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Review

Building Coastal Agricultural Resilience in Bangladesh: A Systematic Review of Progress, Gaps and Implications

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Abstract: This paper presents the results of a systematic literature review of climate change adaptation and resilience in coastal agriculture in Bangladesh. It explores the existing adaptation measures against climatic stresses. It investigates the extent of resilience-building by the use of these adaptation measures and identifies major challenges that hinder the adaptation process within the country. The review was conducted by following the systematic methods of the protocol of Preferred Items for Systematic Review Recommendations (PRISMA) to comprehensively synthesize, evaluate and track scientific literature on climate-resilient agriculture in coastal Bangladesh. It considered peer-reviewed English language articles from the databases *Scopus, Web of Science* and *Science Direct* between the years 2000 and 2018. A total of 54 articles were selected following the four major steps of a systematic review, i.e., identification, screening, eligibility and inclusion. Adaptation measures identified in the review were grouped into different themes: Agricultural adaptation, alternative livelihoods, infrastructure development, technological advancement, ecosystem management and policy development. The review revealed that within the adaptation and resilience literature for coastal Bangladesh, maladaptation, gender imbalance and the notable absence of studies of island communities were gaps that require future research.

Keywords: climate change; adaptation; resilience; coastal region; agriculture; Bangladesh; systematic review

1. Introduction

Anthropogenic global warming has been altering the climatic systems of the Earth in unprecedented ways. The fifth IPCC report projected that both surface temperatures and sea levels would almost

certainly continue to rise, and the frequency and intensity of extreme weather events are likely to increase throughout the upcoming decades [1]. At the same time, the population of the world is increasing. Projections show that the population will be around 9.8 billion by 2050 [2]. Meeting the food demand of this growing population while adapting to the effects of climate change is one of the major challenges of agriculture [3,4].

Bangladesh is at the forefront of this challenge because of its heavy economic dependence on agriculture, its rapidly growing population and its exposure to multiple natural hazards. Moreover, climate change is exacerbating these natural hazards. The cascading negative effects of climate change impacts across Bangladesh's agro-ecological landscapes could be very severe, especially in the socio-economically disadvantaged coastal regions of the country. Of all of the production sectors in the country, it is widely agreed that the agriculture sector is one of the most vulnerable sectors to climate change due to its almost complete dependence on natural resources and climatic patterns [5]. The IPCC [1] warns that climate change has been adversely affecting Bangladesh's coastal agricultural systems and increasing the risks to food security of the coastal communities. Thus, communities need to adapt their agricultural practices to climate change impacts to ensure food security. Developing more climate-resilient agricultural systems is key to the success of these adaptation efforts [6,7].

Developing and implementing suitable adaptive strategies in agricultural practices to respond to climate change is essential worldwide. At the same time, in places like Bangladesh, understanding how adaptation links to development is also a key challenge. Therefore, scientific research that helps the nation build capacity to generate appropriate conceptualisation of information on climatic risks and adaptation opportunities at different scales is very important [8,9]. Bangladesh's economic, social, environmental and climatic characteristics determine its climate change adaptation strategies and action plan. Academic research can help to explain relationships likely to affect the expected outcomes and to explain existing practices and direct possible future interventions for expected outcomes [10,11]. Hence, it is important to understand what coastal communities and governments in Bangladesh can do to take necessary action for adaption [12], and to what extent these adaptations can build resilience in the agricultural sector. A range of studies [13–17] have explored various aspects of climate change adaptation in coastal Bangladesh. Necessarily, these studies are focused on specific contexts or issues to be addressed. A synthesis of this knowledge could help create a more complete picture of coastal agricultural resilience in Bangladesh by summarising the progress made thus far and identifying the major gaps that need to be addressed.

To address these needs, this paper uses a systematic literature review to explore the existing agricultural adaptation measures used to combat climatic stresses in coastal Bangladesh and how they build resilience. It investigates to what extent these adaptation measures build resilience in the coastal agricultural system and identifies major challenges that hinder the adaptation process, whilst documenting the available evidence. The review will provide inputs for pragmatic policy development for a robust climate-resilient agricultural system in the coastal areas of Bangladesh.

2. Methodology

The systematic protocol of 'Preferred Items for Systematic Review Recommendations' (PRISMA) outlined in Moher et al., [18], Pickering and Byrne [19] and Pickering et al., [20] were used to conduct a systematic literature review. This approach aimed to comprehensively synthesise, evaluate and track the scientific literature on a certain topic of interest [21]. The method involved selecting and categorising papers according to the specific eligibility criteria in order to minimise the potential biases, which occur in a narrative review [22]. A systematic review has higher accuracy, consistency and transparency if exclusion and inclusion criteria are strictly defined and followed [21,23]. After fixing the topic, the inclusion and exclusion criteria were implemented according to the aims and objectives of the research, as shown in Table 1.

Table 1. A summary of the review protocol.

Review Steps	Information
Title	Building coastal agricultural resilience in Bangladesh: A systematic literature review of progress, gaps and implications
Research questions	What are the major climatic stresses across the coastal regions? What approaches to adaptation (including adaptation measures and types of interventions) to climate hazards are used in different research? To what extent are different dimensions of resilience covered in this study? What are the major barriers/challenges in building resilience, as evidenced by the literature? What are the major observed and reported gaps examined in the study?
Keyword search	Agriculture, Resilience, Adaptation, Bangladesh, Climate change, Sea level rise, Salinity intrusion
Search protocol [a]	(TITLE-ABS-KEY (farm* OR agriculture*) AND TITLE-ABS KEY (resilient* OR adapt* OR cope* OR absorb* OR "adaptive capacity" OR adaptation* OR transform* OR persistent* OR adjust* OR "bounce back") AND TITLE-ABS-KEY ("climate change" OR "sea level rise" OR "salinity intrusion") AND TITLE-ABS-KEY (Bangladesh*))
Search strategy and initial selection	Title, year, keywords, abstract
Electronic database	*Scopus, Web of Science, Science Direct*
Inclusion and exclusion criteria	Inclusion: Coastal region in Bangladesh, articles written in English language, published articles from 2000 and onwards and peer reviewed papers Exclusion: Non-English articles, articles published before 2000, non-peer-reviewed academic reports, work done in Bangladesh except in coastal areas

[a] The asterisk represents wildcard search terms.

