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Climate Change Trends and Vulnerabilities in Bangladesh's Crop Sector: A Review of Crop Production Challenges and Resilience Strategies

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A B S T R A C T

Climate change has become one of the most important threats to worldwide agricultural production systems. This paper evaluates how Bangladesh, a prominent developing country in the low-lying Ganges-Brahmaputra-Meghna delta, is susceptible to climate change and assesses present agricultural practices that target sustaining production under these threats. The study synthesizes the ongoing research findings of climatic change tendency, involving the rising of temperature, alteration of precipitation pattern, along with the onward frequency of extreme weather incidence and their complication to crop production. It discusses the key susceptibilities of Bangladesh's crop sector, such as a shortage of irrigation water, the impact of rising temperatures, increasing sea levels and the loss of biodiversity. Moreover, the study explores the resilience strategies and measures adopted by farmers, policymakers and researchers to alleviate the hostile effect of climate change on crop production. With all these considerations, the paper aimed to analyse the current climate change trend, adverse effects to agricultural sectors and existing resilience practices in Bangladesh as well as future strategies against climate change.

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Introduction

Bangladesh is known for being extremely prone to climate instability and alterations (Harmeling, 2008; Agrawala et al., 2003). The nation is located on low-lying floodplains at the point of convergence of three significant Asian rivers, the Meghna, the Ganges, and the Brahmaputra, collectively with their additional tributaries. The economic situation of Bangladesh as well as the country's progress closer to sustainable development are under a great deal of strain due to the country's distinctive geographic location with shifting environmental conditions (MoEFCC, 2022). The estimated population is expected to be 9 crores, or almost 56% of the total, living in "high climate exposure areas," while 5.3 crores are expected to dwell in "very high climate change areas" (The Daily Star, 2023). Bangladesh comes up at number seven in worldwide rankings when its vulnerability to disasters is considered (Eckstein et al., 2021). Climate change is rewriting the rules of existing crop production technologies, inducing both biotic and abiotic stresses where traditional farming practices struggle to cope with the increasing pressure of extreme weather events, soil degradation and pest attack. Elevated temperatures cause heat stress in plants, which decreases yields, particularly in cereal crops such as rice, wheat, maize, and barley during the flowering stage, by disrupting chlorophyll synthesis, enzymatic reactions and protein metabolism (Lobell et al., 2021). When temperatures rise by 4˚C, the result of global warming affects the production of wheat by approximately 66%, along with the output of rice by 28% (MoEF, 2009). Unpredictable patterns of precipitation cause extended droughts, which lower soil moisture content, restrict root growth, disrupt the absorption of nutrients, reduce yield and make the plant more vulnerable to insect and disease infestations (Dai, 2013). According to Anjum et al. (2011), drought stress brought on by climate change severely slows down the rate of CO_2 absorption, stomatal conductivity, and plant water relations, all of which lower yield. Moreover, increased frequency and intensity of excessive precipitation raises the frequency of flooding and prolonged waterlogging, which results in abnormal root functioning, lowering soil oxygen levels, promoting root rot, and decreasing crop yield (Furtak & Wolinska, 2023). Sea level rise due to climate change increases saltwater intrusion in fresh land, including rivers and groundwater sources, which reduces crop yield through an increment of salinity levels in the soil (Baten et al., 2015).

Approximately 11.20 % of the nation's GDP in FY 2022-2023 came from agriculture (BER, 2023). By 2050, fluctuations in the climate with severe events like waterways floods in mid-Bangladesh, along with a shortage of water throughout north-western Bangladesh may cause nearly a third of Bangladesh's agricultural GDP to be permanently lost (World Bank, 2022).

Climate change aggravates ecological conditions by changing several environmental factors, which worsen biodiversity loss by increasing insect pests and weed infestations (Skendžić et al., 2021). High temperatures promote the metabolism and proliferation of disease-causing insects, pests and pathogens, leading to a rapid population explosion (Shahzad et al., 2021). It has the possibility to modify plant blossoming times, mismatch in pollinator flying periods, leading to a species endangered that relies on pollinators for their effective reproduction process (Vanbergen & Initiative, 2013). Nitrogen deposition, uplifting temperature, and CO_2 increment could act together to unsettle this critical mutualism by changing plant chemistry in ways that change flower attraction or nutritional composition for pollinators (Huo et al., 2020). It has been concluded that climate change affects plant microorganisms and crop quality through the anthropogenic introduction of xenobiotics (polycyclic aromatic hydrocarbons, pesticides, etc.), presenting dangers to soil well-being by upsetting soil microbial enzyme activities and system structures (Singh et al., 2019). Moreover, weeds are serious destroyers of crop yields, which can be influenced by the changing conditions of the climate. Generally, any effects of higher CO_2 or climate change that alter the growth or competitiveness of weeds and crops will shift their interactions (Singh et al., 2011). Climate change will likely cause shifts in weed community compositions, their population dynamics, life cycle, phenology, and infestation pressure, resulting in some weed species going extinct while others becoming more aggressive invaders (Anwar et al., 2021). It is projected that by 2095, temperatures in Bangladesh will rise by up to 2.2°C. This increase is expected to result in a doubling of leaf folder pests affecting rice. Conversely, the population of brown plant hoppers is predicted to remain unchanged, while the incidence of potato late blight is expected to decrease (Salam et al., 2019).

This review aims to analyse the present patterns of climate change affecting agricultural production. It will also highlight the agricultural sector's estimated vulnerability to climate change, considering the socioeconomic implications. Additionally, the current study will examine existing climate resilience methods in greater detail in order to maintain crop productivity in the face of climate change, along with an overview of the policies that have been implemented to counteract it.

Materials and Methods

This review studied a plethora of scholarly literature, reviewing over 300 articles concerning the evolving climatic trends and subsequent impacts on Bangladesh. From this extensive pool, a judicious selection process singled out the 50 most seminal works for inclusion. In pursuit of comprehensive insights, an array of data was meticulously gathered from various governmental authorities and esteemed international organizations, including but not limited to the BBS, World Bank, USAID, IFRC, IPCC, UNDP, and WMO. Moreover, a thorough scrutiny of diverse newspaper sources augmented this data gathering endeavour.

Result and Discussion

Climate Changing Trend in Bangladesh

Bangladesh, a subtropical nation in south Asia, has unique geographical features (due to its low-lying topography) that make it vulnerable to climate change. The risks, dangers, and future forecasts related to the spotted climate patterns are elaborated on based on numerous indicators that indicate the topographical and hydrological changes.

