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ADAPTING TO SURVIVE: CLIMATE CHANGE AND BANGLADESH'S AGRICULTURAL IMPERATIVE

SELIM RAIHAN, SHAFA TASNEEM AND BARUN DEB PAL

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Adapting to Survive: Climate Change and Bangladesh's Agricultural Imperative

Selim Raihan[1]
Shafa Tasneem[2]
Barun Deb Pal[3]

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[1] Dr. Selim Raihan is a Professor in the Department of Economics at the University of Dhaka and the Executive Director of the South Asian Network on Economic Modeling (SANEM). Corersponding author. Email: selim.raihan@gmail.com
[2] Shafa Tasneem is a Research Associate at the South Asian Network on Economic Modeling (SANEM).
[3] Dr. Barun Deb Pal is a Research Coordinator at the Foresight and Policy Modeling Unit of the International Food Policy Research Institute (IFPRI) in New Delhi.

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Phone: +88-02-58813075
Email: sanemnet@yahoo.com
Website: www.sanemnet.org

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Executive Summary

Bangladesh's agriculture sector sits at the centre of the country's development challenge. It supports income, employment, food security, and rural livelihoods, yet it is also one of the sectors most exposed to climate change. In FY2023-24, agriculture contributed 11.55% of GDP and accounted for 44.42% of total employment. At the same time, the sector is deeply vulnerable to rising temperatures, erratic rainfall, floods, droughts, cyclones, salinity intrusion, and sea level rise. These shocks directly reduce agricultural productivity and indirectly weaken food security by affecting the quality, availability, and affordability of food. Agriculture is also a major source of greenhouse gas emissions. In 2022, the AFOLU sector, covering agriculture, forestry, and other land use, accounted for 37.83% of Bangladesh's total GHG emissions.

The paper argues that Bangladesh can no longer treat agriculture only as a vulnerable sector requiring protection. Nor can it be viewed only as an emissions source requiring mitigation. It is both. This dual role makes agricultural transformation central to Bangladesh's climate strategy, food security agenda, and rural development pathway. COP30 has reinforced this point by placing agrifood systems, land use, adaptation, and resilience more firmly within the global climate discussion. For Bangladesh, the key issue is whether global commitments, including the promise to triple adaptation finance by 2035, will become predictable and accessible resources for farmers, irrigation systems, climate-resilient crops, early warning systems, and rural infrastructure.

The climate vulnerability of Bangladesh's agriculture is already visible. From 2000 to 2019, the country registered 185 extreme weather events and is still extremely prone to climate-induced displacement. Climate disasters have destroyed more than 250,000 hectares of land that could be grown back into harvest and impacted 850,000 households. A 30% rise in the price of rice between 2014 and 2021 was exacerbated by losses of agricultural land through crop failure. This is deeply important because Bangladesh has 60 million smallholder farmers who maintain 12 million farms, which account for nearly 60% of domestic food production. But the effects extend beyond farms when agriculture is hit. This flows on to food prices, rural incomes, poverty, nutrition, and social stability.

The paper shows that climate risks are not uniform across the country. The northwest faces drought stress, especially in the Barind region. Drought stress situation in the northwest, particularly the Barind region, flash floods, and earthquake just have blighted the northeast. The central area is especially flood-prone due to its proximity to the Padma, Jamuna, and Meghna river systems. Salinity intrusions and cyclones threaten the southwestern and southeastern coastal belts, while flash floods, droughts, steep topography, and landslide risks are a challenge for the Chattogram Hill Tracts. This means the spatial diversity matters for policy. A single agricultural adaptation package at the national level cannot be expected for Bangladesh. Responses to climate need to reflect the differing agro-ecological zones of every land as well as local vulnerabilities and farmer needs across each region.

Agriculture's emissions profile also deserves closer attention. Bangladesh's agriculture is highly intensified, especially through rice cultivation, which can produce up to three rice crops annually. Methane is released from irrigated rice fields, and nitrous oxide emissions are directly attributable to fertiliser use. Then, there are livestock emissions by enteric fermentation and manure management. Bangladesh ranks as the third-largest emitter of methane from rice paddies in the world, behind China and India, says the paper. Another important message is that Bangladesh emits more per square km of agricultural land than comparator countries such as India and Vietnam. This indicates that there are significant opportunities for both mitigation and adaptation from climate-smart crop and livestock management

The policy landscape is broad, but implementation remains uneven. Bangladesh has developed a range of relevant policy frameworks, including NDC 3.0, the National Adaptation Plan 2023-2050, the Bangladesh Climate Change Strategy and Action Plan, the Bangladesh Climate Prosperity Plan 2022-2041, the Bangladesh Delta Plan 2100, the Perspective Plan 2021-2041, and the National Solar Energy Roadmap. These frameworks emphasise climate-smart agriculture, stress-tolerant crops, improved irrigation efficiency, sustainable agro-input management, renewable energy for irrigation, value-chain development, livestock resilience, and better extension services. The policy direction is encouraging. Still, the paper finds that stronger coordination, financing, monitoring, and field-level implementation are needed if these commitments are to produce real changes for farmers.

NDC 3.0 provides an important opportunity to strengthen Bangladesh's climate-resilient and low-carbon agricultural future. It sets AFOLU-sector emission reduction targets of 3.46% below business-as-usual under the unconditional scenario and 8.00% below business-as-usual under the conditional scenario by 2035. The planned measures include solar irrigation, Alternate Wetting and Drying in rice cultivation, short-duration rice varieties, precision fertiliser application, improved livestock feed management, and manure management. However, the conditional targets depend heavily on international financial and technological support. The paper notes that AFOLU-sector investment needs under NDC 3.0 are estimated at USD 6.88 billion, of which USD 6.00 billion is linked to conditional targets.

To assess the economy-wide implications of agricultural transformation, the study applies a recursive-dynamic Computable General Equilibrium model developed by IFPRI. It is a calibrated model based on a Social Accounting Matrix for Bangladesh, and captures all inter-linkages among sectors, households, factor markets, product markets, government from the real side of the economy (real side) as well as investment and external-sector (capital accounts) linkages. This framework enables the paper to analyse not only sectoral output effects, but also implications for GDP, employment, household income, poverty, and factor markets. The baseline scenario assumes annual GDP growth in Bangladesh to be 6.10% till 2035, and this is the background against which interventions in the agricultural sector are evaluated.

The agriculture-sector simulations focus on four interventions and one combined package. These include solar irrigation pump adoption, climate-smart rice cultivation, livestock feed and manure management, forest cover expansion, and a combined agriculture scenario. The solar irrigation scenario assumes 45,000 solar pump sets replacing 200,000 diesel pump sets out of 1.6 million diesel pump sets. The climate-smart rice scenario includes Alternate Wetting and Drying, short-duration seed varieties, and precision fertiliser application. The livestock scenario targets improved feed practices and manure management for 0.2 million cattle. The forestry scenario includes restoring

230,000 hectares of deforested land in hills and plains and reforesting 100,000 hectares in coastal areas.

The results show that Bangladesh's NDC 3.0 agriculture targets can generate meaningful economic and social benefits by 2035. Under the combined agriculture scenario, GDP growth rises from 6.10% under the baseline to 6.41%. GDP in 2035 becomes 3.0% higher than the baseline, and the economy creates 1.28 million additional jobs. Household income rises across all groups, with stronger gains for the bottom 30%, indicating that the benefits are relatively inclusive. The combined package also lifts 0.8 million people out of poverty.

Among individual interventions, forest cover expansion produces the strongest effects on GDP and employment. Solar irrigation also performs well, especially considering the relatively modest scale of the intervention. It produces visible gains in GDP, employment, income, and poverty reduction, suggesting that wider scaling could deliver larger benefits. Climate-smart rice cultivation has a smaller GDP effect, but it has a meaningful poverty-reduction impact. This is important because rice cultivation remains central to food security, rural welfare, and smallholder livelihoods. Livestock feed and manure management shows limited macroeconomic effects, mainly because the intervention is small relative to the overall size of Bangladesh's livestock sector.

The paper identifies several strategic pathways for adaptation and agricultural transformation. In the short and medium term, Alternative Wetting and Drying can reduce water use and lower emissions without compromising rice productivity. Bed planting can reduce input costs, save water, and improve resilience in drought-prone areas. Solar irrigation can reduce diesel dependence and improve farm profitability. Wider adoption of stress-tolerant crop varieties, improved fertiliser efficiency, better water management, and stronger extension services can also help farmers respond to climate risks more effectively. These measures are practical, scalable, and closely linked to the needs of smallholders.

Longer-term transformation will require deeper changes in the agricultural system. The paper highlights the importance of shifting selectively from rice to non-rice crops in suitable areas, expanding food processing industries, improving cold storage facilities, strengthening supply chains, and adopting digital tools such as blockchain and smart contracts for value-chain transparency. It also stresses the need for concessional adaptation finance, trade openness, domestic structural reforms, and stronger institutional coordination. The Bangladesh Climate Development Partnership can play an important role in supporting the implementation of the National Adaptation Plan and accelerating large-scale climate initiatives.

The overall message of the paper is clear. Bangladesh's agricultural transition must be treated not only as a climate adaptation necessity, but also as a central pillar of food security, poverty reduction, rural transformation, and low-carbon development. Sustainable agriculture should therefore be approached as both a climate strategy and a rural development strategy. Solar irrigation deserves serious scaling up. Climate-smart rice cultivation should be expanded with stronger farmer support. Forestry and land restoration should be integrated into rural employment and ecological resilience strategies. Livestock interventions need to be scaled and supported by better technology, incentives, and data systems. Above all, policy ambition must move from documents to delivery. For Bangladesh, the future of agriculture will depend on whether climate commitments can be translated into practical, financed, and farmer-centred action.

1. Introduction

The agriculture sector is a key pillar of Bangladesh's economy. It supports income generation, provides employment to a large share of the population, and remains central to national food security. In FY2023-24, the sector contributed 11.55% of GDP and accounted for 44.42% of total employment (BBS, 2025). Yet agriculture is also one of the sectors most exposed to climate change. Rising temperatures, erratic rainfall, floods, droughts, cyclones, salinity intrusion, and sea level rise affect food security both directly and indirectly by reducing agricultural productivity and weakening the nutritional quality of food. At the same time, agriculture is also a source of anthropogenic greenhouse gas emissions. In the base year 2022, the AFOLU sector, comprising agriculture, forestry, and other land use, accounted for 37.83% of total GHG emissions (Ministry of Environment, Forest and Climate Change, 2025).

COP30 has made this agriculture-climate link even more important for Bangladesh. The discussions in Belém placed agrifood systems, land use, adaptation, and resilience more firmly within the global climate agenda. FAO also highlighted at COP30 that sustainable agrifood systems are not only victims of climate change, but also part of the solution to the climate crisis. This matters for Bangladesh because agriculture sits at the intersection of adaptation, mitigation, food security, rural livelihoods, and poverty reduction. The COP30 outcome also included a commitment to triple adaptation finance by 2035, which is especially relevant for climate-vulnerable developing countries with large adaptation needs. However, the key question for Bangladesh is whether these global commitments will translate into predictable and accessible finance for farmers, irrigation systems, climate-resilient crops, early warning systems, and rural infrastructure.

For Bangladesh, COP30 also reinforces the need to align NDC 3.0 implementation with agricultural transformation. The country cannot treat agriculture only as a vulnerable sector requiring protection, nor only as an emissions source requiring mitigation. It is both. Therefore, the priorities should include climate-smart rice cultivation, solar irrigation, improved water management, better livestock feed and manure management, soil health improvement, agro-processing based on climate-sensitive crop zoning, and stronger agricultural data and early warning systems. The global discussion around NDC 3.0 and agrifood systems shows that countries need clearer implementation pathways, stronger risk assessments, and better financing mechanisms if climate commitments are to produce real change on the ground. For Bangladesh, this means moving from policy ambition to farmer-level delivery. The urgency of this agenda is not abstract; it is already written into the landscape and livelihoods of millions of Bangladeshi farmers.

Different regions of Bangladesh face different climate change phenomena, such as floods, droughts, cyclones, excess rainfall, salinity intrusion, sea level rise, and high temperatures. Climate-related disasters have caused the loss of over 250,000 hectares of harvestable land and affected 850,000 households. Crop failure caused by the loss of agricultural land contributed to a 30% spike in rice prices between 2014 and 2021 (Pörtner et al., 2022). This vulnerable sector sustains a large number of families in Bangladesh. Barois et al. (2024) reported that Bangladesh has around 60 million smallholder farmers across 12 million farms. These farmers supply 60% of domestic food production.

In this context, the study analyses the role of the agriculture sector in the country's GHG emissions and examines the impacts of various climate-related disasters on agricultural production. It also reviews the current climate-change-related policy landscape, including NDC 3.0. Through an economy-wide modelling exercise, the study assesses the impacts of climate change on the macroeconomy and factor markets. It also proposes alternative solutions to address climate change impacts and evaluates their potential economic implications for the overall economy.

The study applies a computable general equilibrium (CGE) model, developed by the International Food Policy Research Institute (IFPRI), to explore the economy-wide effects of climate change impacts on agriculture. IFPRI's standard recursive-dynamic CGE model is an economy-wide simulation tool. Its static and dynamic modules incorporate flexible behavioural features, including nested production functions, imperfect substitution of imported commodities, and linear expenditure systems for consumer demand. Consumers and producers maximise utility and profits based on factor and product prices, which adjust endogenously to establish market equilibrium. In the dynamic module, population growth and urbanisation are set exogenously and affect labour supply, while sectoral capital accumulation is determined endogenously based on past investments. The CGE model is calibrated using a Social Accounting Matrix (SAM) of Bangladesh, which serves as an economy-wide database.

This paper examines the climate-agriculture nexus in Bangladesh, focusing on how climate change threatens agricultural productivity, food security, rural livelihoods, and broader economic development, while also recognising agriculture's role as a source of greenhouse gas emissions. It begins by situating agriculture within Bangladesh's economy and development priorities, before analysing the sector's exposure to natural hazards like floods, droughts, cyclones, salinity intrusion, etc. The paper then assesses agriculture's contribution to national GHG emissions, particularly through the AFOLU sector, and reviews Bangladesh's commitments under the Nationally Determined Contributions, including agriculture-related mitigation and adaptation priorities. It further examines the national policy landscape for climate-resilient agriculture, identifying both progress and remaining gaps in implementation, coordination, financing, and farmer-level delivery. Using the CGE model, the paper evaluates the economy-wide impacts of climate change and alternative agricultural transformation pathways on GDP, employment, household income, poverty, and factor markets. Building on this analysis, it outlines strategic pathways for adaptation and agricultural transformation, including climate-smart rice cultivation, solar irrigation, improved water and soil management, livestock feed and manure management, forest restoration, stronger extension services, and better access to climate finance. The paper concludes by arguing that Bangladesh's agricultural transition must be treated not only as a climate adaptation necessity, but also as a central pillar of food security, rural development, poverty reduction, and low-carbon growth.

