Review

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Review

Climate-Induced Coastal Hazards, Impacts and Adaptation Responses: A Systematic Review

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Abstract: Coastal ecosystems provide a wide range of goods and services for the lives of human beings and aquatic species. Nevertheless, climate-induced extreme events cause unprecedented impacts on these areas, instigating a reduction of aquatic goods and services, destruction of infrastructure, and loss of human lives. Hence, this review investigated the impacts of climate-induced coastal hazards and adaptation responses. A systematic review method was used to address the objectives of this literature review. The main data sources were Research Gate, Google Scholar, Scopus, Web of Science, and PubMed databases. A total of 40 research articles (2012-2023) were selected using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA 2020) methodology. The findings of this review revealed that Bangladesh was the leading country based on the number of studies published on the impacts of climate-induced coastal hazards and coastal adaptations (20%), followed by the USA, which accounts for about 15%. Sea-level rise, coastal flooding, and climate change and variability were the most studied climate-induced coastal hazards, each accounting for 55%, 52.5% and 52.5% respectively. Coastal hazards have had significant impacts on the fishery, water, coastal ecosystems and biodiversity, agriculture, tourism, and infrastructure sectors. Besides, they caused migration and death of humans and animals. About 35% of the articles explored the assessment of vulnerability to climate-induced hazards. Moreover, 32.5% of the articles investigated anticipated climate-induced hazards. Hard, soft, ecosystem-based, and hybrid adaptation measures were used to adapt to the impacts of diverse climate-induced coastal hazards. In conclusion, developing countries are more vulnerable to the adverse impacts of climate-induced coastal hazards than developed countries. The coastal area's vulnerability to climate change risks will continue unless all stakeholders act proactively. Thus, it is suggested that the adaptation policies of vulnerable coastal areas should give due attention to nature-based solutions to reduce the adverse impacts of coastal hazards sustainably.

Keywords: adaptation; climate change; coastal hazards; coastal ecosystems; vulnerability

1. Introduction

There is an increasing consensus that the globe is warming and the earth's climate is rapidly changing due to rising greenhouse gas (GHG) emissions, which are mainly caused by uncontrolled human factors [1,2]. Climate change affects both human and natural systems, including the environment, agriculture, and infrastructure sectors. Thus, it is the most hazardous threat to sustainable development worldwide [3,4]. It imposes a great burden on all nations regardless of geographical boundaries, although the pressure is substantial in coastal ecosystems and marginalized societies. Coastal landscapes refer to land that is found next to the sea, where the boundary of the land meets the water [5]. According to [6], coastal areas play a paramount role in socioeconomic activities. Nevertheless, they are highly vulnerable to climate-induced risks, such as sea-level rise, flooding, erosion, and storm surges [7–9]. This is because of their geographical shape and location. It is predicted that there will be a rise in the incidence of climate-induced coastal hazards [10,11], threatening low-lying coastal areas in the future [12]. According to [13], about one billion people living in low-lying coastal areas will be exposed to coastal threats by 2050, and rapid urbanization and population growth greatly contribute to this risk. Specifically, human pressures intensify the vulnerability of coastal regions to climate-induced coastal hazards, which leads to the loss of biological diversity and habitats [14].

Adaptation refers to "the process of adjustment to the current or expected climate and its effects on modifying harm or exploiting beneficial opportunities" [15]. It is an integrated concept that comprises socioeconomic, environmental, economic, political, and psychological factors [16]. Prior to choosing adaptation strategies, climate vulnerability assessments are essential to have baseline information for developing efficient coastal management plans [17]. In recent times, coastal adaptation to climate-induced stresses has been among the top-priority agenda in the development plans of many countries. This is because an enormous number of people and resources in the coastal areas are exposed to climate risks. According to [18], about 65% of the world's population lives near a coastline. Coastal ecosystems have extraordinarily huge potential in terms of diversified ecosystem services and livelihood activities, including fish cultivation, recreation, and tourism. Different scholars categorize coastal adaptations differently although they represent the same thing. According to [19], coastal adaptations are usually categorized as structural, nonstructural, and ecosystem-based approaches. Furthermore, they can be classified as protection, accommodation, and managed retreats [20]. However, the analysis presented in this review specifically focuses on the following categories as this classification is inclusive of all others: Hard adaptations, soft adaptations, ecosystem-based adaptations (EBAs), and hybrid adaptations [21].

