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Review Article

COASTAL HAZARDS AND VULNERABILITY: A REVIEW

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ABSTRACT
The coast is one of the most dynamic parts of the earth surface. About 23% of the world's population live within 100 km of the coast and about 10 % of the population live in extremely low-lying areas (< 10 m above mean sea level). Many geophysical processes like coastal erosion, storm surges, coastal flooding, tsunamis and sea level rise pose hazards to these people. The intensity of each of these processes is likely to increase under changing scenarios of global climate. A number of methodologies have been proposed from time to time to assessment the vulnerability of coastal areas. Some of these are the CM (Common Methodology), SURVAS (Synthesis and Upscaling of Sea Level Rise Vulnerability Assessment Studies), DIVA(Dynamic Interactive Vulnerability Assessment) CVI (Coastal Vulnerability Index)and CCHZ(Coastal Change Hazard Zone). However, most of these indices consider only the physical parameters. Vulnerability on the other hand, by definition, includes a human component. It is proposed that any assessment of coastal vulnerability must consider both physical and human components of that particular coast. Only such a holistic approach will lead towards an accurate assessment of coastal vulnerability.

INTRODUCTION
The coast is one of the most dynamic parts of the earth surface. They contain some of the world's most sensitive ecosystems like mangroves, wetlands, coral reefs, dunes and beaches. Besides, they are home to a large human population. About 23% of the world's population live within 100 km of the coast (Small and Nicholls 2003). Coastal areas perform many important functions like regulation of water exchange between land and sea, regulation of the chemical composition of sediments and water, storage and recycling of nutrients and human wastes, maintenance of biological and genetic diversity, providing space for agriculture, transportation and navigation, providing means of recreation and tourism as well as providing a variety of information regarding aesthetic, historical, cultural and scientific aspects. These functions can be classified into three groups namely, regulation functions, user-production functions and information functions (de Groot, 1992; Vellinga *et al.*, 1994). While living near the coast is advantageous for the above mentioned reasons, it also exposes the inhabitants to a large number of hazards; sometimes exposure to multiple hazards at a single instance is also common. In the last twenty years (1992-2012), the world has been ravaged by a number of natural disasters, some of which have affected coastal areas severely both in terms of loss of lives and damage of property. These include Hurricanes Andrew and Katrina in the USA, Typhoon Linda in Vietnam and Thailand, Hurricane Mitch in central America, the supercyclone in Orissa, India, tsunamis in Papua New Guinea, Indonesia and Japan and flooding in Mozambique. While the generation of these natural processes is beyond human control, anthropogenic activities sometimes aggravate their intensities. At the same time, the ability of the people living near the coast to cope with the effects of these hazards is often not sufficient. This renders them vulnerable to such hazards. The purpose of this paper is to review the natural hazards and human vulnerability to these hazards.

1. Natural hazards with special reference to coasts:
The words natural hazards and natural disasters have now come into common parlance and are often used synonymously. However, there is a difference between the two terms. Numerous attempts have been made to define these two terms (Fritz, 1961; Burton and Kates, 1964; Cutter, 1993; Quarantelli, 1998;