2. Climate Vulnerability of Bangladesh's Agriculture

Bangladesh is one of the countries that faces the highest level of climate risk. In the 2024 World Risk Index, Bangladesh ranked ninth among the countries vulnerable to extreme weather and other climatic impacts. Between 2000 and 2019, Bangladesh witnessed 185 extreme weather events due to climate change (Huq et al., 2024). Bangladesh is the country most susceptible to climate migration in South Asia. Around 4.1 million individuals, or roughly 2.5 percent of the population, were relocated in 2019 due to climatic disasters (World Bank, 2022).

Bangladesh's agricultural sector faces compounding climate threats that collectively erode productivity, shrink arable land, and deepen food insecurity. Because of the varied effects of climate change on different places, the magnitude of such catastrophes varies significantly with land levels (Al-Amin et al., 2019). Floods, droughts, cyclones, rising temperatures, sea level rise, and salinity intrusion interact in ways that are already measurable, and projections suggest the worst is yet to come. If current trends continue, Bangladesh is expected to generate 13.3 million internal climate migrants by 2050, representing approximately 27 percent of all future South Asian climate migrants, with women bearing a disproportionate share of displacement (Rigaud et al., 2018).

Extreme weather events cause severe and recurring shocks to crop output. The flood in August 2024 caused 33.46 billion BDT worth of agricultural damage across 23 districts of Bangladesh. According to the Ministry of Agriculture, around 372,733 hectares of cropland were affected by flooding (The Financial Express Bangladesh, 2024). The scale of such losses is not new: the flood of 1988 caused 45% agricultural production loss (Karim et al., 1996).

Cyclones add another layer of destruction. Cyclone Sidr in 2007 alone caused a loss of 1.23 million tonnes of rice, with 535,707 tonnes lost in four severely affected districts, 555,997 tonnes in nine badly affected districts, and 203,600 tonnes in 17 moderately affected districts (FAO, 2007). Around 210,000 tonnes of boro rice, 36,000 tonnes of aus rice, and 3,500 tonnes of other food crops, such as potatoes and vegetables, were destroyed in the 1991 cyclone. It also caused massive livestock deaths and resulted in the total loss of freshwater fish populations (Farukh et al., 2019).

Chronic, slower-moving stressors pose an equally serious long-term challenge. During the 1990s, the drought in northwestern Bangladesh caused a rice production shortfall of 3.5 million tonnes (Faroque et al., 2013). Ali et al. (2019) stated that drought led to a 40% reduction in agricultural production and affects 53% of the population in Bangladesh.

Rising temperatures compound this pressure. If the temperature is increased by 2°C to 4°C, cultivation of wheat and potatoes could be severely impaired. Total rice production in Bangladesh is projected to be reduced every year by 7.4% until 2050 (Veer, 2025). A 1°C increase in maximum temperature during the vegetative, reproductive, and ripening stages led to a decline in Aman rice production by 2.94, 53.06, and 17.28 tons, respectively (Miahl et al., 2014).

Even incremental changes in rainfall carry measurable consequences - a 1mm increase in rainfall during the vegetative, reproductive, and ripening stages led to a decline in Aman rice production by 0.036, 0.230, and 0.292 tons, respectively (IUCN, 2023). Salinity intrusion, driven by both sea level rise and over-extraction of freshwater, is projected to reduce one-third of agricultural output by 2050 through climate variability and extreme events (ADB, 2023a).

While productivity declines, the land base available for agriculture is simultaneously shrinking. By 2050, rising seas are projected to claim 17% of national territory and take with it approximately 30% of the country's agricultural land (Veer, 2025). The damage is already visible in coastal districts: rice production in Satkhira fell by 69% between 1985 and 2003 as sea levels rose (IUCN, 2023). Around 77% of the loss was due to converting rice fields to shrimp ponds, and the rest 23% was due to yield loss (Ali, 2006).

Salinity intrusion is accelerating cropland loss across the South. Southern Bangladesh's cropland could shrink by 18% nationally by 2040 (ADB, 2023a). These losses carry visible economic consequences. Shrimp exports from Khulna fell from 42,489 tonnes in FY2011–12 to 33,271 tonnes in FY2021–22, a decline directly linked to salinity-related habitat degradation (The Financial Express Bangladesh, 2022).

Together, these trends point to a structural challenge to Bangladesh's food security. Declining yields, shrinking arable land, and the displacement of farming communities are converging at a pace that outstrips current adaptation measures. With the Asian Development Bank projecting a potential one-third loss of agricultural output by 2050, and with 60 million smallholder farmers who supply 60% of domestic food production already operating under stress (Barois et al., 2024), the stakes for policy action could not be higher.

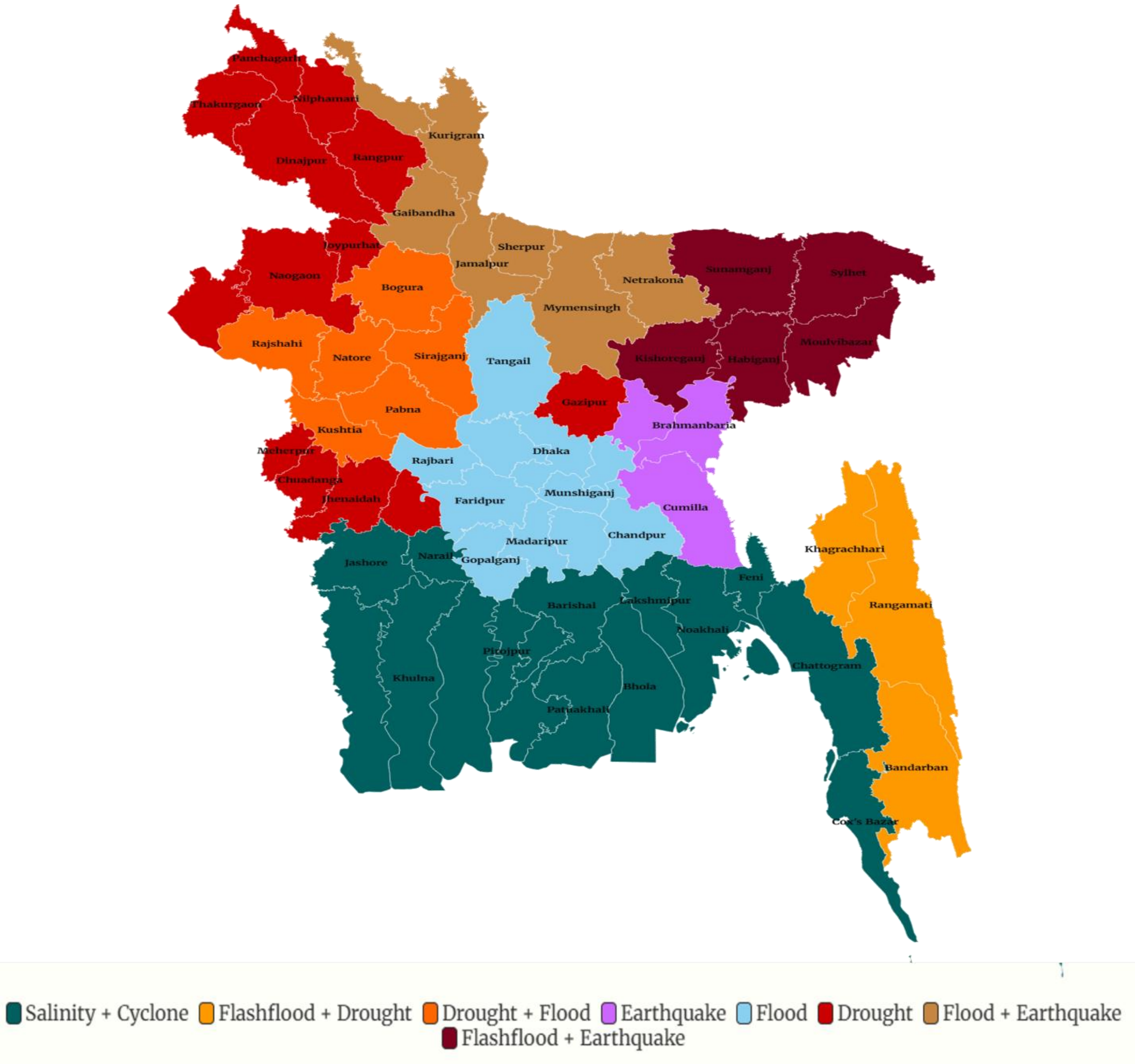
In Bangladesh, agricultural cultivation has been severely limited during the Rabi and Kharif seasons by climatic shocks (Chen et al., 2021). In the northeastern (mainly low-lying and wetland) regions, standing Rabi crops are hampered by floods and extreme rain, which usually occur during the "pre-monsoon" period, which runs from early April to late May. Additionally, Kharif crops in the northern (mainly medium-highland and lowland) regions are impacted by monsoon floods, which typically occur from the end of June to the beginning of October and are caused by excessive rainfall and rising river water levels. There is a variability in the type of climate change based on the region. For example, Bangladesh's upper Barind region is thought to be the most vulnerable to drought. Compared to the other parts of the country, this area experiences less rainfall and is comparatively drier. On the other hand, the central coastal zone of Bangladesh is particularly vulnerable to erosion due to several hydro-climatic causes, such as sea level rise.

Figure 1 presents a district-wise climate hazard map of Bangladesh, illustrating the spatial distribution of major climate hazards across the overall geographical regions.

North-west Region: The north-western districts like Rajshahi, Natore, Pabna, Sirajganj, Bogura, and Kushtia are mainly affected by drought and flood together, showing the seasonal extremities of this region. Pure drought-affected districts are Dinajpur, Rangpur, Nilphamari, Panchagarh, Thakurgaon, Joypurhat, Naogaon, and Chapainawabganj, located within the Barind tract, where rainfall deficiency and low groundwater recharge increase the dry season stress. Drought-affected districts also include Chuadanga, Meherpur, Jhenaidah, Magura, and Gazipur, spreading the drought belt into the west-central zone.

North-east Region: The north-east region, comprising Sylhet, Sunamganj, Habiganj, Moulvibazar, and Kishoreganj districts, is characterized as having flash flood and earthquake hazards. The region is particularly susceptible to both rapid-onset flooding and seismic hazards due to substantial upstream runoff from the Meghalaya hills and its location near active tectonic fault lines. Netrakona and Mymensingh also face flood and earthquake risks, marking the transition between the flood plains and the seismically active north-east.

Figure 1: District-wise Climate Hazard Map of Bangladesh



Source: Adapted from ADB (2021)

Central Region: The central region, comprising Dhaka, Tangail, Manikganj, Faridpur, Rajbari, Munshiganj, Narayanganj, Madaripur, Gopalganj, Shariatpur, and Chandpur, is mainly hit by floods. These low-lying districts are at the confluence of the Padma, Jamuna, and Meghna river systems and are prone to frequent and severe riverine inundation during the monsoon season. Districts like Gaibandha, Jamalpur, Sherpur, Kurigram, Lalmonirhat, and Netrakona face flood combined with earthquake, reflecting both their hydrological exposure and seismic proximity.

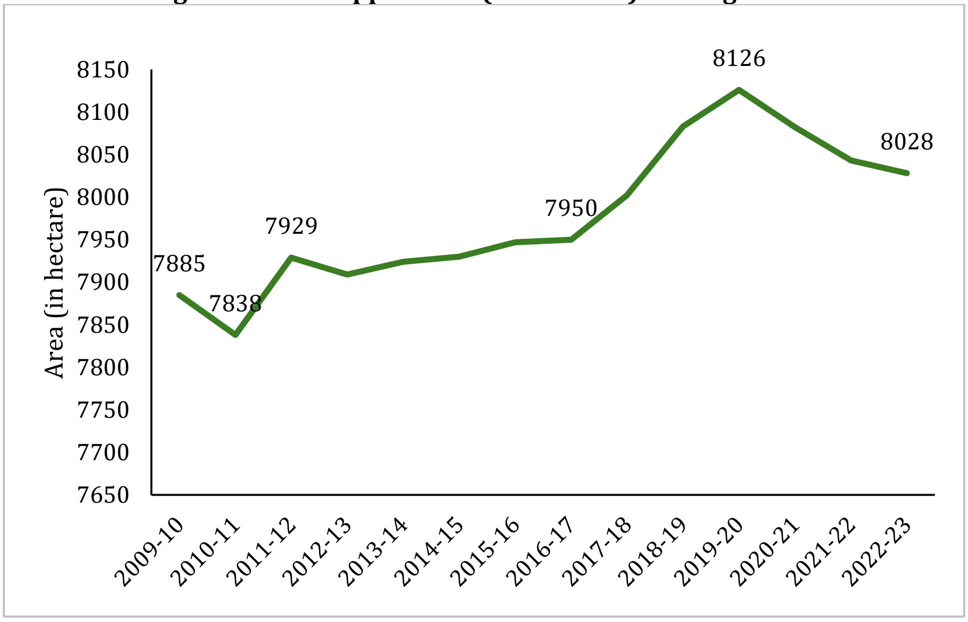
South-west Region: The south-western coastal districts, including Khulna, Bagerhat, Satkhira, Barguna, Patuakhali, Jhalokati, Pirojpur, Bhola, Barishal, Narail, and Jashore, are mostly exposed to salinity intrusion and cyclones. Their location along the Bay of Bengal and within the Sundarbans delta makes them highly vulnerable to tidal surges, cyclonic storms, and saline water ingress into agricultural land and freshwater sources.

South-east Region: The south-eastern districts of Chattogram, Noakhali, Lakshmipur, Feni, and Cox's Bazar are also classified under salinity and cyclone hazards. The classification is due to their extensive coastal exposure along the Bay of Bengal. The districts are subjected to recurrent cyclonic storm surges and saltwater intrusion, which pose significant threats to agricultural productivity and freshwater availability.

Hill Tracts Region: The Chattogram Hill Tracts, including Rangamati, Khagrachhari, and Bandarban, fall under flash flood and drought. This region faces the double challenge of heavy rainfall during the monsoon, which results in rapid runoffs and flash floods, along with extended dry periods in the lean season. The steep topography of the region increases the likelihood of landslides and reduces water retention capacity, making it one of the most physically vulnerable areas in the country.

The spatial distribution of climate hazards in Bangladesh is largely characterized by a specific geographical pattern defined by topography, proximity to water bodies, river systems, and tectonic activities. The southern coastal belt is the most prone to salinity and cyclones, the northwest is the most affected by drought, the central region by flooding, the northeast by flash floods and earthquakes, and the hill tracts by a combination of flash floods and seasonal drought. These overlapping and compounding hazards have far-reaching consequences on the agricultural sector of Bangladesh, affecting yield rates, farm productivity, and the availability of arable land in different regions of the country.