The previous studies assessed the impacts of a single climate-induced hazard and adaptation measures. Due to this reason, comprehensive information on the current and anticipated impacts of multiple climate hazards and coastal ecosystem management at different spatial and temporal scales is lacking. Accordingly, this systematic review aims to address three main objectives: (a) to assess the most frequently occurring climate-induced coastal hazards and vulnerable sectors; (b) to examine the assessments of vulnerability and projected impacts of climate change-induced hazards; (c) to explore the most commonly used adaptation responses to climate change hazards in coastal ecosystems of different countries. This review provides essential information on the climate-induced coastal hazards and adaptation responses in the coastal ecosystems. It helps policy-makers and planners identify and implement the most frequently occurring climate-induced coastal hazards and effective coastal adaptation responses in different sectors. Hence, the aim of this literature review is to examine the status of climate-induced coastal hazards, impacts, and adaptation responses.

2. Materials and Methods

A systematic literature review method was used. Specifically, Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA 2020) methodology were used to select research articles [22]. Research articles (2012 to 2023) were used to gather relevant information for this review. The main data sources were Research Gate, Google Scholar, Scopus, Web of Science, and PubMed databases. This was undertaken using a range of keywords and phrases. Accordingly, about 325 research articles were downloaded. About 184 articles that meet the eligibility criteria were identified. Then, papers that can address the objective of this literature review were selected and organized by reading the abstracts and findings thoroughly. Accordingly, about 119 research articles were rejected out of 184 research articles. Furthermore, the research articles were screened based on three eligibility criteria by reading the abstracts and major findings: (a) the availability of relevant information on the impacts of climate change-induced hazards and coastal adaptation responses, (b) whether the investigations were conducted in the coastal regions or not, (c) the spatiotemporal scale of the analysis. As a result, about 28 research articles were found eligible for this literature review analysis. Besides, all the above identification and screening processes were repeated for the references cited in the 28 eligible investigations. In this regard, about 58 research papers were identified although only 12 research papers were found eligible based on the criteria. Consequently, about 40 research articles were considered in this literature review analysis (Figure 1). Then, a synthesis matrix was prepared on Microsoft Excel by recording the code for each article, title of the paper, year of publication, journal name, objective, method, major findings, and country for further analysis. This literature review had

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two main topics, namely sectoral impacts of climate-induced coastal hazards and coastal adaptations. Quantitative data was analyzed using Microsoft Excel and presented using tables and graphs.

