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Title: Climate Change Effects on Fisheries and Crop Production in Bangladesh: An Econometric Analysis

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ABSTRACT

This research paper presents an econometric analysis of the effect of climate change on fisheries and crop production in Bangladesh, as well as the associated economic losses. The study utilizes annual time series data from 1971 to 2020 and employs various econometric tests. The results reveal that average rainfall, minimum temperatures, and greenhouse gas emissions positively influence fisheries and the production of crops like rice, potato, and jute. Sufficient rainfall and warmer minimum temperatures play a role in boosting fishery and crop yields, while the release of greenhouse gases enhances the rates of photosynthesis and water use efficiency, leading to increased production. Conversely, floods, high temperatures, and changes in arable land area have adverse effects on fisheries and crop production. Floods submerge crops, disrupt fish migration and spawning, and damage fish farms and ponds. Infrastructural development and residential construction negatively affect on fisheries and crop production. The increase in maximum temperature leads to water scarcity and intense weather events, further impacting fish and crop production. Climate change-induced floods cause significant financial losses for farmers, while higher temperatures escalate pest control expenses and alter rainfall patterns, impacting profitability and fish populations. It results in a decline in crop yields, affecting daily wages and consumption, and increasing the financial burden on small-scale farmers. Climate change consistently affects Bangladesh's GDP, will pose harm to agricultural net trade from 2020 to 2050.The fisheries and crop sectors have experienced substantial financial losses over the past decade due to climate change. The study shows that the urgency for preventative action and policy interventions to mitigate the adverse effects of climate change, safeguard livelihoods, ensure food security, and promote sustainable economic development of Bangladesh.

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INTRODUCTION

Climate change is an overarching global occurrence that is widely acknowledged as a significant environmental concern in the current era. Climate change poses a significant concern for both developed and developing nations, with the agricultural sector being particularly vulnerable to its effects (Mackay, 2008). Among nations, Bangladesh stands out as particularly susceptible to the hazards posed by climate-related risks and natural calamities (Agrawala et al., 2003). Its far-reaching impacts are felt across various sectors, with developing countries being particularly vulnerable. Bangladesh stands out as a prime example, facing the dual challenge of a changing climate and a high dependence on agriculture and fisheries for livelihoods and food security. The notable ramifications of climate change encompass sudden fluctuations in temperature, unpredictable precipitation patterns, extreme climate events, greenhouse gas emissions, and so forth.

The Intergovernmental Panel on Climate Change (IPCC, 2014) emphasized that various climatic factors, such as high temperatures, precipitation, greenhouse gas emissions, and cyclones, are having a severe impact on all aspects of agriculture, including production, distribution, and food prices. Despite advancements in farming technology, climatic variables, especially temperature and rainfall, play a crucial role in determining crop production, rural income, and food security (Wheeler and Von, 2013). Climate change poses a substantial risk to crop production in various regions of Bangladesh, exerting a noteworthy influence on the unpredictability of crop yields (Sikder and Xiaoying, 2014).

Bangladesh heavily relies on agriculture, as it not only sustains the well-being of its population but also creates job prospects and greatly influences the nation's economic output. Agriculture sector contributes about 11.38% in FY 2022-23 to the country`s Gross Domestic Product (GDP) and employs around 45.33% of total labor force (BBS, 2022). In the fiscal year 2021-22, the fisheries industry experienced a 2.08% increase in its GDP growth, while its proportionate contribution to the broader agricultural sector stood at 21.83% (Bangladesh Economic Review, 2022).

This sector serves as the backbone of the economy, effectively reducing poverty levels and ensuring a steady supply of food. Additionally, agriculture serves as a major source of export earnings and provides raw materials for various industries like poultry and livestock feed, leather, frozen food, and canned food.

This research paper embarks on an econometric analysis aimed at understanding the implications of climate change on two vital sectors of the Bangladesh economy: fisheries and crop. By assessing the economic losses incurred due to climate change impacts in these domains, we seek to shed light on the magnitude of the challenge and provide valuable insights for policymakers, researchers, and stakeholders involved in climate adaptation and sustainable development efforts.

