Insights on land use, agriculture and food security in Bangladesh: way forward with climate change and development

Savio Rousseau Rozario, Ali Mohammad Rezaie and Mizan R Khan

Savio Rousseau Rozario is working as a Junior Research Officer at the International Centre for Climate Change and Development (ICCCAD). He is in his final year of an MS in Disaster Management from the University of Dhaka and also pursuing a second master's (MSc) in Climate Change and Development from the Independent University Bangladesh (IUB). His research interest lies in disaster risk reduction in terms of climate change and health, nature-based solutions, and early warning systems.

savio.rozario@icccad.org

Ali Mohammad Rezaie is the Research Coordinator at ICCCAD. He holds a PhD in Civil, Environmental and Infrastructure Engineering from George Mason University, and worked as Virginia Sea Grant Graduate Research Fellow. He has worked in multiple research and academic institutions in the USA, UK and Bangladesh on delineating natural processes and their impacts on communities and ecosystems. His current research focusses on nature-based solutions, environmental and resource economics, and management for climate change adaptation and mitigation.

a.rezaie@icccad.org

Professor Mizan R Khan has two hats at ICCCAD: Deputy Director and Program Director of Least Developed Countries Universities Consortium on Climate Change (LUCCC). He holds a PhD in Environmental Policy and Management from the University of Maryland School of Public Policy (UMCP), Maryland, USA.

mizan.khan@icccad.org

Abstract

An extensive review was undertaken of relevant peer-reviewed journal articles, international and national NGO reports, case studies, newspaper articles, factsheets, policy briefs and blogs relating to land use and land cover, agriculture and impacts of climate change in Bangladesh. Scientific studies and projections provide evidence to support the argument that the agricultural sector in Bangladesh is threatened by climate change impacts, rapid population growth and economic growth as reflected by infrastructure development. Furthermore, infrastructure development, such as building roads and housing, is also decreasing available agricultural land area. Urban expansion is attracting more people from rural areas to urban settlements in search of opportunities for better living. Thus, a transformative change has occurred from an agro-based economy to an industrialised one – a trend that is likely to continue. These changes may threaten the ability of the country to produce enough food to meet growing demand in the coming decades. Moreover, a changing climate also brings threats to crop production in the forms of droughts, floods and storms. Brammer (2020b) also noted that climatic changes and impacts are irregular and non-uniform across the nation. Thus, climate projections and trends should be verified with historical and local data and contexts before using them to inform decision-making. Finally, policy support and mandates can backstop climate-resilience actions and transformative agricultural practices to overcome the challenges of food security and climate change in the country. Institutional and community capacity-building can also enhance agricultural development.

Introduction

Economically, Bangladesh is one of the fastest-growing least-developed countries in South Asia. The country has made remarkable progress in agriculture and food security, despite being populous and vulnerable to climate-induced disasters. The current population is approximately 166.7 million with a density of 1278/km^2, making it the eighth most populated country in the world (WPR, 2021). The dense population, geographical location and flat topography make the country susceptible to various natural disasters, such as floods, cyclones,

erosion, earthquakes and droughts. Rapid population growth and economic development have accelerated urbanisation and expanded land use and land cover (LULC) transformation in both urban and rural areas of the country. Unplanned domination by infrastructure and conversion of fallow land often leads to land degradation and loss of ecosystem services (Hasan *et al*, 2017; Hoque *et al*, 2020). Despite these challenges and drawbacks, Bangladesh has managed to produce enough food for its large population and expects to ensure food security in the coming years. This report considers past, contemporary and future aspects of LULC, agriculture and food security in Bangladesh.

