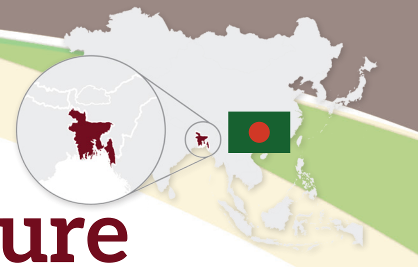

Climate-Smart Agriculture in Bangladesh

Climate-smart agriculture (CSA) considerations

P The agricultural sector in Bangladesh has grown steadily in recent years, driven by an increase in productivity and efficiency achieved through investments in improved technology and mechanization supported by conducive public policies. This has led to considerable improvements in food security as well as rural poverty reduction. 90% of this reduction in the past five years can be attributed to increased farm income.

P A $ I Agriculture in the country is characterized by subsistence production systems largely dominated by small and marginal farmers, yet a significant shift towards commercial farming with high value crops, fisheries and animal products has been evident in recent years. This is expected to contribute to further poverty reduction through improvements in health, nutrition and education outcomes in Bangladesh.

P M Given its abundant water resources, rice paddy production under irrigated conditions is the top contributor to agricultural GHG emissions in Bangladesh. In an effort to reduce these emissions and other environmental impacts, farmers are increasingly applying alternative wetting and drying (AWD) methods of irrigation, using deep placed briquetted urea fertilizer, moving to non-rice crops and incorporating straw stubbles in to rice paddies as an alternative to burning crop residues—the latter contributing to soil organic matter replenishment.

A P Climate-smart agricultural strategies that address saline intrusion (up to 8 km by 2030) resulting from sea level rise and tropical storm swells are especially critical in Bangladesh where many smallholders occupy low-lying, flood prone deltas. CSA interventions can draw on traditional practices like the Sorjan system (tall beds for vegetable and crop production alternating with furrows suitable for submergence tolerant crops and fish production) as well as new practices like vertical gardens. Floating bed cultivation of vegetables in the low lying southern districts, homestead production and roof top gardening of fruits and vegetables are also spreading rapidly.

M A The lack of accessible and reliable climate information among farmers represents a considerable challenge to the scaling out of CSA practices. Strengthening climate information services and making them easily accessible to farmers would greatly improve their capacity to adapt farming practices. For instance, salt intrusion into irrigation canals prevents their use for commercial or household gardening in the southern regions of Bangladesh. Knowing where and when intrusion will occur through the use of simple salinity meters would allow farmers to make crop choices and also plan for appropriate response and mitigation strategies.

A M P I $ Limited financial capital for CSA investments and related activities remains a constraint for many farmers in Bangladesh. Climate index insurance models, for example, have not proven successful at scale. Microcredit has been insufficient in boosting agricultural sector growth as many CSA activities require more macro-credit (e.g. conservation machinery). However, several low risk interventions like pond excavation and ghers (paddy and aquaculture ponds with tall dikes for vegetable production) are more likely to be eligible for commercial funding. Improvements in agro-meteorological services are essential for increased private sector investment in agriculture. More information on the long-term impacts of such investments on natural landscapes is needed in order to ensure sustainability.

I $ New forms of CSA as well as innovative production systems finance need to be explored, including the allocation of domestic funding for priority CSA interventions and strengthening cooperation with development partners to access funds for CSA activities. At the same time, private sector engagement in impact investment initiatives holds considerable potential for advancing the CSA agenda. Creating an enabling environment for private capital will require improved coordination between the ministries involved in climate change planning in Bangladesh.

A Adaptation M Mitigation P Productivity I Institutions $ Finance

The climate-smart agriculture (CSA) concept reflects an ambition to improve the integration of agriculture development and climate responsiveness. It aims to achieve food security and broader development goals under a changing climate and increasing food demand. CSA initiatives sustainably increase productivity, enhance resilience, and reduce/remove greenhouse gases (GHGs), and require planning to address tradeoffs and synergies between these three pillars: productivity, adaptation, and mitigation [1]. The priorities of different countries and stakeholders are reflected to achieve more efficient, effective, and equitable food systems that address challenges in environmental, social, and economic dimensions across productive landscapes. While the concept is new, and still evolving, many of the practices that make up CSA already exist worldwide and are used by farmers to cope with various production risks [2]. Mainstreaming CSA requires critical stocktaking of ongoing and promising practices for the future, and of institutional and financial enablers for CSA adoption. This country profile provides a snapshot of a developing baseline created to initiate discussion, both within countries and globally, about entry points for investing in CSA at scale.

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RESEARCH PROGRAM ON Climate Change, Agriculture and Food Security
CCAFS
CIAT 50 1967-2017

National context

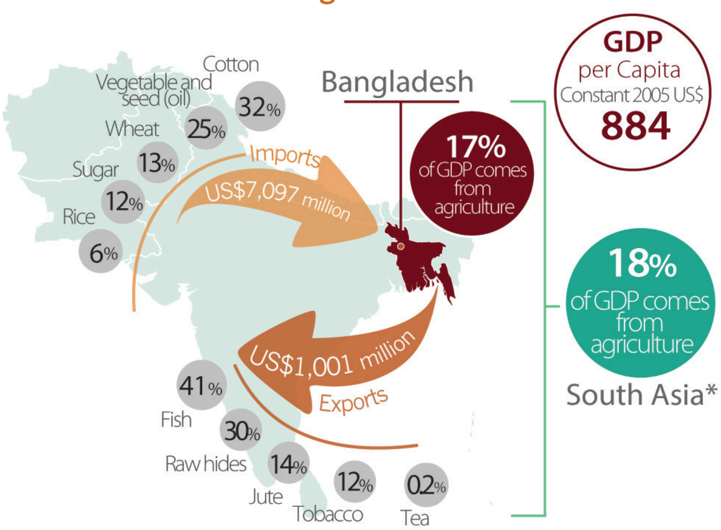
Economic relevance of agriculture

Agriculture is a mainstay of the Bangladesh economy, contributing to 16.5% of the country's Gross Domestic Product (GDP) and serving as the largest employment sector in the country. Approximately 87% of rural inhabitants derive at least a portion of their income from agricultural activities [3]. The population of Bangladesh has almost doubled since the 1980s, reaching approximately 161 million people in 2016. This increase, coupled with high population density (over 1,000 per square km) and growing urbanization and infrastructure build-up for industrialization, has put considerable pressure on arable land, which decreased from 0.11 ha/capita in 1980 to 0.05 ha/capita in 2014 [4]. Ninety-nine percent of farms in Bangladesh are small-scale and fragmented, with an average area of less than one hectare [5].

Sustained policy support for increased food grain production to meet national demand has contributed to improved self-reliance (especially for rice and maize production) in Bangladesh, yet the country still depends heavily on imports for other crops and agricultural products such as wheat, vegetable oil, and cotton[1] [6]. Increases in farm income have contributed substantially to poverty reduction in the past decade[2], yet almost a third of the population still lives below the national poverty line, mostly in rural areas [3, 4]. The country is especially challenged by a lack of economic opportunity [7] and faces moderate inequality in income distribution, ranking 3rd out of eight countries in South Asia on the Gini Index (a score of 0.31 out of 100) [3]. Nearly 40% of the population lacks access to electricity, while another 15% has no access to improved water supplies [4]. Still the economy of Bangladesh has grown steadily over the past decade, consistently achieving GDP growth between 6% and 7% annually.

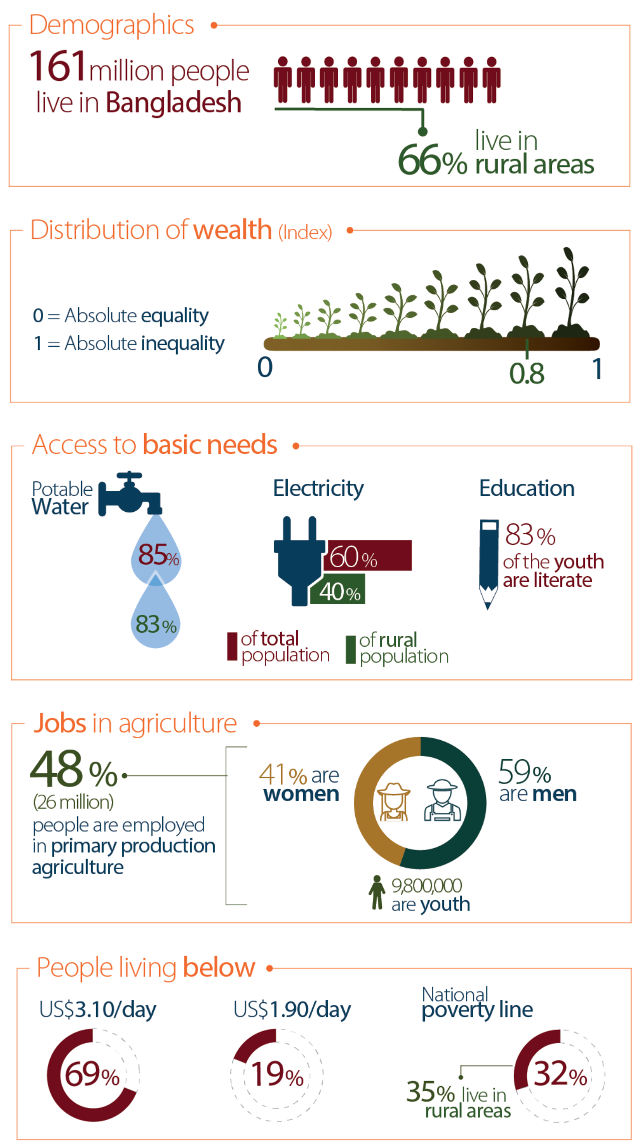
In 2016, Bangladesh received middle-income country status. However, according to the Social Progress Index (SPI), which measures a country's performance in relation to three key societal dimensions[3] (basic human needs, wellbeing and opportunities), Bangladesh scores among the countries with the lowest SPI scores in the world (52.7). Women's empowerment in particular, remains constrained by limited decision-making power and unsatisfactory control over productive resources and income in Bangladesh [8].

Economic relevance of agriculture in Bangladesh[3, 5]



*South Asia: Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, Sri Lanka

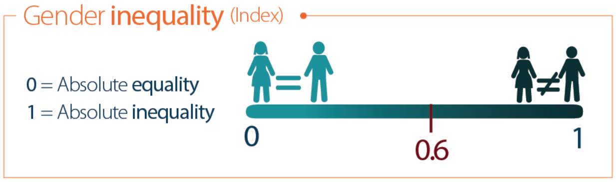
People, agriculture and livelihoods in Bangladesh[3, 5]

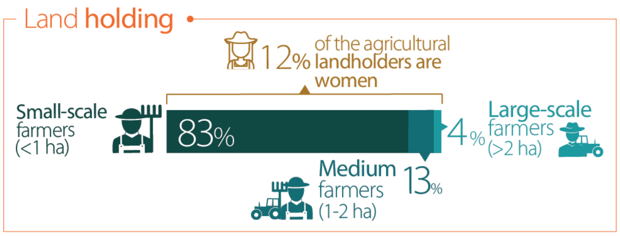


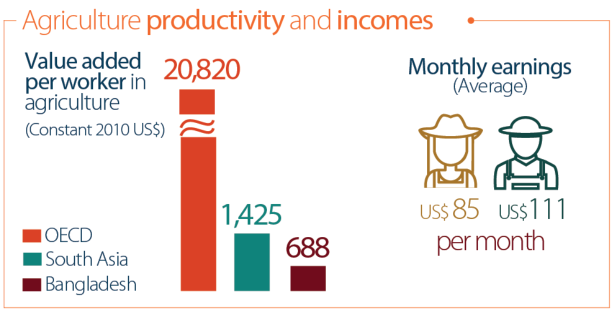
1 Cotton is mainly imported for use in the garment industry, which explains the unfavourable (negative) trade gap of 7:1.

2 Between 2005 and 2010, 90% of the decline in poverty in Bangladesh was associated with increased farm income [3].

3 The SPI indicators relate to: nutrition, water, shelter and personal safety (basic human needs dimension); access to knowledge and information, health, environmental quality (wellbeing dimension); and personal rights, freedom and choice, tolerance and inclusion, access to advanced education (opportunities dimension).



