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Review

Coastal Management: A Review of Key Elements for Vulnerability Assessment

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Abstract: Damaging and accelerated anthropization in coastal areas, as well as the need to adapt to climate change, means we must concentrate on improving management plans based on the diagnoses provided by coastal studies. Among these studies is the vulnerability assessment, obtained from evaluating a set of variables or indicators, which contribute to sustainable development. Since there is no single list of variables to consider in determining coastal vulnerability, 60 vulnerability studies from a period of 29 years (1994–2023), from across the globe, were consulted, and through a statistical mode method, the variables most used by multidisciplinary authors were identified. These studies were organized into groups: ecological, geomorphological, maritime climate, socioeconomic and legislative; creating sets categorized as the minimum indispensable, acceptable, and ideal variables. The results showed that most studies use between six and seven variables from only the maritime climate and geomorphological information groups. The number of variables used by individual studies, on the other hand, was not directly related to the scales (global, national, regional, local), but to the risks, such as flooding and erosion, it resolved. Only two studies included the minimum essential information for the legislative group, which is the presence of protected natural areas. Coastline displacements was the variable most used (43 studies), followed by the geoform type and the rate of sea level change (36), the wave regime (35) and the tidal range (33). The DSSs (Decision Support Systems) for coastal management were also reviewed, showing that these systems focus on a topic with a greater number of variables.

Keywords: coastal vulnerability; vulnerability index; decision support system

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1. Introduction

A total of 84% of countries around the world have an open coastline and/or inland seas [1]. In 2017, the United Nations estimated that around 40% of the world's population, 2.4 billion people, live within 100 km of the coast, and 10%, 600 million people, live at below 10 masl [2]. The often accelerated and disordered anthropization of the planet's coastline, with a global urban growth rate of 3% in those areas [3], gives rise to increased carbon emissions and higher temperatures, the exacerbated use of natural resources and to disturbances that affect coastal ecosystems, as well as an increased exposure of property and infrastructure to natural hazards.

In 2019, extreme wildfires, droughts, floods, and extreme rainfall events occurred worldwide [4], affecting many settlements close to the coastline. Consequently, it was estimated that, based on current climate change scenarios, 30% of the infrastructure located within 200 m of the coastline will probably experience some degree of damage in the next 50 years due to coastal erosion [3]. That is why coastal management should be flexible enough to be able to adapt to particular circumstances. It is the establishment of a framework, based on scientific analysis, for planning that allows various, sometimes unforeseen, issues to be addressed in the interests of the coastal zone in question. Refs. [5,6] explain that vulnerability assessment and analysis are crucial for initiating and supporting coastal management programs in a given region, as well as to public policies regarding disaster relief.

One way of calculating vulnerability is through indices, which analyze indicators or variables that show the current state of the different biophysical and socioeconomic characteristics of the site. For example, Hamid et al. [7] reviewed the current geodetic technologies (information sources) that can be used to characterize the variables used in the CVI (Coastal Vulnerability Index) to improve the effectiveness of coastal management strategies. Anfuso et al. [8] carried out a review of the types of information used in coastal vulnerability assessments, adding seasonal and long-term forcing characteristics as necessary indicators, and explained that these involve local as well as global processes. For their part, Mukhopadhyay et al. [9] suggested integrating the human component into the evaluations, since most of the indices they consulted included only physical aspects. The work of Roukounis et al. [10] also highlighted the importance of selecting variables using a holistic and dynamic approach, which includes social vulnerability. All of these indices can also be used to improve decision-support systems [11]. Despite the many efforts to establish frameworks to determine coastal vulnerability, many countries with a high degree of anthropization on their coasts have not adopted the adequate management tools for the planning of their coastal developments. Over time, this has triggered the loss of physical and ecological connectivity [12]. Barzehkar et al. [13] underlined the difficulty coastal decision makers and planners have in choosing the optimal decision-support tools to assess vulnerability and resilience.

This research presents the state of the art of coastal management legislation around the world, with the aim of providing an overview of the deficiencies and/or advantages found in each country. Likewise, an analysis of scientific publications from 1994 to 2023 was made in order to identify the variables most used in coastal vulnerability studies; the variable were categorized following [14]. Finally, coastal management support systems were consulted to identify the main type of information they use in their analysis.

2. What Is Coastal Management?

Integrated Coastal Zone Management (ICZM) is a process with a technical and scientific basis, legitimized through public policy and aimed at the administration of common goods and public interests. It is oriented towards decision making for the benefit of coastal marine ecosystems, cultural heritage, landscapes, and threats to coastal elements, such as coastal resources, to protect human lives and property from natural disasters, to improve public access to beaches and shores, to maintain or increase the amount of shoreline devoted to water-dependent or water-related uses, and to preserve historical and archaeological sites within the coastal area [15].

ICZM contributes to the restoration of degraded areas and is responsible for managing human activities to prevent, control, or mitigate the harmful consequences and impacts that these may have on the environment [16]. Pérez-Cayeiro et al. [17] mention that as a concept, ICZM has made progress in broadening the geographical scope to include watersheds and marine basins. Recently, Ecosystem-based Management (EbM) has also been incorporated for the sustainable management of natural resources for human use and ecosystem services, which considers humans as part of the ecosystem in decision making [14,18].

In recent decades, many terms have appeared that claim to express similar definitions. However, Barragán [15] mentions that they all assume planning, varying only in the extension of the study area (landward and seaward). These include:

- CEM (Coastal and Estuarine Management)
- CICAP (Cross Intersectoral Coastal Area Planning)
- CLAM (Coastal Lake Assessment and Management),
- CPM (Coastal Planning and Management)

- CZM (Coastal Zone Management)
- ICAM (Integrated Coastal Area Management)
- ICARM (Integrated Coastal Area and River Basin)
- ICARM (Integrated Coastal Area and River Basin Management), ICM (Integrated Coastal Management)
- ICOM (Integrated Coastal and Ocean Management)
- ICP (Integrated Coastal Planning)
- ICZM (Integrated Coastal Zone Management)
- IMCAM (Integrated Marine and Coastal Area Management), IMCZ (Integrated Management of Coastal Zones)
- MCEBM (Marine and Coastal Ecosystem-Based Management)
- ICM (Integrated Coastal Management)
- ICZM (Integrated Coastal Zone Management), WMP (Wetland Management Planning)

Various methodologies have also been developed and are followed by international organizations to describe the ICAM discipline (its plans and programs). However, as Clark [19] clarifies, the ICAM programs are different in each country, although they do have the following stages in common:

- Policy formulation, where goals are set, authorization is given to initiate the strategic process, guide the realization of the program and include executive and legislative actions.
- Strategic planning, or preliminary planning, explores the feasibility and impact of the ICZM program.
- Program development, or a master plan, detailing the ICZM program and allocating responsibilities.
- Implementation starts when the master plan and budgets are approved.
- For Ecosystem-based Management (EbM), the methodology has three stages [18]:
- Visioning (laying foundations). Identification of the area and its key issues. Ensuring that sectors work with a common understanding of the ecosystem. Consulting existing management practices and setting overall objectives.
- Planning (design). Assessment of the ecosystem and governance to create a legal framework for multi-sectoral management. Identifying measurable objectives, prioritizing threats and choosing management strategies.
- Implementation (apply and adapt). Monitoring, evaluation, and adaptation. Continued communication and education. Ensuring financial sustainability.

The three systems converge in the coastal zone: the socioeconomic system; the geomorphological system; and the ecosystem [20]. Vulnerability can be defined for each system individually, but it is important to recognize that in coastal management it is critical that the integrated dimensions of coastal behavior and the resulting impact on the vulnerability of a coastal zone is understood. The dynamics of coastal environments under different hazards must also be considered; the spatial and temporal scales over which coastal vulnerability can be considered are wide ranging [20].

To accurately assess vulnerability in coastal management, it is important not only to have a technical definition, but to understand the social and political implications. Stakeholders usually have different opinions and preferences for decisions and actions to be adopted, which are influenced by their culture, context, knowledge, and beliefs. There will be those who only seek to maintain natural processes and those looking to keep things as they are, or to shift to another desirable state.

The coastal zone has a mix of interests and processes. McFadden et al. [20] considered that it is important to focus on vulnerability as a property of a physical or socioeconomic system, and the term must be related to social relationships between the myriad of stakeholders participating in coastal management. According to Kaluwin et al. [21] the most effective and realistic adaptation strategy for coastal hazards, together with natural variability is integrated coastal management. The development and implementation of national and local coastal management programs will provide the means to address both the short- and long-term issues identified in vulnerability assessments affecting coastal areas.

3. International Regulations

To see how ICZM is carried out in a range of countries, several publications on relevant legislation were examined. Table 1 shows the main instruments found for 19 countries.

Table 1. Summary of the main instruments of coastal management in a range of countries, their main focus, and the spatial area to which they apply.

Country	Law	Year	Main Purposes	Restricted Area
Algeria	Coastal Law	2002 (in force)	Law on spatial planning, protection, sustainable development, sustainable use of resources and urban planning [22].	100 m. Article 18 of the Law states that the strip may be extended up to 300 m.
Brazil	National Coastal Management Law	1997 (in force)	To plan and manage economic activities in the coastal zone in an integrated, decentralized and participatory manner, to guarantee the use, control, conservation, protection, preservation and recovery of natural resources and coastal ecosystems [23].	33 m inland from the high tide line. Also applies to river and lake margins.
Chile	Supreme Decree 475, National Policy on the Use of the Coastal Border	1994 (in force)	To integrate geographical areas, economic development, and environmental conservation related to the coast, plus various sectors of activity and scales of administrative management (national, regional and local) [23].	Areas protected for fishing purposes: An 8 m strip, inland from the highest tide line. Where this is bordered by public property, this strip increases to 88 m.
Colombia	National Environmental Policy for the sustainable development of ocean areas and coastal zones	2000 (in force)	To assign sustainable uses to the nation´s maritime and coastal territory. Harmonize and articulate sectoral coastal development planning, and the conservation and restoration of the goods and services provided by its ecosystems [24].	50 m inland from the mean high tide mark
Croatia	Physical Planning Act	2007	To provide prerequisites for balanced development in accordance with economic, social, and environmental factors. Regulation of building permits [25].	Coastal Protected Area (ACP). Articles 50 and 51 prohibit construction work on the strip 70–100 m inland from the mean high tide mark
Cuba	Law 212 on Coastal Zone Management	2000 (in force)	To promote sustainable development criteria in coastal zone activities. Territorial and urban planning and tourism development schemes [26].	Varies: from 20 m inland of artificial structures to 300 m inland from river mouths
Egypt	Environmental Law	1994	To regulate construction and human activities [27].	200 m from the coastline
France	Coastal Law	1986	Coastal planning, protection, and management. Halt or contain coastal urbanization. Preservation of natural spaces [28].	100 m from the mean high tide mark. This may be extended where there is coastal erosion.
Indonesia	Law Concerning the Management of Coastal Zones and Small Islands	2007	Planning, use, monitoring, and control of coastal and island resources to improve public welfare [29].	At least 100 m inland from highest tide line, depending on the shape and condition of the beach, in the mangrove belt: 400 m
Israel	National Master Plan for the Mediterranean Coast	1983	To prevent development on the coast and resolve conflicts of interest between land uses that require a coastal location [22].	100 m may be extended according to the physical characteristics of the coast.
Italy	Galasso Law #431/1985	1985	Protection of the environment as an elementary value for the legal system [30].	Special attention paid to the 300 m coastal strip, prohibiting any new building.
Mexico *	General Law of National Goods Regulation for the use of territorial sea, navigable waters, beaches, federal zone maritime terrestrial, and filled lands	2004 1991	Defines the length of maritime beaches and the federal maritime terrestrial zone.	20 m from the maximum high tide is recognized as a federal zone. However, the current government (2018–2024) has modified articles 7 and 199 of the General Law of National Assets (LGBN), reducing this to 10 m [31].