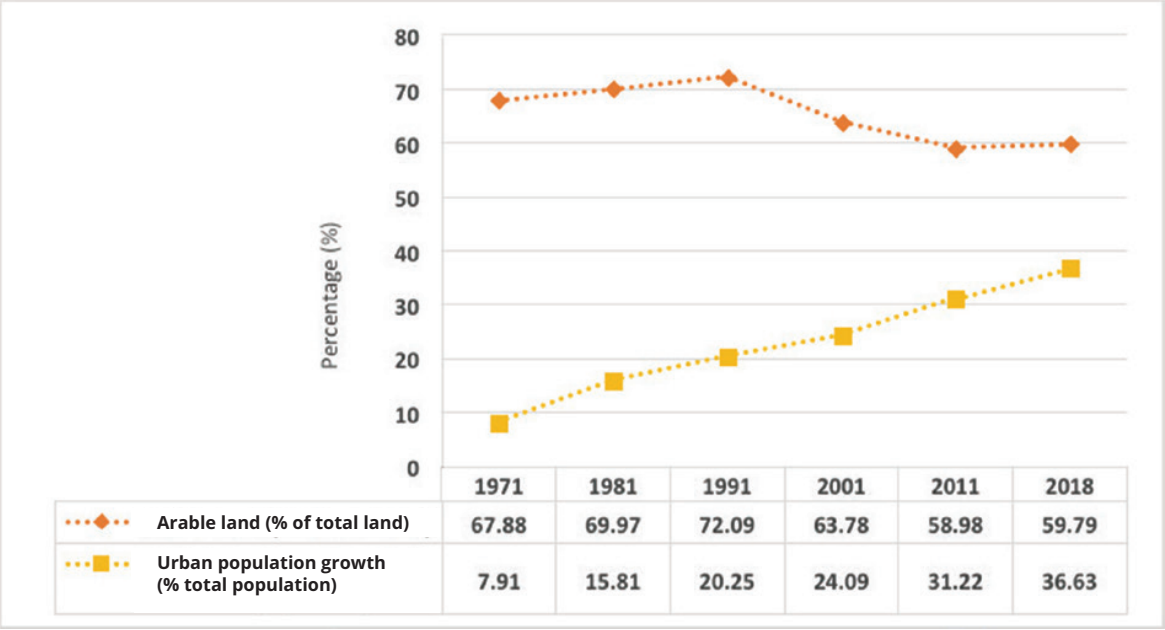
Methodology

An extensive review of relevant peer-reviewed journal articles, international and national NGO reports, case studies, newspaper articles, factsheets, policy briefs and blogs relating to LULC, agriculture and impacts of climate change in Bangladesh was undertaken. Graphs and tables were developed based on the available and accessible data. Landsat 8 data were imported and used to develop the LULC map of Dhaka district from 2014 to 2020, using QGIS (version 3.18 Zurich).

The past, present and future

The most important causes of changes in LULC are rapid population and economic growth, infrastructure expansion, climate change impacts, and conversion of forest areas to shrub lands. In Bangladesh, rapid population growth has decreased the per-capita agricultural land: 0.11, 0.09, 0.07 and 0.06 ha/person in 1981, 1991, 2001 and 2011, respectively (Rai *et al*, 2017). The increase in nuclear families and the division of land among family members, especially in the rural settlements of the country, is leading to agricultural land fragmentation, affecting total crop production (Islam, 2014). The rapid rate of urbanisation is also affecting the change in LULC, as more people are moving to urban areas and cultivated lands are being converted and used for non-agricultural purposes. It is estimated that the country is losing fertile agricultural land at a rate of approximately 80,000 ha annually due to rapid urbanisation, construction of new infrastructure such as roads and housing, and implementation of other development projects (Ahmed, 2011). The current rate of urbanisation in Bangladesh is 3.3 percent growth per annum; Figure 1 illustrates the increase of urban population along with the decrease of available arable land (World Bank, 2020).

Between 1976 and 2010, total agricultural land – including cropland, forest, mangrove, river, lake, *beel* (lake-like stagnant water body), *haor* (bowl-shaped shallow depression), aquaculture, tea estates and saltpans – decreased by 1.12 million ha (Hasan *et al*, 2013). During the same period, there has been an increase in non-agricultural land of 1.22 million ha (Rai *et al*, 2017). According to the United Nations Population Fund's prediction, the population of Bangladesh may reach 201 million (under a low fertility rate scenario) or 245 million (under a high fertility rate scenario) by 2051 (BBS, 2015). Consequently, the country would need to produce and manage food for an additional 35 million people (under the low fertility scenario) within the span of 30 years. Therefore, maintaining and preserving significant amounts of



	1971	1981	1991	2001	2011	2018
Arable land (% of total land)	67.88	69.97	72.09	63.78	58.98	59.79
Urban population growth (% total population)	7.91	15.81	20.25	24.09	31.22	36.63

