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REVIEW ARTICLE

Spatial overview of climate change impacts in Bangladesh: a systematic review

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ABSTRACT

Bangladesh is highly susceptible to facing climate change scenarios. The comprehensive systematic review on climate change impacts in Bangladesh is still absent. This article is set out to analyze the existing literature on climate change impacts in Bangladesh. Ushered by the PRISMA statement (Preferred Reporting Items for Systematic reviews and Meta-Analyses) review method, a systematic review of the Science Direct and PubMed databases resulted in 37 related studies. A meticulous review of these articles produced two distinct themes (i) environmental and biophysical impacts and (ii) socio-economic and human livelihood impacts. These two themes resulted in a total of 29 sub-themes and their ramifications. Twenty-eight of the sub-sub groups have been presented spatially to better understand the distribution of climate change impacts throughout Bangladesh. Some recommendations are mentioned to enhance this study for capturing further comprehensive perspectives.

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Climate change; impacts; systematic review; Bangladesh; Policy implication

1. Introduction

The impacts of climate change are almost ubiquitous, cumulatively in every sector, in every environmental issues and nearly every country including ocean and land geography (IPCC, 2021; Schindler, 2001). As a pressing concern, the Intergovernmental Panel on Climate Change (IPCC) has reviewed a great pool of studies to understand possible impacts of climate change and it has concurred upon two key points. One, primarily, it has provided an obvious explanation of concerns for both in regional and global level impacts. Secondly, it has pointed out sector or dimension-wise impacts mostly in the environment and socio-economic scenarios (IPCC, 2007; IPCC, 2014).

Climate change is evident and it occurs due to the natural causes, discharge of greenhouse gases (carbon dioxide and methane) through human activities, and changes in land use. Research on carbon dioxide emission indicates that from 1832 to 2013 atmospheric (CO_2) has increased from 284 ppm to 397 (Tans & Keeling, 2013), and theoretically global warming has expanded with the rise of greenhouse gases. At the same time, human-induced global warming which is primarily caused by the use of fossil fuel and changes in land use also contribute to a great extent to this problem (National Research Council, 2011; Royal Society, 2010; Solomon et al., 2007; Tans & Keeling, 2013). In addition, a substantive body of literature has confirmed that rises in global temperatures due to climate change have been observed since the middle of the nineteenth century (Böhm et al., 2010; Hansen et al., 2010; Mann et al., 2009; Muller et al., 2013; Parry et al., 2007; Screen & Simmonds, 2013).

IPCC, as the apogee of assessing climate change science, evaluates a holistic assessment of the impacts of climate change and the effects on our changing future as climate change will have an impact on many aspects of society on diverse levels including societal structure, socio-economic and political sector mostly, from global to local scale (IPCC, 1996; Nakicenovic et al., 2000). Researches reveal that among the diverse levels some of the impacted aspects of climate change are agriculture (Abler & Shortle, 2000; Downing et al., 2000), water (Arnell, 1998; Miles et al., 2000), biodiversity (Leemans, 1999; Sykes & Haxeltine, 1998) and coastal zones (Nicholls, 2002; Nicholls & Mimura, 1998).

Deviating from global perspectives, regional implications of climate change impacts particularly in the Asian region are considered to be worse and locally in some countries particularly where the rural livelihoods have a strong dependency on the environment are the worst sufferer (Arouri et al., 2015). Moreover putting extra pressure on the environment to achieve rapid urbanization, industrialization, and economic growth, the overall development dimensions of Asian countries will eventually be impacted and impeded adversely (Chen et al., 2014; Hijioka et al., 2014), unless alternative measures of economic development are pursued like, sustainable economic growth to mitigate extreme negative consequences of climate change.

In this regard, Bangladesh, among Asian countries, is most vulnerable to climate change and severely impacted upon human and material losses, particularly in agriculture (Haque et al., 2019; Islam et al., 2010). Furthermore, human-environment (link between human social system and the ecosystem) interrelationship and socio-ecological (linked network of nature and people) relationship systems are also impacted due to climate change and necessary social provisions like food, fibre, and energy supplies are disturbed greatly (Adger et al., 2005; Jongman et al., 2014; Turner et al., 2003). As a result in broad-spectrum

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economic, social, and environmental aspects are facing great challenges in the face of climate change (Ahmed, 2005).

Given the situations and consequences of climate change impacts on a broad array of fields, a comprehensive and combined study is quite necessary to put all the fragmented pictures in one frame. But, existing studies on particular impacts, based on specific geography, provide fragmented scenarios. Literature gap indicates that climatic vulnerability and impact-based research works are quite common in Bangladesh but there prevails a bridging gap of unifying all the vulnerabilities and impacts in one study and be the cognizance to link between science and policy and science and society in terms of unifying the knowledge at different scales (Rahman et al., 2018). Gaps in literature also identify that climate research has credibility and methodological alignments but adaptation measures alter longitudinally as socio-economic attributes change (Lemos et al., 2012; Rahman et al., 2018). In this regard, contemplating on the void of bridging the knowledge gap between policy and society at different scales, compiling subnational climatic impacts in Bangladesh, this study addresses the current literature gap by providing comprehensive geographical climatic vulnerabilities with a set of policy responses. Given that different geographies in Bangladesh face distinctive levels and types of climate vulnerability, contextualized policy responses are crucial. Moreover, to our knowledge, supported by literature, this study would be the first of its kind to geographically present climate change impacts in Bangladesh with a set of relevant policies.

1.1. A systematic review framework on impacts of climate change in Bangladesh

As a systematic review work is set to examine a precisely constructed question therefore it is required to have systematic and precise methods to examine through the relevant literature in order to accumulate and analyze data that are supposed to be included in the review (Shaffril et al., 2018). In this regard to accomplish the review work, there might be the utilization of statistical method or not (Higgins et al., 2011). Moreover, the rigour of systematic review work is justified through pointing gaps and further provocation of future research (Shaffril et al., 2018).

Considering the importance of this study, the review work examines through the existing literature on different climate change impacted sectors in Bangladesh. Furthermore, scarce work of systematic review work on climate change impacts in Bangladesh provides no detailed procedures to maintain (e.g. searching database, using specific terms) and makes the process harder to replicate, validate and understanding comprehensiveness of the study for future scholars (Greenhalgh & Peacock, 2005).

In Bangladesh, recent trends in climate research indicate a rise in the subnational research works across the country (Rahman et al., 2018). This context provides an excellent opportunity to capture comprehensive geographical impacts of climate change and deliver specific policy responses as impacts and adaptation measures are highly contextual and scale specific (Huq et al., 2015; O'Brien et al., 2004). Considering this favourable juncture of occasion in pursuing this systematic review work, the article has been guided by the research questions of (i) What sectors/ domains in Bangladesh are impacted by climate change? (ii) What is the geographic distribution of climate change impacts across the country? and (iii) What climate change impacts are or have been observed in Bangladesh? The sectors/ domains which were considered the most important to describe climate change impacts were (i) environmental and biophysical impacts and (ii) socio-economic and human livelihood impacts. These two sectors/domains were drawn from the following studies (Agrawala et al., 2003; Biswas, 2013; Huq & Ayers, 2007). Details about the variables and their accounts to get included in this study have been provided in supplementary file 2.

The following section provides a detailed explication of the methodology and how the PRISMA Statement (Preferred Reporting Items Systematic Reviews and Meta-Analysis) approach has been used in this research. The subsequent section has systematically reviewed and synthesized the scientific literature to identify, select and appraise germane research work on impacts of climate change in Bangladesh. Finally, the last section has laid out possible future research priorities in climate change impact areas in Bangladesh.

2. Methodology

This section elucidates the method deployed to retrieve the related articles to understand climate change impacts in Bangladesh. In order to do so, the PRISMA method was employed, and the included resources (Science Direct and PubMed) were used to guide the systematic review, including setting inclusion and exclusion criteria, review process steps (identification, screening, and eligibility), and data extraction and analysis.