Bangladesh, nestled in the fertile Ganges-Brahmaputra-Meghna delta, is endowed with a rich aquatic ecosystem and cultivable land, making fisheries and crop production the backbone of its agricultural sector. However, climate change-induced factors such as rising temperatures, changing rainfall patterns, and greenhouse gas emissions have significantly altered the country's natural environment, thereby directly affecting these sectors. Understanding the economic ramifications of these changes is crucial for formulating effective policies and strategies to mitigate their adverse effects.

To conduct this econometric exercise, we have utilized a combination of secondary annual time series data, including historical climate records, fishery production data, and crop production data. By employing robust econometric models, we aim to establish empirical relationships between climate change variables and fisheries, crop production, and their economic losses due to climate change.

The findings of this research hold immense significance not only for Bangladesh but also for other low-lying and climate-vulnerable regions grappling with similar challenges.

By examining the specific case of Bangladesh, we want to contribute to the existing body of knowledge on climate change economics and offer valuable insights into the dynamics between environmental changes and economic losses in the fisheries and crop production sectors.

MATERIALS AND METHODS

This research utilizes yearly time series data spanning from 1971 to 2020. The data were gathered from various secondary sources. Specifically, the secondary data regarding potato and jute production is obtained from the Bangladesh Economic Review (2022) and the Bangladesh Bureau of Statistics (BBS, 2018). The rice and wheat production data are collected from the United States Department of Agriculture (USDA, 2023). The time series data on fisheries and arable land area is collected from the Food and Agriculture Organization (FAO). Rainfall and temperature data (both minimum and maximum) are assimilated from the climate change knowledge portal. Greenhouse gas emissions data and information on flood-affected areas are obtained from two sources: the CO_2 country profile for Bangladesh by Hannah et al. (2020) and the Bangladesh Water Development Board, respectively.

For estimating purposes, this study focuses on six climate change-related variables in Bangladesh: greenhouse gas emissions, flood-affected area, average rainfall, minimum temperature, maximum temperature, and arable land area. Additionally, five dependent variables were chosen, namely fisheries production, rice production, wheat production, potato production, and jute production. The analysis considers the following models:

$$LNFISHY_t = \alpha_0 + \alpha_1 LNGREHG_t + \alpha_2 LNFLOOD_t + \alpha_3 LNRAINF_t + \alpha_4 LNTEMPRMIN_t + \alpha_5 LNTEMPRMAX_t + \alpha_6 LNARBLA_t + U_t \ldots\ldots\ldots\ldots (i)$$

$$LNRICE_t = \beta_0 + \beta_1 LNGREHG_t + \beta_2 LNFLOOD_t + \beta_3 LNRAINF_t + \beta_4 LNTEMPRMIN_t + \beta_5 LNTEMPRMAX_t + \beta_6 LNARBLA_t + E_t \ldots\ldots\ldots\ldots (ii)$$

$$LNWHEAT_t = \gamma_0 + \gamma_1 LNGREHG_t + \gamma_2 LNFLOOD_t + \gamma_3 LNRAINF_t + \gamma_4 LNTEMPRMIN_t + \gamma_5 LNTEMPRMAX_t + \gamma_6 LNARBLA_t + V_t \ldots\ldots\ldots\ldots (iii)$$

$$LNPOTATO_t = \lambda_0 + \lambda_1 LNGREHG_t + \lambda_2 LNFLOOD_t + \lambda_3 LNRAINF_t + \lambda_4 LNTEMPRMIN_t + \lambda_5 LNTEMPRMAX_t + \lambda_6 LNARBLA_t + \varepsilon_t \ldots\ldots\ldots\ldots (iv)$$

$$LNJUTE_t = \eta_0 + \eta_1 LNGREHG_t + \eta_2 LNFLOOD_t + \eta_3 LNRAINF_t + \eta_4 LNTEMPRMIN_t + \eta_5 LNTEMPRMAX_t + \eta_6 LNARBLA_t + \upsilon_t \ldots\ldots\ldots\ldots (v)$$

Where, LNFISHY = Log of fisheries production, LNRICE = Log of rice production, LNWHEAT = Log of wheat production, LNPOTATO = Log of potato production, LNJUTE = Log of jute production, LNGREHG = Log of greenhouse gas emissions, LNFLOOD = Log of flood affected area, LNRAINF = Log of rainfall, LNTEMPRMIN = Log of minimum temperature, LNTEMPRMAX = Log of maximum temperature, and LNARBLA = Log of arable land area.