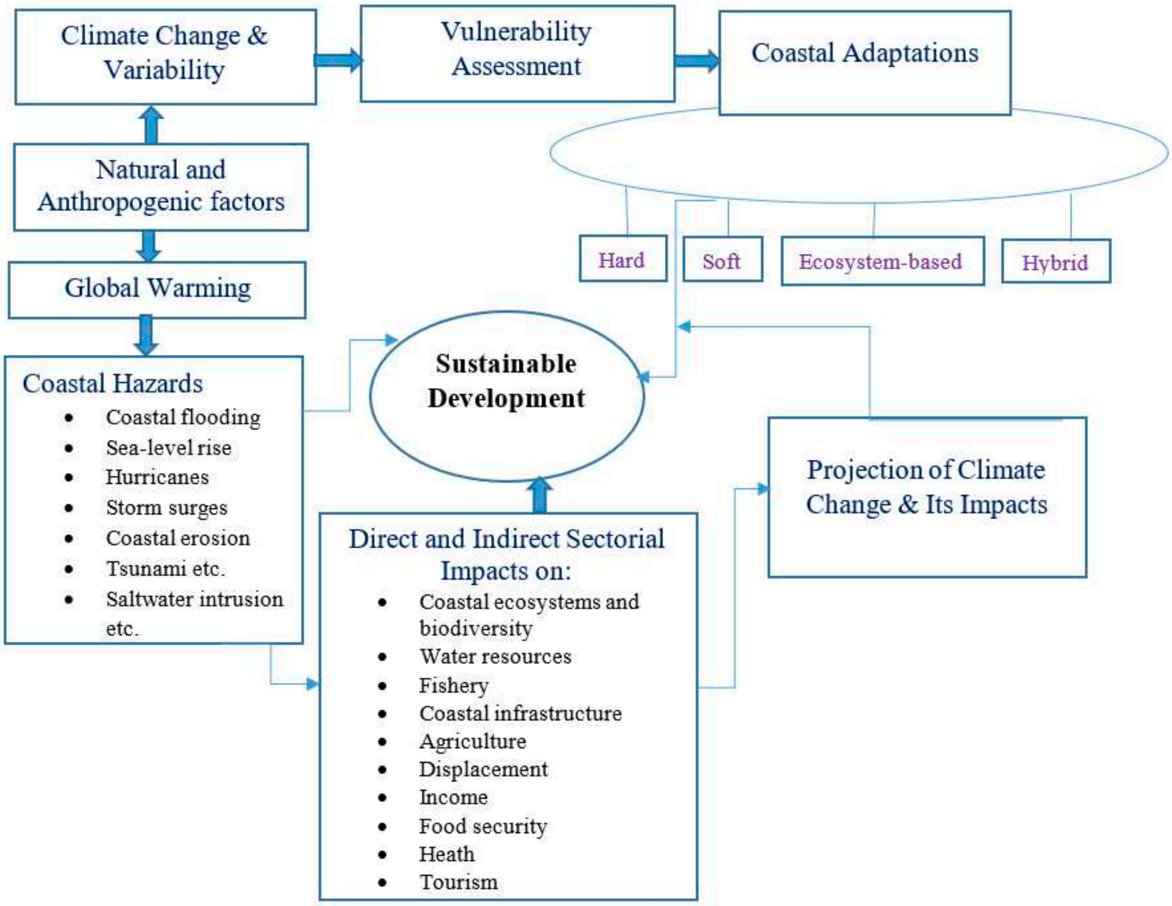

Figure 1. Conceptual Framework.

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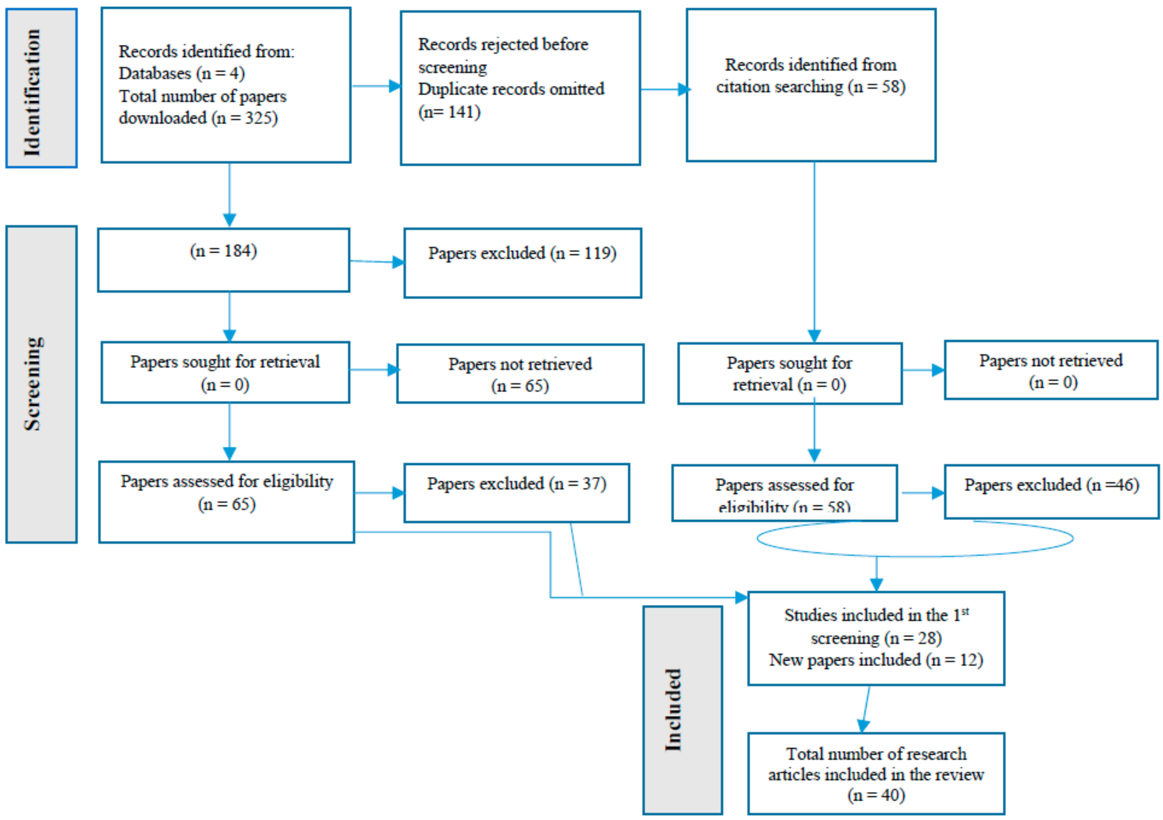

Figure 2. Selection process of literatures. Adapted from ref. [21] and [22].

3. Results and Discussion

3.1. Overview of literatures

The overall research articles (40 articles) incorporated in this review were published in 36 diverse journals. About eight articles were published in four journals, namely Springer, Water, Journal of Hydrology, and Scientific Reports, each accounting for 2 (5%) of the articles. Whereas, the remaining 32 research articles were published in 32 different journals, each accounting for 1 (2.5%) (Appendix A). The latest article was published in 2023, while the oldest article was published in 2012. Moreover, the majority of the articles (27.5%) on the impacts of coastal hazards and adaptations were published in 2021, followed by 2022 (15%) and 2018 (12.5%), while a few articles were published in 2012, 2015, and 2016, each accounting for 2.5%. Figure 1 depicts the distribution of research articles published each year on climate-induced coastal hazards and coastal adaptations, which were used in this review.