2.1. PRISMA

In this systematic review work, PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) guideline has been followed as the PRISMA structure is often practised in the environmental management area (Sierra-Correa & Cantera Kintz, 2015) and provides the benefits of formulating precise research questions, determines inclusion and exclusion criteria and offers a broad investigation of scientific literature within certain time schedule. In a nutshell, the PRISMA guideline is a four-phased flow diagram consists of identification, screening, eligibility and inclusion criteria of the reports that fall under the scope of a review with a 27-item checklist. The 27-item checklist comprises topics such as title, abstract, introduction, methods, results, discussion and financing (Selcuk, 2019). Moreover, PRISMA Statement, in this research, enables to identify rigorously related research work in climate change impacts in different sectors and areas in Bangladesh. In addition, the selected variables for this study in determining the most impacted areas of climate change can further be considered for future policy adaptation research works. Access and more information to PRISMA can be reached at www.prisma-statement.org (PRISMA, 2022).

2.2. Resources

The review resources were obtained through two main journal databases (PubMed and Science Direct database). Science Direct

is one of the largest peer-reviewed literature sources that provides index, abstract & full-text databases with 4000 academic journals and 30,000 e-books of Elsevier. Similarly, PubMed also provides a great literature database with more than 30 million citations.

2.3. Eligibility and inclusion criteria

In this article eligibility and inclusion criteria were maintained through the following considerations. First, choosing literature, only journal articles with empirical data were chosen, and review articles, book, book chapters, book series, report, and conference proceedings were excluded. The second criterion was to include only quantitative and mixed-method studies while excluding qualitative studies. One of the key points of choosing only quantitative and mixed-method studies was that these research papers were based on a large sample which provides a basis for generalizability with the opportunity to replicate in future and are less biased in nature (Carr, 1994). Furthermore, mixed-method studies were the most appropriate since they have a quantitative foundation that is supplemented by qualitative results. Moreover, quantitative studies provide a basis for useful decision making (Bryman, 2016; Rasinger, 2013). Third English language published articles were counted and excluded the non-English publication to avoid any confusion and difficulty in translation. Fourthly, for determining the time frame a total of 14 years (between 2008 and 2021) of research work was considered, an adequate timeframe to observe various impacts of climate change in different sectors in Bangladesh. And lastly, as the paper intends to review climate change impacts in Bangladesh for that reason only articles focused on Bangladesh were selected. For more clarification criteria are briefed in Table 1.

Table 1. Inclusion and exclusion criteria.

Criterion	Inclusion	Exclusion
Literature/ research type	Journal (Research article)	Journals (systematic review), book series, book, chapter in book, conference proceeding
Study method	Quantitative and mixed method	Qualitative method
Language	English	Non-English
Timeline	Between 2008–2021	<2008
Country and territory	Within Bangladesh	Outside of Bangladesh

2.4. Systematic review process

In this paper, the review process was comprised of four stages (Figure 1). The whole review process was performed between February and May 2021 with the initiation of the first stage, identifying keywords, for the search process. Depending on the previous closed to or related studies and thesaurus, keywords related to climate change, climate change impacts, impacts of climate change in Bangladesh, sector-wise impacts of climate change were used (supplementary file 2). The formulation of different keywords related to the research topic was utilized in finding desirable articles. After trying out possible keywords for the articles in two search engines, five duplicate articles were removed. In the second stage, a total of 807 articles were found related to and from there 752 articles were removed based on inclusion and exclusion criteria (Table 1). In the third stage, 55 articles were scrutinized with full-text access. Afterward, with careful examination 18 studies were excluded as they were future modelling studies. For the final stage, 37 studies were selected and reviewed for further qualitative synthesis (Table 2) and spatial analysis.

2.5. Data abstraction and analysis

The included articles were scrutinized, assessed, and analyzed. Concentration was given to the formulated review variables and their sub-categories and their sub ramifications. Review data were extracted by reading the abstract first, then the full articles (in-depth) to identify desirable and appropriate themes and sub-themes. Content analysis was used in performing qualitative synthesis to explore themes related to climate change impacts in Bangladesh. The formulation of sub-themes and their ramifications were established through existing literature and organized by the authors. The spatial presentation of each variable and its themes and sub-themes was based on the reported times in each of the selected articles. All of the spatial graphical presentations were built up utilizing ArcGIS 10.3 software.

3. Result

This review paper was maneuvered based on the two specific main threads and 17 sub-threads and their sub-theme ramifications. Two specific threads are environmental and biophysical impacts (eight sub-threads and their branches) and socio-economic and human livelihood impacts (nine sub-threads and their branches). The results of these combined two threads offer an extensive explication of the climate change impacts in Bangladesh over 14 years of time span.

A total of thirty-seven studies on different regions of Bangladesh, based on the review variables, were scrutinized in this study. As few of these studies were combined with different districts and small administrative regions and it was hard to differentiate them individually. In that case, in order to seek more lucidity and for the convenience of spatial depiction districts wise, as most of the study locations are based on district level and only a few covers sub-districts, spatial presentation of climate change impacts has been demonstrated. Studies which has covered the whole of Bangladesh without any specific boundary indication have been exempted in spatial presentation. Furthermore, regarding publication year 1 article published in 2021, 7 articles in 2020, 6 articles in 2019, 4 studies in 2018, 2 papers in 2017, 3 articles in 2016, 3 papers in 2015, 5 studies in 2014, 2 papers in 2013, 3 papers in 2012, and 1 article in 2008 were found in this study.

3.1. Climate change impacts in Bangladesh

In this whole section, concentration is given on in different impacts of climate change on some chosen fields such as environmental and biophysical impacts and socio-economic and human livelihood impacts.

Table 2. Characteristics and findings from the selected studies.

Authors and years	MS+	Environmental and biophysical impacts													Socio-economic and human livelihood impacts													
		NH													AF			HH							WS					
		C	F	H	D	S	T	CT	SR	ST	SC	CR	S/SI	LC	CD	SF	RP	D	MS	D/C	M	T	CA/B/A	FVW	DW	IR	LL	LL_2	M/D	F/FB
Aziz et al. (2021)	QN							√				√																		√
Shakhawat Hossain et al. (2020)	QN		√	√			√																	√						
Chowdhury et al. (2020)	MM	√						√				√																√	√	
Hossain et al. (2020)	MM		√																									√		
Ahsanuzzaman and Islam (2020)	QN	√	√						√										√									√		
Mahmood et al. (2020)	QN					√			√				√																	
Haque et al. (2020)	QN	√	√										√					√			√				√		√			
Rahman et al. (2020)	QN			√									√					√												
Uddin et al. (2019)	QN					√							√												√					
Rakib et al. (2019)	QN	√	√					√					√		√	√									√					
Islam et al. (2019)	QN			√		√		√	√														√							
Hoque et al. (2019)	QN					√			√														√							
Rakib et al. (2019)	MM	√							√				√												√					
Islam et al. (2019)	QN				√																									√
Salem et al. (2018)	QN							√				√														√				
Rahim et al. (2018)	MM	√	√	√		√		√			√		√															√		
Wu et al. (2018)	QN							√												√										
Muurlink et al. (2018)	QN			√														√												
Call et al. (2017)	QN							√																					√	
Islam et al. (2017)	QN				√										√															
Zaman et al. (2017)	QN		√					√					√																	
Kabir et al. (2016)	QN	√	√		√		√											√		√	√									
Wu et al. (2016)	QN			√																√										
Ahmed & Diana (2015)	MM	√	√	√	√				√	√						√														
Beier et al. (2015)	QN	√	√										√							√		√						√		
Sharmin et al. (2015)	QN							√		√								√												
Banu et al. (2014)	QN							√										√												
Sarker et al. (2014)	QN			√				√							√		√													
Shameem et al. (2014)	MM	√											√	√											√			√		
Wu et al. (2014)	QN			√				√												√										
Bashar and Tuno (2014)	QN			√																	√									
Ahmed et al. (2013)	MM	√	√	√	√				√	√			√			√							√							
Dewan et al. (2013)	QN			√				√														√								
Sarker et al. (2012)	QN			√				√							√		√													
Habiba et al. (2012)	QN				√										√										√	√		√		
Bhuiyan & Dutta (2012)	QN								√				√																	
Hashizume et al. (2008)	QN							√												√										

Environmental and biophysical impacts
NH = Natural Hazards
C = Cyclone
F = Flood
H = Heavy rainfall
D = Drought
S = Storm surge
T = Tidal wave
CT = Changes in Temperature
SR = Sea level Rise
ST = Sea surface Temperature
SC = Season Changed
CR = Changes in Rainfall
S/SI = Salinity/ salinity intrusion or soil salinity
LC = Land-use change

Socio-economic and human livelihood impacts
AF = Changes in Agriculture and Fisheries
CD = Crop Damage
SF = Shrimp/ prawn Farming-
RP = Rice Production
HH = Impacts on Human Health (Diseases)
D = Dengue
MS = Malnutrition and Stunted child
D/C = Diarrhea/ Cholera
M = Malaria
T = Typhoid fever
CA/B/A = Changes in Coastal area/biodiversity/ aquaculture
FVD = Farmland value decreased
WS = Decreases in Water security
DW = Drinking water/ water scarcity
IR = Irrigation water demand
LL = Loss of life
LL_2 = Loss of livelihoods
M/D = Migration/ Displacement
F/FB = Impacts on Forest/ Fish Biodiversity

Abbreviations: MS+=Method of the Study; QN = Quantitative; MM = Mixed method.