To determine the stationarity of the variables, the augmented Dicky-Fuller (ADF) and Phillips-Perron (PP) tests were employed. To show the effects of climate changes on the fisheries and major crops production the fully modified OLS and dynamic OLS models were utilized.

The FMOLS technique proves highly advantageous in various aspects. It ensures reliable parameter estimates even with limited sample sizes. Moreover, it effectively addresses issues such as endogeneity, serial correlation, omitted variable bias, and measurement errors. Additionally, this method accommodates differences in long-term parameters, as observed in the studies by Kalim and Shahbaz (2009) and Fereidouni et al. (2017). To apply FMOLS, it is necessary for the variables to exhibit co-integration at the first difference. In our analysis, five considered models' variables are co-integrated; upon request, the results will be provided.

The DOLS model was initially introduced by Stock and Watson (1993). In order to implement this model, it is necessary for the variables to be co-integrated. This method is particularly valuable for small sample sizes and addresses simultaneous bias by incorporating leads and lags, as suggested by Kurozumi and Hayakawa (2009). By employing this technique, we obtain unbiased estimators that are asymptotically efficient. Similar to FMOLS, it effectively tackles issues of endogeneity and serial correlation, while ensuring the normality of residuals, as demonstrated by Herzer et al. (2006).

RESULTS AND DISCUSSION

Unit Root Test

To assess the stability of the study variables, we employed the augmented Dickey and Fuller (1979) and Phillips and Perron (1988) unit root tests. The findings, presented in Tables 1 and 2, indicate that the unit root tests were conducted twice: once on the original levels of the variables and then on the first difference. Both tests are conducted with constant, constant and trend, and none. The results of both tests depict that all the variables are stationary at the first difference, i.e., their integrated order is I (1).

Table 1. Augmented Dickey-Fuller (ADF) unit root test

Variables	Level			First Difference		
	Constant	Constant and Trend	None	Constant	Constant and Trend	None
LNGREHG	0.50	0.83	0.37	0.00***	0.00***	0.00***
LNFLOOD	0.99	0.30	0.56	0.02**	0.01**	0.00***
LNRAINF	0.13	0.10	0.68	0.00***	0.00***	0.00***
LNTEMPRMIN	0.32	0.20	0.74	0.00***	0.00***	0.00***
LNTEMPRMAX	0.56	0.03**	0.68	0.00***	0.00***	0.00***
LNARBLA	0.86	0.63	0.32	0.00***	0.00***	0.00***
LNFISHY	0.99	0.04**	0.99	0.00***	0.00***	0.02**
LNRICE	0.64	0.17	0.99	0.00***	0.00***	0.01**
LNWHEAT	0.47	0.46	0.95	0.00***	0.00***	0.00***
LNPOTATO	0.93	0.41	0.99	0.00***	0.00***	0.00***
LNJUTE	0.18	0.22	0.79	0.00***	0.00***	0.00***

Source: Eviews software on the basis of annual time series data (1971-2020). Notes: *** p<0.01, **p<0.05, *p<0.10.

Estimated Results of Fully Modified OLS (FMOLS) and Dynamic OLS (DOLS)

The analysis involves five models, and the outcomes are examined using two different methods: fully modified OLS (FMOLS) and dynamic OLS (DOLS). The regression results of FMOLS and DOLS are shown in Table 3. Based on the estimated results, it can be observed that the minimum temperature (LNTEMPRMIN) and rainfall (LNRAINF) have positive and significant impacts on the production of fisheries and crops. Adequate and consistent rainfall is essential for both fish and crops. It provides a reliable water source, promotes optimal plant growth, and enhances productivity. Rainfall also maintains favorable aquatic environments, supporting fish sustenance, reproduction, and survival.

Additionally, moderate rainfall acts as a natural temperature regulator, preventing excessive heat during dry periods. This cooling effect creates favorable conditions for crops and reduces stress on fish, improving their well-being and overall productivity. Rainfall plays a crucial role in conserving natural environments by replenishing groundwater, sustaining soil moisture, and ensuring favorable habitats for fish. It fosters sustainable fish and crop production by preserving habitats and providing an abundance of food sources.