Table 1. *Cont.*

Country	Law	Year	Main Purposes	Restricted Area
Morocco	Coastal Protection and Development Act	1981	Regulates the territorial sea, the contiguous zone, and the exclusive economic zone and the exclusive fishing zone [32].	100 m may be extended due to coastal erosion.
Republic of South Africa	Integrated Coastal Management Bill	1998	To conserve the coastal environment and maintain the natural attributes of coastal landscapes and seascapes, as well as ensure the sustainable use of natural resources. Also tackles coastal zone pollution and development and determines the competencies of State bodies in relation to coastal zones [33].	100 m inland from the high tide mark in urban areas for residential, commercial, industrial, or mixed-use purposes, and 1 km inland in rural areas. These limits can be adjusted, depending on the sensitivity of the shoreline. [34].
Spain	Coastal Law	2013 (in force)	Identification, protection, and sustainable use of the coastline. For administrative functions, low-lying land that is flooded due to water seepage is also included [35,36].	100 m which may be extended to 200 m by agreement between the Autonomous Communities and the municipalities concerned.
Turkey	Coastal Law 3621/3830	Amends Coastal Law 3621, of 1990.	This changes the definition of "shoreline" and adds new clauses regulating buildings, roads, footpaths, and public gardens near shorelines. It also states that building plans near coastlines must be reviewed within one year [37].	100 m on which facilities may be built for the protection of the coastline or for the public interest, only with a land-use planning permit.
Uruguay	National Coastal Space Policy	Draft Decree (2002)	Promotes the sustainable and democratic use of the natural and cultural resources of the coastal space, and regulation of activities and uses in that space [38].	250 m
USA	Coastal Zone Management	1972	Designed to preserve, protect, develop, enhance, and restore the nation's coastal resources. Seeks to balance economic development with environmental protection and control land and water uses [39,40].	Varies in each state, according to coastal characteristics, aims to control the shorelines from the impact of waters and vulnerability to sea level rise. The Environmental Protection Agency review each state's boundary to make any necessary modifications.
Venezuela	Coastal Zones Act	2001 (in force)	Conservation and sustainable use. Improving the use of resources. Administration, use, and management of coasts and riverbanks. Regulation of construction [41].	80 m from the line of the highest tide, for mainland and island territories.

* Related laws. There is still no specific coastal law for an integrated coastal management program.

Humphrey et al. [42] compared coastal management initiatives in the US and Europe, suggesting that since 1972, these initiatives have been successful in individual states of the US and now cover 99% of the nation's coastline. Even so these initiatives certainly fall short of offering an integrated approach on a continental scale, with inconsistencies between management policies and programs at different scales and between states, and often also lack an ecosystem approach. They said that the European initiatives were often inconsistent and there was a lack of coordination between the bodies responsible for their implementation. MITECO [43] also cites as a problem in European coastal management initiatives, the increasing population density on Europe's coasts, but this is countered by the concept of "managed retreat", which has been adopted.

In Spain, for example, Barragán et al. [35] mention that coastal areas are an important part of the economy and the demographic concentration. In 2010, almost half of the population lived on the coast. This has resulted in changes in land use, pollution from agricultural activity and urban runoff, and intensive exploitation of ecosystem services. Recent changes in legislation, for example in the Autonomous Communities of Catalonia and Andalusia, have created bodies to specifically manage concessions and authorizations of the maritime–terrestrial public domain. Also, in the most recent coastal law, most administrative functions are related to the coastal area, which includes lowlands (marshes, lagoons, wetlands, estuaries, etc.) that are flooded by tidal flows and waves. The implementation of Ecosystem-based Management has also helped in achieving a more integrated approach to coastal management.

Ahmed et al. [44] report that in Turkey the main problem in coastal management has been poor coordination between institutions and organizations, often creating chaos and hindering progress. Canada, recognising the importance of communities in management, has increased community involvement and decreased government involvement in a Coastal Action Program [45].

In Africa, where more than half of the population lives in the coastal zone, conflicts on the coast are caused by increasing human pressures, the rapid depletion of natural resources, and the lack of sustainable development, affecting the communities [46], as mentioned in the Pan-African Conference on Sustainable Integrated Coastal Management (PACSICOM), the aim of which is to foster collaboration at different scales between the regions through sustainable coastal management that includes recording the successes and failures of individual countries' initiatives.

In countries such as Algeria, interest in coastal protection and sustainable development is recent, and recent management approaches have been implemented. The main problems on their coasts are population growth and pollution caused by the dumping of industrial waste. The latter has been addressed by a "polluter pays" tax for these companies to contain or reduce this pollution [22]. In Egypt, economic activities along the coast have been affected by climate change, among other factors. It is currently a priority to incorporate measures against this in its policy frameworks for adaptation [27]. In South Africa, they have worked to boost community participation in management issues, recently developing policies that increase their coastal responsibilities [45].

There are extensive areas of coral reefs in Asia, as well as the world's largest mangrove forests, a very high population density (77% of its population live in coastal areas), and the world's highest economic growth rate. The main problems experienced on its coasts are the unsustainable use of coastal resources, pollution, destruction of habitats, damage caused by mismanagement, and population growth. To address these issues, the need to strengthen regulatory systems has been accepted as well as the need to conduct more research into current coastal management of all South Asian countries [47]. For example, Japan has a coastal law, although it focuses on disaster prevention and does not coordinate or integrate aspects of the coast that are addressed in individual laws; new laws and administrative bodies must still be created [48].

In Latin America, Barragán [49] conducted a study, considering four indicators (Policy, Regulations, Institutions, and Instruments) of ICZM to reflect the institutional capacity of 26 countries. He then classified seventeen countries as having the lowest levels (pre-initial and initial), with the only nine in the stage of transition and development. Among the latter were Mexico, Costa Rica, Colombia, Ecuador, and Chile, while Brazil, Belize, Puerto Rico, and the Dominican Republic were found to be still in a developmental situation. Short et al. [50] described how in Brazil, coastal management challenges include land ownership, regulation of tourism and beach bars, urban projects, ensuring accessibility to beaches for the public, biodiversity conservation, cultural maintenance, and erosion control. Complicating matters in Brazil, the country's legislation does not consider dunes as part of the beach, resulting in ecosystem management that is often fragmented. Muñoz [23] suggests Latin American countries should work with other countries where ICZM is more advanced, stating that backward, scarce examples of coastal management in Latin America is due to the lower levels of social and economic development. In the last ten years, some countries in Latin America have made some progress; the cultural similarity between them may help to find an appropriate management model for Latin America.

In Oceania, most people live on the coast, and the use of natural resources is intensive, continuously risking coastal development. Harvey et al. [45] mention that Australian coastal management policies are made using four factors of a global nature: climate change, sustainable development, integrated management, and community participation. Australia's "Regional Marine Planning Initiative" is an additional ecosystem-based management plan (including human use, marine environment, and coastal community relations). At the state level, Victoria has focused on inter-agency coordination and public land planning, while Queensland has focused on understanding coastal processes, South Australia has focused on collaboration between state and local scales, and New Wales has focused on planning. Collaboration between the states in general management issues has recently been facilitated by the Federal Coastal Management Council.

It is important to highlight that, as Barragán [49] mentions, the existence of these instruments does not ensure satisfactory results for the population nor the coastal ecosystems where they are applied.

4. Coastal Vulnerability Indices

It was in the early 1970s that the concept of vulnerability was first coined with reference to the coastal zone. From 1990 onwards, there have been increasing numbers of publications on the theme [51]. Coastal vulnerability spatially identifies the elements (people, infrastructure, and areas) susceptible to damage from coastal hazards (e.g., storm surge and extreme waves causing erosion and flooding). Over time, due to increasing anthropic developments, understanding the concept of vulnerability has required more research into the factors that govern it in order to construct better spatial distributions, and consequently, more appropriate, specific, management strategies [52].

Vulnerability assessments include social, physical, and ecological parameters, with data collection techniques generally involving remote sensing. In situ data are usually obtained for small areas, although supplementing this data with remote sensing is more efficient, cost-effective, and practical when managing multiple scales (large areas). However, the data are not always available (e.g., satellite imagery, lidar, etc.) [53]. Many coastal vulnerability studies focus on hazards associated with sea level rise, ecosystem impacts due to climate change and anthropization, and the impact of these hazards on socioeconomic factors [54].

In Preston et al. [55], environmental management (planning, preparedness, and recovery) is described as paramount in assessing vulnerability to natural hazards. Satta [22] mentions four types of methods that assess vulnerability; sometimes a fifth and sixth category are added:

1. Based on indices or indicators. Quantitative or semi-quantitative assessment that obtains results through a combination of variables;
2. Based on dynamic computer models. Modeling of current and future conditions of geophysical, biological, and/or socioeconomic processes;
3. Decision support tools based on GIS (Geographic Information Systems). They are used for data processing, analysis, and visualization, which support emergency management planning. Some systems mentioned in the previous point are also considered here;
4. Visualization tools. Builds scenarios based on climate change impacts to support management decision makers;
5. Vulnerability curves. They show the expected value of damage that an element could suffer from certain intensities of natural hazards [56];
6. Modeling tools. Hydrodynamic modeling used to project the impact of waves in normal and critical conditions on the coast. That is, the extension of flooding inland and beach erosion. Seenath et al. [57] recognize that using hydrodynamic models is more appropriate to represent flood risk in detail, by generating flow dynamics.