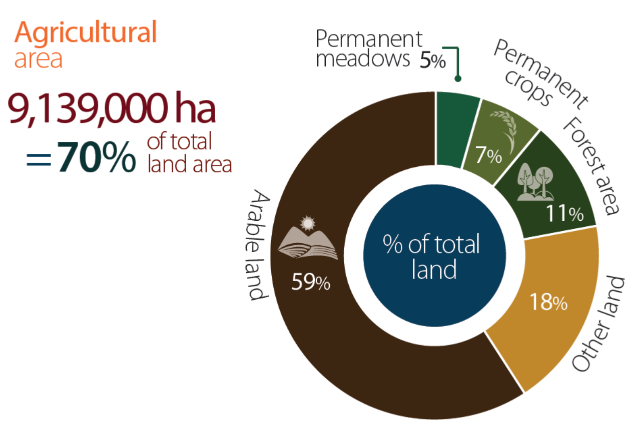




Land use

Agricultural land in Bangladesh covers roughly 9.1 million hectares[4], which is 70% of the country's land area. Around 59.2% of the agricultural area is considered arable, 6.5% is occupied by permanent crops, while meadows and pastures account for 4.6% (area which is expected to decrease). Forested area represents approximately 11% of total land area in Bangladesh [6]. Due to increased pressure on land from urban and peri-urban expansion, overall cropland area in Bangladesh has diminished in recent years. Meanwhile, intensification has increased significantly and land is double cropped in most areas, with an average cropping intensity of 192% throughout the entire country [9, 10]. In some areas, land can be cultivated with up to three and four crops, especially at higher elevations where high yielding varieties of rice, wheat, potato, sunflower, and mungbean are grown [5].

Land use in Bangladesh [5, 6]



Agricultural production systems

Despite its relatively small size (147,570 km^2), Bangladesh is a very diverse country in terms of topography, soils and climate. Water resources are plentiful in the rainy season—although many areas face scarcity in dry months—and the country's nutrient-rich alluvial soils are highly fertile, allowing for the cultivation of a variety of food and cash crops throughout the year. Agriculture in Bangladesh has in the past traditionally been subsistence-oriented. However, it is transforming rapidly into more commercial production of high value crops, livestock and aquaculture. Most farms grow field crops and vegetables (including home gardens), raise trees for fuel, fruits and timber, and rear livestock such as cattle and poultry. Many farmers in Bangladesh also participate in pond aquaculture production [11] and commercial shrimp culture in saline-prone areas of southern districts.

The country has been classified into 30 Agroecological Zones (AEZs) based on topography, flooding, and soil type (a map of AEZs is found in Annex 1). These AEZs are further subdivided in 88 agroecological sub-regions and 535 agroecological units. This CSA Profile focuses on two major regions in the country: the northern region—key for agricultural production—and the southern region where high exposure to extreme climate events (e.g. cyclones, tropical storms) and changes in climate and socio-economic vulnerability significantly challenge the region's agricultural productivity [9]. All major crops discussed in this profile are cultivated both in the northern and southern regions of Bangladesh, although crop suitability varies between regions.

Rice is the country's dominant crop (77–80 percent of cultivated land devoted to paddy) and a key component of the population's diet. Bangladeshis are the world's second largest per capita consumers of rice at 200 kg/year. Three main paddy rice systems are farmed in the country: *aman* (dependent on the tropical monsoon rains, which usually occur between June and October); *boro* (in winter); and *aus* (in spring). *Aman* monsoon summer rice occupies 70% of all cultivable land in Bangladesh [6]. Boro, meanwhile, is dry-season, irrigated rice system predominantly using high yielding varieties (HYVs) grown between December and May. It occupies approximately 60% of the cultivable area. *Boro* is often considered "risk-free" since it is mostly grown before the spring storms or cyclones. As such, it has the highest rice yields (reaching eight tons/ha), almost double that of monsoon rice. The third paddy type, *aus*, is a direct-seeded and rainfed variety occupying only 20% of the *Aman* rice area. *Aus* rice yields are usually the lowest in Bangladesh, due to the prevalence of traditional varieties and greater storm and cyclone risk during this season. In 2014, of the total rice production in the country, *aus*, *aman* and *boro* rice accounted for 7%, 38% and 55%, respectively [12]. Improved agricultural production over the past years has been largely associated with increased rice yields from HYVs and hybrids rather than expansion of cultivated area.

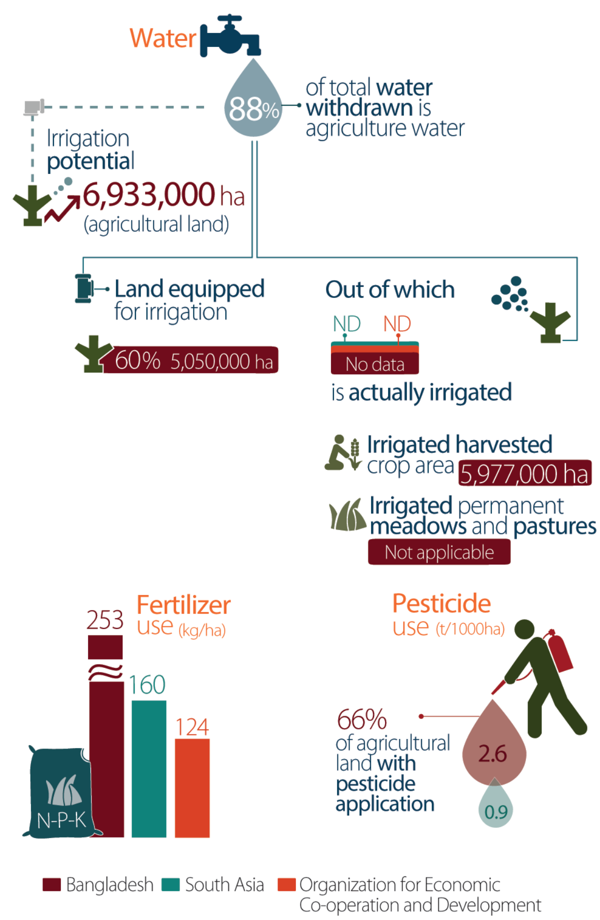
4 While FAO states the area to be 9.1 million hectares, the Bangladesh Ministry of Agriculture claims the area to be 7.9 million hectares in size.

Jute, an important fibrous commercial crop, has also been cultivated in Bangladesh for centuries. According to the Indian Jute Mill Association, Bangladesh accounts for 48% of the global jute production, a figure that is expected to rise despite increased risks from monsoon flooding. The crop is preferred for its resistance to floods during the monsoon season and is sometimes planted as a substitute for monsoon rice. Jute is effective in rotation and relay cropped with other crops given its deep root system and abundant vegetation, both contributing to improved soil fertility. The country has invested in considerable jute crop research and was the first to map the genomes of two local jute species. With the recent approval of genetically modified organisms (GMOs) for cultivation by the Government of Bangladesh (GoB)—currently limited to eggplant and blight resistant potatoes—there is potential to expand jute production through further research and the adoption of modified varieties. Retention of rainwater by in excavated canals for jute retting has further opened up opportunities for jute cultivation.

Other key crops in Bangladesh include wheat, mustard, and maize, often sown after the Aman rice crop in winter (October-March). Maize is especially productive in Bangladesh given the widespread adoption of hybrid varieties and irrigation, explaining the country's high yield performance relative to the surrounding region. The country has also seen increased demand for mungbean in recent years, leading to a swift expansion in the production area of that crop [5]. Mungbean is a short-duration crop, especially well-suited for cultivation between spring, summer, or fall cropping seasons. Finally, vegetable production has also increased in Bangladesh during recent years, given the availability of improved seeds, changes in consumption patterns and the profitability of vegetables in local markets.

Bangladesh ranks third and fourth in the world for fisheries and aquaculture production. Fisheries and aquaculture play a major role in employment: about 17 million people (11% of the total population) are associated with the fisheries sector, with 5 million people involved in marine fisheries. Bangladesh's fisheries sector subdivides into aquaculture (52.5% of total production) and capture fisheries, of which inland capture accounts for 29%, and marine and coastal capture for 18.5% of production. In 2014-15, the total sector value was estimated at US$ 3.6 billion. Fish provides 56% of animal protein consumption in Bangladesh [13]. Pond and seasonal floodplain aquaculture supply about 42% of total yearly fish production in the country [10] and are highly profitable relative to many field and commercial crops [6]. Fish feed, fingerlings and other inputs have become more readily available in the country, fostering both homestead and commercial fish production. Livestock production, meanwhile, contributes to only 13% of agricultural GDP and 2.5 % of total GDP in Bangladesh [14]. Even though livestock represents 13% of agriculture GDP, it employs about 20% of the labor force full-time and 50% part-time. Over 70% of rural households are engaged in livestock production, and income from livestock contributes a large share of the smallholder and landless farmers' livelihoods [15]. Three commodity groups dominate the livestock production systems in Bangladesh: cattle and buffalo milk, large and small ruminant meat, and poultry meat and eggs. Dairy production in particular is an important economic activity in Bangladesh, providing 3.6 million households with supplementary income. Poultry production, however, plays an outsized role in the subsector, contributing to almost 40% of all meat production and representing the fastest growing segment of the livestock industry [16]. Bovine (cattle and buffalo) and small ruminant (goat) production has also grown in recent years, much of it owing to cattle export bans from India to Bangladesh. This has led to an increase, although nascent, in rural calve-fattening operations. Milk production also remains small-scale given the lack of dairy cooperatives and fodder for dairy cattle. The use and importance of cattle and buffalo as draft power for field preparation and transport is decreasing because of the rapid expansion of three-wheel tractors' use in Bangladesh. In 2014, more than 550,000 power tillers were used to prepare more than 80% of Bangladesh's crop land [17].

Agriculture input use in Bangladesh[4, 6, 48]



5 Almost all global jute is produced in the Ganges River Basin (India and Bangladesh).

The following infographic shows a selection of agriculture production systems central to food security and sector performance in Bangladesh. The importance of each system is determined based on its contribution to economic growth, productivity, and nutrition quality indicators in the country. For more information on the methodology regarding production system selection, see Annex 2.

Production systems key for food security in Bangladesh[5, 6]

Land use (% of total harvested area); Yields (Crops: kg/ha, Cattle: kg/animal, Pond aquaculture: kg/ha)

Production system	Land use	Yield – Bangladesh	Yield – South Asia
Aman rice	70%	2,322	No data
Boro rice	61%	3,934	No data
Aus rice	14%	2,089	No data
Jute	9%	2,079	2,268
Spices	7%	5,925	2,178
Oilseeds	5%	1,992	2,718
Vegetables	5%	8,821	13,164
Wheat	5%	2,901	1,446
Pulses	4%	1,115	524
Maize	3%	6,642	2,826
Cattle	5%*	Meat 103	Meat 131
Pond aquaculture	NA	3,725	No data

Bangladesh / South Asia

* Permanent meadows and pastures as % of total land

NA: Not applicable

Food security and nutrition

A major accomplishment for Bangladesh has been achieving food security – despite frequent natural disasters and population growth over the past 40 years, food grain production has tripled between 1972 and 2014, from 9.774 to 35.731 million tons [18].

Bangladesh made significant progress in ensuring the nutrition and health of its population and in meeting the Millennium Development Goals (MDG) targets of halving hunger by 2015. Rice self-sufficiency has been achieved (with inter-year fluctuations) and calories from fish, meat and vegetables have been rising sharply for the past five years as the country experiences significant economic growth. Per capita calorie intake was estimated at 2,318 kilocalories (kcal) per day in 2010, above the minimum requirement of 2,122 kcal/day. However, the country's Food Security Index and the Global Hunger Index scores remain among the lowest in South Asia [19].

Approximately 17% of the population is classified as undernourished, with child underweight and wasting rates at 36% and 16% respectively. The areas most prone to stunting are in the northeast and the southeast. Although these rates have been declining over the years[6], they indicate that food and nutrition insecurity in Bangladesh remains a problem that stems not only from limited availability of food for some vulnerable sections of people, but also a lack of access to high quality foods. Limited market access, price volatility and climate impacts (e.g. rainfall variability, drought, floods, and cyclones) each contribute to food insecurity in the country [20].

