



CLIMATE-SMART AGRICULTURE INVESTMENT PLAN

BANGLADESH

Investment opportunities in the agriculture sector's transition to a climate resilient growth path



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RESEARCH PROGRAM ON Climate Change, Agriculture and Food Security





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MINISTRY OF FISHERIES AND LIVESTOCK • THE WORLD BANK • CALIFORNIA ENVIRONMENTAL ASSOCIATES • INTERNATIONAL CENTER FOR TROPICAL AGRICULTURE • INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS • BANGLADESH CENTRE FOR ADVANCED STUDIES • CLIMATE CHANGE, AGRICULTURE AND FOOD SECURITY

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Foreword

The agriculture systems in Bangladesh face a growing number of climate-related vulnerabilities. Climate has become increasingly variable over the past few decades, with droughts, seasonal and flash flooding, and extreme temperatures occurring more frequently and the sea level rising. Going forward, it will be critical to have an understanding of how best to address the trade-offs and synergies between achieving agricultural and economic goals on one hand and preparing for emerging climate challenges on the other. The use of evidenced-based decision making is a key part of this process. In response, the World Bank is supporting the Government of Bangladesh to integrate climate change considerations into the agriculture policy agenda through a Climate Smart Agriculture Investment Plan (CSAIP). CSAIP is a commitment of the Bank's Agriculture Global Practice under the IDA18 agenda to support 10 countries to develop national CSA strategies and investment plans.

The CSAIP for Bangladesh is the outcome of a partnership between the Government of Bangladesh, led by the Ministry of Fisheries and Livestock through the Government's Inter-Ministerial Steering Committee¹ for the CSAIP and the World Bank.

The CSAIP builds on existing strategy documents, including Bangladesh's Nationally Determined Contribution (NDC) and the 7th Five Year Development. It was developed through a process that combines an innovative model developed specifically for the CSAIP, scenario analysis, and consultations with strategic actors in the public and private sectors, civil society, and farmer groups. The results indicate that Climate Smart Agriculture (CSA) – an approach to agriculture that integrates across productivity increases, strengthened resilience and climate change mitigation – has the potential to make the national development targets for the agriculture sector in 2041 reachable despite the challenge of climate change. CSA in particular has the potential to greatly increase the production of meat and dairy in the context of climate change. Scaling-up CSA would also enable sustained self-sufficiency in rice production whilst at the same time the shifting to a more diversified portfolio of crops.

The CSAIP identifies a set of concrete investment opportunities that are aligned with the Nationally Determined Contribution (NDC) and the Bangladesh Delta Plan 2100. We look forward to implementing these investments with the Government of Bangladesh and other partners.

Md. Raisul Alam Mondal

Secretary

Ministry of Fisheries and Livestock

Mercy Miyang Tembon

Country Director for Bangladesh and Bhutan

The World Bank Group

¹Committee membership: Ministry of Agriculture, Ministry of Planning, General Economics Division, Ministry of Water, Ministry of Finance, Finance Division, Ministry of Finance, Economic Relation Division, Ministry of Land, Ministry of Environment and Forests, Department of Fisheries, Department of Livestock, Agriculture Extension Department, Department of Environment, Water Development Board, Forest Department, World Bank Representative, Focal Point from Lead Ministry.

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The report “Bangladesh Climate Smart Agriculture Investment Plan (CSAIP)” was developed by a core team from the World Bank and Government of Bangladesh Inter-Ministerial Committee for the CSAIP led chaired by the Ministry of Fisheries and Livestock and comprised of Ministry of Agriculture, Ministry of Planning, General Economics Division, Ministry of Water, Ministry of Finance, Finance Division, Ministry of Finance, Economic Relations Division, Ministry of Land, Ministry of Environment, Forest and climate change, Department of Fisheries, Department of Livestock, Agriculture Extension Department, Department of Environment, Water Development Board, Forest Department, World Bank Representative, Focal Point from Ministry of Fisheries and Livestock . The World Bank Group core team consisted of Manievel Sene (Task Team Leader), Tobias Baedeker (Task Team Leader), Alemayehu Zeleke, Shaikh Moniruzzaman, Martin Wallner, Sebastian Heinz, Md. Mansur Ahmed, Xueling Li, Sandhya Srinivasan, all of the World Bank’s Food and Agriculture Global Practice.

The report is based on invaluable contributions of colleagues from collaborating institutions. These include: California Environmental Associates Consulting (CEA) and a team consisting of Antonius Gagern and Michael Berger who led the development of investment packages; a combined team consisting of the International Center for Tropical Agriculture (CIAT), with Godefroy Grosjean, Felicitas Roehrig, and the International Institute for Applied Systems Analysis (IIASA), with Aline Mosnier, which led the analysis and developed the Bangladesh Climate Smart Investment Plan Model; and Dr Abu Syed, Dr. Atiq Rahman, Bangladesh Center of Advanced Studies, who advised on the process, procured data and provided inputs in the CSAIP and implementation support throughout the project. The report was copyedited by Dina Towbin of Dina Towbin and Associates LLC and the graphic design was done by Brad Amburn and Fernanda Rubiano. The report benefitted greatly from comments from peer reviewers, Grant Milne and Ranjan Samantaray of the World Bank as well as Pramod Aggarwal (Regional Program Director, CIMMYT) at different stages of report development. The report benefitted from invaluable guidance and suggestions of many stakeholders who participated in two consultation workshops in September 2017 and April 2018, and separate consultation meetings throughout the process. The list of stakeholders who took part in the consultation and provided valuable feedback is provided at the end of this report . The team also wishes to thank all stakeholders who shared their views in qualitative interviews conducted during the report.

Abbreviations

| | |
|-----------------|---|
| AAPRESID | Argentine Association of Direct Sowing Producers |
| AIS | Agricultural Innovation System |
| Amul | Anand Milk Union Limited |
| AWD | Alternate Wetting and Drying |
| BARC | Bangladesh Agricultural Research Council |
| BARD | Bangladesh Academy for Rural Development |
| BARI | Bangladesh Agricultural Research Institute |
| BAU | Business as Usual |
| BBDF | Bangladesh Biogas Development Foundation |
| BBS | Bangladesh Bureau of Statistics |
| BCAS | Bangladesh Center for Advanced Studies |
| BCCSAP | Bangladesh Climate Change Strategy and Action Plan |
| BDP2100 | Bangladesh Delta Plan 2100 |
| BFRI | Bangladesh Fisheries Research Institute |
| BHWDB | Bangladesh Haor and Wetland Development Board |
| BINA | Bangladesh Institute of Nuclear Agriculture |
| BioCF | BioCarbon Fund |
| BIRDEM | Bangladesh Institute of Research and Rehabilitation for Diabetes, Endocrine and Metabolic Disorders |
| BLRI | Bangladesh Livestock Research Institute |
| BP | Buried Pipe |
| BRAC | Bangladesh Rural Advancement Committee |
| BRRRI | Bangladesh Rice Research Institute |
| BWRI | Bangladesh Wheat Research Institute |
| CAHW | Community-Based Animal Health Worker |
| CBA | Cost Benefit Analysis |
| CC | Climate Change Scenario |
| CCERA | Climate Change and Environmental Risk Atlas |
| CDAIS | Capacity Development for Agricultural Innovation Systems |
| CIFs | Climate Investment Funds |
| CIMMYT | International Maize and Wheat Improvement Center |
| CIP | (Bangladesh) Country Investment Plan |
| CSA | Climate-Smart Agriculture |
| CSAIP | Climate Smart Agriculture Investment Plan |
| DAE | Department of Agricultural Extension |
| DAM | Department of Agricultural Marketing |
| DLS | Department of Livestock Services |
| DOF | Department of Fisheries |
| DOLE | Department of Livestock Extension |
| DRM | Disaster Risk Management |
| EAS | Extension and Advisory Service |
| ENPV | Expected Net Present Value |
| ERR | Economic Rate of Return |
| FAO | Food and Agriculture Organization of the United Nations |
| FAOSTAT | Food and Agriculture Organization statistical database |
| FCPF | Forest Carbon Partnership Facility |
| FIAC | Farmers Information and Advisory Center |
| GCF | Green Climate Fund |
| GEF | Global Environment Facility |
| GHG | Greenhouse Gas |
| HVC | High-Value Non-Rice Variety |
| IDCOL | Infrastructure Development Company Limited |
| IFPRI | International Food Policy Research Institute |
| ILMM | Integrated Livestock Manure Management |
| IMPACT | International Model for Policy Analysis of Agricultural Commodities and Trade |
| INIA | Instituto Nacional de Investigación Agropecuaria |
| IRR | Internal Rate of Return |
| IRRI | International Rice Research Institute |
| IUCN | International Union for Conservation of Nature |
| KDCMPUL | Kaira District Co-operative Milk Producers' Union Limited |
| KGF | Krishi Gobeshona Foundation |
| KTDA | Kenya Tea Development Agency |
| LDCF | Least Developed Countries Fund |
| LDDP | Livestock and Dairy Development Project |
| MFD | Maximizing finance for development |

| | |
|------------------|--|
| MOA | Ministry of Agriculture |
| MOFL | Ministry of Fisheries and Livestock |
| NAEP | National Agricultural Extension Policy |
| NAPA | National Adaptation Programme of Action |
| NATP | National Agriculture Technical Project |
| NATP-2 | Second Phase of the National Agriculture Technology Program Project for Bangladesh |
| NDC | Nationally Determined Contribution |
| NIE | National Implementing Entity |
| NoCC | No Climate Change Scenario |
| NPV | Net Present Value |
| ODA | Official Development Assistance |
| PKSF | Palli Karma Sahayak Foundation |
| PMCA | Participatory Market Chain Approach |
| PPCR | Pilot Program for Climate Resilience |
| PPP | Purchasing Power Parity |
| PRAN | Programme for Rural Advancement Nationally |
| RBCF | Results-Based Climate Finance |
| RBF | Results-Based Financing |
| RCP | Representative Concentration Pathway |
| RDA | Rural Development Academy |
| SAARC | South Asian Association for Regional Cooperation |
| SCA | Seed Certification Agency |
| SCCF | Special Climate Change Fund |
| SDGs | Sustainable Development Goals |
| SHOUHARDO | Strengthening Household Ability to Respond to Development Opportunity |
| SI | Solar Irrigation |
| STI | Science, Technology, and Innovation |
| TCAF | Transformative Carbon Asset Facility |
| UNDP | United Nations Development Programme |
| UNFCCC | United Nations Framework Convention on Climate Change |

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ES

Executive Summary

The Bangladesh Climate Smart Agriculture Investment Plan (CSAIP) highlights the potential of investments into Climate Smart Agriculture (CSA) in achieving the Government's vision of a climate resilient growth path for the agriculture sector by unifying national goals in an integrated analytical framework across agriculture productivity, resilience to climate change and emission.

Key messages

- Bangladesh's agriculture sector is under threat from climate change. Most worryingly, sea level rise may reduce available cropland by 24% in Coastal Divisions across growing seasons.
- Under Business as Usual, the sector is projected to stagnate and key national production targets by 2040 are likely to be missed unless action is taken.
- Climate-Smart Agriculture (CSA) – integrating productivity increases, strengthened resilience and reduced emissions- offers technologies that have the potential to set the sector on a resilient growth path that would dramatically close gaps towards 2040 targets and diversify production and value creation. Growth potentials of >50% over 2015 levels exist for non-rice crops, livestock and fisheries.
- Five CSA Investment Packages have been identified with a total volume of US\$809 million (US\$2 billion, PPP). They are informed by stakeholder input and extensive quantitative modeling, robust to uncertainty and primed for financing by leveraging the World Bank Group's framework for maximizing finance for development and climate finance sources.
- The CSAIP has four critical impact pathways: (1) it lays out strategic initiatives in the crops, livestock, fisheries sectors in support of the Bangladesh Delta Plan 2100, to be implemented under the 8th Five Year Plan; as well as (2) provides analytical inputs into the ongoing update of Bangladesh's Nationally Determined Contribution (NDC).

Bangladesh's agriculture sector is under threat from climate change

Bangladesh's crops, livestock, and fisheries have had impressive growth since independence in 1971. Since 1995, the country's agricultural productivity growth has been among the highest in the world. The fastest-growing subsector is aquaculture. Overall agriculture sector growth accounted for 90 percent of poverty alleviation between 2005 and 2010. Agriculture supports 87 percent of rural households.¹ The production structure, which is heavily concentrated on rice, constrains future

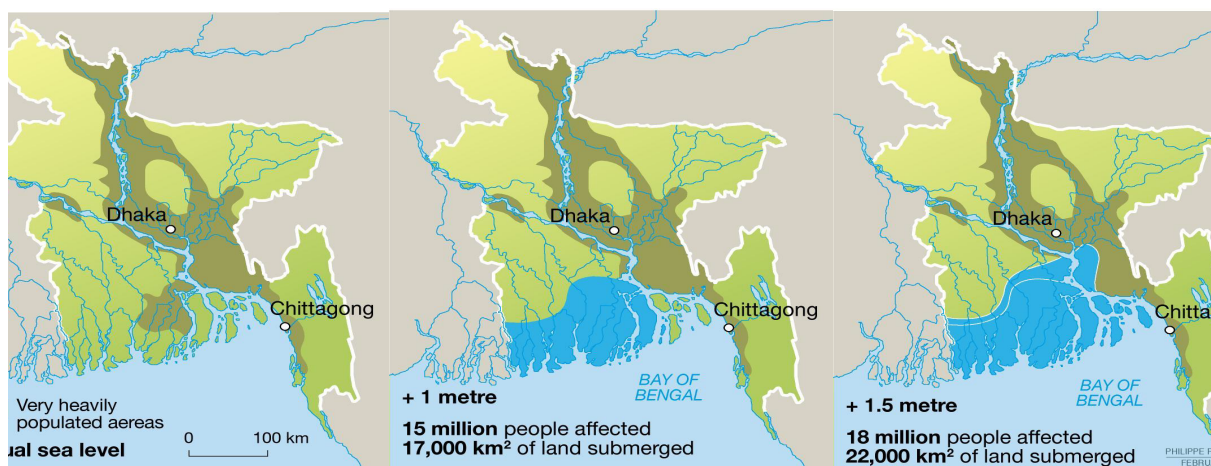
growth because decreased rice productivity has reduced agricultural growth from 4.7 to 2.4 percent from 2007-2011 to 2012-2016. More recently, the share of agriculture in total GDP has declined from 28 percent in 1990 to just 13 percent in 2018 and contributed to a decline in employment growth and to a slowdown in poverty reduction. Concentration on rice production discourages diversification and makes the sector highly vulnerable to climate shocks.

Bangladesh is among the countries most vulnerable to climate change. The country is currently experiencing sea level rise, saltwater intrusion, mean temperature increases, and higher rainfall variability. Floods, tropical cyclones, storm surges, and drought will become more frequent and more severe. Cyclone activity and saltwater intrusion will impact the south, southwest, and southeast coastal regions in particular. By 2050, increasing storm surges will put almost 30 million people at risk.²

Climate change poses a serious threat to agricultural growth. Rising maximum temperatures will negatively impact crop yields for aman and boro rice, both of which are major staple crops.³ Moreover, rain-fed monsoon rice is highly vulnerable to water supply volatility.ⁱⁱ High water stress can lead to rice yield losses as high as 70 percent.ⁱⁱⁱ

Sea level rise and salinization of inland water sources are the greatest threats to the agriculture sector. With two-thirds of the country at an elevation of less than 5 meters, Bangladesh is highly exposed to rising sea levels, particularly in the southern region.^{iv} Rising sea levels and salinization are already being felt across coastal areas. Approximately 62 percent of coastal land has been affected by soil salinity.⁷ Salinity intrusion is predicted to advance 8 kilometers north by 2030, reducing land availability for farming. Intrusion of saltwater into rivers and canals complicates production of non-salt-resilient crops. By 2040, cropland could shrink by almost 18 percent in southern Bangladesh and by 6.5 percent nationally.⁸ By 2100 sea level rise could reach up to 1 meter, leading to the inundation of 14 percent of southern areas.^v

Figure ES.1 Flood Map of Bangladesh



The Bangladesh Climate Smart Agriculture Investment Plan (CSAIP) outlines five integrated investment packages across three CSA dimensions: productivity, resilience, and mitigation. Whereas existing policy frameworks tend to single out specific aspects of visions and vulnerabilities, the CSAIP quantifies trade-offs across CSA options and prioritizes investments that improve productivity, resilience, and mitigation.

The CSAIP is not an independent development plan, it was developed to inform the implementation of major existing policies and policy formulation processes. Most importantly this includes the Bangladesh Delta Plan 2100 and the ongoing update of the Nationally Determined Commitment (NDC), as well as the implementation of CSA-relevant portions of the seventh and eighth five-year plans. Preparation of the CSAIP relied on three methodological building blocks

- **First, a 2040 vision for the agriculture sector was defined using quantitative targets across the three CSA dimensions.** Extensive multistakeholder consultations identified production and reducing vulnerability to climate change as key metrics. Workshop participants proposed a Nationally Determined Contribution (NDC) emission reduction contribution proportional to the agriculture sector’s share of total emissions (table ES.1).

Figure ES.2 Cropland Loss through Climate Change

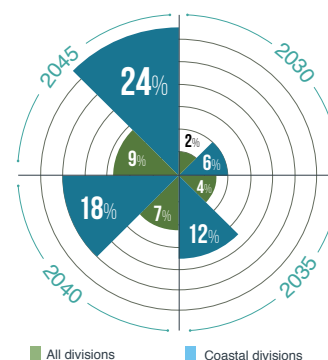
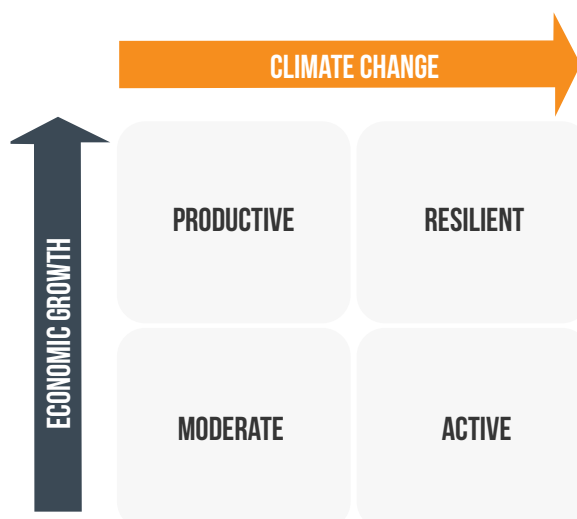


Table ES.1 Overview of agriculture sector goals across CSA dimensions

| | Rice | Non-rice crops | Livestock and fish |
|------------------------------|--|--------------------|-----------------------|
| Production | Reach self-sufficiency. | Double production. | Meet national demand. |
| Adaptation/resilience | Meet nutritional requirements after postharvest losses. | | |
| | Increase value and profitability of production. | | |
| | Decrease income dependence on rice. | | |
| Mitigation | Decrease water use in irrigation. | | |
| | Place 20% of rice under AWD | | |
| | Decrease NO ₂ emissions by 30%. | | |
| | Increase use of organic fertilizer by 35%. | | |
| | Reduce emissions by 5% (unconditional) and 15% (conditional to funding) (NDC). | | |

- **Second, four future scenarios were developed along two uncertainty drivers: intensity of climate change and pace of economic growth.** The scenarios aligned with those of the Bangladesh Delta Plan 2100. Because of the deep uncertainty surrounding climate change projections, four scenarios (productive, resilient, moderate, and active) were identified (figure ES.3). A CSA package is considered robust only if it has positive impacts under all scenarios.
- **Third, a quantitative model was built to explore the impact of CSA on the sectors performance under climate change.** The model covered three rice types (one for each

Figure ES.3 Four CSAIP scenarios



growing season), nine non-rice crops, and seven livestock/fisheries commodities disaggregated at the division level.

Agriculture sector projections under climate change

The country will not meet key agriculture development targets under business as usual (BAU). Due to sea level rise and population growth, self-sufficiency targets for 2040 can be met only for rice and tubers (figure ES.4). Furthermore, greenhouse gas (GHG) emissions are expected to rise by 2 percent between 2015 and 2040, exceeding unconditional reduction targets set in Bangladesh’s NDC. In addition, water consumption will increase by 0.8–1.7 million liters per year, exacerbating water scarcity, which in some areas will become even worse under climate change.

CSA Pillar 1 –Production: CSA enables growth and diversification under Climate Change

CSA will allow Bangladesh to maintain rice self-sufficiency and greatly increase non-rice crop production. CSA will slightly increase rice production above 2015 levels (figure ES.5). Under BAU projections, production of non-rice crops will fall short of government targets by 56 percent. CSA narrows this gap to 17 percent, with an average growth potential of 66 percent above 2015 levels across scenarios. Rising yields of non-rice crops under CSA will be driven mostly by other cereals such as wheat and tubers.