Figure 2: Net cropped area (in hectares) in Bangladesh



Source: Compiled from Yearbook of Agricultural Statistics

Owing to climate change impacts, there has been an impact on the yield rate, productivity, arable land, etc. Figure 2 shows the net cropped area from 2009-10 to 2022-23. There was a decrease in the early years, dropping to a low of 7,839 hectares in 2010-11. From 2011-12 onwards, there was consistent growth through 2019-20. The cropped area size peaked at 8,126 hectares in 2019-20, then declined slightly in recent years. It reached 8,028 hectares in 2022-23. So, we can see an up-down trend where there seems to be a consistent effort to increase the cropped area. However, due to climate change effects and other factors like urbanization, the cropped area has seen a dip.

3. Agriculture as a Source of GHG Emissions

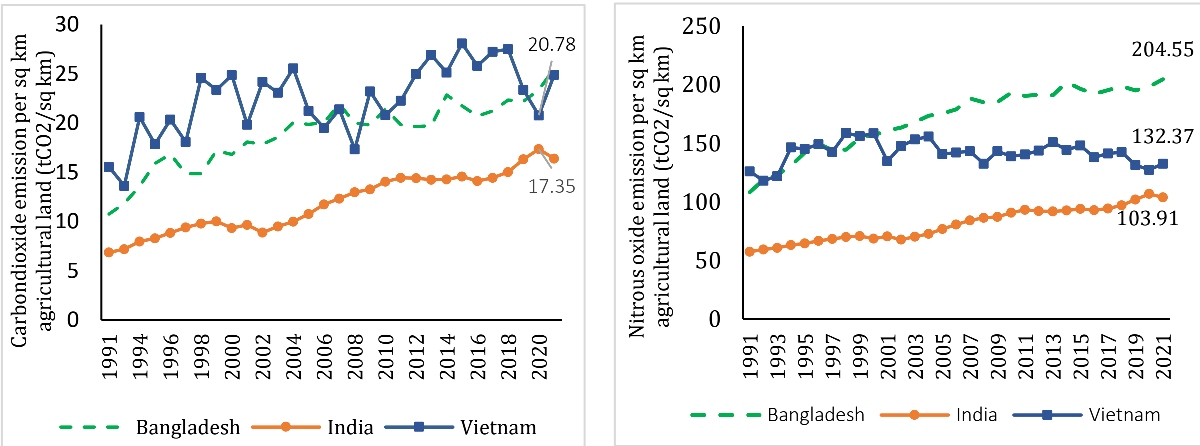
Bangladesh's agriculture sector is highly intensified, producing up to three rice crops annually. Rice cultivation (particularly through irrigation) emits significant amounts of a major greenhouse gas, methane (Habib et al., 2023). The AFOLU sector's total GHG emissions include methane emissions from rice fields, nitrous oxide emissions from nitrogen-based fertilizers, and methane emissions from livestock enteric fermentation and manure management (Raihan et al., 2023).

Over the years, Bangladesh has experienced an increasing trend in greenhouse gas emissions, with a higher degree of methane emissions. Figure 3 shows the country comparison of greenhouse gas emissions per square km of agricultural land – (a) Carbon dioxide, (b) Nitrous oxide, and (c) Methane – from the agriculture sector for Bangladesh, India, and Vietnam from 1991 to 2021. Even though Bangladesh's total GHG emissions remain relatively low in the global context, its emissions per square kilometer of agricultural land are significantly higher than those of its peer countries like India and Vietnam. In the case of all three mentioned gas emissions, India has a significantly lower emission rate among the three countries. Meanwhile, Vietnam has made considerable progress in reducing its GHG emission intensity, whereas Bangladesh's emission rates have worsened over time.

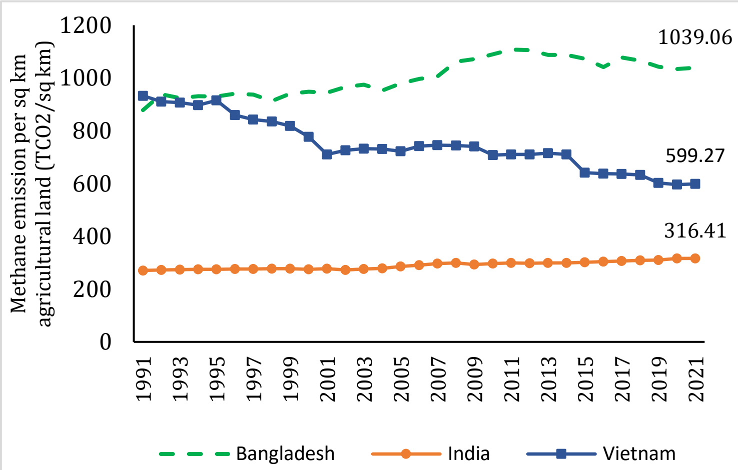
Figure 3: GHG emission trend from the agriculture sector

(a) Carbon dioxide emission

(b) Nitrous oxide emission



(c) Methane emission



Source: Authors' calculation from the World Development Indicator Database

The rice cultivation process is responsible for the emission of methane (CH4) and nitrous oxide (N2O). 12% of global anthropogenic methane emissions, or 1.5% of the warming effect of all greenhouse gases, are caused by flooded rice paddy fields. Bangladesh is the 3rd largest emitter of methane from rice paddies globally at 5.7 Tg/year, after China (8.2 Tg/year) and India (6.5 Tg/year). Together, China, India, Bangladesh, Vietnam, and Thailand account for 78% of all global rice methane emissions (Chen et al., 2025). Compared to CO2, the global warming potential (GWP) of CH4 is 27-30 times higher, and N2O is 273 times higher over 100 years (Chen et al., 2024a). Moreover, primarily due to groundwater pumping, the rice irrigation process in the dry season contributes to the 4% of the country's agricultural GHG emissions (Maniruzzaman et al., 2025).

Livestock significantly contributes to greenhouse gas emissions, showing an increasing trend. Das et al. (2020) estimated that the GHG emission from livestock in 2018 was 66,586 Gg/year CO2e. The authors predicted the emissions to rise to 80,618, 94,638, and 113,098 Gg/ year CO2e in 2030, 2040, and 2050, respectively. The share of enteric CH4, manure CH4, direct and indirect N20 emissions in the total GHG emissions was 44.0%, 3.6%, 51.5%, and 0.9%, respectively, in 2018. Between 1990 and 2020, the amount of manure that dissolved out into the water rose from 236.49 to 493.75 kilotons, while GHG emissions climbed from 7451.26 to 13,244.45 kilotons CO2e (Mahal et al., 2024).

Fertilizer use contributes to GHG emissions due to the overuse of nitrogen-based fertilizers like urea. As a result, nitrous oxide and methane are emitted. A 1% increase in fertilizer consumption leads to 0.28% increase in GHG emissions in the long run (Raihan et al., 2023). It is also found that increased fertilizer use leads to increased nitrous oxide emissions (Aziz and Chowdhury, 2023).

Due to heavily intensified agriculture and high livestock density, Bangladesh's agricultural sector is one of the largest emitters of the country. However, the adoption of climate-smart crop and livestock management can offer significant mitigation and adaptation opportunities.

4. Nationally Determined Contributions (NDCs) and Agricultural Commitments

4.1. GHG Emission Targets of Bangladesh in NDCs

To mitigate and adapt to climate change-related challenges, each country is required to develop and submit Nationally Determined Contributions (NDCs) outlining its climate action plans and emission reduction targets. NDCs are one of the major products of the Paris Agreement in 2015. Earlier, each country used to produce Intended Nationally Determined Contributions. Bangladesh submitted its Intended NDC in 2015 with emission reduction targets for the power, industry, and transport sectors. In INDC 2015, land-use change and forestry (LULUCF) sector emission data were not modelled due to a lack of necessary data (Ministry of Environment and Forest, 2015). An implementation roadmap was later developed in 2018. An interim NDC was published in 2020.

In the second version of NDC in 2021, the country included additional sectors following IPCC guidelines for ensuring coverage that is comprehensive. The preparation of this NDC involved stakeholders from relevant ministries and agencies. Bangladesh's second NDC in 2021 outlines various mitigation and adaptation actions for various sectors, including agriculture, industry, energy, etc.

2012 has been considered the base year while updating the NDC in 2021. The Third National Communication of Bangladesh was followed in this case, which detailed the national GHG emission inventory for 2012. In the base year 2012, the agriculture sub-sector under the Agriculture, Forestry and other Land use (AFOLU) sector generated the highest GHG emission, 45.87 MtCO2e out of the total 169.05 MtCO2e emission. In percentage, the sub-sector alone contributed about 27.13% of the total emission. While projecting the Business-as-Usual (BAU) scenario in 2030, a 2.4 times (409.4 MtCO2e) increase was found compared to the base year. In the AFOLU sector, the emission under the BAU scenario by 2030 was 55.01 MtCO2e, which is 13.44% of the total emission (Ministry of Environment, Forest and Climate Change, 2021).

Bangladesh published its third NDC in September 2025. It sets more ambitious climate targets for 2035, advancing beyond the INDC and NDC 2.0. The year 2022 was adopted as the base year for NDC 3.0, aligned with the BTR1/NC4 GHG Inventory reporting process. Total GHG emissions in 2022 reached approximately 252.04 MtCO_2eq across four sectors: Energy, IPPU, AFOLU, and Waste. Among these, AFOLU was the second-highest emitting sector, releasing 95.35 MtCO_2eq, equivalent to 37.83% of total emissions (Ministry of Environment, Forest and Climate Change, 2025).

The AFOLU sector covers five key areas: enteric fermentation and manure management from livestock, rice cultivation, fertilizer application, aquaculture, and forest land. Within AFOLU, livestock is the largest source of GHG emissions in 2022. Agricultural activities and forestry/land use changes follow as the next significant contributors.

Table 1 shows that Bangladesh set an ambitious target of reducing GHG emissions by 15% from the BAU level under the conditional scenario, while 5% from the BAU level by 2030 in the INDC. In the AFOLU sector, the BAU scenario is developed based on projections of rice cultivation area and livestock population for 2035 from pertinent authorities, while forestry-related emissions are sourced from the Bangladesh Forest Department. It is to note that a conditional scenario means the target can be achieved contingent upon technical and financial support from the global community. In 2021, a more realistic goal was set of reducing GHG emissions to 6.73% below BAU under the unconditional scenario and 15.12% below BAU under the conditional scenario.

Table 1: GHG emission target of Bangladesh in INDC and NDC 2.0 and 3.0

	Emission at BAU Scenario	Overall target		Target related to agriculture	
		Unconditional	Conditional	Unconditional	Conditional
2015		GHG emissions reduced by **12 $MtCO_2e$** or 5% below BAU in 2030 (in the power, transport, and industry sectors)	GHG emissions reduced by **36 $MtCO_2e$** or 15% below BAU in 2030 (in the power, transport, and industry sectors)	No target set for the LULUCF sector	
2021	**Total**: 409.41 $MtCO_2e$ by 2030 **AFOLU Sector**: 55.01 $MtCO_2e$ (13.44%) with agriculture and livestock (13.35%)	GHG emissions reduced by **27.56 $MtCO_2e$** or 6.73% below BAU in 2030	GHG emissions reduced by **61.9 $MtCO_2e$** or 15.12% below BAU in 2030	GHG emissions reduced by **0.64 $MtCO_2e$** or 2.3% below BAU in 2030	GHG emissions reduced by **0.4 $MtCO_2e$** or 0.65% below BAU in 2030
2025	**Total:** 418.40 $MtCO_2e$ by 2035 **AFOLU Sector:** 110.89 $MtCO_2eq$ (26.5%) with livestock (12.80%) and agriculture (9.25%)	GHG emissions reduced by **26.74 $MtCO_2e$** or 6.39% by 2035	GHG emissions reduced by **58.23 $MtCO_2e$** or 13.92% below BAU in 2035	GHG emissions reduced by **3.84 $MtCO_2e$** or 3.46% below BAU in 2035	GHG emissions reduced by **8.87 $MtCO_2e$** or 8.00% below BAU in 2035

Source: Ministry of Environment, Forest and Climate Change, 2015, 2021, and 2025

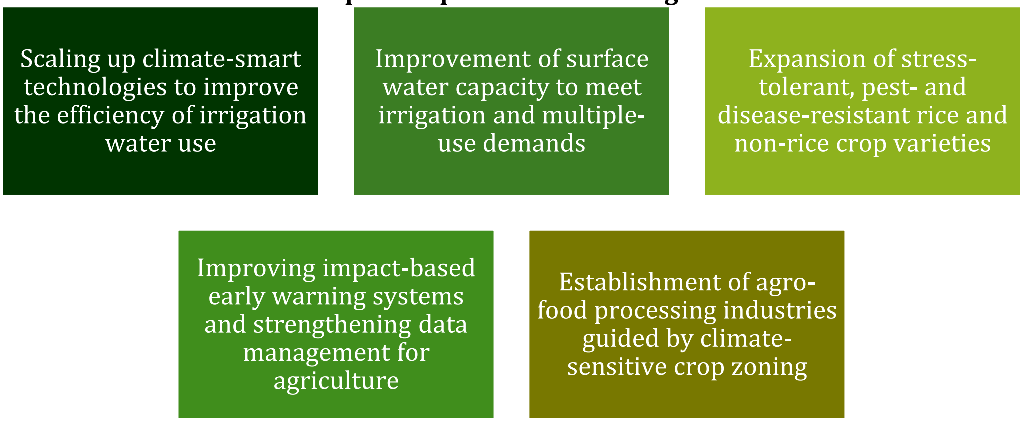
In 2025, the total emission reduction target has been set to 6.39% under the unconditional scenario and 13.92% under the conditional scenario by 2035. The target for the AFOLU sector has been set a little more ambitiously, with 3.46% below BAU under the unconditional scenario and 8.00% below BAU under the conditional scenario. NDC 3.0 has stated that if NDC 2.0 and NDC 3.0 targets are fully implemented, Bangladesh is expected to reach its highest GHG emissions in the period of 2029- 2030 and to gradually decrease thereafter.

4.2. Climate Change Adaptation: Agriculture

Adaptation is central to Bangladesh's response to climate change, given its high vulnerability to sea-level rise, extreme weather events, salinity intrusion, river erosion, floods, and droughts. In order to ensure coherence and alignment across national policies, plans, and international commitments, NDC 3.0 draws directly on the National Adaptation Plan (NAP) in setting its adaptation priorities. Agriculture is one of the eight thematic areas of adaptation interventions under the NAP. Of the 113 adaptation interventions identified in the NAP, 65 have been incorporated into NDC 3.0 as national adaptation priorities. These priorities primarily reflect short to medium-term interventions and are considered feasible for implementation by 2035. The adaptation action in NDC 2021 comprised two components: steps that Bangladesh has already taken and steps that are priorities for the future long-term vision. NAP was not followed to draw inputs for adaptation actions in that version.

