanker P., Dickinson N. M., Epstein P., Guston D. H., Hall J. M., Jaeger, C., Janetos A., Leary N., Levy M. A., Luers A., McCracken M., Melillo J., Moss R. N., Nigg J. M., Parry M. L., Joanne M., Ribot J. C., Schellnhuber H. J., Seielstad G. A., Shea E., Vogel C, Wilbanks T. J., 2000 Assessing vulnerability to global environmental risks. Report of the Workshop on Vulnerability to Global Environmental Change: Challenges for Research, Assessment and Decision Making, 22–25 May, Airlie House, Warrenton, Virginia. Research and Assessment Systems for Sustainability Program Discussion Paper 2000–12. Cambridge, MA, Environmental and Natural Resources Program." Belfer Center for Science and International Affairs (BCSIA), Kennedy School of Government, Harvard University.

Colding J., 2007 Ecological land-use complementation for building resilience in urban ecosystems. Landscape and Urban Planning 81:46-55.

Colding J., Folke C., Elmqvist T., 2003 Social institutions in ecosystem management and biodiversity conservation. Tropical Ecology 44:25-41.

Costanza R., d'Arge R., de Groot R., Farber S., Grasso M., Hannon B., Limburg K., Naeem S., O'Neill R. V., Paruelo J., Raskin R. G., Sutton P., Van den Belt M., 1997 The value of the world's ecosystem services and natural capital. Nature 387:253-260.

Cuc L. T., Rambo A. T., 1993 Too many people, too little land: the human ecology of a wet rice growing village in the Red River delta of Vietnam. O Honolulu : East-West Center, Program on Environment, Occasional paper no. 15, 207 pp.

Cutter S. L., 1993 Living with risk: the geography of technological hazards. Edward Arnold, London, 214 pp.

Cutter S. L., 1996 Vulnerability to environmental hazards. Progress in Human Geography 20:529-539.

Cutter S. L., 2003 The vulnerability of science and the science of vulnerability. Annals of the Association of American Geographers 93:1-12.

Cutter S. L., Finch C., 2008 Temporal and spatial changes in social vulnerability to natural hazards. Proceedings of the National Academy of Sciences of the USA 105(7):2301-2306.

Cutter S. L., Mitchell J. T., Scott M. S., 2000 Revealing the vulnerability of people and places: a case study of Georgetown County, South Carolina. Annals of the Association of American Geographers 90:713-737.

Cutter S. L., Barnes L., Berry M., Burton C., Evans E., Tate E., Webb J., 2008 A place-based model for understanding community resilience to natural disasters. Global Environmental Change 18:598-606.

Dahdouh-Guebas F., Jayatissa L. P., Di Nitto D., Bosire J. O., Lo Seen D., Koedam N., 2005a How effective were mangroves as a defence against the recent tsunami? Current Biology 15:443-447.

Dahdouh-Guebas F., Hettiarachchi S., Lo Seen D., Batelaan O., Sooriyarachchi S., Jayatissa L. P., Koedam N., 2005b Transitions in ancient inland freshwater resource management in Sri Lanka affect biota and human populations in and around coastal lagoons. Current Biology 15:579-586.

Danielsen F., Sørensen M. K., Olwig M. F., Selvam V., Parish F., Burgess N. D., Hiraishi T., Karunagaran V. M., Rasmussen M. S., Hansen L. B., Quarto A., Suryadiputra N., 2005 The Asian tsunami: a protective role for coastal vegetation. Science 310:643-655.

Davidson-Hunt I. J., Berkes F., 2003 Nature and society through the lens of resilience: toward a human-in-ecosystem perspective. In: Navigating social-ecological systems: building resilience for complexity and change. Berkes F., Colding J., Folke C. (eds), Cambridge University Press, Cambridge, UK, pp. 53-82.

Davis I., 1978 Shelter after disaster. Oxford University Press, Oxford, 142 pp.