Table 2. Phillips-Perron (PP) unit root test

Variables	Level			First Difference		
	Constant	Constant and Trend	None	Constant	Constant and Trend	None
LNGREHG	0.48	0.91	0.38	0.00***	0.00***	0.00***
LNFLOOD	0.23	0.46	0.65	0.00***	0.00***	0.00***
LNRAINF	0.45	0.20	0.74	0.00***	0.00***	0.00***
LNTEMPRMIN	0.10	0.32	0.82	0.00***	0.00***	0.00***
LNTEMPRMAX	0.46	0.10	0.74	0.00***	0.00***	0.00***
LNARBLA	0.80	0.32	0.38	0.00***	0.00***	0.00***
LNFISHY	0.99	0.21	0.99	0.00***	0.00***	0.00***
LNRICE	0.64	0.13	1.00	0.00***	0.00***	0.00***
LNWHEAT	0.57	0.46	0.90	0.00***	0.00***	0.00***
LNPOTATO	0.93	0.48	0.99	0.00***	0.00***	0.00***
LNJUTE	0.20	0.23	0.96	0.00***	0.00***	0.00***

Source: Eviews software on the basis of annual time series data (1971-2020). Notes: *** p<0.01, **p<0.05, *p<0.10.

Zakaria et al. (2014) stated that in the northeastern regions, the yield of Aman rice crop is primarily determined by rainfall rather than maximum temperature, indicating that rainfall has a more significant impact on rice production in this area. Warmer minimum temperatures have the potential to extend the growing seasons for crops, promoting prolonged periods of photosynthesis and growth, ultimately leading to enhanced crop yields as they safeguard against frost damage and create favorable conditions for crop development throughout the early and late stages of the growing season. The extension of fish spawning seasons due to warmer minimum temperatures enables an elongated period of reproductive activity, leading to enhanced recruitment of young fish and consequently increasing the abundance of fish available for capture, thereby positively influencing fisheries production.

The maximum recorded temperature (LNTEMPRMAX) has an adverse and significant impact on both fisheries and crop production. Maximum temperatures induce heat stress in crops and fish, reducing yields and disrupting physiological processes. Fish experience decreased appetite, impaired reproduction, heightened disease susceptibility, and mortality under elevated temperatures. Additionally, increasing maximum temperatures lead to water scarcity, affecting crops and fish through stunted growth, reduced yield, and harm to aquatic habitats, oxygen levels, and food availability. Furthermore, these temperature increases are linked to more frequent and intense extreme weather events, damaging crops, fish habitats, and resulting in losses, mortality, and habitat degradation, with further disruptions to crop growth, waterlogged soils, and impacts on fish reproduction and abundance through altered water chemistry and spawning grounds. In consonance with the World Bank (2021) the rising maximum temperatures in Bangladesh negatively affect key staple crops like Aman rice, Boro rice, and wheat, leading to yield reductions. Heatwaves, droughts, and increased atmospheric carbon dioxide contribute to these challenges, with certain crops experiencing partial mitigation while others, like wheat, face significant declines. Taking into account other factors, it is clear that climate change will likely cause a substantial decrease in net rice production in Bangladesh. The proper tillering and panicle development in wheat require a minimum temperature below 15°C for at least 60 days; however, a 4°C increase during the growth period significantly reduces the duration of cool temperatures, particularly impacting panicle development and potentially causing grain sterility (Karim et al., 1996). Research by Ahmed and Diana (2016) indicates that rising water temperatures outside the optimal range of 22-30°C negatively affect fish production, with even slight increases of 1-2°C causing sub-lethal effects on tropical fish species. The lengthening of hot seasons and frequent occurrence of high temperatures, accompanied by heatwaves, have forced fish farmers to limit their work hours during the summer months due to the intensified temperatures.

