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The economic effects of climate change in Bangladesh: A mini review

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ABSTRACT

Climate change is a global issue, and it would mainly occur by natural processes. However, it is largely driven by human induced activities since the mid-20th century, and resulted adverse impacts on environment, health, and economy. Recently, climate change effect is no more an anticipation but become a reality manifesting its bleak clutches in many parts of the world. The depressing volatile climate hits many poor, filching their dreams of happy life putting them in the peril state. The present study attempted to peruse the recently published literatures related to the cause and effect of climate change on the economic sector of Bangladesh. The review does not include all-encompassing impacts rather focuses on the economic sectors upon which the sustenance of the local people depends. It is that revealed a future threat of frequent flood, cyclone, storm surges, drought, and salinity likely to be more severe, the notion of which already has become apparent. These hazards are projected to put the economy of the country at risk and impede the envious development ensued in the last decade. The implication of the study would aid in policy making strategy to cope the climate change effect of the country's economic sectors.

INTRODUCTION

Climate change is a globally concerning issue. The effect of climate change has globally drawn much attention of the scientists and policy makers in the recent decades. It occurs by both human-induced activities and the resulting large-scale shifts in weather patterns. The First World Climate Conference in 1979 brought the scientific evidence of changing the climate by human (Depledge and Lamb, 2005; Hossain et al., 2023), however, the severe consequences of climate change became clear exclusively after the formation of Intergovernmental Panel on Climate Change (IPCC) (Houghton, 2007; Nomani et al., 2022). It is now well recognized in the scientific and political arena that climate change consequently poses a serious threat to the developing countries with low adaptive capacities (Adedeji et al., 2014; Korman and Barcia, 2012; Stern and others, 2006; Timsina and Shrestha, 2014; Tol, 2008; Yohe and Schlesinger, 2002). Climate change has an adverse impact in all aspects of human development including livelihoods, food security, safe water and sanitation, health care and shelter. The developing countries are more vulnerable to climate-related extremes because of their limited adaptability to the occurrences of hazardous incidents (Pouliotte et al., 2009; Khatun et al., 2022).

Climate change is not remaining as a local issue now, local changes affect globally, thus it turns into a truly global issue with tremendous inferences to ecological, economic and health of the vulnerable people. Since the industrial revolution, shifting of atmospheric composition hasten the changes at a rate exceedingly more than the natural pace (Chen et al., 2021; Rahman, 2023). However, the causal propeller of climate change is complicatedly interlinked with a wide spectrum of effect on the environment that heightens the uncertainty. The possible penalties of abrupt changes in climate are augmentation of extreme climatic events that poses a serious threat to the developing countries particularly the poor non-industrialized countries are under increasing

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threat (Ruamsuke et al., 2015; Wheeler and Von Braun, 2013).

Bangladesh is one of the most vulnerable country due to the destructive history in the past. Many factors are responsible for it including its unique geography, low-lying plain and flood plains domination, highest population density, alarming levels of poverty and excessive dependence on nature. The effect widely felt is mostly on biodiversity, ecosystem, water resources, and human livelihoods in a cascading order (Xu et al., 2009; Dasgupta et al., 2018). It invariably affects the Socio-ecological Systems (SES) and their processes (Jongman et al., 2014) that provide fundamental needs directly or primary materials for society as food, fibre and fuel (Neil et al., 2005; Turner et al., 2003). These effects were exemplified by the cyclone Sidr of 2007 in the Southwest coast of Bangladesh. This cyclone caused massive destruction to the Sundarbans the largest single tract of mangrove forests in the world, collapsing millions of forest-dependent livelihoods and eventually mass emigration of people (Hoque et al., 2019; Shamsuddoha et al., 2013). The most affected sector of climate change is the agricultural sector (Auerbach et al., 2015; Gainetal, 2012; Hossain and Huq 2013; Huqetal., 2012). Indeed, weather change events worsening the livelihoods of small-scale farmers: those poor-poorest- and marginalized farmers via harming their indigenous knowledge based or traditional farming practices (Gainetal, 2012; Huq et al., 2012; Karim et al., 2012).

The influence of climate change is more likely to vary with the regions or localities, Bangladesh is not the exception. Most of the climate change impacts in Bangladesh are likely to come from the Southern part, that is, the Bay of Bengal and the adjoining North Indian Ocean (Chandio et al., 2022; Islam et al., 2021). The coastal area of Bangladesh consisting of 720-km coastline is a part of the flat Ganges Delta, which is intersected by large tidal rivers discharging into the Bay of Bengal (Allison et al., 2003; Rahman and Bhattacharya, 2006). The country's coastal zones and small islands are generally lying less than 3m above seabed and are extremely prone to climate–induced disasters for example flooding, cyclones and storm surges, and salinity intrusion affecting existing soil and water sources (Lauria et al., 2018; Mirza, 2003). The increasing Sea Level Rise (SLR) which is increased at least 2.5 mm per year in the Bay of Bengal since 1950 and an increase of 15 to 38 cm by 2050 will deepen the severity of cyclones and storm surges, and disrupt many aspects of existing water resources management and larger tracts of productive land (Kumar et al., 2002). Further, the levels of water salinity fluctuate in the coastal area in Bangladesh, due to seasonal rainfall patterns and upstream withdrawal of freshwater (i.e., the operation of the Farakka Barrage) during the drier months (Ahmed and Khan, 2023; Rahman and Ravenscroft, 2003). Integrated Regional Information Networks (2007) showed an increase of 45% river salinity in the Southern districts including Patuakhali, Pirojpur, Barguna, Satkhira, Bagerhat and Khulna since 1948 due to the saline water intrusion. It is likely to increase in the coming because of further reduced river flows, increased upstream withdrawal, and longer-term climate change–induced decreases in dry season rainfall and sea-level rise (Hossain et al., 2020; Khan et al., 2011).