De Loe R. C., Kreutzwiser R., 2000 Climate variability, climate change and water resource management in the Great Lakes. Climatic Change 45:163-179.

Derissen S., Quaas M. F., Baumgärtner S., 2011 The relationship between resilience and sustainability of ecological-economic systems. Ecological Economics 70:1121-1128.

Dolan A. H., Walker I. J., 2004 Understanding vulnerability of coastal communities to climate change related risks. Journal of Coastal Research 39(2):1317-1324.
Dow K., 1992 Exploring differences in our common future(s): the meaning of vulnerability to global environmental change. Geoforum 23:417-436.
Downing T. E., Patwardhan A., 2004 Assessing vulnerability for climate adaptation. In: Adaptation policy frameworks for climate change, developing strategies, policies, and measures. Lim B., Spanger-Siegfried E. (eds), Cambridge University Press, Cambridge, pp. 67-90.
Downing T. E., Gawith M. J., Olsthoorn A. A., Tol R. S. J., Vellinga P., 1999 Introduction. In: Climate, change and risk. Downing T. E., Olsthoorn A. A., Tol R. S. J. (eds), Routledge, London, pp. 1-19.
Downing T. E., Butterfield R., Cohen S., Huq S., Moss R., Rahman A., Sokona Y., Stephen L., 2001 Climate change vulnerability: linking impacts and adaptation. Report to the Governing Council of the United Nations Programme, United Nations Environmental Programme, Nairobi, Kenya.
Dreze J., Sen A., 1990 The political economy of hunger. Oxford, Clarendon Press, 16 pp.
Duke N. C., Meynecke J. O., Dittmann S., Ellison A. M., Anger K., Berger U., Cannicci S., Diele K., Ewel K. C., Field C. D., Koedam N., Lee S. Y., Marchand C., Nordhaus I., Dahdouh-Guebas F., 2007 A world without mangroves? Science 317:41-42.
Eakin H., Luers A. L., 2006 Assessing the vulnerability of social-environmental systems. Annual Review of Environment and Resources 31:365-394.
Eggert H., Olsson B., 2009 Valuing multi-attribute marine water quality. Marine Policy 33(2):201-206.
Ellis F., 2000 Rural livelihood diversity in developing countries. Oxford University Press, Oxford, 287 pp.
Folke C., 2006 Resilience: the emergence of a perspective for social-ecological systems analyses. Global Environmental Change 16(3):253-267.
Folke C., Carpenter R., Elmqvist T., Gunderson L., Holling C. S., Walker B., 2002 Resilience and sustainable development: building adaptive capacity in a world of transformations. Ambio 31(5):437-440.
Folke C., Colding J., Berkes F., 2003 Synthesis: building resilience and adaptive capacity in social-ecological systems. In: Navigating social-ecological systems: building resilience for complexity and change. Berkes F., Colding J., Folke C. (eds), Cambridge University Press, Cambridge, UK, pp. 352-387.
Folke C., Hahn T., Olsson P., Norberg J., 2005 Adaptive governance of social-ecological systems. Annual Review of Environment and Resources 30:441-473.
Fraser E. D. G., Mabee W., Slaymaker O., 2003 Mutual vulnerability, mutual dependence: the reflective notion between human society and the environment. Global Environmental Change 13:137-144.
Freeman III A. M., 1995 The benefits of water quality improvements for marine recreation: a review of the empirical evidence. Marine Resource Economics 10:385-406.
Füssel H. M., 2004 Coevolution of the political and conceptual frameworks for climate change vulnerability assessments. In: Proceedings of the 2002 Berlin Conference on the Human Dimensions of Global Environmental Change ''Knowledge for the Sustainability Transition, The Challenge for Social Science''. Biermann F., Campe S., Jacob K. (eds), Global Governance Project, Amsterdam, the Netherlands, pp. 302-320.
Füssel H. M., 2007 Vulnerability: a generally applicable conceptual framework for climate change research. Global Environmental Change 17:155-167.
Füssel H. M., Klein R. J. T., 2006 Climate change vulnerability assessments: an evolution of conceptual thinking. Climatic Change 75:301-329.
Gallopin G. C., 2003 A systemic synthesis of the relations between vulnerability, hazard, exposure and impact, aimed at policy identification. In: Handbook for estimating the socio-economic and environmental effects of disasters. Economic Commission for Latin American and the Caribbean (ECLAC), ECLAC, Mexico, D.F., pp. 2-5.