Food security, nutrition, and health in Bangladesh [3, 6, 21]

Food security

Score 0-100*

	Score
Global**	57
Bangladesh	37
South Asia	46

1 of 6 people is undernourished

* Takes into account aspects of affordability, availability, and quality

** Refers to the 113 countries included in the Index

Food aid (2012)

188,248 metric tons (cereals 96%)

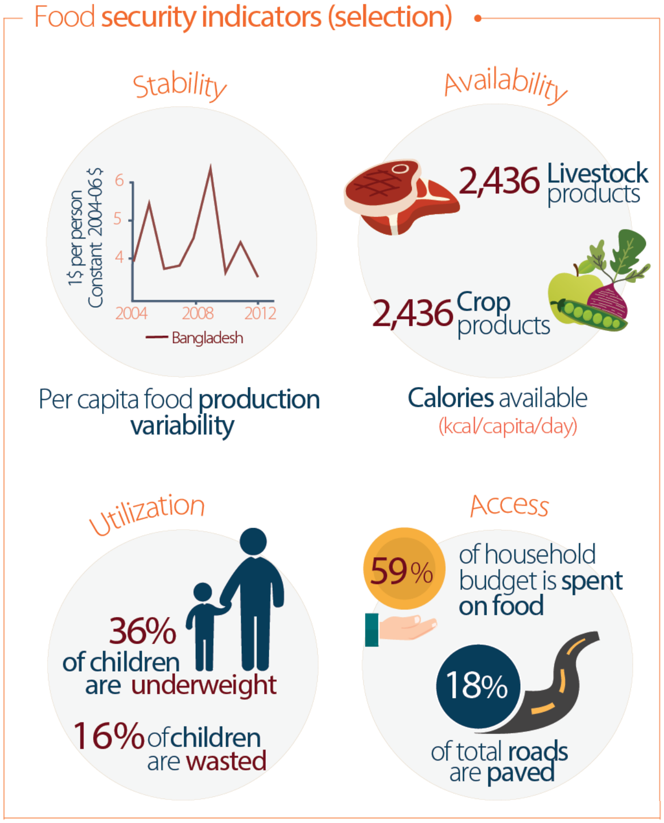
Emergency 4,940 mt

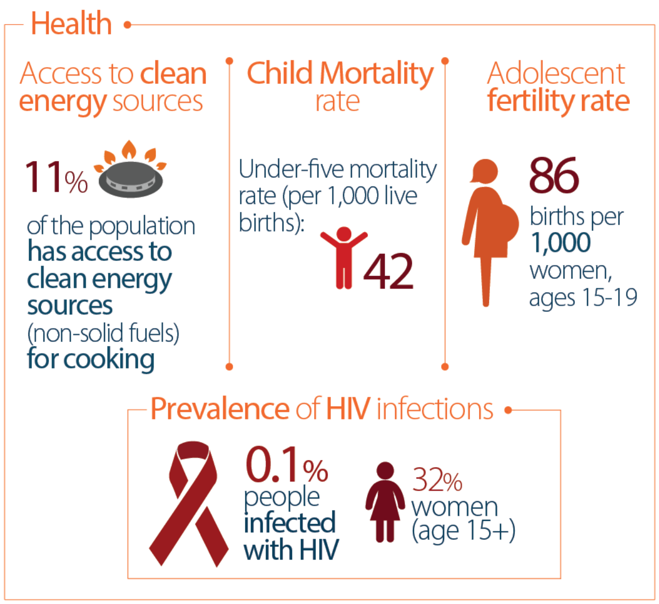
Project aid 183,390 mt

Programme aid No data

Changes in total food aid (from 2012 to 2011) 95%

6 Between 1997 and 2007, Bangladesh achieved one of the fastest reductions in child undernourishment in history. The rate of stunting among children under five decreased from 55% in 1996-97 to 36% in 2014. Maternal undernutrition, measured by body mass index (BMI) had also declined from 52% to 17% during the same period [19]. All this was attributed to the country's improved economic performance (with an economic growth of 6-7% per year).

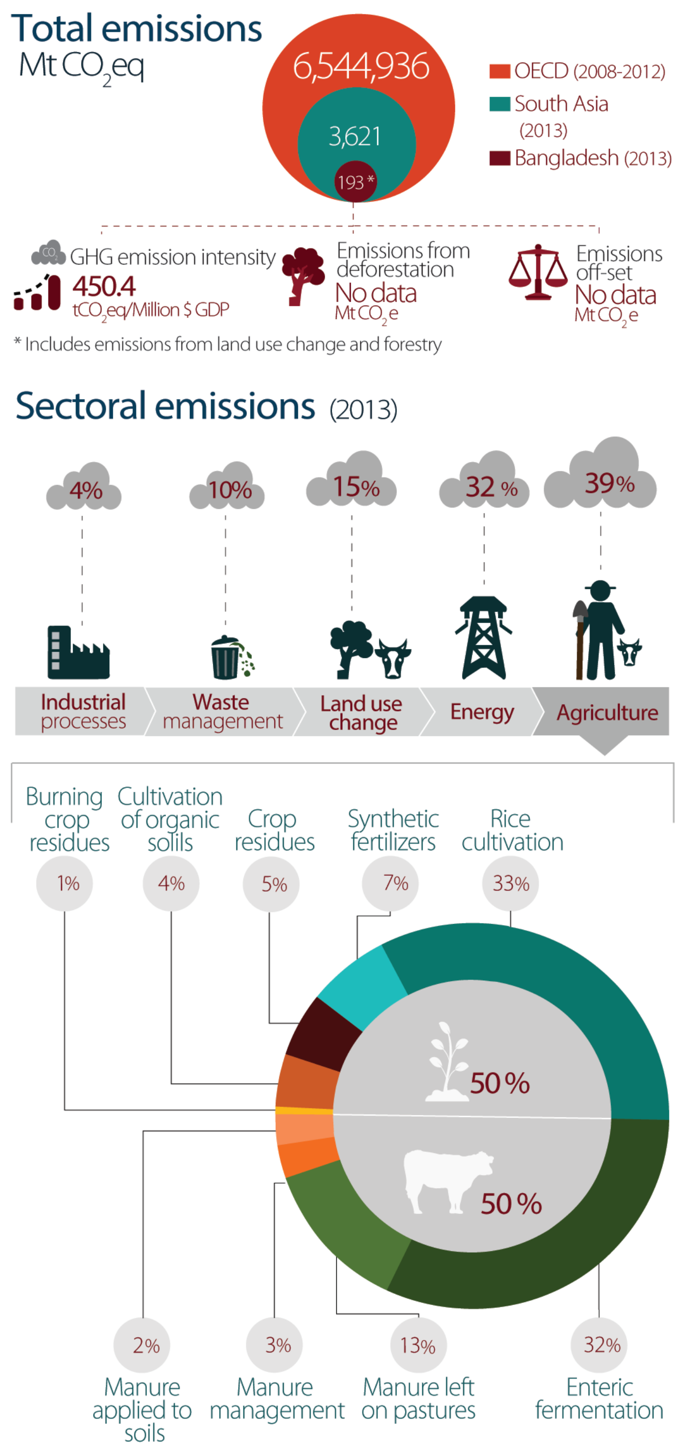




Agricultural greenhouse gas emissions

Bangladesh's GHG emissions reached 192 megatons of CO2 in 2014, placing the country in the bottom quarter of emitters globally [5, 22]. While the CO2 intensity of the economy is relatively low, it has been increasing steadily over the past decades. Bangladesh's annual CO2 footprint has increased by 3.6% in 2011 compared to the year before, driven by GDP growth rates of 6-7%. Agriculture contributes to 39% of the country's GHG emissions. Cropland and enteric fermentation (livestock production) contributed equally to agricultural GHGs in 2013. Compared to other sectors, such as energy whose emissions increased by almost 500% between 1990 and 2013, agricultural emissions in Bangladesh have remained relatively stable, increasing by about 30% in that same time period [22]. Nevertheless, the agriculture and livestock sector remains the main source of emissions in the country in absolute terms.

Greenhouse gas emissions in Bangladesh [6, 22]



The Department of Agriculture extension service recommends a variety of agricultural practices to farmers for mitigating GHG emissions, including: midseason drainage, off-season incorporation of rice straw[7], substitution of urea with ammonium sulphate, use of deep placed briquetted urea for rice, replacement of roughage with feed concentrates, use of dome digesters, conservation agriculture practices including zero or minimum tillage coupled with residue management, use of biofuel instead of fossil-fuels, high efficiency fertilizer application, and artificial and participatory woodlot plantation [23].

Challenges for the agricultural sector

Agricultural growth and development is key for food security in Bangladesh, yet the sector is facing several challenges that hinder development and cause stagnating growth rates. Some of those challenges relate to: gradual loss of arable land, declining soil fertility and salinization; insufficient investment in agricultural research and training; inadequate credit support for farmers and an unfavorable land-tenure system, resulting in low level technology uptake of a predominantly small-scale farming structure; outmigration and labor shortage in rural areas resulting in rising wage rates; and the need to cope with increasing impacts of climate change and related extreme weather events [24, 25. 26, 27].

The overriding challenge in Bangladesh is to support farmers out of low profitability rice cultivation through the reduction of labor costs through improved mechanization and water conservation through on-farm irrigation efficiency. Promoting suitable mechanization in Bangladesh needs to be seen not only as a substitution of machines for scarce rural labor on profitability and efficiency grounds but as a potential rehabilitation, mitigation and adaptive strategy to address shrinking timer period between cropping systems, allowing climate vulnerable farmers quick planting and harvesting of crops as well as transportation and livelihood means [28].

Over the past decades, Bangladesh's high population growth led to a stark decline in per capita agricultural land availability. The trend is exacerbated by the increasing non-agricultural use of cultivable areas resulting from unplanned urbanization (e.g. for housing), road construction, and other infrastructure projects. Limited availability of farmland and on-farm livelihood opportunities further drives the rural labor force to seek employment in cities, further fueling urbanization trends while causing labor shortages in rural areas [27].

Declining land availability also means that, to sustain food production, crop productivity in Bangladesh has had to increase. The government sought to achieve this by subsidizing fertilizer use in the country, leading to a spectacular rise in fertilizer use from 0.36 kg/ha in 1995 to more than 298 kg/ha in 2007, and with it an almost three folds increase of crop yields per hectare over this same time period [26, 27]. Although this led the country to achieving rice self-sufficiency, the habit of growing rice predominantly in monoculture together with imbalanced use of chemical fertilizer and inadequate irrigation management also resulted in depletion of soil fertility and soil organic matter [12, 27].

Given these and other trends, crop growth rates of cereals have been declining over the past years, and rice yields remain below the levels registered in other South Asian countries. Wheat and maize imports in Bangladesh are expected to stay unchanged in the near future, to meet the national demand. Besides, the predominant focus on rice production (which accounts for 75% of crop production in the country) means that many farming households are under risk of malnourishment due to a lack of diversification [26]. To counteract this, the government adopted a Crop Diversification Program in 2008. Slowly but steadily, farmers are now increasingly engaged in diversifying production, focusing particularly on high value crops such as flowers or early potatoes, entering new markets, as well as integrating more livestock in to farming systems [26]. For example, farmers in the Northwest forgo monsoon rice production to grow early potatoes, getting a significantly higher price they would get during the usual potato season.

Finally, Bangladesh's growing livestock sector is plagued by a variety of constraints, such as inadequate availability of quality fodder and feed, lack of quality control, lack skilled labor and qualified personnel, vulnerability to climate change and insufficient veterinary and animal health services and related livestock research, among others [15]. Animal disease is responsible for almost 50% of all animal deaths in the country. Limited permanent grazing land, inefficient livestock marketing practices, and a lack of access to improved animal breeds further limit the sub-sector's performance and size [29]. A comprehensive livestock production plan was adopted by the GoB in 2005, but has yet to translate in to meaningful productivity gains in the sector.

Agriculture and climate change

According to the Global Climate Risk Index[8], Bangladesh is the most climate change vulnerable country in the world [30]. Today, and in to the coming decades, the country is likely to be negatively affected by sea level rise and saltwater intrusion, mean temperature increases (1.7°C by 2050), rainfall variability, and an increase in the frequency and intensity of extreme weather events. Each of these factors will have considerable impacts on agricultural production in the country.

Situated in an alluvial delta plain, Bangladesh has five major river systems that often change locations, depending on siltation and flow. The country is thus highly vulnerable to sea level rise and salinization of inland water sources. A 2009 study by the Bangladesh Soil Resource Development Institute [31] found approx. 62% of coastal land (1.06 million out of 1.7 million hectares) to be affected by some

7 Farmers in Bangladesh rarely burn the straw in their fields, given its value as cattle feed. Hence, emissions from straw burning represent less than 1% of GHG emissions in the country. In the villages that lack access to gas or cylinder gas, manure is burned for fuel.

8 The Index analyses the extent to which countries have been affected by the impacts of weather-related events (e.g. losses related to storms, floods, heat waves etc.)

degree of soil salinity, ranging from very slight (0.328 million hectares), slight (0.274 million hectares), moderate (0.189 million hectares), strong (0.161 million hectares) to very strong (0.101 million hectares). Salinization is expected to advance 8 km further north in the country by 2030, further reducing land availability for farming. While infusion of salt water into the rivers and canals remains a challenge for crop production, it also brings opportunities for salt-water shrimp production, which has expanded recently due to its higher profitability compared to other crops (such as rice) [32].