Figure ES.4 Projected production of agriculture products under BAU and CSA

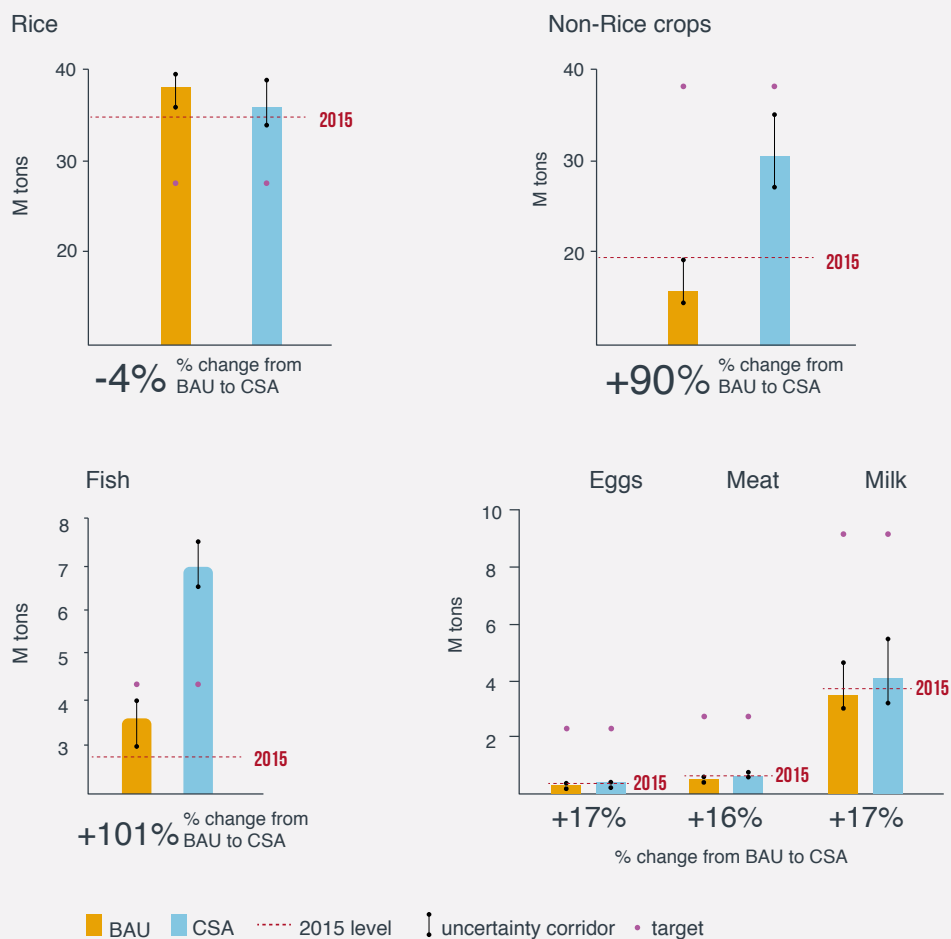
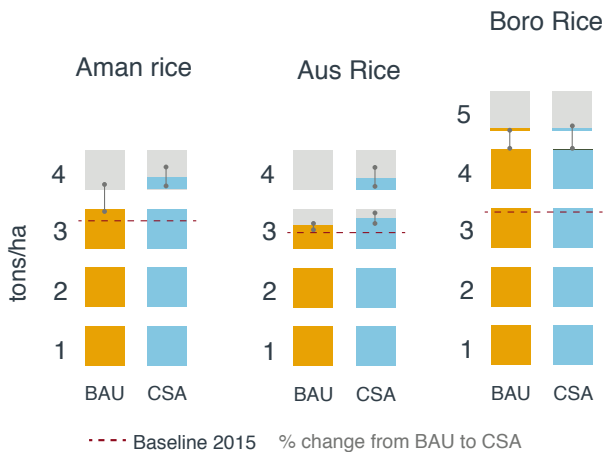


Figure ES.5 Rice yields under BAU versus CSA



CSA will help Bangladesh expand livestock production. Increased crop production creates greater feed availability, which translates into higher outputs of milk. Under CSA, milk and egg production will exceed BAU by 17 percent and meat output will expand by a cross-scenario average of 16 percent. Milk and meat production are highly sensitive to climate change and economic development, as indicated by the error bars in Figure ES.4. While these production increases fall short of projected demand, livestock interventions may be the most impactful given the currently very low (milk and meat) productivity compared to other countries in the region.

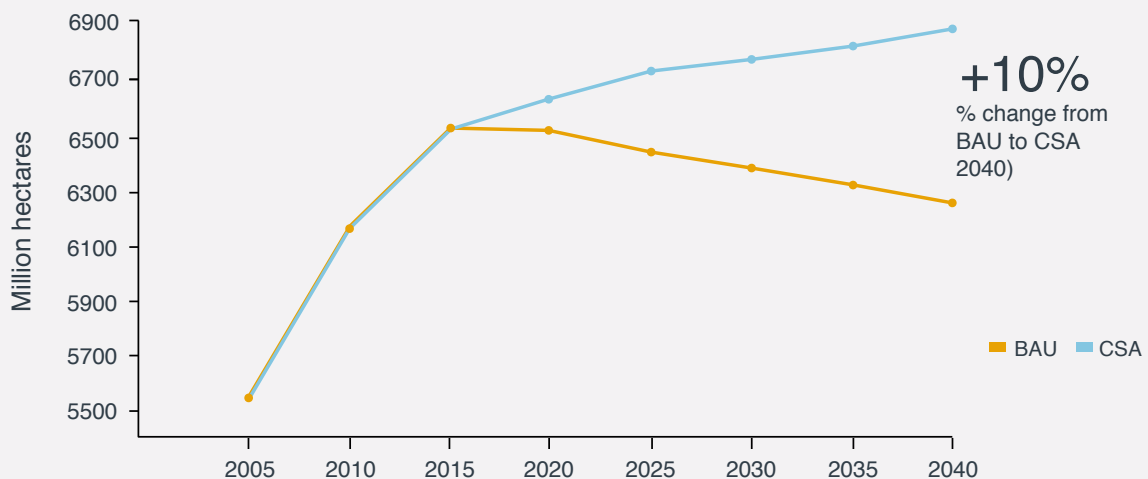
Under CSA, fish production could far exceed government targets. Under CSA, fish output could double by 2040 compared to BAU, rising from less than 3 million tons in 2015 to a cross-scenario average of more than 7 million. This will allow Bangladesh to cover the population’s increasing demand for protein. Shifting homestead ponds from extensive to semi-intensive could create significant yield increases.

CSA Pillar 2—Resilience: CSA reduces vulnerability and improves resilience

CSA can make agriculture less vulnerable to climate change. CSA outperforms BAU under intense climate change scenarios. CSA technologies include climate-resilient germplasms, more efficient fertilization and water use, improved planting, increased cropping intensities, and improved climate-smart animal husbandry and aquaculture technologies.

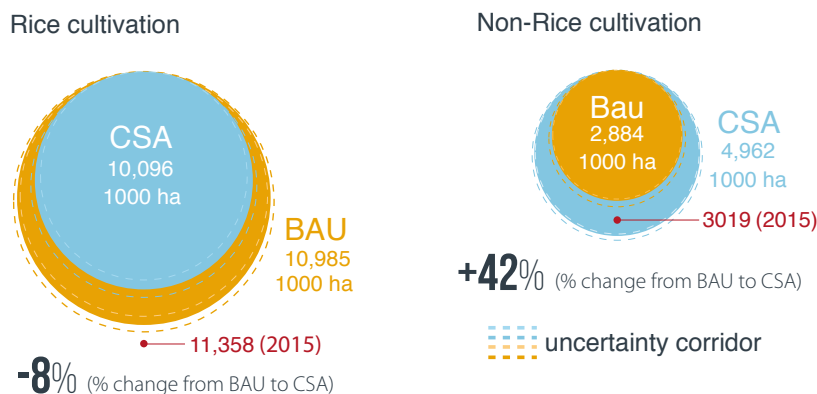
CSA can reduce the negative impacts of sea level rise. Deployment of salt-resistant boro rice and wheat varieties, as well as submergence-tolerant aman rice strains, could result in 10 percent more arable land compared to BAU. In addition, increased yields and higher cropping intensities in areas unaffected by sea level rise could counteract the effects of rising sea levels (figure ES.6).

Figure ES.6 Available cropland under BAU and CSA



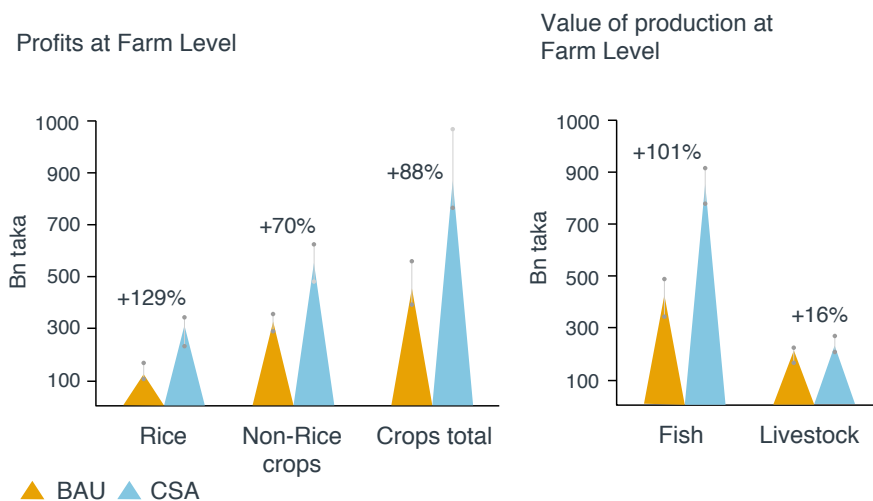
Rising incomes under CSA increase the resilience of rural farming households. Even if exposure to climate risks remains constant, prosperity can reduce a household’s risk sensitivity and improve its adaptive and coping capacities.¹¹ Thus, poverty reduction represents a key resilience-building strategy.

Figure ES.7 Crop diversification under BAU versus CSA



Under CSA, diversification creates larger resilience gains. Diversification reduces farmers’ production risks and increases income opportunities. As a result, farmers’ profits could increase 70 percent over BAU, driven by greatly increased acreage of higher-value crops (figure ES.7) and fuel cost savings associated with CSA technologies such as solar irrigation, buried pipe irrigation, and alternate wetting and drying (AWD). Aquaculture production value could double, and livestock production value could increase by 16 percent (figure ES.8).

Figure ES.8 Profits and value of production at farm level under BAU versus CSA



Note: Costs for inputs were unavailable or not sufficiently reliable at the time of writing, so production values are presented for fish and livestock instead of profits.

CSA Pillar 3—Emissions: CSA enables the agriculture sector to reach NDC targets

CSA could yield significant mitigation co-benefits. CSA technologies would allow Bangladesh to reduce its GHG emissions by 9 percent by 2030 compared to BAU and contribute to Bangladesh’s

unconditional NDC target (figure ES.9). Emission reductions would be driven mainly by decreased methane emissions thanks to AWD technologies, diversification toward less emission-intensive crops, and enhanced livestock productivity. Current CSA technologies are not sufficient to meet the conditional NDC target of a 15 percent reduction compared to emissions projected under BAU by 2030. By 2040, the difference between BAU and CSA will widen to 17 percent, reaching 12.6 million tons.

Translating the benefits of CSA into investment packages

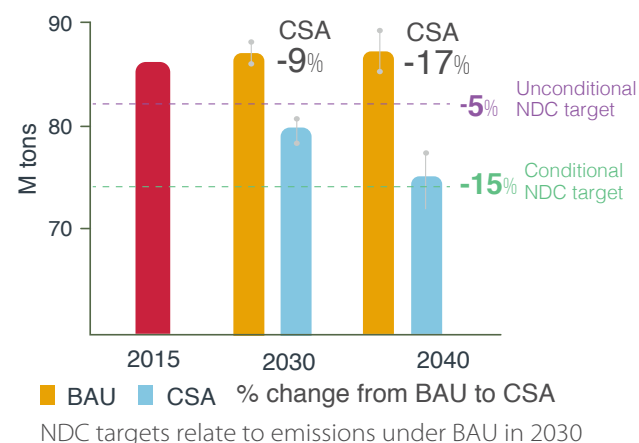
Five investment packages were developed to combine high potential impact with economic and political feasibility. During several workshops, content experts evaluated the impact, transformative capacity, scale, feasibility, and desirability of 10 packages. Four packages had particularly high scores in alignment with government strategies and potential for high adoption rates over the next five years. The four packages were amended to incorporate aspects of the unselected packages. Later, the team added a fifth package focused on building climate resilience in the haor areas of northeastern Bangladesh.¹² An overview of investment propositions is provided in table ES.2.

The five packages have a total investment volume of US\$809 million (US\$2 billion, PPP). The amounts reflect the need investment volume required to implement the interventions from a public sector perspective. They are informed by stakeholder input and extensive quantitative modeling, robust to uncertainty and primed for financing by leveraging the World Bank Group's framework for maximizing finance for development and climate finance sources.

Some packages are interlinked and benefit from concurrent implementation. For example, one impediment to livestock productivity is poor feed quality, directly addressed by Package 3: Resilience through Diversification. Diversification is highly beneficial to the implementation of Package 4: Livestock Upstream Value Chain Development, which fosters higher productivity and expanded production. Package 2, which promotes women-run small-scale production of livestock, would also benefit from crop diversification and higher-quality feed, making Packages 2, 3, and 4 highly complementary.

Trade-offs between packages can exist. For instance, Package 1 is designed to improve research and development, mainly focusing on rice varieties whereas Package 3 is focused on diversification away from rice. Policy makers must decide to what extent they would like to see non-rice crop cultivation expand at the expense of arable land dedicated to rice cultivation. In principle, Bangladesh can remain rice self-sufficient even if more area is used for growing non-rice crops. But the robustness of rice self-sufficiency (and the country's ability to export rice) will vary according to the chosen level of diversification.

Figure ES.9 Effect of CSA technologies on GHG emissions



INVESTMENT OPPORTUNITIES

IMPACT* POTENTIAL

INVESTMENT VOLUME

COST-BENEFIT* ANALYSIS

**PACKAGE 1:
AGRICULTURAL INNOVATION SYSTEM (NATIONAL)**

Facilitate **collaborative development**, deployment and evaluation of new varieties by intensifying inter-ministerial collaboration and by setting up knowledge-sharing platforms

Invest in **innovative farmer** cooperatives that connect farmers' needs with research and market demand

Foster **private sector research** in varietal development by establishing predictable seed certification mechanisms and short- to medium-medium term intellectual property protection

Helps to maintain **rice self-sufficiency**

Expansion of production **5%** over 2015 production levels significantly less land

Decreased sensitivity of rice yields to salinization and various extreme events

Demand gap for **quality seeds** closed

US\$ 117 M
US\$ 300 M PPP

IRR **24%**
ERR **31%**
NPV US\$ **67M**

**PACKAGE 2:
GENDER-SENSITIVE DEVELOPMENT OF HOMESTEAD PRODUCTION (SOUTH)**

Improve **gender-sensitive public-private** extension services for disease control and prevention

Boost **pond aquaculture productivity** by promoting better water quality management and the use of high-quality fingerlings as well as high-quality feed

Run **production and nutrition-related** education campaigns

Increase
Crop production **27%**
Livestock production **19%**
Pond aquaculture **19%**

EMISSIONS

Decrease
Crop cultivation **8%**
Livestock **12%**

Potential emission savings of up to **1.4M TONS OF CO₂E** per year if fish protein substitutes meat proteins

US\$ 125 M
US\$ 320 M PPP

IRR **27%**
ERR **34%**
NPV US\$ **87M**

**PACKAGE 3:
RESILIENCE THROUGH DIVERSIFICATION (NORTH)**

Promote **high-yielding** restorative non-rice crop systems through providing farmers with improved non-rice crop seeds and through encouraging the adoption of alternative cropping patterns

Improve **farmers' access** to markets e.g., by developing cold storage systems for non-rice commodities

Rice production remains constant at 2015 levels with massively increasing profits

For non-rice crops

Production increases **94%**
Profits are raised by **77%**

Water use drops by **10 MLT/YEAR**

GHG emissions drops by **8M TCO₂E/YEAR**

US\$ 196 M
US\$ 500 M PPP

IRR **25%**
ERR **31%**
NPV US\$ **79M**

**PACKAGE 4:
LIVESTOCK - UPSTREAM VALUE CHAIN DEVELOPMENT (NATIONAL)**

Establish a **national dairy** development board that brings together policy, the private sector and extension services to increase dairy value-chain efficiency

Improve **farmers' access** to high-quality feed, to on-farm cooling units as well as to effective extension services

Foster **value-added** use of manure to improve profitability and to lower methane emissions

Production volume and value in milk and meat increases **17%**

An overall emission reduction of

Milk **20%**
Meat **13%**

US\$ 254 M
US\$ 650 M PPP

IRR **24%**
ERR **30%**
NPV US\$ **32M**

**PACKAGE 5:
CLIMATE-RESILIENT AGRI-LIVELIHOOD DEVELOPMENT (HOAR AREAS)**

Research **short-lived and flood-tolerant rice varieties** (see package 1)

Promote **high-yielding restorative non-rice** crop systems (see package 3)

Promote **homestead** farm development, e.g., gardening, floating gardens and duck rearing

Establish **beel** nurseries and fish sanctuaries

Significant additional income generation opportunities from the diversification into additional crops

Strengthen resilience of agriculture production driven by the use of flood tolerant varieties and diversification away from overreliance on rice production

Significant emission savings where rice crops are substituted with the production of other crops

US\$ 117 M
US\$ 300 M PPP

IRR **30%**
ERR **39%**
NPV US\$ **113M**

* All values refer to the year 2040 compared to BAU

* Median ERR of WB projects in agriculture and rural development sector 23%

CSAIP Package Financing

Table ES.3 Overview of financing options for prioritized CSA investment packages

| Package | Function and focus | Maximizing finance for development (MFD) | Climate finance |
|---|--|---|---|
| Package 1 Agricultural Innovation System | Rice and non-rice crops | <ul style="list-style-type: none"> Incentivize private sector R & D through licensing, seed certification, and intellectual property protection. Strengthen business environment and investment policies to increase investment flows and access to finance. | <ul style="list-style-type: none"> Grants from dedicated international funding sources such as Green Climate Fund (GCF) through national implementing entity Commercial finance for farming cooperatives NGO finance for climate-adaptive seed R & D Bi- and multilateral financing for capacity building and exchange of technical know-how on seed R & D |
| | National | <ul style="list-style-type: none"> Invest in research/innovation hubs and climate/weather information systems. Develop risk-sharing instruments to lower producer costs and speed failure recovery. | |
| Package 2 Gender-Sensitive Development of Homestead Production | Cross-sectoral | <ul style="list-style-type: none"> Strengthen business environment and investment policies to lower market barriers and transaction costs, tie in homestead producers, and increase investment flows and access to finance. Coordinate extension services with and leverage private sector participation. | <ul style="list-style-type: none"> Microfinance for small-scale livestock and pond aquaculture Public and multilateral funds injected through NGOs and climate funding for homestead enterprises State-owned banks and local governments providing or mobilizing funds to facilitate CSA practices |
| | Khulna and Barisal | <ul style="list-style-type: none"> Improve supply chains for agricultural inputs. Mainstream women into policies, expand education, and extend gender-sensitive extension services. | |
| Package 3 Resilience through Diversification | Rice and non-rice crops | <ul style="list-style-type: none"> Develop risk-sharing schemes and other incentives and pathways to profitability for non-rice crops. Strengthen business environment and investment policy to increase fund flows and improve access to finance. Formalize food systems, value chains, and markets to increase attractiveness for investment. | <ul style="list-style-type: none"> Public funds from local governments and concessional finance from development partners, including climate funding, for infrastructure Community, philanthropic, or commercial finance for small-scale infrastructure Conditional credit mechanisms or leasing/factoring schemes to encourage non-rice production |
| | Dhaka, Rangpur, Rajshahi and Sylhet | | |
| Package 4 Livestock Upstream Value Chain Development | Livestock and crops | <ul style="list-style-type: none"> Strengthen business environment and investment policy and incentivize R & D and integration of livestock with input and energy sectors. | <ul style="list-style-type: none"> Strengthen business environment and investment policy and incentivize R & D and integration of livestock with input and energy sectors. Provide funding and support financing for cold storage networks. Promote veterinary extension services. |
| | National | <ul style="list-style-type: none"> Provide funding and support financing for cold storage networks. Promote veterinary extension services. | |
| Package 5 Climate-Resilient Agri-livelihood Development (hoar areas) | Rice and non-rice homestead farming and fish sanctuaries | <ul style="list-style-type: none"> Support development of value chains and logistical and cold chain infrastructure. Formalize production by improving market access for producers by lowering transaction costs and removing entry barriers. Promote farmer cooperation to formalize production networks, increase market links and profit sharing, and access to finance. Invest in R & D and suitable seed and food systems. | <ul style="list-style-type: none"> Low-risk finance access through adaptation finance Public-private partnerships with development partners, GCF, and other climate and local government funds for homestead production systems Finance beel nurseries and fish sanctuaries through the public with development partners, GCF, and other climate and local government funds R & D led by public sector for new rice varieties and restorative systems with private sector participation |
| | Sunamganj and Sylhet | | |

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- ² Rajendra K. Pachauri and Leon Meyer. 2014. "Climate Change 2014 Synthesis Report Summary for Policymakers." Intergovernmental Panel on Climate Change, Switzerland. https://www.ipcc.ch/site/assets/uploads/2018/02/AR5_SYR_FINAL_SPM.pdf.
- ³ Md Amin, Junbiao Zhang, and Mingmei Yang. 2015. "Effects of Climate Change on the Yield and Cropping Area of Major Food Crops: A Case of Bangladesh." *Sustainability* 7 (1): 898–915. <https://www.mdpi.com/2071-1050/7/1/898/pdf>.
- ⁴ Rezaul Mahmood, David R. Legates, and Mark Meo. 2004. "The Role of Soil Water Availability in Potential Rainfed Rice Productivity in Bangladesh: Applications of the CERES Rice Model." *Applied Geography* 24 (2): 139–59. https://www.researchgate.net/publication/255482152_The_Role_of_Soil_Water_Availability_in_Potential_Rainfed_Rice_Productivity_in_Bangladesh_Applications_of_the_CERES-Rice_Model.
- ⁵ Kazi Iqbal and Md Abu Bakar Siddique. 2015. "The Impact of Climate Change on Agricultural Productivity: Evidence from Panel Data of Bangladesh." *Journal of Developing Areas* 49 (6): 89–101.
- ⁶ Bangladesh, Ministry of Agriculture and FAO (Food and Agricultural Organization of the United Nations). 2013. Master Plan for Agricultural Development in the Southern Region of Bangladesh. Dhaka: Ministry of Agriculture, Government of Bangladesh and FAO. www.fao.org/3/a-au752e.pdf.
- ⁷ Mainul Ahsan. 2010. "Saline Soils of Bangladesh." Soil Resource Development Institute, Ministry of Agriculture, Dhaka. srdi.portal.gov.bd/sites/default/files/files/srdi.portal.gov.bd/publications/bc598e7a_df21_49ee_882e_0302c974015f/Soil%20salinity%20report-Nov%202010.pdf.
- ⁸ Bangladesh, General Economics Division, Planning Commission. 2015. "Seventh five-year plan, FY2016–FY2020: Accelerating Growth, Empowering Citizens." https://www.unicef.org/bangladesh/sites/unicef.org.bangladesh/files/2018-10/7th_FYP_18_02_2016.pdf.
- ⁹ Bangladesh, Ministry of Agriculture and FAO (Food and Agricultural Organization of the United Nations). 2013. Master Plan for Agricultural Development in the Southern Region of Bangladesh. Dhaka: Ministry of Agriculture, Government of Bangladesh and FAO. www.fao.org/3/a-au752e.pdf.
- ¹⁰ Stephane Hallegatte, Adrien Vogt-Schilb, Mook Bangalore et al. 2017. *Unbreakable: Building the Resilience of the Poor in the Face of Natural Disasters*. Washington, DC: World Bank Group. <http://documents.worldbank.org/curated/en/512241480487839624/Unbreakable-building-the-resilience-of-the-poor-in-the-face-of-natural-disasters>.
- ¹¹ This package was developed upon request from the Ministry of Fisheries and Livestock on the occasion of report validation by the Inter-Ministerial Steering Committee in March 2019. As such it did not follow the same prioritization method and remains less developed than the other packages (for instance, estimation of quantitative impacts is still ongoing).