Gallopin G. C., 2006 Linkages between vulnerability, resilience, and adaptive capacity. Global Environmental Change 16:293-303.
Goodman-Elgar M., 2008 Evaluating soil resilience in long-term cultivation: a study of pre-Columbian terraces from Paca Valley, Peru. Journal of Archaeological Science 35:3072-3086.
Green C., Penning-Rowsell E., 2007 More or less than words? Vulnerability as discourse. In: Managing coastal vulnerability. McFadden L., Nicholls R. J., Penning-Rowsell E. (eds), Elsevier, Amsterdam, pp. 29-43.
Gunderson L. H., Holling C. S. (eds), 2002 Panarchy: understanding transformations in human and natural systems. Island Press, Washington DC, 450 pp.
Gunderson L. H., Holling C. S., Pritchard L., Peterson G. D., 1997 Resilience in ecosystems, institutions and societies. Beijer International Institute of Ecological Economics, Discussion Paper Series No. 95.
Hanley N., Bell D., Alvarez-Farizo B., 2003 Valuing the benefits of coastal water quality improvements using contingent and real behavior. Environmental and Resource Economics 24:273-285.
Hewitt K., 1983 The idea of calamity in a technocratic age. In: Interpretations of calamity from the viewpoint of human ecology. Hewitt K. (ed), Allen and Unwin, Boston, pp. 3-32.
Hewitt K., Burton I., 1971 The hazardousness of a place: a regional ecology of damaging events. Department of Geography Research publication 6, University of Toronto, Toronto, Canada, 154 pp.
Holling C. S., 1961 Principles of insect predation. Annual Review of Entomology 6:163-182.
Holling C. S., 1973 Resilience and stability of ecological systems. Annual Review of Ecology and Systematics 4:1-23.
Homer-Dixon T., Blitt J., 1998 Ecoviolence: links among environment, population, and security. Lanham, Maryland, Rowman and Littlefield Publishers, Inc., 237 pp.
Hudson R., 2010 Resilience regions in an uncertain world: wishful thinking or a practical reality? Cambridge Journal of Regions, Economy and Society 3:11-25.
Hughes T. P., Bellwood D. R., Folke C., Steneck R. S., Wilson J., 2005 New paradigms for supporting the resilience of marine ecosystems. Trends in Ecology and Evolution 20:380-386.
Huq S., Rahman A., Konate M., Sokona Y., Reid H., 2003 Mainstreaming adaptation to climate change in least developed countries. International Institute for Environment and Development, London, 38 pp.
Ionescu C., Klein R. J. T., Hinkel J., Kavi Kumar K. S., Klein R., 2005 Towards a formal framework of vulnerability to climate change. NeWater Working Paper 2 and FAVAIA Working Paper 1, Potsdam Institute for Climate Impact Research, Potsdam, Germany, 20 pp.
IPCC (Intergovernmental Panel on Climate Change), 2001 Technical summary, climate change 2001, impacts, adaptation, and vulnerability. A Report of Working Group II of the Intergovernmental Panel on Climate Change. Availabnle at: http//www.grida.no/climate/ipcc_tar/wg2/pdf/wg2TARtechsum.pdf. Accessed: September, 2015.
IPCC (Intergovernmental Panel on Climate Change), 2007 Synthesis report, Intergovernmental Panel on Climate Change Fourth Assessment Report. Available at: http//www.ipcc.ch/pdf/assessment-report. Accessed: December, 2015.
Janssen M. A., Kohler T. A., Scheffer M., 2003 Sunk-cost effects and vulnerability to collapse in ancient societies. Current Anthropology 44:722-728.
Jarosz L., 2004 Political ecology as ethical practice. Political Geography 23:917-927.
Jones R., Boer R., 2003 Assessing current climate risks. Chapter 4 of the Working Draft of the Adaptation Policy Framework, New York, United Nations Development Programme. Available at: http//www.undp.org/cc/pdf/APF/TP%20final/Tech.Paper_4.qxp_30Aug04.pdf. Accessed: February, 2014.