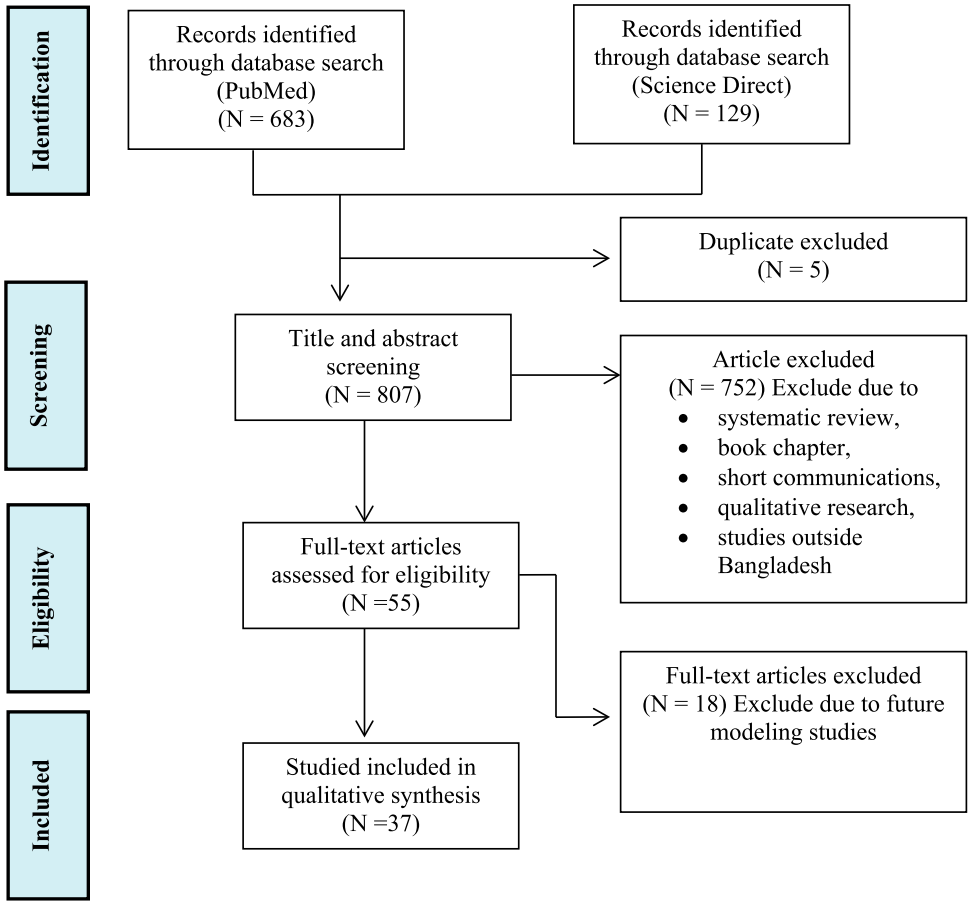

Figure 1. The flow diagram of the study.

3.1.1. Environmental and biophysical impacts

This section provides insights on eight distinct environmental and biophysical impacts such as natural hazards, changes in temperature, sea-level rise, sea surface temperature, season change, changes in rainfall, salinity or salinity intrusions, and land-use change.

For the first environmental and biophysical impact, natural hazards, there are six different hazards namely cyclone, flood, heavy rainfall, drought, storm surges, and tidal wave. As natural hazards, in this study, had six classifications and a total of 29 studies out of 37 studies focused on at least one natural hazard. The most common natural hazards are heavy rainfall (13 studies), cyclone (11 studies), and floods (11 studies) while drought and storm surge are found in 6 and 5 studies respectively. (Shakhawat Hossain et al., 2020) and (Kabir et al., 2016) reported tidal wave incidents mostly in coastal regions and some districts nearby the big rivers in Bangladesh.

Similarly, changes in temperature are the most reported impact creating environmental variables in Bangladesh. A total of 16 studies reported temperature rise issue in Bangladesh. Exclusively in the study of Sarker et al. (2014) and Sarker et al. (2012) described the only positive impact of temperature rise in producing the agricultural product of Aus, Aman, and Boro rice. Likewise, a higher number of studies reported temperature rise issue in Dhaka and most of them investigated the relationship between temperature rise and the escalation of various waterborne and vector-borne diseases, except one study, (Call et al., 2017), described the migration/displacement issue in Matlab.

Accordingly, sea level rise has been found as the third most impact creating variable, a total of 8 studies are reported. The problem of sea-level rising is mostly reported in coastal regions and Mongla upazila under Bagerhat district appears as the highly reported area on this issue. One study (Bhuiyan & Dutta, 2012) reported seal-level rise issue in adjacent areas of Gorai River. Simultaneously, changes in sea surface temperature and changes in rainfall both variables had been reported in 3 studies. Ahmed and Diana (2015) and Ahmed et al. (2013) depicted the negative consequences of sea surface temperature in Mongla upazila under Bagerhat district in shrimp and prawn farming activities.

In the same way, changes in rainfall patterns were reported in three studies. Chowdhury et al. (2020) reported changes in rainfall pattern in the Khulna district while Aziz et al. (2021) and Salem et al. (2018) described rainfall pattern changes in Sylhet and Rajshahi districts respectively. Only one study (Rahim et al., 2018) was found to list and describe impacts of season change primarily in changes of rainfall time.

At the same time, salinity/salinity intrusion/soil salinity (11 studies) and land-use change (1 study) problems were highly observed in coastal districts. Due to the proximity to the sea, coastal areas were reported with salinity problems. Salinity intrusion was highly reported in Bagerhat, Satkhira districts. These studies (Rakib et al., 2019; Uddin et al., 2019; Rakib

et al., 2019) and Haque et al. (2020a) listed salinity problem in the Satkhira region. Particular crucial sectors like agro-economy, economy and human health in this area are in great jeopardy due to the high salinity conditions and the situation only aggravates during the cyclonic storm surge. Some particular unions in Satkhira districts namely Gabura, Burigoaliny, Munshigonj, Atulia, and Padmapukur are at high risk of salinity. Due to high tides and other climatic reasons salinity has increased several folds over the previous decades. This particular work of Zaman et al. (2017) has highlighted the possibility of the increase of salinity in Bagerhat districts by about 0.5–2 PPT (parts per thousand) as the spatial variability is more conspicuous and higher concentration was noticed in the northern part of the district. In the Barguna district, Rahim et al. (2018) mentioned the maximum salinity problem from March to June. Due to high salinity, both in water and soil, agricultural activities are highly negatively impacted and cultivatable lands are left to fallow. Livelihoods related to agriculture are halted to put a stop. Mahmood et al. (2020) observed the salinity problem in nearby regions of the Meghan estuary and their study affirmed that estuarine islands namely Char Nizam, Char Lakshmi, Char Momtaz, Char Kasem, Sona Char, Char Piya, Maluvi Char/ Choto Deep are containing a high concentration of ground salinity. Another study carried out by Ahmed et al. (2013) reported the salinity problem in Mongla upazaila in the Bagerhat district. Their study confirmed that seasonal water salinity in the Pashur River has been witnessed to increase 2–5 ppt in recent year. In addition, the study by Shameem et al. (2014) in Bagerhat districts was observed in reporting land-use change. Land-use change in coastal regions is pushing agro-ecosystem being replaced with brackish water aquaculture. The process of land-use change is introducing a set of problems in the southwest coastal region of Bangladesh including soil and water salinization, degradation of agricultural land, pressure on shrimp farming are prominent (Figure 2).