Scopus, *Web of Science*, and *Science Direct* were selected as the appropriate databases for this study because most of the articles pertaining to the relevant discipline, were found in these databases. Only full-text peer-reviewed original research articles were selected, because these articles maintain a standard of work with detailed methods, results, etc., and have credibility as a result of the peer-review process. The time chosen for the search was between the years 2000 and 2018 because significant research into adaptation began in 2000 and has continued. Only articles written in English were considered for this review because English was the main language used in research and academic publishing, with over 90% of academic articles published in English [24].

2.1. Search Protocol and Selection Methods

A total of 809 articles were initially obtained for possible inclusion from the 3 databases, and these papers were assessed using the four major steps for selecting articles for a systematic review, i.e., identification, screening, eligibility and inclusion. Articles were initially screened to ensure their relevance to the study's aims and objectives. Then the inclusion/exclusion criteria presented in Table 1 were used to assess the relevance of each article. After removing duplicated papers, we obtained 380 articles in the identification step. Then, in the screening step, 228 papers were excluded due to having an unrelated focus. Therefore, 152 papers were assessed for eligibility by studying their full text. In this eligibility step, 37 articles were excluded because the study area did not include coastal areas, and another 59 articles did not meet other eligibility criteria. In the final step, 44 papers were included, and after that, a snowball search was undertaken to include more articles and to find out if any relevant articles had been missed. A snowball search uses the reference list or citations in a paper to identify additional papers [25]. Snowball sampling is an effective method for identifying sources published in obscure journals that may be missed from common databases, although potentially onerous because the sample grows at an exponential rate [26]. In this study, articles cited within the set of articles were assessed for inclusion, with 10 found to meet the criteria. Therefore, finally, 54 full-text relevant articles were obtained and reviewed. A summary of the review protocol is shown in Figure 1.

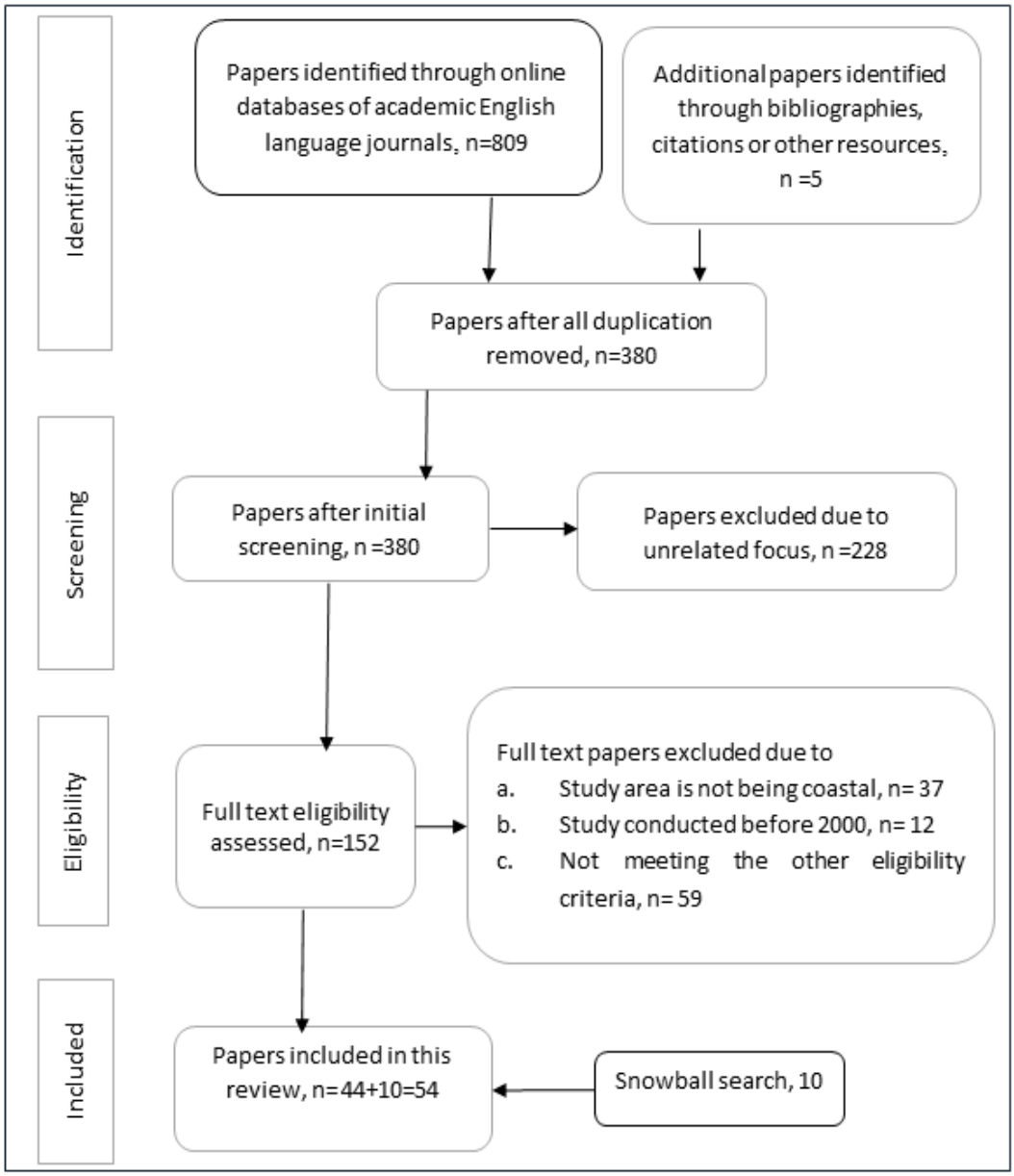

Figure 1. Papers obtained after the identification, screening, eligibility phases and snowball search of the review, using the Preferred Items for Systematic Review Recommendations (PRISMA) technique.

2.2. Review Limitation

This study was focused on peer-reviewed articles in English. However, this means the study excluded work on adaptation published in other sources, such as non-scientific literature or in non-English journals. Another limitation was that the study considered only 3 databases to identify articles concerned with adaptation and resilience in coastal agriculture in Bangladesh. The inclusion of a different combination of databases may add further outcomes.