Temperature

Bangladesh is located in a subtropical area and highly vulnerable to the adverse effect of climate change, which are mainly expressed as a rise in air temperatures. Bangladesh's historical climate has included yearly mean temperatures of about 26°C, with annual variations ranging from 15°C to 34°C. The wintertime period (December-February) is cooler and less humid than the summer season (April-September), which coincides with the highest temperatures. The mean temperature has risen significantly during the last thirty years by 0.5°C from 1976 to 2019, which is a cause for concern (World Bank, 2021a). When analysing the years from 1980 to 2022, the yearly average temperature of Bangladesh shows a clear onward trend, with values ranging from 25.09°C to 26.6°C, regarding minor deviations. With only a few tiny variations, the average yearly temperature stays at 25.58°C (DoE, 2023). However, Figure 1 shows that some years had greater departures over the average, suggesting significant variations in temperature throughout the period in question. The trend of rising temperatures has picked up dramatically in the last several decades. The average temperature increased by 0.39°C during the years 1991 to 2000. Between 2001 and 2010, the bump in temperature became more significant, rising by 0.53°C. The increase persisted between 2011 and 2019, with a notable peak of 1.06°C (Figure 1). Additionally, there has been a rise in the lowest temperatures during the winter and monsoon seasons, with increases of 0.45°C and 0.52°C, respectively (DoE, 2023). According to Ahmed et al. (1999), Bangladesh's expected temperature rise from the base year of 1990 is predicted to reach 1.3°C by 2030 and 2.6°C by 2075. In a different study, IOC (1993) predicted that by 2030, there will be fluctuations of 0.7°C in the monsoon months and 1.4°C in the winter. According to projections, there would be changes in the winter of 2.1°C and the monsoon of 1.7°C in 2075 (Yu et al., 2010). Making use of baseline data from 1961 to 1990, Karmakar (2000) showed that between 2050 and 2100, yearly average maximum temperatures are predicted to rise by 0.40°C and 0.73°C, respectively. The pattern of rising temperatures emphasizes how urgently comprehensive measures to mitigate the effects of climate change in Bangladesh are needed.

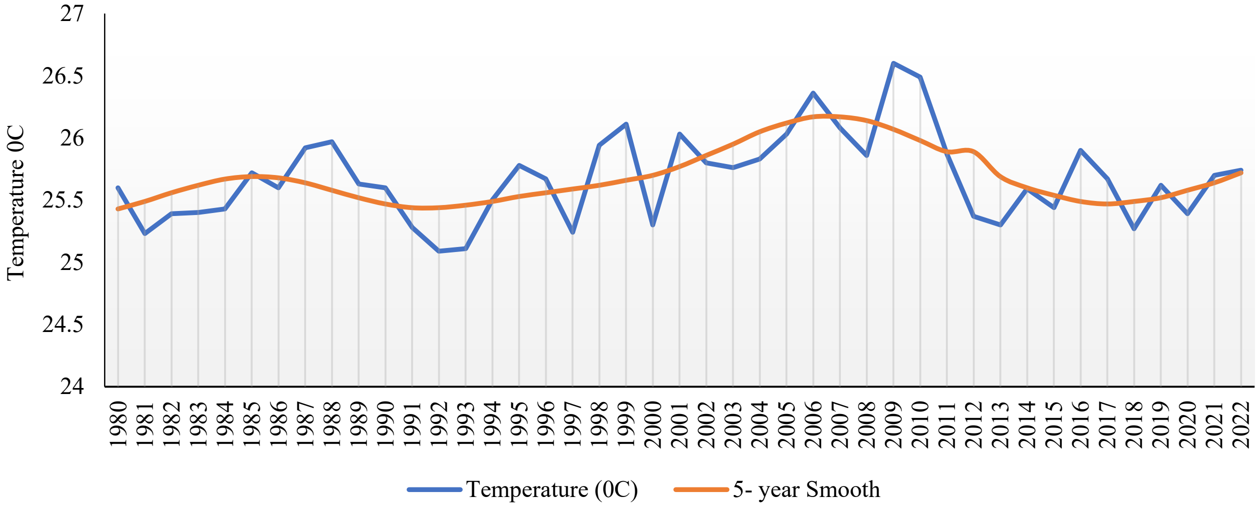

Figure 1. Average temperature in Bangladesh (1980-2022)
Source: World Bank (2021a)

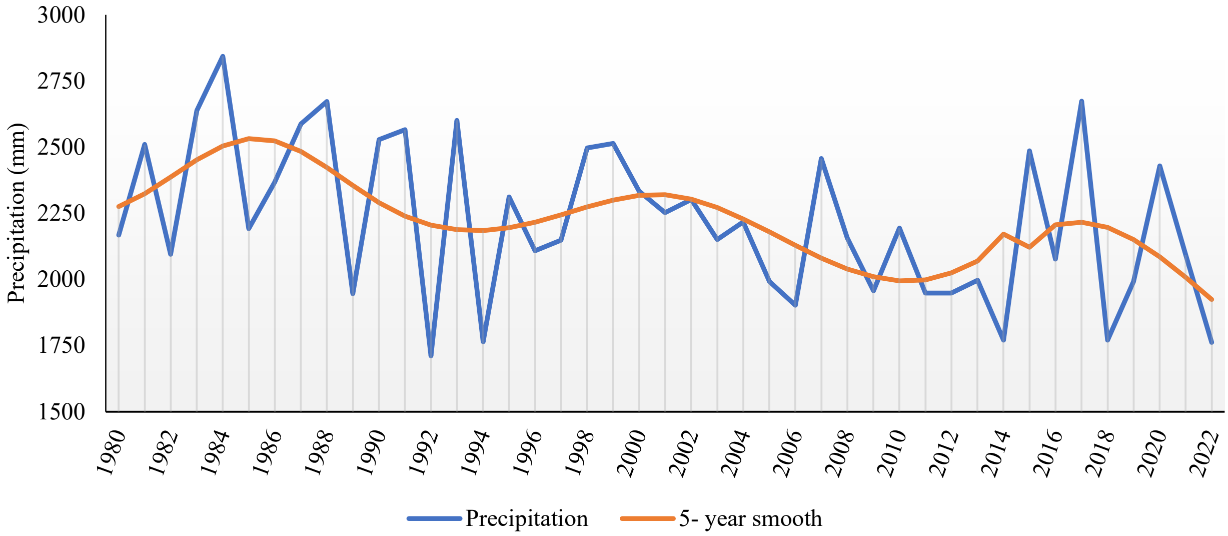

Figure 2. Average annual rainfall in Bangladesh (1980-2022)
Source: World Bank (2021a)

Rainfall

Climate change is predicted to alter the kind and quantity of rainfall, while the exact degree of this alteration is yet unknown (Wasimi, 2009). This change is expected to increase the unpredictable nature of extreme weather events, making it more difficult to estimate the frequency of extreme rainfall events because there might not be a consistent set of values for statistical extrapolation (Linacre, 1992). Based on data from 1990, it is projected that the average annual evaporation in Bangladesh will increase slightly by 2075 while remaining relatively stable up to 2030 (Ahmed et al., 1999). Although the country as a whole receives 2320 mm of rain on average each year, some areas receive up to 6000 mm on average (Hossain et al., 1987b). The average amount of precipitation has been steadily dropping during the previous forty years. The average rainfall from 1981 to 1990 was 2413.50 mm. Right after that, there was a decline with an average of 2250.38 mm in the following decade (1991-2000). The mean annual precipitation throughout the years 2001-2010 and also 2011-2020 showed lowering patterns at 2157.83 mm and 2109.11 mm, respectively (Figure 2). This declining tendency continued throughout the next two decades. The ongoing decade, 2021-2030, sees this negative pattern continuing (World Bank, 2021b). Precipitation is expected to increase somewhat in the winter and moderately in the summer of 2030. Nonetheless, a notable increase in winter evaporation is anticipated by 2075. More precipitation is expected during the monsoon season, while less precipitation is expected in the winter. This suggests that more summertime flooding may result from heavier rainfall, whereas winter drought conditions may be exacerbated by less precipitation and warmer weather. Moreover, significant upward trends in precipitation are anticipated for the northeastern and southeastern areas of Bangladesh, with expected increases ranging from 10 to 80 mm during the near-future period (2015-2044), 40 to 200 mm in the mid-century timeframe (2045-2074), and 40 to 260 mm in the far-future era (2075-2100) (Bhattacharjee et al., 2023).