Section

1

Introduction

1.1 The Climate Smart Agriculture Investment Plan (CSAIP) in Bangladesh

Bangladesh's agriculture sector is the country's main source of food security, employment, and poverty alleviation. More than 70 percent of Bangladesh's population and 77 percent of its workforce lives in rural areas. Nearly half of all Bangladeshi workers and two-thirds of workers in rural areas are directly employed in agriculture. About 87 percent of the nation's rural households rely on agriculture for at least part of their income. With one of the fastest rates of productivity growth in the world (averaging 2.7 percent per year since 1995, second only to China), Bangladesh's agriculture sector accounted for 90 percent of the country's reduction in poverty between 2005 and 2010. This growth has also allowed the country to triple its rice production since it gained independence in 1971 and to halve its food deficit—and with it the number of malnourished people—since the mid-1990s. In 1991, nearly two-thirds of Bangladeshi children were underweight; today that number is less than one-third.¹

Bangladesh faces growing demand for food and pressure from rapid land use change including significant losses of arable land. Population increases to an estimated 186 million by 2030 and 202 million by 2050, increasing income levels, and rapid urbanization at a rate of 3.5 percent annually² are expected to shift diets away from rice and wheat toward animal-based diets. At the same time, while Bangladesh produces almost all of its own rice, current yield trends indicate production will not be able to satisfy growing demand for cereals (including rice), which is projected to increase 21 percent by 2030 and 24 percent by 2050.¹ Given the increasing population density and continued loss of arable land caused by urbanization and other factors, enhancing the productivity of rice and other staple foods remains crucial. These trends suggest that Bangladesh must sustainably increase food production on far less arable land per capita to continue to strive for self-sufficiency in agricultural production.³

¹ Bangladesh: Food Utilization. 2017. FAOSTAT. www.fao.org/faostat/en/#country/16.

² Country Fact Sheet on Food and Agriculture Policy Trends. FAO. 2016. <http://www.fao.org/3/a-i5890e.pdf>

³ J. Timsina, J. Wolf, N. Guilpart et al. Can Bangladesh produce enough cereals to meet future demand?. *Agricultural Systems* vol. 163 (2018): 36-44. doi:10.1016/j.agsy.2016.11.003

Climate change is expected to further exacerbate these challenges. Agriculture (consisting of crops, livestock, forestry, and fisheries) is the most important sector in the Bangladeshi economy. It is extremely vulnerable to climate change as rising sea levels, increasing temperatures, variable rainfall, and humidity impact crop yield and livestock and fish production. Climate change is predicted to raise sea level by around 30 centimeters by 2050 and could make an additional 14 percent of the country extremely vulnerable to floods by 2030.⁴ With two-thirds of Bangladesh's landmass less than 5 meters above sea level and 30 percent of its arable land in coastal areas,⁵ the country is highly vulnerable to sea level rise, cyclones, storms, and storm-induced tidal flooding. Increased soil and water salinity is projected to cause a 15.6 percent yield reduction in high-yielding rice varieties before 2050.⁶ Overall production of rice is also projected to decline in all three rice growing seasons by 8–17 percent by 2050.⁷ At the same time, extreme heat, floods, cyclones, sea level rise, salinity intrusion, and increasingly irregular rainfall negatively affect livestock production and growth, as well as species composition in fisheries, including a projected 0–10 percent potential decrease in fish production.⁸ Overall, climate change is projected to increase the poverty head count ratio and risk of chronic poverty in different warming scenarios.⁹ An estimated 5.3 million poor people will become highly vulnerable to the effects of climate change by 2050.¹⁰

In addition to increasing productivity, agricultural policy must strengthen the resilience and reduce the emission intensity of food production. Achieving these objectives requires increasing investment to improve food and nutrition security for the growing global population. It also requires boosting incomes for the world's poor, many of whom rely on agriculture for their livelihoods. At the same time, agriculture sector investments must increasingly address the vulnerability of agriculture to climate change–induced increases in variability in the short term and major shifts in climatic conditions in the medium and long terms. Finally, strategies that provide cobenefits for mitigation are critical in limiting the rise in global average temperatures to 2°C. Approaches to identifying agricultural investments that combine these interconnected goals of productivity, resilience, and mitigation are increasingly referred to as climate-smart agriculture (CSA). In this context, the analysis of trade-offs between CSA pillars must be a key element of the analysis.

⁴ Poverty Reduction Strategy Paper. IMF Country Report No. 13/63, March 2013. <https://www.imf.org/external/pubs/ft/scr/2013/cr1363.pdf>

⁵ Julie Nash, Uwe. Grewer, Louis Bockel et al. 2016. Accelerating Agriculture Productivity Improvement in Bangladesh: Mitigation co-benefits of nutrient and water use efficiency. CCAFS Info Note. Published by the International Center for Tropical Agriculture (CIAT) and the Food and Agriculture Organization of the United Nations (FAO).

⁶ Susmita Dasgupta, Mainul Huq, Zahirul Huq Khan et al. (2014) Cyclones in a changing climate: the case of Bangladesh, *Climate and Development*, 6:2, 96-110, DOI: 10.1080/17565529.2013.868335. <https://www.tandfonline.com/doi/abs/10.1080/17565529.2013.868335>

⁷ Md Abdur Rashid Sarker, Khorshed Alam, and Jeff Gow (2012). Exploring the Relationship Between Climate Change and Rice Yield in Bangladesh: An Analysis of Time Series Data. *Agricultural Systems* 112: 11-16. <https://pdfs.semanticscholar.org/36fd/5c7e34e51e21e653e33677032fe803d8962d.pdf>

⁸ J.A. Fernandes, S. Kay, M. A. Hossain et al. 2016. Projecting Marine Fish Production and Catch Potential in Bangladesh in the 21st Century Under Long-Term Environmental Change and Management Scenarios. *ICES Journal of Marine Science* 73, no. 5: 1357-1369. <https://academic.oup.com/icesjms/article/73/5/1357/2296500>

⁹ The World Bank, Adams et al. 2014. Turn down the heat : confronting the new climate normal (Vol. 2) : Main report (English). Turn down the heat. Washington, DC : World Bank. <http://documents.worldbank.org/curated/en/317301468242098870/Main-report>

¹⁰ The World Bank, Dasgupta et al. 2014. River salinity and climate change : evidence from coastal Bangladesh (English). Policy Research working paper ; no. WPS 6817. Washington, DC: World Bank. <http://documents.worldbank.org/curated/en/522091468209055387/River-salinity-and-climate-change-evidence-from-coastal-Bangladesh>

Medium- and long-term planning in agriculture must be robust to uncertainties brought on by climate change and other factors. Medium- and long-term projections of climatic changes, as well as changes in other types of variables, are highly uncertain. People are not very accurate at predicting what the future will look like. Nevertheless, policy makers in all countries must make decisions with far-reaching consequences, such as decisions on land use, water management, crop research, and so on. New approaches to decision making under uncertainty enable policy makers to make more robust, forward-looking decisions. In contrast to previous approaches, these new approaches avoid attempting to reach a single “best guess” prediction of the future and instead map out a range of possible futures against which to explore the robustness of investments. Such approaches have been successfully piloted and are ready for use by agriculture policy makers.

The World Bank considers climate-smart agriculture (CSA) a strategic priority investment in response to climate change in agriculture. The executive directors of the International Development Association (IDA) of the World Bank Group have recognized the need to address several concerning trends in the world’s poorest countries, including the growing demand for food, the unsustainable pressure of current agricultural practices on agricultural landscapes, the increasing threat of climate change to agricultural productivity, and agriculture’s significant contribution to greenhouse gas emissions. In combination, these trends threaten to weaken national economies, erode the resilience of critical ecosystems, and severely undermine food security for some of the most economically vulnerable people in the world.¹¹ In response to these threats, the IDA18 Replenishment report states, “Participants agreed that focus on climate-smart agriculture and forestry in IDA18 is critical to deliver increased production, increased resilience, and lower emissions.” Further, “IDA18 will support the development of 10 country level climate smart agriculture strategies and investment plans.”¹²

1.2 Vulnerability of Bangladesh’s agriculture sector to climate change

Bangladesh is among the countries most vulnerable to climate change impacts. According to climate change vulnerability and risk assessments such as the Climate Change and Environmental Risk Atlas (CCERA), the Global Climate Risk Index by Germanwatch, and the country index of the Notre Dame Global Adaptation Initiative, Bangladesh ranks as one of the most climate-vulnerable countries in the world and features very low adaptive capacity, or readiness for climate-associated challenges. This is in part due to a lack of proper infrastructure and a large rural population that lives at or below the poverty line. The World Bank estimates that climate change–related economic losses depress gross domestic product (GDP) annually by 0.5 to 1 percent.¹³ Bangladesh is experiencing sea level rise, saltwater intrusion, mean temperature increase, higher rainfall variability, and an increase in the frequency and intensity of extreme weather events.¹⁴ This situation will worsen in the coming years.

¹¹ FAO 2015. Climate Change and Food Systems: Global Assessments and Implications for Food Security and Trade. <http://www.fao.org/3/a-i4332e.pdf>

¹² The World Bank. 2017. Towards 2030: Investing in Growth, Resilience and Opportunity. IDA18 replenishment Final Report . Washington, DC : World Bank <http://documents.worldbank.org/curated/en/471761467993490105/pdf/106194-BR-IDA18-Towards-2030-Investing-in-Growth-Resilience-and-Opportunity-PUBLIC-IDA-R2016-0142.pdf>

¹³ The World Bank. 2016. Bangladesh: Building Resilience to Climate Change. Washington, DC : World Bank. <http://www.worldbank.org/en/results/2016/10/07/bangladesh-building-resilience-to-climate-change>

¹⁴ S. Agrawala, T. Ota, A.U. Ahmed, J. Smith et al. 2003. Development and Climate Change in Bangladesh: Focus on Coastal Flooding and the Sunderbans. Organisation for Economic Co-operation and Development (OECD): Paris, France. <https://search.oecd.org/environment/cc/21055658.pdf>

Bangladesh is highly exposed to sea level rise and salinization of inland water sources. At the national level, total cropland losses could reach 6.5 percent by 2040. The regions with high exposure to sea level rise and salinity intrusion are located in southern Bangladesh.¹⁵ A 2009 study from the Bangladesh Soil Resource Development Institute indicates that approximately 62 percent of coastal land (equivalent to an area of 1.06 million out of 1.70 million hectares) is already affected by some degree of soil salinity, ranging from very slight (0.328 million hectares) to very strong (0.101 million hectares).¹⁶ Salinity intrusion is predicted to advance 8 kilometers north in the country by 2030, implying a significant reduction in land available for agriculture. Intrusion of salt water into rivers and canals presents a serious challenge to crop production. However, salinization may bring opportunities for saltwater shrimp production, which has expanded recently due to its higher profitability compared to other crops such as rice.¹⁷

Bangladesh is likely to face more hot days and heat waves, longer dry spells, and greater drought risk.¹⁸ The country has been facing higher temperatures over the last three decades. Annual mean temperature is projected to experience a rise of 1.0°C by 2030, 1.4°C by 2050, and 2.4°C by 2100, but the change will not be evenly distributed throughout the year. The average increase in winter season temperatures (in December, January, and February) is predicted to be slightly more pronounced: 1.1°C by 2030, 1.6°C by 2050, and 2.7°C by 2100. Predictions for the average temperature increase during the monsoon months (May/June through September) are 0.8°C by 2030, 1.1°C by 2050, and 1.9°C by 2100.¹⁹

Bangladesh will experience higher rainfall variability, more complex rainfall patterns, and diverse exposure to climate risks. Most of the climate models show that precipitation will increase during the summer monsoon.²⁰ Rainfall is expected to increase in Bangladesh by 9–12 percent by 2050. However, rainfalls in Bangladesh are distributed unevenly from north to south and from east to west, resulting in a diversity of rainfall patterns and thus climate risks across the country. For example, the hilly areas of northwestern Bangladesh are prone to drought, whereas the northeastern freshwater wetland often faces delayed rainfall or early flash flooding. The central floodplains experience flash floods and riverbank erosion, the hilly areas are exposed to landslides, and urban areas in Bangladesh are plagued by rainwater drainage issues.²¹ Rainfall patterns also vary between summer and winter seasons. Almost 80 percent of rainfalls in Bangladesh occur during the monsoon season (May/June

¹⁵ Climate Change 2014 Synthesis Report Summary for Policymakers. 2014. Intergovernmental Panel on Climate Change. https://www.ipcc.ch/site/assets/uploads/2018/02/AR5_SYR_FINAL_SPM.pdf

¹⁶ Master Plan for Agricultural Development in the Southern Region of Bangladesh. Ministry of Agriculture, Government of the People's Republic of Bangladesh & FAO, 2012. www.fao.org/3/a-au752e.pdf.

¹⁷ Final Report on Ganges Coordination and Change Enabling Project (G5). BRAC, CPWF: Dhaka, Bangladesh 2014. <https://cgspace.cgiar.org/handle/10568/56871>

¹⁸ Amin, Md, Junbiao Zhang, and Mingmei Yang. 2015. Effects of Climate Change on the Yield and Cropping Area of Major Food Crops: A Case of Bangladesh. *Sustainability* 7, no. 1: 898-915. <https://www.mdpi.com/2071-1050/7/1/898/pdf>

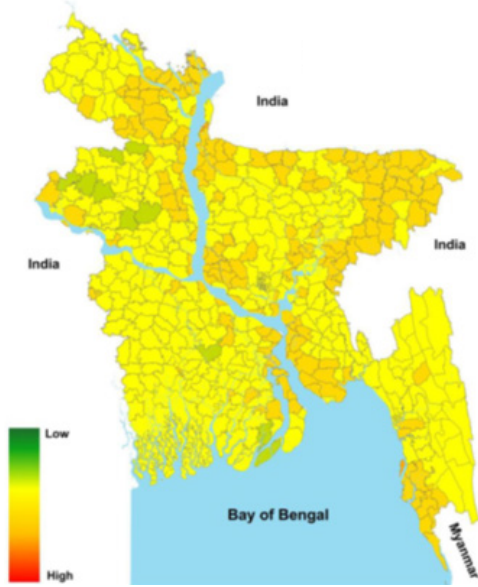
¹⁹ S. Agrawala, T. Ota, A.U. Ahmed, J. Smith et al. 2003. *Development and Climate Change in Bangladesh: Focus on Coastal Flooding and the Sunderbans*. Organisation for Economic Co-operation and Development (OECD): Paris, France. <https://search.oecd.org/environment/cc/21055658.pdf>

²⁰ Monirul Qader Mirza. 1997. *Modeling the Effects of Climate Change on Flooding in Bangladesh*. Ph.D. Thesis, International Global Change Institute (IGCI), University of Waikato, Hamilton, New Zealand. https://www.researchgate.net/publication/33689587_Modeling_the_effects_of_climate_change_on_flooding_in_Bangladesh

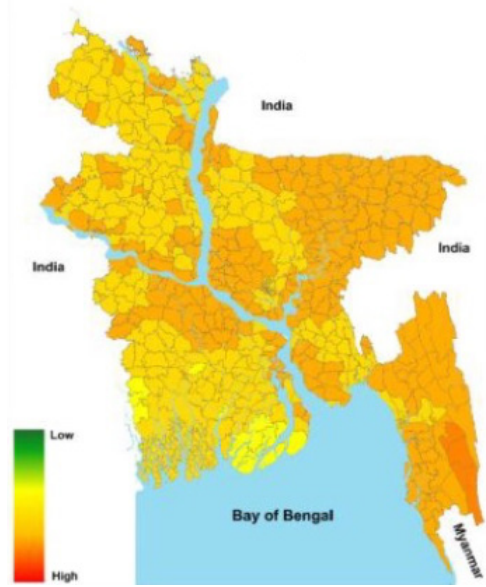
²¹ The World Bank, Gautam et al. 2016. *Dynamics of rural growth in Bangladesh : sustaining poverty reduction* (English). Washington, D.C. : World Bank. <http://documents.worldbank.org/curated/en/951091468198235153/Dynamics-of-rural-growth-in-Bangladesh-sustaining-poverty-reduction>

Figure 1.1 Vulnerability of agriculture to climate change¹

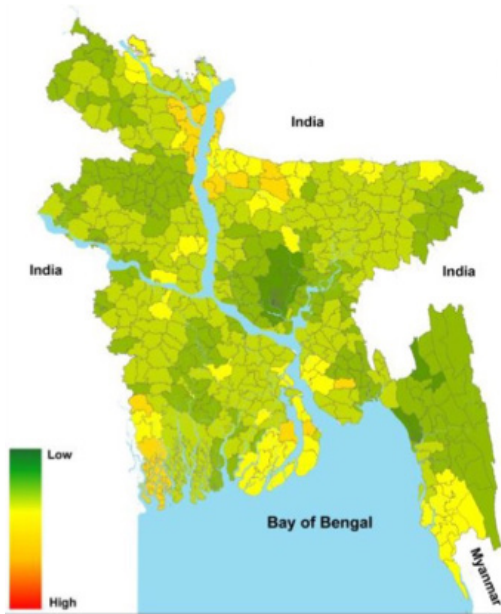
a. Crop yield



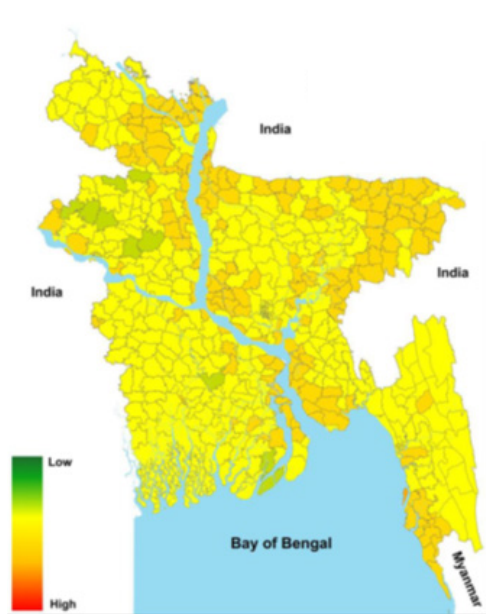
b. Livestock and poultry health



c. Cultured fish



d. Captured fish



through September). The remaining 20 percent of rainfalls is spread across the remaining months of the year, including the winter months, when high-yielding boro rice is grown.²²

Bangladesh is susceptible to cyclones and other extreme weather conditions. Extreme weather can cause deaths and significant damage to land and infrastructure. The value of household damage and losses due to climate change and natural disasters between 2009 and 2014 was estimated at 184.25 billion Bangladesh taka. The most extensive damage and losses were caused by flood (23.23 percent) and cyclones (15.41 percent). Between 2009 and 2014, hailstorm and drought were also major causes of crop damage and loss, and storm and tidal surge had a significant impact on fishery.²³ Scientists predict that floods, tropical cyclones, storm surge, and drought will become more frequent and more severe in the near future.²⁴ Storm surges occurring at increased frequency would put almost 30 million people at risk by 2050.²⁵ High tide increases the severity of cyclones.²⁶ The south, southwest, and southeast coastal regions of Bangladesh are increasingly susceptible to severe tropical cyclones and associated saltwater intrusion.

Erratic and uneven distribution of rainfall patterns and changes in temperature produce harmful effects on major food crop yields. While aman rice has long been the dominant staple crop, contributing around 57 percent to the total share of rice production, by 2005–06 it had decreased to 40 percent of total rice production. Rain-fed monsoon rice is highly vulnerable to water supply volatility, which is caused by changes in seasonal monsoon occurrence.²⁷ Early monsoon arrival can cause flood damage when rice seedlings are submerged during the early growth stages, especially when farmers are not using submergence-tolerant varieties. Late monsoon arrival can lead to water stress. Studies show that high water stress during the flowering and maturing stages can lead to rice yield losses as high as 70 percent.²⁸ Increased concentration of carbon dioxide may benefit irrigated winter boro rice, but rising temperatures during the flowering period and decreased sunlight for winter crops are both likely to negatively impact crop yield.