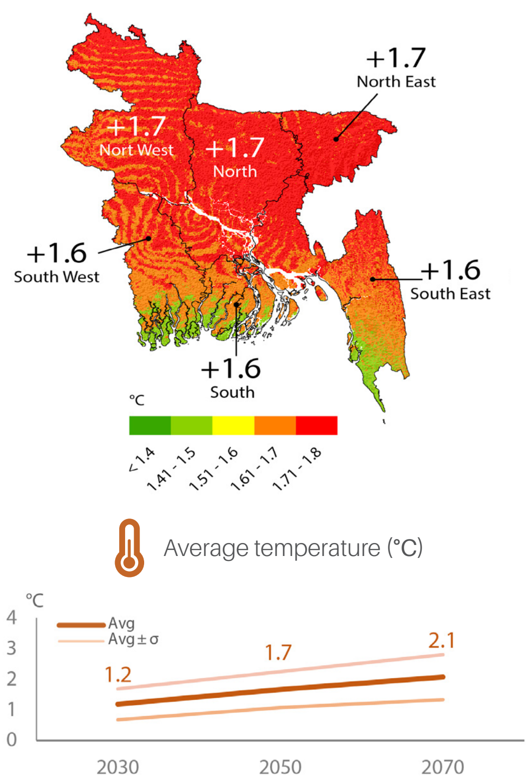
Approximately 60% of Bangladesh's area is characterized by a tropical savanna climate, while another 30% is considered tropical monsoon [33]. Rainfall patterns vary from North to South and from East to West in the country, except during monsoon months (May through September). The hilly areas of northwestern Bangladesh are prone to drought, for example, while the northeastern freshwater wetland often faces delayed rainfall or early flash flooding. While the central floodplains experience flash floods and riverbank erosion, and the hilly areas experience landslides, urban areas in Bangladesh are plagued by rainwater drainage issues [3]. Most rainfall in Bangladesh occurs in the summer months between June and October, while the winter months (November to February) receive only 4% of the annual rainfall. Early monsoon rain in April 2017, for example, caused heavy flooding in northeastern haor (vast low depression areas) that damaged pre-mature *boro* paddy. On the whole, rainfall is expected to increase in Bangladesh by 9-12% by 2050.

Since yields of summer monsoon rice depend on consistent, predictable rainfall, disruptions in normal monsoon behavior can produce significant losses in rice yields all over South Asia, including Bangladesh. Rain-fed monsoon rice, for example, which constitutes over 38% of total rice production in Bangladesh, is highly vulnerable to water supply volatility, caused by changes in seasonal monsoon occurrence [34]. On one hand, early monsoon arrival can cause flood damage when rice seedlings are submerged in early growth stages, especially when farmers are not using submergence-tolerant varieties. On the other hand, late monsoon arrival can lead to water stress. Results from the CERES-Rice model indicate that high water stress during flowering and maturing stages can lead to rice yield losses as high as 70% [35]. Increased concentration of carbon dioxide in the atmosphere may benefit *boro* rice production, yet these effects are most likely neutralized by rising temperatures during the flowering period and decreased sunlight during the winter crop season, both negatively impacting yield. Since this rice crop is 100% irrigated, fluctuations in rainfall are less likely to affect the crop.

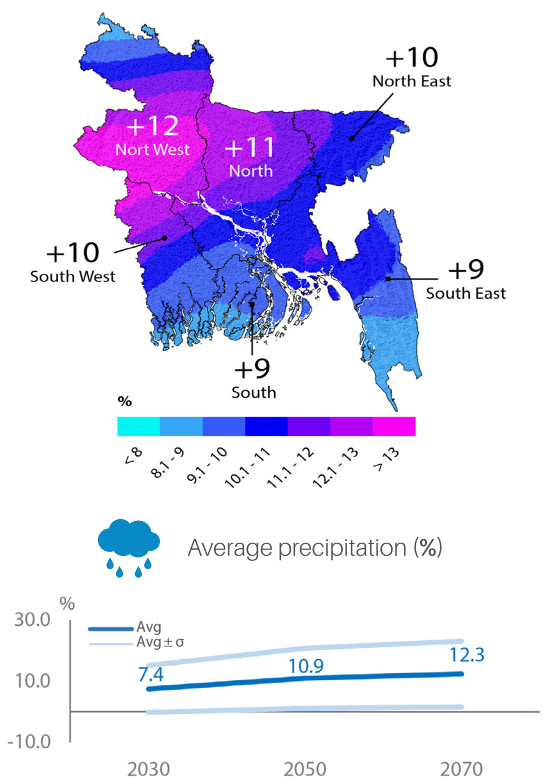
Extreme weather conditions (floods and cyclones) are expected to increase in frequency and intensity in Bangladesh [36, 37, 38]. Losses related to the 2007 and 2009 cyclones were estimated at around two million metric tons of rice, enough to feed 10 million people. The south, southwest, and southeast coastal regions of Bangladesh are increasingly susceptible to severe tropical cyclones and associated saltwater intrusion.

Projected changes in temperature and precipitation in Bangladesh by 2050 [36, 37, 38]

Changes in annual mean temperature (°C)

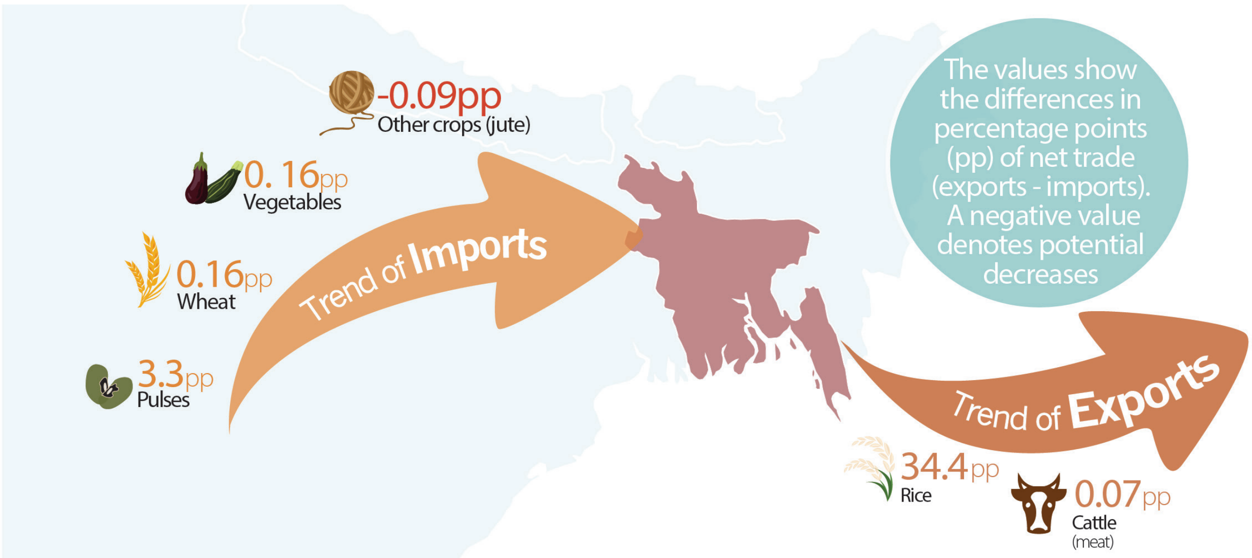


Changes in total precipitation (%)



Potential economic impacts of climate change

The impact of climate change on net trade in Bangladesh (2020-2050) [39]



An analysis using the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT)[9] [398] for Bangladesh shows that climate change has mixed effects on agricultural production potentially contributing to increase in yields and land area for some crops, and decreases for others[10]. In general, most production systems in Bangladesh are projected to be at least somewhat adversely affected by climate change. The specific impacts depend on the production system in question, with pulses, wheat, and oilseed-rapeseed facing the most negative impact.

While subject to considerable within-country variability, the model demonstrates overall yield declines in maize, pulses, vegetables, jute and wheat, and increases for milk and meat yields by the year 2050. For example, 2050 pulse yields under climate change are 8.8% lower than the projected value if climate change did not occur. This is followed by wheat and oilseed-rapeseed with 6.4% and 6.3%, respectively, as the greatest reductions in yield. By 2050 rice, yields of vegetables (as a group), and other crop[11] (including jute) are 5.3%, 5.7%, and 3.3% less than the NoCC value in 2050, respectively.Cattle herd sizes are projected to increase substantially—by roughly 52% over the 2020 value—under both CC and NoCC scenarios, yet the increase is slightly greater under CC by 0.2 percentage points (pp). Furthermore, the impact of climate change on area cultivated is mostly negative, with the exception of rice and oilseed-rapeseed.

With regards to changes in agricultural net trade, the model also suggests that Bangladesh may become more dependent on imports of pulses, other crops (including jute), vegetables (as a group), and wheat. Thereby, the dependence on imports of other crops (including jute) is projected to be lower under conditions of climate change as compared to NoCC by 0.09pp, while the dependence on imports of pulses, vegetables (as a group), and wheat is projected to be greater under CC than NoCC by 3.3pp, 0.16pp, and 0.16pp, respectively.

Likewise, the modeled results suggest that cattle meat exports will increase both under the CC and NoCC scenarios (but the difference between scenarios is insubstantial at +0.07pp).

Most notably, the model results indicate that Bangladesh may transition from being a net importer to a net exporter of rice under both CC and NoCC. This transition is likely to be more pronounced under CC by 34pp as compared to the NoCC scenario.

Ultimately, changes in demand are driven by relative commodity prices present in the global and national marketplace. For this reason it is important to examine changes in supply-side drivers.

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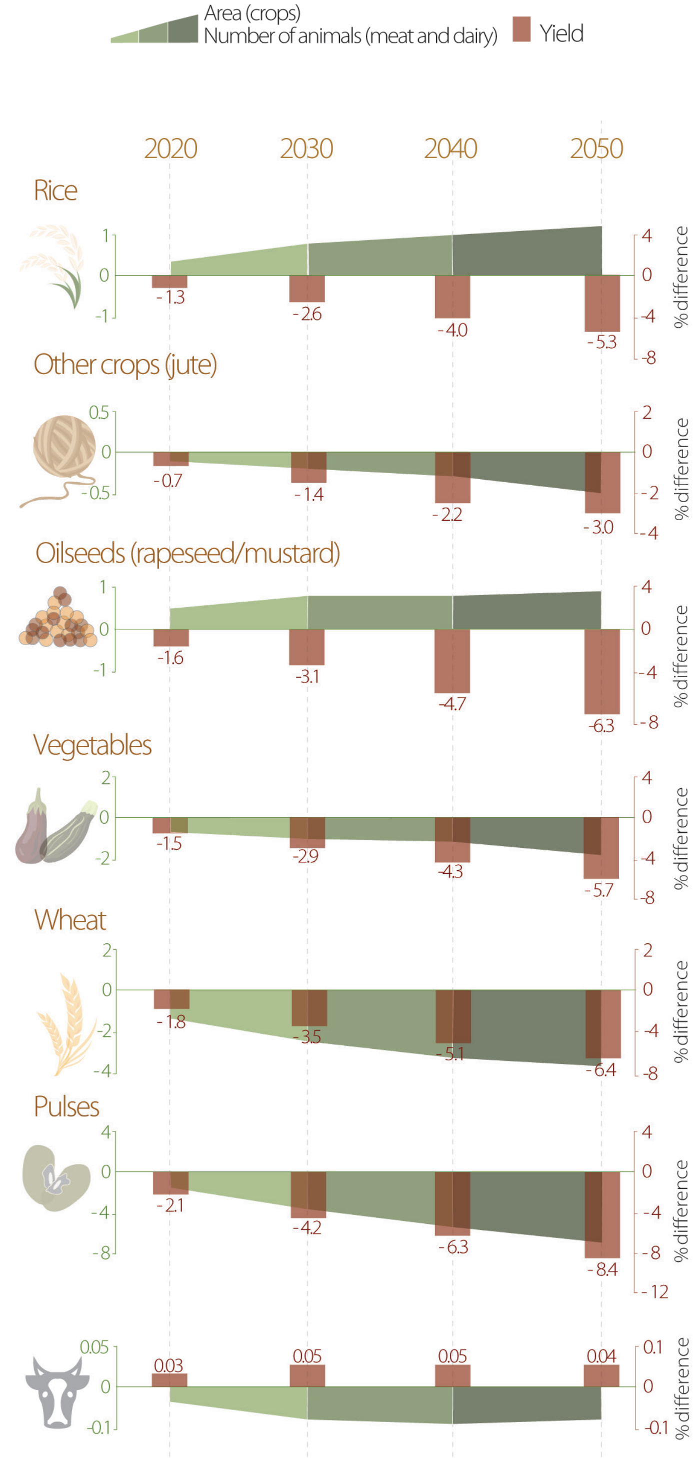
9 IMPACT, developed by the International Food Policy Research Institute (IFRPI) [39], is a partial equilibrium model using a system of linear and non-linear equations designed to approximate supply and demand relationships at a global scale. This study used the standard IMPACT model version 3.2, less the IMPACT-Water module. The tool uses the General Algebraic Modeling System (GAMS) program to solve a system of supply and demand equations for equilibrium world prices for commodities. The tool generates results for agricultural yields, area, production, consumption, prices and trade, as well as indicators of food security.