Sea level rising

Due to its distinct geographic location and ongoing environmental changes, Bangladesh is among the world's most at-risk nations for the effects of sea level rise. Bangladesh constitutes a very low-lying country, with the majority of its landmass located three meters or less below sea level and a large portion of its inhabitants residing around the coast (Nishat & Mukherjee, 2013). In accordance with the Government of Bangladesh's Coastal Zone Policy (CZPo, 2005), 19 of the 64 districts, or 147 Upazilas, are located in the coastal zone. More than 35 million people live in the Ganges-Brahmaputra-Meghna delta, which makes up the majority of Bangladesh's coastal region. Sea level fluctuations affect about 30% of the nation's arable land because its coastal location (Haque, 2006). According to tidal measurements collected along Bangladesh's coast, sea level rise is occurring far more quickly than the world average (Khan et al., 2000). It has been revealed that, sea level rise rates vary across the Bay of Bengal, with the Ganges coastal floodplains experiencing an increase of 5.3 to 5.8 millimeters per year, the Meghna estuary floodplains rising by 4.2 to 5.3 millimeters annually, and the Chattogram coast showing a slower rise of 3.7 to 4.2 millimeters per year, highlighting the necessity for region-specific adaptation strategies (Partha Shankar Saha, 2024). Moreover, sea levels are expected to rise by 10 cm, 25 cm, and 75 cm by 2020, 2050, and 2100, respectively (Table 1) which will affect the agricultural production system adversely (World Bank, 2000).

Flood

Due to its low-lying geography and high population density, Bangladesh faces severe flooding risks exacerbated by climate change, with annual floods affecting 30% to 70% of the country (Litchfield, 2010). Furthermore, the UNDP has ranked the nation as the world's sixth most flood-prone nation (Rawlani & Sovacool, 2011). Between 1972 and 2022, Bangladesh witnessed 86 instances of catastrophic flooding throughout the nation, covering a geographical region of 747,230 km^2. The resulting floods claimed 42,279 lives and significantly impacted the lives of over 396 million people (DoE, 2023). The floods that occurred in 1954, 1955, 1974, 1987, 1988, 1998, 2004, 2007, 2017, 2019 and 2020 all resulted in significant destruction of property along with a significant number of fatalities (BWDB, 2021). The majority of those incidents occurred during monsoon floods in riverine areas. Other forms of flooding are additionally rather prevalent, including floods caused by storms or cyclones, urban flooding, riverbank flooding, etc. (Baten et al., 2018). Approximately one-third of the nation experiences extreme flooding each decade, and in extreme cases of flooding, almost 60% of the nation is submerged (Brouwer et al., 2007). According to the investigation, by 2070-2099, compared to 1971-2000, the amplitude of maximum water levels might grow by 16% in a low-emission situation while 36% annually under a high-emission situation (Dhaka Tribune, 2023). Bangladesh's substantial humanitarian and financial consequences from flooding are predicted to rise dramatically as a result of climate change unless more is done to develop endurance and implement mitigation strategies. Figure 3, displays percentages of the entire Bangladeshi territory that has experienced flooding since 1980.

Table 1. Possible impacts of different forms climate change in Bangladesh

Year	2020	2050	2100
Sea level rise	10 cm	25 cm	75 cm
Land below SLR	2% of the total land=2500 km^2.	4% of land=6300 km^2.	17.5% of land =25000 km^2. Patuakhali, Khulna and Barisal regions most affected.
Storm surge	-	A cycle like 1991 happens again with a 10% increase in intensity, storm surge goes from 7.1 to 8.6 m with 0.3 m SLR	Storm surge goes from 7.4 to 9.1 m with 1 m SLR
Salinity	Increase	Increase	Increase
Flooding	20% increase in areas subject to flooding.	Increase flooding in Meghna and Ganges floodplain.	Both inundation area and flood intensity will increase tremendously. Devastating flood may cause crop failure for any year.

Source: World Bank (2000)

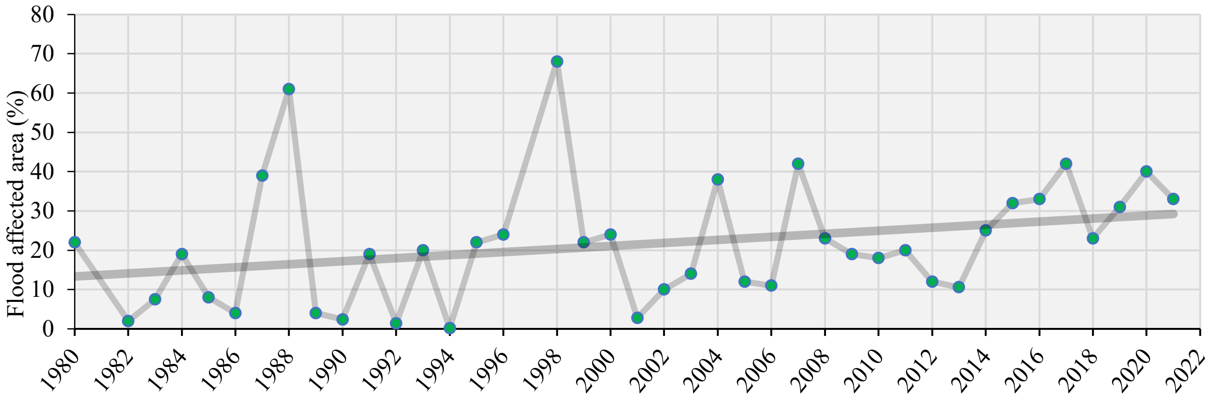

Figure 3. Annual flood affected area (%) in Bangladesh (1980-2021)
Source: Bangladesh Water Development Board, (Annual Flood Report 2021)

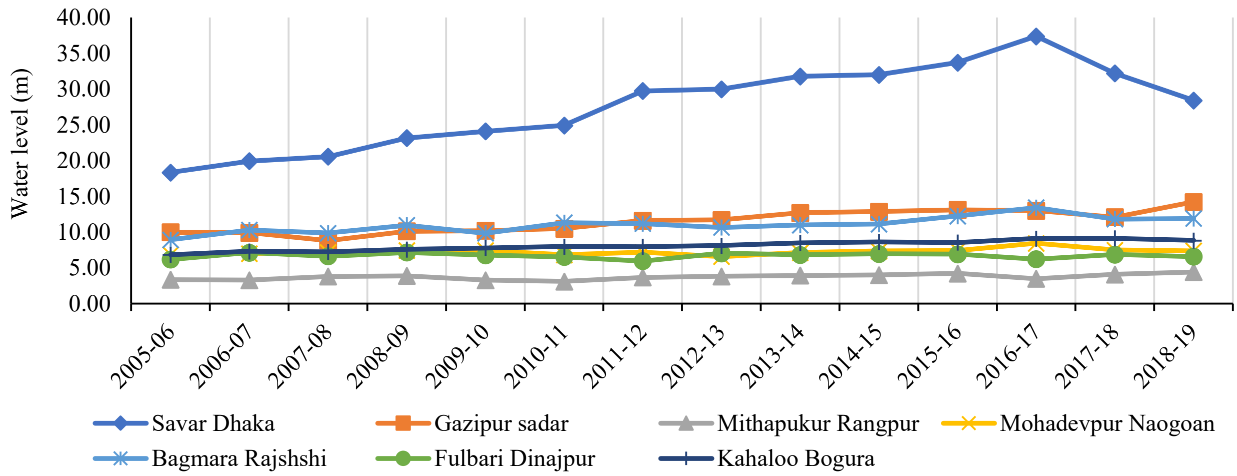

Figure 4. Changes in the depth of groundwater (Jan- Mar) over time
Source: BADC 2020, Minor irrigation survey report 2010-19