²² Bangladesh has a subtropical monsoon climate characterized by wide seasonal variations in rainfall, moderately warm temperatures, and high humidity. Four meteorological seasons are recognized as- pre-monsoon (March, April and May), monsoon (June to September), post-monsoon (October and November) and winter (December, January and February). Generally, pre-monsoon months are hot and humid, monsoon months are humid and rainy, post-monsoon months are quite hot and dry but the winter months are cool and dry. The mean annual temperature is about 25°C. Mean monthly temperature ranges from 18°C in January to 30°C from April to May. Highest temperatures in the year range between 38°C and 41°C. The average annual rainfall is about 2,200 mm a year and over 80% occurs during the southwest monsoon period (late May to mid-October).

²³ Md. Rafiqul Islam. 2016. Bangladesh Disaster-related Statistics (2015). Climate Change and Natural Disaster Perspectives. Bangladesh Disaster-related Statistics 2015. Climate Change and Natural Disaster Perspectives. Impact of Climate Change on Human Life (ICCHL). Programme, BBS

²⁴ Climate-Smart Agriculture in Bangladesh. CIAT, World Bank (2017). CSA Country Profiles for Asia Series. International Center for Tropical Agriculture (CIAT). World Bank, Washington, D.C. 28 p. <https://ccafs.cgiar.org/publications/climate-smart-agriculture-bangladesh/#.XNtn3tNKiqA>

²⁵ Rajendra K. Pachauri and Leon Meyer. 2014. "Climate Change 2014 Synthesis Report Summary for Policymakers." Intergovernmental Panel on Climate Change, Switzerland. https://www.ipcc.ch/site/assets/uploads/2018/02/AR5_SYR_FINAL_SPM.pdf.

²⁶ Mitchell, John FB, Jason Lowe, Richard A. Wood, and Michael Vellinga. "Extreme events due to human-induced climate change." *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 364, no. 1845 (2006): 2117-2133. <https://royalsocietypublishing.org/doi/abs/10.1098/rsta.2006.1816>

²⁷ Rezaul Mahmood, David R. Legates, and Mark Meo. 2004. The Role of Soil Water Availability in Potential Rainfed Rice Productivity in Bangladesh: Applications of the CERES Rice Model. *Applied Geography* 24, pp. 139-159.

²⁸ Kazi Iqbal and Md Abu Bakar Siddique. 2015. "The Impact of Climate Change on Agricultural Productivity: Evidence from Panel Data of Bangladesh." *Journal of Developing Areas* 49 (6): 89–101.

The impact of climate change on agricultural production is negative but not evenly distributed.

Research has shown that a higher maximum temperature negatively impacts crop yields for aman rice, boro rice, and wheat but not aus rice. Lower minimum temperatures do not significantly affect aman rice, though they benefit the yield of other crops, such as aus rice, boro rice, and wheat.²⁹ Likewise, an analysis using the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) for Bangladesh shows that climate change potentially contributes to increases in yield and land area for some crops but decreases for others. While the IMPACT model demonstrates overall yield declines in maize, pulses, vegetables, jute, and wheat, it reveals minor increases in yield for milk and meat by 2050. For example, by 2050 pulse yields will likely face a further decline of 8.8 percent under the climate change scenario (CC) compared to the no climate change scenario (NoCC). Moreover, scientists predict a 6.4 percent decline in wheat and a 6.3 percent decline in oilseed-rapeseed. Negative impacts to crop areas due to climate change are also anticipated. Most of Bangladesh's crops, with the exception of rice and oilseed-rapeseed, face a decrease in cultivated area. In general, most production system models project negative impacts due to climate change, with pulses, wheat, and oilseed-rapeseed suffering the most adverse effects.³⁰ The distribution of agricultural vulnerability varies in each subsector (figure 1.1).

Significant impacts of climate change to agricultural production imply important changes in agricultural net trade. The IMPACT model suggests that Bangladesh may become more dependent on imports of pulses, vegetables (as a group), wheat, and other crops (including jute). Meanwhile, the model shows that cattle meat exports will increase under both the CC and the NoCC scenarios, even though the difference between scenarios is not substantial.³¹

To date, climate change and agriculture sector development strategies have not provided a coherent road map to deal with climate risk. The linear nature of most strategies stands in contrast to the climatic uncertainties that will play a significant role in the agriculture sector's future development. Also, the large number of objectives in today's agriculture sector, from strong production growth and resilience building to increasing environmental sustainability, make integration very challenging. Consequently, the evidence on which strategies are built is often lacking in depth and breadth. Crucial interlinkages with other sectors, such as water, environment, disaster risk management, and so on, are often lacking at the ministries in charge of agriculture (agriculture, fisheries, livestock, and forestry). Finally, strategies tend to focus singularly on investments to the detriment of the required enabling environment actions and capacity- and institution-building efforts necessary to bring investments to fruition. These deficits undermine the robustness and effectiveness of agricultural development plans and create suboptimal capacity to respond to the uncertainty induced by changes in climate, technology, socioeconomic conditions, and so on.

The Bangladesh CSAIP offers an opportunity to make the agriculture sector more productive and climate resilient. To achieve Bangladesh's Sustainable Development Goals (SDGs) in the livestock, fisheries, and agriculture sectors—especially self-sufficiency in food commodities—the sector must

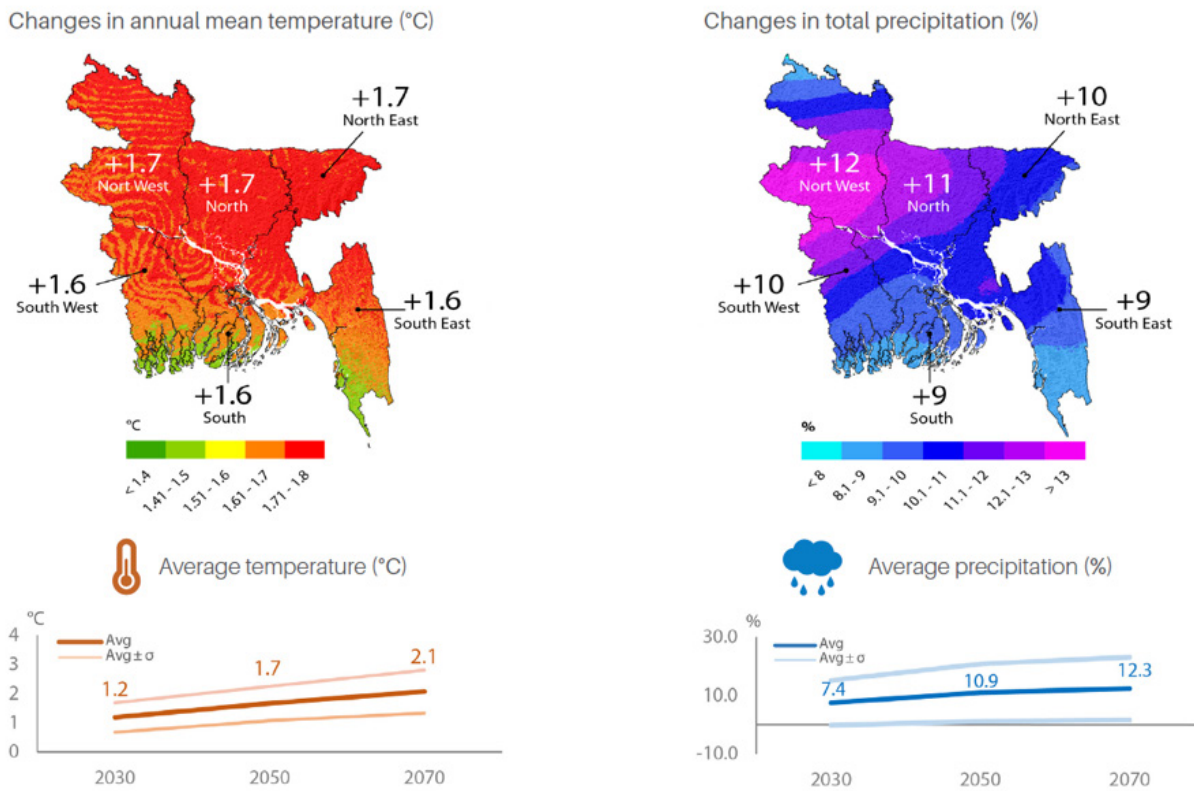
²⁹ Amin et al. 2015. Effects of Climate Change on the Yield and Cropping Area of Major Food Crops: A Case of Bangladesh. *Sustainability* 7, no. 1: 898-915. <https://www.mdpi.com/2071-1050/7/1/898/pdf>

³⁰ Climate-Smart Agriculture in Bangladesh. CIAT, World Bank. 2017. CSA Country Profiles for Asia Series. International Center for Tropical Agriculture (CIAT). World Bank, Washington, D.C. 28 p. <https://ccafs.cgiar.org/publications/climate-smart-agriculture-bangladesh#.XNtn3tNKiqA>

³¹ Climate-Smart Agriculture in Bangladesh. CIAT, World Bank. 2017. CSA Country Profiles for Asia Series. International Center for Tropical Agriculture (CIAT). World Bank, Washington, D.C. 28 p. <https://ccafs.cgiar.org/publications/climate-smart-agriculture-bangladesh#.XNtn3tNKiqA>

become more resilient to climate change. The Bangladesh CSAIP aims to identify opportunities for investment that help the country to reach SDG-based goals, implement CSA-relevant portions of the seventh and eighth five-year plans, reach Nationally Determined Contribution (NDC) and Bangladesh Delta Plan 2100 (BDP2100) goals, and create cross-sectoral synergies. Therefore, CSAIP focuses on opportunities across agricultural commodities that increase production, even in the face of climate change-related shocks. When possible, projects with climate mitigation cobenefits are also prioritized.

Figure 1.2 Projected changes in temperature and precipitation in Bangladesh by 2050



1.3 Purpose and overview of the report

This report details the process and findings of the Bangladesh CSAIP and provides a learning opportunity for future CSAIPs. This report primarily provides an account of the agricultural landscape in Bangladesh, details the methodology used to identify and prioritize four potential investment packages, and provides in-depth guidance on the planning and implementation of these packages. This report also serves as a learning opportunity for future CSAIPs. The Bangladesh CSAIP marks the first time that a national government has worked with the World Bank Group to create an agricultural development plan that takes into consideration the three pillars of CSA (production, resilience, and mitigation) and meaningfully addresses the long-term uncertainties of climate change.

Structure of the report. The remainder of this report is structured as follows. Chapter 2 (Methodology) describes how a combination of quantitative modeling and stakeholder engagement was used to identify, prioritize, and analyze key investment opportunities for the Government of Bangladesh. Chapter 3 (Analytics: Business as Usual) introduces the trends and challenges of agricultural production before the background of risks and vulnerabilities induced by climate change. Chapter 4 (Analytics: The Impact of Climate-Smart Agriculture) presents the results of the prioritization exercise. Chapter 5 (Investment: Climate Smart Agriculture Opportunities) provides an in-depth assessment of prioritized CSA packages. Chapter 6 (Conclusions) presents lessons learned about the CSAIP scope and methodology.

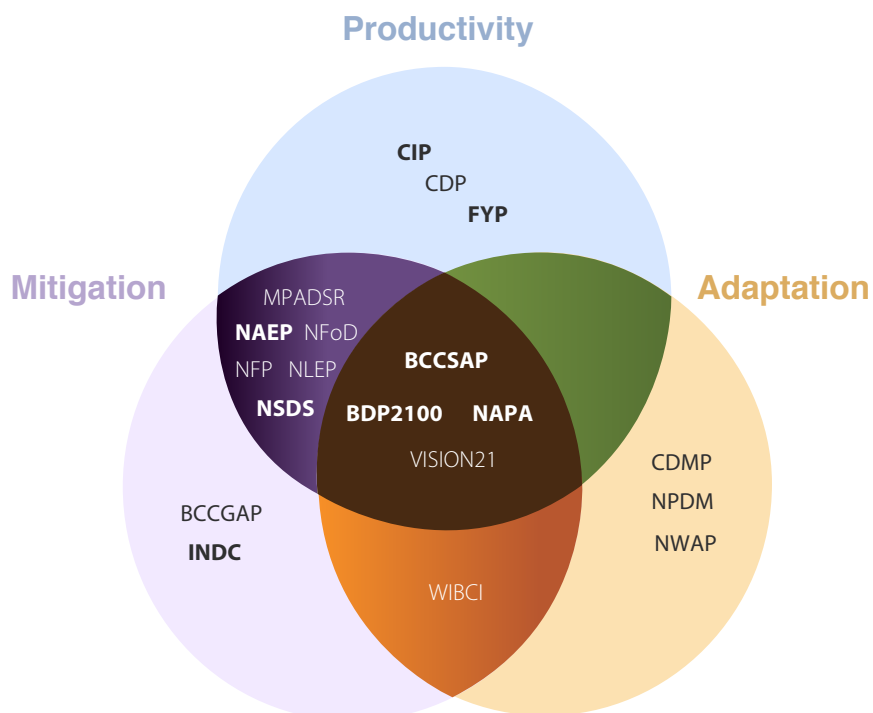
Section 2

Methodology

2.1 Vision and goals

Bangladesh's agriculture sector has been the center of the country's development goals for many decades. As part of the CSAIP, the most relevant frameworks for the current development agenda such as the Bangladesh Country Investment Plan (CIP) were analyzed (figure 2.1). A detailed overview of the nine assessed frameworks is provided in Appendix A.

Figure 2.1 Integration of qualitative and quantitative approaches into CSAIP



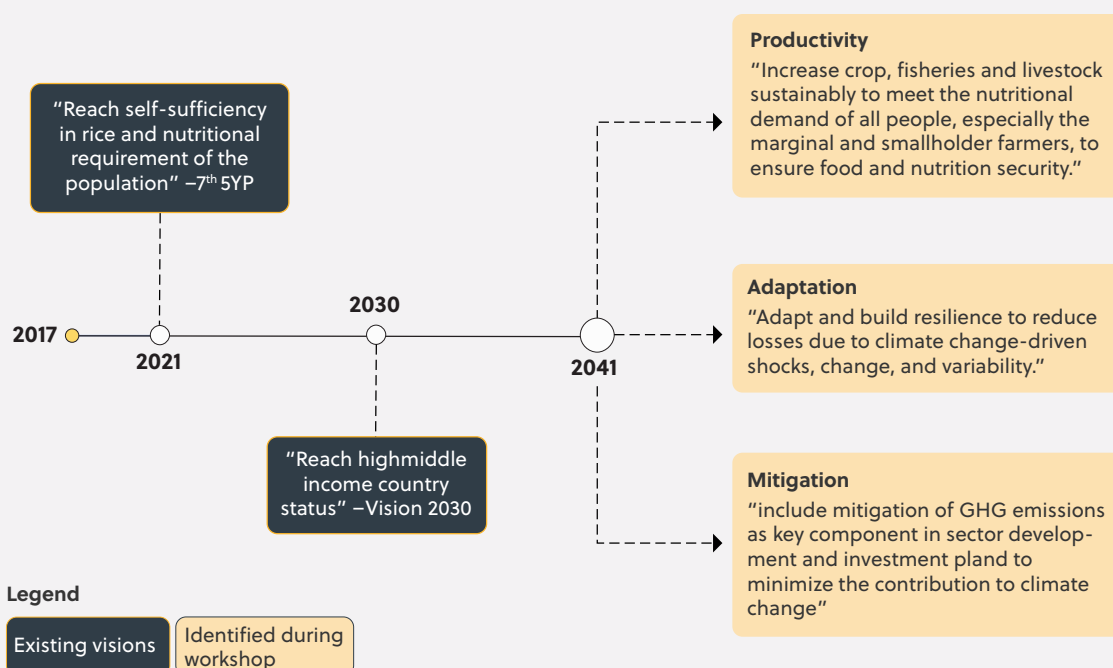
Note: Bolded items have been assessed in detail for this report.

Policy instruments focus on self-sufficiency as the primary development goal of the agriculture sector, with resilience as a close second. A high-level exploration of goals and metrics across policy frameworks between 2005 and 2017 suggests that policies focus on increasing yield, particularly through capacity building and policy formulation and enforcement. Meanwhile, adaptation/resilience goals are either treated as secondary or presented as comprehensive yet unquantifiable aspirations. Regardless, their importance is highlighted across planning frameworks, with a clear emphasis on increasing resilience given the uncertainties and risks posed by climate change. While documents that specifically target emissions (such as NDCs) identify some sectors specifically, emissions targets from agriculture are not specified.

The CSAIP is the first attempt to unify visions and goals from different CSA pillars. Bangladesh has long acknowledged the complexity and trade-offs of agricultural development planning. However, existing policy frameworks tend to single out specific aspects of sector visions and vulnerabilities, such as the need for adaptation or the need for increased production. The CSAIP is the first attempt to quantify trade-offs across CSA pillars and prioritize investments to increase productivity without undermining resilience or mitigation goals.

Technical workshops confirm the validity and urgency of most development priorities outlined in the policy frameworks. During technical workshops aimed at formulating quantifiable visions across CSA pillars, cross-sectoral expert groups developed a vision for production, climate resilience, and climate mitigation in the agriculture sector through 2041, a date identified by the group as a suitable medium-term milestone for ambitious sector reform (figure 2.2). Increased productivity and decreased losses emerged as key metrics across working groups for the CSA goals of production and resilience. Although Bangladesh has not determined a carbon reduction target from the agriculture sector in its NDC, workshop participants acknowledged that mitigation must become a more prominent optimization variable wherever it can be framed as a co-benefit. In other words, when two equally valid pathways exist for development, the reform with greatest mitigation benefits should be chosen.

Figure 2.2 Overview of high-level sector visions identified in stakeholder workshops



Goals established during the technical workshop resembled existing policy frameworks but featured greater recognition of triple-win opportunities in CSA. Workshop participants were asked to produce specific, measurable goals in the areas of production, climate adaptation, and climate mitigation. Many of the goals matched those of existing policy frameworks, such as rice self-sufficiency and nutrition security. Where Bangladesh's policy frameworks lacked specific and measurable targets, however, workshop participants added important goals, particularly for mitigation. A summary of policy framework goals vetted by sector-specific experts during the technical workshop and additional goals that emerged from the workshop are summarized in Table 2.1 Overview of targets across CSA pillars. The nine key policy frameworks addressing CSA are explored in more detail in Appendix A.

Table 2.1 Overview of agriculture sector goals across CSA dimensions

| | Rice | Non-rice crops | Livestock and fish |
|------------------------------|--|--------------------|-----------------------|
| Production | Reach self-sufficiency. | Double production. | Meet national demand. |
| Adaptation/resilience | Meet nutritional requirements after postharvest losses. | | |
| | Increase value and profitability of production. | | |
| | Decrease income dependence on rice. | | |
| | Decrease water use in irrigation. | | |
| Mitigation | Place 20% of rice under AWD | | |
| | Decrease NO ₂ emissions by 30%. | | |
| | Increase use of organic fertilizer by 35%. | | |
| | Reduce emissions by 5% (unconditional) and 15% (conditional to funding) (NDC). | | |

2.2 Quantitative model

The quantitative model is a simplified representation of the agriculture sector, capturing all subsectors and CSA dimensions. This Excel-based accounting model was custom built for the context of Bangladesh's agriculture sector. It allows decision makers to explore impacts of and trade-offs across investment options with regard to food security, production, greenhouse gas (GHG) emissions, profits, and water use. Results are computed in five-year intervals from 2005 to 2050. The period 2005–2015 was used to calibrate and ensure the model's capacity to reproduce past trends. Scenarios can be changed manually in the Excel tool, and results are automatically updated.

At present, the quantitative model captures climate change impacts through their effects on crop, livestock, and fishery yields. As a result, the model does not allow policy makers to explore climate change–driven disaster risks in the sector. Drawing on a multitude of other studies, however, policy makers have explored the impact of extreme weather events and have included their findings in the CSA investment packages. For example, policy makers reflected their concern for extreme weather events in their concrete recommendations for how to strengthen disaster risk management in the low-lying southwestern parts of Bangladesh.

The quantitative model structure is simple and broad in its comparison of different agricultural practices across a long list of desired outcomes. The model uses geographically disaggregated data at the division level (for the seven divisions of Bangladesh), three rice types (one for each growing season), nine non-rice crops, and seven livestock/fisheries commodities. The production

of each commodity is calculated as a function of the arable land dedicated to it and the yield per hectare. There is no more land available for cropland expansion in Bangladesh, and with climate change some arable land area has already been lost due to sea level rise. Moreover, urbanization has also caused a reduction in arable land. The productivity per hectare is a combination of exogenous yield improvement, which depends on economic growth, climate change impact, and adoption of CSA technologies. The main output variables include GHG emissions, water use, value and profit of production, and per capita supply and demand. A key feature of the model is the impact of 12 of the most common and promising CSA technologies in the country on the output variables. In each case, the adoption of the technologies is constrained to the area of land for which the technology is suitable. The impact of CSA technologies on productivity is controlled via multipliers derived from empirical data, literature reviews, and expert interviews. Appendix B provides a detailed description of the model, including data sources, exogenous drivers of yield and land use change, and descriptions of the CSA technologies explored in the model.

Capabilities of the quantitative model range from high-level gap analysis to technology-specific impact evaluation. The model's Excel-based interface allows experts and laypeople to explore the dynamics of the agriculture sector in Bangladesh related to key influencing variables. Example scenarios include arable land availability across the three main growing seasons, climate change and economic development scenarios, level of CSA technology adoption, and share of the cultivated area dedicated to rice versus other crops. The main outcomes of the models, which can be monitored across scenarios, are the self-sufficiency gap (per commodity and division), the change in farm-level value and profitability, the GHG emissions from crops and livestock production, and water use. While the model is not optimized, it allows for the exploration of dozens of relevant policy objectives as a function of the major decision tools at the disposal of a farmer or a top-down planner. Key limitations of the model are that it is not dynamic and does not allow the user to optimize for specific variables.