10 The IMPACT model scenarios are defined by two major components: (i) the Shared Socioeconomic Pathways (SSPs), which are global pathways that represent alternative futures of societal evolution [40, 41] and (ii) the Representative Concentration Pathways (RCPs), which represent potential greenhouse gas emission levels in the atmosphere and the subsequent increase in solar energy that would be absorbed (radiative forcing) [42]. This study used SSP 2 and RCP 4.5 pathways.

11 The category "other crops" covers a variety of different types of crops, including jute, in accordance with suggestions made by IFPRI experts.

Climate change impacts on yield, crop area and livestock numbers in Bangladesh [39]



*A negative value denotes potential decreases in area and yield expressed as percentage change in a climate change scenario vs. non climate change

CSA technologies and practices

CSA technologies and practices present opportunities for addressing climate change challenges, as well as for economic growth and development of the agriculture sector. For this Bangladesh profile, practices are considered CSA if they enhance food security as well as at least one of the other objectives of CSA (adaptation and/or mitigation). Hundreds of technologies and approaches around the world fall under the heading of CSA.

Many of the CSA practices identified here have been used by farmers in the southern coastal plains of Bangladesh for centuries, in response to increasing floods and cyclones. Initially used for shrimp farming, for example, traditional gher farming (see Case Study below)—an aquaculture pond in non-saline wetlands with raised dikes for vegetable production—has grown increasingly complex, allowing for the production of shrimp, fish, and prawns. Climbing vine-type vegetables are also commonly grown on trellises over the pond. Meanwhile, floating vegetable gardens have also been introduced in tidal flooded areas, using water hyacinth layered with soil—an old practice which is now expanding in the Southern coastal plains as a climate risk management strategy. Kangkong (water spinach) cultivation was always done near ponds, and with improved varieties, production can be expanded.

In low-lying waterlogged regions, farmers in Bangladesh have historically utilized a host of ridging and furrowing methods. The Sorjan system, for example—a variation on pyramid cropping—is a system of tall beds for vegetable and crop production alternating with furrows, or trenches, planted with submergence tolerant plants or used for fish production. Rice field fish rings, or concrete rings in rice paddies that protect fish when paddies dry up, have also been implemented [43]. Production of small indigenous fish in these canals is an increasingly common practice in Bangladesh, offering even small pond holders access to nutritious food and better incomes.

The adoption rate of this practice is still low among farmers in the Northern and Southern regions. While these practices were first introduced decades ago, they are quickly expanding today. A variant of this practice is locally referred to as the 'hari' system in which gher operators grow fresh water fish in ponded water in the rainy season and then drain out excess water on their own expenses to enabling landowners to grow boro paddy in dry months [44]. Institutional support for the identification of appropriate rice varieties, and improved access to credit and technology packages can promote such practices in a more profitable and environmentally friendly way.

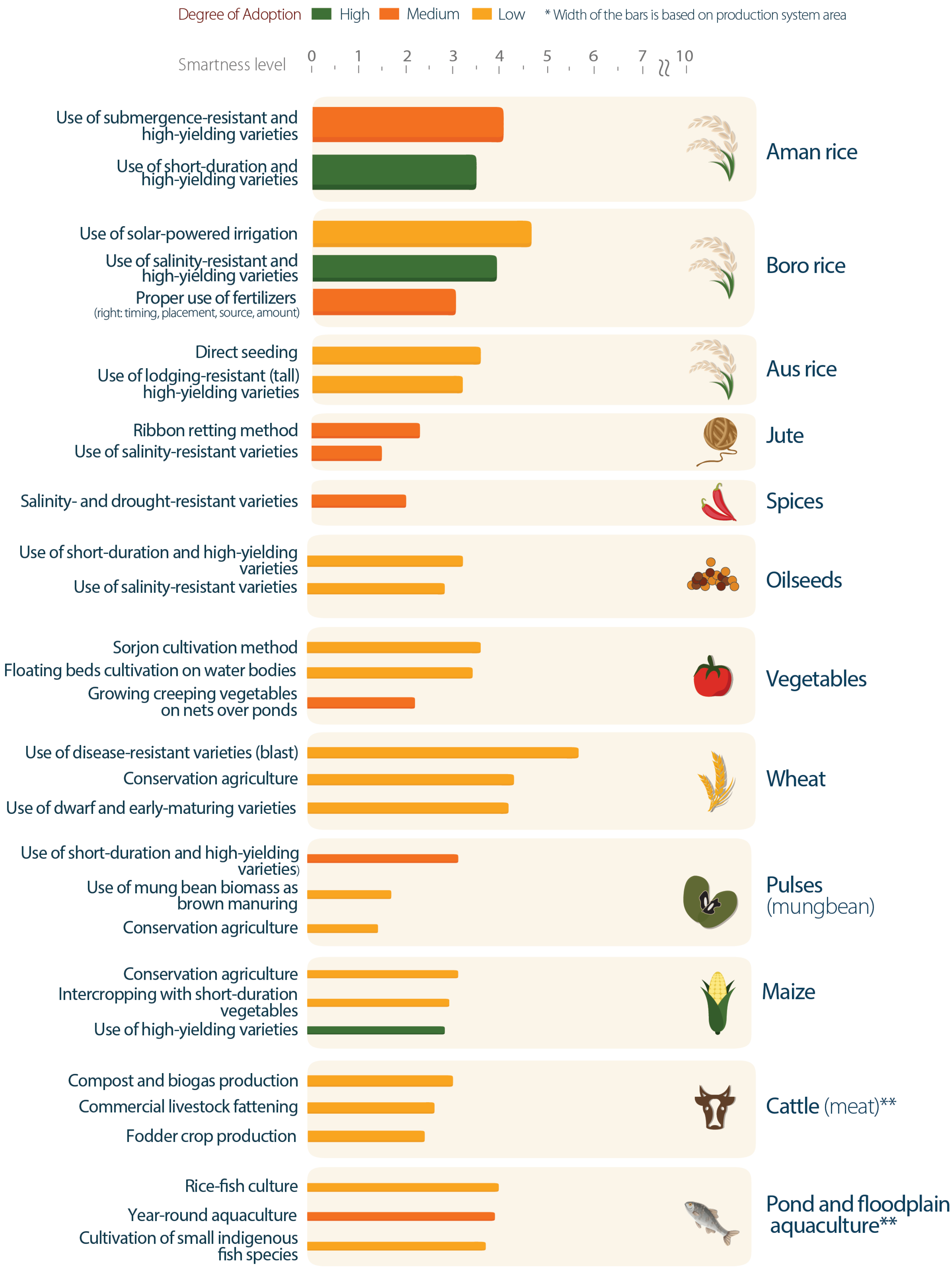
Over the past 40 years, saltwater intrusion into the tidal rivers of Bangladesh has become especially acute. Changes in the sea level are very likely to further exacerbate this situation. The use of salt-and submergence tolerant, high yielding crop varieties is therefore an important, if underutilized, adaptation strategy under these conditions. Access to improved seed in Bangladesh is constrained by a sluggish process between seed release and use (it takes around 15 years for seed to be readily available to growers). Most of the released seed is multiplied through the Bangladesh Agriculture Development Corporation, but because it is not 'marketed', new releases are not demanded and thus, not multiplied sufficiently. Consequently, adoption of tolerant varieties remains low throughout the country. However, in response to the losses caused by changes in seasonal monsoon occurrence, the availability of submergence-tolerant rice varieties, released seven years ago, has improved significantly over the past years, especially for the farmers in areas prone to flash flooding.

After the monsoon period, the winter in Bangladesh is dry, devoid of much rainfall. Thus, any salt in the ground is evaporated to the soil surface, rendering it saline. Vegetable towers—potted vegetables supported by bamboo and polythene—have been introduced to counter this salinity challenge.

Barriers to the adoption of these and other CSA practices by small-scale farmers in Bangladesh include the limited availability of credit, unfavorable extension staff to farmer ratios for the dissemination of new technologies and practices, and the limited implementation of novel financing mechanism and safety net protection. Index-based crop insurance, for example, was modeled by Oxfam in cooperation with a private insurer, yet the lack of a clear business model still makes it difficult for the GoB to scale up such interventions.

The following graphics present a selection of CSA practices with high climate smartness scores according to expert evaluations. The average climate smartness score is calculated based on the practice's individual scores on eight climate smartness dimensions that relate to the CSA pillars: yield (productivity); income, water, soil, risks (adaptation); energy, carbon and nitrogen (mitigation). A practice can have a negative/ positive/ zero impact on a selected CSA indicator, with 10 (+/-) indicating a 100% change (positive/ negative) and 0 indicating no change. Practices in the graphics have been selected for each production system key for food security identified in the study. A detailed explanation of the methodology and a more comprehensive list of practices analyzed for Bangladesh can be found in Annexes 3 and 4, respectively.

Selected CSA practices and technologies for production systems key for food security in Bangladesh



** Unidentified production system area

Case study: Ghers of Bangladesh

In Southern Bangladesh, the livelihoods and food security of many rural families depend upon half acre ponds. These ponds, or 'ghers' in Bangal, are dug with wide and tall embankments offering resilience against flood and cyclone damage and providing an elevated platform on which to grow vegetables and other crops. The ponds themselves serve as a bed for paddy rice and, following harvest, prawns. Ghers are a traditional farming method in low-lying, water abundant regions of Bangladesh.

This case study chronicles Radha Rani and her husband, Rabin Mandal, as they institute changes to their traditional gher practices. Radha joined a training classes in 2013 along with 24 women and men from her village to receive training based on indigenous knowledge and newly emerging gher management practices known to increase productivity. With this knowledge, Radha now dreams of a better future for her family.


Photo Md. Saifullah. Worldfish / CSISA-BD

After the training, Radha explained the new technologies to her husband who could not attend the classes and convinced him to integrate this new knowledge in to their existing practices. Now, they work as a team to prepare their own nursery and ensure the stocking density of the shrimp is adequate, buying quality feed and ensuring water quality. Radha also learned how to cultivate vegetables on the dikes, so she and Rabin purchased vegetable seeds including cucumber, cabbage, beans and ladies' finger (okra), which she later planted.

Recognizing Radha's enthusiasm, the trainer established a demonstration area in her gher site with a signboard showing both her and her husband's names. Radha's husband, a day laborer and originally skeptical of her ability to proficiently manage the gher operations, changed his attitude when watching Radha take on new responsibilities in his absence using the newly learned techniques. Radha, along with an entire community of empowered women, takes pride in her contributions now on their gher.

In November 2013, Radha and her husband harvested the first batch of prawns, which they sold for a total US$ 720 against a cost of US$ 420. By using the new techniques, they were able to achieve a 30% decrease in production costs and nearly seven times more income from the previous year. Meanwhile, their vegetable crops sold for US$ 134 against a cost of US$ 83. After the prawn, they have planted winter irrigated rice and are preparing the nursery to stock the next batch of prawn.

Given this level of return, it is no wonder that the gher movement in Bangladesh is attracting financing from domestic banks. Many private and government banks (such as Krishi Bank) are investing in ghers and pond excavations given their relatively low risk and profitable returns. Though they represent major landscape modifications, the economic and resilience benefits of creating ghers remain high, with potential to be replicated in other parts of the country.

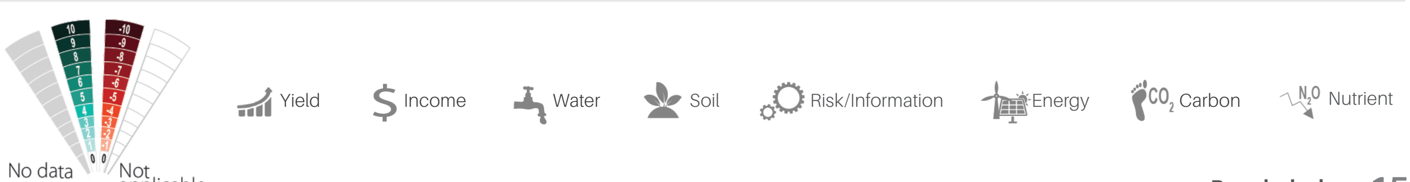
Radha's husband was exuberant about his wife's new ability to farm and increase their family's income. The neighboring women now meet with Radha and, just like her, feel encouraged to be involved with their husbands in the ghers. On a field day at Radha and Rabin's gher site, about 100 neighbors, both men and women, gathered to witness the transformation of Radha and Rani's farming operation. Seeing what can be accomplished by working together, gher farming in their community has now become a family affair.

