Chapter 2
Review of the Existing Risk Assessment Methods

Abstract This chapter deals with examination of existing risk assessment methods related to this topic carried out on a global basis; evidently, such a list is not exhaustive.

In past decades, the increase of human occupation and interests along coastal areas (Crowell et al. 2010) as well as in the knowledge of coastal processes and associated hazards (Komar 1998; Méndez-Lázaro et al. 2014), favored elaboration for several coastal sectors around the world, of vulnerability maps obtained through the use of Geographical Information Systems (GIS), computer-assisted multivariate analysis and numerical models (LOICZ 1995).

In Europe, and specifically Northern Ireland (UK), McLaughlin et al. (2002) developed a GIS based coastal vulnerability index at local, regional and national scales. In Germany, Burzel et al. (2010) elaborated integrated flood risk analysis for extreme storm surges for an estuarine area and an exposed island. De Pippo et al. (2008) and Anfuso and Martinez (2009) respectively analysed vulnerability of coastal sectors located in Campania and Sicily (Italy). Özyurt et al. (2008), Özyurt and Ergin (2009, 2010) and Ergin (2011) proposed an assessment method to determine the associated vulnerability to Sea level Rise for different coastal areas in Turkey.

With respect to Spain, Sánchez-Arcilla et al. (1998) evaluated the Ebro delta vulnerability over different time scales and Di Paola et al. (2011) investigated coastal vulnerability of the Canary Islands. Mendoza and Jiménez (2006, 2009) and Bosom and Jiménez (2011) analysed coastal vulnerability of the Catalonian coast to storm events. Malvárez and Domínguez (2000), Domínguez et al. (2005), Del Rio and Gracia (2009) and Santos et al. (2013) assessed vulnerability for different coastal sectors of Andalusia; meanwhile maps concerning the entire regional territory have been elaborated by Ojeda-Zújar et al. (2009). In Portugal, vulnerability maps have been elaborated by Coelho et al. (2009), Ceia et al. (2010) and Carrasco et al. (2012), among others.

In Morocco, Snoussi et al. (2008), Anfuso and Nachite (2011) and Raji et al. (2013) investigated coastal vulnerability to Sea Level Rise and storm events.

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In China, Li and Li (2011) analysed the vulnerability assessment of storm surges in the coastal area of Guangdong Province.

In the USA, "Coastal Zone Hazard Maps" have been prepared for coastlines affected by hurricane Hugo (Bush et al. 1996) and the "National Flood Insurance Program" has been created by the government (Kelly 2000) under the supervision of the Federal Emergency Management Agency (Crowell et al. 2007a, b). Key engineering components of this program have been the Flood Insurance Studies, which were prepared in order to determine the elevation of the 1 % annual chance flood, which is a flood height that has a 1 % chance of being equaled or exceeded during any given year, sometimes referred as the "100 y flood" too. In this sense, several zones with different hazard levels have been determined along coastal USA zones using coastal storm surge analysis by using tsunami, hurricane, or coastal storm surge models such as the FEMA Standard Storm Surge Model (Surge), the Advanced Circulation Model (ADCIRC), or the Danish Hydraulic Institute Mike 21 hydrodynamic models and tide gauge analyses from long-term NOAA or United States Army Corps of Engineers tide gauge records (Crowell et al. 2010).

In Central and South America, Lizárraga et al. (2001) presented a vulnerability matrix combining beach width at Rosario (Mexico) with the probability of damage to landward structures and Szlafsztein and Sterr (2007) carried out a GIS—based vulnerability assessment of coastal natural hazards in the state of Pará, Brazil. Whereas Rangel and Anfuso (2009) and Rangel and Posada (2013) determined coastal vulnerability to erosion along several sectors of the Caribbean coast of Colombia.

Most of the above mentioned works were based on the use of indexes for combining different types of variables into a single measure: this is one of the most common methods of assessing coastal sensitivity, e.g. among others Cooper and McLaughlin (1998) and McLaughlin et al. (2002).

Few preliminary studies, Lizárraga et al. (2001), Domínguez et al. (2005), Anfuso and Martinez (2009) and Rangel and Anfuso (2009) used and combined among them a limited, easy to calculate number of parameters, essentially beach width, coastal erosion/accretion rates and land use typologies. Rates of coastal erosion/accretion, if available, constitute reliable data on the spatial distribution of erosive processes and associated hazard and can advantageously substitute numerous secondary parameters at some place difficult to calculate and/or overlapping among them (Williams et al. 2001).

In recent studies, the Coastal Vulnerability Index (CVI) and its adaptations are the most used techniques (Klein and Nicholls 1999). The CVI approach combines the coastal system susceptibility to change with its ability to adapt to changing environmental conditions and yields a relative measure of the system natural vulnerability to the effect of hazards as chronic and storm related coastal erosion processes, climate change associated processes, etc. The application of this methodology, under a GIS environment or multivariate analysis, is based on the modelling of a certain number of variables related to the specific hazard analysed and their interactions over the coastline. As a result, the main output is generally a set of colour-coded sensitive maps, thus allowing the most sensitive areas to be easily identified (Gornitz 1990; LOICZ 1995; Bush et al. 1996; Cooper and McLaughlin 1998; Kelly 2000; Ojeda-Zújar et al. 2009; Raji et al. 2013).