Figure 1. Available arable land (% of total land) and urban population growth (% total population), 1971–2018 (Source: World Bank, 2020)

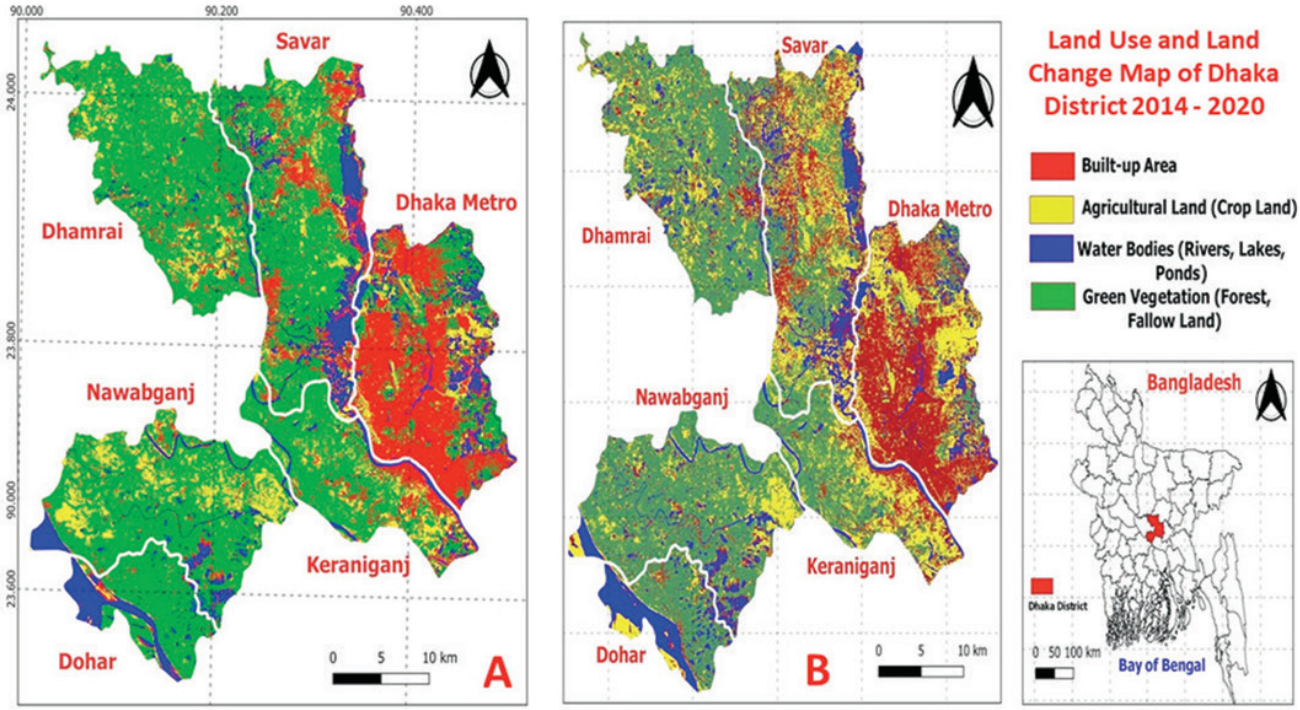
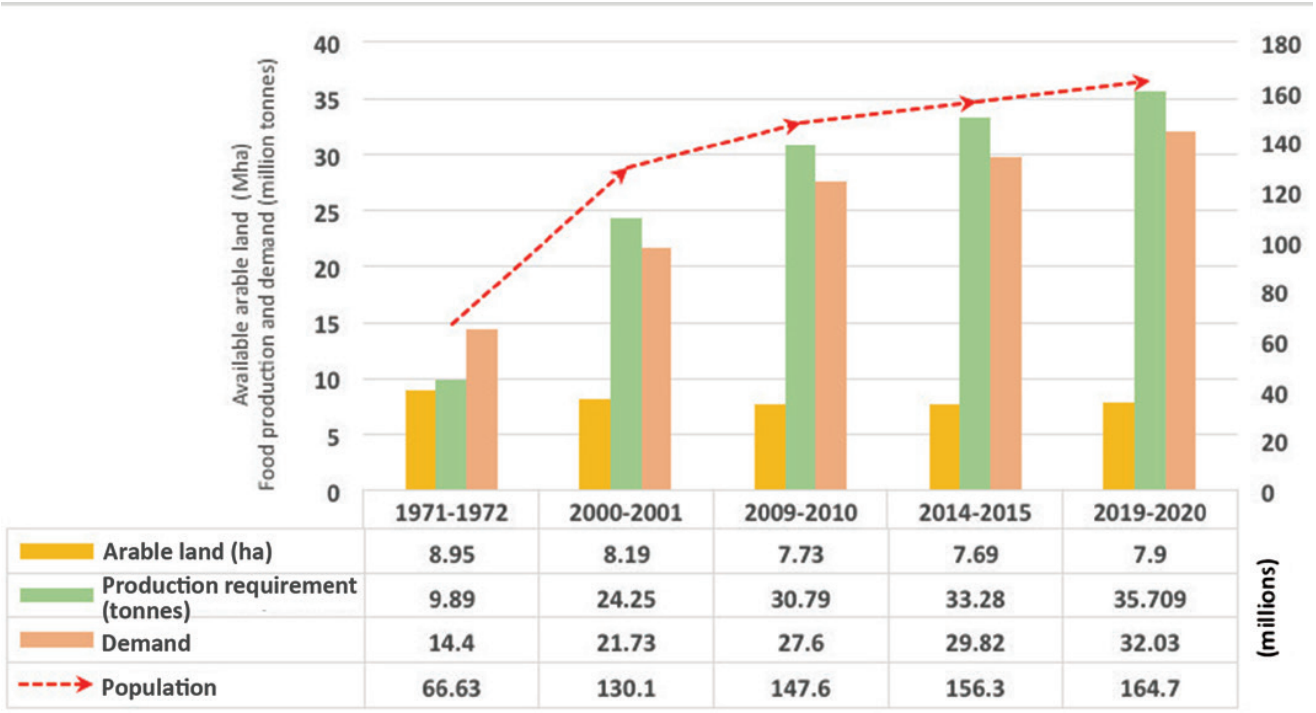