CSA goals and targets are derived based on existing policy frameworks and the first technical workshop to guide decision making in the CSAIP. The in-depth assessment of past policy frameworks and the expert consultations during the first technical workshop provide a set of measurable indicators for each CSA pillar (production, resilience, and mitigation cobenefits). These indicators may be used as a quantitative measure of agricultural practices (business as usual) and potential reform alternatives (CSA investments). Box 2.1 provides an overview of the measurable indicators for each CSA pillar that can be explored with the CSAIP model.

Box 2.1 Outcome indicators of the cost-benefits analysis

Production

Production goals have been well defined in past policy frameworks, often in the form of quantitative production targets based on nutritional requirements. Key production variables that can be explored with the CSAIP model include

- Self-sufficiency, measured as the gap between feasible supply and nutritional recommendations
- Tons produced per commodity
- Yield per commodity (tons per hectare per year)
- Value produced per commodity

Resilience

Most adaptation and resilience targets identified in national planning frameworks do not lend themselves to quantification (for example, awareness, technology transfer, and access to finance). Resilience and adaptation goals that best reflect existing policy aims and that can be explored with the CSAIP model include

- Rice production value as a percentage of total value
- Percentage increase in production value of non-rice crops
- Water use and water use intensity
- Variance of production value across climate scenarios

Mitigation

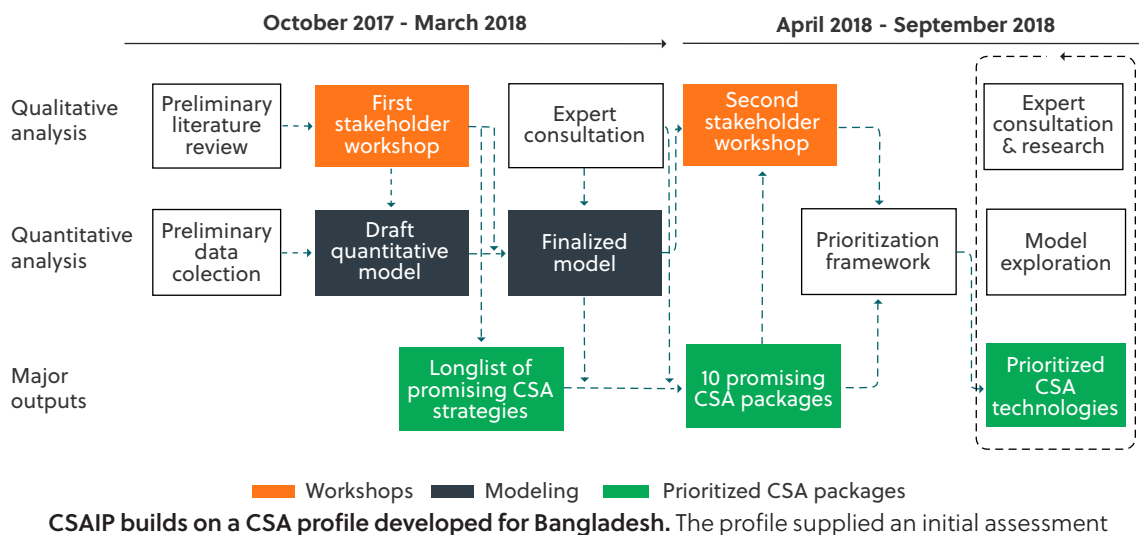
GHG targets for carbon dioxide (CO₂), nitrous oxide (N₂O), and methane have been set for some, but not all, components of agricultural production, in particular livestock and rice. Mitigation variables that can be explored across scenarios and CSA practices with the CSAIP model include

- GHG emissions (in tons per commodity)
- Emissions intensity (in tons of carbon dioxide equivalent [CO₂e] per ton of production)

2.3 Methodological overview

CSA opportunities identified in this report are based on quantitative modeling, stakeholder engagement, expert interviews, and a literature review. A collaborative, stakeholder-driven process was used to identify the vision, goals, and strategies and to prioritize the most promising climate-smart intervention packages for Bangladesh's agriculture sector. This process was supported by an Excel-based accounting model that simulates current and projected aspects of Bangladesh's agriculture sector under different scenarios to inform stakeholder discussions and decision making in the prioritization process.

Figure 2.3 Schematic overview of the methodological approach



of the climate and agriculture context, a long list of promising technologies, and an overview of policies and financing options for CSA in the country.

The CSAIP process expands on existing Bangladesh initiatives and policy frameworks. At least nine national initiatives have considered CSA-related goals since 2005 and have moved the country toward its goals of self-sufficiency, poverty reduction, nutrition security, and resilience. These policy documents were analyzed in detail to build off of existing planning frameworks rather than reinvent them. The analysis of planning documents provided a thorough understanding of challenges, aspirations, targets, and strategies in the past and in the decades to come. Past goals and strategies mirror the political will and ambition of the country and set the tone for an ambitious yet realistic CSAIP.

The first technical workshop helped validate and expand the new focus on climate-smart agriculture. During a two-day technical workshop in Dhaka in September 2017, a mostly technical group of stakeholders, including national ministry officials, technical organizations, civil society organizations, private sector figures, and academics, set visions and targets for the four major agricultural subsectors for the next two to three decades. Participants joined forces to identify technologies, policies, and market-based mechanisms that would help Bangladesh reach its identified goals. The workshop sessions were designed to learn from past efforts (“Where are CSA adoption rates low and why?”) and understand the most promising approaches for the future (for example, demonstrated successes that are ready to be scaled up and new approaches that promise success).

The second technical workshop helped narrow solutions and design a prioritization framework for CSAIPs. During the second technical workshop, sector-specific experts validated the emerging hypotheses about the most impactful and practical CSA packages for a CSAIP. During the workshop, a prioritization framework was developed and tested. Technical experts provided key insights about the strengths, weaknesses, opportunities, and strengths for each of the 10 short-listed CSA opportunities. Based on these insights, four final CSAIP packages were developed.

Scenarios of future worlds

CSAIPs use scenario analysis to identify CSA packages that are robust across various climate change and economic growth projections. A key component of CSAIPs is to evaluate the robustness of CSA technologies against an uncertain future. In order to test for robustness, a scenario analysis completed by the BDP2100 Planning Commission was used to build the quantitative model. The scenario analysis considers the amount of economic development and the severity of climate change impacts as key factors of uncertainty in the outcomes of CSAIP. The scenario analysis also considers related factors that are exogenous to CSAIP and correlated with the two key drivers of economic development and climate change (figure 2.4).

Figure 2.4 Scenarios of future world



Note: The levels of urbanization (between 70% in the productive scenario and 48% in the stagnation scenario) and population (170–200 million people by 2050) are adopted from BDP2100.

Data collection

Official statistics were used when available. The statistical data for the model were largely gathered from different publications of the Bangladesh Bureau of Statistics (BBS). Historical areas and production of crops, livestock, and fisheries in Bangladesh were taken from the BBS agricultural census data, published annually in the *Yearbook of Agricultural Statistics of Bangladesh*. Data were taken from the 2005, 2010, and 2015 publications. In addition, livestock data were gathered from the 2008 livestock census published by BBS. However, because there were significant gaps in the livestock census data available from BBS, the data were supplemented with data from the statistical database of the Food and Agriculture Organization of the United Nations (FAOSTAT). Population and consumption data were also retrieved from BBS publications. The most important sources were Population Projection of Bangladesh: *Dynamics and Trends* (BBS 2015) and *Household Income and Expenditure Survey* (BBS 2010, 2016).

The literature review focused on Bangladeshi sources first. Data on the effects of CSA technologies on crop and livestock systems were gathered during a literature review. Wherever possible, journal articles with results from Bangladesh were prioritized, including articles from international journals with a high impact factor or from Bangladeshi scientific journals with a lower impact factor (for example, *Bangladesh Journal of Animal Science and Bangladesh Journal of Agricultural Research*). Data and information on the quantitative impact of CSA technologies are highly location-specific and scarcely available; thus the gaps in the data were substantial. To fill these, sources from neighboring countries (for example, India and Vietnam) were prioritized, and expert interviews were conducted to validate the information found. In several cases, CSA technology data from local experiments and reports were extrapolated to the national level. Further data and information were gathered from gray literature, such as government reports and handbooks, or unpublished manuscripts from various national government organizations or research institutes, such as the Bangladesh Livestock Research Institute (BLRI), Bangladesh Agricultural Research Council (BARC), and Department of Agricultural Extension (DAE).

Expert interviews helped fill important gaps and validate the data. Expert interviews were held to compensate for gaps in the data and to validate assumptions and information gathered from statistical databases and the literature. Interviews were held mainly with experts from Bangladesh Livestock Research Institute (BLRI), Bangladesh Agricultural Research Council (BARC), Bangladesh Bureau of Statistics (BBS), Department of Agricultural Extension (DAE) of the Ministry of Agriculture (MOA), Department of Livestock Extension (DOL) of the Ministry of Livestock and Fisheries (MOLF), Bangladesh Center for Advanced Studies (BCAS), Bangladesh Agricultural Research Institute (BARI), Bangladesh Rice Research Institute (BRRI), Bangladesh Wheat Research Institute (BWRI), Food and Agriculture Organization of the United Nations (FAO), Bangladesh Biogas Development Foundation (BBDF), International Maize and Wheat Improvement Center (CIMMYT), International Food Policy Research Institute (IFPRI), and Barind Multipurpose Development Authority.

A field trip to High Barind Tract provided firsthand information about local farming conditions, needs, challenges, and strategies for one of the most climate change-vulnerable regions in Bangladesh. Several interviews were held with farmer groups, extension officers, government officials, and researchers to better understand the challenges and development priorities of the region. This provided important background information about farming strategies and farm household priorities, as well as technical and institutional needs and barriers to technology adoption.

Adoption of climate-smart agriculture technologies

This section summarizes the assumptions underlying the quantitative results section of this report. The model allowed for a large number of user-defined assumptions regarding the adoption rates of commodity-specific CSA technologies. Table 2.2 provides an overview of CSA technologies explored in the quantitative model. Appendix B provides an overview of adoption rates assumed for each technology under the CSA scenario.

Table 2.2 Overview of CSA technologies explored in the quantitative model

| CSA technology | Applied to | Description |
|--|-----------------------------|---|
| Acid soil management | All crops | Half of the cropland currently on very acid soil is treated with lime to return it to the productivity levels of moderately acidic soils. |
| Salt-tolerant varieties | Boro rice, aman rice, wheat | These allow cultivation on saline soils during rabi and improve crop yields during kharif 2. |
| Submergence-tolerant varieties | Aman rice | These can be completely submerged in water for extended periods without significant yield loss. They are suitable for areas with medium to high flood proneness, typically during kharif 2. |
| Short-duration drought-resistant varieties | Aman rice, aus rice | Besides having drought tolerance, these mature one month earlier. |
| Alternate wetting and drying (AWD) | Boro rice | Periodic drying and reflooding of the rice field in irrigated lowland reduces water use and rice methane emissions. |
| Buried pipe (BP) | Boro rice | Water is channeled through enclosed underground pipes instead of moving irrigation water through open channels from the well to the fields. This reduces water loss from evaporation and spills. |
| Solar irrigation (SI) | Boro rice | This replaces diesel as the source of energy for the water pump. |
| Deep urea placement | Boro rice, aman rice | With the help of specialized tools, small urea briquettes are placed about 20–30 cm deep in the soil, directly at the root of the plant. |
| Crop diversification | All crops | The share of rice in the total cultivated area is reduced in rabi and kharif 1, and the share of other crops proportionally increases. |
| Increasing intake of protein-rich fodder grass and feed concentrate | Cattle | This can be used to increase milk production by an average of 30% in crossbred and indigenous cattle. Farmers can grow fodder grass on fields as a rabi crop and increase feed availability for cattle. |
| Increasing the share of crossbred cows in the total cattle population | Cattle | This can significantly increase overall dairy and meat production. |
| Biogas production | Cattle | This form of manure and crop residue management reduces emissions while producing energy for cooking and a biofertilizer (slurry). |
| Integrating small indigenous and highly nutritious fish cultivation into carp ponds | Fish (aquaculture) | This increases total yield per hectare and nutrition security. It is assumed that from a current adoption share of 2% in the north and 7% in the south, the adoption share would reach 20% in the north and 50% in the south in the CSA scenario. |
| Intensification of pond fish production | Fish (aquaculture) | This is assumed through the transition of all extensive systems to semi-intensive systems by 2050. Some intensification of fish production in floodplains is assumed, with an annual productivity growth of 9%. |

2.4 Prioritization

Solution space of climate-smart agriculture

Climate-smart agriculture is not a new concept for farmers in Bangladesh. Although climate change has become prominent recently, farmers in Bangladesh have long lived with challenging climatic conditions. It is no surprise that farmers' practices aim at maximizing productivity despite climatic challenges. Traditional practices include *gher* farming, which uses an aquaculture pond with raised dikes in nonsaline wetlands for vegetable production; floating vegetable gardens; and ridging and furrowing methods in waterlogged areas (such as the sorjan system). More recent practices include salt- and submergence-tolerant high-yielding crop varieties, drip irrigation, AWD, and deep urea placement.

A long list of success stories and promising approaches were identified. During the first stakeholder engagement workshop, attendees identified and discussed strategies that included success stories with significant potential for scaling up, strategies that might be promising in the future, and strategies that have been tried but showed low adoption rates. The many dozens of success stories and promising strategies identified during the first stakeholder engagement workshop (BCSAIP Appendices, Appendix C) showcase the innovative, dynamic, and diverse solution space of CSA in Bangladesh.

Despite a large solution space, CSA technologies suffer from low adoption rates in Bangladesh.

Barriers to the adoption of CSA practices by small-scale farmers in Bangladesh are manifold. The most prominent barriers are the limited availability of credit/incentives, unfavorable extension staff-to-farmer ratios for the dissemination of new technologies and practices, limited implementation of novel financing mechanisms and safety net protections, inefficient supply chains and inaccessible markets, and inefficient agricultural innovation systems that unnecessarily delay the cycle of research, development, piloting, scaling, and adaptive improvements. To improve CSA uptake by farmers, the research and innovation system must be more inclusive and demand-driven to meet farmers' economic and social needs, priority investment, and technical, financial, organizational, and institutional capacity. Hence, the CSAIP should include medium- and long-term reforms, including reforms to agricultural research, the extension and advisory system (including the private sector), the enabling environment for the private sector and agricultural policy. This will help transform the institutional framework and the ecosystem of CSA technology and service delivery.

Narrowing down the solution space and prioritizing CSA packages

The Bangladesh CSAIP focuses on a small number of promising CSA packages. This report provides a deep dive into a few very promising CSA interventions rather than a comprehensive list of potentially viable practices. This approach was chosen to focus on high-impact opportunities that are in line with governmental priorities and to allow for in-depth analysis of the most promising approaches. CSA is not new to Bangladesh, and solutions need to be well contextualized and adapted to the local conditions to overcome low adoption rates. Lessons learned must be carefully taken into account, and the enabling environment for key solutions must be broadly understood.

A set of eligibility criteria and selection criteria determined the focus of the CSAIP report. In order to narrow the solution space, a two-step process was used. As a first step, 10 CSA packages were identified based on their hypothetical impact on sector vision and goals.³² The packages were informed by a thorough review of CSA-relevant policy and planning frameworks of the Government

³² See BCSAIP Appendices for detailed description of the 10 short-listed CSA packages.

of Bangladesh since 2005, the gap analysis resulting from the quantitative model, and the first stakeholder workshop. As a second step, the 10 packages were discussed in detail with subsector experts during the second stakeholder workshop. The results were then translated into a quantitative ranking of CSA packages across a set of eligibility and selection criteria.

The triple bottom line of CSA was applied as an initial criterion for eligibility. The initial solution space for CSA practices encompassed all successful and potentially successful practices to increase productivity, increase resilience, or decrease GHG emissions. Then the CSAIP packages were filtered to include only those that significantly contributed to all three CSA pillars simultaneously.

Impact and practicality were used as the key variables of CSA package ranking. Each of the 10 CSA packages was ranked across five selection criteria measuring impact (as defined in planning frameworks and identified in stakeholder workshops) and five selection criteria measuring practicality and feasibility. Rankings (from 1 = *does not apply* to 10 = *fully applies*) were based on in-depth conversations during the second stakeholder workshop in Dhaka. Impact and practicality scores are shown in Table 2.3.

Eligibility and selection criteria closely tracked with the Green Climate Fund's selection criteria. The criteria used for the prioritization of CSAIP packages were closely aligned with those of the Green Climate Fund (GCF) to ensure compatibility. Appendix D provides an overview of how CSAIP prioritization tracks with GCF criteria, a fund established by the United Nations Framework Convention on Climate Change (UNFCCC) to assist developing countries in achieving climate mitigation and adaptation benefits. Given the similarity between CSAIP and GCF criteria, there is an increased likelihood of funding for both mitigation and adaptation finance.

Table 2.3 Scoring for 10 candidate packages across 10 selection criteria

| | | Rice | | Non-rice | | Livestock | | | | Fisheries and aquaculture | |
|-----------|---|--|---|---|--|---|---|--|---|--|---|
| Impact | Initial package proposals | Increase water efficiency in rice production | Increase rice productivity despite climate change | Strengthen non-rice crops in South Bangladesh to decrease rice dependency | Boost non-rice crop production in North Bangladesh | Source sufficient protein for productive livestock sector | Reduce vulnerability of livestock assets to natural disasters | Turn livestock waste into an energy asset? | Develop low carbon climate resilient milk supply chains | Manage fisheries in seasonally flooded plains to increase yields | Sustainable intensification of Gher systems |
| | Increases production and contributes to self-sufficiency goals | 3 | 6 | 3 | 4 | 6 | 3 | 1 | 4 | 4 | 3 |
| | Contributes to food and nutrition security of the rural poor in light of climate change | 2 | 7 | 5 | 6 | 5 | 6 | 2 | 6 | 7 | 4 |
| | Minimizes environmental externalities (water, fertilizer) | 5 | 4 | 2 | 6 | 4 | 3 | 4 | 4 | 8 | 4 |
| | Provides demonstration effects and spill-over effects in ag sector | 2 | 8 | 3 | 4 | 7 | 3 | 3 | 4 | 2 | 2 |
| | Increases the commercialization of the agriculture sector as targeted by GoB | 4 | 5 | 3 | 5 | 7 | 3 | 6 | 7 | 3 | 2 |
| Practical | In line with GoB priorities | 6 | 8 | 5 | 6 | 8 | 5 | 4 | 6 | 8 | 5 |
| | Promises high adoption rates at near-future institutional capacities | 6 | 3 | 2 | 5 | 3 | 4 | 2 | 2 | 4 | 5 |
| | Allows for efficient use of financial and human resources | 3 | 6 | 2 | 5 | 6 | 6 | 2 | 2 | 2 | 3 |
| | Offers opportunities to leverage public-private finance | 5 | 2 | 1 | 4 | 4 | 3 | 4 | 4 | 2 | 7 |
| | Supports climate commitments of Bangladesh (NDCs) | 7 | 6 | 3 | 7 | 4 | 8 | 7 | 5 | 8 | 7 |

Analytics: Business as Usual

3.1 Impact of climate change and economic development on key model variables

This section summarizes the projections of key production drivers under different climate change and economic development scenarios. As discussed in the section describing the quantitative model and in BCSAIP Appendices, Appendix C, the underlying model of this CSAIP projects target variables (by commodity and division) as a function of available cropland and productivity. Both are affected by climate change and economic development.

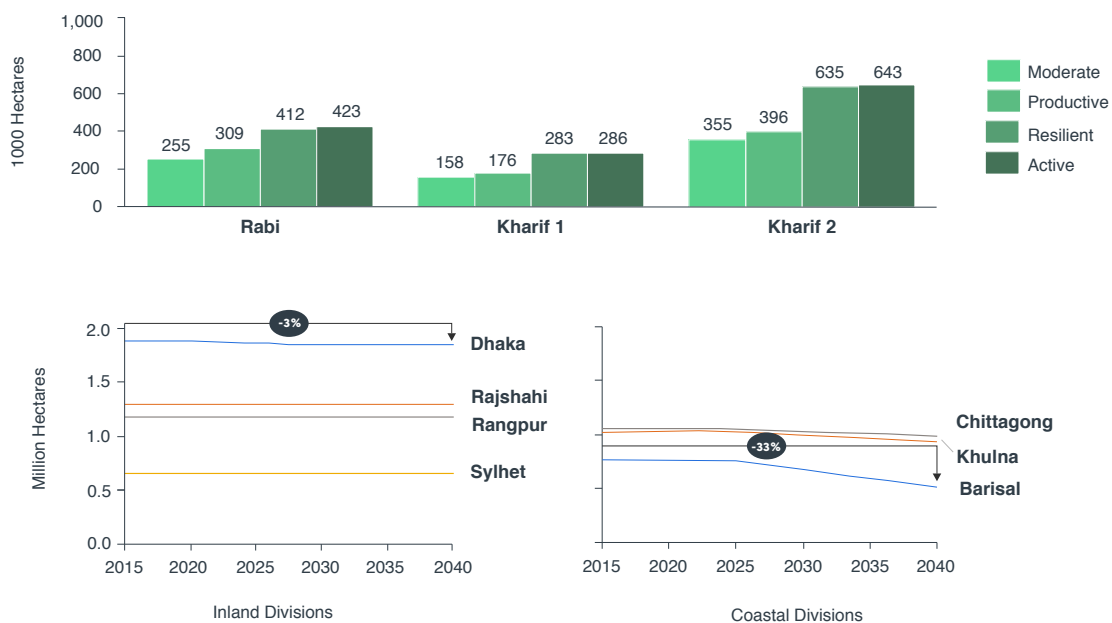
Loss of available cropland due to urbanization and sea level rise is the most powerful driver of production loss. Recurrent flooding and erosion in floodplains cause sand casting, which significantly reduces arable land for agriculture. In the coastal region, sea level rise and erosion further exacerbate the shortage of suitable agricultural land. Urbanization drives arable land loss through conversion of land from agricultural to residential. This means that in order to maintain crop production at current levels or higher, the loss of arable land must be counteracted by continual increases in productivity to maintain the key priority of self-sufficiency in food staples.