Bangladesh is deltaic country, located at very low altitudes is mostly vulnerable to floods due to receiving the water from the three-world mighty river system, the Brahmaputra, the Ganges, and the Meghna originated in the upstream (World Bank, 2010; Raihan et al., 2022). The adverse climate change even pushed the country's seasons to reduce from six to three characterized by hot summer, short winter and moderate to high rainfall in monsoons (Denissen, 2012; Hossain et al., 2022). There are wide-ranging literatures providing expedient evidences and discussion of the numerous ways of climate change throughout the country (Bari et al., 2016; Basak et al., 2013; Islam and Nursey-Bray, 2017; Titumir and Basak, 2012; Vij et al., 2018). Of them, the majority of the literature focuses on trends of changes (Khan et al., 2019) and particular regions of the country considering a specific sector. Despite the list of published research articles on climate change impacts covering different sectors of local, sub-national and national levels are on rocket rise, no published study has mingled the prevailing knowledge available at different scales in the single form (Hossain et al., 2022; Rahman et al., 2018; Rahman et al., 2021). Methodically

analyzed and abridged knowledge from existing, often cross-scalar, scientific literature is paramount important in assessing the gap for further research attention (Ford et al., 2012). Although it is common in the developed country to synthesize existing knowledge (Arnell, 2010; Ford et al., 2011; Ford and Pearce 2012; Tompkins et al., 2010), the relevant equivalent researches are scanty in the developing countries like Bangladesh. The country has recently made considerable economic progress in the world (World Bank, 2019). With the help of a large influx of foreign remittance and big infrastructural investments, the country becomes a member of middle-income country by 2021. If she desires to do, it will require countering the major risk faces from climate hazards. Moreover, Bangladesh has stepped up its efforts to implement the Sustainable Development Goals (SDGs) and goal 13 calls for immediate action to check the climate change impacts as a major concern (Ceesay and Fanneh, 2022; Siddique et al., 2022). Thus, understanding the comprehensive aggregated information on the underlying causes of climate change along with its impact on economic sector of the country could lead to aid the policy makers to develop a pragmatic solution to tackle the possible change and thereby minimize the possible impacts. It can also be served as a leverage and argument in the negotiation table of international community to demand adequate funding to ensure climate resistant development.

In economics literature, the study quantifying the impacts of climate change on economic development has expanded notably over the last three decades (Nordhaus, 2017). Bangladesh declared Vision 2021 for her longer development and making the vision a reality National Perspective Plan 2010-2021 stated that: “Vision 2021 lays down a development scenario where citizens will have a higher standard of living, will be better educated, will face better social justice, will have a more equitable socio-economic environment and the sustainability of development will be ensured through better protection from climate change and natural disasters. The associated political environment will be based on democratic principles (Alamgir et al., 2021; GOB, 2012; Delaporte and Maurel, 2018; Reza et al., 2023). Several researches noted the devastating effect of climate change on economic and financial system of Bangladesh. As an agrarian country, severe effect on agriculture, a key driver of economy ultimately disrupts the livelihoods of dominating marginal farmers and all other developmental initiatives. In context of vulnerability, the evaluation of consequences on sector wise is foremost important to formulate a concerted action plan for mitigating the effect of climate change. Hence, the present study aims to write a mini-literature on the climate change and its consequences on various economic sectors of Bangladesh.

Climate Effects

The effects of climate change on Bangladesh economic sectors

Bangladesh is forming one of the largest deltas in the Earth comprising 147,570 sq. km area and belongs monsoon type climate (Rahman and Anik, 2020; WRI, 2017). The country is in the range of average temperature from 13 to 26 °C and 25 to 31 °C during the cool and hot season respectively, whereas the least and highest annual rainfall lies between 1400 mm per year to 3000 mm per year (BMD, 2020). In recent years, the climate of the country is behaving more unpredictable way (Hoque and Haque, 2016; Rahman, 2013). Shahid et al. (2012) and Shahid (2010) analyzed the temperature and rainfall patterns and found that average daily temperature has risen by 0.103 ^{0}C/ decade over the last 4 decades. The cool, dry season has also decreased in length (Chowdhury et al., 2021; Thomas et al., 2013). Several models adapted for climate study predicting that extreme events are likely to be more severe and frequent in future, and jeopardize the existing burden and make new risks for the soil and people of Bangladesh (Table 1).

Table 1: Some future climate change scenarios in Bangladesh (World Bank, 2010a)

Year	2020	2050	2100
Sea level rise	10 cm	25 cm	1 m
Land below SLR	2% of the total land area (2500 km^2)	4% of land (6300 km^2)	17.5% of land =25000 km^2
Salinity intrusion	Increase	Increase	Increase
Flooding	20% increase	Further increase	Both flood intensity and inundation area will increases severely. Devastating flood may result crop failure for any year.
Drought	Increase	Increase	Increase

Climate stresses: Current and historical perspectives of Bangladesh

The study used historical time series data for temperature and rainfall to envisage the variations and to project the future changes. The data clearly projected the future increase of temperature of 0.5 ^{0}C by the next 30 years (Figure 2). At the same time, rainfall data also projected a decrease by about 10 mm (Figure 1). The data showed an uneven distribution of rainfall throughout the periods of between 1901 and 2018 even though it might hide the real scenario of the weather that has record of being erratic. Total rain could be the same in a year but excessive rainfall for successive days or without rain for some months resulted in severe flood or drought respectively.