Figure 2. The spatial distribution of LULC of Dhaka zilla, Bangladesh, between (A) 2014 and (B) 2020 (Source: Landsat 8 image)

agricultural land is crucial to ensure food security, economic growth and the livelihood of the people. Figure 2 shows the change of LULC of Dhaka zilla from 2014 to 2020.

Despite loss of agricultural land, in terms of agricultural production and advancement Bangladesh has set global milestones. Currently, the country ranks first in jute export, second in jackfruit production, third in freshwater fish and vegetable production, fourth in rice production, sixth in potato production, and eighth in mango and guava production (Islam F, 2021). Agriculture is one of the most important sectors in Bangladesh's economy because it addresses the challenges of food security, livelihoods and economic growth. The sector



	1971-1972	2000-2001	2009-2010	2014-2015	2019-2020
Arable land (ha)	8.95	8.19	7.73	7.69	7.9
Production requirement (tonnes)	9.89	24.25	30.79	33.28	35.709
Demand	14.4	21.73	27.6	29.82	32.03
Population	66.63	130.1	147.6	156.3	164.7

Figure 3. Available arable land, food demand and grain production for the growing population in Bangladesh, 1971–2020 (Source: World Bank, 2020, 2021; Hussain, 2011)

has been a powerful driver in reducing poverty in Bangladesh since 2000, and accounted for 90 percent of the reduction in poverty from 2005 to 2010 (World Bank, 2016). More than 65 percent of the people in the country are directly or indirectly involved in this sector, and it is the primary source of income for 87 percent of the rural population (World Bank, 2016). In 2020, the agricultural sector contributed 13 percent to the country's gross domestic product (GDP), with a total employment rate of 38 percent (World Bank, 2021). Despite the rapid population growth and vulnerability to natural disasters, Bangladesh has made remarkable progress over the last four decades in terms of achieving food security. For instance, food grain production tripled from about 10 million to 34 million tonnes between 1972 and 2014 (World Bank, 2016). The country also made notable progress in rice production, which is the staple food of the country. In 1971, the production of rice was 10.6 million tonnes, but this had tripled to 36.3 million tonnes in 2020 (Hassan, 2021). Similarly, wheat and maize production have also shown steady increases over the last few decades. The annual production of potato has increased substantially from 1 million tonnes in the mid-1980s, to a present level of 10 million tonnes. There have also been increases in the production of oilseed (450 000 tonnes in 1987/88 to more than 1 000 000 tonnes in 2019), freshwater fisheries (growth of 5 percent per annum over the last two decades), and livestock (1.5 percent contribution to the total GDP) (BBS, 2019). Some crops, (*eg* jute, sugarcane and pulses) have shown a declining trend in yields.