Chart 1 highlights the list of national adaptation priorities set by Bangladesh in the agriculture sector. The priorities include expanding climate-smart agriculture, expanding stress-tolerant variants, improving surface-level water capacity, etc. As climate risks intensify, Bangladesh's need for adaptation financing is expected to increase significantly. Based on estimates from the National Adaptation Plan (NAP) and sectoral assessments, the country's annual investment requirement for adaptation is projected to reach USD 12–14 billion by 2035. While domestic resources will contribute to meeting these needs, international support remains critical. In this context, Bangladesh emphasizes the importance of enhanced access to the Green Climate Fund (GCF) and the Adaptation Fund, the fulfilment of the Paris Agreement commitment to scale up adaptation finance to achieve parity with mitigation, and expanded opportunities for technology transfer, South–South cooperation, and capacity building.

Chart 1: National adaptation priorities for the agriculture sector in NDC 3.0



Source: Compiled by Authors from Ministry of Environment, Forest and Climate Change (2025)

Ministry of Environment, Forest and Climate Change (2021) reported that Bangladesh currently spends 6-7% of the annual budget (1 billion USD) to ensure climate resilience. The amount is around five times below the World Bank estimates of 5.7 billion USD for climate adaptation by 2050.

Other than the mitigation and adaptation actions mentioned in the NDC, the Government of Bangladesh has researched to develop crop varieties resistant to drought, cold, waterlogging, diseases, pests, and salinity to adapt to climate change. Ministry of Environment, Forest and Climate Change (2022a) highlighted some of the climate change-tolerant variants shown in Chart 2.

Chart 2: Various stress-tolerant crops of Bangladesh

Early harvest short-duration rice varieties	•BRRI dhan 62 (100 days) •BRRI dhan 66, 71 (113 days) •BINA dhan 7, 11, 16, 17, 19-22 (100-120 days) ***Typical varieties require 140 - 150 days**
Drought tolerant early varieties	•BRRI dhan 42, 43 (100 days) •BRRI dhan 57 (100-105 days), 66 and 71 (also short duration) •BINA dhan-17, 19, 21
Salt tolerant rice varieties	•BRRI dhan 23, 40, 41, 55, 67, 73 (8 ds/m) •BRRI dhan 53, 54, 61, (6 ds/m) •BRRI dhan 47 (8-12 ds/m), 97(8-14 ds/m), 99 (8-10 ds/m) •BINA dhan 8, 10, 23
Flooding tolerant varieties	•BRRI dhan 51 •BRRI dhan52 •BRRI dhan79 •BINA dhan 11, 12, 23
Stress tolerant other crop varieties	•BARI Gom 22, 23, 24 (heat tolerant); •BARI Gom 25, 26, 30, 31 (early maturing heat tolerant); •BINA Gom 1 & BARI Hyb •Hybrid Maize 16

Source: Ministry of Environment, Forest and Climate Change (2022a)

4.3. Climate Change Mitigation: Agriculture

The mitigation action of NDC has highlighted some of the achievable but ambitious planned activities of the government to mitigate the impacts of GHG emissions. The actions are categorized into two parts: Unconditional contribution and Conditional contribution. The unconditional contribution includes the mitigation actions from relevant ministries that would be implemented based on current local-level capacity and financed through internal resources, while the conditional contribution consists of proposed mitigation actions that require international support (Ministry of Environment, Forest and Climate Change, 2025).

Table 2 highlights the mitigation actions for agriculture under unconditional contribution in the NDC 3.0. In the unconditional scenario, GHG emissions would be reduced by 3.84 MtCO2e or 3.46% below BAU in 2035 from the AFOLU (agriculture) sector. For this, a specific target on enhanced use of solar energy and reduction of greenhouse gas emission from rice fields, fertilizer use, etc, has been mentioned in the following table:

Table 2: Priorities and mitigation actions for the agriculture and livestock sector in an unconditional scenario

Priorities		Mitigation Action
Agriculture	**Enhanced use of solar energy**	Implementation of 45000 solar irrigation pumps (generating 1000MWp) for agriculture. 10% of this target will be unconditional, i.e., generating 100 MWp.
	Scaling up Alternate Wetting and Drying (AWD) in rice cultivation	Targeting 30% of the country's Boro rice cultivation area under the Alternate Wetting and Drying (AWD) irrigation practice, with 10% to be achieved unconditionally through domestic resources
	Expand areas under short- duration rice varieties	Targeting 30% of Aman and Boro rice cultivation area under short-duration rice varieties, with 40% of this goal to be achieved unconditionally
	Precision fertilizer application	No target under unconditional contribution
Livestock	**Feed management**	Improving feed by replacing straw/low-quality roughage with HYV fodder/silage: 0.2 million crossbred dairy cows
	Manure management	Targeting improved management of 30% of total manure through biogas (15%), vermicompost (10%), and biochar (5%) applications, with 10% of this goal to be achieved unconditionally

Source: Compiled by Authors from Ministry of Environment, Forest and Climate Change (2025)

It is mentioned in the NDC 3.0 that under the conditional contribution scenario, GHG emissions are expected to decrease by 8.87 MtCO2e (8.00%) below business-as-usual levels by 2035 in the AFOLU sector. This reduction is in addition to the cuts proposed in the unconditional scenario. The conditional mitigation measures will only be implemented if Bangladesh receives external financial and technological support. Table 3 highlights the mitigation actions under conditional contribution.

Table 3: Priorities and mitigation actions for the agriculture and livestock sector in a conditional scenario

Priorities		Mitigation Action
	Enhanced use of solar energy	Implementation of 45000 solar irrigation pumps (generating 1000 MWp) for agriculture/forestry/fish farms. 90% of this target will be conditional, i.e., generating 900 MWp
Agriculture	**Scaling up Alternate Wetting and Drying (AWD) in rice cultivation**	Targeting 30% of the country's Boro rice cultivation area under the Alternate Wetting and Drying (AWD) irrigation practice, with 90% to be achieved conditionally contingent on international climate finance and support.
	Expand areas under short- duration rice varieties	Targeting 30% of Aman and Boro rice cultivation area under short-duration rice varieties, with 60% of this goal to be achieved conditionally
	Precision fertilizer application	Implementing 10% of the total rice cultivation area under Push Type Prilled Urea Applicator technology to improve fertilizer use efficiency and reduce emissions
Livestock	**Feed management**	Improving feed by replacing straw/low-quality roughage with HYV fodder/silage: 1.5 million crossbred dairy cows
	Manure management	Targeting improved management of 30% of total manure through biogas (15%), vermicompost (10%), and biochar (5%) applications, with 90% of this goal to be achieved conditionally

Source: Compiled by Authors from Ministry of Environment, Forest and Climate Change (2025)

Some of the key challenges in implementing the adaptation and mitigation targets include – lack of knowledge and awareness among many relevant stakeholders, lack of basic data collection on a regular basis, and lack of financial support. Moreover, it is mentioned in NDC 2021 that minimal reduction from rice fields, as the sector community has some concerns regarding it hampering the food security of the country. To enhance the emission reduction from rice fields, further research and technology transfer will be needed.

NDC 3.0 has proposed an investment need of 6.88 billion USD in the AFOLU sector to fulfil the targets set in the document. Of them, 0.88 billion will be unconditional, and 6.00 billion will be for conditional targets. The sectoral breakdown will be published in the NDC 3.0 Implementation Plan. Table 4 highlights some policy measures for the AFOLU sector (particularly for crop agriculture and livestock) mentioned in NDC 3.0.

Table 4: Policy measures for agriculture and livestock sector mentioned in NDC 3.0

Intervention Type	Focus Area	Priority Measures (NDC 3.0)
Technology-based	**Precision Agriculture**	• Promoting IoT-based and app-enabled precision agriculture for real-time monitoring of soil, water, and crop conditions • Promoting smart agriculture practices to ensure food and nutrition security
	Biochar (Crop)	• Producing biochar from agricultural and livestock waste residues for soil carbon enhancement and other industrial purposes
	Livestock Technology	• Adopting rumen manipulation techniques, including ionophores, 3-NOP, seaweeds, and herbal feed additives to lower enteric methane
Practice- based	**Water & Rice Management**	• Promoting practices that save water and reduce methane emissions, while keeping yields stable • Promoting appropriate agroforestry practices in areas including homesteads, croplands, and fruit orchards. Promote water-saving and salinity-adaptive cropping practices in vulnerable coastal and drought-prone areas
	Feed Management (Livestock)	• Ensuring enhanced feed management and precision feeding by formulating balanced diets, promoting concentrate-to-roughage balance, and encouraging starch and lipid supplementation • Expanding fodder production and processing systems, including legume cultivation, roughage chopping/shredding, and development of total mixed rations (TMR) with market-led value addition • Supporting the adoption of rumen manipulation practices using ionophores, 3-NOP, seaweeds, and herbal feed additives to lower enteric methane emissions

Intervention Type	Focus Area	Priority Measures (NDC 3.0)
	Manure Management	• Strengthening livestock manure management through anaerobic digestion, biogas, vermicomposting, and organic fertilizer production
Knowledge-based	**Farmer Training & Extension**	• Training of farmers for the larger scalability of AWD, Prilled Urea Applicators, and other Climate Smart Agricultural practices • Extension services and farmers' training to enhance climate awareness in daily farming choices, particularly among women and the youth
	Climate Smart Housing (Livestock)	• Promoting climate-smart livestock housing and management, including the establishment of climate-resilient dairy housing at the farm level
	Animal Health & Breeding	• Promoting sustainable animal breeding and reproduction through crossbreeding programs, lactation improvement, and efficient reproductive management • Improving preventive animal health care with expanded vaccination coverage and deworming programs for major livestock diseases
Data & Governance	**Agricultural Data Systems**	• Developing higher-tier baselines and databases for AWD to improve GHG accounting accuracy
	Livestock Data & R&D	• A unified national real-time livestock database that harmonizes conflicting data sources for tracking sector performance and evidence-based policymaking • Strengthening national livestock R&D and innovation capacity for developing country-specific emission coefficients that reflect local animal genotypes, physiological traits, and climatic conditions

Source: Compiled by Authors from Ministry of Environment, Forest and Climate Change (2025)

Moreover, as a country contributing less than 0.5% of global GHG emissions yet bearing a disproportionate burden of climate impacts, Bangladesh frames loss and damage as a core climate justice issue. Reports suggest that disasters in Bangladesh cause average annual losses of about US$3 billion, roughly 2% of the country's GDP (Amadio et al., 2022). NDC 3.0 outlines a range of conditional actions, including comprehensive needs assessments, a National Loss and Damage Fund, parametric insurance schemes, anticipatory early warning systems, and programs to address slow-onset processes such as sea level rise and salinity intrusion — all contingent on grant-based finance from historically polluting countries. Critically, NDC 3.0 draws on the 2025 ICJ Advisory Opinion, which affirmed that states have binding obligations under international law to provide financial and technical support to climate-vulnerable nations to address loss and damage, strengthening Bangladesh's legal and moral basis for demanding full international support for recovery and resilience-building.

4.4. Equality and Social Inclusion: Agriculture

NDC 3.0 recognizes that climate change is a multidimensional challenge that cannot be addressed through sector-specific actions alone. By integrating cross-cutting issues such as gender equality, human rights, youth participation, and inclusive development, it aims to make climate action more effective and sustainable. The framework places strong emphasis on mainstreaming GEDSI principles to ensure that vulnerable groups - particularly women, children, youth, and persons with disabilities - are not left behind. Supported by national and global commitments, this inclusive approach strengthens resilience, promotes social justice, and ensures that both mitigation and adaptation efforts generate broader social and economic benefits.

As part of its institutional measures, NDC 3.0 calls for establishing dedicated GEDSI units and focal points with adequate resources and clear mandates across ministries. It also emphasizes capacity-building for climate and inclusion focal points, along with the active participation of vulnerable groups in NDC implementation through inclusive local planning. In addition, it promotes mainstreaming inclusive employment, skills development, MSMEs, and innovation led by women, persons with disabilities, and other vulnerable groups. Some proposed actions for the AFOLU sector mentioned in NDC 3.0 are:

- Promoting climate-smart agriculture by empowering women and youth farmers
- Strengthening access to land-ownership rights and financial services for vulnerable groups
- Incorporating traditional ecological knowledge into forest management practices.
- Encouraging vegetable cultivation in homestead areas.

NDC 3.0 is also committed to responding to the needs of children and youth. It emphasizes strengthening low-carbon, climate-resilient child protection systems and safeguarding children, women, persons with disabilities, and other vulnerable groups from climate-related risks. For instance, in the agriculture sector, youth engagement is promoted through demonstration plots, agri-clubs, and peer learning to support youth-led climate-smart agriculture. It also encourages youth-led awareness initiatives and the promotion and installation of community-based biofertilizer and biogas systems.

5. National Policy Landscape for Climate-Resilient Agriculture

As one of the most climate-vulnerable countries, it is crucial to implement strategies that protect and sustain our agricultural productivity. Bangladesh has developed an extensive national policy architecture for climate-resilient agriculture, spanning adaptation planning, emissions reduction, renewable energy, and long-term structural transformation. The key ministries driving this agenda — Environment, Agriculture, Fisheries and Livestock, Food, and Disaster Management — operate under a shared mandate to build sectoral resilience. Finance Division (2023) reported a 1.44 times increase in climate budget from FY2019-20 to FY2023-24. While the breadth of policy commitment is commendable, implementation quality varies considerably across frameworks.

National Adaptation Plan 2023-2050 emphasizes developing climate-resilient agriculture, promoting stress-tolerant crops and livestock, developing community-based cooperative farming systems, enhancing sustainable agro-input management, and expanding innovative agricultural practices like hydroponics, community seedbed, etc. Agriculture, fisheries, aquaculture, and livestock are among the eight distinct sectors mentioned in NAP. One of the six national goals set by NAP is to develop climate-resilient agriculture for food, nutrition, and livelihood security (Ministry of Environment, Forest and Climate Change, 2022c). Under this goal, four strategic actions are highlighted. The actions are given in Chart 3:

Chart 3: Strategic actions mentioned in the National Adaptation Plan of Bangladesh

Promote the extension of climate-smart agriculture	Develop climate resilient agriculture, fisheries and livestock	Manage sustainable agro-inputs and transformative value chains	Strengthen extension services for agriculture, fisheries and livestock

Source: Ministry of Environment, Forest and Climate Change (2022c)

Table 5: Adaptation interventions for agriculture in NAP

Sl	Interventions for NAP	Priority	Duration
1	Extension of climate-smart technologies for increasing irrigation water use efficiency	High	Medium to long term
2	Augmentation of surface water for irrigation and multipurpose use	High	Medium to long term
3	Extension of stress-tolerant, pest and disease-resistant rice and non-rice crops	High	Medium to long term
4	Introduction and scaling up of innovative and indigenous agriculture	Moderate	Medium to long term
5	Crop diversification	Moderate	Medium to long term
6	Farm modernization	High	Medium to long term
7	Increased fertilizer use efficiency for enhancing production	High	Medium to long term
8	Extension of good agricultural practices (GAP), modern agriculture technology (MATH), and sloping agricultural land technology (SALT)	High	Medium to long term
9	Strengthening and development of impact-based early warning systems and data management for agriculture	High	Medium to long term
10	Improvement of storage or post-harvest facilities, transport, communication, and e-commerce-based market facilities for agricultural products	High	Medium to long term
11	Development of agro-food processing industries based on climate-sensitive crop zoning	High	Medium to long term
12	Development of e-commerce and engagement of women, people with disabilities, and youth for e-commerce-based entrepreneurship	Moderate	Medium to long term

Source: Ministry of Environment, Forest and Climate Change (2022c)

Under risk level SSP 5-8.5, NAP has identified excessive rainfall, extreme heat, cold spells, early or frequent flash floods, increased salinity, frequent cyclones, and sea level rise as high-risk climate hazards for crops. For fisheries and aquaculture, frequent river floods, frequent flash floods, increased salinity, and sea level rise are marked as high-risk climate hazards. In order to achieve the vision and 6 goals, NAP has formulated 23 adaptation strategies under 8 sectors. 12 adaptation interventions for agriculture (Table 5).