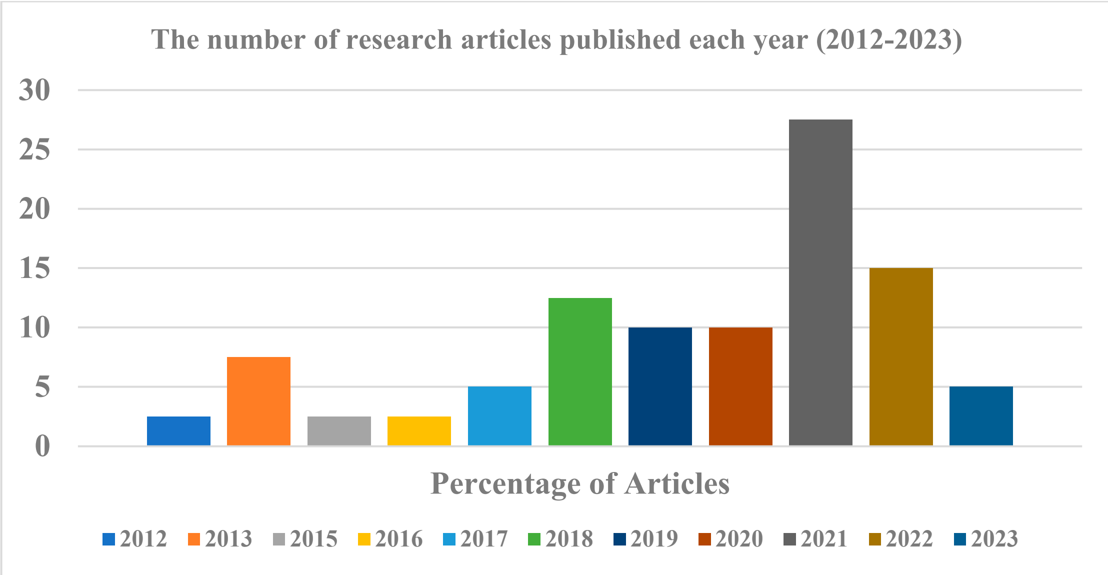

Figure 3. The number of research articles published each year (2012-2023).

The findings of this review pointed out that Bangladesh was the leading country based on the number of studies published on the impacts of climate-induced coastal hazards and coastal adaptations (20%) [16,23], followed by USA [24,25], which accounts for about 15% (Table 1). Furthermore, both the number of investigations that were conducted on global scales (reviews) and in India had the third rank [26,27]. Different studies showed that Bangladesh is the most vulnerable country to increasing climate change-related hazards because of its socioeconomic conditions and geographical location (being a low-lying deltaic country). Particularly, coastal areas of Bangladesh are being frequently attacked by cyclones, sea level rise, coastal erosion, storm surges, and saltwater intrusion, which results in terrible effects on low-lying coastal zones. These coastal hazards cause additional pressure and have direct adverse impacts on coastal ecosystems, biodiversity, economy, and food security. As a result, a significant number of people were suffering from health problems and displaced at different time scales [28,29]. In contrast, Tanzania [30], Kenya [31], Algeria [32], Germany [33], Italy [34], Malaysia, Taiwan [35], Vet Nam [36] and Barbados [37] were the counties where a few research articles published, each accounting for 2.5%. Regarding the continental, about 20 (50%) of the studies out of 40 studies were conducted in Asia, followed by North America 6 (15%) and Europe and Africa each accounting for about 4 (10%) investigations (Table 1). The majority of countries that were affected by the adverse impacts of climate-induced hazards are developing countries. This could be because of the substantial amount of urban populations and total populations of less-developed countries living in the low-lying coastal areas. In addition, they have low development which can limit their adaptive capacity. This situation would make the adaptation planning of these countries very much more challenging.

Table 1. The number of articles published in different countries of the world (2012-2023).