Cyclone

Bangladesh's positioning in the northern half of the Bay of Bengal and the North Indian Ocean (NIO) makes it particularly susceptible to cyclones (Ali, 1996a). The northern portion of the Bay of Bengal's funnel-shaped topology exacerbates the frequency of tropical cyclones, which annually impact thousands of people. In addition to having all four categories of cyclones; cyclonic storm, severe cyclonic storm, very severe cyclonic storm, as well as super cyclonic storm, the nation witnessed roughly 0.93% of all tropical cyclones worldwide (Ali, 1999b). In Bangladesh, the frequency of catastrophic cyclones has risen dramatically in the past few decades. Bangladesh was struck by 36 tropical cyclones (TCs) between 1970 and 2023 (Hossain & Mullick, 2020; World Bank, 2024). Based on available data, Bangladesh experiences on average 1.15 tropical cyclones annually. Since 1970, cyclones have wiped out the lives of over 450,000 individuals living in Bangladesh. Among these most deadly storms are Cyclones Gorky (1991) and Bhola (1970), which claimed the lives of 140,000 individuals as well as 300,000 people, respectively (Saha & James, 2017). Furthermore, the Intergovernmental Panel on Climate Change notes that as upcoming tropical cyclones intensify, Bangladesh's coastal flooding caused by cyclonic storm surges will probably get worse (IPCC, 2007). The present setting entails 14% and 69% additional areas than the present baseline assumption that are susceptible to flooding depths of over a meter and 3 meters, correspondingly. In the severe case, a cyclone with a 10-year return time is expected to become significantly stronger by 2050 and would impact 43% of the entire exposed area, which is 17% greater than it does now (BDP2100, 2018).

Groundwater Depletion

Groundwater plays a crucial role in the struggle against impoverishment, ensuring the availability of nutritious food and drinking water, the advancement of good jobs, growth in socioeconomic status and the ability of economies and society to withstand the effects of global warming. Bangladesh is primarily dependent on underground water for agriculture; between 71 to 94% of its groundwater is abstracted for this purpose (Margat & Van der Gun, 2013). It is commonly known that the overuse of groundwater over the past ten years has resulted in a significant depletion of water bodies. According to UN (2022) estimates, Bangladesh is the sixth-most-extracted groundwater-producing nation in the world annually. Water levels reach their lowest extent near the end of the summer season due to groundwater removal along with other diversions (Khaki et al., 2018; Mojid et al., 2019). In addition to these various causes, lowering levels of soil water could additionally be the consequence of reduced precipitation along with the dissipated replenishment it generates, as well as additional variables like altered agricultural practices or reduced river flows. (Pena-Arancibia et al., 2020). The recognized patterns of the depth of groundwater drops in certain parts of northwest Bangladesh have been attributed to widespread irrigation practices using groundwater (Kirby et al., 2015; Mojid et al., 2019; Salem et al., 2017). Bangladesh's agricultural sector relies heavily on the growing of rice. Boro rice, which might require up to 11,500 m^3 of water per hectare for production, accounts for over 70% of the agricultural output during the driest times of the year (Chowdhury, 2010). The hydrograph was created using data collected in AWLRs (Automatic Water Level Recorders) from various Bangladeshi areas between 2006 and 2018, to understand the groundwater depletion trend. Gazipur Sadar in the Gazipur district saw the greatest reduction, as can be apparent in the illustration (Figure 4). The greatest groundwater depth declines during a dry period occurred in March 2017 that increased by 8.96 meters over the preceding two years.

Impact of Climatic Changes in Agriculture

Temperature and Rainfall

Numerous regions of Bangladesh are currently experiencing agricultural disruptions as a direct consequence of temperature and rainfall variations. Climate change would have a significant negative influence on Bangladesh's agricultural output; yields of rice and wheat are predicted to fall by 28% and 68%, respectively (Rezvi, 2018). Crops require precise temperature ranges for optimal growth, and a 10% rise can significantly decrease monsoon rice yields by 2.94, 53.06, and 17.28 tons per hectare during development, reproduction, and maturation stages, respectively (Islam et al., 2008a). The possibility of cultivating wheat and potatoes could be greatly hampered by changes in temperature (by 2^0 and 4^0 degrees Celsius), and losses from production could be more than 60% of the potential yields (Karim, 1993). The probability of growing wheat and potatoes would be substantially reduced with temperature changes of 2 and 4 degrees Celsius (Hossain et al., 2020a). Furthermore, temperature sensitive crop yield has the potential to be significantly impacted by temperature increases, particularly Bangladesh's rabi crops. The increased respiration efficiency of cultivated crops due to climate change causes them to require more carbon for consumption, accelerate phenological improvement, and degrade tissue more quickly. Seasons are also impacted by temperature variations, which can potentially cause plants to become more susceptible to harmful thresholds along with enhancing the probability of evapotranspiration (Solomon, 2007; Hatfield et al., 2011). Bangladesh produces 0.8 million tons of pulses, 0.9 million tons of oilseeds, and around 9.0 million tons of potatoes annually. The ideal temperature range for all of the above crops is 18-25°C. Such crops are extremely susceptible to changes in moisture, fog and clouds. An increase in temperatures will probably lead such crops to become discontinued (Biswas et al., 2018). Rising temperatures (3^0C) have reportedly been linked to changes in Bangladesh's GDP, which have been predicted to range around -0.854% in 2027, reaching -2.491% in 2047, followed by -7.591% in the near future (Kompas et al., 2018).

Climate factors, such as variations in the current pattern of precipitation, can lead to a number of challenges in agriculture, such as crop failure in the earliest phases of development, and they can also have an impact on Bangladesh's key crops long-term productivity. Due to the rapidly declining groundwater level, which is now the biggest threat to the production of boro rice, the task of guaranteeing food security is going to be extremely difficult for the nation. Upcoming average monthly precipitation could fluctuate greatly from normal levels, depending on environmental change situation forecasts. It is assumed that monsoon precipitation will increase by 27% in 2070 and by 11% in 2030 (Biswas et al., 2018). A one-millimeter increase in precipitation throughout the development, reproductive, and aging stages reduced the yield of monsoon rice by 0.036, 0.230, and 0.292 tons, respectively (Amin et al., 2014). Rahman and Lateh (2017) carried out a spatial-temporal assessment over a 40-year period (1971-2010) involving 34 meteorological stations in Bangladesh. They concluded that Bangladesh's recent climate change is predicted to raise its average temperature by 0.2ºC every ten years. Regarding precipitation, they recorded an increasing yearly tendency of 7.13 mm from 1971 to 2010, but a decreasing premonsoon (-0.75 mm) along with a post-monsoon (-0.55 mm) every year. The findings indicate that there is considerable fluctuation in pre-monsoon and post-monsoon rainfall (44.84-85.25%). This variability is likely to have an adverse effect on the agricultural sector, as pre-monsoon rains are crucial for preparing land for rainfed rice production. Floods and waterlogged conditions brought on by heavy precipitation may additionally result in the destruction of crops. The anticipated deviations in the country's temperature and precipitation are shown in the following Table 2.