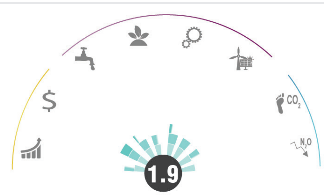
(Adapted from the Cereal System of Intensification in South Asia project (CSISA WorldFish) used with permission from the author, Afrina Choudhury. This and further case studies can be found in: "Life-Changing Stories of Successful Women Farmers" of the Cereal Systems Initiative for South Asia in Bangladesh (CSISA-BD) [45]).

Table 1. Detailed smartness assessment for top ongoing CSA practices by production system as implemented in Bangladesh.

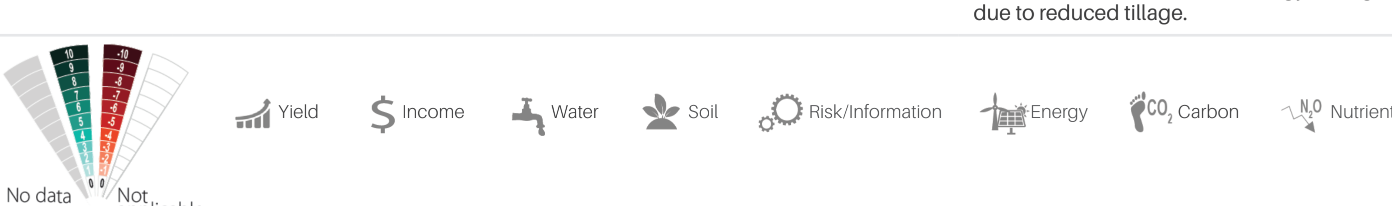
CSA practice	Region and adoption rate (%) <30 30-60 60>	Predominant farm scale S: small scale M: medium scale L: large scale	Climate smartness	Impact on CSA Pillars
Aman rice (70% of total harvested area)				
Use of submergence-resistant and high-yielding varieties	Northern >60%	S M		**Productivity** Promotes high yields per unit area, hence potential increase in income. **Adaptation** Reduces the risk of crop losses caused by temporary or permanent flood conditions. **Mitigation** Promotes above- and below-ground carbon sinks through increased accumulation of dry matter.
	Southern 30-60%	S M		
Use of short-duration and high-yielding varieties	Northern >60%	S M		**Productivity** Promotes high yields per unit area, hence potential increase in income. **Adaptation** Increases resilience to biotic stress and climate shocks. Enhances water use efficiency. **Mitigation** Provides moderate reduction in GHG emissions per unit of food produced.
	Southern 30-60%	S		
Boro rice (61% of total harvested area)				
Use of solar-powered irrigation	Northern <30%	M L		**Productivity** Increases yield per unit area, especially during the dry season. Ensures income diversification. **Adaptation** Minimizes water use per unit of product, increasing water use efficiency and resilience to climate shocks. **Mitigation** Reduces GHG emissions due to reduced fuel/energy required for pumping and/or carrying water for irrigation.
	Southern <30%	M L		
Use of salinity-resistant and high-yielding varieties	Southern 30-60%	S M		**Productivity** Increases farmers' capacity to limit the crop exposure to climate risks. In the long term, increases in soil biomass accumulation can enhance soil fertility. **Adaptation** Increases in yield stability due to increased resilience to stress caused by salinity. **Mitigation** Provides moderate reduction in GHG emissions per unit of food produced. Promotes carbon sinks through increased accumulation of biomass.

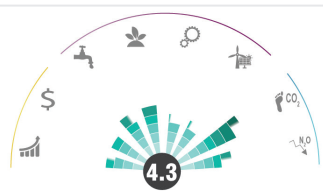
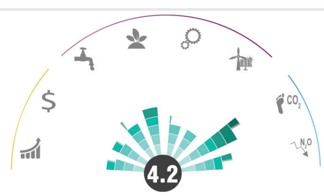
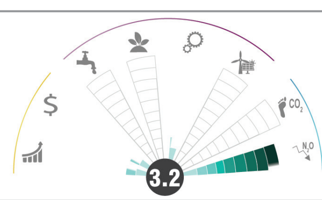
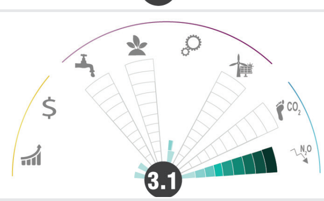
CSA practice	Region and adoption rate (%) <30 30-60 60>	Predominant farm scale S: small scale M: medium scale L: large scale	Climate smartness	Impact on CSA Pillars
Boro rice (61% of total harvested area)				
Use of salinity-resistant and high-yielding varieties	Northern 60%>	S M		**Productivity** Increases farmers' capacity to limit the crop exposure to climate risks. In the long term, increases in soil biomass accumulation can enhances soil fertility. **Adaptation** Increases in yield stability due to increased resilience to stress caused by salinity. **Mitigation** Provides moderate reduction in GHG emissions per unit of food produced. Promotes carbon sinks through increased accumulation of biomass.
Aus rice (14% of total harvested area)				
Direct seeding	Northern <30%	S M		**Productivity** Leads to potential increases in yield in the long term. **Adaptation** Reduces soil degradation and erosion. Increases water availability. Frees up time for decision-making. **Mitigation** Reduces GHG emissions related with soil tilling. Increases soil carbon stock when implemented comprehensively.
	Southern <30%	S M		
Use of lodging-resistant (tall) high-yielding varieties	Southern <30%	S M		**Productivity** Promotes high yields per unit area, hence potential increase in income. **Adaptation** Reduces the risk of crop losses caused by temporary or permanent flood conditions. **Mitigation** Promotes above- and below-ground carbon sinks through increased accumulation of dry matter.
	Northern <30%	S M		
Jute (9% of total harvested area)				
Ribbon retting method	Northern 30-60%	S M		**Productivity** Reduces fiber damage increasing the production of high-quality fiber. **Adaptation** Reduces time of conventional retting by 4-5 days. Can save half of the water normally. Reduces environmental pollution compared to the conventional retreat. **Mitigation** Provides moderate reduction GHG emissions per unit of produce.

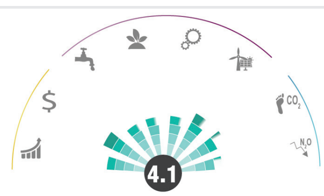
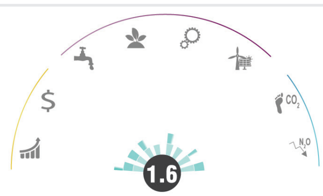


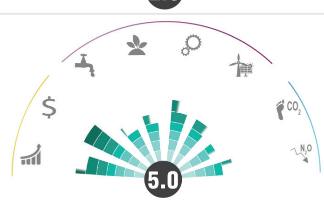
CSA practice	Region and adoption rate (%) <30 30-60 60>	Predominant farm scale S: small scale M: medium scale L: large scale	Climate smartness	Impact on CSA Pillars
Jute (9% of total harvested area)				
Ribbon retting method	Southern <30%	S M		**Productivity** Reduces fiber damage increasing the production of high-quality fiber. **Adaptation** Reduces time of conventional retting by 4-5 days. Can save half of the water normally. Reduces environmental pollution compared to the conventional retreat. **Mitigation** Provides moderate reduction GHG emissions per unit of produce.
Use of salinity-resistant varieties	Southern <30%	S M		**Productivity** Reduces time of conventional retting by 4-5 days. Can save half of the water normally. Reduces environmental pollution compared to the conventional retreat. **Adaptation** Reduces time of conventional retting by 4-5 days. Can save half of the water normally. Reduces environmental pollution compared to the conventional retreat. **Mitigation** Provides moderate reduction GHG emissions per unit of produce.
	Northern 30-60%	S M		
Spices (7% of total harvested area)				
Salinity- and drought-resistant varieties	Southern <30%	S		**Productivity** Increases in yield stability due to increased resilience to salinity stress. In specific cases could enhance organoleptic properties of the produce. **Adaptation** Increases farmers' capacity to limit the crop exposure to climate risks. In the long term, increases in soil biomass accumulation can enhance soil fertility. **Mitigation** Provides moderate reduction in GHG emissions per unit of produce. Promotes carbon sinks through increased accumulation of below-ground biomass.
	Northern <30%	S		
Oilseed (5% of total harvested area)				
Use of short-duration and high-yielding varieties	Southern <30%	S		**Productivity** Promotes high yields per unit area hence an increase in income and profit due to reduced production costs. **Adaptation** Optimizes the use of available soil moisture contributing to avoid crop loss. Increases water use efficiency. **Mitigation** Provides moderate reduction in GHG emissions per unit of food produced.

CSA practice	Region and adoption rate (%) <30 30-60 60>	Predominant farm scale S: small scale M: medium scale L: large scale	Climate smartness	Impact on CSA Pillars
Oilseed (5% of total harvested area)				
Use of short-duration and high-yielding varieties	Northern <30%	S		**Productivity** Promotes high yields per unit area hence an increase in income and profit due to reduced production costs. **Adaptation** Optimizes the use of available soil moisture contributing to avoid crop loss. Increases water use efficiency. **Mitigation** Provides moderate reduction in GHG emissions per unit of food produced.
Use of salinity-resistant varieties	Southern <30%	S		**Productivity** Increases in productivity stability due to increased resilience to stress caused by salinity. **Adaptation** Increases farmers' capacity to limit the crop exposure to climate risks. In the long term, increases in soil biomass acumulation can enhance soil fertility. **Mitigation** Provides moderate reduction GHG emissions per unit of food produced. Promotes carbon sinks through increased below-ground accumulation of biomass.
	Northern <30%	S		
Vegetables (Tomato, aroid gouds etc.)(5% of total harvested area)				
Sorjon cultivation method	Southern <30%	S		**Productivity** Increase vagetable production throughout the year. Increases economic return from fallow land. **Adaptation** Increases farmers' capacity to limit the crop exposure to tidal water submergence. **Mitigation** Contributes to increase the above-ground biomass constituting a carbon sink.
	Northern <30%	S		
Floating beds cultivation on water bodies	Southern <30%	S		**Productivity** Increases in income due to harvesting of multiple crops in one season. Generates aditional additional income from the sale of seedlings produced. **Adaptation** Reduce risk of complete crop failure. Allows optimum use of natuaral and local available resources. Creates additional cropping area. **Mitigation** Protects soil structure and organic carbon reserves. Promotes fuel and energy savings due to reduced tillage.



CSA practice	Region and adoption rate (%) <30 30-60 60>	Predominant farm scale S: small scale M: medium scale L: large scale	Climate smartness	Impact on CSA Pillars
Vegetables (Tomato, aroid gouds etc.)(5% of total harvested area)				
Floating beds cultivation on water bodies	Northern <30%	S		**Productivity** Increases in income due to harvesting of multiple crops in one season. Generates additional income from the sale of seedlings produced. **Adaptation** Reduce risk of complete crop failure. Allows optimum use of natuaral and local available resources. Creates additional cropping area. **Mitigation** Protects soil structure and organic carbon reserves. Promotes fuel and energy savings due to reduced tillage.
Wheat (5% of total harvested area)				
Use of disease-resistance varieties (Blast)	Southern <30%	S		**Productivity** Reduces production costs. Enhance crop production and quality, hence potential increases in income. **Adaptation** Increases farmers' capacity to limit the crop exposure to crop damage caused by diseases. Reduces the need for external inputs for crop protection. **Mitigation** Reduces GHG emissions by reducing the use of synthetic pesticides (fungicides) therefore the carbon footprint reduction per unit of food produced.
	Northern <30%	S		
Conservation agriculture)	Southern <30%	M		**Productivity** Higher profits due to increased crop yields and reduced production costs. **Adaptation** Increases moisture retention due to mulching and cover crops. Reduces soil erosion. **Mitigation** Reduces fuel requirements for tillage. Mulching and cover crops increase soil carbon capture and soil organic matter.
	Northern <30%	S M		
Pulses (4% of total harvested area)				
Use of short-duration and high-yielding varieties	Southern 30-60%	S M		**Productivity** Promotes high yields per unit area hence an increase in income and profit due to reduced production costs. **Adaptation** Increases water use efficiency. Reduces crop exposure to climate shocks due to a shorter crop cycle. **Mitigation** Provides moderate reduction in GHG emissions per unit of food produced.
	Northern 30-60%	S M		