3.1.2. Socio-economic and human livelihood impacts

A total of nine socio-economic and human livelihood impacts were identified in this study namely changes in agriculture and fisheries (7 studies), impacts on human health (14 studies), changes in coastal area/biodiversity/ aquaculture (3 studies), farmland value decreased (1 study), decreases in water security (there are two sub-sub-themes in this section drinking water scarcity 6 studies and irrigation water scarcity 2 studies), loss of lives (1 study), loss of livelihoods (7 studies), migration/displacement (2 studies) and forest/fish biodiversity (2 studies) (Table 2).

In order to delineate climate change impacts on agriculture and fisheries three subcategories have been formulated; crop damage, shrimp/prawn farming, and rice production. Results show climate change has negative impacts on these three subcategories. A total of 7 studies reported climate change impacts on the agriculture and fisheries sector among which 5 studies described crop damage, 3 studies listed damage in shrimp/prawn farming and 2 studies reported rice production. Islam et al. (2017); Sarker et al. (2014) and Habiba et al. (2012) reported Rajshahi, Bogra, and Chapai Nawabganj districts are most vulnerable to crop damage in facing climate change conditions. On the other hand, according to Ahmed and Diana (2015) and Ahmed et al. (2013) Mongla upazila under the Bagerhat district is mostly affected by climate change in shrimp/prawn farming. Sarker et al. (2014) and Sarker et al. (2012) listed both positive and negative impacts of temperature and rainfall on rice production. Particularly in producing Aus, Aman, and Boro rice both temperature and rainfall have positive and negative impacts simultaneously.

At the same time, climate change has highly negative impacts on human health, as literature has been identified four specific vector-borne and water-borne diseases directly associated with temperature change and rainfall. Dengue and Diarrhea/Cholera appeared as the most prevalent diseases related to climate change and 6 studies have been reported on each disease. Similarly, Malaria and Typhoid fever are listed in 3 and 2 studies respectively. In the case of dengue, Dhaka city has been found with the most frequent cases of dengue disease. The work of Rahman et al. (2020); Muurlink et al. (2018); Sharmin et al. (2015), and Banu et al. (2014) confirmed the incidences of dengue in Dhaka city due to climate change consequences. One of their studies found that in a particular month an increase of an additional rainy day in the total rainy days of the month shoots up the chances of dengue incidence by 6% in the succeeding month. Another study described that one-month prior minimum monthly temperature or two months prior number of rainy days in a row is the two best predictors of a dengue outbreak. Among other regions, Khulna, Bagerhat, and Cox's Bazar also happened to have reported in two studies in each region with dengue infection incidences. For the occurrence of diarrhea/cholera disease, Dhaka was also identified with the highest event of infected cases. Wu et al. (2018); Wu et al. (2016); Wu et al. (2014) and Hashizume et al. (2008) found evidence of diarrhea/cholera circumstances related to rainfall and temperature changes. The second hot spot of diarrhea/cholera circumstances was identified in the Bagerhat district. On the other hand, malaria was highly noticed in Khulna, Bagerhat, Satkhira, and Cox's Bazar districts. In addition, Haque et al. (2020) reported the occurrences of diarrhea, dysentery, and other waterborne diseases in coastal regions. The typhoid fever incidence was reported in Sarankhola, Bagerhat, and Dhaka districts.

Similarly, Hoque et al. (2019) and Islam et al. (2019) reported climate change impacts on the coastal area and was highly noticed in Cox's Bazar district. The result in the study of Hoque et al. (2019) confirmed that approximately 122 km of coastline in Chittagong and Cox's Bazar districts fall within the high to the very high vulnerable region in facing coastal hazards. High storm surge, shoreline erosion, and high sea-level rise was reported as the most influential factors for accelerating coastal vulnerability. Ahmed et al. (2013) reported the impact of climate change on prawn farming in Mongla upazila under the Bagerhat district. Changes in biodiversity in fish production from aquaculture and total water area used in aquaculture were examined in the study of Islam et al. (2019) in different regions of Bangladesh and the study found that Mymensingh, Panchagarh, Lalmonirhat, Nilphamari, Thakurgaon, Sunamganj, Dinajpur, and Kurigram, Satkhira, Noakhali, Lakshmipur, and Cox's Bazar were highly

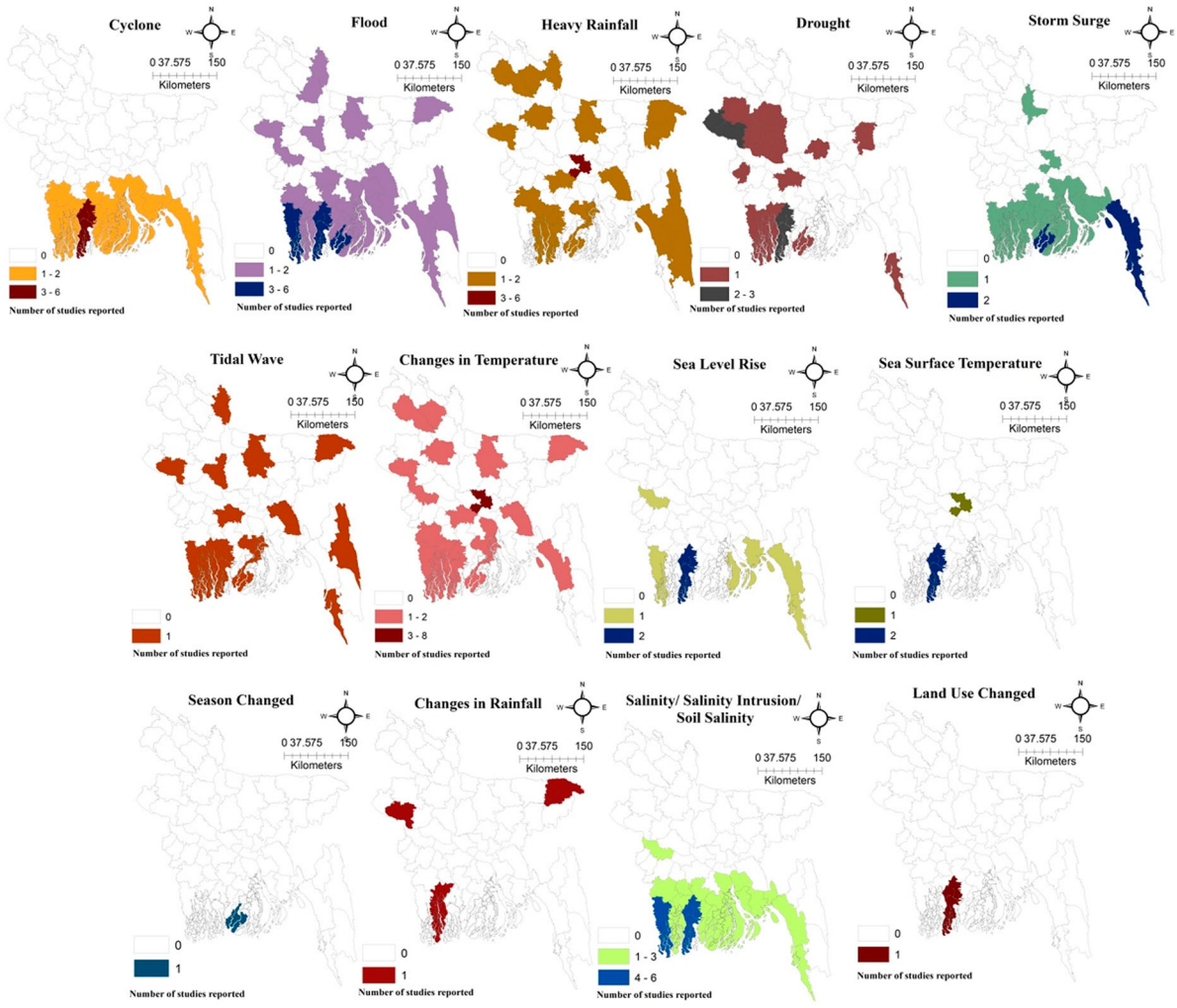

Figure 2. Environmental and biophysical impacts (Occurrence of various natural hazards and other environmental impacts) of climate change in different regions of Bangladesh. (For more visuals see Supplementary file 2, supplementary figure 1).

vulnerable in the aquaculture sector in facing climate change impacts.