While floods are common in major parts of the country, northern parts experiences seasonal drought in November to December due to uneven distribution of rainfall (BMD 2020; Xenarios et al., 2014). The country has been experiencing such erratic pattern of extreme events in the last few decades that is attributed to the climate change by many researchers (Rahman et al., 2018; Sarker et al., 2012). For future projections, several models have been used to predict the change in climate systems of Bangladesh (Agrawala et al., 2003; Immerzeel, 2008; May, 2004). May (2004) conducted a study on tropical Indian Ocean's rainfall pattern and predicted increasing tendency of heavy rainfall events in Bangladesh. While Immerzeel (2008) projected seasonal rainfall increases for the period of 2000 to 2100, with more increases in the monsoon season (June-September) compared to other seasons. In comparison to 2010, it has been predicted that mean annual temperatures is increased by 1.8°C and 2.7°C by the 2060s and 2090s respectively (Karmalkar et al., 2012; Kais and Islam, 2018). Again, Bangladesh is expected to be wetter 4% more by 2050s (World Bank, 2010a). However, mixed projections for the dry winter season where rainfall decreases (Khatun and Islam, 2010) and in some models predicted increases of about 10% by the 2070s (Roy et al., 2009). Overall higher temperature and erratic rainfall resulted ecosystems degradation and wetlands drying up (Al Mamun and Al Pavel, 2014; Nadiruzzaman et al., 2021).

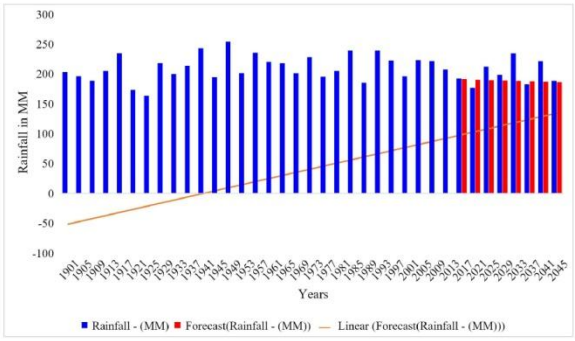

Figure 1: Average rainfall of Bangladesh in different years (Compilation based on data collected from World Bank online database).

Climate hazards appeared to be a common disaster in Bangladesh, frequently hit the country's economy. In between 1999 to 2018, there were 191 hazard events took place in Bangladesh that claimed hundreds of thousands of deaths,

destruction of households, forest and agriculture (Eckstein et al., 2019). In 2012, an estimate showed that the climate induced damages in the previous three decades incurred an appraised loss of approximately $16 billion (Rahman et al., 2021; The Asia Foundation, 2012).

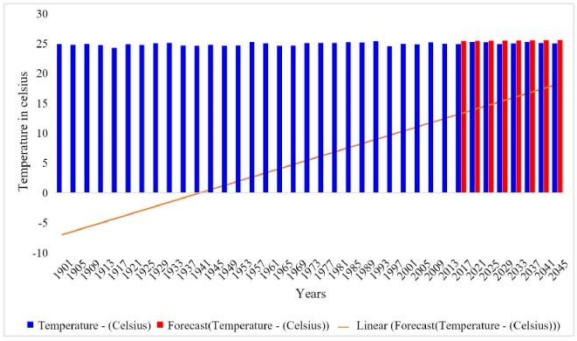

Figure 2: Temperature (Celsius) of Bangladesh in different years (Compilation based on data collected from World Bank online database).

According to global climate risk index 2020 (Eckstein et al., 2019), Bangladesh is mostly affected country secured the 7th in ranking with respect to risk index. Average weighted ranking of long-term Climate Risk Index (CRI) based on the last two decades effect, the country is just after Dominica, Nepal and Thailand. Death toll in Bangladesh is just after Myanmar. In Myanmar, a sudden catastrophe, cyclone Nargis in 2008 killed 95% of the damages and fatalities of the last two decades making the country mostly affected than the regular climatic hazards exposed country Bangladesh (Kais and Islam, 2019). According to Notre Dame-Global adaptation Initiative (ND-GAIN) data of 2020, Bangladesh is one of the most vulnerable countries, country rank is 162, vulnerability score 0.546 and readiness score 0.267.

Bangladesh has little improvement in vulnerability, and only around 7% reduced while readiness increased over the same time by 9% (Figure 3). Readiness reflects how much country is prepared in terms of economic, social and governance to curb the effect of climate change by adopting different adaptation measures. Despite the several efforts and initiatives taken by government, Bangladesh is still behind the India in terms of climate sensitivity (Hadi, 2019; Mojid, 2020). The results indicate that country is till far-reaching away from the pragmatic efforts to reduce the vulnerability, sensitivity and increase the readiness to face the challenge of climate change consequences.

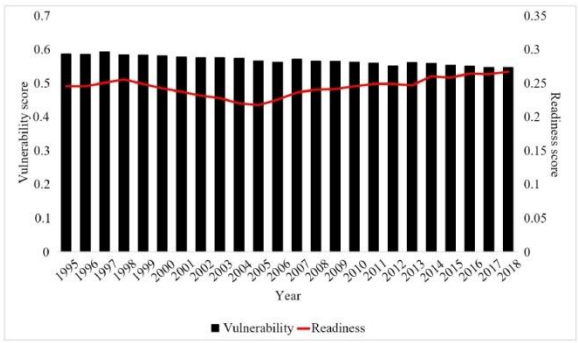

Figure 3: Vulnerability and Readiness score of Bangladesh (Data retrieved from ND-GAIN)

Who are to blame for Climate Change: Global and Bangladesh perspectives

There have been numerous dialogs on who to be blamed for climate change? Developing country or developed country? Though we do not have straight forward answer, the simple perception is that all countries share the blame, responsible for endangering the environment and leaves it in peril condition for coming generations. Yet, it is manifestly clear that industrialized developed countries are responsible for the lion's share of committing unexpected changes in the climate (Figure 4).