Flood and Cyclone

In Bangladesh, flooding is widely acknowledged as the most frequent and damaging climate related calamity. The most susceptible sector of the economy to flooding is agriculture, resulting in massive crop devastation annually (Yu et al., 2010). The environmental conditions of Bangladesh are responsible for an increase in the incidence and extent of floods, according to Rahman and Salehin (2013). On average, between 30 and 70 percent of the nation floods each year (Ahmed, 2006). There are significant occurrences of flooding, including the 1998 flood that submerged 68% of the country, caused 33 million people to be relocated, and destroyed 100,000 km2 of agricultural land (Rashid, 2000). Meanwhile, catastrophic flooding incidents such as the 2004 and 2007 monsoonal floods impacted 38% and 42% of the land area, respectively. It was determined that 89% of the Aus rice area, 93% of the total rice-growing area, and 73% of the jute-growing area were severely disrupted because of the 2004 flood. In 2007, a flood harmed 14 million people, inundated about 42% of the nation's terrain, and plunged 2.1 million hectares of fertile land (Huq et al., 2010). The most devastating floods in recent times devastated Bangladesh's northeast in June 2022, mostly affecting the regions of Sunamganj and Sylhet. This catastrophic incident completely destroyed 83,394 hectares of crops; it resulted in financial losses to cattle of 28.1 million US dollars and it additionally destroyed sanitation facilities and waterways (Sheikh, 2022). Approximately 27,000 hectares of agricultural land in the Chattogram area had flooded. According to estimates, Tk135 crore worth of destruction was caused by the flood to Aman crops on 14,000 hectares of cropland, Aus on 4,500 hectares, Aman seedbeds on 3,700 hectares, and vegetables on 5,100 hectares (Azad, 2023). The projected agricultural loss is indicated in the accompanying Table 3 from 2007 to 2022.

Crop productivity is severely harmed by cyclones. Due to its natural surroundings and proximity to a tropical cyclone, Bangladesh's coastal region is especially prone to cyclonic storms, floods, and other natural calamities (Ahmed & Rahman, 1999).

Table 2. Projected temperature & rainfall changing trend in Bangladesh

Year	Temperature Changes (°C) mean			Precipitation Changes (%) mean		
	Annual	DJF	JJA	Annual	DJF	JJA
2030	1.0	1.1	0.8	5	- 2	6
2050	1.4	1.6	1.1	6	- 5	8
2100	2.4	2.7	1.9	10	- 10	12

Note: DJF represents the months of December, January and February, usually the winter months. JJA represents the months of June, July and August, the monsoon months Source: National Adaptation Programme of Action, Bangladesh (2005)

Table 3. Loss in production (M. ton) due to major floods from 2007 to 2022

Crops name	Loss in production (M. ton) due to floods from 2007 to 2022								
	2007-08	2008-09	2009-10	2011-12	2014-15	2015-16	2017-18	2020-21	2021-22
Aus	94164	990	-	7519	7077	17395	64482	1255.26	54569
Aman	230681	113465	-	70014	125250	102254	734905	29364.34	-
Boro	-	-	369591	-	-	97592	-	-	21304
Jute	46145	-	-	-	-	-	33895	4498.01	-
Sugarcane	116387	-	-	-	-	-		5166	-
Vegetables	99614	670	-	5242	79	-	41275	3682.31	-
Banana	7014	-	-	-	-	-	352	405.72	-
Pineapple	2815	-	-	-	-	-		-	-
Papaya	2386	30034	-	-	-	-		-	-
Maize	1743	745	-	-	-	-		-	-
Ginger	1084	-	-	-	-	-		-	-
Chilies	2204	622	-	2542	-	-	740	378.39	-
Betel leave	230	-	-	-	-	-	4129	692.42	-

Source: BBS 2014, BBS 2023, (*M. ton= Metric ton)

Table 4: Cropped area damaged by several cyclones in Bangladesh

Name of the cyclone	Year	Damaged agricultural land
Sidr	2007[a]	Approximately 644 000 hectares
Aila	2009[b]	More than 123,000 hectares
Mahasen	2013[c]	Approximately 32,633 hectares
Fani	2019[d]	Approximately 63,063 hectares
Bulbul	2019[d]	Approximately 22,836 hectares
Amphan	2020[d]	Approximately 1,76,007 hectares
Yaas	2021[e]	Approximately 12,151 hectares
Sitrang	2022[f]	Approximately 10,200 hectares
Midhili	2023[g]	Approximately 29,000 hectares

([a] Relief Web, 2007), ([b]Relief Web, 2009), ([c]Parvez, 2013), ([d]Dhali, 2020), ([e]Islam *et al.*, 2021d) ([f]The Business Standard, 2022), ([g]Ali, 2023c),

Cyclones have the most detrimental effects on human life since they destroy crops, homes, animals, and transportation infrastructure, in addition to driving up the number of accidental human deaths. When it comes to devastating cyclones in Bangladesh, the 1991 storm devastated 280,000 acres of cultivated land, 60% of livestock and 80% of poultry stocks. Having a maximum speed of 225 Kmh^{-1}, the 1991 cyclone struck Bangladesh and annihilated roughly 138,000 people, with total losses estimated at US$ 4 billion (Kausher et al., 1996). According to Ali (1996a), the average wind velocity of the cyclone will fluctuate between 248 Kmh^{-1} and 275 Kmh^{-1} wherever the temperature rises by 2 ^{0}C and 4 ^{0}C. Any rise in storm surge water could quickly flood the low-lying, flat areas of the nation. Such unusual incidents will seriously harm the infrastructure, food safety, the agricultural sector, the economy, and eventually the survival of the nation. However, in 2007, cyclone Sidr killed 468,000 cattle and destroyed 16,10,000 hectares of arable land, resulting in a massive economic loss assessed to be worth US$ 3 billion (Shamsuddoha & Chowdhury, 2007). The destructive hurricane Amphan made landfall in the coastal area in 2020. By May 22, approximately 2,233 km^2 of land had been flooded. In Bangladesh and India, there have been reports of devastation to some 3,200 km of roads and 400 km of riverbanks, which have hampered response operations and exposed additional areas to flooding (IFRC, 2020). The agricultural loss in Bangladesh as a result of many cyclones is displayed in Table 4 due to different cyclones.

Scarcity of groundwater

Groundwater level is currently being drastically lowered by climate change, which is now the biggest danger to agriculture productivity. In Bangladesh, the harvesting of groundwater for irrigation during the growing of rice has increased rapidly as a result of the expansion of the cultivable area with irrigation, especially for dry season irrigated rice. Groundwater accessibility in Bangladesh is undoubtedly being impacted by climate change, as evidenced by reports of declining groundwater depth in the country's Northern regions (Mustafa et al., 2019). To ensure the sustainable use and/or effective execution of groundwater, the outflow of water in the northwest regions of Bangladesh must be reduced by 60% of its current level. The groundwater table is expected to drop five to six times more quickly in 2026-2047 compared to the baseline era (1985-2006) if the existing expanding upward trend in the removal of groundwater persists. This is because both climate change and increased groundwater extraction are having an impact on the extent of groundwater (Hossain et al., 2020a). Furthermore, according to Mustafa et al. (2019), in order to maintain the environmental sustainability of groundwater in Bangladesh's northwest, withdrawal of groundwater requires being reduced by more than 50% of current uses. In the years 2016-17, 2017-18, 2018-19, 2019-20, 2020-21, 2021-22, and 2022-23, the overall area under irrigated crop was 55.27, 55.57, 55.87, 56.27, 56.54, 56.88, and 57.20 lakh hectares, respectively (BBS, 2023). Because there was absolutely no replenishment from precipitation or above-ground flows, such massive extraction has reduced subsurface water stores. Many researchers have indicated that the world's greatest groundwater declines are found in northern Bangladesh and northern India, up to Assam (Tiwari et al., 2009; Rodell et al., 2009; Wada et al., 2010). Therefore, the state of groundwater would be far-reaching for additional extraction of groundwater owing to agriculture, considering this unpredictability and massive groundwater extraction for irrigation. Various environmentally friendly farming methods, along with additional water management techniques should be implemented in order to guarantee the appropriate and sustainable use of groundwater.