In the IPCC (Intergovernmental Panel on Climate Change) glossary, the vulnerability index is defined as a dimensionless metric that simplifies complex and interactive parameters into an easy and useful-to-understand form, for use as a management tool [58]. It is obtained by applying an equation to a set of subscripts representing the values taken by the variables under consideration. The equations normally used can be the weighted sum of the subindexes, a weighted sum that multiplies a weight assigned per subindex or component, or by applying to any of the above, a dividend equivalent to the number of indicators and/or a square root. The data for each indicator can be obtained from information sources of government institutions, generated through geoprocessing in a GIS with satellite imagery and/or field work. These data can be quantitative (mostly expressed in units) or qualitative parameters, from which long-term trends can be studied.

Many studies have been carried out over the years to assess coastal vulnerability with indices. Gornitz et al. [59] were the first to construct a vulnerability index in the 1990s, using seven variables for erosion and flood hazards. In more recent work, the number of variables has changed, as has what each variable refers to, the ranges of the subindices assigned to the variables, and the equation. The concept of a "coastal vulnerability index" or "coastal vulnerability" in scientific databases such as Web of Science and Science Direct show that the number of publications related to these studies has increased, with more than 1000 articles published per year from 2016 to 2019, and over 2000 in 2020. Table 2 shows 60 vulnerability studies carried out over a period of 29 years from 1994 to 2023, indicating the scale, risk factors (flood or erosion), the index used, and the number and type of variables incorporated by the authors (the complete table is in the Appendix A of this work). This selection of 60 studies was made by identifying only those that calculated coastal vulnerability through indices and variables. Figure 1 shows the locations of the study areas covered in these 60 studies. From Figure 1, it can be seen that most of these studies focus on Europe, followed by South Asia, perhaps reflecting the socioeconomic situation and perception of risk. It is advisable to consider the frequency and constant updating of said studies by study areas, in relation to social interest, as a determinant that supports decision making.

Table 2. Summary of the 60 coastal vulnerability studies.

Reference	Spatial Scale	Risk Factors	Index Name	No. of Variables	Types of Variables
[60]	Regional	Flooding and erosion	CVI—Coastal Vulnerability Index	7	Physical
[54]	Local	Flooding	CSoVI—Coastal Social Vulnerability	11	Hydro-geological, socioeconomic, politico-administrative
[61]	National, regional, and local	Erosion	National, regional and local vulnerability	22	Coastal features, coastal forcing, socioeconomic
[62] *	Local	Flooding and erosion	CFSI—Coastal Flood Susceptibility Index and CESI—Coastal Erosion Susceptibility Index.	18	Coastal Erosion, Susceptibility Index, Coastal Flood Susceptibility Index
[63] *	Regional	Flooding and erosion	Multi-criteria decision mapping method	10	Physical
[64]	Global, regional, and local	Erosion	CCVI—Combined Coastal Vulnerability Index.	14	Physical coastal vulnerability index
[65]	Global and regional	Flooding and erosion	Global and regional index	11	Factors for DIVA (Dynamic Interactive Vulnerability Assessment), socioeconomic, physical
[66]	Regional	Flooding and erosion	CVI—Coastal Vulnerability Index	7	Physical
[67]	Regional	Flooding and erosion	CVI—Coastal Vulnerability Index	8	Physical
[68]	Regional	Flooding and erosion	CVI—Coastal Vulnerability Index	8	Physical
[69] *	Regional	Flooding and erosion	Coastal vulnerability index using AHP-derived weights	11	Social vulnerability, physical vulnerability
[70]	Regional	Flooding	CVI—Coastal Vulnerability Index	6	Physical
[71]	Regional	Flooding and erosion	CVI—Coastal Vulnerability Index	6	Physical
[72]	Local	Flooding and erosion	CVI—Coastal Vulnerability Index	6	Risk variables

Table 2. *Cont.*

Reference	Spatial Scale	Risk Factors	Index Name	No. of Variables	Types of Variables
[73]	Regional	Flooding and erosion	CVI—Coastal Vulnerability Index	9	Relative risk variables
[74]	Local	Erosion	CVI—Coastal Vulnerability Index	16	Physical
[75]	Regional	Erosion	CVI—Coastal Vulnerability Index	4	Physical
[76]	Regional	Erosion	PVI—general vulnerability of the site	17	Coastal Social Vulnerability Index, Coastal Physical Vulnerability Index
[77]	Regional and local	Erosion	Physical and socio-economic vulnerability	23	Physical, socioeconomic
[78]	Regional and local	Flooding	Flood vulnerability index	31	Social, economic, ecological, physical
[79]	National, regional and local	Flooding and erosion	CVI—Coastal Vulnerability Index	7	Physical
[80]	Regional and local	Flooding and erosion	Relative vulnerability of different coastal environments to SLR	19	Physical, social
[11]	National, regional, and local	Hydro-meteorological and hydrological phenomena	CVI—Coastal Vulnerability Index	12	Physical, social
[81]	Regional	Flooding and erosion	CVI—Coastal Vulnerability Index	7	Physical
[82]	Regional and local	Flooding and erosion	Social vulnerability index	16	Physical, social
[83]	Local	Flooding and erosion	Overall climate vulnerability	9	Environmental exposure, socioeconomic sensitivity, adaptive capacity
[84]	Regional	Erosion	Coastal vulnerability	3	Physical
[85] *	Regional	Flooding and erosion	CVI—Coastal Vulnerability Index combined with the analytical performance-based approach (AHP)	6	Physical
[86]	Regional and local	Flooding and erosion	CVI—Coastal Vulnerability Index	11	Physical, Socioeconomic
[87] *	Regional	Flooding and erosion	CVI—Coastal Vulnerability Index	8	Physical
[44] *	Regional and local	Erosion	General vulnerability	13	Physical, socioeconomic
[88]	Regional	Flooding and erosion	CVI—Coastal Vulnerability Index	5	Physical
[89]	Regional	Flooding and erosion	CVI—Coastal Vulnerability Index	8	Physical
[90]	Regional	Flooding and erosion	CVI—Coastal Vulnerability Index	7	Coastal forcing and coastal features, Socioeconomic subindex
[59] *	Regional	Erosion	Combined Vulnerability Index	14	Terrestrial, marine and climatological variables
[91]	Local	Erosion	Coastal erosion vulnerability index	10	Coastal variables, inland variables
[92]	Regional	Flooding	CVI—Coastal Vulnerability Index	6	Physical
[93]	Regional	Flooding and erosion	CVI—Coastal Vulnerability Index	6	Physical
[94] *	Local	Flooding and erosion	CVI—Coastal Vulnerability Index	5	Physical
[95]	Regional	Flooding and erosion	ICVI—Integrated Coastal Vulnerability Index.	7	Biophysical, external stressors, socioeconomic
[6] *	Regional	Flooding and erosion	CVI—Coastal Vulnerability Index	15	Ecological, socioeconomic
[96]	Local	Flooding and erosion	CVI—Coastal Vulnerability Index	9	Physical, socioeconomic
[97]	Local	Flooding and erosion	TVI—Total Vulnerability Index	11	Socioeconomic Vulnerability Index, Coastal Vulnerability Index

Table 2. *Cont.*

Reference	Spatial Scale	Risk Factors	Index Name	No. of Variables	Types of Variables
[98]	Regional and local	Flooding and erosion	CVI—Coastal Vulnerability Index	6	Physical
[70]	Regional	Flooding and erosion	CVI—Coastal Vulnerability Index	6	Physical
[5] *	Regional	Flooding and erosion	CVI—Composite Vulnerability Index	16	Standardized coastal characteristics vulnerability subindex, Standardized vulnerability to coastal forcing sub-index, Standardized socioeconomic vulnerability subindex
[99]	Local	Erosion	Coastal dune vulnerability index	10	Excessive Scouring Vulnerability Index, Storm Erosion Vulnerability Index
[100] *	Regional	Flooding and erosion	CVI—Coastal Vulnerability Index	9	Physical
[101]	Regional	Flooding and erosion	CVI—Coastal Vulnerability Index	6	Physical
[102]	Local	Flooding and erosion	Vulnerability to the effects of climate change	8	Physical and socioeconomic
[103] *	Regional	Flooding and erosion	CVI—Coastal Vulnerability Index	9	Physical and socioeconomic
[104]	Regional	Erosion	Coastal erosion vulnerability (CEV)	32	Environmental and socioeconomical
[105] *	Regional	Erosion	CVI—Coastal Vulnerability Index	15	Physical and socioeconomic
[106] *	Regional	Flooding and erosion	CV—Coastal Vulnerability	7	Physical and environmental
[107]	Regional and local	Flooding and erosion	CVI—Coastal Vulnerability Index	9	Physical
[108]	Local	Flooding and erosion	CVI—Coastal Vulnerability Index	7	Physical and socioeconomic
[109] *	Regional and local	Flooding and erosion	CVI—Coastal Vulnerability Index	11	Physical and geological
[110] *	Regional	Flooding	CVI—Coastal Vulnerability Index	22	Physical, climatic and socioeconomic
[111]	Regional and local	Erosion	CVI—Coastal Vulnerability Index	6	Physical and social
[112]	Regional and local	Flooding and erosion	CVI—Composite vulnerability index	15	Biophysical, sensitivity and adaptative capacity

* Studies that assigned weights to their variables.

To identify the most relevant variables for coastal vulnerability studies, the variables of the studies in Table 2 were categorized following Silva et al. [14]. In total, six information groups are suggested: ecology, geomorphology, geology, marine climate, socioeconomic, and legislation, organized in three relevance categories: 1—minimum indispensable, 2—acceptable, and 3—ideal. These categories allow us to go from the general to the detailed, by increasing the number of variables when calculating vulnerability:

- Category 1 variables are mainly qualitative and easy to characterize over time. These variables alone provide an overview of the level of vulnerability of the coast.
- Category 2 variables allow a more precise analysis and representation of the study of coastal conditions. These qualitative and quantitative variables require more time for consultation, analysis, and characterization.
- Category 3 variables, for the most part, are dependent on those that precede them, as they are calculated parameters that require the lower categories in order to be obtained. They also require a greater computational resource, making their processing and retrieval times longer. Example: "Degree of anthropization".