According to the findings, it becomes evident that the severity of flooding (LNFLOOD) negatively impacts both the productivity of fisheries and the production of major crops. Floods inflict direct harm on standing crops, causing substantial reductions in yield as floodwaters uproot or fracture crop stems, harm leaves, and bury plants in sediment deposits, while the excess moisture and prolonged humidity resulting from floods increase crop vulnerability to diseases and pests. Floods disrupt fish migration and spawning, hindering access to suitable breeding and feeding grounds and ultimately reducing spawning success, and fish production. Floods in low-lying areas can result in severe devastation to fish farms, aquaculture facilities, and infrastructure, with complete submergence or destruction of fish farms and ponds resulting in the loss of stocked fish and vital infrastructure. The procedures used in aquaculture are significantly impacted by these floods, which result in huge financial losses and a decrease in fish productivity. Hossain and Majumder (2018) opined that floods in Bangladesh pose a significant threat to agricultural productivity, resulting in substantial losses as a significant portion of the country's land area is annually submerged, and the risk of intense flooding is projected to increase further due to climate change. This has led to a significant annual loss of rice production, averaging 0.5 million metric tons between 1962 and 1988.In accordance with Ahmed and Diana (2016), fish farming communities are facing an increased occurrence of floods, particularly during the peak aquaculture season, due to intensified monsoon rainfall. Farmers consider floods as the primary threat to their harvest, as they lead to physical damage to ponds and heighten the vulnerability of fish farming operations, resulting in significant losses. Biswas (2013) stated that the mortality rate of juvenile shrimp rises in the event that the water temperature surpasses 32°C, as reported by CEGIS. Concurrently, there is a likelihood of a surge in fish diseases.

The extent of cultivable land (LNARBLA) has a significant and adverse impact on the productivity of fishes and agricultural crops. Although Bangladesh's arable land has increased slightly in recent times, infrastructure improvements could have a detrimental impact on crop output due to changing water flow, waterlogging, pollution, limited storage and transportation, a lack of access to capital and technology, and the diversion of resources from agriculture. The dense population in Bangladesh leads to residential construction on arable land, which contributes to the decline in crop production due to reduced land availability for cultivation, increased land fragmentation, limited access to agricultural resources, intensified competition for water, soil degradation, and the conversion of fertile land into residential areas. The conversion of natural habitats, like wetlands, rivers, and coastal areas, due to arable land expansion disrupts fish populations by limiting their crucial spawning, feeding, and nursery grounds, causing a decline in fisheries production. Infrastructure development, including dam construction, water diversion projects, river channelization, embankment construction, inadequate drainage systems, wastewater mismanagement, a lack of fish-friendly infrastructure, limited storage and processing facilities, inefficient transportation networks, and restricted access to credit and technology, can all also contribute to the decline in fish production in Bangladesh despite the slightly increasing arable land areas. According to Rozario et al. (2021) infrastructure development, including roads and housing, reduces agricultural land area. Urban expansion attracts rural residents in search of better opportunities, leading to a transition from an agro-based economy to an industrialized one, which is likely to continue. As reported by Cunjak (1996), alterations in the aquatic environment due to land-use practices, such as water extraction, fluctuating water flow patterns, and the presence of erosion or sedimentation, have an impact on the habitat of fish.

Table 3. Regression Results of FMOLS and DOLS

Independent Variables	Model 1: Dependent Variable: Fisheries		Model 2: Dependent Variable: Rice		Model 3: Dependent Variable: Wheat		Model 4: Dependent Variable: Potato		Model 5: Dependent Variable: Jute	
	FMOLS	**DOLS**	**FMOLS**	**DOLS**	**FMOLS**	**DOLS**	**FMOLS**	**DOLS**	**FMOLS**	**DOLS**
LNGREHG	0.99**	1.32	-0.06	1.09	-3.29***	-0.37	1.10*	2.50	1.56***	3.92***
LNFLOOD	0.02	-0.09	-0.01	-0.14	-0.12	-0.79	-0.03	-0.23	-0.10**	-0.51**
LNARBLA	-8.07***	-8.91***	-4.57***	-4.81***	-4.97**	-8.25***	-11.62***	-12.35***	-1.73***	-2.18**
LNRAINF	-0.01	0.98	0.00	0.95	1.70	5.66**	0.50	1.93	0.16	1.22
LNTEMPRMIN	13.48***	21.96**	10.56	17.33	14.54	39.78**	17.15**	32.19**	1.96	14.38**
LNTEMPRMAX	-13.40**	-23.54**	-9.89**	-14.06*	-17.07	-53.64**	-12.77	-26.86*	-4.821	-10.88
R-Square	R^2=0.91	R^2=0.97	R^2=.85	R^2=0.97	R^2=0.47	R^2=0.94	R^2=.89	R^2=0.97	R^2=0.58	R^2=0.90