Kaplan M., Renaud F. G., Lüchters G., 2009 Vulnerability assessment and protective effects of coastal vegetation during the 2004 tsunami in Sri Lanka. Natural Hazards and Earth System Sciences 9:1479-1494.
Kasperson J. X., Kasperson R. E., 2001 International workshop on vulnerability and global environmental change. SEI Risk and Vulnerability Programme Report 2001-01, Stockholm Environment Institute, Stockholm, Sweden, 35 pp.
Kasperson R. E., Kasperson J. X., Turner B. L., Dow K., Meyer W. B., 1995 Critical environmental regions: concepts, distinctions and issues. In: Regions at risk: comparisons of threatened environments. Kasperson J. X., Kasperson R. E., Turner B. L. (eds), Tokyo: United Nations University Press, pp. 1–41.
Kasperson R. E., Dow K., Archer E., Caceres D., Downing T., Elmqvist T., Eriksen S., Folke C., Han G., Iyengar K., Vogel C., Wilson K., Ziervogel G., 2005 Vulnerable people and places. In: Ecosystems and human wellbeing: current state and trends. Hassan R., Scholes R., Ash N. (eds), Island Press, Washington, DC, pp. 143-164.
Kates R. W., 1985 The interaction of climate and society. In: Climate impact assessment: studies of the interaction of climate and society. Kates R. W., Ausubel H., Berberian M. (eds), Wiley, Chichester, UK, pp. 3-36.
Kates R. W., Clark W. C., Corell R., Hall J. M., Jaeger C. C., Lowe I., McCarthy J. J., Schellnhuber H. J., Bolin B., Dickson N. M., Faucheux S., Gallopin G. C., Grübler A., Huntley B., Jäger J., Jodha N. S., Kasperson R. E., Mabogunje A., Matson P., Mooney H., Moore B. 3rd, O'Riordan T., Svedlin U., 2001 Environment and development. Sustainability science. Science 292:641-642.
Kathiresan K., Rajendran N., 2005 Coastal mangrove forests mitigated tsunami. Estuarine, Coastal and Shelf Science 65:601-606.
Kelly P. M., Adger W. N., 2000 Theory and practice in assessing vulnerability to climate change and facilitating adaptation. Climatic Change 47:325-352.
Khan S., 2012 Vulnerability assessments and their planning implications: a case study of the Hutt Valley, New Zealand. Natural Hazards 64:1587-1607.
Kjellstrom T., Corvalan C., 1995 Framework for the development of environmental health indicators. World Health Statistics Quarterly 48:144-154.
Klein R. J. T., Nicholls R. J., 1999 Assessment of coastal vulnerability to climate change. Ambio 28:182-187.
Klein R. J. T., Smit M. J., Goosen H., Hulsbergen C. H., 1998 Resilience and vulnerability: coastal dynamics or Dutch dikes? The Geographical Journal 164(3):259-271.
Lahsen M., Sanchez-Rodriguez R., Lankao P. R., Dube P., Leemans R., Gaffney O., Mirza M., Pinho P., Osman-Elasha B., Smith M. S., 2010 Impacts, adaptation and vulnerability to global environmental change: challenges and pathways for an action-oriented research agenda for middle-income and low-income countries. Current Opinion in Environmental Sustainability 2:364-374.
Levin S., Barrett S., Aniyar S., Baumol W., Bliss C., Bolin B., Dasgupta P., Ehrlich P., Folke C., Gren I. M., Holling C. S., Jansson A. M., Jansson B. O., Mäler K. G., Martin D., Perrings C., Sheshinski E., 1998 Resilience in natural and socio-economic systems. Environment and Development Economics 3:222-235.
Lewontin R. C., 1969 The meaning of stability. Brookhaven Symposia in Biology 22:13-24.
Lipietz A., 1996 Geography, ecology, democracy. Antipode 28(3):219-228.
Liverman D. M., 1990a Drought impacts in Mexico: climate, agriculture, technology, and land tenure in Sonora and Puebla. Annals of the Association of American Geographers 80:49-72.
Liverman D. M., 1990b Vulnerability to global environmental change. In: Understanding global environmental change: the contributions of risk analysis and management. Kasperson J. X., Kasperson R. E. (eds), Tokyo, UNU Press, pp. 27-44.
Ludwig D., Mangel M., Haddad B., 2001 Ecology, conservation, and public policy. Annual Review of Ecology and Systematics 32:481-517.
Luers A. L., 2005 The surface of vulnerability: an analytical framework for examining environmental change. Global Environmental Change 15:214-223.