Likewise, findings of Shakhawat Hossain et al. (2020) reported the decreased value of farmland in Kurigram, Mymensingh, Rajshahi, Barisal, Comilla, Sylhet, Rangamati districts as a result of climate change, and the results indicated that temperatures and precipitation contributed to dictate farmland value, mostly high temperature, and low rainfall. Floods also worked as an influential factor in reducing farmland value too.

Accordingly, drinking water scarcity due to the occurrence of various natural disasters, predominantly storm surge, leaves the coastal region with the problem of scarce fresh drinking water resources. Haque et al. (2020); Uddin et al. (2019); Rakib et al. (2019); Rakib et al. (2019) and Shameem et al. (2014) listed the most water scarcity problem in Khulna, Satkhira, and Bagerhat districts. In Satkhira district Rakib et al. (2019) found that due to salinity intrusion freshwater scarcity was high and most people use the pond and contaminated tube well water as sources of drinking water. Moreover, most of the coastal regions were found in shortages of safe drinking water resources. In the case of high irrigation water demand, reported in the study of Habiba et al. (2012), observed in Rajshahi and Chapai Nawabganj districts, as these regions were examined with frequent drought events. As groundwater was mostly used in both agriculture and domestic purposes and drought event is frequent, the demand for water in agricultural purpose was observed highly.

Simultaneously, Haque et al. (2020) reported the consequences of climate change and the occurrences of various natural disasters in coastal regions and incidents of fatalities. Lack of institutional and coping capacity coupled with other regional vulnerabilities was accounted for the loss of lives during various natural disasters. Likewise, in reporting the loss of the means of livelihoods Bagerhat district was highly noticed. Beier et al. (2015) and Shameem et al. (2014) observed the consequences of salinity on the means of livelihoods. Moreover, the loss of cultivatable land due to soil salinity also impedes traditional livestock farming and limits the means of livelihood. Similarly, migration/displacement due to the result of climate change was observed in the study of Chowdhury et al. (2020) and Call et al. (2017) in Khulna and Matlab correspondingly. The study of Call et al. (2017) corroborated the fact that temperature increase speeds up the temporary migration process but flood and increased precipitation conditions put a hold on the migration process. While

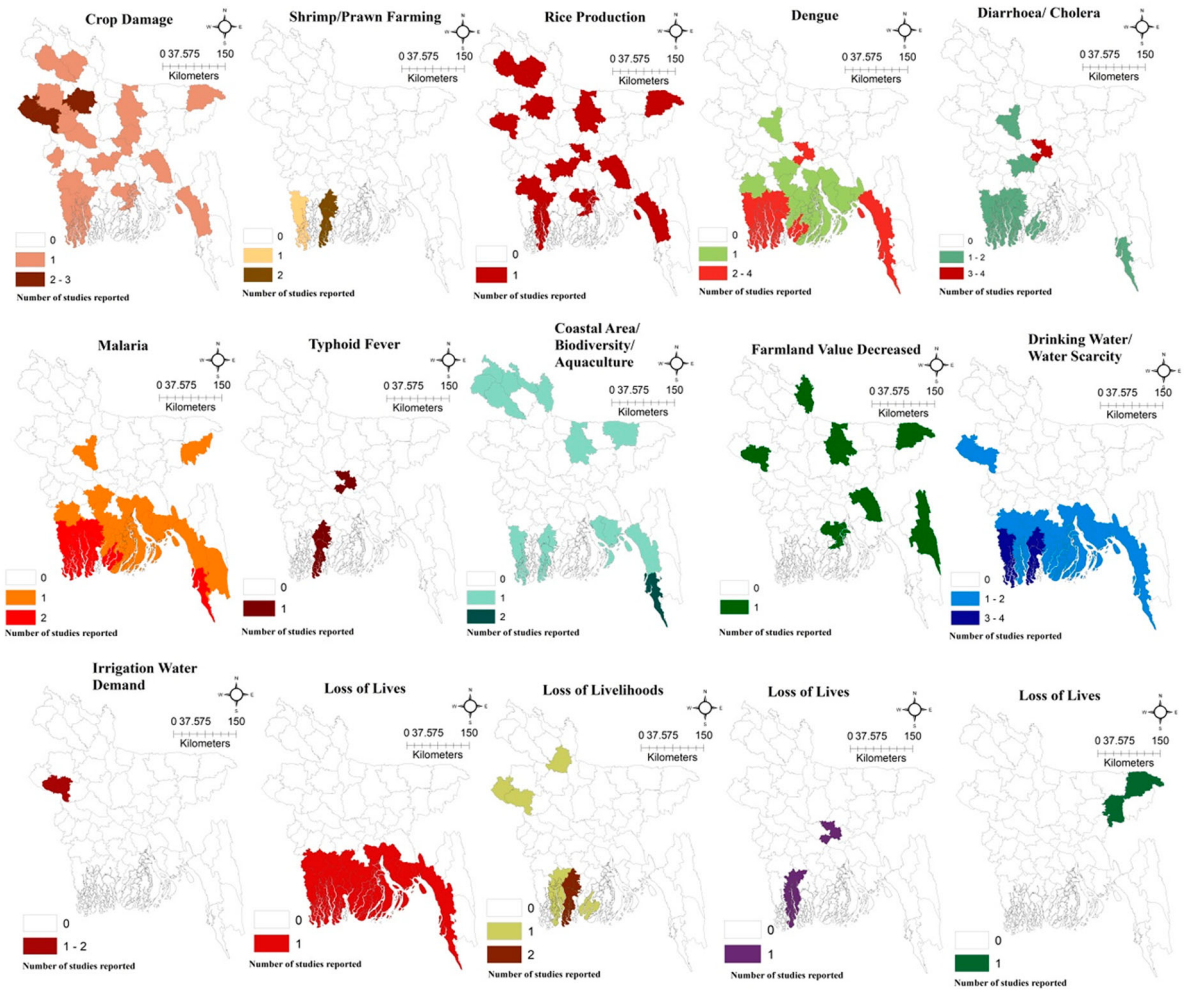

Figure 3. Socio-economic and human livelihood impacts of climate change in different regions of Bangladesh. (For more visuals see Supplementary file 2 supplementary figure 2).

Chowdhury et al. (2020) depicted the migration process in the Koyra, Khulna districts due to the tidal wave, riverbank erosion, and frequent hit of the cyclone. In addition, impacts of climate change in forest/fish biodiversity were listed in the study of Islam et al. (2019) and Aziz et al. (2021) in Habiganj (Rema Kalenga Reserved Forest) on forest diversity and Sylhet districts on fish biodiversity respectively. The findings indicate that the erratic and heavy rainfall and temperature fluctuation are responsible for declining fish biodiversity. In observing the decline in forest diversity, Islam et al. (2019) scrutinized the negative impact of drought in the growth of Chukrasia tabularis tree species in the tropical forest of Bangladesh (Figure 3).

3.2. Climate change research trends and spatial depiction of climate change in Bangladesh

In this research work, climate change impacts in Bangladesh were captured during the period of 2008–2021. (From Figure 4) In the beginning, in 2008, research work was scarce, based on our searching criteria, only temperature change was reported. A great leap was observed in 2012 and a total of 13 climatic incidents were reported. Reports on various climatic variables were observed to increase until 2015. Literature reported less climate change impact-related variables during the year of 2016 and 2017. After that, the momentum was gained and more variables were observed and listed in literature. As this review article reviews 29 different climatic variables and among these 27 of them reported only in 2020. In determining trends in specific climatic variables (from Figure 5), temperature change throughout the course of 2008–2021 was highly pronounced. Heavy rainfall, cyclones, flood, and salinity/ salinity intrusion were subsequently the most reported climatic variables in the literature. Other than these variables sea-level-rise, loss of livelihoods, drought, drinking water scarcity, incidence of diarrhea/cholera, and storm surge incidences were reported more than five times since 2008.