Source: Eviews software on the basis of annual time series data (1971-2020). **Notes: *** p<0.01, **p<0.05, *p<0.10.**

We got the positive and significant impacts of greenhouse gas emissions (LNGREHG) on fisheries and crop production, which were not expected. Greenhouse gas (GHG) emissions have positive impacts on fisheries and crop production. Eutrophication, stimulated by GHG emissions, enhances nutrient availability and primary production, supporting fishery productivity. GHG emissions also facilitate the development of integrated farming systems like aquaponics, where fish waste fertilizes crops, promoting sustainable food production. Elevated CO_2 levels resulting from GHG emissions promote the growth of phytoplankton, benefiting fish populations and forming the base of the marine food chain. Some fish species, particularly shellfish, benefit from increased carbon dioxide (CO_2) levels, improving their shell and skeletal formation. Warmer temperatures associated with GHG emissions extend the growing season for crops, leading to increased yields. Additionally, elevated CO_2 levels enhance photosynthetic rates and water-use efficiency in plants, resulting in improved crop growth and quality. In a study by Ainsworth et al. (2002) found that CO_2 levels significantly boosted crop yields by improving photosynthetic rates and water use efficiency. The research provides strong evidence supporting the positive impact of greenhouse gas emissions on crop production. Parmesan and Yohe (2003) observed that rising sea temperatures and changing ocean currents lead to shifts in fish populations and the expansion of fish habitats, resulting in increased fishery production in specific regions. Their findings provide supporting evidence for the positive effects of greenhouse gas emissions on fish production.

Economic losses

The growth cycles of crops can be affected by climate change, causing a decline in yields. This can be attributed to the rise in temperatures, alterations in precipitation patterns, and the heightened occurrence of adverse weather conditions such as floods and droughts. Consequently, crop productivity is adversely affected, resulting in reduced harvests and financial hardships for farmers. Bangladesh is highly susceptible to recurrent inundation, and the issue can be further amplified by the effects of climate change. Deluges have the capacity to devastate crops, erode valuable topsoil, and deposit sediment, thereby compromising the land's fertility. Farmers encounter substantial financial losses when their agricultural products become submerged or impaired as a consequence of floodwaters. Elevated temperatures can foster the proliferation of pests such as insects and fungi, leading to amplified crop devastation and necessitating supplementary efforts for pest regulation. The expenses associated with pest management and safeguarding crops surge, thereby adversely affecting the profitability of farmers. Altered precipitation patterns have the potential to induce water scarcity, particularly during crucial phases of crop growth. Consequently, farmers are compelled to depend heavily on irrigation, thereby amplifying their consumption of water and incurring additional expenses. Such costs encompass various aspects like fuel or electricity required for water pumping, thereby exerting financial pressure on farmers and potentially compromising their overall profitability.

In July 2022, Bangladesh encountered the most meager rainfall in the past 41 years, leading to adverse consequences such as escalating food prices and a decline in household income (The Daily Star, 2022). Insufficient precipitation particularly impacts paddy yields, especially in the northern region of our country. This decrease in paddy production not only affects farmers but also has an influence for daily wage laborers. Because a considerable number of unskilled agricultural laborers lack alternative means of sustenance. The resulting loss and damage to livelihood opportunities compel local residents, particularly those reliant on daily wages, to promptly adjust in unfavorable ways, such as reducing meals and limiting food consumption. Women engaged in daily wage labor are forced to adapt by depleting their minimal savings, cutting back on food intake, facing limited access to other essential goods, assuming the financial burden of loans, etc.