Some of the key initiatives mentioned in the Adaptation Plan are:

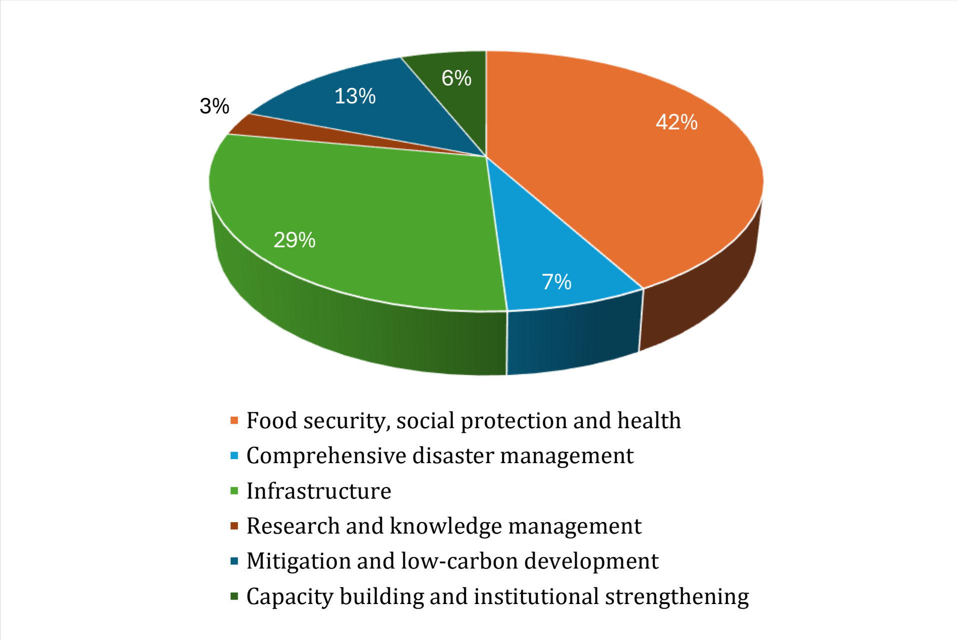
- Developing climate-resilient agriculture for food, nutrition, and livelihood security
- Promoting extension of climate-stress-tolerant breeds, farmhouse, and fodder
- Developing climate-resilient fisheries, aquaculture, and livestock
- Managing sustainable agro-inputs and transformative value chains
- Development and extension of dietary food manipulation
- Strengthening extension services for agriculture, fisheries, and livestock
- Community-based cooperative farming system development and extension
- Introducing Integrated Multi-Trophic Aquaculture in suitable areas
- Developing seaweed farming as a sustainable blue food and the pathway to carbon neutrality
- Mapping open water fisheries resources
- Extension of bio-fortified crop varieties
- Upscaling of indigenous agriculture
- Introducing and upscaling of innovative (hydroponic, high-value crops, community seedbed, etc) agriculture

Bangladesh Climate Change Strategy and Action Plan (BCCSAP) 2009 emphasizes establishing climate-resilient cropping, fisheries, and livestock systems. It also highlights the need for conducting gender-focused climate impact studies, assessing threats to agriculture, and developing GIS-based vulnerability maps for targeted interventions. The strategy is structured around six pillars, including 'Food Security, Social Protection, and Health.' (Ministry of Environment, Forest and Climate Change, 2009). With collaboration from the Ministry of Agriculture, the Ministry of Water Resources, the Ministry of Fisheries and Livestock, BRRI, BARI, NARS, etc., various medium to long-term programs under the food security theme are:

- Institutional capacity and research towards climate-resilient cultivars and their dissemination
- Development of climate-resilient cropping systems and production technologies
- Adaptation against drought, salinity, submergence, and heat
- Adaptation in the fisheries sector
- Adaptation in the livestock sector

To implement the pillars mentioned in BCCSAP, the national budget is allocated every year. Figure 4 shows that among the budget allocated for BCCSAP implementation, around 42% was allocated for food security, social protection, and health in 2023.

Figure 4: Climate-relevant allocation (%) across BCCSAP thematic areas in FY2023-24



Source: Finance Division (2023)

Bangladesh Climate Prosperity Plan 2022-2041 introduces climate-resilient practices like vertical farming and rooftop gardening, replaces diesel-powered irrigation with solar energy, promotes off-farm employment, and fosters public-private partnerships for sustainable agriculture. Under the priority area 'Comprehensive Climate and Disaster Risk Financing and Management', the plan aims to enhance productivity by 2.5% per annum by 2025 and 5% per annum by 2030 (Ministry of Environment, Forest and Climate Change, 2022b). Some of the key measures for climate-resilient food security mentioned in the plan are:

- Enhancing agricultural productivity towards food security in the climate-vulnerable regions such as the Coastal Belt, Barind Areas, Char and Wetlands Lands Haor, and Hill Tracts.
- Promoting decentralized and localized activity for food processing and marketing industries to secure a greater share of the value chain for communities that are generating the primary agricultural outputs.
- Supporting low-cost, climate-resilient, and culturally appropriate food security solutions like rooftop gardening, hydroponics, floating beds, and the Sorjan system.
- Introducing climate-adaptive insurance with premium subsidies and capital support to reduce risk and attract investment in agricultural insurance.

Bangladesh Delta Plan 2100 outlines comprehensive strategies to address climate change challenges in the agricultural sector. Recognizing that agriculture is likely to face significant output losses due to climate impacts, the plan focuses on enhancing resilience and promoting sustainable practices (GED, 2018). Key strategies include:

- Diversifying agricultural output and livelihoods;
- Lowering emissions (GHGs) from agricultural land;
- Encouraging the establishment of commercial farms;
- Introducing the Aquaponics farming system to culture fish and plants together;
- Using Nanotechnology in agriculture for processing, distribution, and packaging;

- Introducing a precision agriculture model;
- Encouraging solar power in irrigation;
- Preserving ecosystems for plants, wild animals, fish, birds, etc., and encouraging fruit tree plantation;
- Improving Wetland Management in Haor Areas for the development of fisheries;
- Maintaining biodiversity to ensure long-term fish availability;
- Sustainable marine fisheries resources management;
- Producing climate resilient Livestock;

Perspective Plan of Bangladesh 2021-2041 aims to support sustainable agriculture through crop diversification, precision farming, modern irrigation, Good Agricultural Practices (GAP), and agro-processing development to reduce post-harvest losses and enhance farmer income (GED, 2020). Six strategic approaches for sustainable agriculture are:

- Bringing unfavourable agri-ecosystems under productive, sustainable agricultural practices;
- Intensifying crop cultivation in productive agricultural land, maintaining the sustainability of soil health;
- Sustainably intensifying agricultural production systems without bringing new land under cultivation;
- Increasing resilience of crop and livestock production systems in the face of climate change;
- Diversifying agricultural output by involving more plant species or varieties, animal breeds, off-farm activities, and employment;
- Coping with uncertainty in developing responses due to uncertainty about the scale and eventual nature of adaptation needed to address climate change

National Solar Energy Roadmap, 2021-2041, is formulated by the Sustainable and Renewable Energy Development Authority (SREDA). To increase solar power generation by 2041 is its current goal (SREDA, 2020). Among its targeted initiatives, the irrigation of solar pumps is of importance to agriculture.

- Bangladesh's Sustainable and Renewable Energy Development Authority (SREDA) has established renewable energy targets for solar irrigation, planning 700 MW capacity between 2021-2030 and an additional 460 MW from 2031-2041.
- GoB has launched various projects to promote the use of Solar Irrigation Pumps (SIPs) across the country. to expand Solar Irrigation Pump (SIP) adoption nationwide. Key government agencies serving as project implementers include the Bangladesh Agricultural Development Corporation (BADC), Bangladesh Rural Electrification Board (BREB), Barind Multipurpose Development Authority (BMDA), and the Infrastructure Development Company Limited (IDCOL).
- To ensure affordable irrigation water pricing for farmers, IDCOL provides substantial financial assistance by covering up to 85% of project costs through various funding sources and grant programs. Currently, IDCOL operates two distinct financing approaches for off-grid solar irrigation initiatives: the Fee for Service Model and the Ownership Mode.

Almost all of the recent national policy documents focus on climate-smart agricultural policies. Almost all of the policies largely align with Bangladesh’s climate goals stated in the NDC. The documents have more or less equal focus on the crop, livestock, poultry, and fisheries. The policies talk about increasing research and production of stress-tolerant seed variants, assessing the threats to livestock and fisheries, introducing renewable energy for the irrigation process, having a community-based cooperative farming system, enhancing off-farm activities to reduce post-harvest loss, etc. The policy actions enhance climate resilience and ensure sustainable agricultural growth in the face of climate change challenges.

However, it is believed that the NAP implementation process will strengthen policy creation, improve governance structures, and establish an organized system for successful execution. This process is expected to facilitate the development of essential policies, including the Local Level Adaptation Program of Action, City Climate Action Plan, and Youth-Led Adaptation Plan. Furthermore, the NAP implementation will assist in revising the Bangladesh Climate Change Strategy and Action Plan (BCCSAP) along with other sector-specific strategies, ensuring they are harmonized with NAP objectives while incorporating social inclusion principles.

Table 6 highlights the alignment of Bangladesh's key national plans and strategies in addressing climate-resilient agriculture. The National Adaptation Plan is found to be highly complementary to the Perspective Plan 2021-2041, the Bangladesh Delta Plan 2100, and the Sustainable Development Goals, notably SDG13, indicating a coherent cross-framework approach to climate adaptation. Likewise, the Bangladesh Climate Prosperity Plan is highly consistent with both the 8th Five-Year Plan and the National Agriculture Policy, which together focus on food security, diversification of agriculture, and establishment of sustainable, climate-resilient supply chains. Collectively, these alignments suggest that the Bangladesh national planning landscape is broadly aligned around a shared vision of climate resilience, but the main challenge is to effectively implement across these overlapping frameworks. Effective implementation will require stronger institutional coordination across the ministries responsible for these overlapping frameworks, along with sustained financing, robust monitoring mechanisms, and clear accountability structures to ensure that policy alignment on paper translates into measurable outcomes on the ground.

Table 6: Alignment between national plans and strategies

Environment and Climate Policies	**National Plans**	**Alignment**
National Adaptation Plan	Perspective Plan of Bangladesh 2021-2041	Achieving food and nutrition safety and transforming agriculture to become a high-income country is one of the aims of the Perspective Plan 2021-2041. The process of transformation through climate-resilient development is well complemented by the vision and goals of NAP.
	Bangladesh Delta Plan 2100	There is a direct link between 53 CC adaptation projects and 23 NAP interventions. The two strategies are complementary and highly synergistic
	Sustainable Development Goals	NAP is an important national platform for achieving SDG13, which combats climate change and its impacts by 2030

Environment and Climate Policies	National Plans	Alignment
Bangladesh Climate Prosperity Plan	8th Five-Year Plan	The 8FYP seeks to tackle challenges concerning nutrition, food security, food safety, production capacity, sustainability, and climate change effects by implementing nationwide interventions with support from development partners. The Bangladesh Climate Prosperity Plan describes the creation of climate-adaptive agricultural and fisheries supply chains. This framework would encompass national disaster risk financing and management systems designed to protect food and water security through the adaptation of food distribution networks to climate-related changes
Bangladesh Climate Prosperity Plan	National Agriculture Policy and the National Adaptation Plan (NAP)	National Agriculture Policy and National Adaptation Plan (NAP) emphasize enhancing productivity to increase crop yields, minimizing climate-related risks, and encouraging expansion into non-crop agricultural sectors, including fishing, livestock, and dairy farming. In line with these two strategic frameworks, the prosperity plan will focus on establishing an economically viable and environmentally sustainable agricultural production system. This will involve furthering agricultural diversification while securing food and nutritional needs through enhanced farm productivity, improved input supply systems, supportive pricing policies, reliable water access, accessible agricultural credit, and strengthened marketing infrastructure.

Source: Authors' compilation from various sources

6. Economy-wide Impacts of Climate Change on Agriculture: CGE Model Analysis

6.1. The Methodology of the Economy-wide Modelling

This study examines how Bangladesh's climate commitments, particularly the targets under NDC 3.0, can contribute to the country's broader development objectives. The central question is straightforward but important: how would achieving the NDC 3.0 targets help Bangladesh attain its national economic development goals? To answer this, the study applies an economy-wide recursive dynamic Computable General Equilibrium (CGE) model to compare Bangladesh's business-as-usual growth path with alternative scenarios in which NDC 3.0 targets are achieved. The comparison allows the study to estimate the incremental economic, social, and environmental benefits of climate action up to 2035.

The analytical approach begins with a business-as-usual baseline. This baseline tracks the likely evolution of the Bangladesh economy to 2035 without additional policy interventions linked to NDC 3.0. The study then introduces sector-specific climate actions and compares the resulting development outcomes with the baseline. In this way, the model does not simply ask whether climate action reduces emissions. It asks a broader development question: what additional gains could Bangladesh achieve in terms of GDP, employment, poverty reduction, undernourishment, household income, and structural transformation if it implements its NDC 3.0 commitments?

In this paper, the modelling exercise focuses on the agricultural sector. This sector was selected through a review of the NDC 3.0 document, with particular attention to which targets could be translated into model-based scenarios. The selection was also informed by a review of relevant literature, expert consultations, policy engagement, and stakeholder discussions. In agriculture, the model considers climate-smart agriculture measures, including reduced post-harvest losses, improvements in soil organic matter, expanded solar irrigation and water management, improved cattle sheds, manure management, forest cover, and land-use change.