These increases in production of crops, despite limited agricultural land, were achieved through the introduction of high-yielding varieties (HYV), adaptation of modern crop varieties, adequate irrigation through shallow and deep tube wells, flood management and control, consistent policy frameworks, government subsidies on seed and chemical fertilisers, and public investment in agricultural technology, rural infrastructure, and human capital (World Bank, 2016; Asaduzzaman, 2021; BRKB, 2021). Figure 3 summarises these trends.

This promising progress, however, is not a reason for complacency. As mentioned above, the rising population of the country may become a threat to food security, because the demand for food will increase as the agricultural land area is decreasing (Hussain, 2011; Xu *et al*, 2020).

The late Hugh Brammer concluded that Bangladesh needs to increase agricultural production in line with population growth, and also to ensure employment opportunities outside of agriculture. He also considered that the rapid population increase in the country is a greater immediate problem for development planning than the current rate of climate change. Hence, the Government, donor agencies and NGOs should emphasise and prioritise the need to feed and employ the growing population (Brammer, 2017).

Impacts of climate change on agriculture

The impacts of global climate change are a massive threat to crop production and food security in the country. The agricultural sector relies on climatic factors such as precipitation, temperature, radiation, light intensity and sunshine duration. Each crop requires a different temperature range for optimal vegetative and reproductive growth. When temperatures fluctuate and either falls below the range or exceeds the upper limit, crop production is hampered (GoB, 2012). For instance, with a 4°C increase in temperature, rice and wheat production will decrease by 28 percent and 68 percent, respectively (Karim *et al*, 1996).

The recently published Intergovernmental Panel on Climate Change (IPCC) sixth assessment report (AR6) predicts that intense heatwaves and temperature events will become frequent in the South Asia region, including Bangladesh, this century (IPCC, 2021). The rising temperature will affect the growth of sensitive crops and will also reduce the duration of winter. This will hamper the productivity of *rabi* (winter-sown) crops. It has also been reported that an increase of 1–2°C, combined with lower solar radiation, will cause sterility in rice spikelets, reducing the yield of HYV of *aus* (crop season: July–August), *aman* (December–January) and *boro* (March–May) rice.

Dramatic changes in temperature, humidity and radiation will also encourage pest infestation, disease outbreaks, and growth of microorganisms, and have a negative effect on soil organic matter (GoB, 2012). An increased number of warm days and heatwaves with low humidity and high wind speeds will increase the evapotranspiration rate, which could lead to drought conditions, especially in the north-west of the country. From 1961 to 1991, nineteen droughts occurred in Bangladesh, and every year, 0.45, 0.40 and 0.34 million ha of land are affected during *rabi* (mid-November to mid-March), pre-*kharif* (end of March to early May) and *kharif* (May to early November) seasons, respectively. The north-west is an important agricultural hub for Bangladesh, and for the last few decades there has been a reduction in rainfall in this region (from 151 mm during 1994–2003 to 138 mm during 2004–2013) due to the rise in temperature and static humidity, leading to a higher evapotranspiration rate.

The decrease in rainfall has made the region highly dependent on groundwater irrigation, but due to

the lower precipitation, groundwater resources are also diminishing, creating a threat to agricultural yield. Conversely, other parts of the country receive adequate rainfall and the IPCC AR6 report projects an increase in rainfall in these regions (IPCC, 2021). This may result in severe floods and waterlogging, leading to crop damage. For example, a prolonged increase of 1mm rainfall decreases *aman* rice production at the vegetative, reproductive and ripening stage by 0.036, 0.230 and 0.292 tonnes/ha, respectively (GoB, 2012).