Spatial representation of climate change impact indicates that coastal regions are highly reported with various climate change impact scenarios mostly with environmental and biophysical impacts. Among coastline districts, Bagerhat district was highly impacted with a wide range of climatic variables. Amid the entire reviewed variables cyclone, flood, salinity, and drinking water scarcity were the highly reported variables in coastal districts. Other climate-vulnerable districts in coastline were Satkhira, Khulna, Barguna, Cox's Bazar, Chittagong, Barisal, and Bhola. On other hand, in Northeastern and Northwestern districts environmental impacts of climate change are conspicuous in flood, heavy rainfall, drought, tidal wave and

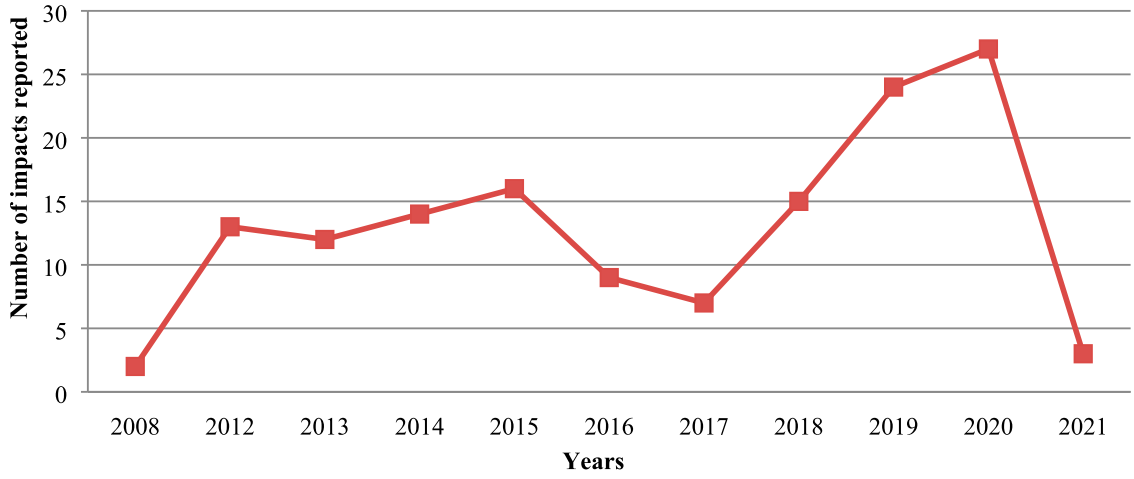

Figure 4. Trends of research works and record of the impacts (reported number of the selected variables in the research papers) of climate change over the periods of (2008-2021) 14 years in Bangladesh.

temperature change. Due to these environmental impacts, both Northeastern and Northwestern districts face climatic challenges in agriculture, crop damage and rice production and in some cases biodiversity/aquaculture loss. Variations of different variables in different geography indicate that climate change impacts in Bangladesh are not evenly distributed and geography has strong links with climate change impacts.

4. Discussion

This study is a carefully attempted endeavour to rummage through the existing works of literature and analyze systematically the impacts of climate change in Bangladesh on some selected variables. There are some climatic variables continuously altering various sectors in Bangladesh. This review article has rigorously reviewed articles from two databases resulted in a total of 37 articles linked to the impacts incurred in different areas due to climate change conditions. The results demonstrate that Bangladesh is impacted in different ways and different important areas due to the consequences of climate change. This review paper examines two themes and 17 sub-themes and their sub-sub-theme ramifications. The two main themes of climate change impacts, based on literature, are environmental and biophysical impacts and socio-economic and human livelihood impacts.

Findings show that in Bangladesh, environmental and biophysical impacts of climate change are predominantly severe mostly in coastal regions while northwestern and northeastern regions face particular environmental impacts like drought, temperature change, flood, and in some cases heavy rainfall. On the other hand, natural hazards like cyclone, flood, heavy rainfall, and salinity are very frequent in coastal zones and so far, from 1877 to 1995, Bangladesh has experienced a total of 154 cyclones among which 43 were appeared as severe (Dasgupta et al., 2014). The worst tropical cyclone, Sidr, in November 2007 was by far the more catastrophic in 10 years (GoB, 2008). Successively in May 2008 cyclone Nargis, April 2009 cyclone Bijli and in May 2009 cyclone Aila thrust upon coastal Bangladesh (Dasgupta et al., 2014).

In case of flood, some parts of northern regions and whole coastal regions of Bangladesh are highly affected. Moreover, one-fifth of the country is inundated each year due to flood. In Bangladesh, extreme flood cases were observed in the years 1974, 1987, 1988, 1998, and 2004 (Banerjee, 2010). Heavy rainfall scenario was observed in some southeastern, southwestern, northeastern and northwestern districts. Due to the country's geophysical position in some cases heavy rainfall contributes to flooding conditions and river erosion (Shahid, 2010). In Bangladesh, it is expected that by 2030 monsoon rainfall is about to increase by 10%-15% (Jakobsen et al., 2005). In witnessing the drought problem northwestern and southwestern districts were highlighted. As plausible reasons two types of droughts are more likely to explain the problem, one is due to anomalies in the succession of rain and dry seasons, and the other is caused by anomalies in rainfall. In the last 50 years trend, the country has suffered from 20 drought situations (Habiba et al., 2010).

On the other hand sea level rise, due to glacier melting, also appears as a threat to the coastal regions of Bangladesh (Dasgupta et al., 2014). In this regard, coastal lives and properties are in a highly vulnerable situation. It's been estimated that a 1 m rise in sea level would bring a serious catastrophe to coastal Bangladesh and with the decimation of Sundarbans mangrove forest (Agrawala et al., 2003); (Butzengeiger & Horstmann, 2004). Sea-level rise issues due to the climate change scenarios are also giving rise to frequent flood occurrences (CEGIS, 2010). Recent projection, considering extreme scenarios, estimates that by 2050 extreme flood events will increase significantly. Considering the base period of 2005 in calculating extreme climatic scenarios of 2050 and 2100 respectively shows that sea-level rise would increase this flooding scenario up to 6% and particularly in the central coastal zone up to 8% (Mojid, 2020). Sea surface temperature, an evident result from global warming and the greenhouse effect, also increases the chances of occurring cyclones (Dasgupta et al., 2014). Natural disasters listed in this review paper are more likely to occur in the coastal zone of Bangladesh due to hydrological and geo-morphological conditions (Mojid, 2020). All of these natural disasters during the period