The core modelling framework is built around a 2022 Social Accounting Matrix (SAM) for Bangladesh. The SAM provides a consistent economy-wide database that captures the flow of income and expenditure across producers, households, government, investors, and the rest of the world. It allows the model to trace how changes in one part of the economy affect other sectors and institutions. This is particularly important for climate policy analysis, because climate action in agriculture can generate effects far beyond the targeted sector.

The SAM for the Bangladesh economy has 80 sectors in the database. This level of sectoral detail allows the analysis to capture production patterns and supply-chain linkages with considerable precision. Agriculture is represented through 27 primary products and 17 processed products. The energy sector distinguishes solar and hydropower, while the transport sector differentiates between internal combustion vehicles and electric vehicles. This sectoral structure is important because the transition to a low-carbon economy is not uniform across the economy. Different sectors face different constraints, technologies, emissions profiles, and adjustment costs. A detailed sectoral framework, therefore, helps identify where the largest gains, risks, and trade-offs may arise.

The model also includes a household survey module. The population is divided into 20 household groups, based on rural and urban per capita expenditure quintiles. This makes it possible to assess how climate policies affect different types of households. Such distributional analysis is particularly important for Bangladesh, where climate risks, poverty, food insecurity, and employment vulnerabilities are unevenly distributed across regions and social groups. A policy that raises aggregate GDP may still have unequal effects across households. The household module, therefore, helps the study assess not only the macroeconomic effects of climate action but also its implications for poverty, undernourishment, and household welfare.

Labour markets are also disaggregated by education levels. This feature allows the model to capture the employment implications of climate-related policy shifts. Green transport, renewable energy, and climate-smart agriculture may create new jobs, but the type of jobs created will depend on the skill composition of labour demand. At the same time, some sectors may face adjustment pressures as production technologies and energy systems change. By separating labour by education levels, the model can examine how climate action affects different categories of workers and whether the transition may require complementary investments in skills, training, and labour-market support.

The recursive dynamic structure of the CGE model allows the analysis to move beyond a one-period static comparison. The model tracks the economy over time, linking current outcomes to future economic conditions. Population growth and urbanisation are introduced exogenously, affecting labour supply and household demand. Sectoral capital accumulation is determined endogenously, based on past investment patterns. This means that policy shocks introduced in one period can influence future production capacity, investment, employment, and income. The dynamic structure is therefore well-suited to assessing Bangladesh's development trajectory up to 2035.

A key strength of the CGE framework is that it captures economic linkages across sectors, factor markets, product markets, institutions, and the external sector. Producers use factors such as land, labour, and capital, along with intermediate inputs, to produce goods and services. These goods and services are then sold to households, the government, investors, other producers, or foreign buyers. Some goods are exported, while imported goods enter domestic markets and compete with domestic production. Prices adjust to ensure that supply equals demand across markets. This equilibrium-based structure allows the model to capture both direct and indirect effects of policy changes.

The model also maintains macroeconomic consistency. It keeps track of government revenue and expenditure, savings and investment, and the current account or foreign exchange balance. This is essential for climate policy analysis. Many green transition measures require investment, subsidies, public spending, or changes in imports of capital goods and technologies. These measures may affect fiscal balances, external balances, and investment flows. The CGE model ensures that these economy-wide constraints are reflected in the results rather than treated as external assumptions.

Data reconciliation is a central part of the methodology. The modelling database brings together information from national accounts, balance of payments data, household surveys, labour force surveys, government accounts, public finance studies, firm and industry studies, programme evaluation studies, and firm surveys. Each source contributes a specific element. National accounts provide GDP by sector, product supply and use, and transaction costs. Balance of payments data provide information on trade flows, remittances, foreign investment, and development assistance. Household surveys provide data on consumption, diets, labour income, land and enterprise earnings, taxes, and transfers. Labour force surveys provide information on employment and earnings by sector. These different data sources are reconciled into a coherent SAM and then used to calibrate the CGE model.

The SAM structure links production, income generation, income distribution, consumption, investment, government finance, and external transactions. Activities receive income from marketed output. Commodities are used for intermediate demand, private consumption, public consumption, investment demand, and exports. Factors receive value-added payments, which are then distributed to households as factor incomes. Households also receive transfers and remittances, and allocate their income across consumption, savings, and direct taxes. The government receives revenue from producer taxes, tariffs, VAT, excise taxes, direct taxes, and foreign aid, while also spending on consumption, transfers, savings, and investment. The rest of the world account records imports, exports, foreign payments, remittances, grants, and foreign savings.

The supply-chain structure of the model is also important. Activities combine labour, land, capital, and intermediate inputs to produce output. This output is then transformed into commodities, which may be sold domestically, exported, or combined with imports to form a composite supply. Composite supply is then used by households, government, investors, and producers. The model allows price-driven substitution in selected parts of the system, while assuming no substitution in others. This structure reflects the fact that producers and consumers can adjust their behaviour when relative prices change, but only within technological and institutional limits.

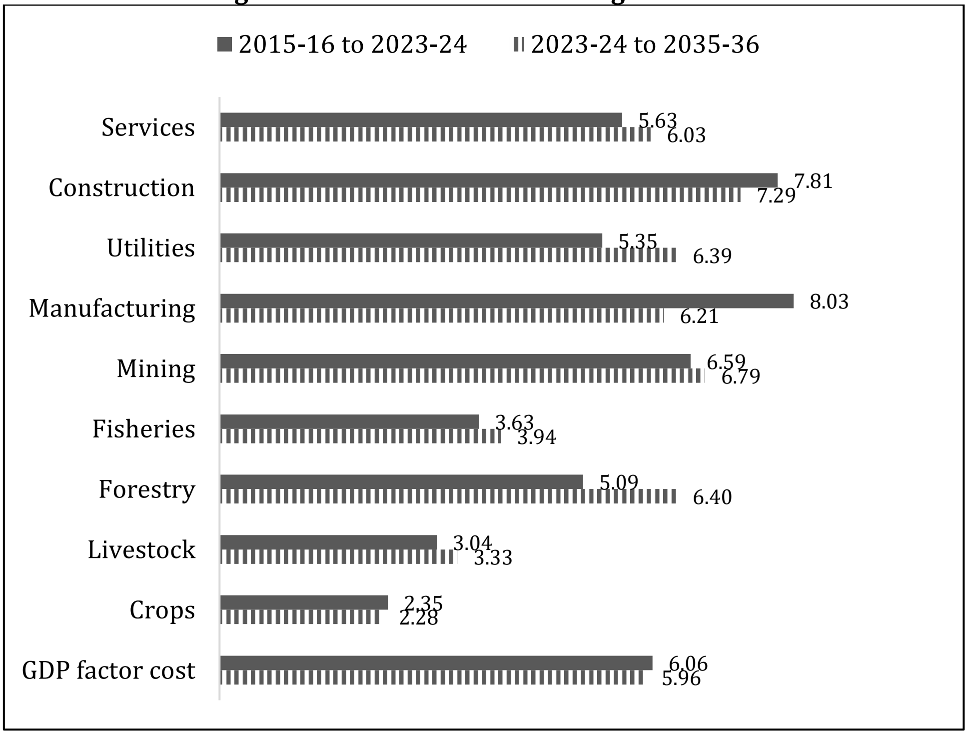
Through this framework, the study can simulate how specific NDC-related interventions affect the broader economy. The study's outcome indicators include GDP gains, job creation, poverty, undernourishment, household income, sectoral production, electricity generation, changes in the vehicle fleet, and other relevant development outcomes. This is important because Bangladesh's climate transition cannot be assessed only through emissions reductions. The central issue is whether climate action can support a wider development strategy. If well designed, decarbonisation can reduce vulnerability, improve productivity, create jobs, lower future economic losses, strengthen food security, and support more inclusive growth.

6.2. Baseline scenario

The baseline scenario provides the reference path for assessing the economy-wide effects of agriculture-sector decarbonisation and climate-smart interventions. It represents Bangladesh's projected growth trajectory up to 2035 without additional NDC 3.0-related policy interventions. Under this baseline, GDP is projected to grow at an annual average rate of 6.10% during 2023-24 to 2035-36, broadly continuing the country's recent historical growth pattern (Figure 5). The baseline is driven by population growth, productivity growth, and changes in cropped area. Productivity is introduced through the shift parameter in the production function, while labour is assumed to be mobile across activities. Low-skilled workers are allowed to remain unemployed, while high-skilled workers are assumed to be fully employed. Capital, however, is assumed to be immobile across activities.

The macroeconomic closure assumptions also shape the baseline results. The exchange rate is fixed, and foreign savings adjust to clear the external market. Given the tax rate, the government budget deficit adjusts to balance government accounts. The savings rate is also scaled so that aggregate savings equal aggregate investment. These assumptions create a consistent economy-wide framework for comparing the agriculture-sector interventions with the business-as-usual path.

Figure 5: Baseline and historical growth rate



Source: Dynamic recursive CGE model of Bangladesh

6.3. Agriculture-Sector Decarbonisation Scenarios

The agriculture-sector decarbonisation scenarios are designed around Bangladesh's NDC 3.0 targets for 2035. These targets cover three broad areas: crop production, livestock, and forestry. In the crop sector, the targets include the adoption of 45,000 solar irrigation pump sets, bringing 30% of Boro cultivated area under the Alternate Wetting and Drying method, the adoption of short-duration seed varieties on 30% of rice cultivated area, and precision fertiliser application on 10% of rice area. In the livestock sector, the targets include improved feed practices through high-yielding fodder cultivation for crossbred dairy cows and 30% manure management. In the forestry sector, the targets include restoring 230,000 hectares of deforested land in hills and plains and reforesting 100,000 hectares in coastal areas.

These agriculture-sector measures are not limited to emissions reduction. They also address productivity, input efficiency, rural livelihoods, and resilience. Solar irrigation can reduce dependence on diesel pumps and lower irrigation costs. Climate-smart rice cultivation can reduce water and fertiliser use while improving yields. Better livestock feed and manure management can reduce emissions intensity and raise productivity. Forest restoration can support carbon sequestration, land rehabilitation, biodiversity, and rural employment. The combined agriculture package, therefore, links climate mitigation with agricultural transformation.

Scenario building for the agriculture sector

The agriculture-sector simulations are built around four individual scenarios and one combined scenario (Table 7). The first is AG_SOL, or the adoption of solar irrigation pump sets. This scenario assumes the installation of 45,000 solar pump sets, replacing 200,000 diesel pump sets out of a total of 1.6 million diesel pump sets. Solar pumps are assumed to reduce diesel consumption by 30% and increase electricity consumption by 10%. The scenario also assumes that lower-cost irrigation will help farmers manage land more effectively, thereby improving productivity and profitability.

The second scenario is AG_RIC, or climate-smart rice cultivation. It combines three interventions: bringing 30% of Boro rice cultivation under the Alternate Wetting and Drying method, adopting short-duration seed varieties on 30% of rice area, and applying precision fertiliser on 10% of rice area. These measures are expected to reduce irrigation costs, improve yields, lower fertiliser use, and reduce the fertiliser import bill. This scenario is particularly important because rice remains central to Bangladesh's food security, rural livelihoods, and agricultural emissions profile.

The third scenario is AG_LIV, which focuses on livestock feed and manure management. Out of 26.5 million cattle, the scenario targets 0.2 million cattle for improved feed practices and manure management. Improved feed practices are assumed to increase fodder production and raise milk yields. At the same time, manure management can help reduce emissions associated with livestock production. However, the relatively small scale of the intervention limits its macroeconomic effect.

The fourth scenario is AG_FOR, or the expansion of forest cover. It assumes the restoration of 230,000 hectares of deforested land in hills and plains, along with the reforestation of 100,000 hectares in coastal areas. This would bring an additional 1.3% of land area under forest cover. The scenario also assumes that forestry, which has been one of the higher-growth areas within agriculture and allied activities in the past, will maintain its growth momentum in the future.

The fifth scenario is AG_ALL, which combines all four agriculture-sector interventions. This combined scenario captures the broader effect of climate-smart agriculture, solar irrigation, livestock improvement, and forest expansion working together. However, as with other sectoral packages, the combined impact should not be interpreted as a simple sum of the individual scenario impacts, since interactions across sectors, input markets, factor markets, and household income channels matter.

Table 7: Scenario building: Agricultural sector

Scenarios	Descriptions	Assumptions
AG_SOL (Adoption of Solar Irrigation Pump Sets)	• 45000 solar pump sets • Replace 200000 diesel pump sets of a total of 1.6 million diesel pump sets	• Solar pump sets will reduce diesel consumption by 30% and increase electricity consumption by 10% • Low-cost irrigation will help farmers to better manage their land, improving productivity and profitability
AG_RIC (Climate Smart Rice cultivation)	• 30% Boro rice cultivation under the Alternate Wet and Dry method • 30% area under short-duration seed varieties • 10% area under precision fertilizer application	• Savings in irrigation cost and improved yield • Reduce fertilizer consumption and thereby the import bill for fertilizer

Scenarios	Descriptions	Assumptions

AG_LIV (Livestock Feed & manure management)	• Of 26.5 million cattle, 0.2 million cattle will be targeted for
	  ◦ Improved feed practice
	  ◦ Manure management
		• Improved feed practice will increase fodder production
		• Milk yield will increase

AG_FOR (Expanding area under forest cover)	• Restore deforested 230,000 ha area in hills & plains
	• Reforestation of 100,000 ha in coastal areas
		• Additional 1.3% area will be under forest cover
		  ◦ One of the high-growth sectors within agriculture and allied in the past
		  ◦ This momentum will continue in the future

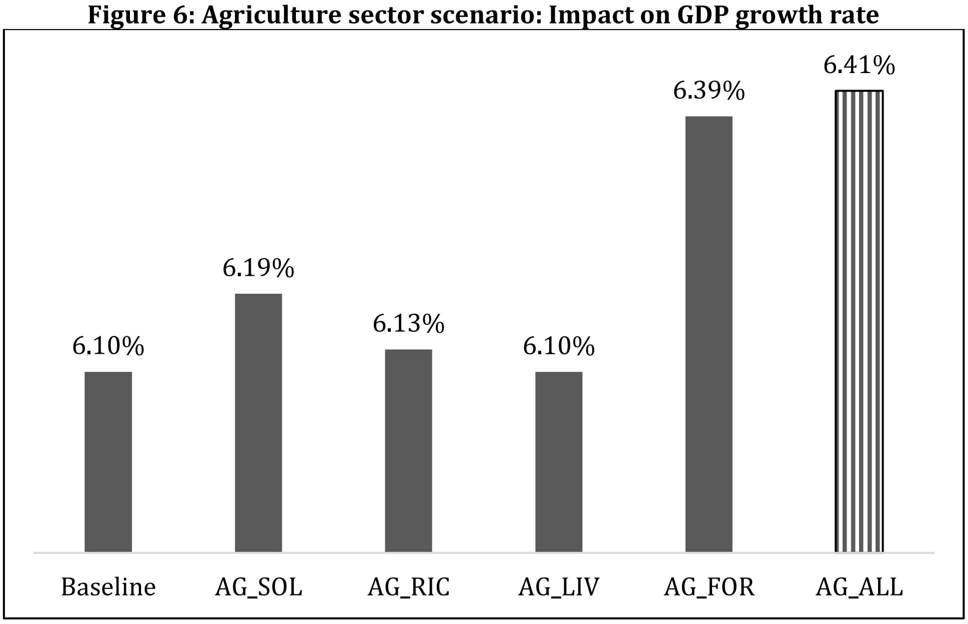
AG_ALL	**Above all scenarios combined**	

Source: Model scenario building based on the Ministry of Environment, Forest and Climate Change (2025).