Drought

Due to its geographical position, Bangladesh is one of the most vulnerable countries in the world to natural disasters (Afrin, 2016). Every five years, there are significant nationwide droughts in Bangladesh (Selvaraju & Bass, 2007). Up to 47% of the nation, where 53% of people currently reside, is allegedly at risk of drought (Biswas et al., 2018). One common catastrophe throughout the nation is drought. In 1973, 1978, 1979, 1981, 1982, 1992, 1994, 1995, 2000, 2006, and 2009, Bangladesh was hit by severe droughts (Al Mamun et al., 2024). The production rates of a variety of crops are adversely affected by climate change, groundwater scarcity, irregular rainfall, and high temperatures, especially in Bangladesh's northwest (Mishra & Singh, 2011). Drought is a major threat to crops grown in the pre-kharif (mid-March to mid-May) and Rabi (mid-November to mid-March) seasons (Mohsenipour et al., 2018). Approximately 2.32 million hectares of land have been damaged by droughts of various severity per year (Habiba et al., 2011). Drought not only damages agriculture but also has adverse impacts on society and the environment, including loss of livelihoods, migration, increased food prices, decreased biodiversity, disease, destruction of land, and a host of other issues. A common drought occurrence damages 2.32 million hectares (ha) of cropland each year (Kharif season) and 1.2 million hectares (ha) per year (Rabi season) (CEGIS, 2013). According to research by Rahman et al. (2007), the northwest of Bangladesh had a 25-30% decrease in agricultural production due to drought. Each year, drought causes about 17% of the Aman harvests to be lost (Alam, 2015). Drought-related yield decreases range from 45-60% for rice and 50-70% for highland crops in extremely severe cases. In mild droughts, rice yield loss ranges from 10-30%; in severe droughts, it could reach 70-90% (Biswas et al., 2018). An extreme climatic change scenario (60 percent water stress) could result in a 55-62 % reduction in dry season or boro rice production (Selvaraju & Baas, 2007).

Sustainable Agricultural Practices in Bangladesh to Mitigate The Global Warming Effect

Bangladesh is currently dealing with the effects of global warming, including rising temperatures, unpredictable rainfall and prolonged droughts. These factors are putting forth it difficult for farmers to maintain crop productivity. In response to current challenges, Bangladeshi farmers are implementing climate-resilient agriculture techniques and devising creative ways to ensure their survival. Climate-smart agriculture (CSA) is an environmentally conscious farming approach designed to promote sustainable agricultural practices and rural development while addressing the challenges posed by environmental deterioration to food production. This approach recognizes that reducing greenhouse gas emissions while simultaneously boosting resistance to the consequences of climate change is necessary to feed a growing population. Currently used sustainable farming methods include the following:

Coastal Region

Sack Method

In coastal areas, government officials and local NGOs implemented the sack method to prevent fruits and vegetables from being carried away by floods. Families found great success with sac farming in assisting them in adjusting to situations of getting waterlogged and saltwater intrusion (Angrish et al., 2006). The process of sac farming involves putting manure in a bag with nutrient-rich soil, adding a few gravels to the bottom for optimum drainage, leaving a few holes in the interior for air circulation, and then placing plant material on top to thrive. Sack farming is used to grow vegetables such as bottle gourd, gourd brinjal, cucumber, and chili. Sack farming's key advantages are its portability, efficiency, profitability, improvements to nutritional stability and decreased agricultural risk (IWMI, 2015).

Sorjan Method

This unique approach is intended for regions in which conventional crop cultivars are unable to produce acceptable yields due to significant soil salinity and extended inundation. Raised beds are created by dividing the area into raised subplots and removing dirt from nearby locations. Whereas the submerged sections or ditches are utilized for periodic fish production throughout the monsoon, raised planting beds are employed for the year-round production of vegetables, fast-growing fruits, and other crops. The Sorjan is surrounded by ditches or canals that supply irrigation and water throughout dry periods. The land is split up into multiple subplots in this instance. There's an interminable trench to hold water between two distinct subplots. Each subplot is elevated by removing soil from the side that borders it. The plot's ideal dimensions are 8.0 × 2.5 × 4.5 meters. A number of factors, including the extent of the plot, might alter it. The raised bed is mostly used for growing fruits and vegetables, sugarcane cultivation, and dhaincha. In the channels that separate the two distinct beds, indigenous fish are raised. While more deeper permits rice-fish or rice-duck farming in addition to vegetable and nursery cultivation, shallow Sorjan is best suited for the continuous cultivation of vegetables (Sattar & Abedin, 2012). Sorjan has proven to have major financial advantages. In the first year, for example, it yielded Tk. 121,227 in net earnings from 0.55 ha of land, compared with Tk. 15,570 from a single crop of aman rice, indicating a 678% rise in net earnings (Chaki et al., 2023).

Double Layer Mulching

Double-layered mulching, implementing straw at the top and bottom of a small hole was demonstrated to lessen soil salinity by approximately 30 percent. In the country's coastal region, sweet gourd is produced using a double-layer mulch technique, which results in a better yield (18.5 t ha^{-1}) effectiveness (Shawkhatuzamman et al., 2023). Under this approach, producers get ready for their field by using a power tiller and tilling it three times before planting. Pits are sufficiently excavated when there is a 2.0-meter gap between each pit and between each line. Throughout the pit setup, compost along with a low amount of fertilizer are administered. Next, sprouted seeds are put down in a pit. Intercultural operations that are required are carried out when they are.

Pitcher (Kolosh) irrigation to grow watermelon

Salinization rises and groundwater for watering becomes scarce on land throughout the summertime. During the dry period, water is added to crops such as watermelon, sweet gourd, bitter gourd, etc. using pitchers, popularly called as Kolosh. Farmers living in Batiaghata Upazila in Khulna and Fakhirhat Upazila in Bagherhat district are making good use of the pitcher irrigation technology (also known as Kolosho irrigation) that SMRC and SRDI implemented for areas that became available by November. Pitchers are pierced to create a bottom hole that is roughly one inch in diameter. A jute string that is between half and one-meter long is placed into the hole. After that, the pitchers of water are lowered to a depth of 5 to 9 cm into pits (known as mada in this area), and the jute strips are stretched out at an identical level to allow the saturated jute to constantly hydrate the earth and lower the salinity surrounding the root zone. Three to four crop seeds are sown in each of the pits surrounding the pitcher. Producing watermelon, sweet gourd, and cucumber in pits during the dry season is a low-cost approach that involves growing rabi crops in locations with mild salinity (Mada).