Chapman, 1999; Perry and Quarantelli, 2004). Without trying to redefine these two terms, we would like to differentiate between them. The earth is geologically active and experiences gradual but continuous changes in climate. Thus, it is always exposed to natural anomalies or hazards. Natural hazards are those processes which have the potential to affect human population. These processes may be induced by hydrometeorological, geological or even biological factors. A hazard becomes a disaster only when it affects a population adversely. Thus, there appears to be a cause and effect relationship between the two. It is difficult to ascertain when a hazard turns into a disaster, although it is clear that the inability of the people to respond to the hazard adequately induces the disaster. It is a concept known as vulnerability and will be dealt with in the next section. Natural hazards induced by hydrometeorological factors include floods, debris flows, mudflows, cyclones, storm surges, snow avalanches, sand or dust storms. Geological hazards take the form of tsunamis, earthquakes, volcanic eruptions, surface collapse, liquefaction etc. Biological hazards include outbreak of epidemics and infections of plants and animals and even attack by wild animals on humans.
It is also important to differentiate between hazard and risk. Both are also used synonymously, but there is a subtle difference. While hazard implies a physical or man-induced process that has the potential to afflict humans, the term risk also indicates the probability of the hazard occurring. The difference between the two terms is explained succinctly by Okrent (1980) through an example of two men crossing an ocean. One man is in a rowing boat while the other in a liner. While the main hazard (big waves and deep water) is the same for both the persons, the risk (of being drowned) is greater for the person in the rowing boat. Thus, risk also bears a behavioural connotation, which is a determinant of vulnerability (Kaiser 2006).
Since this review is focused on natural hazards in coastal areas, the remaining part of this section will deal with coastal hazards.

1.1 **Coastal hazards:**

Since the coast is very dynamic and is inhabited by an ever-increasing population, it is subject to a number of natural hazards. Natural hazards of the coast- termed as coastal hazards hereafter- include erosion, storms and associated storm surges, tsunamis and flooding (Kaiser, 2006). In addition, sea level rise has also emerged as modern forms of coastal hazards. These are briefly reviewed below:

1.1.1 **Coastal Erosion:**

Erosion entails removal of sediments by waves, tides and currents. It is a major problem around the world. Globally, about 70% of the sandy beaches are experiencing acute erosion (Bird 2000). The reasons for this include increased storminess, coastal submergence, decreased sediment movement, changes in the directional component of wave climate and human activities (Bryant, 2005). Besides, sea level rise also accentuates the problem of coastal erosion. Leatherman *et al.* (2000) found out that long term retreat of sandy shores averages about 150 times that of sea level rise. Soft coasts (made of chalk, clay etc) and coral reefs are particularly prone to such sea level rise induced erosion. Besides directly impacting coastal erosion, the rising sea levels also bring about indirect coastal erosional effect by affecting lagoons and tidal basins. As the morphology of these basins and lagoons respond to the rise of sea level, they experience a change in their overall sediment balance, which increases erosion in the open coast (Capobianco *et al.*, 1999).

1.1.2 **Storms and associated storm surges:**

Storms are one of the most potent forms of natural hazards in the world. Storm damage in the coasts results from the interactions of winds, waves and rising water levels. Besides, the impact of the storms depends on the intensity of the driving events as well as the natural and human-induced changes to the coastal system. In addition to being impacted directly by the storm, coastal areas are also affected by the storm surges i.e. a rise in the water level following a storm. Several factors determine the intensity of the storm surge. These include the effects of sea surface temperature, pressure, winds, waves, the earth's rotation and the amount of rainfall received (Harris, 1963; Betts *et al*., 2004). In addition, the depth and morphology of the ocean as well as nearshore bathymetry can also influence storm surge height. The largest known storm surge height is 13 m caused by tropical cyclone Mahina in north Queensland in 1899 (Nott and Hayne, 2000). Storm surge causes flooding in various forms. Therefore, an accurate prediction of storm surge height is an important task. A large number of models are available for this purpose (see Bode and Hardy, 1997 for a review); however, very few explicitly embrace the effect of tides. A notable exception in this regard is the GCOM2D model developed by McInnes *et al*. (2003). This model combines a cyclone model with tidal effects to predict wave height under storm condition. An advantage of this model is that it allows the incorporation of projected changes in cyclone behaviour due to climate change brought about by the greenhouse effect.