The most obvious limitation of this study was that no inter-sectoral studies were found. This may be due to a lack of inter-sectoral studies, but the focus on agriculture may also have excluded studies where agriculture was not the primary focus. Analysis of inter-sectoral papers may inform unanticipated results and reveal more severe consequences of climate change [27]. There was also a large gap in the knowledge of how sector-based policies and actions make it difficult to respond to the inter-sectoral impacts of climate change [28].

3. Results and Discussion

To address the research questions, the authors examined the 54 identified articles according to 6 components, namely, (i) climatic stresses identified, (ii) types of intervention approaches, (iii) adaptation measures, (iv) dimensions of resilience, (v) major barriers to building (agricultural) resilience and (vi) major gaps. Figure 2 illustrates the framework used to structure the analysis of the papers. The following sections provide a discussion of these six identified components after some additional information on the context of the studies is presented in the paragraph below.

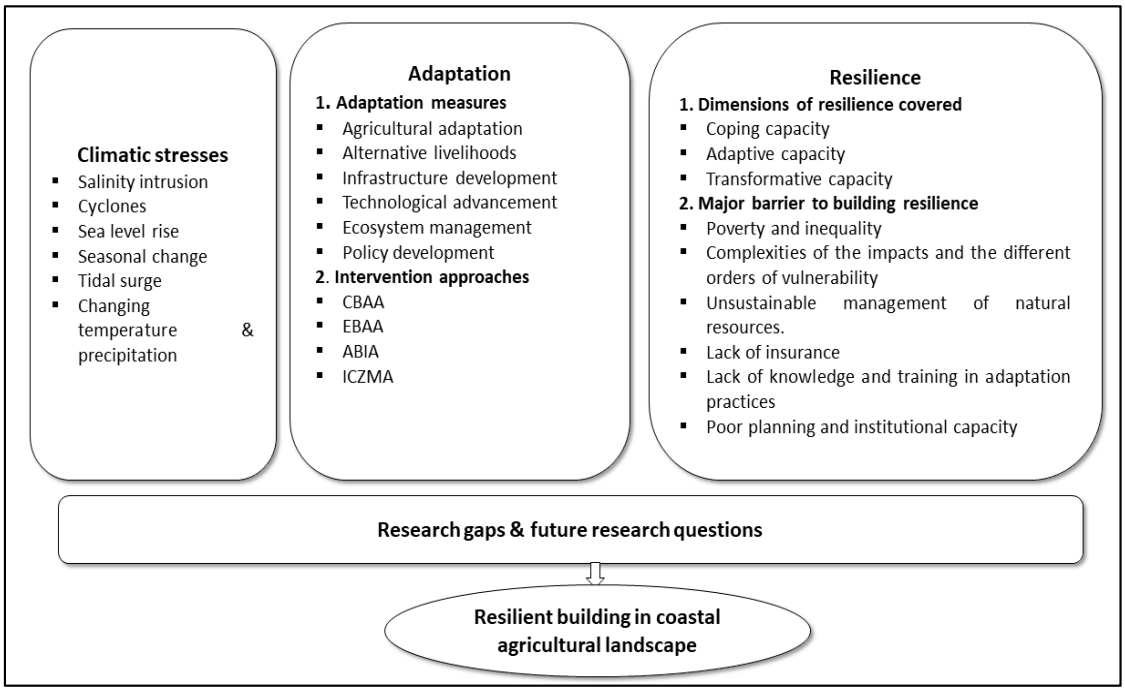

Figure 2. Framework of the review study.

Among the identified articles, 37% used quantitative methods focusing on face to face interviews and focus group discussions (FGDs), 17% used qualitative research methods focusing on in-depth interview and key informant interviews, 33% used mixed research methods and 13% focused on reviews, which included published research materials and secondary data, such as data from the Bangladesh Bureau of Statistics (BBS). In addition, Figure 3 presents a map visualizing the number of studies focusing on each of the coastal regions of Bangladesh. We have categorized the coastal belt into three major coastal regions, i.e., South West, South Central and South East region. As shown in the map, around 70% of the studies were held in the South West regions of coastal Bangladesh (Figure 3), and within this region, research was undertaken in Satkhira, Sundarban, Mongla, Khulna, Bagerhat and Narail Districts. Among these districts, the majority of the studies' locations were in the Satkhira District, whereas comparatively few studies (around 15% in each region) were held in the South Central and South East regions. The study areas within the South Central regions are Bhola, Patuakhali, Borguna and Pirojpur, and in the South East regions, the study areas are Noakhali, Chittagong, Cox's Bazar and Hatia.