Impact on GDP growth

The agriculture-sector results show that sustainable agriculture and allied-sector interventions can raise Bangladesh's growth trajectory above the baseline (Figure 6). Under the baseline, GDP is projected to grow at 6.10% per year. If all agriculture-sector targets are achieved under AG_ALL, GDP growth rises to 6.41%. This is a moderate but meaningful increase, especially given that several agriculture-sector interventions are relatively targeted in scope rather than economy-wide industrial reforms.

Figure 6: Agriculture sector scenario: Impact on GDP growth rate



Source: Dynamic recursive CGE model of Bangladesh

Among the agricultural interventions, forest cover expansion has the strongest effect on GDP growth. The forestry scenario raises growth to 6.39%, reflecting the relatively large scale of the forestry target compared with other agriculture-sector measures. This suggests that land restoration and reforestation can contribute to growth through forestry output, employment generation, rural economic activity, and related value chains.

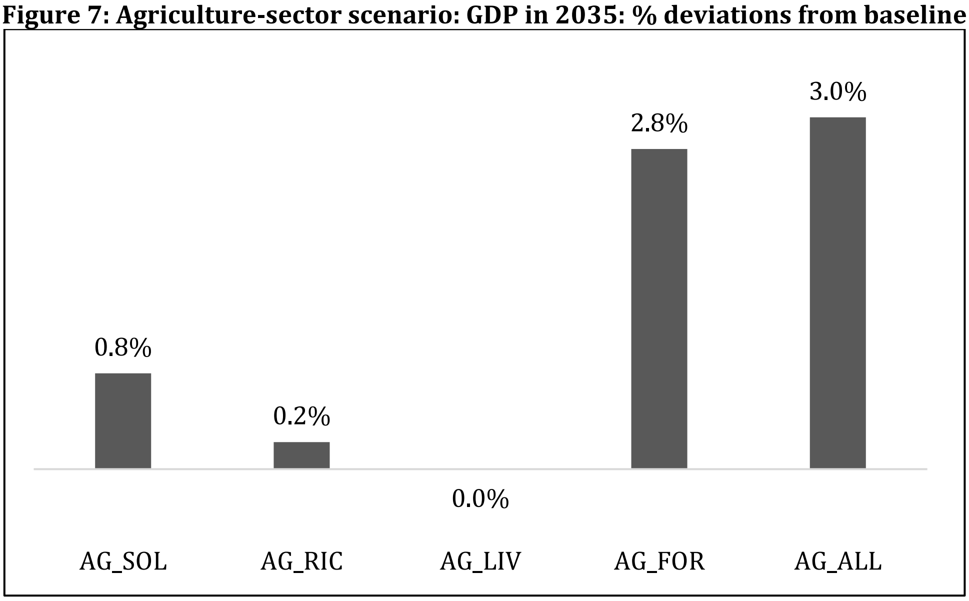
Solar irrigation has a smaller effect on GDP growth, but it remains important. The gain is modest because the intervention replaces only a fraction of the total diesel pump stock. Yet even within this limited scale, solar irrigation can improve farm profitability, reduce diesel use, lower irrigation costs, and support cleaner agricultural production. Climate-smart rice cultivation and livestock feed and manure management produce smaller macroeconomic growth effects, but they may still carry important benefits for emissions, resilience, input efficiency, and food security.

Impact on GDP under agriculture-sector interventions

The GDP deviation results provide a clearer picture of the size of the agriculture-sector impact in 2035 (Figure 7). Under the combined AG_ALL scenario, GDP is projected to be 3.0% higher than the baseline. This indicates that agriculture-sector climate interventions can generate economy-wide gains, even though many of the shocks originate in specific agricultural activities.

The largest individual GDP impact comes from AG_FOR, which raises GDP by 2.8% above the baseline in 2035. This strong effect reflects the scale of the forest restoration and reforestation targets. It also suggests that forestry should be treated not only as an environmental or conservation activity, but also as part of the rural development and climate-resilient growth agenda.

Figure 7: Agriculture-sector scenario: GDP in 2035: % deviations from baseline



Source: Dynamic recursive CGE model of Bangladesh

The AG_SOL scenario raises GDP by 0.8% above the baseline. This is notable because the intervention is relatively small: 45,000 solar pump sets replace 200,000 diesel pump sets out of a total of 1.6 million diesel pump sets. Despite this limited reach, the model shows a meaningful GDP gain. The result points to the productivity and cost-saving potential of solar irrigation. If scaled further, the economic gains could be larger.

The AG_RIC scenario raises GDP by 0.2%. This effect is smaller at the aggregate level, but climate-smart rice cultivation may still have major relevance for farmers, food security, irrigation management, fertiliser efficiency, and emissions reduction. The AG_LIV scenario shows almost no GDP effect. This is likely due to the small scale of the livestock intervention relative to the size of the national cattle herd.

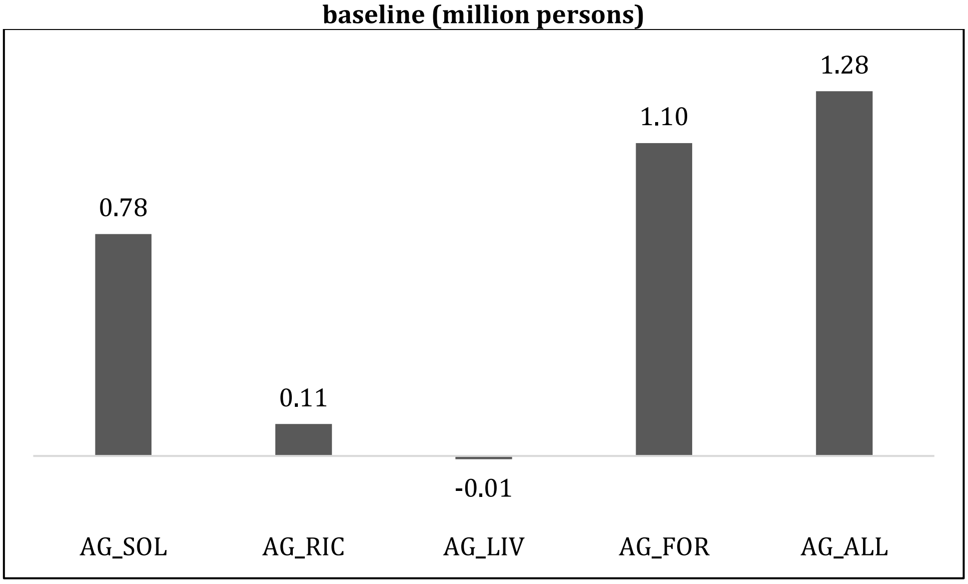
Impact on employment

The agriculture-sector scenarios also generate employment gains, though the impacts vary across interventions (Figure 8). Under the combined AG_ALL scenario, the economy creates 1.28 million additional jobs in 2035 compared with the baseline. This reflects the role of agriculture and allied sectors in absorbing labour, particularly in rural areas.

The strongest employment effect comes from AG_FOR, which creates 1.10 million additional jobs. Forest restoration and reforestation are labour-intensive activities, especially during planting, maintenance, land management, nursery development, and related rural services. This makes forestry expansion a potentially important source of green rural employment.

The AG_SOL scenario creates 0.78 million additional jobs. Solar irrigation can stimulate employment through installation, maintenance, equipment supply, irrigation services, and higher agricultural productivity. It can also increase labour demand indirectly if lower irrigation costs encourage more efficient land use and higher farm output. The AG_RIC scenario creates 0.11 million additional jobs, while AG_LIV shows a very small negative effect of 0.01 million jobs. The limited employment effect of AG_LIV again reflects the narrow scale of the intervention.

Figure 8: Transforming the agriculture sector: Additional jobs created in 2035 compared to baseline (million persons)



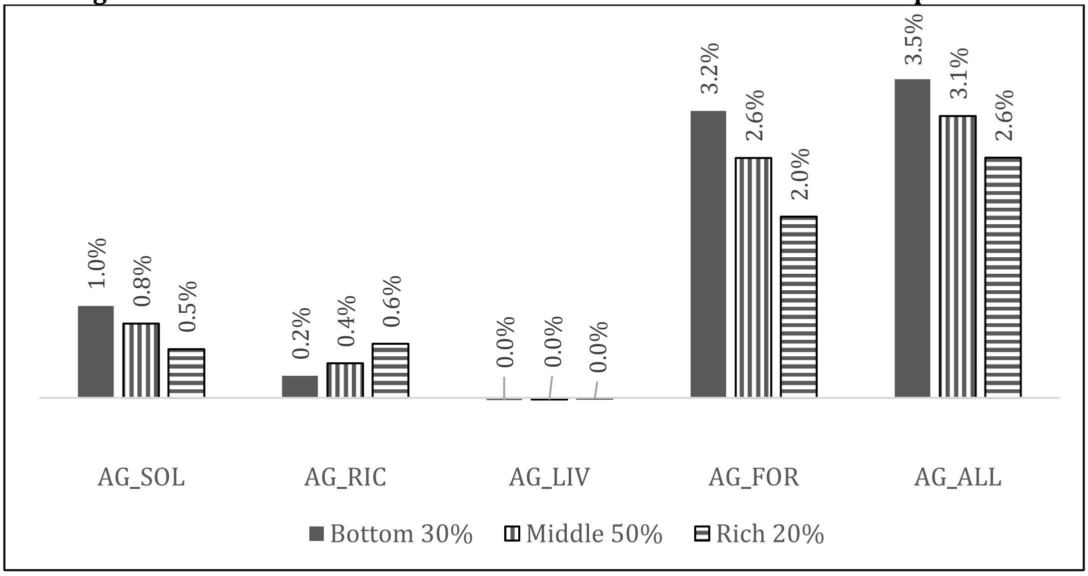
Source: Dynamic recursive CGE model of Bangladesh

Impact on household income

The household income results show that sustainable agriculture can support inclusive growth (Figure 9). Under the combined AG_ALL scenario, household income rises by

3.5% for the bottom 30%, 3.1% for the middle 50%, and 2.6% for the rich 20%, compared with the baseline. Poorer households, therefore, gain proportionately more than richer households. This is an important result because agriculture remains closely linked to rural livelihoods, smallholder income, food prices, and poverty reduction.

Figure 9: Agriculture sector scenario: Additional income of households as compared to baseline



Source: Dynamic recursive CGE model of Bangladesh

Among the individual scenarios, AG_FOR generates the largest household income gains. It raises income by 3.2% for the bottom 30%, 2.6% for the middle 50%, and 2.0% for the rich 20%. This reflects the strong employment and income effects of forestry expansion. Since poorer households are more likely to depend on rural labour markets and natural-resource-linked livelihoods, they benefit relatively more.

The AG_SOL scenario also has progressive income effects. It raises household income by 1.0% for the bottom 30%, 0.8% for the middle 50%, and 0.5% for the rich 20%. Lower irrigation costs and improved farm profitability likely explain these gains. AG_RIC produces smaller but positive income effects, while AG_LIV has almost no effect on household income. Overall, the results suggest that agriculture-sector decarbonisation can be pro-poor when it lowers input costs, raises rural productivity, and creates employment.

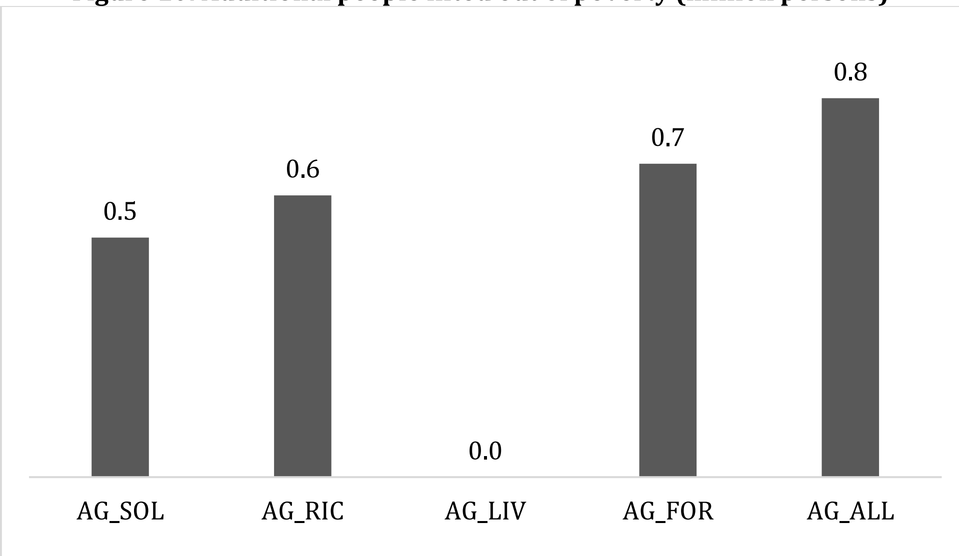
Impact on poverty

Poverty results reinforce the inclusive potential of sustainable agriculture (Figure 10). Under the combined AG_ALL scenario, an additional 0.8 million people are lifted out of poverty by 2035 compared with the baseline. This is a significant impact, especially because many agriculture-sector interventions directly affect rural households and smallholder livelihoods.

Among the individual scenarios, AG_FOR lifts 0.7 million people out of poverty, reflecting its large employment and income effects. AG_RIC, or climate-smart rice cultivation, lifts 0.6 million people out of poverty. This is particularly important because rice cultivation is closely tied to food security and rural incomes. Even though the GDP effect of AG_RIC is modest, its poverty impact is sizeable. This shows that macroeconomic impact and poverty impact do not always move in the same proportion. A targeted intervention in a sector closely connected to poor households can have a stronger welfare effect than its aggregate GDP number might suggest.

The AG_SOL scenario lifts 0.5 million people out of poverty. This reflects the importance of irrigation cost savings, productivity improvements, and farm profitability. The AG_LIV scenario has almost no poverty reduction effect, consistent with its very limited GDP and employment impacts. The broader message is that sustainable agriculture can reduce poverty when interventions reach smallholders, lower production costs, and improve the productivity of labour and land.