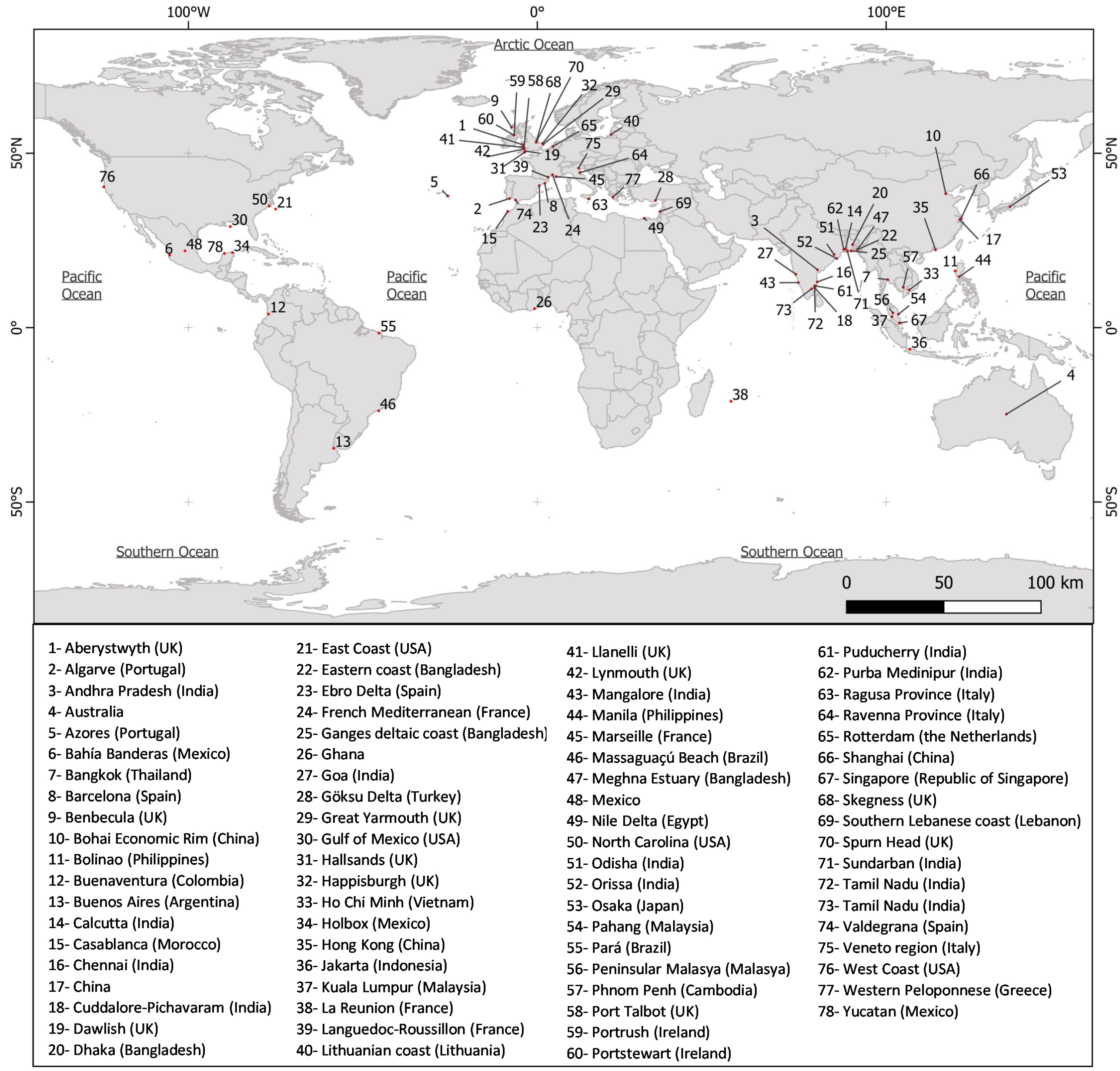

Figure 1. Location of the study areas of the 60 papers analyzed (Table 2). There are papers with more than one study site.

In order to be able to work with these variables, the 653 registered indicators in the database (Table A1 in Appendix A) were revised and analyzed, renaming those that referred to the same thing in a homogeneous way. To facilitate the queries and to apply the method of the statistical mode of variables, the information groups were reassigned according to the scheme in Figure 2, in which the geomorphological and geological groups were combined to avoid redundancy.

In the access database manager, queries were made using sentences with SQL (Structured Query Language) to obtain the name of the information groups, the name of the variable, and the number of repetitions:

Database SQL statements

```
SELECT Group, Variable_Name, COUNT(*) AS No Repetitions
FROM VulnerabilityStudies
GROUP BY Information_group, Variable_Name
HAVING COUNT(*) > 1
```

ORDER BY Variable_Name

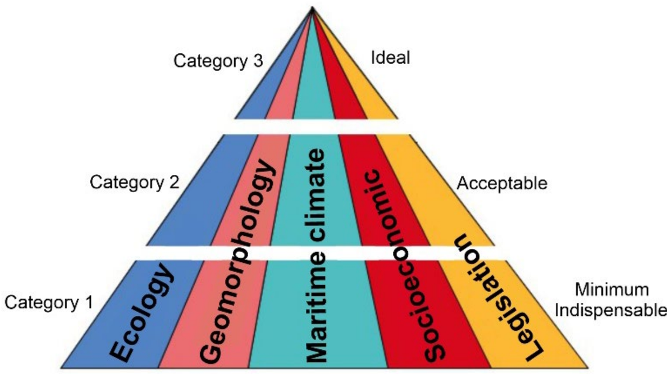

Figure 2. Outline of categories and elementary information groups for decision making. Modified from Silva et al. [14].

5. Most Relevant Variables for Coastal Vulnerability Studies

In terms of scales, the studies covered local, regional, and/or national levels. In the 60 studies, there were 12 local, 34 regional, and the remainder were applied at various scales. The number of indicators varied considerably at all scales, i.e., the authors did not follow a pattern of considering a higher number for the local scale or a lower number for the regional scale. However, the variables for the local scale required more precision in data collection or characterization, for example: River flow (m^3/s), Dean parameter, soil permeability, etc. Most of the studies (40) refer to solving flood and erosion hazards, while 14 studies only refer to erosion and 4 only refer to flooding.

Regarding the names assigned to the vulnerability indices, the most commonly used in the 30 studies was “CVI- Coastal Vulnerability Index”. Other names found were: CSoVI-Coastal Social Vulnerability, CCVI-Combined Coastal Vulnerability Index, PVI-General Site Vulnerability, ICVI-Integrated Coastal Vulnerability Index, TVI-Total Vulnerability Index and SEVI-Standardized SocioEconomic Vulnerability Sub-Index. However, it is common to find that authors name the index according to the variables analyzed, the scale, or the risks addressed.

The lowest number of variables or indicators considered to assess vulnerability was three [84], and the highest number was thirty-two [104]. The majority (18 studies) used six or seven variables in their method, most of them considering physical aspects, such as shoreline displacement (erosion/accretion), wave height, and rate of sea level change [60,63]. The names of the indicators and what they refer to also varied widely. Some authors combined variables that other authors separated or named differently.

As mentioned earlier, to avoid redundancy in this study, the geological aspects were merged into the geomorphology information group, i.e., only five information groups were used: ecology, geomorphology, marine climate, socioeconomic, and legislation.

Following the variables identified in the studies shown in Table 2, of the thirty-one variables were selected, eight of them were assigned in Category 1: Ecosystem type, Main geoform, Type of coast, Land use, Population density, Distance from the population, Sea level rise, and Protected natural area. In Category 2, 15 variables were included: Degree of ecosystem deterioration, Shoreline displacements, Sediment characteristics, Coastal orientation, Coastal slope, Wave regime, Tidal range, Current regime, Wind speed, Anthropization in rivers, Coastal protection structures, Economic activity, Historical or cultural value of the area, Roads, and GDP and Protection measures and spatial planning. Finally, in Category 3, eight variables were considered: Potential migration of ecosystems, Subsidence or soil geology, Extreme swell, Sea level change rate, Degree of anthropization, Population growth rate, HDI, and Tourist density.

In various studies, “the presence or absence of rivers” was addressed as a variable, as well as “the distance of the infrastructure to them”. However, here it was proposed as "anthropization of rivers", since this variable would represent alterations to the supply of sediment and water quality to the coast, also taking into consideration the characteristics of the sediments, due to their importance in erosion and flooding risks. Therefore, when studying the influence of estuarine zones on coastal dynamics, sustainable coastal management plans could prohibit development in these areas [113–115].

Figure 3 shows the number of times the variables were repeated in the studies shown in Table 2, their relevance category, and their information group. The order shown in Figure 3 allows all groups of information to have at least one variable assigned to represent them; the variables in Category 1 would serve to make summary recommendations in a preliminary and quick analysis, but not to make decisions about the design of projects, which require more specific variables, which can start with those in Category 2, and finalize with Category 3.

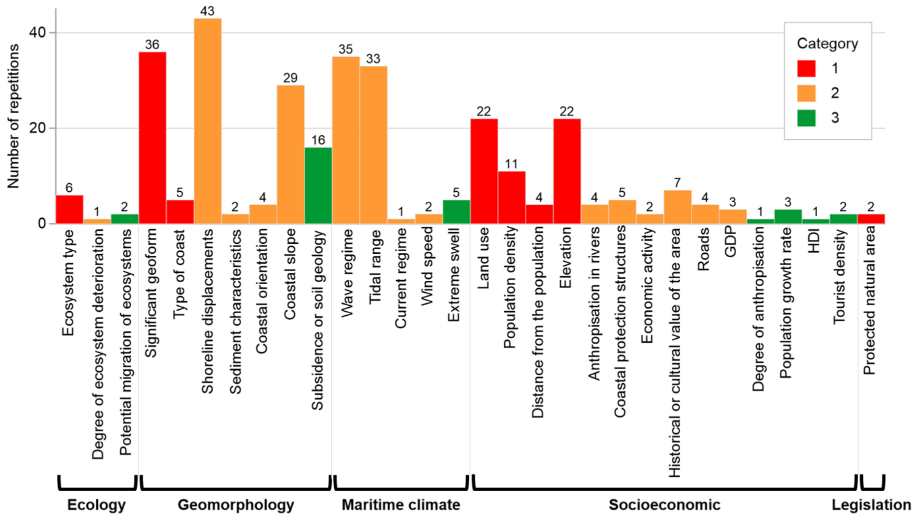

Figure 3. Variables classed by information group and relevance category, showing the number of repetitions of each variable in the studies listed in Table 2.