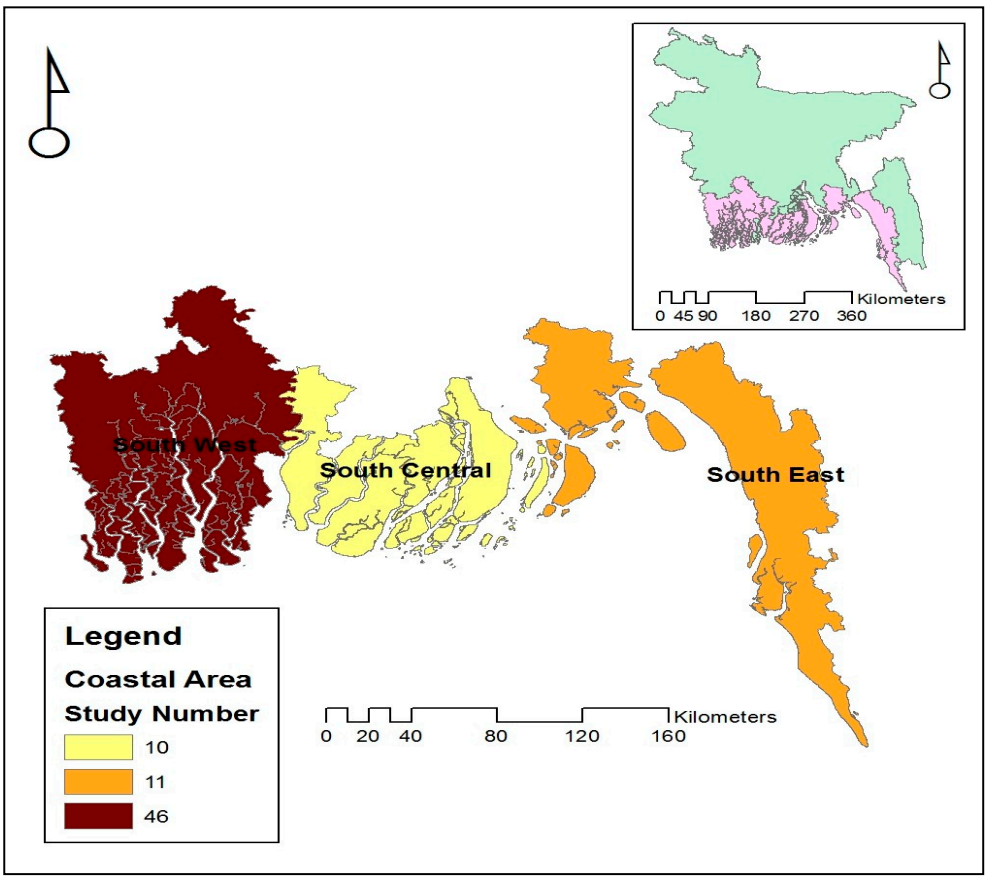

Figure 3. Map presenting the locations of the study regions of the reviewed and analysed studies.

3.1. Climatic Stresses Identified across Regions

Different types of bio-physical risks are associated with climate change. The review highlighted that the most severe risks to coastal regions are salinity intrusion, cyclones, seasonal changes, tidal surges, sea level rise and temperature and precipitation (Table 2). All of these climatic stresses to agriculture are widely recognised as those that occur due to climate change [1]. The risk of storm surges and salinity intrusion will be increased by rising sea levels and changes to precipitation and flooding regimes. Climate change is projected to increase the intensity of cyclones, and possibly increase their frequency. Cropping seasons have been shifting due to changes in seasonal variability, such as uneven rainfall and changes in temperature. Hence, these multiple stresses and related climate change impacts are highly inter-related.

The current review suggested there is no geographical correlation in terms of climatic stress across the studies. Generally, most studies suggested that everywhere along the coastal region is vulnerable to all of these climatic stresses, emphasising the multiple and related challenges faced in the region. However, most of the studies were focused on responses to salinity and its causes and effects in the coastal areas. This possibly implies that salinity is perceived as the greatest risk to agriculture, or at least that is the most urgent concern. The higher number of studies with a salinity focus may be due to the inclusion of salinity and sea-level rise in the search terms. However, these issues are a major focus of Bangladesh's agricultural policy, which the research is studying, and thus we would expect these to be the most discussed issues [29]. Sea-level rise and the ensuing loss of land is a 'slow emergency' that will impact people unevenly and over a longer period but will result in an absolute loss that is difficult to adapt to. In contrast, salinity is affecting yields across the region, creating immediate economic pressure and concerns, however, there is a range of technological and alternative practices available to respond to it [16,30].

Table 2. Climatic stresses identified in this review.

Climatic Stresses	Study Region	Number of Studies [a]	References
Salinity intrusion	South West, South Central, South East	26	[6,13,31–53]
Cyclones	South West, South Central, South East	15	[14,16,17,30,32,50,54–62]
Sea level rise	South West, South Central, South East	9	[14,16,32,42,55,57,60–62]
Seasonal change	South West,	7	[6,7,16,51,61,63,64]
Tidal surges	South West, South Central, South East	4	[16,32,55,56]
Changing temperature and precipitation	South West, South East, South Central	4	[50,64–66]

[a] Note that some studies investigated several stresses.

3.2. Types of Intervention Approaches

A variety of intervention approaches have been used or investigated in different studies (Table 3): A community-based adaptation approach (CBAA), integrated coastal zone management approaches (ICZMA), an ecosystem-based adaptation approach (EBAA), and an asset-based index approach (ABIA). More than half of the reviewed papers (60%) identified the CBAA intervention approach followed by ICZMA, EBAA and ABIA; 20%, 10% and 10%, respectively (Figure 4). In the CBAA approach, which focuses on livelihood improvement and understanding people's behaviours and perceptions, qualitative and mixed research methods were the most common. In the EBAA intervention approach, which focuses on adaptability, ecological modernization and aquatic ecology, only qualitative and mixed methods were used. In the ABIA intervention approach, which covers economic analysis and production outcomes, only a quantitative research method was used for investigation. The ICZMA intervention, which focused on coastal afforestation and coastal policy implication used all four types of research methods for investigation (Figure 4).

Table 3. Papers are classified according to intervention approaches and adaptation themes in coastal Bangladesh from 2000 to 2018.

	Publication Details
Intervention Approaches [a]	
CBAA	[16,34,35,48,49,51,54,60,62,68–70]
EBAA	[63,66]
ABIA	[17,44]
ICZMA	[32,34,39,67]
Adaptation Themes	
Agricultural adaptation	[13,15,33–35,38,39,42,44,45,47,53,63,64,71]
Alternative livelihoods	[6,14,16,30,34,35,39–41,51,52,58–60,64,67,72]
Infrastructure development	[14,34,36,42,50,56,57,67,69,73]
Technological advancement	[6,37,48,50,64,65,68,74]
Ecosystem management	[31,32,34,54,55,63,68,69] [14,39,41,42,48,56,60,66,71,72]
Policy development	[16,31,44,61–63,66]

[a] CBAA—Community-Based Adaptation Approach, ICZMA—Integrated Coastal Zone Management Approaches, EBAA—Ecosystem-Based Adaptation Approach and ABIA—Asset-Based Index Approach.

The research methods used largely reflect the focuses and aims of the different approaches. In adaptation discourses, CBAA is considered to be a more successful approach because of its strong engagement with local people in framing adaptation planning and activities, with wider transformative potential for farming governance [52,54]. Moreover, people use CBAA intervention approaches to promote resilience through the revision of national and sectoral policies by identifying the gaps between policy and practice from practical experience and knowledge [60]. ICZMA is a combination of strategies and policies, which are designed to reduce the effects of climate change. It includes several management plans, such as the development of embankments, irrigation projects, desalinisation pumps and pushing fishing, including shrimp farming, etc. [31,67]. EBAA focuses on the management of natural resources to create a buffer from the worst impacts climate change has on the species and well-being of communities. This approach helps to enhance the resilience of ecosystems through

conservation and the sustainable use of biodiversity and ecosystem services, which underpin a comprehensive adaptation strategy [54,63].