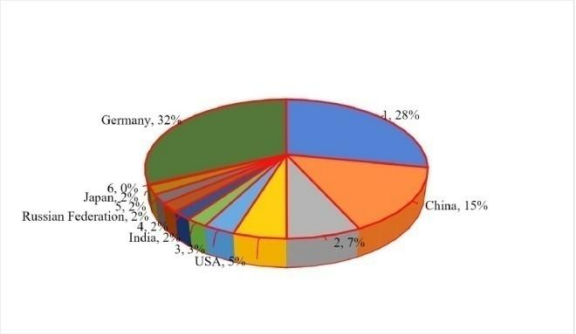

Figure 4: Bangladesh and the top ten countries that emitted the most CO_2 in 2018 in the world (Compilation based on data collected from World Bank online database).

At least publicly available data from emission database for global atmospheric research, an EU science hub of European Commission is the evidence supporting the argument. Latest publicly available data of EDGAR for carbon footprint showed that China emitted highest CO_2 (28%) followed by USA (15%) and India (7%). Bangladesh shared only 0.22% of the total CO_2 emission, one of the lowest in the globe even though the country is the most sufferers of the consequences of such notorious gas emission by the industrialized country. When worldwide humanitarian network the International Federation of the Red Cross and Red Crescent Societies (Alamgir et al., 2018; IFRC, 2009) stated that environmental refugees are more than political refugees now, the United Nations High Commissioner for Refugees (UNHCR, 2016) estimated that due to natural disaster at least 50 million people will be displaced worldwide by 2050. However, the historical data showed the rise of emission of notorious gases in Bangladesh since 1990 (Figure 5). Sector wise emission data of Bangladesh showed that Agricultural sector emitted maximum CO_2 (83.56 MT) followed by Electricity and heat generated sources (36.3 MT) and input from the industries of the country was only 9.12 MT (Figure 6). Thus, unambiguously it can be inferred that Bangladesh is bearing the burden of the climatic affliction brought by other developed countries. When the debate comes about the liability, the argument would come to an unpleasant end (Hossain and Majumder, 2018; Sarkar et al., 2019).

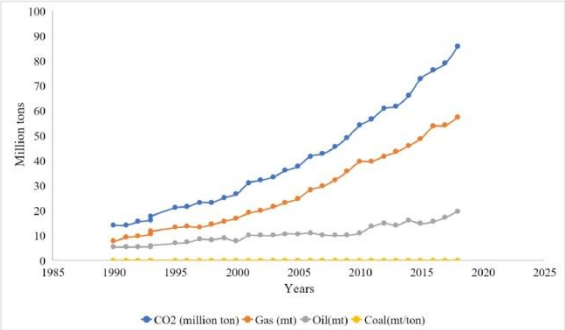

Figure 5: Annual CO_2 emissions and major contributing fuel of Bangladesh (Compilation based on data collected from World Bank online database)

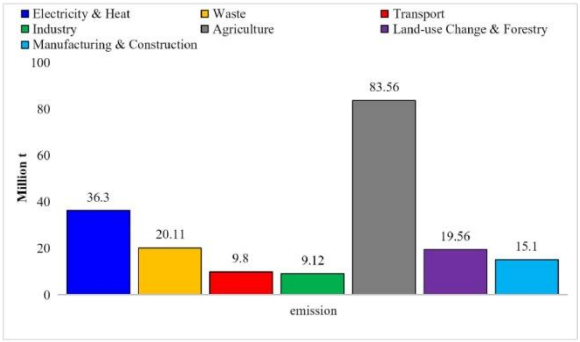

Figure 6: Greenhouse gas emissions by sector of Bangladesh in 2016 (Compilation based on data collected from World Bank online database)

Extreme climatic hazards

The country constantly faced with the various kind of climate hazards such as floods, cyclones, heat waves, cold waves, droughts, storms, hail storms, shoreline recession, tidal surges, salinity intrusion, riverbank erosion and relative sea-level rise. However, climatic hazards that directly addressed or associated within the perspectives of Bangladesh have been grouped into: rainfall-driven, wind-driven, temperature-driven and multiple processes driven (Murshed and Saadat, 2018; Roy and Haider, 2019) in the following discussion.

Rainfall-driven climatic hazards

In Bangladesh, rainfall acts as a primary driver for hydrological processes (Chowdhury and Ward 2004; Sarker et al., 2019). Related studies indicates different percentage of annual rainfall during the rainy season, to exemplify, approximately 72% (Ahasan et. al., 2010), more than 71% (Ayesha et al., 2016; Shahid 2010a), more than 75% (Hossain et. al., 2014) or about 85% (Roy, 2013) of the country's total rainfall. The annual rainfall of the other seasons is winter (2%), summer (19%) and autumn (8%) in Bangladesh (BMD, 2020). The rate of yearly mean rainfall increment is about 5.5 mm/year and the maximum increase (16.5 mm/year) is observed in the northern region (Ayesha et al., 2016). However, rainfall uncertainties including frequency and intensity lead to makes rainfall-driven climatic hazards.

Floods

Bangladesh is a country that has a unique setting for flooding incidences. In a detailed literature review, Masum (2019) found that 60% of the total land is exposed to minimum one extreme flood hazard in every decade, and about 64% of the total coastal region is harmed by upto 90cm seasonal shallow flooding (Minar et al., 2013). Empirical examination by Mirza et al. (2003) predicted that flooding is both deeper and wider in future, such as 6% by 2030s and 14% by 2050s in Bangladesh. In response to such projections, Bangladesh would require US$5.7 billion by 2050 for total adaptation to inland monsoon floods and storms (World Bank 2012). The major floods impacts (damage) were estimated as $378 million in 1984, $1.0 billion in 1987, and $1.2 billion in 1988 (MoDMR, 2020).