Country	Number of articles
Bangladesh	8
USA	6
Global	5
India	5
Egypt	2
Greek	2
Philippines	2
Tanzania	1
Kenya	1
Algeria	1

Germany	1
Italy	1
Malaysia	1
Taiwan	1
Vet Nam	1
China	1
Barbados	1
Total	**40**

3.2. Climate-Induced Coastal Hazards and Sectoral impacts

3.2.1. Coastal hazards

Sea-level rise, coastal flooding, climate change and variability (rainfall and temperature), cyclones, storm surges, coastal erosion, saltwater intrusion, hurricanes, and typhoons were found to be the main climate-induced coastal hazards. Particularly, sea-level rise (22) was the most studied (55%) climate-induced coastal hazard, whereas both coastal flooding and climate change and variability (rainfall and temperature) were the second most addressed coastal hazards (21), each accounting for 52.5% (Table 2). It is believed that the melting of glaciers due to global warming is the major cause of the increment in sea-levels. Coastal populations and settlements are exceedingly vulnerable to sea-level rise, and current and projected sea-level rise have exacerbated extreme climate impacts. Sea-level rise could be also the cause of coastal flooding and put a significant number of people at risk. In contrast, hurricanes (12.5%) and typhoons (7.5%) were the least-studied coastal hazards. The majority of articles 28 (70%) investigated more than one climate-induced coastal hazard, while the rest of 12 (30%) of the articles examined a single climate-induced coastal hazard. Sea-level rise was investigated in combination with other climate-induced coastal hazards in about 17 articles (42.5%) out of 40 articles and as a single hazard in about 5 articles (12.5%). Climate change and variability were examined as a single coastal hazard in 3 articles (7.5%). Moreover, coastal flooding, cyclones, hurricanes, and typhoons were studied as a single climate-induced coastal hazard, each accounting for about 1 article (2.5%). Sea-level rise was studied in all countries but for China, India, Taiwan, Philippines, Algeria, Kenya and Tanzania.

Table 2. Climate-induced hazards addressed in the reviewed articles.

Coastal Hazards	Number of articles	Percentage
Sea-level rise	22	55%
Coastal flooding	21	52.50%
Climate change and variability (Rainfall & temperature)	21	52.50%
Cyclones	13	32.50%
Storm surges	11	27.50%
Coastal erosion	11	27.50%
Salt water intrusion	7	17.50%
Hurricane	5	12.50%
Typhoons	3	7.50%

3.2.2. Impacts of coastal hazards on different sectors

The results indicated that climate-induced coastal hazards have devastating impacts on the water, agriculture, coastal ecosystems, biodiversity, and coastal infrastructures. Furthermore, the fishery and tourism sectors as well as the income, food security, health, and migration of coastal communities were significantly affected (Table 3). Climate change and variability tremendously impact the timing and quantity of water and its quality adversely [38]. It also affects the water balance components, namely precipitation, runoff, and evapotranspiration, and the water-quality components including sediment and nutrient loads [39]. Specifically, temperature and precipitation intensity increased surface runoff, streamflow, sediment, and total phosphorous load [25]. Reduction in rainfall amounts caused fluctuations in the water flows in the River Nile [40]. Moreover, climate-induced extreme events, especially drought, excessive rainfall, sea-level rise, rising temperatures, and changes in sea surface salinity have direct and indirect impacts on coastal fishery activities [36] and affect the sustainability of aquaculture production [41]. The finding of [42] also stated that the livelihoods of fishery-based and farming communities is extremely affected by coastal hazards. The indirect impacts of climate-induced coastal hazards on the fishery sector are in the production, interaction, distribution, and abundance of species. It can also be noted that disease outbreaks are one of the indirect impacts, which can be caused principally because of heatwaves and extreme rainfall. Typhoons and floods can destroy aquaculture systems by damaging ponds, production machines, equipment, and infrastructures. A study by [36] also revealed that climate-induced coastal hazards can influence coastal fishery and aquaculture activities either positively or negatively. The positive impacts are associated with changes in species, fishing, and aquaculture farming areas created by certain climate-induced coastal hazards. Regarding the agriculture sector, the findings of [30] showed that agricultural productivity has declined because of inadequate rain. For example, farmers in Pande village of Tanzania used to obtain 5-10 bags of maize per acre in the past and the productivity has declined to 3-4 bags per acre. Besides the impact of climate change, non-climatic factors like lack of improved seeds, farm implements, fertilizers, agrochemicals, inadequate extension services, reliable markets, and poor road infrastructures were affecting the farmers' agricultural productivity in Tanzania. Thus, the impact on the four dimensions of food security (availability, accessibility, utilization, and stability) would be very significant. Moreover, rise in temperature, highly erratic rainfall, floods, and frequent drought occurrences results in crop infestation and diseases, which in turn affect farmers' livelihood through affecting agricultural productivity and food security in Philippines [43].