ABIA is used to analyse the maximum likelihood factor where variability in ownership and quality of assets and amenities determine the ability to manage climate change impacts. In this approach, the environmental stressors and livelihood responses are geospatially correlated with poverty [44]. All these interventions are designed to reduce the impacts of climate change.

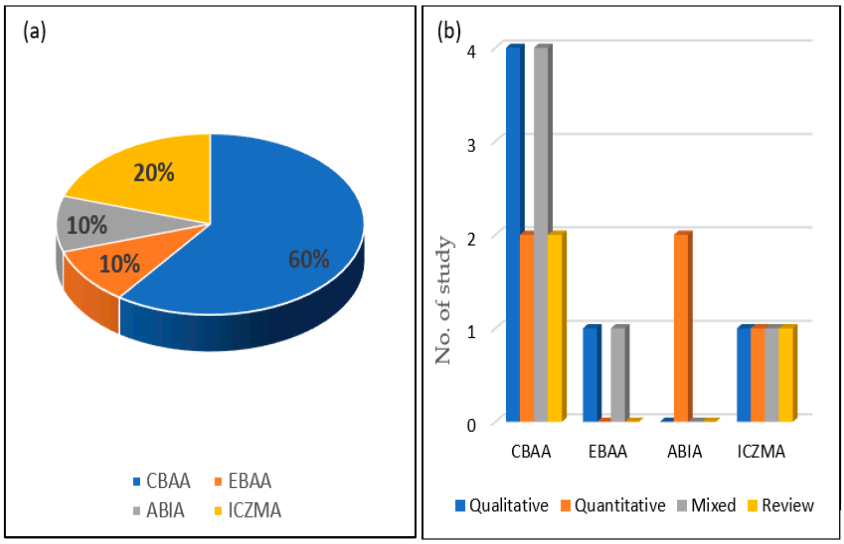

Figure 4. (**a**) Types of intervention approaches in different studies (Left) and (**b**) types of research method used within the intervention approaches (Right).

3.3. Adaptation Measures

The reviewed papers revealed a wide range of adaptation measures taken by communities to improve agricultural resilience (Table 4). Each activity addressed the different climate stresses identified below.

Table 4. Number of studies [a] that investigated adaptation measures based on major themes against climate stresses.

Theme	Adaptation Measures and Activities	Salinity	Cyclones	Seasonal Change	Tidal Surge	Sea Level Rise	Temperature & Precipitation
Agricultural adaptation	Prawn culture, crab culture, integrated farming, mixed farming, agricultural practices homestead farming, floating gardening	8	1	2		1	2
Alternative livelihoods	Migration, non-farm employment, small business, wage employment	3	3	3	3	5	
Infrastructure development	Establishment shelter, embankment building, irrigation system management, construction of ponds	2	5	1		2	
Technological advancement	Salt tolerant rice variety, HYV rice, new varieties of other crops, area specific weather forecasting, weather-index insurance,	4	1	2			1
Ecosystem management	biodiversity conservation, aquatic and terrestrial ecosystems management, coastal afforestation & reforestation programs, reducing deforestation & forest degradation	7	5		2	5	
Policy development	Policy development, mainstreaming adaptation to climate change	2	2			2	1

[a] Note that some studies investigated more than one theme and/or several stresses.

The adaptation measures identified in the reviewed papers were collated into six different themes to simplify the discussion (Table 3), and each theme is discussed in the following sections. Note that no single type of measure was able to address all the climate stressors, and some of the most commonly studied interventions around agricultural adaptation are, to some extent, addressing salinity, seasonal change and temperature and precipitation changes. Hence, a range of practice changes and interventions are going to be needed throughout coastal Bangladesh in order for agriculture to become genuinely climate-resilient.

3.3.1. Agricultural Adaptation

This theme gathered all adaptation options and practices discussed in the academic literature with a focus on agricultural systems in coastal Bangladesh (Table 3). Most of these studies e.g., [14,37,62,70] highlighted the multiple climatic stresses, which are considered to intensify the vulnerability of agricultural systems in Bangladesh. Therefore, adequate agricultural adaptation strategies will be critically important for sustainable management and climate resilience of agricultural systems [75]. Existing adaptation practices in coastal agriculture involve the selection of salt-tolerant crop varieties and alternative crops, adaptation of different agricultural practices such as planting time and cropping season duration, nutrient management, water management and rainwater harvesting in ponds [45,50].

These anticipatory adaptation practices, such as changing planting times, cropping patterns, soil management, etc., not only reduce climate change impacts on coastal livelihoods but also result in potential economic benefits. The literature review also found that aquatic ecosystems are becoming more important for sustainable livelihoods across the coastal communities of the country. For instance, prawn culture, crab culture and integrated prawn–fish–rice farming can provide a wide range of social, economic and environmental benefits [35]. The fact that these interventions can have positive development aspects likely accounts for the significant number of studies that include them. However, as Table 4 shows, they are limited in the stresses that they address. This suggests that an overly strong focus on interventions with economic benefits may not effectively build resilience to all climate change impacts.

3.3.2. Alternative Livelihoods/Transformational Adaptation

Alternative livelihood strategies involve interventions and initiatives to subsidise the harmful effects of climate change on the livelihood of affected local communities. Alternative livelihoods can be achieved by substituting the current activities of affected people with new livelihood activities to provide equivalent benefits [39]. In cases where farming communities become unable to manage their livelihood activities due to adverse climatic impacts, they tend to switch to alternative livelihoods [76]. This can take place with help from both government and non-government organisations, as reported in some studies [14,49].

Furthermore, outbound migration is recognised as an alternative livelihood strategy [47,52,58] in cases where local adaptation measures are partially or fully unsuccessful. Some studies show that the impact of salinity on agriculture, along with other climatic stressors (i.e., flood, riverbank erosion), changes existing settlements significantly. Such situations, i.e., unprofitable and laborious farming systems, often encourage young individuals to migrate and become involved in non-farming activities [48]. Alternative livelihoods are discussed as a response to most of the climate stresses. These adaptation responses increase resilience by creating alternative sources of income or food security. However, it should be noted that in some cases, these alternative livelihoods, such as migration, demotivate farmers from farming activities and hence can reduce the resiliency of agriculture.