On the other hand, the warming of water temperatures shifts in ocean currents, and modifications in aquatic ecosystems have the potential to diminish the number of fish in the region. This decrease in fish populations may lead to reduced fishing yields, causing a substantial decline in income for fishing communities and a decrease in profitability for the industry. Fluctuations in temperature and rainfall patterns can affect the innate migration routes of fish, leading to a mismatch between fish distribution and fishing activities. Consequently, this disparity can lead to diminished catches and financial losses for fishermen who heavily rely on the regular seasonal movement of fish. Moreover, the inconsistent and unpredictable patterns of rainfall and temperature variations will have an impact on fish readiness, maturity, and gonad development during the spawning season. Furthermore, rising temperatures may result in a rise in disease outbreaks in aquaculture, threatening livelihoods and food security. Climate change has the potential to intensify the susceptibility of fishing communities in Bangladesh. Diminished fish catches and income have the capacity to augment poverty levels and escalate the issue of food insecurity within these communities. Moreover, the depletion of fishing-related resources and livelihoods can impede the capacity of these communities to recuperate from climate-induced calamities, thereby exacerbating the economic losses. Furthermore, apart from the inherent factors contributing to environmental and climatic degradation, Bangladesh's fisheries industry encounters formidable obstacles caused by human-generated contamination, which also instigates economic losses in the fishing industry.

The fisheries industry in Bangladesh is being severely affected by the devastating consequences of natural calamities, particularly floods. Year after year, Bangladesh experiences the detrimental effects of flooding, causing significant hardships. A notable example is the unfortunate events of 2017, when over 10,200 fish farmers in the northern districts of the country collectively suffered a staggering financial loss amounting to TK. 773 crore (Billah and Billah, 2020). In the year 2019, the fishing industry experienced a significant setback, amounting to a substantial financial loss of $5.5 million. This unfortunate occurrence was a result of the devastating cyclone named Bulbul, which wreaked havoc on approximately 11,223 hectares of ponds and fish farms (The Business Standard, 2021a). Over the last year and a half, the coastal area of Bagerhat has been hit by severe calamities such as tidal surges, floods, and storms, resulting in a significant financial loss of Tk 55.2 crore for fish farmers (The Business Standard, 2021a).

As reported by the World Bank (2021) by 2010, it was predicted that river flooding would harm approximately 1.6 million people in Bangladesh each year, assuming protection against floods that occur once every 25 years. This had an annual GDP impact of around $2.6 billion. However, these figures are likely to climb as a result of variables such as development and climate change. Climate change alone is expected to increase the number of people impacted by flooding by 5.3 million per year by the 2030. This will also have a huge economic impact on the country's GDP, amounting to approximately $25 billion.

Conforming to the Global Climate Risk Index (CRI) 2021, Bangladesh is identified as the seventh most vulnerable country to climate change. The CRI, a report published by German watch, a non-profit environmental think tank based in Berlin, confirms that Bangladesh maintained the same ranking in the CRI 2020. The study examined four key factors: total number of deaths, deaths per 100,000 individuals, economic losses measured in US dollars using purchasing power parity (PPP), and losses relative to gross domestic product (GDP). Based on an analysis of data spanning 20 years from 2000 to 2019, the CRI 2021 reveals that Bangladesh encountered severe consequences due to climate change. During the 2000 to 2019 period, the country experienced 185 extreme weather events, resulting in the loss of 11,450 lives and economic damages amounting to $3.72 billion. The report highlights that Bangladesh is ranked fifth in terms of economic losses, indicating a persistent vulnerability of its economy to climate-related disasters. These occurrences adversely affect various aspects such as human health, economy, agriculture, and the overall ecosystem (The Business Standard, 2021b).

The latest report from the IPCC (2022) warns that Bangladesh faces a significant economic threat due to climate change, with potential losses ranging from 2.0 % to 9.0 % of its GDP by the middle and end of this century. If there are no modifications to the current worldwide actions, Bangladesh would experience economic consequences amounting to 2% of its GDP each year by the year 2050. This figure would further expand to 9.4% by the year 2100. The report also predicts that the country will experience extreme heat and humidity, leading to a rise in sea levels that could result in the displacement of four million people from their homes. Furthermore, climate change poses a serious risk to the country's industry and agriculture. By the middle of the century, approximately 1.0 to 2.0 million people in southern Bangladesh are in danger of being displaced, and there could be a decline of 12% to 17% in rice production and 12% to 61% in wheat production (IPCC, 2022).