The population, land use of cities, transportation, and economy were increasingly affected by flooding, tsunami, and storm surges in India [44]. Besides, hurricanes, El Niño, severe storms, and sea-level rise resulted in the inundation of major cities, destruction of coastal infrastructure, increased saltwater intrusion, and damage to coastal aquifers in India and the USA [11,45]. According to [46], the rising total precipitation is the main cause of the increasing sea-level and inundation coverage. However, it can be argued that the melting of ice and glaciers because of the increasing average temperature might be the cause of sea-level rise. Tropical cyclones and tidal waves cause tidal floods and riverbank erosion, which could have negative impacts on the structure of homes, income, wealth, and employment of the people in Bangladesh [23]. According to [47], the business operations were damaged by natural calamities, including fishing and agricultural livelihood, which led to loss of income. A study by [16] also reported that cyclones pose serious threats to people's income, since agricultural lands are converted into aquaculture and people are forced to engage in jobs with lower earnings in Bangladesh. Diverse studies also showed that cyclones, sea level rise, and storm surge indicate terrible impacts on the coastal ecosystems and biodiversity, which in turn, affect the economy and food security of low-lying coastal communities [29,48]. The riverbank erosion, hurricanes, cyclones, temperature and rainfall intensity, and sea-level rise pose great pressure on the coastal communities by increasing the frequency of storms, loss of biodiversity, degradation of ecosystems, risk of famine, health problems, and displacement [11,32,49,50]. Moreover, the findings of [31] revealed that flooding, changes in precipitation, and beach structure had substantial impacts on the tourism sector in Kenya (Table 3).

Table 3. Climate-induced coastal hazards and sectoral impacts.

Coastal Hazards	Impacts	Source
Increasing cyclones, flooding, sea-level rise, storm surge, tsunami, hurricanes, El Niño, riverbank erosion,	Adverse effects on population, coastal ecosystems, biodiversity, transportation, people's income, employment, food security, the inundation of major cities, loss of coastal infrastructure, increased	[11,16,23,27,29,44,48,50–52]

inundation, rising water tables and salinity intrusion	saltwater intrusion, damage to coastal aquifers and endemic species	
Rising temperatures and precipitation, decrease in rainfall amounts and variability	Poses serious threats to the quantity and quality of water, results in rise in surface runoff, streamflow, sediment and total phosphorous load, the fluctuations of water flows in the rivers and inundation of the coastal areas	[25,36–38,43,44]
Natural disasters, water scarcity, drought, coral reef bleaching, changes in beach structure	They had direct and indirect impacts on the fishery-based communities by affecting aquaculture production sustainability, agricultural livelihood, tourism, health and migration.	[31,36,41,42,47,49,53]

3.3. Vulnerability to climate-induced hazards and projections of climate change

Out of the total (40) reviewed articles, about 30% and 27.5% of the articles addressed the assessment of vulnerability to climate-induced hazards and projected climate-induced hazards respectively (Table 4). Besides, only 2 (5%) of the articles addressed both assessments [32,46]. In total, about 35% of the articles explored the assessment of vulnerability to climate-induced hazards, while about 32.5% of the articles investigated anticipated climate-induced hazards. According to the findings of [32], the water and agricultural sectors are the major vulnerable sectors to climate change in Algeria. In Algeria, climate change vulnerability is expressed through numerous features such as resource scarcity, increase in water demand, reduction in water flows, evaporation of surface water, deterioration of water infrastructures, floods, and other extreme events and threats to wetlands. The projection of sea-level rise will intensify the risks of coastal flooding in the future [53]. The assessment of vulnerability to climate-induced hazards in terms of the three dimensions of vulnerability (exposure, sensitivity, and adaptive capacity) is crucial for effective adaptation planning. It is also considered an essential strategy to protect natural resources, human health, and the environment in developing the strategic development of a nation [32,53]. Besides, the investigation of the anticipated climate-induced hazards would help to design effective adaptation responses proactively and reduce the pressure of climate change on coastal ecosystems, biodiversity, water resources, agriculture, coastal infrastructures, and the lives of human beings. Several studies reported that the projection of coastal vulnerability to climate change can help create effective adaptive responses and conservation planning although it shows intrinsic uncertainties [46,54–56]. In the absence of high adaptation and given projections, the impacts of sea-level rise are projected to escalate over this century, specifically in the low-lying coastal areas of the world [57].

Table 4. Proportion of vulnerability to and projected climate-induced hazards addressed by the studies.

Assessment	Number of studies addressed only one of the assessments	Percentage	Number of studies addressed both assessments	Percentage	Total Percentage
Vulnerability to climate-induced hazards	12	30%	2	5%	35%
Projected climate-induced hazards	11	27.50%	2	5%	32.50%