3.3.3. Infrastructure Development

Some studies suggested that building new infrastructure and maintaining existing infrastructure are necessary to meet food security and physical safety needs, hence limiting the impacts of climate change in coastal areas [30,41,67]. Common types of infrastructure development that could protect

communities from natural hazards are listed in Table 3, and include the establishment of shelters [57] and building embankments [36,67,69]. Studies also suggest that infrastructure-related community-based strategies could be a good way for natural hazard-prone communities to adapt and for reliable management of water resources [69]. Infrastructure can help in building resilience to a range of climate stressors by improving physical security, such as providing shelters [57] or by improving resource management, such as the building of embankments or irrigation systems [36,67,69]. Improved physical security helps in building resilience to extreme events and in helping communities return to agriculture after cyclones. Infrastructure to improve resource management can help in flood mitigation and sea-level rise or in improving agriculture. However, infrastructure can be expensive and unavailable to many. Furthermore, there are limits to the effectiveness of infrastructure for disaster prevention—ultimately, given severe enough storms or sea-level rise, infrastructure will be overwhelmed [7]. Similarly, improvements in irrigation can be dependent on the quality and availability of water resources. Finally, there are equity issues with infrastructure. It is likely that infrastructure will benefit some communities but may create more problems for others. Irrigation might help some but could deplete water resources for others. Similarly, embankments might protect land downstream, but the water has to go somewhere and thus may affect those upstream.

Nonetheless, the review suggests that infrastructure is being used to address many of the issues faced in coastal Bangladesh, especially the effects of cyclones. No studies included tidal surge infrastructure, but this can, to some extent, be addressed by coastal infrastructure. Hence, it is likely that infrastructure interventions will be an important part of building climate-resilient agriculture.

3.3.4. Technological Advancement

A range of agricultural management practices and technologies can assist farmers' resilience to climate change in Bangladesh. Moreover, the adaptation of innovations in both agricultural and non-agricultural systems is crucial to building resilience in coastal areas [77]. In this literature review, three different types of technological advancement and innovation were found to be the major focus of discussions. Firstly, farming innovation, which includes the introduction of varieties of rice, which are salt-tolerant and high yield [43,48]. Secondly, financial innovation such as weather-index insurance, crop weather insurance and the provision of agricultural credit [65,74]. Thirdly, innovations in climatology and weather forecasting, which include area-specific weather forecasting [74]. All of these innovations are likely to be important for improving the resiliency of agriculture.

Studies highlight technology as being a common adaptation approach to salinity and climate variability. Salt-tolerant rice varieties are an immediate response to increased salinity. However, plants still have limits as to what level of salinity they can tolerate, thus salt-tolerant crop varieties may be a temporary solution. Improved weather forecasting, as well as innovations in farming practice, might be able to mitigate some of the changes to climate variability by providing farmers with better information and alternative approaches to managing their crops. These rely heavily on agricultural extension and knowledge sharing and require farmers to be open to change. Financial innovations, including insurance, may also help with climate variability as well as with cyclones by protecting incomes. However, these also require knowledge and a high level of technical and financial literacy.

3.3.5. Ecosystem Management

The coastal areas of Bangladesh contain a rich diversity of habitats and ecosystems, wildlife and forests, along with densely inhabited human settlements. As a part of building resilience in the degraded coastal regions, some studies focused on ecosystem management. Ecosystem management aims to manage the land, the water and living resources in an integrated way, while also recognising humans and their cultural diversity as part of the ecosystem [35], promoting conservation and sustainable land use in an equitable way [78]. This ecosystem-based adaptation approach has received much attention [63], although there are still questions over what ecosystem-based adaptation entails.

Ecosystem management in coastal Bangladesh includes biodiversity conservation, management of aquatic and terrestrial ecosystems, coastal afforestation and reforestation, and reduction in deforestation and forest degradation. These support agricultural resilience by improving and protecting the ecosystem services [39,66,69].

This adaptation approach was most commonly identified in the studies as a way of addressing changes in climate variability and salinity. This emphasises that water provisioning and regulating ecosystem services are crucial to agriculture and that environmental management can help in mitigating climate change impacts. Such ecosystem-based adaptation interventions can be difficult to implement and often have long-term and diffused positive impacts, meaning that they can be seen as ineffective in the short term. However, the protection of ecosystem integrity can have a range of benefits, and it is fundamental in the effective management of landscapes.

3.3.6. Policy Development

This theme describes government policy development and implementation for supporting and mainstreaming adaptation to climate change [61,62]. It also covers factors such as climate change adaptation awareness, knowledge and the practices of adaptation options, which may influence policy and governance [64]. Since the coastal regions are more vulnerable to multiple climatic stressors, such areas may demand policy privilege [79], especially in agricultural adaptation and infrastructure development. Importantly, the studies noted that it would be preferable for policy programs to be area-specific instead of a one-size-fits-all approach. Area/program-specific policies can help build adaptive capacity to climatic impacts [6,66]. Moreover, these policies should be integrated or consistent with other inter-sectoral issues, particularly in relation to the country's sustainable development planning [49].

Policy development can address any of the stressors identified for coastal Bangladesh, although the studies reviewed here only highlighted policy developments that addressed salinity, cyclones, sea-level rise and changing temperature and precipitation. It is highly recommended that policy development should aim to be area-specific and seek to enhance adaptive capacity.

3.4. Dimensions of Resilience Covered in This Review

All these adaptation measures can help to make coastal agriculture in Bangladesh more resilient. Resilience can be perceived as a process of reconciling humanitarian responses to disasters with long-term sustainable development efforts. Béné et al., [80] grouped these resilience responses into three different aspects: (a) Coping capacity to build buffers against shocks or make them able to persist with business as usual scenarios, (b) adaptive capacity to adjust by introducing some technologies/innovation, for instance, adoption of salt-tolerant varieties to saline prone areas, and (c) transformative capacity to transform old systems into new ones, for instance changing livelihoods or migration. Resilience can be any combination of these three dimensions, and consideration of these aspects helps in analysing the systems' ability to cope, adapt or transform with different types and complexities of climate change impacts. Importantly, Bene et al. [80] emphasise that, ideally, building resilience demands interventions to strengthen the three components at multiple levels [80].

The review of the literature showed that the majority of the studies (24 studies) focused on adaptive capacity, followed by 7 studies, which focused on transformative capacity, and 5 studies, which focused on coping capacity. A few studies focused on a combination of coping and adaptive capacity (6 studies), and fewer still considered the coping and transformative capacity (1 study) to build resilience (Table 5).