It can be seen in Figure 3 that there are no variables in Category 1 for Maritime climate. In this case, the "Main coastal modeler" variable could be added as a basic (Category 1) characteristic if quantitative maritime climate variables of Category 2 are not available, since modeling agents determine the sedimentary budgets at the local level, as well as determine sediment transport distributions and maintain a correlation with the morphology of the coast [116]. Also, in the literature and in practice, coastal protection and management measures are developed according to the main hydrodynamic forcing. For example, the design of structures for coasts is governed by waves and tides, the construction of infrastructure at a certain distance of the coast is governed by the tide, etc.

Industrial activity in coastal areas results in pollution at different scales and the destruction of ecosystems [117]. Identifying the type of port indicates the magnitude of the related infrastructure, that is, the degree of anthropization caused due to the human activity it produces [118]. In this sense, the variable "Protection measures and spatial planning" could be incorporated to evaluate the presence of shelters and the existence of municipal civil protection and urban development programs, as they offer protection for the population against an imminent risk, emergency, or disaster [119].

Finally, the "Local, state and federal regulations on ecosystems, land use, and specific activities" variable could evaluate the existence of regulatory instruments for the three scales, such as those of conservation of ecosystems, land use, and economic activities, so this variable could also be added. In this sense, the selected list of variables would increase from 31 to 36.

Regarding the weight of the variables, only 17 studies used a method that justifies them (AHP—Analytical Hierarchical Process or HACA—Hierarchical Agglomerative Cluster

Analysis), assigning the weights based on the opinions of experts. On the other hand, to calculate the vulnerability indices, this method was not applied, since authors such as [48] mention that the relative importance assigned to the variables is subjective and would be specific to a region or site due to the spatial variations. That is, on beaches with cliffs, the hierarchy of variables would be different from that of sandy beaches.

In terms of management recommendations that the 60 studies establish, it was found that not all authors addressed this point in depth. Most of them used general terms to say that "the maps generated in their work allow the identification of the areas most susceptible to the risk factors caused by sea level rise, in addition to being taken as a useful tool for decision makers and for establishing adaptation measures".

When formulating measures for better protection and adaptation against risk to support Integrated Management Plans for Coastal Zones, it is necessary to include the study of the zones of influence, which range from hydrographic basins to estuarine areas, the quantification of coastal erosion and flooding through numerical models, and the transition from science (modeling, monitoring, indices) to management/engineering policy and practice. Samaras, et al. [120] mentions that studying the basin-coast system would allow us to improve the understanding of the evolution of coastal morphology. Regarding the quantification of erosion and flooding, Alvarez-Cuesta et al. [121,122] (Part 1, 2), explain the need to know the magnitude of the risk in order to develop projections and the evaluation of different adaptation strategies. Finally, it is also necessary to understand how knowledge works in practice, in order to incorporate the results of science into policies, accepting that scientific knowledge is different from local knowledge; effort is needed to feed the scientific–political interface.

With respect to climate change, addressed by various authors, its impacts and implications mean that it is a factor that all vulnerability studies in the future must consider in their evaluations. Bearing in mind that from any perspective the characterization of variables leaves a historical precedent that can be consulted, which is related to society; either for comparative use in evolution, or to identify trends and make forecasts.

In order to evaluate the changes in society caused by climate change, it is necessary to use the tools published by the IPCC on the topics of coastal protection and adaptation to a changing climate, such as the RCP (Representative Concentration Pathway), SSPs (Shared Socioeconomic Pathways) and SPAs (Shared climate Policy Assumptions) [123]. Thus, any management recommendations made will be supported by the possible scenarios cited. SSPs are climate change scenarios of projected socioeconomic global changes up to 2100, as defined in the IPCC Sixth Assessment Report on climate change in 2021. These are based on socioeconomic factors, such as demographic and economic growth, that are combined to identify trends. O'Neill et al. [124] points out that combining key factors allows for better scenarios to be created (applied by SSP and SRE—Special Report on Emissions Scenarios).

It is clear that continued research on the elementary variables for decision making is vital, in this context. Likewise, the legislative variables proposed in Categories 2 and 3 can support SPAs. Samaras et al. [125] explain that climate policies can be characterized in terms of their attributes, such as measuring the set of climate policy instruments that have been made to achieve certain objectives. Finally, it is important to take into consideration that the constructed scenarios are under the reference of the climatic forcings given by the RCP, since according to [125], these facilitate the combining of scenarios so that they have the same forcing values.

6. Decision Support Systems (DSS)

In Barzehkar et al. [13], a review of the tools that are used for decision support was made with the following classifications:

- DST (Optimal Decision Support Tools). Examples: MCDA (Multiple Decision Analysis Methods), Artificial Neural Network (ANN), GIS (Geographic Information Systems) for data integration, AHP (Analytic Hierarchy Processes), WLC (Weighted Linear Combination).

- DSS (Decision Support Systems). Examples: Those mentioned in Table 3, plus others such as Theseus and those summarized in its first table [126], SIDSS (Smart Irrigation Decision Support System) [127], Marxan [128], CATSIM (Catastrophe Simulation) [129], among others, many of which are composed of at least one DST.
- DSI (Calculation of decision support indices) (See previous section).

Hybrid methods are now commonly found; these may include the use of geographic information systems, multi-criteria tools, numerical modeling, weighted linear combination of indicators, statistical methods, etc. The integration of DST in a DSS, accompanied by DSI, can offer better guidance towards the integration of parameters (qualitative and quantitative) to give high-quality results, reduce uncertainty, and be used as a query in decision making.

The importance of the DSS lies in being able to identify the appropriate buffer zones, areas with high degrees of vulnerability that require protection, areas with high resilience where future developments could be built, and to calculate the economic investment involved in addressing such practices in all of these areas. The aim is to increase the safety of people and property, to plan appropriate mitigation and adaptation measures, and to maintain the long-term sustainability of the coastal environment [13]. Zanuttigh et al. [126] mentioned some challenges in implementing DSS:

- The independent approach to processes, when in fact they are linked by nature. By not considering the influence that one has on the other could alter the results or make them static. For example, in the face of flooding, a DSS would separately obtain the losses of land value, loss of life, and other effects of flooding or the example of predators mentioned in Table 3, concerning the limitations of the Ecopath DSS with Ecosim.
- It is very difficult to include cost–benefit analyses, since the combination of mitigation measures is non-linear and difficult to represent, as the benefits may span entirely different scales.
- Users may make a poor analysis by relying on the results for each calculated scenario only. It is recommended that multiple scenarios be run, e.g., 10-, 50- and 100-year storms, and to multiply the maps by the probability of occurrence, and then sum these to obtain average vulnerability maps.

Finally, Arcidiacono et al. [130] mention that the main group of people using the DSS are not decision makers or coastal managers/administrators, but students. It is suggested that the author's guides for the models do not properly address the former, and that they allude to the detail and specifications of the input data required, which may lead the user to make assumptions and, consequently, to a range of uncertainty in the results.

Table 3. Main characteristics of the most commonly used DSS (Decision Support Systems).

DSS	Target	Method	Variables	Study Units	Limitations	Types of Information
DIVA (Dynamic Interactive Vulnerability Assessment) [131]	Assesses the biophysical and socioeconomic consequences of sea level rise and socioeconomic development, considering coastal erosion, coastal flooding, wetland change, and salinity intrusion. Explicitly incorporates a range of adaptation options, including beach regeneration in response to erosion.	DIVA is based on climate and socioeconomic scenarios, including coastal tourism, sea level, land use, coastal population, and GDP. For erosion, it uses the Bruun rule.	It associates up to 100 data values with each segment by having a global database, and up to 2100 global and regional scenarios.	Divides the world's coastline into 12,148 coastal segments of varying length.	DIVA can consider erosion on sandy beaches as continuous, even though it may be supported by rocks or on a barrier island. The results can also be used for comparison between different regions and nations of the world, but not for coastal management analysis, where more complex morphodynamic methods are needed.	Geomorphological, biophysical, and socioeconomic.

Table 3. *Cont.*

DSS	Target	Method	Variables	Study Units	Limitations	Types of Information
MARXAN with zones (Software for optimal conservation based land-and sea-use zoning) [132]	Provides land use zoning options for biodiversity conservation, to minimize the total cost of implementing the zoning plan while ensuring a variety of conservation and land-use objectives are achieved.	A staged approach is used, building multiple scenarios to which cost and zoning data structures are added.	The number of variables required depends on each defined study unit. Only some studies require more than 30 different biodiversity variables.	Habitats are created that can be subdivided into biogeographic regions, depth zones, or planning units. Each one with its respective characteristics and input data.	It does not simultaneously consider different types of zones, to reflect the range of management actions seen as part of a conservation plan. The planning units and their features are limited by the memory address space of the application (currently 2 GB).	Socioeconomic and ecological data from coastal and marine systems.
MicroLEIS DSS (Mediterranean Land Evaluation Information System) [133]	Focuses on soil protection through improved agricultural land use, by determining the suitability of soil for different types of crops in tropical and sub-tropical regions. Based on geoenvironmental factors that automate the evaluation process and results in a table of attributes.	Its design is based on integrating many software tools: climate, soil and crop databases, statistics, multi-criteria tools, neural networks, web and GIS applications, and other information technologies.	The terrain attributes used in MicroLEIS DSS correspond to the following three main factors: soil/site, climate, and crop/management.	Cultivation area/local scale	It has only been tested on Mediterranean soil. It is mainly used by students rather than decision makers.	Soil morphology and biophysics.
INVEST (Integrated Valuation of Ecosystem Services and Tradeoffs). [130]	Allows geographical, economic, and ecological accounting of ecosystem services, according to specific land use or land cover types. To obtain habitat quality and carbon sequestration, for example, thus determining potential changes in ecosystem services caused mainly by changes in land use.	Integrates 17 models that value ecosystem services, biophysical processes, and processes with economic value. Where each service is modeled separately.	Each model that makes up INVEST requires input of data on ecosystem services and biophysical properties of land use types.	Ecosystem area/municipal or local level	Requiring very specific, detailed data, their assumptions are often simplified with a considerable margin of uncertainty.	Ecological and socioeconomic.
Ecopath with Ecosim (EwE) [134]	Combines software for ecosystem trophic mass balance analysis (Ecopath, version 6.6.8), with a dynamic modeling capability (Ecosim) to explore past and future impacts of fishing and environmental disturbances, as well as to explore optimal fishing policies.	Ecopath parameterizes models based on two equations: one to describe the production term, one for the energy balance for each group. Ecosim expresses the biomass dynamics through a series of coupled differential equations.	Biomass accumulation rate per year, seasonal species migration data, seasonal production and consumption rates.	Ecosystems/local level	Cumulative changes in ecosystem processes, among others, cannot be predicted in the software. For example, if the presence of a predator is reduced, the number of its prey may increase, but only for a certain time, as predicting the behavior of other factors, such as the presence or increased hunting of other predators is not possible to estimate in the first conception.	Ecological, social and legislative aspects of fishing

7. Conclusions and Discussion

Integrated coastal zone management is a geopolitical process that involves a series of key actors and interest groups, in addition to government institutions [135]; public participation is key, and various countries have incorporated it as part of an integrated approach, contributing, in turn, to the useful evolution of coastal vulnerability studies. Coastal management aims to make decisions to benefit coastal areas that are facing significant, constant challenges. Barzehkar et al. [13] state that to improve the robustness and flexibility of decision making, it is necessary to choose the optimal and integrated tools that allow vulnerability to be efficiently assessed and that consistently produce results of high quality for administrators.