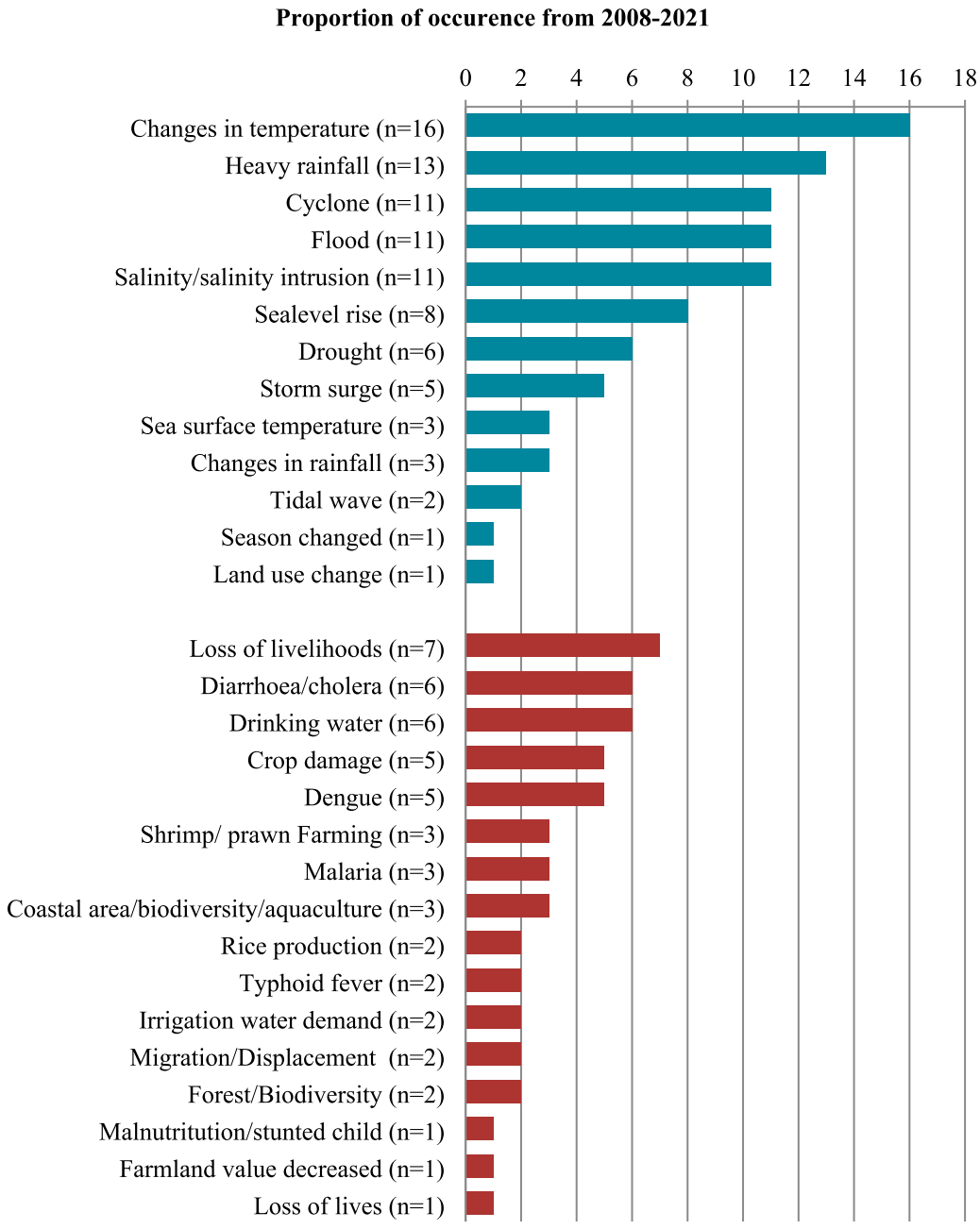

Figure 5. Number of occurrences of the selected variables from both categories, Environmental and Biophysical Impacts and Socio-economic and Human Livelihood Impacts, from the years of 2008–2021.

of 1990–2008, on average, caused the damage around US$ 2.2 billion and took away 8241 lives per year with the decline in GDP by 1.81%. Among this devastation, only cyclone Sidr in 2007 caused an estimated cost around 3 billion USD with damage to agriculture and thousands of lost lives (Harmeling, 2010).

In Bangladesh, crop and agriculture are highly susceptible to the climate change. Findings show that northwestern districts particularly Rajshahi and Chapai Nawabganj face crop damage problem due to drought and irrigation water scarcity while coastal regions have salinity and flood issues. Considering this, studies carried out in these regions are particularly focused on determining the climatic vulnerability of rice production and possible adaptation practices (Islam et al., 2017). Findings also depict that climatic variables such as temperature and rainfall play a vital role in determining rice production for Aus, Aman, and Boro rice. For Aus and Aman rice maximum temperature is conducive while minimum temperature is effective for Boro rice production (Sarker et al., 2014). In the case of rainfall, Aus and Aman rice thrive in rainy conditions while Boro rice does not have any significant relationship with total rainfall (Sarker et al., 2012). Climate change impacts the coastal community in shrimp cultivation in terms of reducing livelihood patterns, closing livelihood means, and reducing agricultural activities accelerates through the shrimp diseases, cyclones, and market malfunctions (Shameem et al., 2014). This particular problem is evident in coastal areas notably in Satkhira and Bagerhat districts.

Climate change has an extending impact on human health in Bangladesh. Particular health issues like the increasing cases of dengue and diarrhea/cholera incidences are more conspicuous in the Dhaka district. Coastal districts have also been observed with increasing cases of dengue, malaria, diarrhea, and typhoid fever too. Plausible health impacts related to climate change have been explained due to environmental and socio-economic conditions along with behavioural adaptations (Bickerstaff & Walker, 2001); (Mercer et al., 2012); (Daniel et al., 1994). Moreover, climatic variables like temperatures and precipitation are related to vector-borne diseases like dengue and malaria (Al-Amin et al., 2013). The case of increasing childhood diarrhea risk in rural Bangladesh is also significantly related to meteorological factors. On the contrary dengue transmission is also significantly associated with rainfall Wu et al. (2014) and Rahman et al. (2020). Witnessing cholera incidences in Bangladesh it has been perceived that a positive effect of EÑSO with 2 month lag in the fall period is significant (Pascual et al., 2000). Moreover, forced migration due to climate change consequences will make people unable to cope with urban environment and there will be increased cases of various water-borne diseases (Mojid, 2020).

Water security, which is more of a decreasing state of water security described in this study among many of the numerous challenges of water security, due to extreme weather events either in experiencing prolonged drought or soil salinity caused by cyclone, storm surge or tidal wave is common in Bangladesh which both results in drinking water and irrigation water scarcity. This persistent problem is more prevalent in coastal areas mostly in Khulna and Satkhira districts. Water shortages are acute both in agricultural use and drinking use in these regions. On the other hand for agricultural use shortages of water have also identified in Rajshahi and Chapai Nawabganj district. For this pressing problem Haque et al. (2020b) reported in few districts of Bangladesh after natural disasters safe drinking water was inadequately experienced resulted in health problems. The increasing number of natural hazards in coastal regions also explain this issue as salinity intrusion with storm surge and tidal wave incidences give rise to soil salinity, salinity intrusion in surface and groundwater which is propelling the transformation of freshwater resources and degrading agro-ecological condition (Shameem et al., 2014). As a consequence numerous agricultural problems are stemming from this problem and other subsectors of agriculture are also getting hit with salinity problems and farmers are experiencing reduction in soil fertility and water retention capacity, root and stem damage of crops, and various crop diseases (Rakib et al., 2019). It is evident that sea-level rising is causing acceleration of salinity intrusion both in surface water and soil in coastal estuaries. Comparing salinity affected land in Bangladesh in 1973 and 2000 was 83.3 million hectares (Mha) and 102 Mha respectively which has further been increased by 105.6 Mha in 2009. Projection estimates a mean increase of 26% salinity by 2050 and this increase will cause a shortage in freshwater along with loss in agriculture (Mojid, 2020).

Different regions in the Satkhira district namely, Munshigonj, Burigoaliny, Gabura, and Atulia unions were observed with notable drinking water scarcity. In all these regions people either had no access to pure drinking water or entirely dependent on contaminated water and as a natural source of pure drinking water people greatly rely on rainwater (Rakib et al., 2019). Combining all the impacts of climate change to understand a comprehensive spatial depiction in assessing the most vulnerable geography of Bangladesh coastal regions and their settlements are the true portrait of climate change victims in all regards. Moreover, being faced with serious complications in agriculture, health, and food security migration process appears not as a choice but to follow forcedly (Mojid, 2020).