Table 5. Dimensions of resilience responses covered by the studies in coastal Bangladesh from the year 2000 to 2018.

Resilience Dimensions	No. of Studies [a]	Publication Details
Coping capacity	5	[30,37,42,50,73]
Adaptive capacity	24	[31,32,35,40,41,44–50,56,60–63,65–69,71,74]
Transformative capacity	7	[14,16,33,39,51,53,68]
Coping and adaptive capacity	6	[6,17,34,38,57,64]
Coping and transformative capacity	1	[72]

[a] Note that some studies did not explicitly discuss specific types of capacity and were not included.

This suggests that communities and the government in Bangladesh recognise the need for more than coping capacity. Climate change is likely to bring impacts and changes where simply coping is not enough. However, there is limited focus on transformation. Undertaking transformation requires a significant transition and is likely to occur in response to dramatic change or to take place over a long time. The focus on adaptive capacity suggests that the approach in Bangladesh is focused on using innovation and technology to adjust with climate change while largely maintaining the same approaches to agriculture and development. The question remains, however, whether this will be enough in coastal Bangladesh, where multiple climate change impacts are increasingly changing the landscape, especially through sea-level rise and accompanying salinity.

Importantly, the literature reviewed here suggested that most of the transformative action [14,16,68] that is undertaken results in other problems because of a lack of good planning, rules and regulations [31]. In addition, effective responses to these challenges on a massive scale demand improved effectiveness of local and national institutional arrangements and collective strategy development and action to develop a more resilient system [68].

3.5. Major Barriers to Building Resilience

There is a range of barriers and challenges, which hinder the planning and implementation of climate adaptation measures to building systemic resilience. Based on the literature review, the major barriers to climate change adaptation and resilience-building in the coastal areas of Bangladesh are as follows: (i) Poverty and inequality [39,44,64]; (ii) complexities of the impacts and vulnerabilities [7,69]; (iii) unsustainable management of natural resources [39,47]; (iv) lack of insurance [74,81]; (v) lack of knowledge and training in adaptation practices [61,64,72]; and (vi) poor planning and institutional capacity [35,51,61,63].

3.5.1. Poverty and Inequality

Poverty and inequality were a common theme throughout the papers (see, for example [39,44]). There is limited land tenure per farmer [82], low coping capacity, and limited access to loans, training, extension services and market facilities [64]. For example, in many cases, decision-making powers may be limited to a few of the elite or powerful people within the community. Traditional gender roles mean that women may have limited access to information or not participate in decision-making. These inequalities can mean that the socio-economic conditions for farmers rarely improve. Some farmers have significant land and resources and are better able to build resilience by pursuing alternative crops or investing in infrastructure. This, in turn, exacerbates inequality by making some more resilient and better able to adapt than others.

3.5.2. Complexities of the Impacts and Vulnerability

The multiple climatic events that are exacerbated by climate change impact all spheres of life, including agriculture, health, biodiversity, water resources and human livelihoods. Adaptation actions and strategies are hindered by these complex impacts [69]. Huq et al. [7], identified three orders of impacts that stop/hinder the adaptation process. The first order impacts are immediate impacts due to

climate change, which mainly affects the physical and infrastructural assets of a community. These first-order impacts slow recovery processes because of the intensity and frequency of climatic events and the ever-increasing residual impacts. The second-order impacts are changes in land use and production patterns due to the first-order impacts; any future disaster sets back the whole recovery process and leads to third-order impacts, which cause households to be unable to cope with and adapt to, the impacts. Therefore, it is likely that different communities will require climate change adaptation plans specific to their context and the order of impact they are facing.

3.5.3. Unsustainable Management of Natural Resources

Unsustainable management of natural resources is one of the major challenges in adaptation because it is hard to be resilient when natural resources are degraded. Environmental degradation generally makes the ecosystems that agriculture relies on more vulnerable, which increases the risk to climate change. In addition, options for harnessing ecosystem services are limited once the environment is degraded. In Bangladesh, most agricultural adaptation is autonomous in the long term, which may lead to unsustainable management of natural resources [39] and which could become a barrier to building resilience to climate change globally [47]. For instance, farmers in Satkhira are practicing shrimp culture, which involves crab fattening in the aquatic ecosystem in an unsustainable way and creates another layer of challenges for the production system [39]. Without proper planning, it is difficult to address the ever-changing climatic events and to manage natural resources.

3.5.4. Lack of Insurance

Adaptation takes place in a resource-restricted social, political and institutional context. The strategies available for poor people are mostly unsustainable and contribute to maintaining levels of poverty. Such strategies include forced migration, borrowing money and selling labour in advance [51,58,64]. Crop insurance is a valuable climate adaptation tool that can offer farmers the capacity to plan and put aside funds for the long term against their adverse situation [81]. Insurance schemes help farmers to farm with an element of security, which helps to build resilience in their farming system. However, Akter et al. [74] suggest that most farmers are either insurance averse or their investment in insurance is conditional on climate change risks and the utility of adaptation. Moreover, the existing insurance scheme design is complex, and the inclusion of the most vulnerable variables further limits the uptake of crop weather insurance [74].

3.5.5. Lack of Knowledge and Training in Adaptation Practices

Adaptation strategies that increase agricultural resilience will be facilitated by improved knowledge about agricultural systems and practices of modern adaptation technologies, extension services and training. It is evident that without validated knowledge about these adaptation strategies, interventions may develop into instances of unsustainability [64,72]. In fact, in Bangladesh, most agriculture adaptation is mainly autonomous in the long term, which, as noted above, may lead to unsustainability that hinders the adaptation process [39]. However, if farmers have enough knowledge and training, autonomous adaptation can be effective and avoid the challenges of implementing government policy and strategy in highly varied contexts. This knowledge and training require the effective exchange of information by raising awareness and building adaptive capacity [61].

3.5.6. Poor Planning and Institutional Capacity

Adaptation may not succeed because of poor planning or poor institutional capacity [63] in part due to the complexity challenges discussed above. In addition, adaptation limits can result in unintended consequences, an adaptation may not succeed in reducing vulnerability, or adaptation might risk increasing it [83]. Therefore, policy and planning need to be aimed at achieving more resilient communities [84] Efficient policy options and coordination with different organisations, stakeholders and financial support are fundamental to mainstream adaptive capacity in Bangladesh [35,51,61,63]. To support

this, building institutional capacity is essential in addressing climate change risks. Without institutional capacity and good governance, development and implementation of policies will be highly limited.