Flood comes both as a blessing and a curse, and influences the agricultural yield to a great extent. Floods recharge groundwater, carry nutrients and sediments, enrich aquatic systems, generally benefit ecosystems, and improve waterway connections. However, in Bangladesh floods can also result in dire consequences. From 1988 to 2007, several floods were recorded, inundating 70 percent of the land area. These floods destroyed some 485 600 ha of cropland and, during the flood of 1988, crop production was reduced by 45 percent (Karim *et al*, 1996). Prolonged floods have delayed *aman* planting, and during the pre-monsoon season flash floods have become common in the Haor basin area, damaging the *boro* production (GoB, 2012). In a recent report (Mamun, 2020), the Ministry of Agriculture estimates that the recent extensive floods submerged 159 000 ha of agricultural land, damaging crops with a net worth of over BDT 13 billion (USD 151.672 million).

Tidal flooding and storm surges hamper agriculture in the coastal areas. The United Nations Development Programme reports Bangladesh to be the most exposed country to tropical storms, with an average of four cyclones striking the country every year (Saha & Khan, 2014). Another study (Farukh *et al*, 2019) reports that from 1960 to 2010, some 52 severe cyclonic storms have hit the country, causing grave impacts on the agriculture and livelihoods of the coastal population. The 1991 cyclone destroyed 210 000, 36 000 and 3500 tonnes of *boro*, *aus* and other food crops (potatoes, vegetables), respectively (Farukh *et al*, 2019). The Ministry of Agriculture estimates that the recent cyclone Amphan affected crops on 176 007 ha with a total crop loss of USD 6.72 billion in 17 coastal districts (Shovon, 2020; Wardad, 2021).

Bangladesh is also vulnerable to sea-level rise (SLR) (Brammer, 2020a). The World Bank has projected an increase of 0.1, 0.25 and 1m in sea level by 2020, 2050 and 2100, which would affect 2, 4 and 17.5 percent of the land area, respectively (GFDRR, 2011). Rising sea level can increase salinity intrusion in coastal areas, resulting in a hostile environment for plants, reducing crop productivity, and reducing sources of fresh drinking water. According to the Soil Resources Development Institute, between 1973 and 2000, the amount of salinity-affected land increased from 83 million ha to 102 million ha, with an expansion of 26 percent in the last 35 years into formerly non-saline areas (Haider, 2019). However, salinity intrusion has inspired farmers to practise the more-profitable shrimp farming rather than crop production (Brammer, 2017). Rice production in Satkhira district in 2003 fell to 1151 tonnes, a loss of 69 percent compared to 1985. Some 77 percent of the total decrease was due to conversion of rice fields to shrimp ponds, and the remaining 23 percent due to rice yield loss (GoB, 2012). Although shrimp farming is being promoted and supported by government and donor agencies (Hossain & Hasan, 2017), this initiative has been criticised because it dramatically changes the natural environment, and creates social problems by displacing tenant farmers and seasonal agricultural labourers (Brammer, 2017).

Small-scale famers (owning less than 0.60 ha of land) dominate the agricultural sector and are considered the most vulnerable group in terms of natural disasters. Lack of resources, land, education, income, capacity and access to infrastructure, and limited access to agricultural credit, make small-scale farmers susceptible to social challenges and climate-induced natural disasters. Brammer (2020a) identified nine natural disasters (flood, drought, tropical cyclone, line squall, riverbank erosion, burial by new alluvium, soil salinisation, earthquake and landslide) that threaten crop production.

Measures and policies

In spite of the challenges caused by global climate change and population growth, the agricultural sector of Bangladesh thrives, ensuring food security and stability. The introduction of high-yielding and stress-tolerant varieties of crops; deep-water irrigation techniques; promotion of localised adaptation measures; better flood management; a consistent policy framework; government subsidies on seed; chemical fertiliser; better land management; private and public sector initiatives and investments in agricultural technologies, tools and research; improved early warning systems; and human capital are some of the factors that have helped the agricultural sector of the country to flourish in the recent times (Asaduzzaman, 2021; BRKB, 2021; GoB, 2012). Table 1 shows some key measures taken to adapt to the impacts of natural disasters and climate change in different climate-vulnerable areas.