Droughts

Historical data set and remote sensing techniques for drought studies showed that Bangladesh is exposed to drought hazard on an average of 2 to 2.5 years (Hossain et al., 2019; Mondol et al., 2017). Their findings reinforced by the study carried out by Rahman and Lateh (2016) that drought had occurred 29 times in Bangladesh during the 1950–2011 periods. The extreme drought events in Bangladesh after independence is shown in Table 2. Karim and Iqbal (2001) produced drought risk map where northern, north-western, and south-western regions of Bangladesh is more prominent for drought.

Table 2: Extreme drought events in Bangladesh (After 1971) (FAO, 2007)

Year	Impacts
1975	affected more than half of the population and 47 % of total area.
1978-79	reducing rice production by about 2 million tons and directly affecting about 42% of the cultivated land and 44% population.
1982	loss of rice production around 53000 tons while wheat damaged about 36000 tons
1989-90	Loss 3.5 million tons of rice production; rivers in Northwest Bangladesh dried up and with dust storms in many districts.
1994-95	Severe damage of rice, jute and cash crop (bamboo mostly in Northwest region)
1995-96	again northwestern region affected
2006	about 25-30 per cent rice yield reduction in Northwestern part.

Land slide and Subsidence

It has been calculated that 12 extreme landslides hit southeast hilly region of Bangladesh during last five decades (Sarker and Rashid, 2013). Flash floods and mud-slides due to heavy rains caused loss of 130 people in 2007, and after 10 years other landslides in the same regions killed at least 152 lives (Ahsan et al., 2013; Nomani et al., 2022). On the other hand, coastal regions of Bangladesh faces 5.6 mm/year average net subsidence rate (Masum, 2019).

Wind-driven climatic hazards

Wind direction and wind speed are the main causal factor of the damage and deaths by wind- driven climatic hazards.

Cyclones, tropical storms and storm surges

Several research reports have been noted that out of 07 cyclones and depressions that cross the coast of Bangladesh per year at least one struck in every year, and one severe cyclone had occurred in every 3 years (Ahammad et. al., 2013; Quader et. al., 2017). Ubydul et al. (2012) found that 718,000 peoples lost their lives by 18 severe cyclones during 1960-2007 periods. Wherein, the 1970's and 1991's tropical cyclone was the deadliest two, which had a death toll of up to 300,000 and 138,000 respectively (Mallick et al., 2011; Rahman, 2023). Strom surge height and wind velocity further worsen normal life by increasing the cyclone high-risk areas in Bangladesh by 35% and 40% in the 2020s and 2050s respectively (CEGIS and DoE, 2011).

Tornados, windstorms, hailstorms and lightning

Over the period of 30 years, there are 191 tornados averaging 6.3 tornados/year had struck caused 5,373 human life deaths in Bangladesh (Masum, 2019). Besides, local convective wind storm triggered death toll upto 80 along with 1000 injury and makes homeless thousands of people yearly (Peterson and Dewan, 2002; Yamane et al., 2010). Though hailstone is not a frequent phenomenon, but an incidence of hailstone had killed 92 people on 1984, and worldwide heaviest hailstone

(1.02kg) recorded in 1986 in Bangladesh (Ismailov, 2014; WMO, 2017). Additionally, lightning fatalities reached on an average 300 people every year in this country (Biswas et al., 2016; Ceesay and Fanneh, 2022).

Temperature-driven climatic hazards

In Bangladesh, the overall temperature rise will be higher in future than the present (Tanner et al., 2007), and depressed living standards of approximately 134 million people (World Bank, 2018).

Sea-level rise

CCC (2016) projected that the rate of relative sea-level rise of the Bay of Bengal (5.05–10 mm/year) has been much higher than global mean sea level (3–3.4 mm/year) rise. According to World Bank (2000), 2%, 4% and 17.5% total land as of Bangladesh may be affected by 2020, 2050 and 2100 respectively.

Heat waves, cold waves and dense fog

While Hannah et al. (2017) has recorded 39 heat-wave days during 1989 to 2011 periods, Sarker and Ahmed (2015) expected to increase cold waves and dense fog in future in the country.

Multiple processes driven climatic hazards

Volume of scientific research supports interaction of multiple climate variables (i.e., temperature, rainfall, and wind) increase the extreme climatic events. Such as-

Salinity hazards

Bangladesh has experienced from 2 to 10 times river salinity increase between 1970 and 2010 periods (Hossain et al., 2015), and more than half (53%) of the coastal regions have already been affected by that salinity (Dasgupta et al., 2014). In future, the land area exposed to high salinity will increase around 24% and interrupting traditional practices around 14 million people by 2050 (Baten et al., 2015; CEGIS and DoE, 2011).

Erosion

In connection with economic losses, riverbank erosion is deemed to be the most deleterious hazard in Bangladesh (Penning-Rowsell et. al., 2013). It displaces nearly 200,000 people from 20 (32% of the country) of the total 64 districts of Bangladesh in every year (CEGIS, 2012).

The urban dimension of climatic hazards

A number of studies suggest that climate change will lead to multifaceted environmental degradation in urban areas: floods and heavy rainfall induced waterlogging, cloudburst, groundwater depletion and urban heat waves etc. (Araos et al., 2016; Black et. al., 2013; Jiang et al., 2018). In Bangladesh, the rate of population migration from rural area at about 0.53% per year, then such unmanaged expansion hampers the economic function of urban areas (Masum, 2019).

Economic nexus of climate change

In relatively recent years, a huge body of literature has exerted their efforts to quantify the impact of extreme climate events on economic activity provide with the long-run and short-run consequences (Cashin et al., 2017; Hsiang 2016; IPCC, 2014) and surveys by Dell et al. (2014) and Tol (2009). A number of literatures have also tried to evaluate the costs of zero mitigation and benefits of policy implementation on climate change (Millner, 2013; Revesz et al., 2017).