3.6. Major Gaps

The review identified some gaps in the literature concerning various socio-environmental aspects of climate resilience: (i) Maladaptation, (ii) gender inequality, and (iii) geographical disparity in the coverage of coastal island communities.

3.6.1. Maladaptation

The review identified maladaptation as a major gap in the resilience literature concerning agriculture in coastal Bangladesh. In the context of climate change, maladaptation can be understood as 'an action taken ostensibly to avoid or reduce vulnerability to climate change that impacts adversely on, or increases the vulnerability of other systems, sectors or social groups' [85]. For instance, Antwi-Agyei et al. [86] explored how some climate change adaptation measures end up with maladaptive outcomes in the climate vulnerability hotspots of northern Ghana. The authors identified some adaptive practices, including intensification and extensification of agriculture and irrigation schemes in rural Ghana, which delivered maladaptive outcomes, causing increased environmental pollution (by intensive use of agrochemicals), deforestation (in dryland farming systems) and conflict (due to competing demand for water). Our review noted a tendency within the climate resilience literature to occasionally report on negative impacts of adaptive measures (which increase vulnerability), rather than systematically linking those practices with maladaptive practices in the context of Bangladesh. For instance, prawn cultivation has been mentioned in the studies Afroz and Alam [31], Shameem et al. [53] and Johnson et al. [44] as being harmful for the local environment, causing soil degradation, pollution and loss of farmlands for local farmers. Future studies should provide context-specific evidence about the maladaptive practice that will allow both policymakers and other development partners to avoid further maladaptive interventions [87]. Having a clear understanding of what maladaptation is would help to avoid mistakes in planning processes, which would be a key step in the wider process of building climate resilience in coastal Bangladesh.

3.6.2. Gender Inequality

Despite an emergent body of work on resilience, a notable absence exists in the understanding of women's roles in creating and sustaining resilience in the context of climate change [88]. Only a few studies were found that examined the relationship between gender and climate resilience in Bangladesh, for instance, the livelihood improvement of women [16] adaptation of agricultural technologies [77] and gender gap in farmers' weather-index insurance product preferences [65]. Therefore, initiating research in this area would generate significant policy implications. Little is known about how the existing climatic stressors are perceived and managed by the affected females in households, especially in the coastal areas of Bangladesh [88]. Hence, the overarching questions should include how coastal resilience is perceived from a gendered perspective, and what roles are played by women in creating and sustaining resilience at household, community and organisational levels.

3.6.3. Geographical Disparity in the Coverage of Coastal Island Communities

Most of the published literature on climate resilience has been concerned about mainland coastal areas throughout the world. However, island communities in Bangladesh are not given sufficient attention [89]. This study reviews some research that uses data from coastal mainlands but found hardly any empirical research or secondary review covering issues of island communities in Bangladesh. One exception is Parvin et al., [30] which examined different coping mechanisms in respect of types of hazards on Hatia Island, in the South Central coastal area. Therefore, further research is necessary to understand the adaptation of communities and groups living on islands in Bangladesh. This will help in successful adaptation planning and effective implementation [90]. Moreover, there remain

considerable gaps in the understanding of the influence of culture and cultural practices, along with social/external interventions in building resilience among island communities. Further research should explore these practices to gain a deeper understanding.

4. Conclusions and Further Recommendations

This systematic review of the literature examined the existing agricultural adaptation measures taken to ameliorate the risks posed by climate change in coastal Bangladesh. Our research is motivated by the fact that although many studies have covered issues of coastal agricultural resilience in Bangladesh, the findings are fragmented, and the actual coverage in the literature was unknown. Therefore, the present study structured the existing research findings over an 18-year period, and identified major barriers to resilience and indicated areas for future research in the context of coastal agricultural resilience in Bangladesh. Overall, this study contributes to the coastal climatic resilience literature in several ways. First, the study results provided a framework and classified various findings from 54 published articles into 6 categories. The authors identified various climatic stressors in the literature and grouped their focus into three coastal sub-regions, namely, South West, South Central and South East Bangladesh. Then, various types of intervention approaches in the coastal climate adaptation discourse (e.g., CBAA, ICZMA, and EBAA, amongst others), which are deemed to reduce the climate change impacts on coastal agricultural communities in Bangladesh, were identified. Moreover, in response to different climatic stressors, a range of adaptation measures that were intended to improve agricultural resilience were documented. Knowing such adaptation measures will help to improve the coordination of adaptation interventions in the future. Further, this study examined the extent to which important aspects of a resilience response (i.e., coping capacity, adaptive capacity and transformative capacity) have been covered in existing research, which arguably also characterises the current scenario of resilience building in coastal Bangladesh. Thus, the present study suggests that both climate researchers and policymakers largely continue to emphasise adaptive capacity, with little focus given to strengthening transformative capacity. In order to make resilience more inclusive (e.g., considering the interest of the poor, who are mostly impacted by climatic stress), this study argues that transformative capacity must be strengthened. This review also identifies barriers and practical challenges to climate adaptation actions (such as poverty and inequality, lack of insurance, lack of training, amongst others) and provides insights into how to overcome some of these obstacles.

However, inclusive adaptation to building resilience is not an easy process. The review uncovered gaps in the research, including gaps in identifying maladaptation practices, women's involvement in resilience practices, and, in the coverage of climate and resilience literature, a notable absence of studies into island (including Chars) communities. Therefore, further research is required to bridge these gaps. Primary research can expand the geographical coverage of adaptation in regions based on climate stresses, as no geographical correlation in terms of climate stress across the regions was noticed. Furthermore, cross-sectoral analysis for knowledge integration is crucial because ignoring cross-sectoral issues of climate change may bring unexpected consequences, which can also hinder climate resilience and adaptation measures in coastal Bangladesh. Outcome-oriented analyses that evaluate adaptation interventions, adaptation programs and/or policies are necessary, but a significant challenge. Such research could support more evidence-based adaptation policies and more accurately find gaps in policy processes to build climate resilience agriculture in Bangladesh.

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