Figure 10: Additional people lifted out of poverty (million persons)



Source: Dynamic recursive CGE model of Bangladesh

7. Strategic Pathways for Adaptation and Agricultural Transformation

Climate change adaptation policies and frameworks emphasize using diverse technological solutions for enabling better responses to evolving environmental challenges. These strategic approaches can be organized into two parts: (a) short and medium-term strategies, which can be deployed within 1-5 years, and (b) long-term strategies, which encompass transformative technologies like advanced climate modeling systems that require extended planning horizons of 10-30 years for full implementation and optimization. Depending on the context of Bangladesh, some short-term, medium-term, and long-term strategies are mentioned below:

7.1. Short- and medium-term strategies:

Alternative Wetting and Drying (AWD) technique: As a carbon mitigation approach in agriculture, the most common and widely used method is Alternative Wetting and Drying (AWD). It is a scientifically proven irrigation method. However, among the contributors to agricultural GHG emissions in Bangladesh, rice paddy production under irrigated conditions remains at the top (International Center for Tropical Agriculture

(CIAT) & The World Bank, 2017). To reduce these emissions and other environmental impacts, increasing AWD methods of irrigation can be a sustainable solution.

AWD can reduce up to 20% of water usage and 30% of greenhouse gas emissions (International Rice Research Institute, 2025). Around 45-90% of methane and nitrous oxide emissions can be reduced by using the AWD technique compared to the continuous flooding technique (Linquist et al., 2015). Moreover, without having any effect on rice productivity, it can reduce irrigation water usage by 15-35% (Siopongco et al., 2013). In terms of irrigation costs, around 30 million USD can be saved annually if 50% of Bangladesh's dry-season rice fields adopt AWD (International Rice Research Institute, 2025). AWD can be a very effective technique as it benefits both in terms of water conservation and cost reduction by employing a minimal technological investment. As a result, it will be a win-win solution for both the farmers and the environment.

Bed planting: Bed-planting method is an evolving planting method in the Barind tract of the region, especially for crops like wheat and maize farming. This method is also being used for seasonal crops like potato, maize, lentil, and mungbean (The Financial Express Bangladesh, 2021).

Bed planting technology both minimizes environmental impact and works in areas susceptible to frequent natural disasters. It ensures fertilizers are positioned in place, facilitates uniform water flow, optimizes water usage, and reduces diesel consumption. The technology significantly streamlines agricultural operations by reducing both labour intensity and cultivation time. The seeding cost is also much lower than the conventional method. Conventional cultivation using 2-wheel or 4-wheel tractors involves considerable expense, with seeding costs (encompassing land preparation, seeding, and basal fertilizer application) ranging from Tk. 8,000-24,000 per hectare across various crops, including mustard, wheat, and maize. In contrast, Bed Planting technology provides a highly economical alternative, reducing these costs to just Tk. 4,500-6,500 per hectare. While the investment in a 2-wheel tractor is high (1-1.5 lakh taka), the bed planting adds only Tk. 60000-70000 to the cost (Consortium for Scaling-up Climate Smart Agriculture in South Asia (C-SUCSeS), 2024).

Integrated Soil Fertility Management (ISFM): Integrated Soil Fertility Management (ISFM) has become a vital approach to enhancing crop productivity while safeguarding and improving soil health. ISFM can double productivity and increase farm-level income by 20-50%, given that the process is implemented correctly (Centre for Coordination of Agricultural Research and Development for Southern Africa (CCARDESA), 2019). ISFM is the combined application of the following approaches:

a. Organic fertilizers (green manure, compost, and crop residues).
b. Locally available soil amendment methods (e.g., lime and biochar).
c. Techniques like germplasm, agroforestry, crop rotation, intercropping, etc.
d. Limited use of inorganic or mineral fertilizers

In ISFM, inorganic or mineral fertilizers are considered the last option, which is used when optimal results cannot be achieved using other interventions. ISFM can reduce greenhouse gas emissions by enhancing the uptake of nitrogen-based fertilizers by crops and promoting soil carbon sequestration (Centre for Coordination of Agricultural Research and Development for Southern Africa (CCARDESA), 2019). It can be considered as a medium-term strategy. FAO (2023) recommended mainstreaming ISFM by including the organic and mineral fertilizers, foliar and basal applications, along with pH correction using liming.

Water conservation: With increasing water variability due to climate change, be it in the form of drought or flood, it poses significant threats to agricultural sustainability. For this, water conservation is of utmost importance. Some of the technologies for water conservation include rainwater harvesting, precision irrigation methods including drip irrigation and sprinkler irrigation, Alternate Wetting and Drying (AWD) techniques for rice cultivation, subsurface irrigation through buried pipes, solar-powered irrigation systems, Alternate Furrow Irrigation (AFI) for row crops, and the capture and reuse of wastewater and greywater for agricultural purposes (Asian Disaster Preparedness Center (APDC), 2021).

Along with adapting these technologies, policy frameworks should also be inclusive. There should be an increased focus on creating a more inclusive environment to ensure smallholder farmers' access to resources. Policymakers should consider integrating social assistance programs, such as cash transfers, crop insurance schemes, and disaster relief funds. Besides this, recognizing women's contributions to agriculture, ensuring equal access to resources and training is necessary. Moreover, developing sophisticated meteorological and agricultural monitoring networks that provide timely alerts about weather patterns, pest outbreaks, and market fluctuations to enable proactive farmer responses will also be useful.

7.2. Long-term transformations

Precision agriculture: Precision agriculture can be a sustainable solution to the problem of depleting natural resources in Bangladesh. Precision farming is a center for solving the overarching issues of the traditional agricultural process (Balasundram et al., 2023; Bin et al., 2023; Challa et al., 2024). The advanced technologies used in precision agriculture help in enhancing crop production as well as minimizing environmental waste and impact.

- Farmers can monitor their fields efficiently by using modern tools like sensors, drones, satellites, and GPS-enabled machinery.
- Soil sensors are used to measure moisture levels. It helps in enabling precise irrigation. Precise irrigation technologies, such as drip and subsurface irrigation systems, can reduce water wastage up to 30-40% (The Daily Star, 2025) and thus are gaining popularity due to their efficiency in reducing higher water usage.
- Drones and satellites capture crop images to detect issues like diseases, pests, and nutrient deficiencies, and weed control (Lakhiar et al., 2024).
- GPS and sensor data allow farmers to make timely decisions on when plants should be planted and adjust fertilizer applications based on the varying conditions of the field, which reduces waste (Abioye et al., 2022).

Gathering real-time data on soil moisture, pH, temperature, and electrical conductivity, it helps determine plant water stress and nutrient requirements and allows farmers to make informed decisions.

Nanotechnology: Nanotechnology is another promising field for the future of agriculture. A key component of raising agricultural yield is the use of nanotechnology in seed technology. Due to a shortage of high-quality seed, the agricultural sector is unable to produce the intended amount. Seed is a nano-gift from nature to humanity. The full potential of seeds can be realized through the use of nanotechnology (Rakibuzzaman et al., 2018). Moreover, nano-fertilizers and nano-pesticides provide precision targeting as well as targeted nutrient delivery to the plants, which allows for minimal environmental impact (The Daily Observer, 2024).

Aquaponics: Aquaponics is a sustainable food production system that creates a symbiotic relationship between hydroponics and traditional aquaculture. The secret to an aquaponic system is that the water is recycled through biological filtration, and the waste products of the biological system are used as nutrients for the other system (Azad and Salam, 2025).

Green and leafy vegetables that can be grown in aquaponics: Okra, radish, le lettuce, water spinach, Indian spinach, tomato, capsicum, cucumber, cabbage, carrots, mints, and other leafy vegetables and plants (Azad and Salam, 2025; Salam et al., 2013)

Fish are cultivated in tanks in the majority of aquaponic systems, but not all fish species are appropriate. Only tank culture is appropriate for fish that are resilient and can withstand a broad range of water quality parameters. Consequently, tilapia is the foundation of the majority of commercial aquaponic systems in Bangladesh (Salam et al., 2014).

Along with adapting these advanced technologies, enhanced efficiency requires a comprehensive approach encompassing infrastructure development, technological innovation, policy restructuring, and sustainable methodologies. There should be a focus on transitioning to non-rice crops in some areas to reduce GHG emissions from rice paddies. In this case, alternative farming of rice and other crops like pulses can be considered an efficient option. Moreover, focusing on the potential of Bangladesh's food processing market is crucial for economic growth. Expanding food processing industries can create value-added products, reduce post-harvest losses, and generate employment opportunities. Additionally, strengthening supply chains and investing in modern technology can enhance export potential and ensure higher returns for farmers. Market forecasts suggest the processed food sector, now valued at $4.8 billion, will grow to $5.8 billion by 2030 (The Business Standard, 2025).

In terms of infrastructure, a cold storage facility is of utmost importance for the betterment of agriculture in Bangladesh. Literature suggests Bangladesh has a well-developed system for storing grains, but there is not enough cold storage for perishable items. The country can only store 6-7 million metric tons of products in cold storage facilities right now, which should be increased (FAO, 2023).

In order to transform agri-food value chains in Bangladesh, Rashid et al. (2024) advocated for blockchain and smart contracts to enhance the capacity of blockchain through automating transactions and enforcing agreements without any intermediaries. Moreover, to better support agricultural commercialization and the value chain, increasing the smallholder farmer productivity and competitiveness is necessary.

Otherwise, it will not be possible to transform from subsistence-based to commercial-based agriculture (ADB, 2023b).

Higher agricultural productivity, higher adaptation efficiency, and less labour market distortions reduce investment needs for adaptation by improving the productive allocation of capital. Therefore, trade openness and accessing concessional finance for adaptation can help maximize the effectiveness of climate investments as well as ensure food security in lower-income countries (Chen et al., 2024b). Moreover, domestic structural reform is necessary to facilitate investments for adaptation and improve efficiency and agricultural productivity.

For an economically viable, inclusive, low emission, i.e., JUST transition, NDC 3.0 has chalked out a few transition measures for the AFOLU sector. Some transition measures include climate-smart agriculture, organic farming, AWD, vermicompost, residue management, etc. For livelihood support, risk insurance, value chain access for smallholders and SMEs for women and youth-led enterprises, extension services, etc., have been recommended.

Role of NAP implementation and Bangladesh Climate Development Partnership: Bangladesh Climate Development Partnership (BCDP) has a big role to play in implementing the National Adaptation Plan 2023-2050. NAP provides a comprehensive framework to tackle climate change-related issues. BCDP serves as a comprehensive, multi-sector collaboration bringing together diverse stakeholders to accelerate large-scale climate initiatives. This is supported by the Asian Development Bank. This partnership framework is designed to urgently advance both low-carbon development pathways and climate resilience strategies that are fundamental to realizing Bangladesh's long-term national vision.

In the official phase of implementing the NAP, strategic planning through a coordinated platform, along with institutional leadership, is fundamental. Implementing this plan also requires a huge amount of investment, estimated at $230 billion over the next two decades (The Daily Star, 2024). As a significant portion of climate adaptation finance comes from the national source, a proper mechanism for climate financing mobilization and improved collaboration is vital. In this case, BCDP can come into play, which facilitates mobilizing the climate finance, accelerating policy reforms, improving capacity for innovative climate projects, etc (ADB, 2024).

8. Conclusion

Bangladesh’s agriculture sector stands at a critical juncture. In this backdrop, it confronts the dual crisis of profound climate vulnerability and an urgent need for a global sustainable development pathway. The impacts of climate change are already being felt throughout the food production systems, and they will affect land availability, rural livelihoods, and increase the vulnerability of farming communities. Floods, droughts, cyclones with antecedent salinity intrusion and rising temperatures today, coupled with sporadic rainfall, are no longer just distant vulnerabilities; they are redefining agricultural futures. CGE modelling simulations confirm this concern. They demonstrate how climate change could threaten Bangladesh's economic growth and social development, primarily through the impact on agriculture. Under high-impact scenarios, we see GDP contracting, very negative impacts on employment, and poverty reduction becomes even more difficult. Within this framework, the scaling up of climate-smart agriculture provides one of the largest, constant, and tangible pathways for both mitigation and adaptation.

The Government of Bangladesh has already made important progress in responding to these challenges. Various policy frameworks, action plans, and sectoral strategies now acknowledge the significance of climate-smart agriculture, sustainable farming practices, technological innovations, and subsequent ecosystem management. These are encouraging steps. But the size of this challenge needs more. Improving the status quo on agricultural emissions and climate vulnerability will require enhanced institutional coordination, scaled up and well-targeted investment, and more effective implementation in the field. Practical assistance, extension services, finance, and climate-resilient infrastructure are necessary for policies to reach farmers - especially smallholders.

Bangladesh's third NDC provides a timely opportunity to reinforce the country's commitment to a climate-resilient and low-carbon agricultural future. But ambition alone will not be enough. The next phase must focus on institutional capacity, innovation, and result-oriented delivery. Climate commitments need to be translated into measurable actions in irrigation, rice cultivation, livestock management, soil health, forestry, and water management. This is especially important because agriculture is not only a vulnerable sector. It is also central to employment, food security, poverty reduction, and rural transformation.

The agriculture-sector simulations show that Bangladesh's NDC 3.0 agriculture targets can contribute meaningfully to growth, employment, household income, and poverty reduction by 2035. Under the combined AG_ALL scenario, GDP growth rises from 6.10% under the baseline to 6.41%. GDP in 2035 becomes 3.0% higher than the baseline, and the economy creates 1.28 million additional jobs. Household income rises across all groups, with stronger gains for the bottom 30%, indicating that the benefits are relatively more inclusive. The combined package also lifts 0.8 million people out of poverty.

Among the individual interventions, forest cover expansion produces the strongest effects on GDP and employment. Solar irrigation also performs well, particularly given the relatively modest scale of the intervention. This suggests that scaling up solar irrigation could generate wider gains in productivity, income, fuel savings, and rural employment. Climate-smart rice cultivation has a smaller GDP effect, but its poverty-reduction impact is meaningful. This is important because rice cultivation remains closely linked to food security, rural welfare, and smallholder livelihoods. Livestock feed and manure management shows limited macroeconomic effects, largely because the intervention is small relative to the size of the livestock sector. However, this does not mean the area is unimportant. With better scaling, stronger technology adoption, and improved farm-level incentives, livestock-related interventions could play a larger role in reducing emissions intensity and improving productivity.

From a policy perspective, three messages stand out. First, sustainable agriculture should be treated not only as a climate strategy, but also as a rural development strategy. Second, solar irrigation deserves serious scaling up because even a limited intervention produces visible gains in GDP, employment, household income, and poverty reduction. Third, agriculture-sector transformation must be linked with renewable energy expansion. Otherwise, higher agricultural and forestry activity may increase overall energy demand and import dependence. A well-designed agricultural transition can support low-carbon development, but it will be most effective when combined with clean energy, rural infrastructure, stronger extension systems, climate finance, technological innovation, and direct support for smallholder farmers.

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