Table 1. Some significant measures undertaken in different climate-vulnerable areas of the country

Measures	Drought-prone areas	Saline- and storm-prone areas	Flood-prone areas
Application of interventions	• Introduce drought-tolerant and short-duration crop varieties	• Introduce saline-tolerant and short-duration crop varieties • Planting deep-rooted fruits and crops	• Introduction of flood-resistant varieties • Change in cropping pattern • Short-duration *boro* rice cultivation for flash-flood regions
Structural measures	• Excavate mini ponds, ponds, ditches to harvest rainwater • Alternative wetting and drying (AWD) method for rice production	• Floating cultivation • Cage culture • Sarjan technology • Rainwater harvesting	• Floating cultivation • Cage culture
Non-structural measures	• Encourage farmers to follow traditional and innovative practices such as zero-tillage, priming, mulching, relay cropping, dryland farming • Encourage famers to adopt homestead gardening • Adjustments to planting time • Encourage farmers to cultivate fewer water-loving crops (maize, wheat, linseed, pulses, oil crops)	• Early warning and preparedness measures	• Encourage farmers to grow pulses (mung bean, lentil), vegetables and oil seeds • Capacity-building in homestead bag planting • Use of green manure
Research and innovation (cultivars developed)	• Cereal crop (rice etc.): BRRI dhan 33,42,43,56,57, BINA dhan 07, BARI gom-25,26, BARI sharisha 11,16 • Oil crop: BINA Til-1,2, BARI-1,2 • Sugar cane: Iswardi-20	• Crop: BRRI dhan 23,40,41,47,53,54,55 BINA dhan 08, BARI gom 25, BARI sharisha 10 • Sugar cane: Iswardi-38,39,40	• Crop: BRRI dhan 28,46,51,52 • Sugar cane: Iswardi-38,39,40

Source: BRKB (2021); Hassan AFR *et al* (2019); Groom (2012); Ministry of Agriculture (2021).

Government entities, the private sector, and international and local organisations and institutes have contributed to the development of the agricultural sector of Bangladesh. Since the 1980s, the private sector has played a significant role by introducing modern technologies and tools, conducting extensive research and building the capacities of the farmers. It has also provided HYV seeds, bio-fertiliser, green manure, earthworm compost, pesticides, machinery, fish feed and poultry feed. These measures have enhanced poultry production, allowed off-season vegetable production, and increased rice, maize and wheat yields. For example, international organisations such as the International Maize and Wheat Improvement Center (CIMMYT) have been working on the development and expansion of wheat and maize production in the country through robust scientific research and capacity-building at field level. Private sector actors such as Square Agro, ACI, Energypac, Agro-G Ltd, Supreme Seed and Lal Teer have set standards in quality seed production, distribution and retail. The Government urges the private sector to contribute more to agriculture to help make farming a profitable sector by investing in agro-processing, maintaining backward and forward linkages in the sector to ensure fair prices to the farmers, and to add maximum value to the products.

Government policy makers are well aware of the importance of national food security, especially in the context of population growth and climate change impacts. Table 2 outlines some key insights from relevant national policies on agriculture and food security. These policies focus on ensuring food, nutrition and livelihood security by increasing production, crop diversification, enhancing the supply chain, and effective use of natural resources.

Table 2. National policies related to agriculture and food security (2000–2021)