It is now well-settled that individual to community, city to country is experiencing the reality of climate change around the globe. The broad spectrum effects of climate change puts economic sectors of many countries at the risk, pushes the people to the insecurity of food and habitat. As a direct consequence of more than 12000 intense climatic incidents, between 1999 and 2018, about 495000 people have eroded worldwide and US$ 3.54 trillion (in PPP) losses were incurred (Chandio et al., 2022; Eckstein et al., 2019). Slow-onset processes will add an additional burden in the future. The Adaptation Gap Report prepared by UNEP (2016) warned that global adaptation costs much more higher in future due to slow–onset process: It can be two to three times higher than current global estimates by 2030, and potentially four to five times higher by

2050". Similarly, the IPCC estimates in its recent Special Report on "Global Warming of 1.5°C" that the "mean net present value of the costs of damages from warming in 2100 for 1.5°C and 2°C (including costs associated with climate change-induced market and non-market impacts, impacts due to sea level rise, and impacts associated with large scale discontinuities) are US$ 54 trillion and US$ 69 trillion, respectively, relative to 1961–1990" (Eckstein et al., 2019; Hossain et al., 2020). In-depth regional study by Woetzel et al. (2020) summarized that about US$ 1.2 trillion capital stock are at risk of flood, which further jeopardized between US$ 2.8 and US$ 4.7 trillion of Gross Domestic Product GDP per year by 2050 in Asia. Additionally, they find that Asian nations must need to invest annually US$1.7 trillion in infrastructure development through 2030 due to adversity of climate change.

Climate change will influence the growth of national economies and eventually levels of livelihood by many channels. Kahn et al. (2019) carried out a cross-country analysis for long- term impact of climate change on economic performance using stochastic growth model and panel data set of 174 countries over the 1960-2014. Their results indicate that Climate change could affect the output level through reduced investment and decreased labour productivity in most economic sectors. Such prediction supports by the empirical study (Horowitz, 2009) where higher temperature negatively related with the income, and Brown et al. (2011) projects large variability in precipitation could reduce the long-term economic growth and trap people in poverty in poor countries. Unfortunately, research on climate change believed that 80% of the damages may be concentrated in developing countries (Mendelsohn et al., 2006). The projection is reinforced by several researches (Felbermayer and Groschl, 2014; Klomp, 2016; Panwar and Sen, 2019).

However, in line with much of the literature, climate change poses significant risks to some sectors lower output due to direct impacts of climate variability, then other sectors must reduce output because of transfer of effects through the intermediate inputs markets (Haque, 2006; Zaman and Islam, 2012). According to Asian Development Bank (ADB) during the 2040-2059 periods, Bangladesh will lose 36.49% of its GDP per capita to climate change (Auffhammer, 2019).

In Bangladesh, two of the economic indicators, GDP and Consumer Price Index (CPI) are anticipated to be severely affected by the consequence of climatic change (Islam et al., 2020; Raihan 2014). Eckstein et al. (2019) showed the losses per unit GDP (%) in mostly affected countries in 2018 as Dominica 20.8%, Nepal l0.4%, Thailand 0.87%, Bangladesh 0.41%, Vietnam 0.47%, Pakistan 0.53%, Philippines 0.57%, Haiti 2.38%, Myanmar 0.83% and Puerto Rico 3.76%. The author used ADB (2011) data to predict the country's GDP that shows to fall by 4.3% to 8% by 2030 and 2100 respectively (Figure 12). Likewise, Raihan (2014) showed an increase of consumer price index by 2.5 to 6% over the same period.

One study for Bangladesh showed that due to the lack of ability to face the challenges about USD 2.7 billion of investments out of USD 4.7 billion national budget were at risk of implementation properly due to climate change (Hedger, 2011; Rahman et al., 2019). Such estimation reflected by World Bank (2010a) findings that between 1980 and 2010, the government invested US$ 10 billion for physical development to increase the resilience required further investment each year. A report submitted to World Bank by Dasgupta et al. (2010) estimated more than USD 2.4 billion with an yearly recurrent cost of USD 50 million for strengthening the physical and non-physical infrastructure like polders, afforestation, shelters, housing, early warning. Government spends 6%–7% of the total annual budget for mitigation and adaptation of climate changes (UNEP, 2013) though it is insufficient, need to increase 5 to 6 folds (MoFA, 2018). Forthcoming effect of climate change would be a menace on the economic sector of the country, predicted to incur huge losses of GDP, the loss of which might be an excruciating affliction for the socioeconomic structure of the country (Golub and Golub, 2016). If economic sector is severely affected, it would affect the resilience in the long run. The more GDP the better resilience the less impact. An estimated damage of US$2 billion by adverse climate effect could induce 2.6% loss of GDP that

is much higher than a rich country like for 2.6% of GDP on which same havoc may incur 0.14% of GDP loss (Ahmed and Khan, 2023; WDI, 2016).

Climate change and sectoral economics

In this review, it has been evident that knowledge has emerged to analyze empirically and theoretically the link between climate change and major economic sectors. After applying the screening described in the methodology, 18 articles from the empirical, theoretical and special reports literature were identified and selected to explain the nexus between climate change and economy. All these publications proposed (either explicitly or implicitly) hypotheses with the sense that climate change affect sectoral economics, and available evidences supports those assumptions. Thus, this study focusses only on those results identified in reviewed literature.

This inescapable effect can be observed in every aspect of the economic structure of Bangladesh starting from procuring raw materials to distribution of end products to the consumers. The impacts will work in multiple ways such as increasing poverty, reducing production, loss and damage of productive lands as well as reduction in economic activities. Although burden will not share equally, significant economic sectors like agriculture, fisheries, manufacturing etc. exhibit momentous transformations due to climate change.