1.1.3 **Tsunamis:**

Because of the low frequency at which they occur, tsunamis have been termed as "the under-rated hazard" (Bryant, 2008). However, the last decade has seen two major tsunamis (Southeast Asia in 2004 and Japan in 2011) which had devastating consequences both in terms of loss of lives and economic damage. In addition, smaller tsunamis took place in Samoa and Chile in 2009 and 2010 respectively that killed a number of people. This series of events have highlighted the impact that these events can have. Tsunamis are sea waves generated as a result of earthquakes, volcanic eruptions, terrestrial or submarine landslides and even asteroid impacts. Earthquakes are by far the largest producers of tsunamis, but only those earthquakes can cause tsunamis, which occur within the upper 100 km of the oceanic crust (Bryant, 2008). The velocity at which these waves travel can be variable. Although they cannot be seen in the open ocean, the height of tsunamis reaching the coast can range from 2 m to 40 m (Bryant, 2008). Nearshore topography may further amplify the height of the waves. The height of tsunami waves during the 2004 tsunami was about 50 m in Indonesia, 20 m in Thailand, 10-15 m in India and 11 m in Sri Lanka (Choi *et al*., 2006; Tsuji *et al*., 2006). These waves can also inundate areas not only near the coast but also those inland. In Indonesia, the run-up of the 2004 tsunami travelled inland for 5000 km (Choi *et al*., 2006).

1.1.4 **Coastal flooding:**

Flooding can occur due to a variety of reasons. Kaiser (2006) distinguished between permanent flooding and episodic flooding. Permanent flooding results in permanent degradation of land from coastal wetlands and deltas. The rate of loss depends on slope, sediment availability and the resilience of the ecosystem to cope with adverse events (Kaiser, 2006). Episodic flooding, on the other hand, is usually the result of surges in ocean water caused by cyclones and tsunamis. The flooding caused in Southeast Asia in 2004 and in New Orleans in 2005 are examples of episodic flooding caused by surges due to Hurricane Katrina and the tsunami respectively. Kaiser (2006) suggests that episodic flooding causes more damage that permanent inundation. The ability of the increased water level (flooding) to cause damage depends on the susceptibility of the site to being flooded and its associated effects. Low elevation, reduced dune height, beach recession and improper developmental activities may all enhance the susceptibility of coastal flooding (Burston, 2007).

1.1.5 **Sea level rise:**

Sea level rise (SLR) is one of the oft-cited effects of global warming (rise in global temperature due to enhanced emission of greenhouse gases). It is a particularly ominous threat because about 10% lives within an elevation of 10 m above mean sea level (McGranahan *et al*., 2007). SLR will affect all components of the coasts like beaches, lagoons, estuaries, deltas, coral reefs, mangroves etc (see Nicholls *et al*., 2007 for a detailed discussion of these effects).

Prior to the early 1990s, the main source of data regarding sea level changes were the tide gauges (Douglas, 2001). Since the 1990s, satellite altimetry has been used to measure the relative changes in sea level. In combination, these two methods have provided the following interesting observations regarding sea level fluctuations:

a) According to Miller and Douglas (2004), tidal gauge data indicate that the global sea level has risen, on average, by 1.5-2.0 mm/year in the last century and since 1993, the rate has increased to 3 mm/year (Church and White, 2006).

b) There are large regional variations of sea level (Cazenave and Llovel, 2010).

c) Since 2003, the mean rate of global sea level rise has declined to 2.5 mm/year ± 0.4 mm/year (Ablain, 2009).

The latest IPCC Report, however, predicts that the global sea level will rise by about 600 mm by 2100 AD. This means the annual rate of increase would be 6.45 mm. Furthermore, if the ice caps continue to melt, there could be a 1 m rise of the sea level by the end of the twenty first century (Pfeffer *et al.*, 2008). Kaiser (2006) suggests that even if greenhouse gas emissions are reduced or stopped in the near future, sea level will continue to rise at an accelerated rate due to climatic lags. This has been termed as 'commitment to sea level rise' by Wigley (1995). This rise of sea level will manifest itself along the coastal stretches in five forms- erosion of beaches and bluffs, increased flooding and storm damage, inundation of low-lying areas, intrusion of salt water into aquifers and higher water tables (Gornitz, 1991; Nicholls and Leatherman 1995). The impacts would be spatially variable depending on local factors, but low-lying areas of the developing countries are likely to be the worst hit (Nicholls *et al.*, 2007).