Luers A. L., Lobell D. B., Sklar L. S., Addams C. L., Matson P. A., 2003 A method for quantifying vulnerability, applied to the Yaqui Valley, Mexico. Global Environmental Change 13:255-267.

MacMahon B., Pugh T. F., Ipsen J., 1960 Epidemiologic methods. Little Brown, Boston, 302 pp.

Mahendra R. S., Mohanty P. C., Bisoyi H., Kumar T. S., Nayak S., 2011 Assessment and management of coastal multi-hazard vulnerability along the Cuddaloree-Villupuram, east coast of India using geospatial techniques. Ocean and Coastal Management 54:302-311.

Manuel-Navarrette D., Gomez J. J., Gallopin G., 2007 Syndromes of sustainability of development for assessing the vulnerability of coupled human–environmental systems. The case of hydrometeorological disasters in Central America and the Caribbean. Global Environmental Change 17(2):207-217.

May R. M., 1972 Will a large complex ecosystem be stable? Nature 238:413-414.

McCarthy J., 2002 First world political ecology: lessons from the wise use movement. Environment and Planning A 34(7):1281-1302.

McCarthy J. J., Canziani O. F., Leary N. A., Dokken D. J., White K. S. (eds), 2001 Climate change 2001: impacts, adaptation and vulnerability. Cambridge University Press, Cambridge, 1005 pp.

McLaughlin P., Dietz T., 2008 Structure, agency and environment: toward an integrated perspective on vulnerability. Global Environmental Change 18(1):99-111.

Menoni S., Molinari D., Parker D., Balio F., Tapsell S., 2012 Assessing multi faceted vulnerability and resilience in order to design risk-mitigation strategies. Natural Hazards 64:2057-2082.

Metzger M. J., Leemans R., Schroter D., 2005 A multidisciplinary multi-scale framework for assessing vulnerabilities to global change. International Journal of Applied Earth Observation and Geoinformation 7:253-267.

Meyer W. B., 1996 Human impact on the Earth. Cambridge University Press, 253 pp.

Millennium Ecosystem Assessment (MEA), 2005 Ecosystems and human well-being: synthesys. Island Press, Washington, DC, 137 pp.

Moser C. O. N., 1998 The asset vulnerability framework: reassessing urban poverty reduction strategies. World Development 26(1):1-19.

Nelson D. R., Adger W. N., Brown K., 2007a Adaptation to environmental change: contributions of a resilience framework. Annual review of Environment and Resources 32:395-419.

Nelson D. R., Brown P. R., Darbas T., Kokic P., Cody K., 2007b The potential to map the adaptive capacity of Australian land managers for NRM policy using ABS data. CSIRO, Australian Bureau of Agricultural and Resource Economics, prepared for the National Land and Water Resources Audit. Available at: http//www.nlwra.gov.au/Natural_Resource_Topics/Socio-economic/index.aspx.