Several indexes have been used in different fields of study. They constituted a useful tool to simplify datasets categorizing them in order to establish relations that make their analysis easier (McLaughlin 2001). In the last two decades, development of coastal indexes has received much attention as they have been used for studying a range of process such coastal erosion (Forbes et al. 2003; Del Rio and Gracia 2009; Anfuso et al. 2010) or sea level rise (Gornitz and Kanciruk 1989; Gornitz et al. 1994; Thieler and Hammer-Klose 2000; Snoussi et al. 2008; Dwarakish et al. 2009; Özyurt and Ergin 2009).

Simple indexes assessed the physical vulnerability of the coast. Most of them have been derived from the initial work by Gornitz (1990), which proposed an index that was widely applied in the United States and adapted to be used in other parts of the world. In this sense, Gornitz (1990), in a study concerning the East coast vulnerability to SLR, considered seven variables, e.g. relief, rocky type, landform, vertical movements, shoreline displacement, tidal range and wave height. In a following study devoted to evaluate U.S.A. vulnerability to storms, hurricanes and SLR, Gornitz et al. (1993) introduced variables related to wave energy, tropical storms, hurricanes occurrence probability, etc.

In order to study characteristics and vulnerability of different coastal sectors of Italy, Dal Cin and Simeoni (1994) proposed the use of 15 variables including wave energy, longshore transport, evolution rates, width of the foreshore, sediment size, beach and nearshore slope, presence of defensive structures and ports, etc. To assess beach stability, Simeoni et al. (2000) proposed the application of the System theory based on the use of 14 physical parameters including cliff characteristics, presence of dunes, tidal range, etc. In a study carried out in Australia, Abuodha and Woodroffe (2006) considered 7 variables, e.g. dune height, barrier types, beach types, relative sea level change, erosion/accretion rates, mean tidal range and wave height. Özyurt and Ergin (2009) carried out a study on vulnerability of selected coastal areas of Turkey to SLR taking into account five main types of variables (coastal erosion, flooding due to storm surge, inundation and salt water intrusion to ground waters resources and to river/estuaries) which included a total amount of 22 sub-variables. Similar variables were also used by Özyurt and Ergin (2010).

Combined indexes were more complex and also examined aspects such as economic and social vulnerability (McLaughlin et al. 2002; Boruff et al. 2005; Szlafsztein and Sterr 2007). Gornitz et al. (1993) and Cooper and McLaughlin (1998) highlighted the importance of including demographic and other socioeconomic parameters in the classification procedure and as the omission of them limits the evaluation of vulnerable areas. According to McLaughlin et al. (2002), the absence of socioeconomic parameters in most of used indexes is due to the lack of suitable data and to the difficulties in ranking them on an interval or rational scale.

In their study, previous authors selected the socioeconomic parameters according to the availability of up-to-date data and to their useable format and relevance to coastal areas. Specifically, McLaughlin et al. (2002) considered the following socioeconomic variables: population, cultural heritage, roads, railways, land use and conservation status. Despite the economic value of some of them (e.g. roads, railways and land use) which are easy to calculate, in general, investigated variables are difficult to evaluate because they present great spatial and temporal distribution (e.g. population) or their intrinsic characteristics (e.g. cultural heritage and conservation status). According to McLaughlin et al. (2002), archaeological and historical monuments are also important in social and cultural terms and not only in economic terms; due to the difficulties in ranking them, previous authors decided to rank all sites with archaeological remains in the highest category. The incorporation of conservation issues raised very important difficulties too because the uncertainty in the criteria to follow and to the fact that such features are formed by natural wave forcing processes. In this sense, their maintenance cannot be carried out by protecting them by natural processes which have to continue to operate to keep them "alive".

Szlafsztein and Sterr (2007) in a study regarding the coastal vulnerability linked to natural hazards in northern Brazil, introduced socioeconomic parameters as the total population and total population affected by floods, density of population, non-local population, poverty and municipal prosperity. Similar studies were carried out in China by Li and Li (2011) and took into account: Social economic index (e.g. population, roads, industrial and agricultural value and residential land), Land use index (farming, aquaculture and arable land), Eco-environmental index (beaches and wetlands, mangroves and rivers), Coastal construction index (coastal engineering, highways and buildings), Disaster-bearing capability index (seawalls, labour population and financial revenue).

Other studies took into account only land cover types or population density, e.g. De Pippo et al. (2008), Coelho et al. (2009), Del Rio and Gracia (2009) and Santos et al. (2013). De Pippo et al. (2008) investigated vulnerability in Northern Campania Region (Italy) taking into account the percentage of anthropogenic covered surface; Coelho et al. (2009) mapped coastal vulnerability to wave actions along a costal sector of Portugal by applying a methodology based on the use of 9 variables, one including socioeconomic activities, e.g. ground cover, which ranged from forest to industrial and Del Rio and Gracia (2009) and Santos et al. (2013) considered both land cover and population density in Cadiz area (SW Spain). Last, Burzel et al. (2010) classified damages into tangible and intangible ones depending on whether or not the losses can be directly assessed in monetary values. Tangible losses comprise damages of buildings and infrastructure, agricultural and industrial losses, as well as costs associated with evacuation, rescue operations and reconstruction. Intangible losses may be categorized into two groups: social and environmental losses and include loss of life and health impacts, cultural losses and damages to the environment.

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