Policy	Year	Insight related to agricultural development
National Adaptation Programme of Action (NAPA)	2005	To enhance safety nets, insurance, behavioural changes and communication to reduce climate-induced risk, the policy promotes investments in the agricultural sector and social protection measures
National food policy	2006	The key objective of this policy is to ensure an adequate and stable supply of safe and nutritious food, and also enhance the purchasing power of the people to ensure accessibility and adequate nutrition
Bangladesh Climate Change Strategy and Action Plan (BCCSAP)	2009	Out of the 144 priority actions of the BCCSAP, food security is considered as the key issue to be addressed
National Seed Policy	2010	The policy emphasises best-quality seed production for improved varieties, and proper distribution among farmers to improve crop production, per-capita farm income and export earnings
Perspective Plan of Bangladesh, 2010–2021	2012	The plan aims to eliminate food deficiency and for the country to become self-sufficient in food production, meeting the nutritional requirement of the population by 2021
National Agricultural Policy	2018	This policy focusses on ensuring food security, increasing productivity and production of crops, and promoting crop diversification to ensure nutritious and safe food for all. At the same time, it also highlights farmers' income enhancement, improving marketing systems, and ensuring profitable agriculture by efficient utilisation of natural resources
Bangladesh Delta Plan 2100	2018	Agriculture, food security and livelihoods are considered as cross-cutting issues of the plan
National Food and Nutrition Security Policy of Bangladesh	2019	In order to fulfil the relevant Sustainable Development Goals (SDGs), and national and international commitments by 2030, this policy focusses on food and nutrition security
National Agricultural Mechanization Policy	2020	To achieve sustainable, nutritious food production and security, this policy highlights the transition to profitable, efficient and commercial agriculture through agricultural mechanisation
8th Five Year Plan (FYP), 2020–2025	2020	The plan focusses on maintaining food security through farm production, the supply chain, price policy, water supply, farm credit, marketing support enhancement, and also encouraging diversification of crops. It also aims to promote farm income, and address the unemployment problem through innovative activities (fisheries, livestock, fruit, flowers, dairy, vegetables)
Perspective Plan of Bangladesh, 2021–2041	2021	The plan's vision is to bring about paradigm shifts in agriculture to enhance productivity, a service sector of the future providing the bridge for the transformation of the rural agrarian economy to a primarily industrial and digital economy
Nationally Determined Contribution (NDC)	2021	A study conducted by the International Maize and Wheat Improvement Center reports that the agricultural sector of Bangladesh will emit approximately 87 Mt CO_2 per capita into the atmosphere by 2030 and 100 Mt per capita by 2050 (CIMMYT, 2021). The agriculture sector being one of the major contributors to greenhouse gas emissions, the Government of Bangladesh highlighted the issue, along with forest and other land use, in the NDC and developed the Forest Reference Level (FRL) before submitting to the United Nations Framework Convention on Climate Change

Sources: GED (2012, 2020); Mallick *et al* (2012); Ministry of Agriculture (2018, 2020); Ministry of Food (2006, 2019).

Conclusions and way forward

Scientific studies and projections provide evidence to support the argument that the agricultural sector in Bangladesh is threatened by climate change impacts, rapid population growth and economic growth as reflected by infrastructure development. Furthermore, infrastructure development, such as building roads and housing, is also decreasing available land area. Urban expansion is attracting more people from rural areas to urban settlements in search of opportunities for better living. Thus, a transformative change has occurred from an agro-based economy to an industrialised economy – a trend that is likely to continue. These changes may

threaten the ability of the country to produce enough food to meet growing demand in the coming decades. Moreover, the changing climate also brings threats to crop production in the form of droughts, floods and storms.

Comprehensive measures need to be taken, therefore, at all levels, to overcome future challenges and ensure food security and the wellbeing of both urban and rural populations. The Government is working with the private sector to achieve the desired goals by providing subsidies, improving technology, expanding research, and introducing cutting-edge technologies. Special attention should be given to safeguarding and incentivising smallholder farmers, who are usually the most vulnerable producers and livelihood groups. Local people possess generations of experience that helps them to be creative and to overcome and adapt to the challenges of adverse natural conditions. Local and indigenous knowledge can provide socially acceptable and technically feasible solutions to the impacts of climate change. However, financial support and technical assistance are needed to facilitate these adaptation actions (Brammer, 2017).

Brammer (2020b) noted that climatic changes and impacts are irregular and non-uniform across the nation. Thus, climate projections and trends should be verified with historical and local data and contexts before using them to inform decision-making. Additionally, the country can develop nationwide, robust and extensive climate information and services for farmers to reduce crop damage and enhance production. These initiatives should be built on comprehensive research and data, and tailored to meet user needs. Big data can facilitate adoption of climate-smart crop production and livestock management, to reduce greenhouse gas emissions from the agricultural sector.

Finally, policy support and mandates can backstop climate-resilience actions and transformative agricultural practices in order to overcome the challenges of food security and climate change in the country. Institutional and community capacity-building can also enhance agricultural development. The establishment of 'farmers' schools' and 'farmer support centres' can provide the necessary knowledge, technology and support to the farmers to increase the efficiency of crop production. Developing facilities for health and education, and employment opportunities in the rural and suburban areas can limit urbanisation and enhance the wellbeing of farmers. In cities, farmers' markets can incentivise local farmers to sell their produce directly to consumers, to ensure a fair price for the farmers. Thus, a combination of proactive initiatives, actions and plans can lead to a resilient and prosperous agricultural sector in Bangladesh to secure food security and safety for the growing population, despite the challenges of climate change.

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