1.2 Coastal hazards & climate change:

Global warming leads to changes in the earth's climate, which in turn, has the potential to change the magnitude and frequency of coastal hazards. A body of evidence from the west (Pacific) coast of USA point toward increased wave heights, erosion, storminess and flooding due to climate change and associated SLR (Komar, 1986; Graham and Diaz, 2001; Allen and Komar, 2000, 2006; Ruggiero *et al.*, 2010). Another aspect that can aggravate the problem is El Niño. El Niño will definitely affect the effects of SLR and increased storminess, but the extent to which it will do so is still not known as there are uncertainties regarding the magnitude and frequency of future El Niños in a warmer world. While some studies like Trenberth and Hoar (1997) have suggested a significant increase in El Niño-like conditions in the future, resulting in increased shoreline recession (Kaminsky *et al.*, 1998), others have either suggested lesser frequency of El Niños or no change from present day frequencies (Collins, 2005; van Oldenborgh *et al.*, 2005). These enhanced biogeophysical effects will impact upon the socio-economic sectors of the coast in terms of loss of land and resources as well as reduction in their economic, cultural and ecological values (Klein and Nicholls, 1999; Table 1).

2. Vulnerability:

Vulnerability is a term that has become very common now. In simple terms, it may be defined as the propensity of a human being or community to be harmed negatively by some changes in the living condition as a result of a natural or human-induced process. While there is no universally accepted definition of vulnerability (Cutter, 1996; O'Brien *et al.*, 2004) and neither is it clear how it can be used as a tool in environmental assessments (Gallopín, 2006; Füssel, 2007), it has now become a very important component of studying man- environment relationship. Indeed, a number of major reviews have been published in the last years (Adger, 2006; Eakin and Luers, 2006; Turner, 2010; Toro *et al.*, 2012). The surge in vulnerability research is perhaps due to the perception that the propensity to be harmed negatively is going to increase due to climatic changes being brought about by global warming (Heltberg *et al.*, 2009).

Table 1: Impact of changed (enhanced) biogeophysical processes on socio-economic sectors (adapted from and modified after Klein and Nicholls, 1999:183)

Sectors	Bio-geophysical effects					
	Flood frequency	**Erosion**	**Inundation**	**Rising water table**	**Saltwater intrusion**	**Biological effects**
Water resources	×	×	●	●	●	●
Agriculture	●	×	●	●	●	×
Human health	●	×	●	×	×	×
Fisheries	●	×	●	×	×	●
Tourism	●	●	●	×	×	×
Human settlements	●	●	●	●	×	×
Legend:	● Affects		× Does not affect			

Vulnerability research originates from three distinct areas of study: (a) studies having a bio-physical framework, (b) studies from a political economy perspective and (c) those resulting from the ecological concept of resilience (Eakin and Luers, 2006). So having defined vulnerability it is equally important to define the terms resilience and adaptive capacity.

The term 'resilience' was developed by ecologists to refer to a system's ability to embrace disturbance and change while maintaining the relationships that determine its relationship (Holling, 1973). Underlying Holling's ecological resilience concept is the fact that the ecosystem has the ability to reorganize itself so as to maintain its structure and function (Eakin and Luers, 2006).

Different terms have been used to refer adaptive capacity, but from the perspective of vulnerability, it may be defined as the capacity of the system to increase or at least maintain the quality of life of its individual members in a given environment or range of environment (Gallopín *et al.*, 1989).