Gross domestic product losses

The monetary cost of climate change is measured in terms of GDP and expected to be very high. A study (Yu et al., 2010) using General Circulation Model (GCM) demonstrated that climate change associated with a pronounced detrimental impact on GDP in Bangladesh. On the contrary, ADB (2014) estimated by integrated assessment model, for 1990 to 2008, average extreme climate event-related losses amounted to 1.8% of GDP per year in Bangladesh, and to compensate such decrease in real GDP, the investment-GDP ratio would have to increase an additional 0.03% in 2030, 0.075% in 2050, 0.17% in 2080, and 0.23% in 2100.

Agriculture, fisheries and livestock sector

Climate change will significantly reduce the crop yield, and it has already been recorded in the coast-zone in Bangladesh during dry period (Baten et al., 2015; Clarke et al., 2015) and details is shown in (Figure 7). For instance, coastal land contributes for the 20% of the total rice production, but salinity caused 20%–40% yield loss throughout the year in those areas of Bangladesh (Bala and Hossain 2010; Hoque and Haque 2016; Tanzinia 2016; Zahangeer et al., 2017). Moreover, IPCC (2001) assessment for future predicts that rice and wheat production would likely to be decline by 8%–17% and 32% by 2050 compared to 1990 base year in Bangladesh. Additionally, Rahman and Rahman (2015) found that Southern region of Bangladesh may lose 40% of productive land by 2080 due to sea-level rise induced hazards.

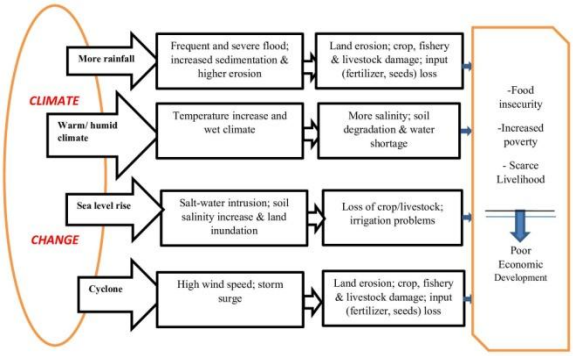

Figure 7: Climate Change Impacts on Agriculture (Source: Authors' elaborations)

The fisheries sector contributes to 3.65% of the GDP in Bangladesh and helps to provide livelihood for more than 12 million people of the country (Chowdhury et al., 2010; DoF, 2016). However, climate change elevating the stress on fisheries resources due to loss of critical habitat, which could affect the level of poverty (Wilson, 2006

Equally important, livestock sector represents less than 3% of GDP, but 20% of inhabitants directly depend on this sector (MOFL, 2019). It is predicted that Bangladesh may loss 5% of milk production and 20% of grazing land by 2050 (MOEF, 2012). Additionally, climate change aggravated cyclones and floods can kill several thousands of cattle, like Cyclone Sidr killed 1.8

million head of cattle in 2007 (Hoque et al., 2022; Khan et al., 2023).

Amplification of climate-sensitive diseases

The information screened for this review showing a palpable shortage of climate-health nexus study in Bangladesh. Researchers forecast climate change will accelerate the burden of climate-sensitive diseases such as dengue, cholera and malaria (Islam et al., 2022; Mahmood, 2012); while droughts lead to rise the levels of gastrointestinal diseases and dysentery (Deyetal., 2012), then drinking water salinity presents higher risk of hypertension particularly among pregnant women and young adults in coastal Bangladesh (Khanetal., 2014; Nahian, et al., 2018; Talukder et al., 2017). After Sidr (cyclone in 2007), an assessment by the Bangladesh Government (2008) found a widespread outbreak of respiratory and waterborne disease, and other related infections. Such adversity makes people less productive that undermines overall socio-economic development (IUCN and UKaid, 2016; Raza et al., 2023). Similar evidence illustrated by Kabiret al. (2016a) from a cross-sectional study using multistage cluster sampling framework that health care expenditure increased after the extreme weather events in Bangladesh.

Forest and biodiversity

The share of GDP contribution from the forestry sector in Bangladesh accounts for around 3% and employed 2% of labour force, but GDP figure does not count the value of non-timber forest products (DF, 2020). Academic evidence demonstrated that multiple components of climate change likely to adversely affect forest biodiversity, carbon sink, biomass productivity, and the well-being of forest dependent communities (Chaturvedi, 2016; Hossain et al., 2022). Thus, Bangladesh would need an additional 75 million USD for forestry to adapt climate related disturbances by 2050 (World Bank, 2010).

Tourism

Bangladesh Tourism Board offers at least 43 destination based tourist spots (BTB, 2020), predominantly characterized by outdoor and nature tourism. However, their scenic beauty as brand image negatively affected because of climate change impacts and extreme events (IUCN & UKaid, 2016). Also, loss of tourism infrastructures, damage to roads or lowering the beach will require re-defining tourist seasons or re-orientation in tourist spots (Hossain and Wadood, 2020). This imposes greater challenges affecting directly on economic activities, particularly employment outcomes for local residents (Denissen, 2012).

Escalation of poverty and livelihood vulnerability

Economic impacts of climate change lead to a possible rise in poverty in Bangladesh (Akram, 2012). An estimate by IIED (2019) informed that rural community of this country cost around 2 billion USD per year in terms of prevention or to repair the damage related with climatic events. Moreover, spending money away from primary fundamentals like food, schooling and medical could push peoples to further vulnerability (Alametal., 2017; Hossain et al., 2022). However, all the regions do not share the same burden, but riverine families are struggling most where almost 46 million people depends mainly on natural resources for their livelihood (Lein, 2010). Those poor but affected people borrow from informal sectors at higher interest rate makes them poor to poorer (Akter and Mallick, 2013; Khatun et al., 2022).