According to farmers, a prominent consequence of climate change is the progressive displacement of the rain-dependent rice season (known as Aman) caused by drought and the delayed arrival of the monsoon. Should this trend persist, rice and wheat yields could potentially decline by 8 % and 32 %, respectively, by the year 2050 (The Financial Express, 2018). In accordance with the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT), a study conducted for Bangladesh reveals that climate change will adversely affect the country's agricultural net trade (exports-imports) from 2020 to 2050. The analysis further indicates that Bangladesh might experience an increased reliance on imported commodities such as wheat, jute, vegetables, and pulses (World Bank, 2017).

From 2009 to 2020, an immense sum of money was incurred as a result of climate change in the agricultural crop sector. As reported by Bangladesh Disaster-related Statistics (2015) and (2021) floods, water logging, drought, and cyclones caused respective losses of 264005.26 million, 35292.7 million, 21455.99 million, and 158115.25 million takas. Figure 1 depicts the losses in agricultural crops, which are 584664.42 million takas. It is crucial to note that the losses incurred by other types of disasters total 105795.22 million takas.

Conversely, an extensive sum of money was also forfeited as a consequence of climate change within the fisheries industry between 2009 and 2020. Figure 1 illustrates that the total amount lost in this sector equates to a staggering 77173.99 million takas. As per the data provided by Bangladesh Disaster-related Statistics (2015) and (2021) floods, water logging, drought, and cyclones caused losses of 42913.77 million, 8747.43 million, 451.65 million, and 13651.46 million takas, respectively, within the fisheries sector. It is essential to highlight that the losses incurred by other forms of disasters reached 11409.68 million takas.

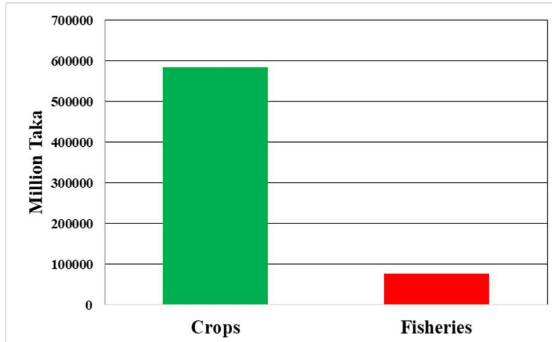

Figure 1. Crops and Fisheries Losses (in Million Taka) by Disaster from 2009 to 2020

Each fiscal year, the government of Bangladesh designates a substantial portion of funds within the national budget to address the impacts of climate change. For the fiscal year 2023-2024, an approximate amount of 16.39 billion takas was earmarked by the Bangladeshi government for this purpose (Finance Division, 2024).

CONCLUSION

This research paper focuses on conducting an econometric analysis to examine the impact of climate change on fisheries and crop production in Bangladesh, and also evaluating the associated economic losses. The study utilizes annual time series data spanning from 1971 to 2020. A range of statistical examinations, including the Augmented Dickey-Fuller test, Phillips-Perron test, Johansen co-integration test, fully modified OLS (FMOLS), and dynamic OLS (DOLS), are utilized in the analysis. The comprehensive analysis reveals that floods, high temperatures, and changes in arable land area have detrimental effects on fisheries and crop production in Bangladesh. Conversely, average precipitation, low temperatures, and greenhouse gas emissions have a positive influence on fisheries and the production of crops such as rice, potatoes, and jute. The rises in temperature, altered rainfall patterns, and floods have adverse economic consequences for fish and crop farmers. The decline in crop yields, particularly rice, due to climate change, impacts daily wages, consumption, and increases the financial burden of loans for small-scale farmers. Furthermore, climate change has a continuous negative impact on the country's GDP each year and is projected to persist in the future. The adverse economic effects of climate change on agricultural net trade from 2020 to 2050 pose significant harm to Bangladesh. Over the period of 2009 to 2020, the fisheries and crop sectors suffered substantial financial losses due to climate change. Every year, the government of Bangladesh allocates significant funds to address climate change-related issues. These findings emphasize the immediate necessity for proactive measures and policy interventions to mitigate the adverse effects of climate change on vital sectors for the safeguarding of livelihoods, ensuring food security, and promoting sustainable economic development in the country.

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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