Space constraints do not permit a full-scale analysis of the concept of vulnerability. However, there are three broad manifestations of vulnerability. These are vulnerability as an exposure to hazards, vulnerability as a social response and vulnerability of places (Cutter, 1996). The magnitude, frequency, duration and impact of biophysical processes fall under vulnerability as exposure to hazards (Burton *et al.*, 1993). Vulnerability as a social response measures how resilient the society is to the hazard exposure and includes such aspects as floods, droughts, epidemics (Cutter *et al.*, 2003; Dwyer *et al.*, 2004). A major determinant of social vulnerability, especially in rural areas, is 'place attachment' (emotional links between a person or community and the physical environment) (Low and Altman, 1992) that determines the extent of hazard preparedness. Recently, it has been proposed that social vulnerability also has a strong temporal component (de Vries, 2011) i.e. a person or community's temporal situation (position in social time) significant influences its vulnerability to natural hazards. Place vulnerability alludes to a situation when a community or person is vulnerable to natural hazards because he lives in an area of high exposure and in a society that is not adequately prepared to cope with the potential hazard (Cutter, 1996).

3.1. **Coastal Vulnerability:**

The coastal zone is highly vulnerable. Therefore, an assessment of the degree of its vulnerability is important since it is related to the way decisions are to be made regarding the reduction of exposure to the impacts of coastal hazards. Various methodologies have been developed to assess the vulnerability of coastal areas to environmental hazards. Most of these methods recognize the need to incorporate human aspects, but few have been able to do so (Cooper and McLaughlin, 1998). Since vulnerability essentially involves humans, only those indices that incorporate socio-economic aspects are reviewed in this paper. These include the CM, CVI and its modification, the CSoVI, SURVAS, DIVA, and CCHZ model.

2.1.1 **Common Methodology:**

The Common Methodology (CM) was a seven-step tool developed by the IPCC's Coastal Zone Management Subgroup (CZMS) to assess the vulnerability of various coastal nations to sea level rise (IPCC-CZMS 1992, Table 2). While assessing vulnerability to sea level rise, the CM considered impacts on population, economic sector, ecological and social assets and on agricultural production. These impacts were studied in relation to a high (1 m) and low (0.3 m) rise of sea level as proposed by the IPCC in 1990 (IPCC-CZMS 1992). It also considered monetary valuations of a nation's vulnerability to SLR (IPCC-CZMS 1992). Critics, however, considered that the data for the parameters considered in it were either inadequate or not easily available (Klein and Nicholls, 1999). Furthermore, an economics-based approach rendered it unsuitable for being of much use to coastal planners (Harvey and Woodroffe 2008). Kay and Waterman (1993) developed a four-stage methodology to overcome these limitations of the CM. The four stages were: (i) consideration of the physical and biological environment of the study area; (ii) consideration of the analysis of vulnerable and resilient conditions that included socio-economic and cultural systems; (iii) consideration of the links between the connected areas, and (iv) formulation of management strategies. Harvey *et al.* (1999) criticized the Kay and Waterman methodology on the ground that there was no spatial and temporal limit of the physical and biological environment of the study area and that, human-induced hazards on the coast are more likely to occur faster than sea level rise. They proposed an eight-stage methodology (Table 3) that laid importance on scale and a holistic approach to coastal vulnerability assessment. Despite these alternatives, authors like Kay *et al.* (1996) considered the CM to be a simple and a very popular methodology.

Table 2: The Common Methodology proposed by the IPCC (Source: IPCC-CZMS, 1992)

Stages	**Activities**
1	Delineate case study area, and specify accelerated sea level rise and climate change conditions
2	Produce inventory of study area characteristics
3	Identify relevant development factors
4	Assess physical changes and natural system responses
5	Formulate response strategies, identifying potential costs and benefits
6	Assess the vulnerability profile and interpret the results
7	Identify future needs and develop a plan of action

Table 3: The modified form of coastal vulnerability assessment (adapted from Harvey *et al.*, 1999:56)

Stages	Activities
1	Definition of the spatial scale of the entire study area using biophysical and socio-economic boundaries
2	Definition of the temporal scale that incorporates current human-induced hazards and potential climate change hazards
3	Collection of data on the relevant biophysical characteristics of the study area
4	Collection of data on the socio-economic, cultural and heritage characteristics of the study area
5	Reiteration of stages 1 to 4 for selected study sites
6	Identification of the relevant legislation, jurisdictions, plans and policies for the study area for the three tiers of government (local, state and federal)
7	Assessment of coastal vulnerability in both qualitative and quantitative terms on the basis of the various techniques utilized in the assessment
8	Setting priorities for current management and further long-term objectives according to the problems identified