Nelson R., Kokic P., Crimp S., Meinke H., Howden S. M., 2010 The vulnerability of Australian rural communities to climate variability and change. Part I: conceptualizing and measuring vulnerability. Environmental Science and Policy 13:8-17.

Nelson E., Mendoza G., Regetz J., Polasky S., Tallis H., Cameron D. R., Chan K. M. A., Dailey G. C., Goldstein J., Kareiva P. M., Lonsdorf E., Naidoo R., Ricketts T. H., Shaw M. R., 2009 Modeling multiple ecosystem services, biodiversity conservation, commodity production and tradeoffs at landscape scales. Frontiers in Ecology and the Environment 7(1):4-11.

Neumann R. P., 2005 Making political ecology. Oxford University Press, London, 207 pp.

Neumann R. P., 2009 Political ecology, theorizing scale. Progress in Human Geography 33:398-406.

O'Brien K. L., Leichenko R. M., 2000 Double exposure: assessing the impacts of climate change within the context of economic globalization. Global Environmental Change 10:221-232.

O'Brien K., Leichenko R., Kelkar U., Venema H., Aandahl G., Tompkins H., Javed A., Bhadwal S., Barg S., Nygaard L., West J., 2004 Mapping vulnerability to multiple stressors: climate change and globalization in India. Global Environmental Change 14:303-313.

OECD, 1993 OECD core set of environmental performance reviews. Environment Monographs, No. 83, Organization for Economic Cooperation and Development, Paris, France, 35 pp.

Olsson P., Folke C., Berkes F., 2004 Adaptive co-management for building resilience in social-ecological systems. Environmental Management 34:75-90.

Ong Che R. G., 1999 Concentration of seven heavy metals in sediments and mangrove root samples from Mai Po, Hong Kong. Marine Pollution Bulletin 39:269-279.

Paulson S., Gezon L. L., Watts M., 2003 Locating the political in political ecology: an introduction. Human Organization 62:205-217.

Pelling M., 2003 The Vulnerability of cities: natural disasters and social resilience. Earthscan, London, 212 pp.

Pelling M., High C., 2005 Understanding adaptation: what can social capital offer assessments of adaptive capacity? Global Environmental Change 15:308-319.

Peluso N. L., Humphrey C. R., Fortmann L. P., 1994 The rock, the beach and the tidal pool: people and poverty in natural resource dependent areas. Society and Natural Resources 7:23-38.

Polsky C., Neff R., Yarnal B., 2007 Building comparable global change vulnerability assessments: the vulnerability scoping diagram. Global Environmental Change 17(3-4):472-485.

Pritchett L., Suryahadi A., Sumarto S., 2000 Quantifying vulnerability to poverty - a proposed measure with application to Indonesia. Social Monitoring and Early Response Unit Research Institute (SMERU) Working Paper, May 2000, Available at: www.smeru.or.id.

Renaud F. G., Birkman J., Damm M., Gallopin G. C., 2010 Understanding multiple thresholds of coupled social-ecological systems exposed to natural hazards as external shocks. Natural Hazards 55:749-763.

Reynolds J. F., Smith D. M., Lambin E. F., Turner B. L. 2nd, Mortimore M., Batterbury S. P., Downing T. E., Dowlatabadi H., Fernández R. J., Herrick J. E., Huber-Sannwald E., Jiang H., Leemans R., Lynam T., Maestre F. T., Ayarza M., Walker B., 2007 Global desertification: building a science for dry land development. Science 316:847-851.

Rosenzweig M. L., 1971 Paradox of enrichment: destabilization of exploitation ecosystems in ecological time. Science 171:385-387.

Ruiz-Ballesteros E., 2011 Social-ecological resilience and community-based tourism: an approach from Agua Blanca, Ecuador. Tourism Management 32:655-666.

Sanchez-Rodriguez R., 2002 Cities and global environmental change. Challenges and opportunities for a human dimension perspective, IHDP 3:1-3.