CSA practice	Region and adoption rate (%) <30 30-60 60>	Predominant farm scale S: small scale M: medium scale L: large scale	Climate smartness	Impact on CSA Pillars
Pulses (4% of total harvested area)				
Use of mung bean biomass as brown manuring	Southern <30%	S		**Productivity** Reduces the cost of crop production and hence increases profit **Adaptation** Improves soil health by increasing organic matter content and microbial activities. Increases possibility of farming in degraded soils. **Mitigation** Reduces requirements of synthetic fertilizers use, thereby related GHG emission during its production and use. Increases above- and below-ground biomass.
	Northern <30%	S		
Maize (3% of total harvested area)				
Conservation agriculture	Southern <30%	S		**Productivity** Potential increases in profits due to increased crop yield and reduced production costs. **Adaptation** Increases moisture retention due to mulching and cover crops, reduced soil erosion caused by heavy rains, and soil tillage. **Mitigation** Reduces fossil fuel requirements for tillage. Mulching and cover crops increase soil carbon capture and SOM.
	Northern <30%	S		
Intercropping with short-duration vegetables	Southern <30%	S		**Productivity** Faster growth and higher feed conversion ratio due to proper housing. **Adaptation** Reduces exposure to adverse climatic conditions, reducing animal stresses (e.g. cold waves). **Mitigation** Allows better manure management, thereby reducing related GHG emissions.
	Northern <30%	S		

CSA practice	Region and adoption rate (%) <30 30-60 60>	Predominant farm scale S: small scale M: medium scale L: large scale	Climate smartness	Impact on CSA Pillars
Cattle (NA)				
Compost and biogas production	Southern <30%	M L		**Productivity** Increases land productivity, product quality and income. Organic fertilizers produced can be used on forages to enhance productivity. **Adaptation** Promotes the use of organic waste and eliminates pathogens. Contribute to cover heating needs, reduces pressure on local resources such as timber. **Mitigation** Reduces the use of nitrogen-based fertilizers, thus reducing nitrous oxide emissions. Reduces methane emissions from manure, and promotes on-farm energy generation.
	Northern <30%	M L		
Commercial livestock fattening	Southern <30%	S		**Productivity** Increases total production and animal productivity per unit area. Increases income and food security. **Adaptation** Promotes the use of alternative feed sources. Integration of cut-and-carry and agroforestry systems can increase farmer's resilience to climate shocks. **Mitigation** Diversification of animal diet can lead to reductions in methane emissions, reducing the amount of GHG emissions per unit of food produced.
	Northern <30%	S		
Pond and floodplain aquaculture (NA)				
Rice-fish culture	Southern <30%	S		**Productivity** Increases in household income and profit due to harvesting of multiple products. Increases productivity per unit area. **Adaptation** Integration of rice crop diversifies the production system, hence reduces the risk of complete failure. **Mitigation** Maintains or improves soil carbon stock and/or soil organic matter content.
	Northern <30%	M		
Year-round aquaculture	Southern <30%	S M L		**Productivity** Increases in household income and profit due to the possibility of harvesting of multiple products throughout the year. Increases productivity per unit area. **Adaptation** Allows production system diversification, hence reduces the risk of complete failure. Optimizes the use of available resources such as land. **Mitigation** Maintains or improves soil carbon stock and/or soil organic matter content.
	Northern <30%	L		

Institutions and policies for CSA

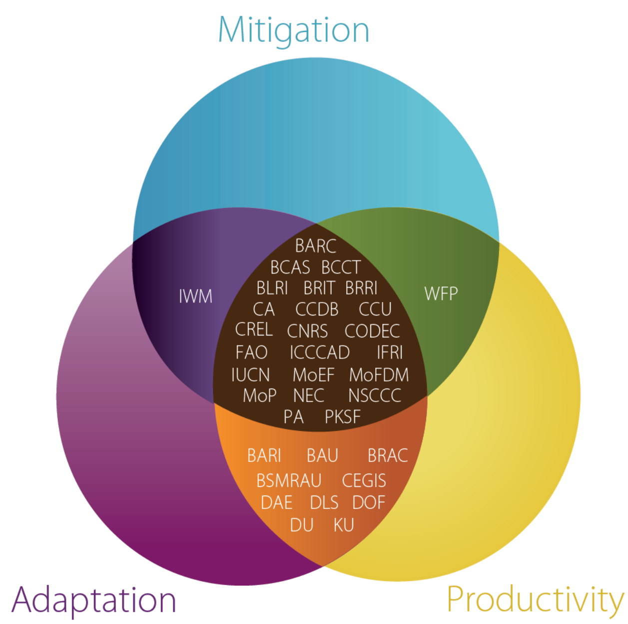
As Bangladesh is one of the countries most affected by climate change, a number of institutions have emerged to address climate-related challenges to the country's agricultural sector. Most universities and national agriculture research institutes, for example, have climate change units or committees that conduct research or help communities adapt to changing climates through direct interaction with farmers. One prominent example is the collaborative research on conservation agriculture and mechanization conducted jointly by Bangladesh Agricultural University and Murdoc University, Australia. Breeding programs of universities and national research institutes have historically collected data regarding changes in temperature or rainfall as part of their work programs, while others have screened for stress tolerance traits in new crop varieties. The Rural Development Academy in Bogra, for example, has been engaged in CSA research on SRI, AWD, raised bed rice cultivation and trichoderma compost use with direct budgetary support from the government.

Additionally, a large number of Non-Governmental Organizations (NGOs), bilateral, and multi-national organizations have initiated projects on climate change mitigation and adaptation in the country. The Delta Plan 2100, for example, funded by the Dutch Government, is a roadmap to alleviate the effects of sea level rise, including the infusion of salinity into Bangladesh's coastal rivers and canals. Meanwhile, the CGIAR has had offices in Bangladesh for decades including the International Rice Research Institute, the International Center for Maize and Wheat Improvement (CIMMYT), WorldFish, and the International Food Policy and Research Institute (IFPRI). WorldFish and CIMMYT are both currently undertaking projects for the CGIAR Research Program on Climate Change, Agriculture, and Food Security (CCAFS) in Bangladesh, coordinated from the regional International Centre for Tropical Agriculture offices in Delhi. Furthermore, BRAC, the largest international NGO in Bangladesh, is working on a modified System of Rice Intensification (SRI) and information sharing and awareness building about climate change adaptation. BRAC is also pursuing CSA practices promoting cultivation of sunflower in saline soils in southern districts of Bangladesh well as buy back sunflower seeds from farmers for oil extraction.

The institutions highlighted in the diagram represent those larger entities that have historically embedded CSA goals (i.e. adaptation, productivity and mitigation) into their research or development agendas. Of the 33 governmental, NGO, and private sector institutes listed, the International Center for Climate Change and Development (ICCCAD) occupies a central coordinating role, especially between the GoB and other actors. Still, coordination of climate change action between actors in the country remains problematic.

The Government of Bangladesh plays an active role in international forums on climate change, becoming a signatory member of the United Nations Framework Convention on Climate Change and the Kyoto Protocol, and through its commitment to the Bali Action Plan and the Paris Climate Agreement. In 1995, the National Environment Management Action Plan (NEMAP) for Bangladesh was formulated, addressing the country-specific climate change challenges identified in the country's Intergovernmental Panel for Climate Change Second Assessment Report. Later, two policies were approved by the GoB: the National Adaptation Programme of Action (NAPA) in 2005 and the Bangladesh Climate Change Strategy and Action Plan (BCCSAP) later in 2009. The NEMAP, NAPA, and finally the BCCSAP were formulated through robust participatory processes involving civil society, NGOs, and other stakeholders. All the ministries and ministerial departments refer to these policies when planning and executing their work.

Institutions for CSA in Bangladesh



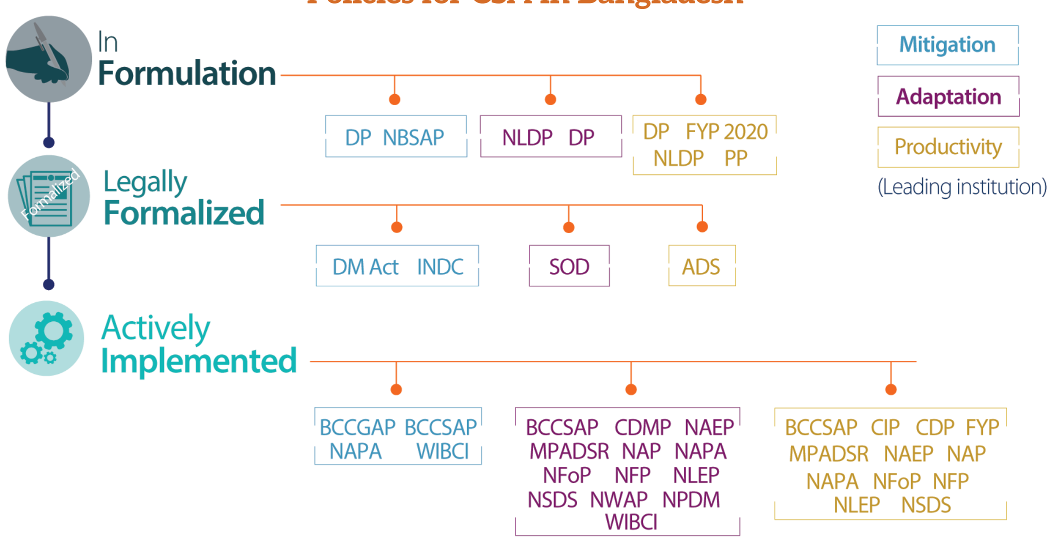
BARC Bangladesh agricultural Research Council **BARI** Bangladesh Agricultural Reseach Institute **BAU** Bangladesh Agricultural University **BCAS** Bangladesh Center for Advanced Studies **BCCT** Bangladesh Climate Change Trust **BINA** Bangladesh Institute of Nuclear Research **BJRI** Bangladesh Jute Research Institute **BLRI** Bangladesh Livestock Research Institute **BRAC** Bangladesh Rural Advancement Committee **BRRI** Bangladesh Rice Reseach Institute **BRIT** Bangladesh Resource Improvement Trust **BSMRAU** Bangobhondo Sheik Mujibur Rahman Agriculture University **CA** Christian Aid **CCDB** Christian Commission for Development in Bangladesh **CCU** Climate Change Unit **CEGIS** Center for Environmental and Geographic Information Services **CNRS** Center for Natural Resource Studies **CODEC** Community Development Centre **CREL** Climate Resilient Ecosystems and Livelihoods **DAE** Department of Agriculture Extension **DLS** Department of Livestock Services **DOF** Department of Fisheries **DU** Dhaka University **FAO** Food and Agriculture Organization of the United Nations **ICCCAD** International Center for Climate Change and Development **IFRI** International Food Policy Research Institute **IWM** International Water Modeling **IUCN** International Union for Conservation of Nature **KU** Khulna University **MoEF** Ministry of Environment and Forests **MoFDM** Ministry of Food and Disaster Management **MoP** Ministry of Planning **NEC** National Environment Committee **NSCCC** National Steering Committee on Climate Change **PA** Practical Action **PKSF** Palli Karma-Sahayak Foundation **WFP** World Food Program

The BCCSAP is built on six pillars, five of which are related to adaptation and capacity building and one to mitigation through low carbon development. The pillars are: a) food security, social protection and health; b) comprehensive disaster management; c) infrastructure development and protection; d) research and knowledge management; e) mitigation and low carbon development; and f) capacity building and institutional strengthening. Altogether, the BCCSAP has 44 programs and 145 projects under these thematic areas. A series of national level consultations with experts and stakeholders were carried out in the formulation process of the BCCSAP [25]. The BCCSAP has attracted over half a billion dollars spent on projects directed towards enhancing resilience through adaptation. The policy has been successful in attracting significant investment in solar energy systems for mitigation purposes. Additional resources have recently been obtained through the newly established Green Climate Fund, through partnerships with the United Nations Development Programme (UNDP) and the German Development Bank.

Another initiative relevant to CSA promotion in Bangladesh is the Policy Research and Strategy Support Program (PRSSP) for Food Security and Agricultural Development, funded by the United States Agency for International Development (USAID) and led by the Ministry of Agriculture and IFPRI. The PRSSP fills the need for demand-driven food and agriculture research, aiming to generate information on critical issues, strengthen analytical capacity within the country, and stimulate policy dialogue. Its main objectives are to work closely with GoB to provide policy and advisory services. It will also promote collaboration between institutions working in climate change and explore effective means to engage decision makers and stakeholder with evidence regarding climate interventions.

Bangladesh's Intended Nationally Determined Contributions (INDCs), submitted in 2015 to the UNFCCC, foresee an unconditional contribution of GHG reduction by 5% from Business as Usual (BAU) levels, and a conditional reduction of 15% from BAU by 2030, subject to sufficient international support. While these mitigation efforts focus solely on the power, transport and industries sectors, the INDCs also outline possible additional conditional agriculture sector contributions, which include: increasing farm mechanization to reduce number (and thus emissions) of draft cattle by 50%, increasing the use of manure and the share of organic fertilizer by 35%, and adopting alternate wetting and drying irrigation in 20% of all rice cultivation, compared to BAU levels. The agriculture targets remain listed as possibilities as they require improved availability of data-sets, as the country currently lacks the ability to quantify the sector's potential contribution to mitigation targets. For the same reasons, targets for the land use, land use change and forestry (LULUCF) sector were not quantified, yet foresee a continuation of coastal mangrove plantation, increased reforestation and afforestation efforts, and promotion of social and homestead forestry [46].