3.4. Coastal Adaptations

Construction of a mega-dam and coast zone management through mangrove forest and coral restoration were reported to cope with water scarcity, coral reef bleaching, changes in precipitation, flooding, and changes in beach structure in Kenya [31]. The growing of drought-tolerant crops, increased frequency of fishing, and cultivation of wetlands were also used to adapt to variability in the amount and rainfall patterns, amplified occurrences of drought, and salinity intrusion into rivers in Tanzania [30]. A study by [36] stated that the impacts of climate-induced coastal hazards on coastal fisheries can be reduced using harvesting early, reinforcing ponds, transferring fish cages, reinforcing the roof with sandbags, monitoring the weather and water quantity regularly, shifting to aquatic species and breeds with better tolerance, changing production seasons and investing in modern technology (Table 5). Non-structural adaptation responses, including community-based adaptation and ecosystem-based adaptation, were engaged to withstand sea-level rise in the USA and India [24,45,58]. In addition, the adverse impacts of cyclones, floods, salinity intrusion, and riverbank erosion on the communities were reduced by transformational adaptations such as system-wide (cyclone shelter), restructuring (concrete housebuilding), path-shifting (migration), innovative (technological development) and multi-scale (reforestation programmes) in Bangladesh [48]. Cyclone shelters have been extensively used to lessen the impacts of climate-induced coastal hazards for the last two decades in the coastal landscapes of Bangladesh. Moreover, the findings of [29] indicated that the construction of embankments and mangrove plantations along the coastline was used to withstand the effects of sea-level rise, salinity intrusion, coastal flooding, cyclones, storm surges, and land erosion. The integration of non-structural and structural approaches was employed to lessen the impact of climate change on watershed systems in China [39]. Do nothing, beach nourishment, soft or hard solutions, including hardening the shoreline, managed or unmanaged retreat as well as regulatory and restriction options on new development were used to adapt to sea-level rise, nuisance flooding, hurricanes, cyclones, and typhoons in the USA [11]. Furthermore, raising the plinth height in the built environment, building mobile beach bars, and warnings using the help of information technology were used as a response to flood risks in India and Barbados [37,44]. According to [59], adaptation plans should reduce people's vulnerability to climate hazards efficiently, be economically feasible, and socially acceptable.

Table 5. Adaptations to coastal hazards.

Climate-induced Hazards/Impacts	Adaptation Responses	Source
Water scarcity, coral reef bleaching, changes in precipitation, flooding, and changes in beach structure	Construction of a mega dam and coast zone management through mangrove forest and coral restoration	[31]
Variability in rainfall patterns and amount, increased incidences of drought, saltwater intrusion	Growing of drought tolerant crops, increased frequency of fishing, cultivation of wetlands and keeping small stocks	[30]
Sea- level rise	Non-structural adaptation measures such as community-based adaptation and ecosystem-based adaptation	[24,45]
Cyclones, flooding, sea-level rise, storm surge, salinity intrusion and riverbank and land erosion	System-wide, restructuring, path-shifting and innovative transformational adaptations. Constructions of embankments and mangrove plantation.	[29,48]
Impacts on watershed systems	Integration of non-structural and structural best management practices	[39]
Sea-level rise, nuisance flooding, hurricanes, cyclones and typhoons, wave action	Do nothing Beach nourishment or adding sand to beaches Preventive actions through soft or hard solutions Managed or unmanaged retreat or realignment•	[11]

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Flood risks	Regulatory and restriction options on new development Raising the plinth height in the built environment; building of mobile beach bars and warnings using the help of information technology	[37,44]
Impacts on coastal fishery	Passive adaptations such as harvesting early and reinforcing ponds and equipment. Proactive adaptations, including monitoring the weather daily, changing to aquatic species with better tolerance and investing in modern technology	[36]

Hard adaptations

Hard adaptations refer to an infrastructural change or improvement, in order to boost the resilience of the community to climate impacts. They vary considerably depending on the specific climate-induced impact. For example, the exposure of communities to floods is minimized by building embankments [28]. Hard adaptations engineered to protect against sea-level rise and coastal flooding include dikes, levees, static seawalls, drainage channels, and dams. Such adaptation efforts aim to protect people and assets physically from climate hazards. However, they may have tradeoffs of causing scour and destabilizing the beach.

Soft Adaptations

They are related to the concept of accommodation, focus on human behavior, and attempt to manage climate-induced threats primarily by regulating land use and development. Such adaptation measures include planned relocation or retreat, altered land use and building controls, elevated floor and increased setback requirements, beach nourishment, livelihood diversification, enhanced awareness, emergency management, and insurance [28]. These adaptation measures aim to make development more resilient to climate-induced impacts and manage threats through public education and awareness. These measures fight against marine intrusion such as sea-level rise and coastal flooding by applying an integrated approach, unlike hard adaptations. Soft adaptations are receiving a growing concern because of the adverse impacts of hard adaptations on erosion and ecosystems. Optimal beach nourishment responses have economic and social benefits and reduce forced migration, though it is a temporary response to sea-level rise. Soft adaptation is mostly focused on beach nourishment as it is an environmentally friendly adaptation response to coastal ecosystems [11].