Sarewitz D., Pielke R. Jr., Keykhah M., 2003 Vulnerability and risk: some thoughts from a political and policy perspective. Risk Analysis 23:805-810.

Schaffelke B., Mellors J., Duke N. C., 2005 Water quality in the Great Barrier Reef region: responses of mangrove, seagrass and macroalgal communities. Marine Pollution Bulletin 51:279-296.

Schilling J., Freier K. P., Hertig E., Scheffrana J., 2012 Climate change, vulnerability and adaptation in North Africa with focus on Morocco. Agriculture, Ecosystems and Environment 156:12-26.

Schmink M., Wood C. H., 1987 The political ecology of Amazonia. In: Lands at risk in the Third World: local-level perspectives. Little P. D., Horowitz M. M. (eds), Westview Press, Boulder, Colorado, pp. 38-57.

Schroter D., Polsky C., Patt A. G., 2005 Assessing vulnerabilities to the effects of global change: an eight step approach. Mitigation and Adaptation Strategies for Global Change 10:573-596.

Sen A., 1981 Poverty and famines: an essay on entitlement and deprivation. Clarendon Press, Oxford, 260 pp.

Sheridan T. E., 2001 Cows, condos, and the contested commons: the political ecology of ranching on the Arizona-Sonora borderlands. Human Organization 60(2):141-152.
Simmie J., Martin R., 2010 The economic resilience of regions: towards and evolutionary approach. Cambridge Journal of Regions, Economy and Society 3:27-43.
Smit B., Pilifosova O., 2001 Adaptation to climate change in the context of sustainable development and equity. In: Climate change 2001: impacts, adaptation and vulnerability. McCarthy J. J., Canziani O. F., Leary N. A., Dokken D. J., White K. S. (eds), Cambridge University Press, Cambridge, pp. 877-912.
Smit B., Wandel J., 2006 Adaptation, adaptive capacity and vulnerability. Global Environmental Change 16:282-292.
Smit B., Burton I., Klein R. J. T., Wandel J., 2000 An anatomy of adaptation to climate change and variability. Climatic Change 45:223-251.
Smith J. B., 1997 Setting priorities for adaptation to climate change. Global Environmental Change 7:251-264.
Smith J. B., Schellnhuber H. J., Mirza M. M. Q., 2001 Vulnerability to climate change and reasons for concern, a synthesis. In: Climate change 2001: impacts, adaptation and vulnerability. McCarthy J. J., Canziani O. F., Leary N. A., Dokken D. J., White K. S. (eds), Cambridge University Press, Cambridge, pp. 914-967.
Smith J. B., Klein R. J. T., Huq S., 2003 Climate change, adaptive capacity, and development. London, Imperial College Press, 356 pp.
Smithers J., Smit B., 1997 Human adaptation to climatic variability and change. Global Environmental Change 7(2):129-146.
Sonwa D. J., Somorin O. A., Jum C., Bele M. Y., Nkem J. N., 2012 Vulnerability, forest-related sectors and climate change adaptation: the case of Cameroon. Forest Policy and Economics 23:1-9.
Sterk M., Gort G., Klimkowska A., Van Ruijven J., Van Teeffelen A. J. A., Wamelink G. W. W., 2013 Assess ecosystem resilience: linking response and effect traits to environmental variability. Ecological Indicators 30:21-27.
Tidball K., Stedman R., 2013 Positive dependency and virtuous cycles: from resource dependence to resilience in urban social-ecological systems. Ecological Economics 86:292-299.
Timmerman P., 1981 Vulnerability, resilience and the collapse of society: a review of models and possible climatic applications. Environmental Monograph No. 1, Institute for Environmental Studies, University of Toronto, Totonto, Canada, 46 pp.
Turner II B. L., 2010 Vulnerability and resilience: coalescing or paralleling approaches for sustainability science? Global Environmental Change 20:570-576.
Turner II B. L., Kasperson R. E., Matson P. A., McCarthy J. J., Corell R. W., Christensen L., Eckley N., Kasperson J. X., Luers A., Martello M. L., Polsky C., Pulsipher A., Schiller A., 2003a A framework for vulnerability analysis in sustainability science. Proceedings of the National Academy of Sciences of the USA 100:8074-8079.
Turner II B. L., Matson P. A., McCarthy J. J., Corell R. W., Christensen L., Eckley N., Hovelsrud-Broda G. K., Kasperson J. X., Kasperson R. E., Luers A., Martello M. L., Mathiesen S., Naylor R., Polsky C., Pulsipher A., Schiller A., Selin H., Tyler N., 2003b Illustrating the coupled human-environment system for vulnerability analysis: three case studies. Proceedings of the National Academy of Sciences of the USA 100:8080-8085.
UNEP, 2006 Marine and coastal ecosystems and human well-being. A Synthesis Report Based on the Findings of the Millennium Ecosystem Assessment, 76 pp.
Vasquez-Leon M., Thor West C., Finan T. J., 2003 A comparative assessment of climate vulnerability: agriculture and ranching on both sides of the US–Mexico border. Global Environmental Change 13:159-173.
Walker B. H., Carpenter S. R., Anderies J. M., Abel N., Cumming G. S., Janssen M. A., Lebel L., Norberg J., Peterson G. D., Pritchard L., 2002 Resilience management in social–ecological systems: a working hypothesis for a participatory approach. Conservation Ecology 6(1):14-24.
Walker B. H., Holling C. S., Carpenter S. R., Kinzig A. P., 2004 Resilience, adaptability and transformability in social–ecological systems. Ecology and Society 9(2):5-11.