3.1.2. **Coastal Vulnerability Index:**
The Coastal Vulnerability Index (CVI) was developed by Gornitz *et al.* (1994). This approach considered eight parameters to assess the vulnerability of a coastal area to anticipated SLR. These parameters were relief, rock type, landform, vertical (tectonic) movement, shoreline displacement, tidal range and wave height (Gornitz *et al.*, 1994). Subsequently many modifications were made to the CVI. For example, Nageswara Rao *et al.* (2008) replaced the relief parameter with coastal slope. They argued that since relief is indicative of a single point whereas slope refers to an area, the latter is better suited for coastal vulnerability assessments. The CVI was used by the United States Geological Survey (USGS) to assess the vulnerability of coastal stretches throughout the United States (Thieler, 2000; Thieler and Hammer-Klose, 1999, 2000a, 2000b) and in other parts of the world also.

The problem with the CVI approach as proposed by Gornitz *et al.* (1994) and adopted by the USGS is its non-consideration of socio-economic data. This problem was recognized early by Gornitz *et al.* (1994), but surprisingly, many subsequent studies in the US by Gornitz and her colleagues (e.g. Gornitz *et al.*, 2001; Jacob *et al.*, 2007) and in other parts of the world (Gibb *et al.*, 1992; Shaw *et al.*, 1998; Abuodha and Woodroffe, 2010; Kumar *et al.*, 2010) still do not consider these parameters, possibly due to non-availability of sufficient data or the problem of ranking the socio-economic variables on interval or ratio scales (McLaughlin *et al.*, 2002). However, any assessment of coastal vulnerability without reference to its social aspects is not useful because "*the occurrence and magnitude of coastal impacts of sea-level rise will be a function of a number of future environmental and socioeconomic developments*" (Klein and Nicholls, 1999: 185). To overcome this problem, a hybrid approach was adopted by Boruff *et al.* (2005) in their assessment of the coastal vulnerability of US counties. They combined the Social Vulnerability Index (Cutter *et al.*, 2003) with the CVI proposed by the USGS to form the Coastal Social Vulnerability Index (CSoVI). The CSoVI considered all the parameters of the CVI and such parameters as poverty, population, development, ethnicity, age and urbanization (Boruff *et al.*, 2005). Additionally, this study used Cutter's (1996) Hazard of Place model of vulnerability to derive the Place Vulnerability Index (PVI) for each of the counties. The PVI was derived by adding the CVI and CSoVI scores and the PVI scores were categorized into low, medium and high classes. When ANOVA was run for each of these three indices, it was found that was significant differences (at 95% confidence level) for each of these indices in the various coasts (Boruff *et al.*, 2005). These differences were brought out by the socio-economic parameters considered. Thus, the significance of the study by Boruff *et al.* (2005) is that it is the first ever comprehensive study of coastal hazard vulnerability in the world.

3.1.3. **Synthesis and Upscaling of Sea Level Rise Vulnerability Assessment Studies:**

The Synthesis and Upscaling of Sea Level Rise Vulnerability Assessment Studies (SURVAS) was developed from the CM to undertake studies on the assessment of future impacts of human-induced SLR at the national and sub-national scales (Nicholls & de la Vega-Leinert 2000). A series of workshops were held under the guidance of leading coastal vulnerability experts to focus on the tools available for assessing the physical susceptibility and socio-economic vulnerability. This project also contributed to the DINAS-COAST project which developed the DIVA tool.