In many cases, vulnerability studies only focus on one area or are limited to the analysis of a few variables. Many authors continue to carry out very limited vulnerability studies, following the CVI proposed by Gornitz et al. [59] and adopted by the USGS 30 years ago, which includes only the physical aspects, ignoring the socioeconomic field and other characteristics [9]. It was also identified that the number of variables in studies can be vastly different, which according to what was reviewed, does not directly depend on the spatial scale of the assessment. According to Dal Cin et al. [136], vulnerability assessments would be more precise if more variables were taken into account. However, Adger [55] points out that for the variables involved, this may imply a risky correlation. In their review, Roukounis et al. [10] mention that geophysical indicators or variables are already standardized in vulnerability studies, but found inconsistencies in the selection of socioeconomic variables. It is, therefore, necessary to periodically carry out reviews to update the definition of the most relevant variables in decision making, considering all the information groups (physical, ecological, legislative, etc.).

Seenath et al. [57] mention that the use of hydrodynamic numerical models for coastal management allows for greater precision when projecting scenarios. They also state that characterization using GIS is easier, faster, and more accessible. However, this has the disadvantage of making an overestimation of the vulnerability assessment probable, which would lead to excessive management. Therefore, they propose identifying the elementary variables for a vulnerability study using indices. This would allow the characterizations to be streamlined into a concentrated, organized framework, thus improving the information base for assessments. It would also reduce the uncertainty of this overestimation, which often results in over management that could be counterproductive, socioeconomically.

The organization of the variables by categories of relevance used in this work offers criteria to identify which variables are easy to characterize, obtain, or calculate. This categorization can also serve as support to generate instruments, such as strategies and plans, linked to scientific knowledge, identifying the set of variables necessary to make recommendations based on an integrated model. It is important to suggest the parameters that are easy to access and understand to planners, so as to reduce uncertainty, thus avoiding that they make assumptions when characterizing them, leading to erroneous results.

Whether it is an academic work or a study for decision makers, the list of variables obtained in this study offers a practical tool for a comprehensive characterization of the study site, based on the contributions of a significant number of works carried out around the world (Figure 1). It was observed that most of the studies were carried out in Europe, which can be attributed to the socioeconomic reality of the region, since they may have the necessary resources to have information available, execute the studies, and eventually implement management strategies. The second region with the largest number of sites analyzed was South Asia; the growing interest in studying vulnerability in this area may be due to the fact that there is a significant population size at risk and that they are exposed to high-intensity hazards.

Regarding the management recommendations provided by the authors in the studies reviewed, they were seen to be ambiguous. Such limited recommendations make it clear that if the objective of your analysis is to support coastal management in the creation of management plans, it is necessary to investigate in detail the criteria and process for the creation of management instruments, which allow better contributions to be made from the scientific area. It is also important that the time scale is stated in the adaptation strategies, as Anfuso et al. [137] explained. The management solutions in these studies must also give the time frame in which they can be carried out (immediate or long-term measures).

It is necessary that future work includes sensitivity tests to support these methodologies, as well as the application of the sets of variables on which they depend; by knowing the behavior of the vulnerability values, it is possible to properly associate them with the management recommendations.

Finally, regarding the DSS, it was found that they do not normally include legislation, and focus on limited outcomes, such as the impact of fishing, decision making in agriculture, etc. It is clearly necessary to integrate legislation data to measure the efforts and effectiveness of management in the area.

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Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Table A1. List of variables and coastal management recommendations of the 60 coastal vulnerability studies.

Reference	Author Variables	Renamed Variables
[60]	Elevation, Sea-Level Trends, Geology, Geomorphology, Horizontal Shoreline Displacement (Erosion/accretion), Wave Heights, Tidal Ranges	Elevation, Sea level change rate, Geology, Coastal geomorphology, Shoreline displacement (erosion/accretion), Wave height, Tidal range
[54]	Sea-level rise, Storm surge, # of cyclones in last 0 years, River discharge, Foreshore slope, Soil subsidence, km of coastline, Population close to CL, Cultural heritage, Growing coastal population, Uncontrolled planning zones	Sea level change rate, Storm surge, Number of cyclones in a time period, River discharge over a period of time, Coastal slope, Subsidence, Coastal length, Total population, Cultural heritage, Population growth rate, Inland fringe with uncontrolled planning zones
[61]	Shoreline type, Rivers, Solid geology, Drift geology, Elevation, Orientation, Inland buffer, Significant wave height, Tidal range, Difference in modal and storm waves, Frequency of onshore storms, Settlement, Cultural heritage, Roads, Railways, Landuse, Conservation designation, Landform, Storm probability, Morphodynamic state (Dean's parameter), Population total, Absent or Present of population	Shoreline type, Presence or absence and type of river, Geology, Elevation, Coastal orientation, Inland buffer, Wave height, Tidal range, Regular wave, Storm surge, Frequency of storms, Type of population, Cultural heritage, Presence or absence and type of roads, Presence or absence of railways, Landuse, Designated managers for conservation areas, Total population, coastal landform, Storm probability, Morphodynamic state, Presence or absence of population

Table A1. *Cont.*

Reference	Author Variables	Renamed Variables
[62]	Predominant morphodynamic state, Exposure to erosion (width of the dry beach), Coastal evolution, Sand bars, Mean dune height, Mean dune width, Vegetation succession continuity, Short-term evolution, Medium term evolution, Long-term evolution, Run-up, Dune discontinuity, Basin Area, Mean river discharge, Distance from the river mouth, Storm surge effect on beach system, Storm surge effect on dune system, Topographic	Morphodynamic state, Dimensions of beach, Shoreline displacement (erosion/accretion), Presence or absence and total number of sand bars, Dimensions of coastal dune, Dune vegetation succession, Run-up, Dune discontinuity, Basin area, River discharge over a period of time, Proximity to the river or river mouth, Storm surge, Elevation
[63]	Coastal geomorphology, Observed erosion trends, Geology, Digital elevation model, Land use, Hydrographic network, Exposure to waves climates and eventually cyclones, Wave height, Tides, Sea level rise	Coastal geomorphology, Shoreline displacement (erosion/accretion), Geology, Topography, Landuse, Sediment contribution from rivers, Storm Frequency, Wave height, Tidal range, Sea level change rate
[64]	Beach width, Dune width, Coastal slope, Distance of vegetation behind the back beach, Distance of built structures behind the back beach, Vegetation cover, Rocky outcrop parameter, Sea defences, Commercial properties, Residential properties, Economic value of site, Population, Coastal erosion, Flood (event) impact	Dimensions of beach, Dimensions of coastal dune, Coastal slope, Distance of vegetation behind the back beach, Distance of built structures behind the back beach, Vegetation cover, Rocky outcrop percent, Percentage of coastal protection structures built, Cadastre, Economic value of site, Total population, Shoreline displacement (erosion/accretion), Flood frequency
[65]	Area X (Total area at elevation X, corresponding to each coastal segment), Coastal slope, Coastal plain characteristics, Wetland data, Wetland migratory potential, Coastal population (living within a zone of 2.5 km on average from the coast), Average coastal population density, erosion and shoreline recession, Vegetation cover, Administrative units, Location of primary rivers in the coastal system	Total area at given elevation, Coastal slope, Coastal geomorphology, Wetland type, Wetland migratory potential, Total population, Population density, Shoreline displacement (erosion/accretion), Vegetation cover, Administrative units, Presence or absence and type of river
[66]	Geomorphology, Coastal slope, Shoreline change rate, Rate of sea level change, Mean tide range, Bathymetry, Storm surge height	Coastal geomorphology, Coastal slope, Shoreline displacement (erosion/accretion), Sea level change rate, Tidal range, Bathymetry, Storm surge
[67]	Shoreline change, Mean sea-level change rate, Significant wave height, Mean tidal range, Regional elevation, Bathymetry, Geomorphology, Storm surges	Shoreline displacement (erosion/accretion), Sea level change rate, Wave height, Tidal range, Elevation, Bathymetry, Coastal geomorphology, Storm surge
[68]	Shoreline change rate, Sea-level change rate, Coastal slope, Significant wave height, Tidal range, Coastal regional elevation, Coastal geomorphology, Tsunami run-up	Shoreline displacement (erosion/accretion), Sea level change rate, Coastal slope, Wave height, Tidal range, Elevation, Coastal geomorphology, Tsunami run-up
[69]	Population, Land-use/Land-cover, Road network, Cultural heritage, Coastal slope, Geomorphology, Elevation, Shoreline change, Sea level change, Significant wave height, Tidal range	Total population, Landuse, Distance from the road network to the coast, Cultural heritage, Coastal slope, Coastal geomorphology, Elevation, Shoreline displacement (erosion/accretion), Sea level change rate, Wave height, Tidal range
[70]	Geomorphology, Historical shoreline change rate, Regional coastal slope, Relative sea-level change, Mean significant wave height, Mean tidal range	Coastal geomorphology, Shoreline displacement (erosion/accretion), Coastal slope, Sea level change rate, Wave height, Tidal range
[71]	Geomorphology, coastal slope, relative sea-level rise rate, shoreline erosion/accretion rate, mean tide range, mean wave height	Coastal geomorphology, Coastal slope, Sea level change rate, Shoreline displacement (erosion/accretion), Tidal range, Wave height