Special Vulnerable Group

In Bangladesh, women disproportionately affected to the impact of climate change than men, as they have limited access to resources and critical knowledge that are needed for mitigation and adaptation (Mondol, 2014; Raihan et al., 2022). The country's national plan for disaster management acknowledges vulnerabilities of women in particular (The Economist Intelligence Unit Limited, 2014). Also, extreme weather-events affect women's ability to take part in economic function by lowering their income sources from traditional practices like home gardening etc. (Ayers et al., 2014). Such inequality limits women's participation adequately to adapt climate

disasters and overall economic growth (Alam and Ahmed, 2008; Islam et al., 2019).

DISCUSSION

In Bangladesh, despite the gravity of climate change effect is immensely highlighted in scientific arena, there is a huge gap between the scientific study and policy making processes to address the consequences of the effect. To increase the knowledge capacity planning, policy formulation and institutions mainly focusing extreme event forecasting, awareness creation and rehabilitation are taking shape in the country. However, there are some policies, which could clash with the responses to climate change, like encourage tourism in vulnerable coast might add risk (Agrawala et al., 2003; Chowdhury et al., 2022). In addition, limited capacity, limited participation of stakeholder, lack of coordination and corruption impede the effectiveness of governmental climate change interventions (Aberman et al., 2011; Delaporte and Maurel, 2018). However, weakness for priority identification and inadequate resilience assessment tools makes the road long in terms of sustainable and effective implementation is widely felt in this review. Although Bangladesh will not be the only victim of climate change consequences, most of the studies covered in this review foresee the grueling effect that has already been appearing in the country (for instance: Dasgupta 2014, Holle 2010; Hossain et al., 2019; Quader et al., 2017; Rahman and Rahman 2015; Sarkar and Ahmed 2015; Sarkar and Rashid 2013). A significant portion of the research has considered damage and losses from flood and intensified cyclone (Dasgupta et al., 2014); but very little studies were undertaken on drought, to explore the population migration-climate change link and groundwater salinity matter. On the other hand, sea level rise emerges as a big concern in the thematic areas of research for Bangladesh delta. The recent science available assumed two major effect of sea level rise for present and future Bangladesh (Faisal and Parveen 2004; Jisan 2018; Lauria et al., 2018). The first one is sea water intrusion that underlies the delta's freshwater aquifers and the second is significant increase in the frequency and severity of inundation.

Geographical features of the country along with its demography and reliance of many livelihoods on weather-sensitive economic sectors compounding the climate change effect to many folds in multifaceted sectors. Empirical results show that climate variability eventually have long-lasting adverse impact of this country's level of economic growth and development (Islam et al., 2021; Yu et al., 2010). In the same vein, predictions from different models consistently reveal that agricultural production in terms of quantity and quality is vulnerable to climate change and can thus cause important changes in farming outcomes (Bala and Hossain 2010; Qianetal, 2019). In addition to new infectious diseases and loss of human lives, human displacement due to the loss of land looks set to exacerbate already overcrowded and impoverished living conditions in urban areas. Cumulative effect of climate change affects the country's forest eco-systems that resulting negative consequences for forest-resource dependent communities. Bangladesh has significant task in front to manage present and upcoming weather-challenges in the tourism sector to opens up a new impetus to the country's growing economy. However, it is still open for discussion that climate sensitive women needs special attention to incorporate into the mainstream economic function. Moreover, climate change impact reduces the ability of private sector and especially, for micro, small and medium- scale enterprises which create jobs and thus, mitigate poverty while fostering economic growth. Also maintaining disaster-damaged infrastructure would divert limited revenue from productive investment to climate response.

However, the whole country is not homogeneously affected; but the coastal areas are severely victimized. The inhabitants of this area were forced to change their occupations from farmers to some floating jobs or compelled to sell their labours. Even in extreme cases many families have been migrating to other areas as adaptation strategy leaving their ancestral properties due to their incapability of bearing the arduous effect of weird climatic patterns. Besides, adaptive capacity also differs within the vulnerable region. A study conducted by Xenarios (2014) compare the saline flood prone southern part with the drought sensitive northern part by integrating socio-

demographic and agro-economic indicator and found that southern regions are more vulnerable to northern regions to climate change.

In the light of growing risk that poses to Bangladesh, the government has responded through a range of plans, strategies, and institutions to identify and help the key areas of economies, ecosystems and societies that are susceptible to climate change cases. However, there is still need to identify potential adaptation and mitigation mechanisms for betterment of the people of this soil.

CONCLUSION

This document provides an observation of the existing instance concerning the broad and categories impacts of climate change in Bangladesh. Public data evidently signify that the country is not liable for the adverse change of climate rather become a scapegoat of the detrimental effect mostly has brought by the industrialized countries. Bangladesh is one of the most adversely affected country experiencing the effect on prominent economic sectors apart from the effect on biodiversity, health and sanitations. Most striking effect is on the agricultural sectors, the heart of rural economy of the country that has been upended the livelihoods of the rural community. The recent climatic pattern such as change of seasons, increase of flood and cyclone frequency, and sea level rise of the Bay of Bengal is the major convulsion to our economy for which the scientists, policy makers and mass people are in anxiety. The huge concern is that the country's readiness score is very poor in compared to its vulnerability score as reported in ND-GAIN database. If significant improvements are not seen in the preparedness to curb the changes or its associated effect, the GDP and consumer price index are projected to be severely affected in the upcoming years. Thus, taking consideration of the various detrimental consequences of climate change on the economy of the country, the policymakers should urgently take the necessary strategic plan reviewing the existing one.

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Conflicts of interests

Theauthorsdeclarethattheyhavenoknowncompeting financialinterestsorpersonal relationships that could have appeared to influence the work reported in this paper.

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