Walker B. H., Anderies J. M., Kinzig A. P., Ryan P. (eds), 2006 Exploring resilience in social-ecological systems through comparative studies and theory development: introduction to the special issue. Ecology and Society 11(1):12-21.
Walker P. A., 2005 Political ecology: where is the ecology? Progress in Human Geography 29:73-82.
Watts M. J., Bohle H. G., 1993 The space of vulnerability: the causal structure of hunger and famine. Progress in Human Geography 17:43-67.
Wilhite D. A., 2000 Drought as a natural hazard: concepts and definitions. In: Drought: a global assessment. Wilhite D. A. (ed), London, Routledge, pp. 3-18.
White G. F., Haas J. E., 1975 Assessment of research on natural hazards. MIT Press, Cambridge, 487 pp.
WHO, 2005 Ecosystems and human well-being: health synthesis. A report of the Millennium Ecosystem Assessment, WHO Press, Geneva, Switzerland, 64 pp.
Wilhelmi O. V., Morss R. E., 2013 Integrated analysis of societal vulnerability in an extreme precipitation event: a Fort Collins case study. Environmental Science and Policy 26:49-62.
Williams G., 1995 Modernizing Malthus: the World Bank, population control and the African environment. In: Power of development. Crush J. (ed), London, Routledge, pp. 158-175.
Wilson G. A., 2012 Community resilience, globalization, and transitional pathways of decision-making. Geoforum 43:1218-1231.
Winchester P., 1992 Power, choice and vulnerability: a case study in disaster management in South India. James and James, London, 225 pp.
Wisner B., Blaikie P., Cannon T., Davis I. (eds), 2004 At risk: natural hazards, people's vulnerability and disasters. (2nd ed.). London, Routledge, 124 pp.
Yan H., Zhan J., Zhang T., 2011 Resilience of forest ecosystems and its influencing factors. Procedia Environmental Sciences 10:2201-2206.
Zhou H., Wang J., Wan J., Jia H., 2010 Resilience to natural hazards: a geographic perspective. Natural Hazards 53:21-41.
Zimmerer K. S., 1994 Human geography and the 'new ecology': the prospect and promise of integration. Annals of the Association of American Geographers 84:108-125.
Zimmerer K. S., Basset T. J., 2003 Political ecology: an integrative approach to geography and environment-development studies. Guildford Press, New York, 312 pp.

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