Productivity projections in the model are based on historic trends but vary widely across future scenarios. Productivity per hectare is a function of GDP growth, climate change (including saline intrusion, drought, and flooding), and the adoption rates of different agronomic technologies. Figure 3.2 shows the projected effects of climate change and economic development on yield. Figure 3.3 shows absolute yield projections for all major crops modeled here. The following conclusions can be drawn:

- Crops that have benefited from recent investments in yield increase (in particular, rice, spices, pulses, and wheat) will continue to see increased yields across all scenarios of climate change and economic development. This is a realistic assumption given the technological advancement underway, the capacity that has been built in respective research institutes, and the priority of such crops in development planning.

- Yield increase will suffer most in the stagnation scenario, which assumes weak economic development and high climate change. Both factors have a similar negative effect on overall yield. Whereas economic development is correlated with having funds and technology to enhance research, capacitate extension services, and invest in technology, climate change is correlated with soil quality, salinity, droughts, and flooding, each of which has a negative impact on overall yield.
- The effect of future scenarios on yield seems particularly pronounced in the case of jute, maize, oilseed, and potato. The low climate change scenarios (congestion and productive) see the yield for these crops steadily growing beyond the 2015 baseline, whereas the high climate change scenarios (stagnation and resilient) see crop yields fall below 2019 levels.

Figure 3.1 Loss of available crop land between 2015 and 2040



Note: The bar graphs show absolute loss by season. The line graphs show loss over time by division.

Figure 3.2 Yield at business as usual (BAU) as a function of climate change (left) and economic development (right)

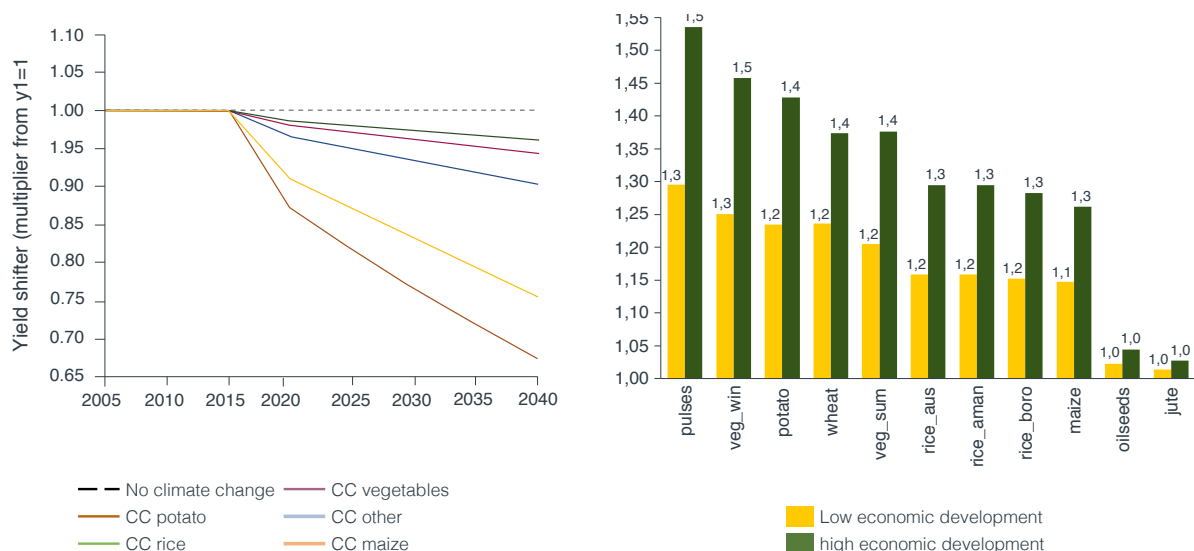


Figure 3.3 Impact of climate change and economic development on projected yield (tons/hectare) under current trajectory (BAU)



3.2 Summary of model projections under business as usual

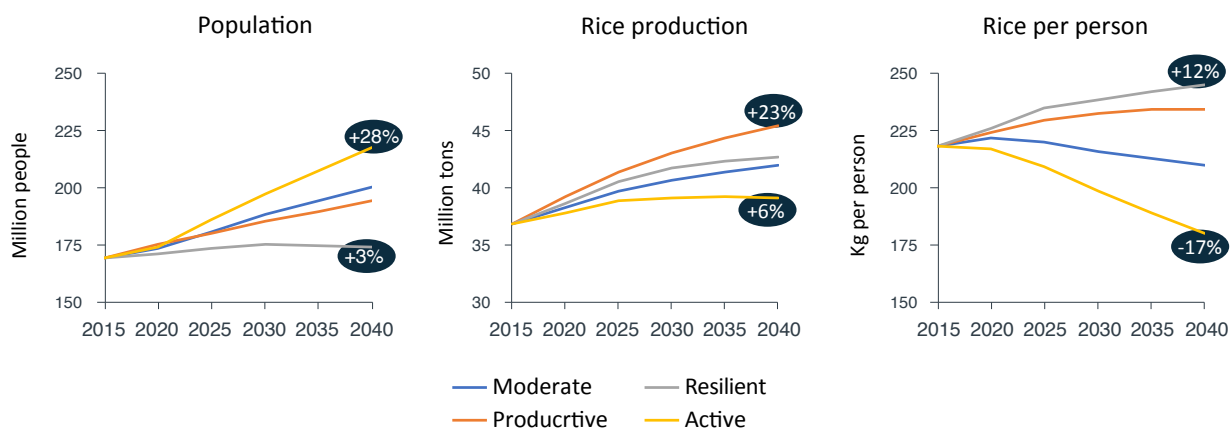
Table 3.1 Summary of model projections under Business as usual (BAU) model projections for key target variables

| | 2040 targets | Model projections under BAU | Relevance |
|--------------------|--|--|---|
| Production targets | Reach rice self-sufficiency. | Current rice production per person can be maintained or increased only in scenarios of high economic growth. | Under model assumptions on yield increase, climate change will not undermine self-sufficiency targets under BAU. |
| | Double production of non-rice crops. | Average production is projected below 20% of target across scenarios. No crop reaches target under any scenario. | There is a significant need to focus on increased production in order to meet 2040 targets. |
| | Meet demand for livestock products. | All livestock products miss target across scenarios. Milk has the highest total gap (0.4–3.4 million tons by 2040, depending on scenario). | Despite projected production increases of up to 2.4% annually for milk in the optimistic scenario, additional investments are required to meet demand. |
| | Increase output from fisheries and aquaculture. | Fish culture is expected to increase by 0.6% annually, compared to 5% annually between 2005 and 2015. | Efforts to expand pond size should instead focus on yield increases, which will require intensification of pond and floodplain aquaculture. |
| Resilience | Meet caloric demand. | Gaps of more than 50% are projected for oils, vegetables, pulses, and all livestock products. | Currently, Bangladesh is not on a path to meet caloric targets of a balanced diet. |
| | Increase farm-level income and profitability. | Production values for rice and livestock are projected to grow fastest, despite extremely low profit margins for boro rice production. Despite ongoing diversification, the share of rice in total revenue will increase from 61% (2015) to 63%–66% (2040). | Farm-level profitability will remain low despite opportunities (in theory) to increase profitability through diversification. High dependence on a single crop undermines resilience to production shocks. |
| | Decrease water use. | Virtually all water used in crop agriculture is earmarked for boro rice. Water demand is projected to increase by 0.8–1.7 million L by 2040 | With increasing drought and infrastructure projects in India, the dependence on water carries risks for future profitability and increases pressure on drinking water. |
| Mitigation | Decrease agricultural emissions to meet NDC targets. | GHG emissions (particularly rice and livestock methane) are projected to increase by approximately 2% between 2015 and 2040. | By 2040, unconditional targets will be missed by 11% and conditional targets by 24%. |

3.3 Production targets

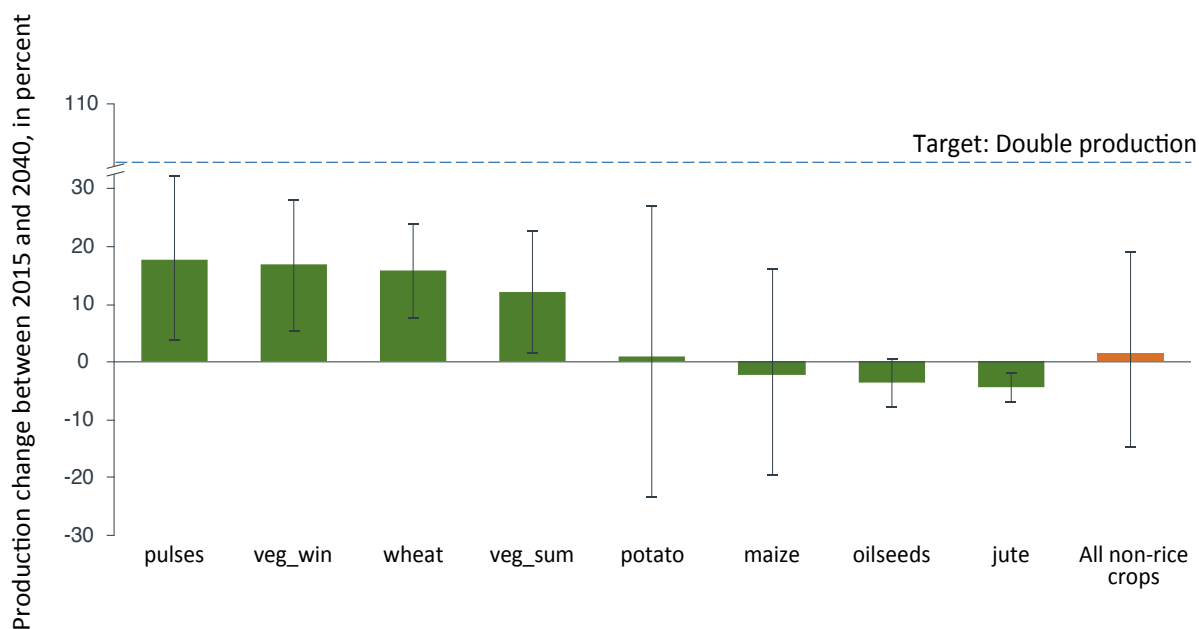
In scenarios of low economic growth, per capita rice production is at risk of dropping below today's levels. Rice production is projected to grow further, reaching somewhere between 39 and 45 million tons per year by 2040. Given the stark differences in population growth under different future scenarios, there is a good chance per capita production will drop below today's levels in the next two decades. In the two scenarios of low economic development, high population growth, and low yield gains, per capita rice production might fall as much as 17 percent below 2015 levels by 2040.

Figure 3.4 Impact of climate change and economic development on rice production at BAU



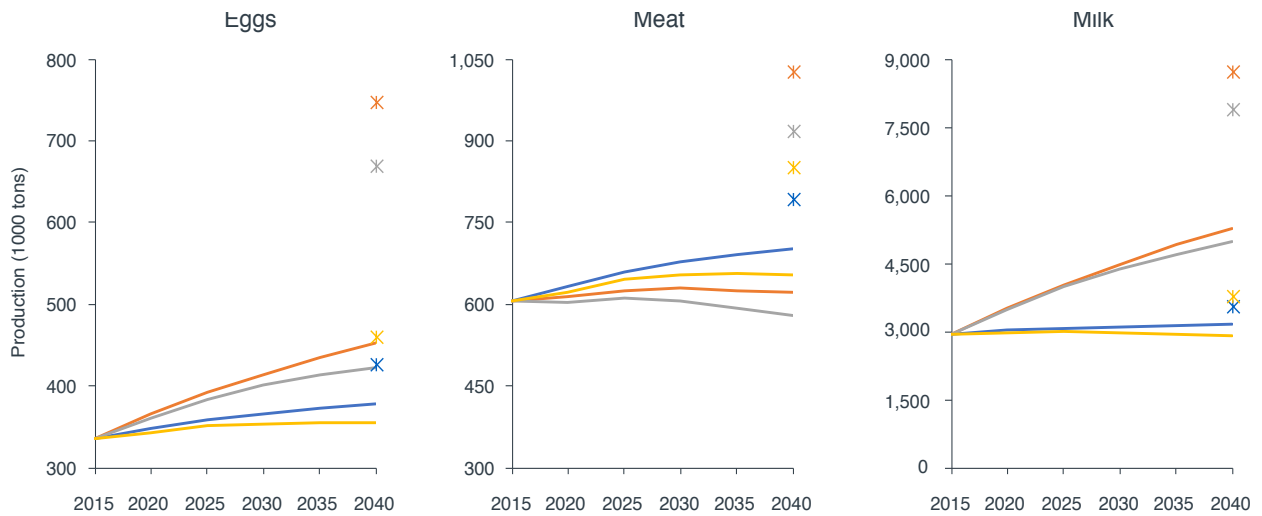
Non-rice crops do not meet the target of doubling production by 2040 under any scenario. In 2015, the production of non-rice crops amounted to 18.8 million tons in Bangladesh, up from 11.6 million in 2005. As suggested by Figure 3.5, the historic increase in non-rice crop production will continue for some crops, but it will be hampered by urban expansion and climate change. Taken together, non-rice crops are projected to increase by only 1 percent by 2040, with upper and lower bounds of 19 percent (22.5 million tons) and -15 percent (16 million tons), respectively. This is in stark contrast to the identified target of doubling production of non-rice crops by 2040. Under BAU, no single non-rice crop is projected to exceed a 20 percent increase in production by 2040.

Figure 3.5 Change in production between 2015 and 2040 for non-rice crops



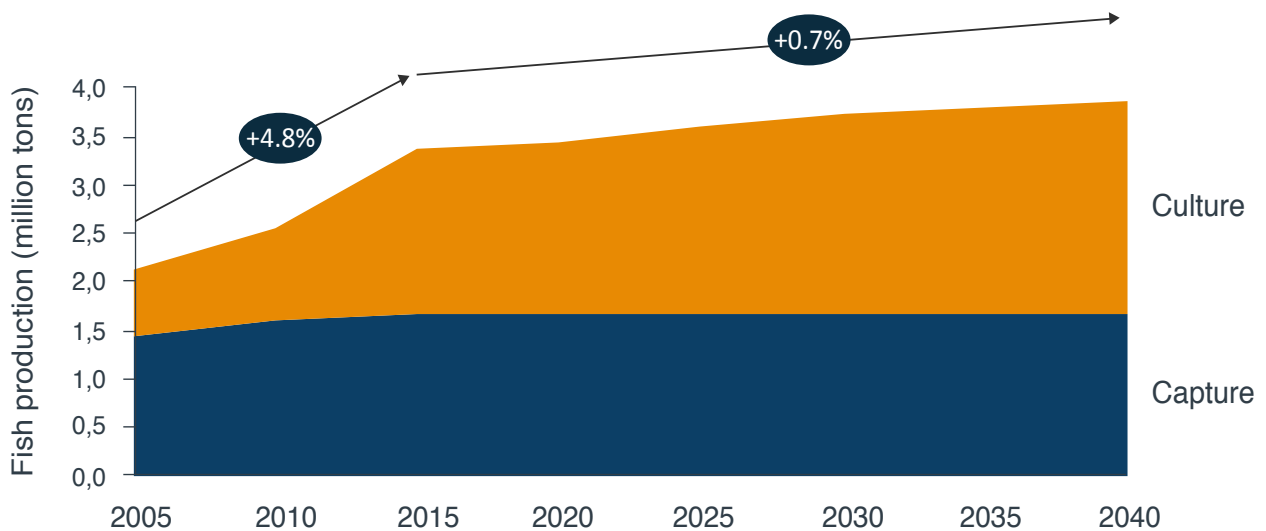
Note: Error bars indicate upper- and lower-bound estimates. Livestock targets are not met under BAU. Milk, meat, and eggs are among the agricultural products with the highest supply gap, in terms of both market demand and nutrition security. It is projected that production of these commodities will increase only slightly over time, thereby missing national targets in every scenario (figure). The importance of animal proteins in childhood development has been highlighted across several key policy instruments. Hence, the projected production gap is a major barrier to meeting the country's nutrition goals.

Figure 3.6 Production (lines) and production targets (asterisks) for key livestock commodities, 2015–2040



Fish production is steadily increasing due to national expansion and intensification of pond aquaculture. With 3.6 million tons of annual production, Bangladesh is one of the largest fish and seafood producers in the world. Capture fisheries are likely to flatten out at their current landing volumes of 1.6 million tons, but the fast growth in aquaculture (mainly pond culture) is projected to continue. This growth will likely be slower than in the past decade (Figure) due to restrictions in available pond area. Although shrimp and prawn culture are quickly gaining importance in Bangladesh, they are not considered in detail in the model.

Figure 3.7 Fish production in Bangladesh, 2005–2040

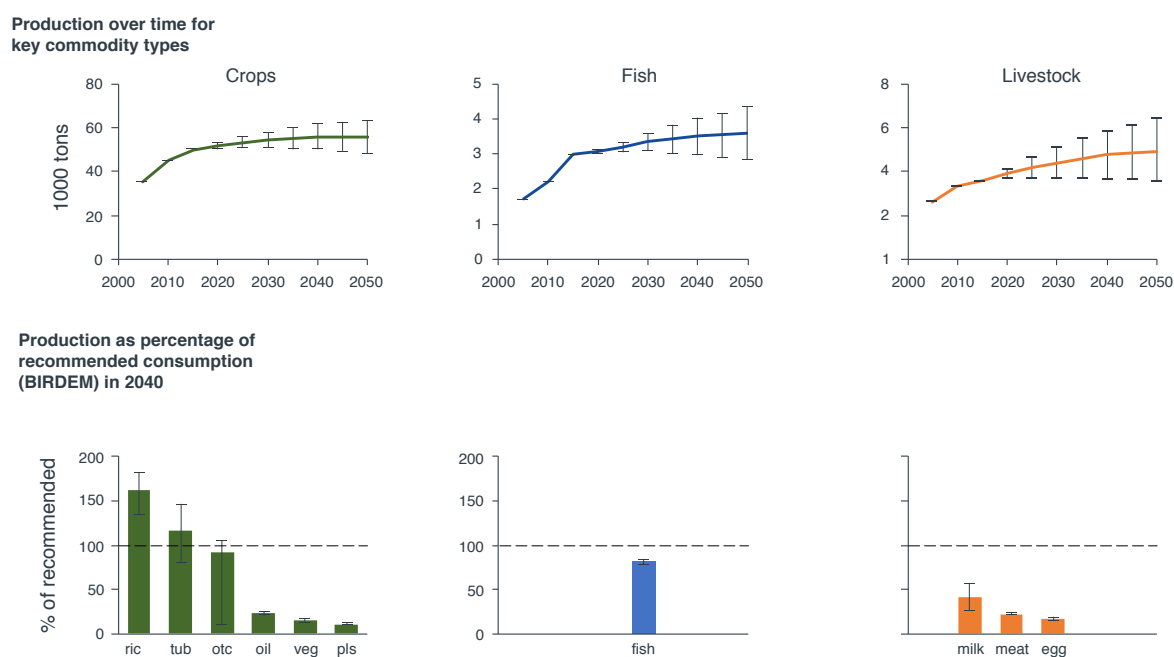


3.4 Resilience targets

Under current trajectories, a self-sufficiency gap will persist for high-demand commodities.

Today's production systems are heavily focused on rice and tubers, which both exceed the production volumes necessary to meet national nutritional demand based on recommendations from the Bangladesh Institute of Research and Rehabilitation for Diabetes, Endocrine and Metabolic Disorders (BIRDEM). There is, however, a large self-sufficiency gap for commodities that are key for early childhood development and nutrition security, such as oils, vegetables, and protein-rich livestock products. Although future worlds. Fisheries production excludes marine capture fisheries (assumed to stay constant over time). Suggests there will be increased production across all key commodities, nutritional demand in 2040 will only be met for rice and tubers. Importantly, the high uncertainties around climate change and future economic development open up the possibility that average values might be too optimistic or pessimistic. For example, by 2040 milk production might reach 4.8 million tons (productive scenario) or only 2.6 million tons (stagnation scenario). This corresponds to 50 percent or 25 percent of nutritional demand, respectively.