3.1.4. **Dynamic Interactive Vulnerability Assessment Tool:**

The DINAS-COAST (Dynamic and Interactive Assessment of National, Regional and Global Vulnerability of Coastal Zones to Climate Change and Sea Level Rise) project, a consortium of European nations, developed the Dynamic Interactive Vulnerability Assessment (DIVA) tool in 2004 to complement the national- and regional-scale studies in Europe (McFadden *et al.*, 2007). It considered information on more than 80 physical, ecological and socio-economic parameters of the world's coastal areas (excluding Antarctica). All of this information is divided into more than 25,000 coastal segments of various lengths, each of which has its own identification number and associated data table (Vafeidis *et al.*, 2004, 2008). This tool is based on the assumption that vulnerability in a particular segment of the coast is a function of several physical and socio-economic parameters that are likely to be affected by SLR.

3.1.5. **Coastal Change Hazard Zonation:**

Zonation mapping is a very popular means of assessing vulnerability to natural hazards. Recently, a probabilistic model of estimating the coastal hazards associated with climate change has been developed. This is known as the Coastal Change Hazard Zone (CCHZ) model (Baron, 2011). In this study, carried out in a small sector of the Pacific coast of USA, zones associated with climate-induced hazards were identified based on the amount of coastal change associated with sediment budget, climate-induced factors (like SLR, storm surge), extreme water level events and erosion hotspots. These changes were estimated in relation to a range of hazard scenarios associated with possible changes to SLR, wave climate and El Niño over a period of several decades. While the estimates of change associated with climatic and extreme water level events were easily quantified based on existing erosion models, those associated with the rest of the parameters were estimated indirectly through such attributes as wave parameters and foreshore slope (see Baron, 2011 for details). Finally, the socio-economic aspects of the study area like roads and buildings were overlain on the hazard zones, so derived, to assess their exposure to the hazards. The CCHZ approach is a very useful one since it is not only probabilistic, but it is also user-friendly, allowing for the manipulation of risk scenarios and time periods.

3.2. Summary of Coastal Vulnerability assessment tools:

The foregoing discussion on the various tools available for vulnerability assessment in coastal areas suggests that an approach that gives equal emphasis on physical and socio-economic characteristics of an area is the most ideal approach for assessing vulnerability. However, none of these models include one very important aspect of the socio-economic setup- perception or human thinking. It is the perception about hazards that is also an important determinant of human vulnerability to them (Burton *et al.*, 1993). This has been termed as Cultural Vulnerability by Donovan (2010). This concept means studying whether faith in indigenous traditions and customs make people more or lesser vulnerable to natural hazards. Sometimes, belief in local customs and traditions save people from being affected by a natural hazard. For example, during the 2004 tsunami in Indonesia, many people were saved because of their belief in an oral history, which prompted them to move to higher areas on seeing the first indications of the tsunami (McAdoo *et al.*, 2006). During a comprehensive study of response to hazard management by people living on the flanks of an active volcano in Indonesia, Donovan (2010) mapped qualitative attributes like cultural intensity (i.e. belief in premonitions, local spiritual leader, traditional signs of warning like animal behaviour etc.) and people's response to government call for evacuation during a recent emergency using GIS. Later statistical analyses revealed that there is a strong correlation between the two attributes. People who refused to evacuate because of their strong belief in cultural (religious) factors were found to be the most vulnerable because they lived directly in the path of potential lava flow if and when the volcano erupts. This is a good example of religious place attachment (Mazumdar and Mazumdar, 2004). This study indicates that even if proper hazard management plans are in place, people might still be vulnerable unless those plans adequately incorporate the cultural factors. Therefore, it is important that any vulnerability assessment takes into cognizance local culture along with the physical and socio-economic attributes.

CONCLUSIONS

The coast is prone to multiple hazards like erosion, flooding, tsunamis, storm surges and sea level rise. The extents to which these occur are likely to increase under scenarios of climate change. As more and more people start to inhabit the coasts, their vulnerability to these hazards will also increase. Any assessment of coastal vulnerability must not only include physical aspects of a particular coast, but also its human components. Only then can a holistic assessment of the vulnerability of that coast to natural hazards be made.

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