5. Policy implications

This review paper was approached by considering the widespread impacts of climate change in Bangladesh and assessing the impacted sectors. A comprehensive spectrum of related sectors and areas was considered to review in this paper based on the available literature. To retain possible impacted sectors literature within the past 14 years was taken into consideration. In order to depict a broader view on the different sectors two broad themes were constructed and further stratifications were chosen based on the available literature. Moreover, spatial depiction of impact-creating variables makes it more conspicuous in terms of adopting policy measures and invoking further study. Policy prescription for this study can be viewed through four specific lenses. Firstly, bolstering adaptation mechanisms of indigenous communities is crucial. Adaptation mechanisms should be disseminated in agriculture, fisheries and livelihood, health, and infrastructure channels. Choosing and providing different adaptation mechanisms should not only be reflected in one side opinion, engagement and combination of both bottom-up and top-down vision is quite essential. For example, environmental factors explain that natural disasters, cyclone, flood, storm surge, sea-level rise, salinity intrusion, and land-use change are more frequent in coastal regions along with heavy rainfall, tidal wave, and temperature change. Necessary infrastructures either to enhance prevention mechanisms or to support emergencies are required to equip coastal regions to stand with negative environmental factors. Secondly, enhanced and revised Disaster Risk Reduction (DRR) mechanisms based on spatial vulnerability context different adaptation strategies are also important to reconsider. Reflecting back on Participatory Disaster Management Programme (PDMP), disaster and climate risk management are better to be handled with an increasing focus on management and prevention mechanisms while putting emphasis on adaptation to climate change. With a strong emphasis on preparedness for natural hazards capacity, knowledge, and infrastructure are required to boost and upgrade with climate change scenarios (Kelkar & Bhadwal, 2007). In this regard, Comprehensive Disaster Management Programme (CDMP) of the Bangladesh government also aims to provide greater focus on disaster preparedness and risk reduction programmes (MFDM & UNDP, 2015). Salinity/ salinity intrusion/ soil salinity is highly acute in Satkhira and Bagerhat districts. Farming and other agricultural subsistence along with safe drinking water are highly impacted due to salinity problems in these two regions. Better adaptation

mechanisms, diversified crops, and fishes with salinity tolerant species are required to introduce in combating the salinity problem. Existing projects on crop diversification and the generation of alternative employment opportunities at the community level should consider as important options in dealing with spatial climate vulnerability. Moreover, in promoting agricultural activities in the saline prone regions floating bed cultivation and practising sorjan system, cropping system with a series of constructed raised beds and lowered sinks, can be followed (Alauddin & Rahman, 2013; Sattar & Abedin, 2012). Thirdly, various local and national development plans should be aligned with geography-specific increasing climatic vulnerability circumstances. For instance, negative impacts of climate change on crop production are visible in Rajshahi, Bogra, and Chapai Nawabganj districts due to drought, temperature change, and lack of irrigation water. National Water Management Plan (NWMP) of 2001 should be reconsidered with geographic vulnerability context and improvement of the existing irrigation infrastructures are required to overcome crop damage situations (Habiba et al., 2012). On the other hand, shrimp and prawn farming is mostly disturbed in the Bagerhat district because of sea-level rise, rainfall change, and cyclones. Human health is mostly disturbed in Matlab, Dhaka district with diarrhea and cholera infection. Some coastal districts are also suffering from diarrhea, dengue, malaria, and typhoid diseases. Increasing rainfall, changes in temperature, and some cases sea surface temperatures are fostering the infection of these diseases. Harnessing city infrastructures and equipping households with a healthy environment and necessary sanitary facilities would help to put a bar on spreading these vector-borne diseases. In this regard, Integrated National Framework for Climate Risk Management (CRM) and Disaster Risk Reduction (DRR) should focus in understanding climate risks and impacts in all levels and initiate capacity building programmes with sectoral and cross-sectoral perspectives and implications (UNDP, 2007). Some socio-economic and human livelihood impacts of climate change like water security, loss of lives, and loss of livelihoods are also remarkable in coastal areas. Drinking water scarcity is highly noticeable in Satkhira and Bagerhat districts with the increasing salinity intrusion. Bagerhat district also experiences loss of means of livelihood due to frequent invasion of natural disasters. In coastal regions, safe drinking water provision management should be considered with great attention for both maintain good health and livelihoods. In accordance with National Adaptation Programmes of Action (NAPAs) socio-economic trends and livelihoods analysis approach is essential and specific sector vulnerability requires specific attentions from multiple stakeholders (Ministry of Environment and Forest. Government of the People's Republic of Bangladesh, 2005). Finally, institutional mapping and stakeholders' engagement to assess the climate risks and opportunities for capacity building should also be viewed with equal importance. All these policy recommendations should be guided by the views, needs and calls of the indigenous people and communities as better adaptation mechanisms, as we cannot halt climate change impacts, would require collaborative efforts among local communities and other institutions, such as government agencies and NGOs.

6. Future direction

Though this research is meticulously planned to capture climate change impacts in Bangladesh but there remains much that is unknown about possible other impacted sectors. Therefore, more comprehensive and elaborate research is required to plan and perform. Constraints of this research can further be considered to divulge a broad spectrum of impacted sectors of climate change in Bangladesh. This study only includes recent articles and most of which are quantitative in nature (30), and only seven studies relied on a mixed-method approach. Qualitative researches were excluded in this research which can be taken into consideration for further research.

The compatibility of PRISMA (a standard systematic review procedure usually deployed in health science) for this environmental research specifically climate change is a good fit however, it demands more standard systematic guidelines for directing future research synthesis (Berrang-Ford et al., 2015). Moreover in the case of qualitative synthesis critically and explicitly detailed reporting analysis methods can easily describe results with transparency and can allow furnished and diverse methods into the knowledge base (Shaffril et al., 2018). For more clarification in methodology and embellishing the qualitative synthesis the work of (Berrang-Ford et al., 2015) can be taken into account to leap forward in attempting future studies to understand the impacts of climate change. Furthermore, the future systematic review endeavour should maintain the following steps to overcome the constraints of this research and capture more significant results.

1. Research questions for future studies can be explored in terms of finding the significance of environmental impacts on a specific geography.
2. Methodology

As this study is only focused in quantitative and mixed method researches further study can consider:

- Include qualitative studies along with quantitative and mixed method researches.
- Findings from the included studies can further be explored in terms of establishing causal or correlational relationship among various impact creating variables.

Resources: Other rich and diversified databases can also yield a wide variety of research papers. In this regard Scopus, Web of Science, Embase, Publons can be considered.

1. Analysis and result presentation
   - In order to enrich findings for future studies a combination of systematic review and meta-analysis can help to reveal a clear picture with specific vulnerability and geographical context.

In addition, more precise and relevant keywords may be formulated for future study as systematic review, in most

cases, is highly relied on searching keywords through electronic databases, which is also the best searching method, but other supplementary methods can be followed in searching literature (Wohlin, 2014) and (Tsafnat et al., 2014). Furthermore, in order to capture a wide range of literature reference tracking procedure can be followed. In order to do that four important procedures can be maintained in retrieving relevant literature. First, explore the reference section of selected articles can produce related relevant articles (Horsley et al., 2009). This process can easily put the researcher in contact with relevant information. Secondly, citation tracking can also lead to the direction of related information. This process allows researchers to go both forward and backward in time. More importantly, this process catches up with research works that were beyond the key search limitation introduced by the researchers (Wright et al., 2014). Thirdly, snowballing of articles as same as citation tracking can produce effective information and retrieve more articles than manual search (Tsafnat et al., 2014). Finally, reaching experts to expedite the search process where literature appears ambiguous (Gøtzsche & Ioannidis, 2012).

7. Conclusion

This paper has discussed and highlighted the impacted sectors of climate change in Bangladesh. Based on the categorized themes, for this systematic review work on which the analysis was performed, two broad impacted areas were identified. Findings show that in Bangladesh climatic variables like natural hazards, temperature change, sea-level rise, and salinity are most prevalent. At the same time, all these climatic variables, directly or indirectly, are altering the scenarios in agriculture, health, and livelihoods of Bangladeshi people. In the agriculture sector crop and fisheries damage, in health sector dengue, diarrhea/cholera and malaria infection are prominent and lastly with these climatic impacts both lives and livelihoods are jeopardized. From spatial depiction, it is evident that coastal regions in Bangladesh appear to be more threatened with climate change scenarios mostly in environmental impacts and the associated threats and vulnerabilities it brings. Other geography like in the Dhaka district temperature and health impacts are high while some northwestern districts face problems in agricultural and water issues.

The findings of this study have practical implications for Bangladesh's climate change policies and programmes, such as the National Adaptation Programme of Action (NAPA) 2005 and Bangladesh Climate Change Strategy and Action Plan (BCCSAP) 2009. The spatial outcomes may guide policymakers in determining which geography is most vulnerable to climate change consequences and what adaptation actions are required to mitigate those impacts.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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