Figure 3.8 Projections of production in tons over time (top) and percentage of nutritional demand met by commodity type (bottom), 2000–2050

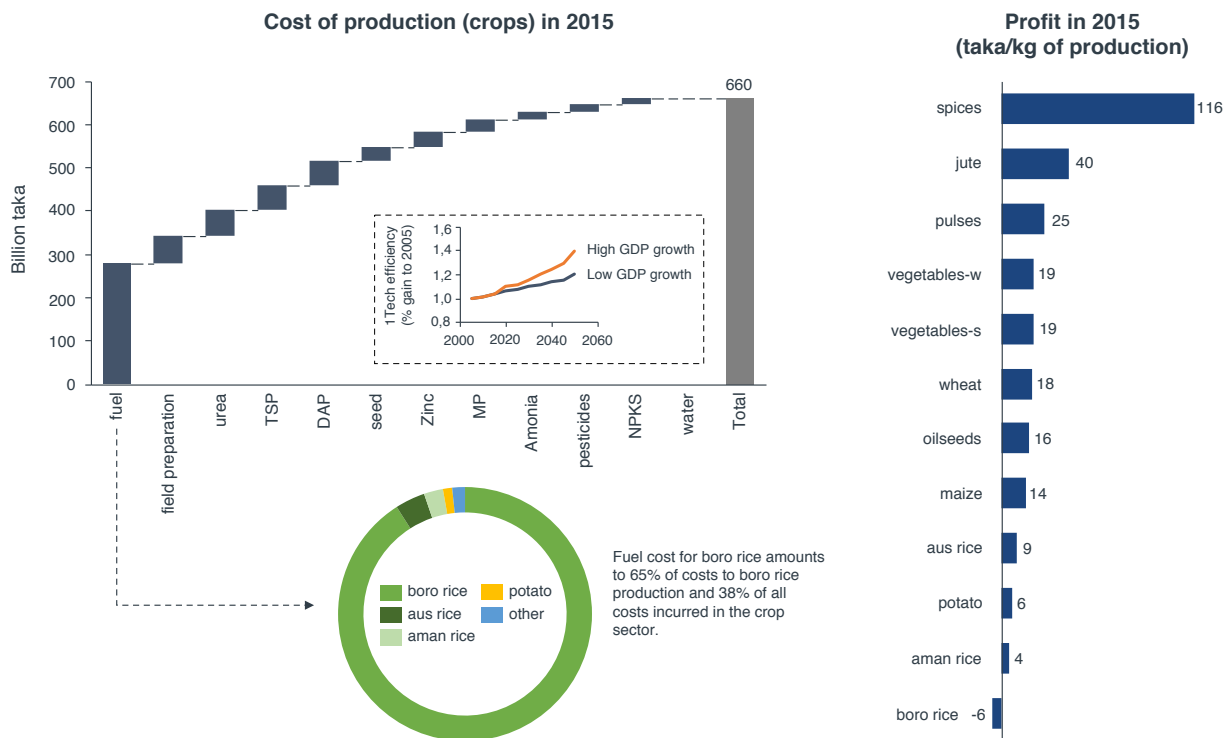


Note: Bar charts indicate average values. Error bars indicate the range of values based on scenarios of future worlds. Fisheries production excludes marine capture fisheries (assumed to stay constant over time).

Demand for high-value products increases disproportionately with economic growth. The current population of Bangladesh is approximately 163 million. High GDP growth is expected to throttle population growth to some extent while helping the emergence of a more affluent urban population. This will, in turn, increase demand for high-value products such as animal protein and vegetables, production of which is projected to fall short of nutritional recommendations. The superior purchasing power of urban populations may increase the stress on nutrition security in rural areas. Because these are country-wide averages, economically disadvantaged households will likely remain vulnerable to supply shortages of important micronutrients.

Income dependence on rice will further increase. In 2015, 61 percent of crop revenue was derived from rice (on a national level), indicating a strong dependence on a single crop for household revenues. Even though increasingly more farmers are diversifying their production, this dependence is projected to increase to between 63.5 percent (congestion scenario) and 66.5 percent (resilient scenario). This is largely due to more optimistic projections of yield increases for rice than for other crops. From an economic standpoint, the strong focus on rice does not make immediate sense given the low profit margins compared to other crops. This is particularly true for boro rice. Figure shows that fuel accounts for 65 percent of production costs for boro rice production and, as a consequence, profit margins are negligible (estimated at –6 Bangladeshi taka per kilogram of boro rice at farm level). Even though these estimates might be slightly off, they show how other crops might be more economically viable than rice. By 2040, technological efficiencies of inputs are expected to increase by 25 percent in the low GDP scenario and 40 percent in the high GDP scenario (as compared to 2005 levels). Assuming constant input costs and farm gate prices, this would slightly increase profitability. However, this increase would apply to all crops, making boro rice no more attractive in 2040 than in 2015.

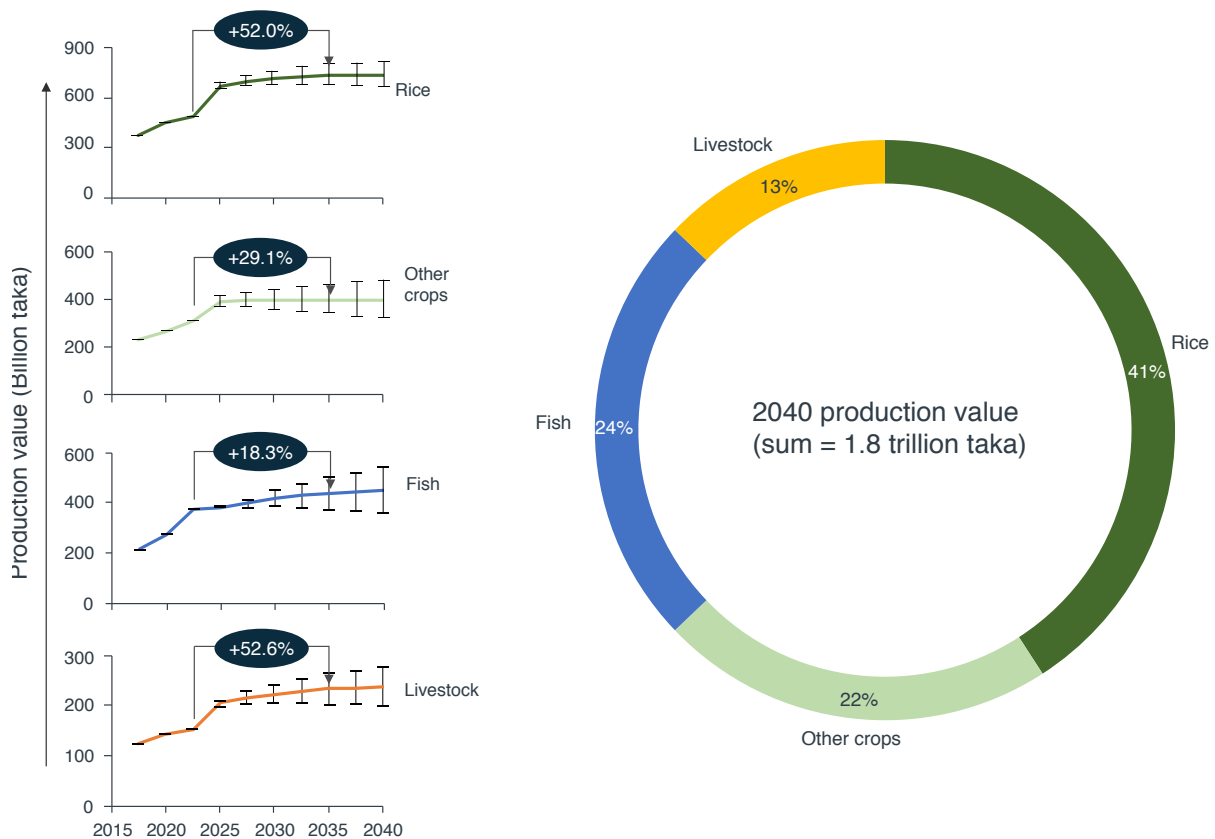
Figure 3.9 Cost items and profitability estimates in 2015



Livestock and rice production are projected to have the largest increases in production value.

In 2015, rice production contributed 37 percent to overall agricultural production value, followed by other crops (23 percent), fish (28 percent), and livestock (12 percent). Under BAU, rice and livestock are projected to have the fastest growth in production value between 2015 and 2040 (approximately 52 percent). However, the contribution of each commodity to overall production value remains relatively stable (Figure). A strong increase in rice value results from crop-specific productivity assumptions that are more optimistic for rice than for non-rice crops. Livestock production is constrained by the availability of roughage, concentrate, grass fodder, and maize, as well as by the animal- and product-specific requirements of each fodder type. Both availability and requirements can be changed through government and private-sector interventions.

Figure 3.10 Production value for major commodities under BAU, 2000–2050



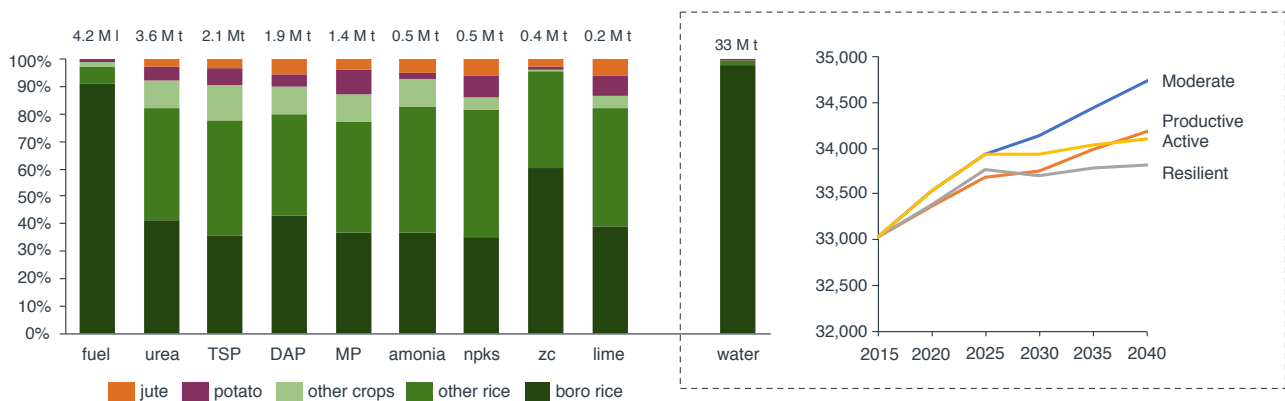
Note: Error bars indicate uncertainties due to climate change and economic development.

Virtually all water used in crop agriculture is earmarked for boro rice. The Ganges–Brahmaputra–Meghna basin is the world’s second-largest riverine drainage basin, with a peak water flow of 1.5 million cusecs (cubic meters per second). However, agrarian demand for water is increasingly competing with hydropower and industrial demand, and more importantly Bangladesh is susceptible to runoff changes caused by extractions of upper-riparian states like India.³⁴ Droughts in dry seasons are increasingly a threat to agricultural production. For the purpose of this report, the assumed target is to reduce overall water dependence while reaching goals of production, resilience, and mitigation.

³⁴ Å. Kolås, L. Barkved, J. Bhattacharjee et al. 2013. Water Scarcity in Bangladesh, Transboundary Rivers, Conflict and Cooperation. Peace Research Institute Oslo. <https://reliefweb.int/report/bangladesh/water-scarcity-bangladesh-transboundary-rivers-conflict-and-cooperation>.

In 2015, more than 80 percent of all inputs were earmarked for rice production (Figure). The most input-intensive crop in Bangladesh’s agriculture is boro rice, contributing to over 40 percent of most inputs. Water use in the agriculture sector and associated fuel use from pumps are almost entirely earmarked for boro rice. Model projections suggest that water use will increase by 0.8–1.7 million liters in the next three decades, with constant distribution of water across rice, spices, and oilseeds. There is no specific or measurable target for water use in any of the major planning frameworks; however, there is mounting concern about the increasing scarcity of water resources.

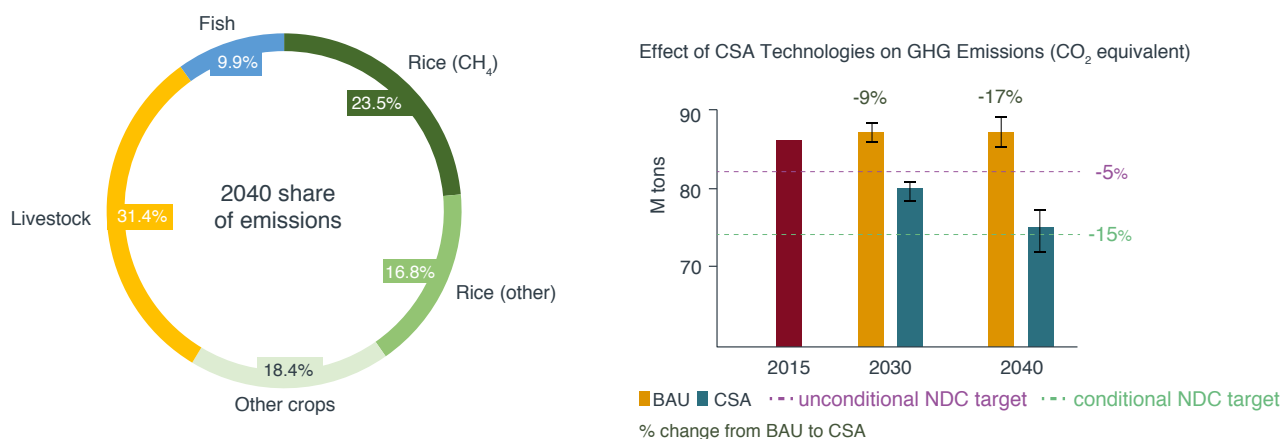
Figure 3.11 Business as usual projections for input use by crop type in 2015 (left) and water use projections (right), 2015–2040



3.5 Mitigation targets

The two mitigation targets focused on in this report are reducing overall CO₂e emissions by 10 percent and placing 20 percent of rice culture under AWD. As shown in figure, GHG emissions under BAU are projected to increase by approximately 5 percent between 2015 and 2040, thereby exceeding the unconditional target by 11 percent and the conditional target by 24 percent in 2040. Methane emissions from livestock and rice will have the greatest impact on sector-wide emissions (31 percent and 23 percent, respectively) in 2040, followed by rice (17 percent), other crops (18 percent), and fish (9 percent). Given the urgency of climate change mitigation and that agricultural emissions represent 40 percent of total emissions, emission levels under BAU are likely not in line with future climate change mitigation commitments. To close this gap, CSA practices will have to focus on either the decreased emission intensity of high-volume commodities (rice) or commodities with high emission intensities (livestock).

Figure 3.12 Projected greenhouse gas emissions from the agriculture sector under BAU



Emission intensity of livestock products tends to exceed global median values. According to FAOSTAT emissions data, the emission intensity (kilograms of CO₂e per kilogram of product) for rice and cereals is below global median levels but significantly higher for major livestock products including eggs, buffalo and cattle meat, and all milk products except for sheep’s milk (Table). The high emissions intensity of livestock products in Bangladesh results from a combination of poor feed and inadequate veterinary services. The highest emission intensities of dairy production, for example, are found in subsistence and extensive dairy systems. A 2017 FAO report suggests, “Improved practices and technologies such as strategic supplementary feeding, and improving the diet quality, adequate animal health control, and improved animal husbandry practices are some of the techniques that can improve dairy productivity and reduce emission intensity.”³⁶

Table 3.2 Emission intensity (kilograms of CO₂e per kilogram of product) for key commodities in Bangladesh, India, and Pakistan and worldwide

| | Rice paddy | Cereals (no rice) | Eggs | Meat | | | | | Milk | | | |
|--|------------|-------------------|------|---------|--------|---------|------|-------|---------|------|------|-------|
| | | | | Buffalo | Cattle | Chicken | Goat | Sheep | Buffalo | Cow | Goat | Sheep |
| Bangladesh | 0.7 | 0.2 | 3.7 | 311.3 | 73.4 | 0.5 | 28.5 | 65.4 | 3.9 | 8.1 | 5.8 | 4.0 |
| India | 0.7 | 0.3 | 0.5 | 66.6 | 108.3 | 0.5 | 44.5 | 45.9 | 0.8 | 1.1 | 1.7 | 7.9 |
| Pakistan | 1.0 | 0.4 | 1.2 | 39.6 | 24.2 | 1.3 | 44.2 | 34.5 | 0.8 | 1.5 | 2.1 | 4.2 |
| Global median | 1.3 | 0.2 | 0.9 | 55.2 | 28.5 | 1.0 | 42.2 | 33.6 | 1.7 | 1.2 | 2.3 | 4.4 |
| Bangladesh deviation from global median | -48% | -15% | 337% | 464% | 158% | -46% | -32% | 94% | 131% | 564% | 150% | -7% |

Source: FAO (Food and Agriculture Organization of the United Nations). 2017. “FAOSTAT: Bangladesh; Food Utilization.” www.fao.org/faostat/en/#country/16.

³⁶ FAO (Food and Agriculture Organization of the United Nations) and New Zealand Agricultural Greenhouse Gas Research Centre. 2017. “Options for Low Emission Development in the Bangladesh Dairy Sector: Reducing Enteric Methane for Food Security and Livelihoods.” FAO, Rome. <http://www.fao.org/3/a-i6822e.pdf>

Section

4

Analytics: The Impact of Climate-Smart Agriculture

4.1 Summary of model projections with climate-smart agriculture

Table 4.1 Overview of CSA impact on key target variables

| | Targets | Impact of CSA | Relevance |
|--------------------|---|---|---|
| Production targets | Reach rice self-sufficiency. | Rice production per person is maintained at close to 2015 levels in three scenarios despite the significant reallocation of cultivated land to non-rice crops. | Rice self-sufficiency is arguably the most important goal of the sector. |
| | Double production of non-rice crops. | Non-rice production experiences a cross-scenario average increase of 66%. | Under BAU, the target cannot be reached for a single non-rice crop. CSA allows for a sustainable diversification. |
| | Meet demand for livestock products. | Demand cannot be met for any of the major livestock products in 2040; however the gap can be closed significantly (by 16%–17%) compared to BAU. | Increased livestock production is constrained by fodder availability in the model. |
| | Increase output from fisheries and aquaculture. | Fish production under CSA doubles compared to BAU in 2040 and exceeds production targets by far. | Fish products are an important source of nutrients and income for economically marginalized households. |
| Resilience | Meet caloric demand. | Dietary supply gaps are closed across all scenarios, with economic development being the key driver for closing the gap. | Increased yield and decreased birth rates under high GDP growth scenarios drive much of the country's ability to meet its dietary self-sufficiency goals. |
| | Increase farm-level income and profitability. | By 2040, farm-level income increases by 23% (420 billion Bangladeshi taka) compared to BAU. Dependence on rice decreases from 41% to 34% and profitability increases for virtually all crops across all divisions. | Resilience against price fluctuations in staple crops is an important target for the sector. |
| | Decrease water use. | Water use under CSA can be reduced by 40% compared to BAU. | Farmers' reliance on water for irrigation will increasingly put them at risk of productivity losses, particularly in arid areas. |

| | | | |
|-------------------|--|--|---|
| Mitigation | Decrease agricultural emissions to meet NDC targets. | Taken together, implementation of CSA can decrease 2015 emission levels by 13 percent by 2040. | The country's NDC states sector-wide goals of 5% (unconditional) and 15% (conditional to funding) emission reductions as compared to a 2015 baseline. |
|-------------------|--|--|---|

Note: The Excel-based agricultural model built to support this CSAIP allows for user-defined assumptions about the adoption of commodity-specific CSA technologies. This section provides a snapshot of one configuration (summarized in Appendix B) and represents the modeler's best understanding of an ambitious yet realistic level of adoption across technologies.

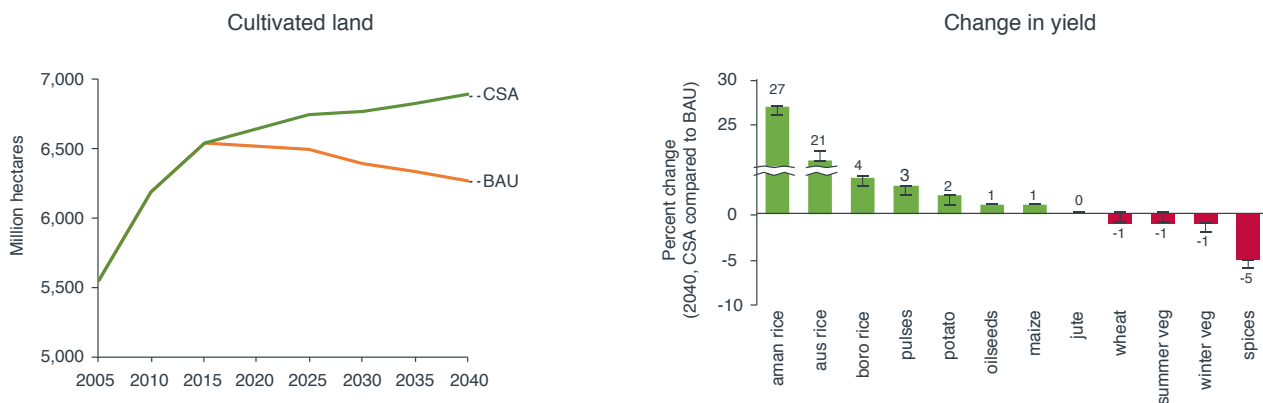
4.2 Production targets

CSA technologies increase the hectares of available crop land and the land's productivity. The projected feasible yield is a function of total feasible production and available cropland. Both of these variables are affected by external factors (such as climate change and economic development) and internal factors (such as policies, technologies, and farm management). Table uses the example of aman rice to demonstrate how feasible yield is affected by external and internal factors. Figure shows how available cultivated land and feasible yield change with CSA if all CSA technologies are implemented. Using averages across future scenarios, cultivated land under CSA is expected to be 600,000 hectares greater than under a BAU scenario. Similarly, the feasible yield under CSA exceeds BAU values by up to 27 percent for aman rice but decreases up to -5 percent for spices.