Table A1. *Cont.*

Reference	Author Variables	Renamed Variables
[72]	Geomorphology, Land use/land cover, Offshore Bathymetry, Coastal slope, Shoreline change, Mean tidal range	Coastal geomorphology, Landuse, Coastal slope, Bathymetry, Shoreline displacement (erosion/accretion), Tidal range
[73]	Shoreline change rate, Sea level change rate, Significant wave height, Tidal Range, Coastal slope, Coastal regional elevation, Coastal geomorphology, Tsunami run up, Storm surge	Shoreline displacement (erosion/accretion), Sea level change rate, Wave height, Tidal range, Coastal slope, Elevation, Coastal geomorphology, Tsunami run-up, Storm surge
[74]	Geomorphology, Shoreline type, Topographic-bathymetric profile, Granulometric distribution, Significant wave height, Wave period, Currents, Wind, Dean's parameter, Dimensionless settling velocity (Ω), Presence of vegetation in the sand dune, beach width, Anthropization, Shoreline change rate, Orientation, Coastal protection structures	Coastal geomorphology, Shoreline type Topographic-bathymetric profile, Granulometric distribution, Wave height, Wave period, Current regime, Wind speed, Morphodynamic state, Dimensionless settling velocity (Ω), Presence or absence of vegetation on the dune, Dimensions of beach, Degree of anthropization, Shoreline displacement (erosion/accretion), Coastal orientation, Presence or absence of coastal protection structures
[75]	Geomorphology, Slope, Population, Erosion rates	Coastal geomorphology, Coastal slope, Shoreline displacement (erosion/accretion), Total population
[76]	Poverty, Age, Development density, Asian and immigrants, Rural/urban dichotomy, Race, Gender, Population decline, Ethnicity (Indian) and farming, Infrastructure employment reliance, Income, Mean tidal range, Coastal slope, Rate of relative sea level rise, Shoreline erosion and accretion rates, Mean wave height, Geomorphology (erodability)	Percentage of people in poverty, Vulnerability of the population according to age, Commercial development density, Percentage of immigrants, Type of population, Vulnerability of the population according to race, Vulnerability of the population according to gender, Population growth rate, Percentage of population dedicated to agriculture, Employment and unemployment, Income, Tidal range, Coastal slope, Sea level change rate, Shoreline displacement (erosion/accretion), Wave height, Coastal geomorphology
[77]	Average elevation, Geology: lithology and sediment type, Geomorphology, Vertical displacement: geological or tectonic and anthropogenic subsidence, Sea level rise, Horizontal displacement of the coastline, Significant wave height, Tidal range, Natural protection level: dunes and mangroves, Hazard from extreme waves, Hazard from storm tides, Total population, Population density, GDP (Gross Domestic Product), Economic participation rate, Human development index: health, education and income, Marginalization index, Poverty, Economics units (tourism sector), Total gross production, tourism gross value added, Productive sectors, Protected natural areas	Elevation, Geology, Coastal geomorphology, Subsidence, Sea level change rate, Shoreline displacement (erosion/accretion), Wave height, Tidal range, Presence or absence of natural protection, Storm surge, Total population, Population density, GDP (Gross Domestic Product), Economic participation rate, Human development index, Marginalization index, Percentage of people in poverty, Amount of infrastructure destined for tourism, GDP (Gross Domestic Product), Gross added value (tourism), Economic Activities, Designated conservation areas

Table A1. *Cont.*

Reference	Author Variables	Renamed Variables
[78]	Population density, Population in flood area, Closeness to inundation area, Population close to coastal, Population under poverty, % of urbanized area, Rural population, Cadastre survey, Cultural heritage, % of disable, Land use, Proximity to river, Ground WL (Natural reservations), Over used area, Degraded area, Unpopulated land area, Types of vegetation, Forest change rate, Topography(slope), Heavy rainfall, Flood duration, Return periods, Soil moisture, Evaporation rate, River discharge, Flow velocity, Storm surge, Rainfall, Flood water depth, Sedimentation load, Yearly volume	Population density, Total population in flood area, Distance to flood area, Total population, Percentage of people in poverty, Landuse, Type of population, Cadastre, Cultural heritage, Disabled population, Proximity to the river or mouth, Designated conservation areas, Overused area, Degraded area, Unpopulated area, Types of vegetation, Rate of forest change, Coastal slope, Frequency of storms, Flood duration, Return periods, Soil moisture, Evaporation rate, River discharge over a period of time, Flow velocity, Storm surge, Precipitation, Flood depth, Sedimentation load, Sediment contribution by rivers
[79]	Relief, Rock types, Landform, Relative sea-level change, Shoreline displacement, Tidal range, Annual maximum wave height	Elevation, Geology, Coastal landform, Sea level change rate, Shoreline displacement (erosion/accretion), Tidal range, Wave height
[80]	Reduction of sediment supply, River flow regulation, Engineered frontage, Groundwater consumption, Land use pattern, Natural protection degradation, Coastal protection structures, Rate of SLR, Geomorphology, Coastal slope, Significant wave height, Sediment budget, Tidal range, Proximity to coast, Type of aquifer, Hydraulic conductivity, Depth to groundwater level above sea, River discharge, Water depth at down stream	Sediment contribution by rivers, Degree of intervention in river flow, Percentage of infrastructure built, Percentage of groundwater, Landuse, Degradation of natural protection, Percentage of coastal protection structures built, Sea level change rate, Coastal geomorphology, Coastal slope, Wave height, Percentage of coastline in erosion or accretion, Tidal range, Distance of built structures behind the back beach, Type of aquifer, Hydraulic conductivity, Depth of groundwater, River discharge over a period of time, Depth of downstream water
[11]	Population density, Type of infrastructure, Material for housing, Shoreline type, Elevation, Distance of built structures to the coastline, Artificial protection structures, Presence or absence of coastal dunes, Presence or absence of mangrove, Presence or absence of coral reef, Dune height, Vegetation	Population density, Type of population, Material for housing, Shoreline type, Elevation, Distance of built structures behind the back beach, Presence or absence of coastal protection structures, Presence or absence of natural protection, Dimensions of coastal dune
[81]	Coastal Slope, Geomorphology, Geology, Sea level change, Shoreline change, Significant wave height, Tidal range	Coastal slope, Coastal geomorphology, Geology, Sea level change rate, Shoreline displacement (erosion/accretion), Wave height, Tidal range
[82]	Geomorphology, Coastal slope, Relative sea-level rise, Shoreline changes, Mean tidal range, Mean significant wave height, Population < 14 years old, Population > 75 years old, Women, Single parent family, Family with > 2 children, Tenants, Average density, Unemployed, No education, Foreigners	Coastal geomorphology, Coastal slope, Sea level change rate, Shoreline displacement (erosion/accretion), Tidal range, Wave height, Vulnerability of the population according to age, Vulnerability of the population according to gender, Characteristics of families, Percentage of tenants, Population density, Employment and unemployment, Percentage of population without education, Percentage of immigrants
[83]	Storm threat (tropical cyclones, storm surge), Sea-level rise, Subsidence, Flooding, drought, People per city, Gross Domestic Product (GDP), National GDP, Existing examples (adaptative capacity), Per capita GDP (adaptative capacity)	Storm surge, Sea level change rate, Subsidence, Flood frequency, Drought frequency, Total population, GDP (Gross Domestic Product), Contribution to national (GDP), Adaptative capacity
[84]	Significant wave height, retreat and accretion rates, Land use	Wave height, Shoreline displacement (erosion/accretion), Landuse

Table A1. *Cont.*

Reference	Author Variables	Renamed Variables
[85]	Historical shoreline change rate, Beach width and height, Underwater slope, Sand bars, Beach sediments, Mean significant wave height	Shoreline displacement (erosion/accretion), Dimensions of beach, Coastal slope, Presence or absence and total number of sand bars, Type of sediment, Wave height
[86]	Historical rate of shoreline change, Coastal slope, Coastal regional elevation, Geomorphology, Rate of relative SLR, Mean tidal range, Significant wave height, Storm surge, Tsunami run-up, Population density, Tourist density	Shoreline displacement (erosion/accretion), Coastal slope, Elevation, Coastal geomorphology, Sea level change rate, Tidal range, Wave height, Storm surge, Tsunami run-up, Population density, Tourist density
[87]	Sea-level rise, Geomorphology, Coastal elevation, Coastal slope, Shoreline erosion, Coastal land use, Mean tide range, Mean wave height	Sea level change rate, Coastal geomorphology, Elevation, Coastal slope, Shoreline displacement (erosion/accretion), Landuse, Tidal range, Wave height
[44]	Elevation, Slope, Geomorphology, Soil texture, Proximity to coastline, Coastal vegetation, Shoreline change, Population density, LULC, Dependent population (age range between 0 and 14, and 6+), Tourist spots, Road network, Literacy rate	Elevation, Coastal slope, Coastal geomorphology, Geology, Distance of built structures behind the back beach, Vegetation cover, Shoreline displacement (erosion/accretion), Population density, Landuse, Vulnerability of the population according to age, Tourist density, Distance from the road network to the coast, Literacy rate
[88]	Geomorphology, Coastal slope, Shoreline change, Mean spring tide range, Significant wave height	Coastal geomorphology, Coastal slope, Shoreline displacement (erosion/accretion), Tidal range, Wave height
[89]	Elevation, Slope, Geomorphology, Shoreline change, Sea level rise, Mean tide range, Bathymetry, Storm surge height	Elevation, Coastal slope, Coastal geomorphology, Shoreline displacement (erosion/accretion), Sea level change rate, Tidal range, Bathymetry, Storm surge
[90]	Sea level rise, Wave height, Settlement, Cultural heritage, Roads and railway, Landuse, Designated conservation areas	Sea level change rate, Wave height, Type of population, Cultural heritage, Presence or absence and type of roads, Landuse, Designated conservation areas
[59]	Elevation, Geology, Landform, Local subsidence, Shoreline erosion/accretion, Mean tide range, Wave height, Annual tropical storm probability, Annual hurricane probability, Hurricane frequency-intensity index, Tropical cyclone mean forward velocity, Annual mean number of extratropical cyclones, Mean hurricane surge	Elevation, Geology, Coastal landform, Subsidence, Shoreline displacement (erosion/accretion), Tidal range, Wave height, Storm probability, Hurricane probability, Frequency of storms, Intensity of the phenomenon, Wind speed, Number of extratropical cyclones, Storm surge
[91]	Beach morphology, Shoreline position, Dune field configuration, Wave exposure, Presence of rivers and/or inlets, Terrain elevation, Vegetation, Coastal engineering structures, Occupation percentile, Soil permeability	Coastal geomorphology, Shoreline displacement (erosion/accretion), Presence or absence of natural protection, Presence or absence and total number of sand bars, Proximity to the river or mouth, Elevation, Vegetation cover, Presence or absence and type of coastal protection structures, Landuse, Soil permeability
[92]	Geomorphology, Coastal Slope, Relative rate of Sea Level Rise, Erosion/Advancement, Average Tidal Height, Average Wave Height	Coastal geomorphology, Coastal slope, Sea level change rate, Shoreline displacement (erosion/accretion), Tidal range, Wave height
[93]	Elevation, Geology, Geomorphology, Shoreline erosion/accretion, Mean tide range, Mean wave height	Elevation, Geology, Coastal geomorphology, Shoreline displacement (erosion/accretion), Tidal range, Wave height