Policies for CSA in Bangladesh



BCCGAP Bangladesh Climate Change and Gender Action Plan (2013) (GOB) **BCCSAP** Bangladesh Climate Change Strategy and Action Plan (2009) (MOA) **CDMP** Comprehensive Disaster Management Progamme (2004) (MoDMR) **CDP** Crop Diversification Programme (2013) (MOA) **CIP** Country Investment Plan for Food, Agriculture and Nutrition 2011-2015 (2010) (ERD) **DM Act** Disaster Management Act (2012) (GOB) **DP** Delta Plan 2100 (2018) (MOA) **FYP** Bangladesh 5-year Plan 2015 (2015) (GOB) **FYP 2020** 8th 5 Year Plan 2020-2025 (2019) (GOB) **INDC** Intended Nationally Determined Contribution (2015) (GOB) **MPADSR** Master Plan for Agricultural Development in the Southern Region of Bangladesh (2012) (MOA) **NAEP** New Agricultural Extension Policy 2012 (2012) (MOA) **NAP** National Agriculture Policy 2013 (2012) (MOA) **NAPA** National Adaptation Program of Action 2009 (2005) (MOA) **NBSAP** Bangladesh updated National Biodiversity Strategy and Action Plan (2016) (MoEF) **NFP** National Fisheries Policy 1998 (1998) (DoF) **NLDP** National Livestock Development Policy 2007 (2007) (DSL) **NLEP** National Livestock Extension Policy 2013 (2013) (DoF) **NFoP** National Food Policy (2006) (GOB) **NPDM** National Plan for Disaster Management **NSDS** National Sustainable Development Strategy (2010) (GOB) **NWAP** National Women's Advancement Policy (2011) (MoWCA) **PP** Perspective Plan to 2040 (2018) (GOB) **SOD** Standing orders on Disaster (2010) (MoDMR) **WIBCI** Weather Index-Based Crops Insurance (2015) (GOB)

The graphic shows a selection of 13 key policies, strategies and programs that relate to agriculture and climate change topics and are considered key enablers of CSA in the country. The policy cycle classification aims to show gaps and opportunities in policy-making, referring to the three main stages: policy formulation (referring to a policy that is in an initial formulation stage/consultation process), policy formalization (to indicate the presence of mechanisms for the policy to process at national level) and policy in active implementation (to indicate visible progress/outcomes toward achieving larger policy goals, through concrete strategies and action plans). For more information on the methodology, see Annex 6.

Financing CSA

The Government of Bangladesh allocated US$1.73 billion to the agriculture sector for the 2016-17 period, representing 4% of the country's total budget[12] . In that same period, the Ministry of Environment and Forest was allocated US$ 125 million, an increase of five percent from last year. The budget for agricultural inputs subsidies was reduced substantially compared to the previous year, from US$ 1.5 billion to US $230 million in 2017. In terms of funds dedicated solely to climate change, the GoB's Climate Change Trust fund has recently received an additional US$ 12 million, raising the fund balance to US$ 375 million [47].

The total annual GoB budget spent on agriculture research in Bangladesh amounts to US$ 72 million. The Krishi Gobeshona Foundation—an agricultural research foundation—operates as an endowment trust fund with World Bank seed money for funding adaptive research projects. Most of the funds supporting agriculture research and any CSA practices comes from bilateral or multilateral funding sources. The World Bank, for example, supplemented the GoB with funds on agriculture research through the first phase of its National Agriculture Technical Project (NATP) and is currently starting NATP II with US$ 200 million to invest over five years.

Bangladesh is home to many micro-credit institutions including the Grameen Bank, a member-owned specialized institution established in Bangladesh by Nobel Peace Prize winner, Muhammad Yunus. The country also plays host to approximately 1,500 NGOs, commercial, and specialized banks such as Bangladesh Krishi Bank, Rajshahi Krishi Unnayan Bank, and a host ofgovernment-sponsored micro-finance projects and programs (the Bangladesh Rural Development Board, Swanirvar Bangladesh, and RD-12, for example). While these institutions provide micro-financing for agriculture, few offer macro-credit to facilitate larger-scale investments that can help the sector transition from subsistence farming to sustainable commercialized agriculture or help establish CSA practices. Banks require collateral for more macro credit and often growers do not possess sufficient capital, and most landowners hesitate using their land deeds for that purpose.

The increasing participation of private sector actors like ACI, PRAN, Lal Teer, and others in agricultural technology diffusion, promotion of scale-appropriate mechanization and seed development should be recognized and facilitated with continuing favorable public policies. This has also implications for wider scale out of CSA practices and technologies, some of which may require higher, long-term costs. Therefore, exploring the economic costs and benefits of CSA adoption, alongside environmental and social considerations, is key to understanding investment priorities.

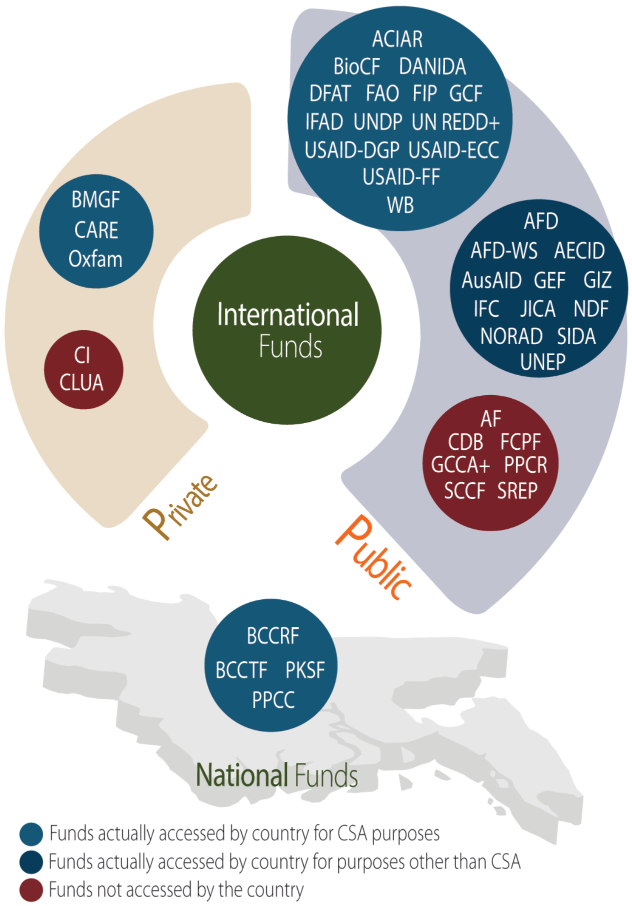
Potential Finance

To date, Bangladesh has yet to attract significant funding from international sources dedicated to climate change adaptation or mitigation. Yet opportunities for CSA financing exist as the country is eligible for Global Environment Facility and GCF funding. Bangladesh will likely continue to be an attractive country for investors, both for development partners and the private sector. The country is one of the most active countries in South Asia when it comes to private 'impact investments', creating a ready space for CSA promotion and scale out, provided that enough information on costs, benefits, and outcomes of such investments are known to the investors. Continuation of funding and alignment of interventions with the major policy documents in Bangladesh i.e. Seventh Five Year Plan (2016-2020), Sustainable Development Goal implementation plan, and various sectoral plans, is also crucial for CSA advancement.

Additionally, while fewer United States Department of Agriculture and USAID Feed the Future projects are now focused on climate change, opportunities still exist to build an enabling environment for increased resilience, and, indirectly, to increase CSA adoption, by focusing on livelihoods, nutrition and health sectors. CSA-related funds from development partners in Europe, China, Japan are likely to emerge, given the international momentum for the topic and the high potential to invest in Bangladesh. The graphic highlights existing and potential financing opportunities for CSA in Bangladesh. The methodology can be found in Annex 7.

12 Agriculture sector allocations have remained constant over the past five years.

Financing opportunities for CSA in Bangladesh



AF Adaptation Fund **ACIAR** Australian Cetre for International Agricultural Research **AECID** Spanish Agency for International Development **AFD** French Development Agency **AFD-WS** French Development Agency-Water and Sanitation **AusAID** Australian Agencyfor International Development **BCCRF** Bangladesh Climate Change Resilience Fund **BCCTF** Bangladesh Climate Change Trust Fund **BioCF** World Bank BioCarbon Fund **BMGF** Bill and Melinda Gates Foundation **CI** Conservation International **CDB** China Development Bank **CLUA** Climate and Land Use Alliance **DANIDA** Danish International Development Agency **DFAT** Department of Foreign Affairs and Trade **DFID** Department for International Development **FAO** Food and Agriculture Organization of the United Nations **FCPF** Forest Carbon Partnership Facility **FIP** Forest Investment Program **GCCA** Global Climate Change Alliance **GCF** Green Climate Fund **GEF** Global Environment Facility **GIZ** German Society for International Cooperation **IFAD** International Fund for Agricultural Development **IFC** International Finance Corporation **JICA** Japan International Cooperation Agency **NDF** Nordic Development Fund **NORAD** Norwegian Agency for Development and Cooperation **PKSF** Palli Karma Shahayak Foundation **PPCR** Pilot Program for Climate Resilience **SCCF** Special Climate Change Fund **SIDA** Swedish International Development Cooperation Agency **SREP** Scaling Up Renewable Energy in Low Income Countries Program **UNDP** United Nations Development Programme **UNEP** United Nations Environmental Programme **USAID-ECC** United States Agency for International Development – Environment and Climate Change **USAID-DGP** United States Agency for International Development – Development Grants Program **USAID-FF** United States Agency for International Development – Feed the Future **UN REDD** United Nations Programme on Reducing Emissions from Deforestation and Forest Degradation **WB** The World Bank

Outlook

Adaptation and mitigation in the agricultural sector is high on the political agenda in Bangladesh, as evidenced by the current policies and international commitments in support of climate smart agriculture. However, in order to create visible results at the farm level, such policies need effective implementation mechanisms and a clear roadmap for attracting additional funding required for operationalizing this vision. In 1997, the government started the process of developing a national Information, Communications and Technology (ICT) strategy that has become a core driver of reforms, employment, growth in various sectors, and improved governance. The ICT sector has increased significantly over the last years and it has the potential to facilitate higher adoption of CSA practices by farmers, through mobile phones and apps. The strengthening of village level information hubs under the Department of Agricultural Extension's Agricultural Information Service at the Union Parishad complex is a potential starting point in this regard.

Strengthening climate and technical information services and making them readily available to farmers would greatly improve their capacity to adapt to changes. For instance, salt intrusion in the canals prevents their use for commercial or household gardening. Knowing where and when this will occur, through community-based data measuring with simple salinity meters, would allow farmers to plan for appropriate response strategies. Additionally, advisory services on the technical implementation of more knowledge-intensive practices, such as the use of briquetted urea (which can reduce use of urea by 30%), through extension agents, could empower farmers to contribute to significant reductions in agricultural emissions. Development of Urea Super Granule applicator and reduction of drudgery in operating this small but delicate equipment is important for popularizing the practice. However, further debate around fertilizer subsidies is a precondition for involving private sector in accelerating the spread of this CSA technology.

Improved coordination among the various institutions implementing CSA projects and programs is essential for the development of a coherent, long-term vision for agricultural development in the country. One step towards achieving this goal is information provision and exchange, in a transparent manner, through multi-stakeholder platforms, joint CSA initiatives, and regular knowledge and experience-sharing opportunities among diverse actors involved in research, policy, and implementation.

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For further information and online versions of the Annexes

Annex 1: Bangladesh's agro-ecological zones
Annex 2: Selection of agriculture production systems key for food security in Bangladesh (methodology)
Annex 3: Methodology for assessing climate smartness of ongoing practices
Annex 4: Long list of CSA practices adopted in Bangladesh
Annex 5: Institutions for CSA in Bangladesh (methodology)
Annex 6: Policies for CSA in Bangladesh (methodology)
Annex 5: Assessing CSA finances (methodology)

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Main authors: Craig A Meisner and Md. Yusuf Ali (independent consultant).

Editors: Chase Sova (CIAT consultant), Andreea Nowak (CIAT consultant), Godefroy Grosjean (CIAT), Felicitas Roehrig (CIAT), Miguel Lizarazo CIAT/CCAFS)

Project leader for Asia: Godefroy Grosjean (CIAT)

Original graphics: Fernanda Rubiano (independent consultant)

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