Ring Method

The strategy was largely used in homestead gardening, where farmers would plant vegetables using a reinforced concrete toilet ring as a defenes against saltwater and flooding. Local NGOs have just re-established it in Shyamnagar, Satkhira in 2021. It possesses the capacity to boost output, flexibility, and a reduction in greenhouse gas emissions.

Usage of raised shrimp farm bund for year-round cropping

Using this method, fruits, vegetables, and some types of trees are grown along the outer edge of shrimp farms. Aman rice with shrimp and/or fish has been transferred onto certain areas known locally as "Gher," or shrimp farms. To protect water and fish throughout dry periods, farmers excavated a ditch near the plot's centre, along the field's edge, or at any corner. Farmers may utilize water from shallow tube wells to keep fish alive. Occasionally, non-saline and mildly (S2) to considerably (S3) saline areas are utilized for boro or winter rice. It is referred to as the "Lockpur model" in the Khulna-Bagerhat district. The trenches around the border, corner, or center are 60-90 cm deep, and the boundary is erected around 60-90 cm higher than the level of floodwaters. Producers utilize nylon netting as a trail for creeping vegetation that is held up by strings, bamboo, or dhaincha in order to nurture crops. Precipitation removes the saline from the soil in the bunds, making it easier to grow vegetables. About a decade ago, the SRDI program, through SMRC, created this particular technology.

Farm-Pond (Khamar-Pokor)

The technique is a recently invented technology or method for preparing a land area for a variety of crops, fruits, and forests by digging up a pond on medium-high (flooded up to 90 cm) to medium-low (flooded 90-180 cm) lands where modern varieties (transplanted Aman rice) are unable to grow because of wetness in the beginning of the dry season or during late drainage. In ponds that have been mined to a depth of 180 to 270 cm, bunds and banks typically measure 90 cm in height and 120-150 cm in breadth. The surface soil remains on top, whereas the mined soil covers the remaining area of the land. SMRC and SRDI advise this kind of land use system, which has already been implemented over the past decade or so in the Khulna district's Batiaghata and Dacope Upazila. It is referred to as "Kuni" technology in Dacope. This kind of innovation aids in removing salt from the soil by washing it away. Aman rice (MV) transplanted, melons, and vegetables cultivated on elevated land; tree (fruit/forestry) crops cultivated on pond bunds or banks; fish cultured in ponds (Talapia: *Oreochromis niloticus*; Silver carp: *Hypophthalmichthys molitrix*).

Dibbling Method

This kind of technology is typically used on a large scale in Bhola, and on a smaller scale in Noakhali and Chittagong. Soils are generally brittle, either clay loam or loam. Pre-Kharif (Aus) season is when the Shaitta rice variety, a local variation, is grown. In March and April, people do dibble. Salinity in March and April should be avoided, as should germinating issues brought on by surface the formation of crusting. Instead, the in-situ dibbling technique for conserving soil water should be utilized. The soil is left undisturbed and rice seeds are buried at 3-6 cm depth. A cavity in the ground is made using a peg that has a diameter of 2.5 to 5 cm.

Agronomic

The coastline region is rather level, although there are topographical disparities between its upper and lower regions, which results in stagnant water in the agricultural land. The middle highland has persistent water that is between 15 and 90 centimeters deep. Many salt-tolerant modern cultivars, such as BRRI dhan47, BRRI dhan53, BRRI dhan54, BRRI dhan55, BRRI dhan61, BRRI dhan97, BRRI dhan99, and BINA dhan-8, BINA dhan-10, are currently offered across the nation by various NARS organizations. It is possible to improve cropping intensity by around 0.602 million hectares in very saline (S1) and slightly saline (S2) locations by using appropriate water and soil conservation techniques and developing salt resistant crop cultivars (Shawkhatuzamman et al., 2023) This technique aids in the leaching of soluble salts, thereby lowering the salinity of the soil because a particular level of irrigation water is maintained in the field for the growth of successful rice harvests. The comparatively lower water level during this time facilitates the dissolution of salts. It is a reality, though, that the region's capacity to cultivate rice harvests throughout the winter is severely limited by the shortage of high-quality water used for irrigation. It is possible to cultivate vegetables and other horticulture crops effectively with raised dyke, ail, or bund.

Drought Prone area

Mini Ponds for rainwater harvesting

In regions with severe water shortages, ponds have the potential to be excavated again, ideally in High Barind Tract Zones. Such mini-ponds can be used for rainwater gathering to provide additional irrigation on agricultural land lacking a watering base. Small farms should ideally have mini-ponds of 5 m × 5 m × 2 m (length × breadth × depth). In accordance with the specifications, it is further advised to dig bigger ponds (10 m × 10 m × 2 m). However, a few farmers desired the convenience of these small ponds situated in a field's corner. It is necessary to raise enough consciousness among local residents regarding the benefits of ponds. Mini ponds have reportedly been shown to boost profits on the same plot of land by up to 23%. According to BARI research (Sagor, 2017), only a small piece of agricultural land (2.5%) is enough to conserve rainwater to supply irrigation, provided crops are correctly chosen.

Homestead gardening

It is necessary to support the regional population's traditional wisdom of ecologically appropriate land maintenance. In regions susceptible to drought, home gardening technologies offer a thriving environment that benefits people, animals, birds, cattle, and various other types of biological diversity. Insects are kept from colonizing the land by adding organic material, ash additives, and household waste products. Vegetables from homestead gardening are occasionally grown for commercial use as well as for domestic consumption. Homestead bamboo species can also be planted since they are excellent soil-binding agents and grow quickly. Including homestead gardening throughout the family system helps to guarantee food safety in the family's residence by providing a variety of elements. In regions susceptible to drought, homestead farming is a useful practice for integrating gender issues into the framework for adapting to global warming.

Mango and Jujube cultivation

A potential replacement crop for managing drought in Barind areas is the mango, often known as Jujube (*Ziziphus jujuba*). Each season, more land is planted with mangoes because the area is renowned for producing higher-quality and more abundant mangoes. The tropical fruit crop known as jujube can tolerate a broad variety of temperatures. The jujube's ability to withstand prolonged drought qualifies as one of its best features. In Barind Tracts, the crop is capable of being grown well with minimal irrigation. Transplanting aman rice has the potential to be interplanted with jujubes across the second kharif season.

Zero tillage wheat and garlic cultivation

In the northern region of Bangladesh, growing wheat with zero-tillage after rice has proven to be the most effective resource-conservation technique yet. This technique involves planting wheat seeds in the entire field immediately after rice has been harvested, with no tillage. A machine is used to dig the hole, and once the seeds are planted, soil is added by hand. Due to its many benefits, zero-tillage wheat contributes to overcoming some limitations in the rice-wheat system. According to (Erensteinet et al., 2008), zero-tillage wheat allows for early planting, assists in preventing unwanted plants, lowers expenses, and conserves moisture. In the low-lying rice growing districts of northern Bangladesh, the practice of zero-tillage garlic production has become more and more prominent over the past few years. Using this approach, rice straw is utilized as mulch when rice is harvested, and garlic is seeded directly into the bed of soil. For vegetative development, garlic farming requires a cool, humid atmosphere; bulb formation requires a somewhat dry phase. Zero-tillage garlic cultivation under rice straw mulch is regarded as a climate-smart technique that provides a cost-efficient and efficient way to boost garlic yield. The BARI introduced zero tillage, which requires very little disruption of the land, in 2020. It has been demonstrated that this technique efficiently uses the nutrients and remaining water from earlier crops. This method works very effectively for small-scale producers and is a good fit with the Chalanbil regions in the regions of Pabna, Natore, and Sirajganj (Chaki et al., 2023).