Table A1. *Cont.*

Reference	Author Variables	Renamed Variables
[94]	Elevation, Dune coverage, Shoreline covered by artificial protection structures, Recent shoreline change, Land cover	Elevation, Percent of coastal dune coverage, Coverage of artificial protection structures (%), Shoreline displacement (erosion/accretion), Landuse
[95]	Type of cliff, Type of beach, Coastal defences, Exposure to swell waves, Exposure to storm waves, Outcrop flooded, Land-use	Type of cliff, Shoreline type Coverage of artificial protection structures (%), Regular waves, Storm surge, Percentage of rock outcrops flooded, Landuse
[6]	Coastline length, Continentality (total coastline/total municipal area), Coastline complexity, Coastal features, Coastal protection measures, Emergency relief-historic cases, Fluvial drainage, Flooding areas, Demographic, Population density, Children population (0- years old population), Elderly population (population older than 70 years old), 'Non-local' population or people born in a different place that they live now, Poverty, Municipal wealth	Coastal length, Total municipal area, Sinuosity and circularity, Coastal landform, Presence or absence of coastal protection structures, Historical, present cases and future directions, Total length of fluvial drainage, Total flood area, Total population in flood area, Population density, Vulnerability of the population according to age, Percentage of immigrants, Percentage of people in poverty, Percentage of built infrastructure
[96]	Rate of the Sea Level Rise, Mean Tidal Range, Significant Wave Height, Shoreline Change Rate, Geomorphology, Regional Coastal Slope, Land Use and Land Cover, Population, Coastal Settlements and Economic Activities	Sea level change rate, Tidal range, Wave height, Shoreline displacement (erosion/accretion), Coastal geomorphology, Coastal slope, Landuse, Population density, Economic Activities
[97]	Population, Population growth rate, Age, Gender, Employment, Source of income, Household size, Sea level rise assessment, Significant wave heights, Coastal topography, Geological Characteristics	Total population, Population growth rate, Vulnerability of the population according to age, Vulnerability of the population according to gender, Employment and unemployment, Income, Household characteristics, Sea level change rate, Wave height, Topography, Geology
[98]	Coastal slope, Subsidence, Displacement, Geomorphology, Wave Height, Tidal range	Coastal slope, Coastal geomorphology, Wave height, Tidal range, Sea level change rate, Shoreline displacement (erosion/accretion)
[70]	Geomorphology, Historical shoreline change rate, Regional coastal slope, Relative sea-level change, Mean significant wave height, Mean tidal range	Coastal geomorphology, Shoreline displacement (erosion/accretion), Coastal slope, Sea level change rate, Wave height, Tidal range
[5]	Coastal slope, Elevation, Rate of shoreline change, Sea level Rise (SLR), Significant wave height, Cyclone track density (Cyclone intensity per year per 0 km radius), Mean tidal range, Landuse, Population density, ate of employed people (%), rate of economic household (%), rate of literacy (%), rate of adult, Rate of children, Disabled people (%)	Coastal slope, Elevation, Shoreline displacement (erosion/accretion), Sea level change rate, Wave height, Track of tropical cyclone, Intensity of the phenomenon, Tidal range, Landuse, Population density, Employment and unemployment, Household characteristics, Literacy rate, Vulnerability of the population according to age, Percentage of disabled people
[99]	Dune crest height, Beach/dune volume after the wave action of a given return-period storm, Beach width, Dune width, Run-up associated with a given return period, Long-term shoreline evolution, Tidal level, Period, Beach slope, Grain size	Dimensions of coastal dune, Dune volume after storm impact, Dimensions of beach, Run-up, Shoreline displacement (erosion/accretion), Tidal range, Wave period, Coastal slope, Granulometric distribution
[100]	Land cover, Backshore relief/elevation, Shoreline/seabed type, Beach types, Relative sea level change, Shoreline stability erosion/accretion, Mean tidal range, Mean wave height, Protective structures	Landuse, Elevation, Geology, Shoreline type, Sea level change rate, Shoreline displacement (erosion/accretion), Tidal range, Wave height, Presence or absence and type of coastal protection structures

Table A1. *Cont.*

Reference	Author Variables	Renamed Variables
[101]	Geomorphology, Coastal slope, Rate of shoreline change, Rate of SLR, Mean significant wave height, Mean tidal range	Coastal geomorphology, Coastal slope, Shoreline displacement (erosion/accretion), Sea level change rate, Wave height, Tidal range
[102]	Sediment transport rate, Subsidence, Rate of the sea level rise, Significant wave height, Tidal range, Shoreline retreat, Seasonal distribution of wave storms, Seawater temperature	Sediment transport rate, Subsidence, Sea level change rate, Wave height, Tidal range, Shoreline displacement (erosion/accretion), Frequency of storms, Intensity of the phenomenon
[103]	Coastal geomorphology, Shoreline change rate, Coastal slope, Significant wave height, Sea-level-rise, Mean tidal range, Population, Settlement Type, Coastal Protection	Coastal geomorphology, Shoreline displacement (erosion/accretion), Coastal slope, Wave height, Sea level change rate, Tidal range, Total population, Type of population, Presence or absence of coastal protection structures
[104]	Sea surface elevation, Land surface elevation, Slope, Sea level change, Significant wave height, Wave direction, Wave period, Tidal range, Wind speed (at 0 m height) Geology, pH of soil, Bulk density of soil, The organic carbon content of the soil, Clay percentage of soil, Sand percentage of soil, Silt percentage of soil, Rainfall, Geomorphology, LULC NDVI, Distance from stream, Distance from road, Population density, Settlement density, Literacy rate, Percentage agricultural worker, Availability of electricity, Availability of drinking water facility, Availability of hospital, Agricultural land density, LULC Changed to Settlement, LULC Changed to Agriculture	Sea surface elevation, Elevation, Coastal slope, Sea level change rate, Coastal geomorphology, Wave height, Wave direction, Wave period, Tidal range, Wind speed, Subsidence or soil geology, pH of soil, Bulk density of soil, The organic carbon content of the soil, Type of coast, Silt percentage of soil, Precipitation, Coastal geomorphology, Landuse, Distance from stream, Distance from the road network to the coast, Population density, Settlement density, Literacy rate, Percentage agricultural worker, Availability of electricity, Availability of drinking water facility, Availability of hospital
[105]	Bathymetry, Geomorphology (landform), Lithology (Rock type), Island, Mangrove, Vegetation, Shoreline change rate, Coastal length, Coastal slope, Sea level rise, Infrastructure, Agriculture, Road, Population density, Gender composition	Bathymetry, Coastal geomorphology, Subsidence or soil geology, Presence or absence of natural protection, Shoreline displacement (erosion/accretion), Coastal length, Coastal slope, Sea level change rate, Road length, Population density, Coastal space and resources between gender
[106]	Sea level inundation, Shoreline change rate, Tide range, Elevation, Coastal slope, Geomorphology, Heavy to extreme rainy days	Flood depth, Shoreline displacement (erosion/accretion), Tidal range, Elevation, Coastal slope, Coastal geomorphology, Precipitation
[107]	Geomorphology, Shoreline change rate, Coastal slope, Rate of sea level change, Mean tide range, Bathymetry, Salinity concentration in ground water, Storm surge height, Coastal protection through mangrove afforestation	Coastal geomorphology, Shoreline displacement (erosion/accretion), Coastal slope, Sea level change rate, Tidal range, Bathymetry, Salinity concentration in ground water, Storm Surge, Presence or absence of natural protection
[108]	Coastal Elevation, Rate of Shoreline change, Coastal Slope, Tidal Range, Sea level rise, Storm Surge, LULC	Elevation, Shoreline displacement (erosion/accretion), coastal slope, Tidal range, Sea level change rate, Storm Surge, Landuse
[109]	Coastal Elevation, Coastal Slope, Bathymetry, Shoreline Change, Coastal Geomorphology, Coastal Land Use, Historical Sea Level, Mean Tidal Range, Mean Significant Wave Height, Storm surge height	Elevation, Coastal slope, Bathymetry, Shoreline displacement (erosion/accretion), Coastal geomorphology, Landuse, Sea level change rate, Tidal range, Wave height, Storm surge

Table A1. *Cont.*

Reference	Author Variables	Renamed Variables
[110]	Elevation, Slope, Drainage density, Proximity to coastline, Rainfall deviation, Cyclone track density, Storm surge height, Flood inundation risk, Population density, Household density, Poverty ratio, % of child population, Dependency ratio, % of agricultural land, Cropping intensity, Literacy rate, Workforce participation rate, % of population living in permanent houses, Road length per sq. km, % of Doctors/lakh/population, % of Household having electricity facility, % of Household having banking facility	Elevation, Coastal slope, Drainage density, Distance of built structures behind the back beach, Precipitation, Track of tropical cyclone, Storm surge, Flood probability, Population density, Household density, Percentage of people in poverty, Vulnerability of the population according to age, Landuse, Literacy rate, Employment and unemployment, Housing services, Road length
[111]	Geomorphology, Elevation, Absolute Sea Level Rise, Historical erosion-accretion, Tidal range, Population density	Coastal geomorphology, Elevation, Sea level change rate, Shoreline displacement (erosion/accretion), Tidal range, Population density
[112]	Geomorphology, Natural habitats, Coastal relief, Sea level rise, Wind, wave and surge, Urbanized area, Agricultural GDP, Population density, Population growth rate, Vulnerable population, Per capita GDP, Communication, Transportation, Education, Medical service	Coastal geomorphology, Presence or absence of natural protection, Elevation, Sea level change rate, Wind speed, Wave Height, Storm surge, Landuse, Population density, Population growth rate, GDP (Gross Domestic Product), Housing services

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