Ecosystem-based Adaptations

They promote more resilient coastal landscapes through the protection of the related ecosystems and they are considered as protective responses that adapt to and supplement natural processes by leveraging the adaptive opportunities linked with ecosystem services. The recovery processes of coastal ecosystems are implemented through soft measures such as the regeneration of dunes, reforestation of native species, and the reduction of use pressures. They also include the restoration of salt marshes, mangroves, and coral reefs, which helps to mitigate marine flooding and coastal erosion and reduce risks for people living in coastal areas [24]. EBAs are preferable as they are flexible, low-regret, low-cost, and provide aesthetic and recreational value. The contribution of ecosystem services to resilience is gaining global attention as a major response to a changing climate, though less is known about their contribution to resilience in monetary metrics. However, the challenges related to hard and soft adaptations outweighed the challenges with EBAs.

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Hybrid Adaptations

There is no single solution that helps to address all socioeconomic and environmental impacts of climate-induced coastal hazards. Hence, an integrated approach depending on the context of social, geographical, ecosystem, and institutional factors is vital in planning and implementing adaptation strategies [39].

4. Conclusions and policy implications

This literature review addressed the impacts of climate-induced coastal hazards and coastal adaptation responses. The majority of investigations on climate-induced coastal hazards and coastal adaptations were conducted in Bangladesh and Asia as country and continent, respectively. Moreover, a significant number of studies do not address the assessments of vulnerability to climate change and the anticipated climate change impacts. The findings of this review also pointed out that developing countries are more vulnerable to the adverse impacts of climate-induced coastal hazards and their low economic development and adaptive capacity would make the situation worse. Sea-level rise, coastal flooding, and climate change and variability were found to be the top three most-studied climate-induced coastal hazards. In contrast, hurricanes and typhoons were found the least-studied climate-induced coastal hazards. To combat the negative impacts of climate-induced coastal hazards, people use different types of hard, soft, ecosystem-based, and hybrid adaptation responses. The integration of different adaptation responses (hybrid adaptations) is believed to be more effective than a single adaptation response in adapting to the impacts of climate-induced coastal hazards on different sectors. In conclusion, the coastal landscape's vulnerability to climate change risks will continue unless all stakeholders act proactively.

The adaptation policy of developing countries, which are extremely vulnerable to climate-induced hazards, should give due attention to nature-based solutions and early warning systems to contribute to the realization of Sustainable Development Goals efficiently by ensuring food security. Nature-based solutions are essential to avoid maladaptive outcomes of hard adaptations. Besides, their land use planning policy should be based on the assessment of vulnerability and projected risks. It is vital if researchers incorporate vulnerability assessments and the projection of coastal hazards while conducting research on the impacts of climate-induced coastal hazards and coastal adaptations. This situation would help to consider the current and anticipated climate change impacts in the national development plans. Finally, it is suggested that empirical and comprehensive investigations on the economic, social, and environmental impacts of climate-induced coastal hazards on diverse sectors should be conducted in the future.

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Appendix A. Proportion of journals that have been used in the literature review

Journal	Number of Articles
Journal of Hydrology	2 (5%)
Springer	2 (5%)
Water	2 (5%)
Scientific Reports	2 (5%)
Advances in Climate Change Research	1 (2.5%)

African Journal of Hospitality	1 (2.5%)
American Journal of Environmental Sciences	1 (2.5%)
Applied sciences	1 (2.5%)
Applied Water Science	1 (2.5%)
Climate Change	1 (2.5%)
Coastal Management	1 (2.5%)
Earth and Environmental Science	1 (2.5%)
Earth Systems and Environment	1 (2.5%)
Economic and Environmental Studies	1 (2.5%)
Environmental Economics	1 (2.5%)
Environmental Science and Policy	1 (2.5%)
Fishes	1 (2.5%)
Frontiers in Environmental Science	1 (2.5%)
Frontiers in Sustainable Food Systems	1 (2.5%)
Geoenvironmental Disasters	1 (2.5%)
Heliyon	1 (2.5%)
Indian Journal of Geo-marine Sciences	1 (2.5%)
International Journal of Scientific & Technology Research	1 (2.5%)
Journal of marine Science and Engineering	1 (2.5%)
Journal of Materials and Environmental Science	1 (2.5%)
Marine Policy	1 (2.5%)
Marine Science and Engineering	1 (2.5%)
Middle East Journal of Scientific Research	1 (2.5%)
Modeling Earth Systems and Environment	1 (2.5%)
Natural Hazards and earth System Sciences	1 (2.5%)
Regional Studies in Marine Science	1 (2.5%)
Royal Society of Chemistry Advances	1 (2.5%)
Science of the Total Environment	1 (2.5%)
Scientific Journal for Damietta Faculty of Science	1 (2.5%)
SN Applied Sciences	1 (2.5%)
Social Change	1 (2.5%)
Total	**40 (100%)**

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