Alternative Wetting & Drying (AWD) irrigation

AWD has been successfully demonstrated to dramatically reduce the consumption of water and arsenic in rice grains, without affecting rice output and releasing less methane throughout the rice-producing process. This technique does not maintain constant flooding of the soil. Instead, following the time the stagnant water has subsided, it is let to run off for a day or longer without getting reflooded (Lampayan et al., 2015). The field water tube used to apply the AWD technique can be formed of bamboo or plastic pipe that is 30 cm long. Its diameter should vary between 10 and 15 cm to ensure the soil is simple to take out using one's hands while the level of the water is apparent. Make multiple openings in the inner tube on every surface to allow water to easily enter and exit within it. So that it sticks out 15 cm over the ground's surface, and drives the hollow tube into the ground. It is important to avoid puncturing the plough pan's bottom. Hand labor is used to remove the dirt within the tube's interior so that the bottom may be seen. The evapotranspiration, water loss, and diffusion that occur in the agricultural field during watering enable the water level to progressively drop. The field's implanted tubes allow for the monitoring of water depths as low as 15 to 20 cm under the surface of the ground. Watering should be used in a crop to restore the groundwater level to an ideal depth of 5 cm after it falls 15 cm under the layer of soil.

Floodplain Area

Agronomic

Over fifty percent of the country's overall rice acreage-roughly 12.0 million hectares when including the Aus, Aman, and Boro seasons-is dedicated to the cultivation of amaranth rice, the majority of which is produced in rainfed conditions. Aman rice is hence extremely vulnerable to flash floods and the monsoon. Five submergence-tolerant rice varieties, BRRI dhan51, BRRI dhan52, BRRI dhan79, BINA Dhan 11, and BINA Dhan 12, evolved and were encouraged by the Bangladesh Rice Research Institute (BRRI) and the Bangladesh Institute of Nuclear Agriculture (BINA). These rice cultivars are appropriate for cultivation during the Aman season (July-November).

Floating agriculture

In certain regions of Bangladesh, a distinct and ingenious farming technique called floating agriculture also referred to as hydroponic agriculture is employed to cultivate crops in regions often impacted by inundation or prolonged instances of water stagnation. This is carried out in Bangladesh's southern flooding areas, specifically in the districts of Barishal, Gopalganj, and Pirojpur (Chowdhury & Moore, 2017; Islam et al., 2019c). Various kinds of crops, including cowpea coriander, ladies' finger, wax gourd, taro, amaranth, pumpkin, spinach, eggplant, hyacinth bean, and tomato, are grown in the floating beds, along with certain spices like ginger, chili, and turmeric (Haq et al., 2004). With only minimal chemical fertilization, output per unit of land could be increased by using this low-tech farming method (Pantanella et al., 2010; Sterrett, 2011). The efficiency of the floating agriculture technique is ten times higher than that of the traditional farming scheme, and it is not dependent on any outside fertilizer to operate (Haq et al., 2004). Because floating gardens facilitate the effective utilization of water hyacinth, which eventually contributes to the maintenance of water quality, reduces mosquito disease outbreaks, and opens up opportunities for fishing, they are ecologically safe (Saha, 2010). Another inherent advantage of floating agriculture includes the utilization of floating platforms as organic substances following crop harvest. Taking into account the average outlay and return, Pavel et al. (2014) calculated the expense and utility of thirty floating gardens. Their research showed that the floating bed sizes had an impact on the benefit-cost ratio (BCR) along with a net return (NR) of 0.26 years. Their analysis also revealed that the projected NR (USD 111.55) and BCR (USD 3.67) for standard (14 × 4 × 3 ft) beds are higher than those for all other dimensions of beds. The results of Abdullah et al. (2014) show that the bed areas of floating gardens and net return have a favourable correlation. Moreover, because this approach is labour-intensive, it also generates employment possibilities in rural regions, which reduces the migration of labour to urban regions. When men and women participate in these activities, gender equity is increased, women are empowered, the development of capabilities occurs, and there are greater social relationships between women (Chowdhury & Moore, 2017; Islam & Atkins, 2007).

Conclusion

From the review, it is clear that environmental degradation as a result of climate change, is increasing day by day, making agriculture more susceptible. Erratic rainfall, frequent drought, sea level rising, frequency of floods, salt water intrusion, increasing frequency of cyclones, groundwater depletion, etc are the most drastic effects of climatic change in Bangladesh. This changing trend will be more dangerous in the future. It is expected that, within 2100, 17.5% of the area will be drawn under the sea which will make the livelihood more difficult through making the food security more insecure. Effective medium- and long-term adaptation strategies are crucial to reducing negative climate impacts and providing a viable path toward resilience. Useful adaptation technologies include the promotion of rice cultivation systems with better water and nutrient-use efficiencies, rescheduling irrigation and fertilizer application to suit changing conditions, training on interpretation of weather forecasts for effective farm decision-making, promotion of biofertilizers and mineral solubilizers for nutrient supplementation, highlighting the importance of blue-green algae in minimizing methane emission from paddy fields, and use of thermophilic bio-inoculants to sustain nutrient flow dynamics in warmer soils. Altering the time of sowing or planting can help farmers regulate the length of the growing season to better suit climate change, as well as help the plants to avoid heat stress during critical growth stages. With climate change and variability increasing pressure on available water resources (and especially, net irrigation requirements), improved water management is one of the most important long-term adaptation options that countries must pursue. According to recent estimates, irrigation efficiency in developing countries is extremely low. Maximizing water-use efficiency can be done by retaining crop residue, reducing soil erosion, increasing soil water holding capacity with improved technology, and increasing infiltration with reduced surface runoff. Water-saving rice cultivation methods like aerobic rice and systems of rice intensification can be promoted as effective adaptation strategies in the future warmer climate.

It’s a great hope that, the farmers of the country practicing different cropping strategies like sorjan practice, sack method, harvesting techniques of rainwater, floating agriculture, mulching etc to mitigate the effects. Besides these, the government has taken several strategies like, the 8th five-year plan of Bangladesh and climate change, the Climate Change Action Plan, National Environment Policy 2018, Ecologically Critical Areas (ECAs) Management Rules 2016, National Biodiversity Strategy and Action Plan (NBSAP) 2016-2021, Bangladesh Biological Diversity Act 2017, Biosafety Policy of Bangladesh Formulation of National Oil and Chemical Spill Contingency Plan (NOSCOP), Improved Management in Wildlife Conservation and Protection, Adoption of the Bangladesh Delta Plan 2100, etc to ensure food security through the crop protection against climatic change effect. Instead of adopting these strategies, Bangladesh is facing endless difficulties in coping with the adverse effect of global warming. In this situation, government institutions, and national and international NGOs should increase their work efficiently. Besides, these new technologies should be introduced against global warming to ensure the sustainable development of agriculture and the livelihood of farmers.

Declarations

Author Contribution

The conceptualization, methodology as well as the project administration together with supervision of the research were handled by Professor Dr. Md. Aminul Hoque. The data collection, investigation, formal analysis and writing of the original draft were undertaken Md. Mejbah Uddin after this. The manuscript was also reviewed and edited by Professor Dr Hoque.

Conflict of Interest

The authors declare no conflict of interest.

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