Table 4.2 Change in yield of aman rice in the Dhaka division as a function of external factors (climate change, economic growth, and historic growth) and CSA-specific factors

| Year | Change to the base yield (2005 values) as a function of | | | | | Implementation rate of CSA technologies |
|------|---|-----------------|----------------|----------------|---------------|---|
| | Historic growth | Economic growth | Climate change | Seed varieties | Fertilization | |
| 2015 | 0% | 0% | 0% | 61% | 4% | 0% |
| 2020 | 22% | 7% | -1% | 61% | 4% | 14% |
| 2025 | 22% | 14% | -2% | 61% | 4% | 29% |
| 2030 | 22% | 21% | -3% | 61% | 4% | 43% |
| 2035 | 22% | 26% | -3% | 61% | 4% | 57% |
| 2040 | 22% | 29% | -4% | 61% | 4% | 71% |

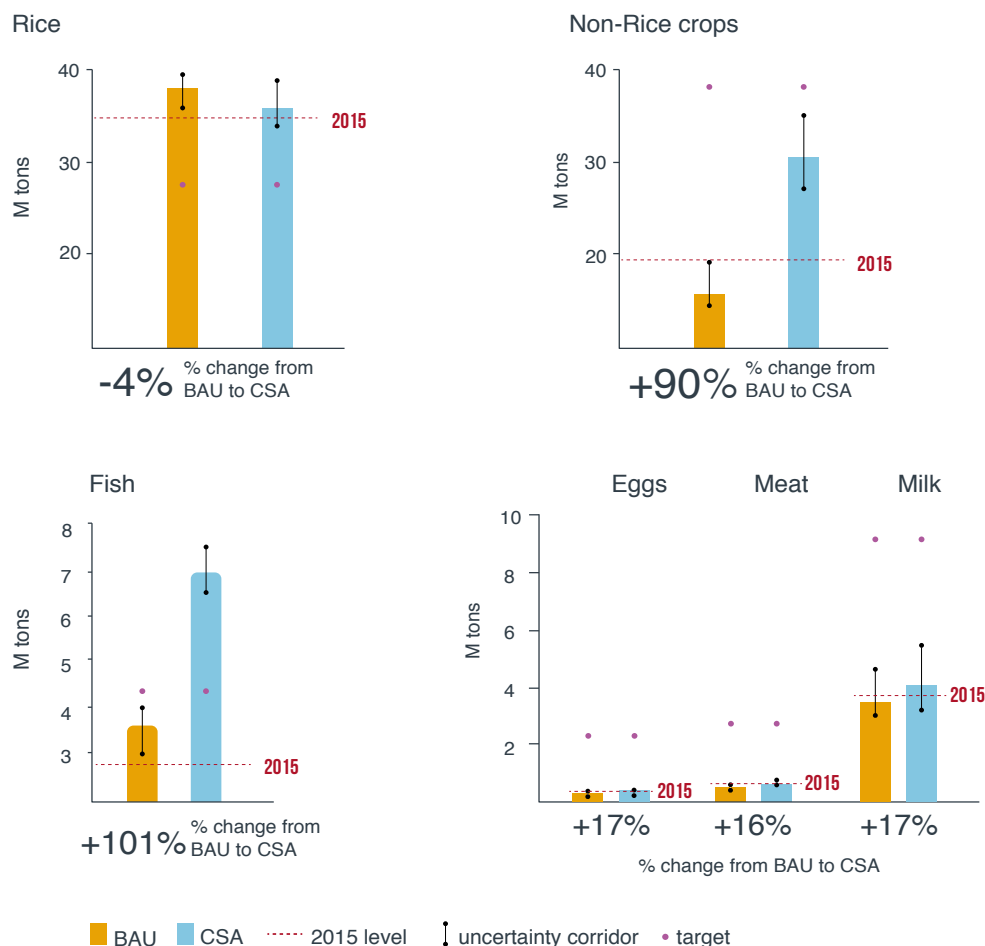
Figure 4.1 Cultivated land (left) and yield (right) under BAU and CSA



CSA increases the productivity of livestock and aquaculture. The application of improved feed for indigenous and crossbred cattle and the application of slurry as a biofertilizer have a compound effect on the productivity of cattle meat (42 percent) and cattle milk (70 percent). The CSA technologies applied to the fisheries and aquaculture sector include integrating small indigenous and highly nutritious fish into carp ponds and intensifying extensive fishpond aquaculture. Although yield is thought to increase by an average of 150 percent when transitioning from extensive to semi-intensive ponds, this change is projected for only 10 percent of overall fishponds in the country. The overall effect on average pond aquaculture productivity hence remains very low, at 3–4 percent compared to BAU. Yield growth in floodplain capture, however, is estimated at 9 percent every year, thereby dramatically increasing the potential of fisheries.

Production targets are met for crops and fish but not for livestock products. Most importantly, the implementation of CSA allows rice production to be maintained at close to self-sufficiency while simultaneously dramatically increasing the production of non-rice crops (Figure). Increased production of non-rice cereals (such as wheat) and of tubers (potato) drives production higher under CSA compared to under BAU. This increased production would allow Bangladesh to reach the ambitious target of doubling the production of non-rice crops, a result that is robust across almost all future scenarios. Similarly, fish production is projected to benefit significantly from CSA implementation, leading to almost doubled production compared to BAU. This is more astonishing considering that BAU projections show a 19 percent increase between 2015 and 2040, even in the absence of CSA. The largest part of this increase comes from floodplain capture fisheries and from pond aquaculture.

Figure 4.2 Projected production in 2040 under BAU and CSA as compared to stated targets



4.3 Resilience targets

The full adoption of all CSA technologies would allow a slight calorie surplus by 2040 in all future scenarios except stagnation (high climate change, low economic development) (Figure). Results differ most significantly along the gradient of economic development. Strong economic development allows for strong yield increases in the crop sector and a subsequent positive impact on fodder availability in the livestock sector. While CSA promises to meet overall caloric targets, animal proteins (except for fish) are far from meeting the recommended dietary demand.

Figure 4.3 Coverage of BIRDEM food requirements by domestic production under CSA by 2040

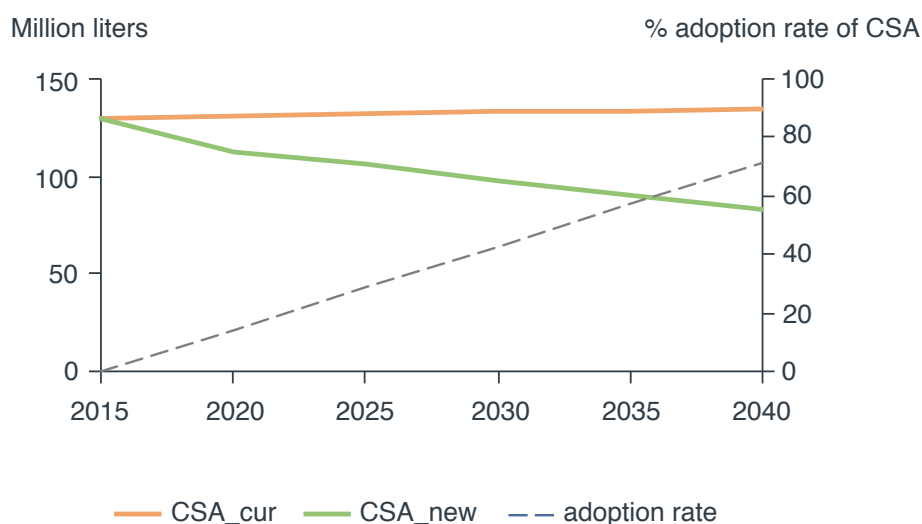


Production value at the farm level more than doubles under CSA. Production value under a CSA scenario would by far exceed production values under a BAU scenario. Summarizes model projections of production value. While values for rice are low (but positive), the largest gains can be expected from fish and non-rice crops. Fish values include aquaculture and floodplain fisheries; the latter contributes the majority of the value increase. A fourfold increase in production value between 2015 and 2040 (annual growth of 22 percent) is assumed. Dependence on rice as a source of income is expected to decrease from 41 percent (across commodities) under BAU to 34 percent under CSA.

CSA consistently leads to increased profitability at the farm level. As a result of increased yield across scenarios of climate change and decreased input costs, CSA outperforms the profitability of current practices across almost all crops and divisions. The magnitude and directionality of these results hold across all future scenarios. The decreased profitability of boro rice and aman rice stems from increased labor costs associated with deep urea placement, an important consideration in the context of CSA adoption. In the absence of other CSA practices that drive up yield or increase the availability of cultivated land (such as improved seed varieties), profitability would be considerably lower.

Water use is projected to decrease by 40 percent under CSA. Decreased reliance on irrigation-dependent boro rice, as well as the increased use of buried pipe systems and AWD would allow the sector to decrease its dependence on irrigation by 40 percent in 2040 compared to BAU levels (Figure).

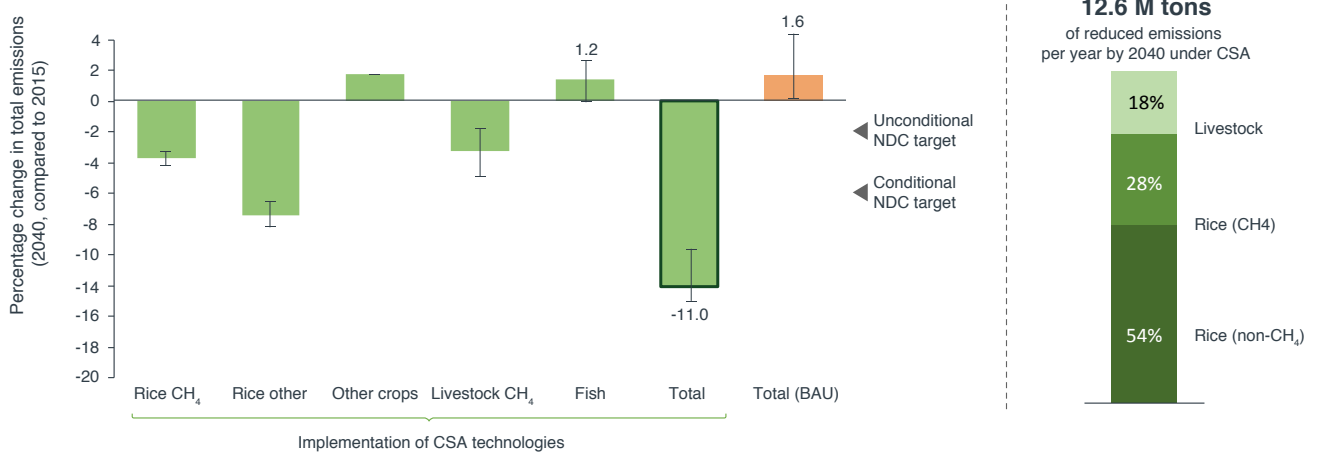
Figure 4.4 Water use from boro rice production under BAU and CSA, 2015–2040



4.4 Mitigation targets

CSA would allow the agriculture sector to contribute to emission reductions proposed in the NDC at the same level as other sectors. Under a BAU scenario, the agriculture sector’s GHG emissions would increase by approximately 2 percent compared to a 2015 baseline. Overall, CSA is projected to decrease 2015 emission levels by 13 percent. As shown in figure 4.5, virtually all emission reductions are expected to come from the crop sector (a total of 12.6 million tons annually by 2040). Most significantly, a decrease in fuel use, deep urea placement, and diversification away from rice production would lead to emission cuts by 6.9 million tons (around an 8 percent decrease from 2015 levels, contributing to 54 percent in overall emission reductions). The decrease in enteric fermentation would create reductions of 3.6 million tons, or 28 percent of overall reductions. The livestock sector is projected to reduce emissions by 3.1 million tons, contributing to 18 percent of overall crop emissions reductions. This points to large productivity gains given that projections show a 90 percent increase in cattle heads between 2015 and 2040. In contrast, according to preliminary calculations, fisheries/aquaculture and non-rice crop emissions would increase by 1.2 million tons and 1.4 million tons, respectively, which must be considered against the backdrop of considerable production increases.

Figure 4.5 Effect of CSA technologies on GHG emissions, 2015–2040



Note: The bar chart indicates the average difference between 2015 and 2040 values. The error bars show the upper and lower bounds of change due to climate change and economic development scenarios.

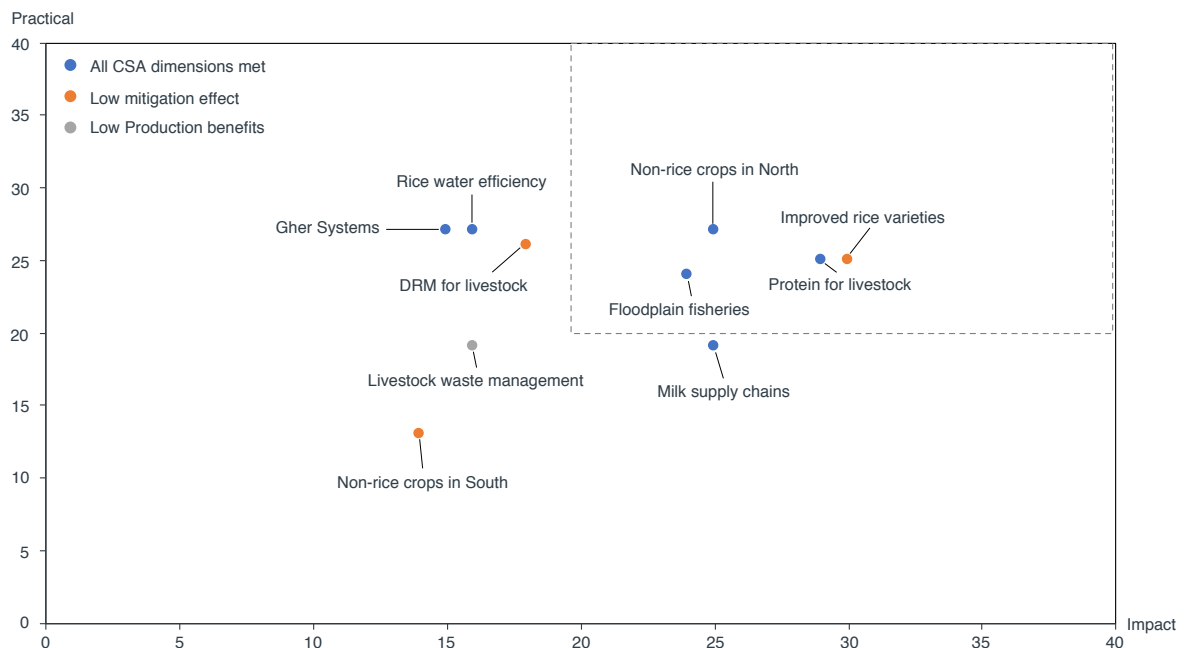
Section 5

Investment: Climate-Smart Agriculture Opportunities

5.1 Formulation of four priority CSA packages for the Bangladesh CSAIP

Four CSA packages were prioritized based on quantitative and qualitative input. Ten CSA packages were short-listed from a large solution space of potential CSA practices in Bangladesh. The packages were then evaluated based on a dozen eligibility and selection criteria. The key criteria included impact (based on policy goals and stakeholder visioning exercises) and practicality (alignment with country priorities and likelihood of success). The quantitative model was used as a starting point in the technical workshop to inform and validate experts' assessments of the impact of each package. The resulting scores (Figure) are not a result of a direct translation of model results into a prioritization matrix but are based on additional expert judgements informed by key results.

Figure 5.1 Solution space of short-listed CSA packages plotted by practicality and impact



The prioritized packages were then reformulated to maximize synergy and incorporate aspects of lower-ranking packages. As a final step in the prioritization of CSAIP packages, the highest-ranking interventions in the short-listed solution space were amended to incorporate valuable aspects of unselected packages. This approach facilitated a semi-quantitative selection process while reducing the risk of irrelevant and partial propositions resulting from a rigid decision-making system. For example, Package 1 takes the prioritized intervention “improve rice varieties” as a starting point for a comprehensive approach to the development and distribution of high-yielding stress-tolerant rice and non-rice crop varieties. Package 2 in turn comprehensively addresses the cross-sectoral challenges women face. The starting point of Package 2 is the vulnerability of poor households to climate change and their inability to benefit from innovative CSA technologies, including floodplain fisheries, pond aquaculture, and livestock DRM. The resulting package is a comprehensive approach to helping homestead agriculture units in southern Bangladesh (particularly women) benefit from powerful but poorly communicated CSA technologies. Hence, the final proposed packages are informed by a thorough process of modeling and consultation, but they do not rigidly adopt the results of filtering exercises.

Overview of final packages

The final packages are inclusive of all subsectors and focus on key CSA goals. The final four CSA packages are summarized in Table and are discussed in the following sections.

Table 5.1 Overview of Package 1

| Package name (short) | Sectoral focus | Impact categories | Regional focus |
|--|-------------------------|--|----------------------|
| 1. Agricultural innovation system | Rice and non-rice crops | Crop productivity (+++) Decreased losses (++) Water use (++) Emission intensity (+) | National |
| 2. Gender-sensitive development of homestead production | Cross-sectoral | Climate resilience (+++) Livestock DRM (++) Diversified income (++) Nutrition security (++) | Southwest Bangladesh |
| 3. Resilience through diversification | Rice and non-rice crops | Diversified income (+++) Water use (++) Climate resilience (++) | Northwest Bangladesh |
| 4. Livestock—upstream value chain development | Livestock and crops | Nutrition security Climate resilience (++) | National |

5.2 Package 1: Agricultural Innovation System

Table 5.2 Change in yield of aman rice in the Dhaka division as a function of external factors (climate change, economic growth, and historic growth) and CSA-specific factors

| | |
|---|---|
| Subtitle | Strengthen the agricultural innovation system to provide the required research and development advances to maintain yield growth in the face of climate change by building adaptive capacity, particularly through adaptive varietal development. |
| Context | Bangladesh has tripled rice production since independence in 1971 and has reached self-sufficiency. However, maintaining this strategic government goal will be as challenging as reaching it. Under a high climate change scenario, available cropland is projected to decrease by approximately 6.5 percent on a national level by 2040 (in Barisal, as high as 30 percent). At the same time, the population is expected to increase to 170–230 million. Even though rice yields are projected to increase by 10–30 percent under BAU, two out of four scenarios project per capita rice availability will drop below 2015 levels. Maintaining current levels of per capita rice availability in a scenario of low economic growth and high climate change (stagnation) would require a yield increase of at least 17 percent over BAU levels. As traditional productivity levers (cropland expansion, higher cropping intensities, expanded irrigation infrastructure, increased fertilizer, and other inputs) are slowly maxing out, the sector will have to rely on an effective agricultural innovation system (AIS) that allows for rapid cycles of research development, testing, and deployment of technologies; a high and sustained adoption rate at the farm level; and mechanisms to identify and prioritize budget and capacity to respond to a dynamic sector in transition across agencies. While high-quality improved seeds are thought to be the most effective way to further increase yield, only a quarter of rice seeds used in Bangladesh are deemed high quality. Package 1 uses the development of higher-yielding and more stress-tolerant varieties as an example of how an efficient agricultural innovation system could accelerate the research and development required for sustainable yield growth despite climate change. Other relevant areas that could considerably benefit from an improved agricultural innovation system include the development and application of biological alternatives to chemical fertilizers and pesticides. |
| Investment opportunities | <ul style="list-style-type: none"> • Invest in platforms that allow close collaboration among stakeholders and promise quick development, deployment, and evaluation of new varieties. • Invest in producer cooperatives that engage directly with seed distributors and research institutions to adapt development and deployment to local environments. • Invest in the private sector and enabling environments to accelerate the development and deployment of new varieties. |
| Potential impact | <ul style="list-style-type: none"> • Close the demand gap for quality seeds and increase yields by up to 10 percent with positive effects under all scenarios, including intense climate change. • The isolated effect of high-yielding and stress-tolerant seeds on GHG emissions is negligible, but increased productivity frees up current rice land for non-rice crops, thereby decreasing emissions and water use and increasing farmer-level profitability. |
| Cost of comparable World Bank projects | <ul style="list-style-type: none"> • Comparable country-level AIS projects in Peru and Bolivia have costs ranging from US\$116 million to 256 million (purchasing power parity [PPP] 2017 US dollars). • Dominating cost categories are (a) extension services and research and (b) institutions, planning, and capacity building. |
| Estimated cost in Bangladesh | <ul style="list-style-type: none"> • US\$ Nominal 2017: US\$117 million (Range: US\$111 to US\$125 million) • US\$ PPP 2017: US\$300 million (Range US\$285 million to US\$320 million) |
| Cost Benefit Analysis | <ul style="list-style-type: none"> • IRR: 24% • ERR: 31% • NPV: US\$ 67 million • ENPV: US\$ 98 million |

Context and problem statement

Bangladesh has achieved impressive growth and innovation in the agriculture sector over the last several decades. Rice production tripled between 1972 and 2014, from 9.8 to 34.4 million tons, and saw one of the fastest rates of productivity growth in the world since 1995, averaging 2.7 percent per year.³⁶ Only China has shown higher rates of productivity growth. Productivity growth accounted for 90 percent of the reduction in poverty in Bangladesh between 2005 and 2010. This intensification occurred through a combination of irrigation, fertilization, access to credit for farmers, and trade liberalization of production inputs that drove the agriculture sector from almost entirely subsistence to semi-intensive systems.³⁷

Rice remains the most important agricultural commodity agronomically and politically. Rice constitutes 95 percent of total food grains produced and consumed in Bangladesh, as well as 75 percent of the daily calories and 55 percent of the daily protein consumed. It covers 77 percent of farmed land area, followed by wheat with less than 3 percent. Rice food systems alone account for 10 percent of GDP.³⁸ Continuing to meet demand is crucial to allow the country to move forward. Forward-looking policies for the country, including the Vision 2030 and the National Agricultural Plan, emphasize continued self-sufficiency of production, particularly in rice, as Bangladesh reaches higher middle-income nation status and experiences further population growth.

Climate change, urbanization and population growth are challenging the status quo of rice self-sufficiency.

1. **Sea level rise, saline intrusion, and erosion are reducing the amount of arable land.** Arable land is decreasing in Bangladesh by more than 1 percent per year due to a combination of saline intrusion and sea level rise in the southern regions and erosion from annual river flooding across the country. To a lesser extent, urbanization also limits the amount of land that is available for farming.
2. **Changes in precipitation are projected to exacerbate seasonal fluctuations in water availability.** Precipitation during monsoon season is expected to increase, and rain during the dry season is expected to decrease. The increased intensity makes growing crops more challenging, as they must be able to withstand submerged or waterlogged soils and dry soils. Drought is anticipated to spread, particularly in the northwestern portion of Bangladesh where boro is grown.
3. **With population projected to increase to 170–230 million by 2050, pressure on rice production will increase.** Much of the increased demand will come from urban areas, where population density is increasing.
4. **Maintaining self-sufficiency will require significant increases in production per hectare.** In order to adequately prepare for a possible future marked by strong climate change and low economic development (stagnation), significant yield increases are required. Figure 5.2 shows that the projected

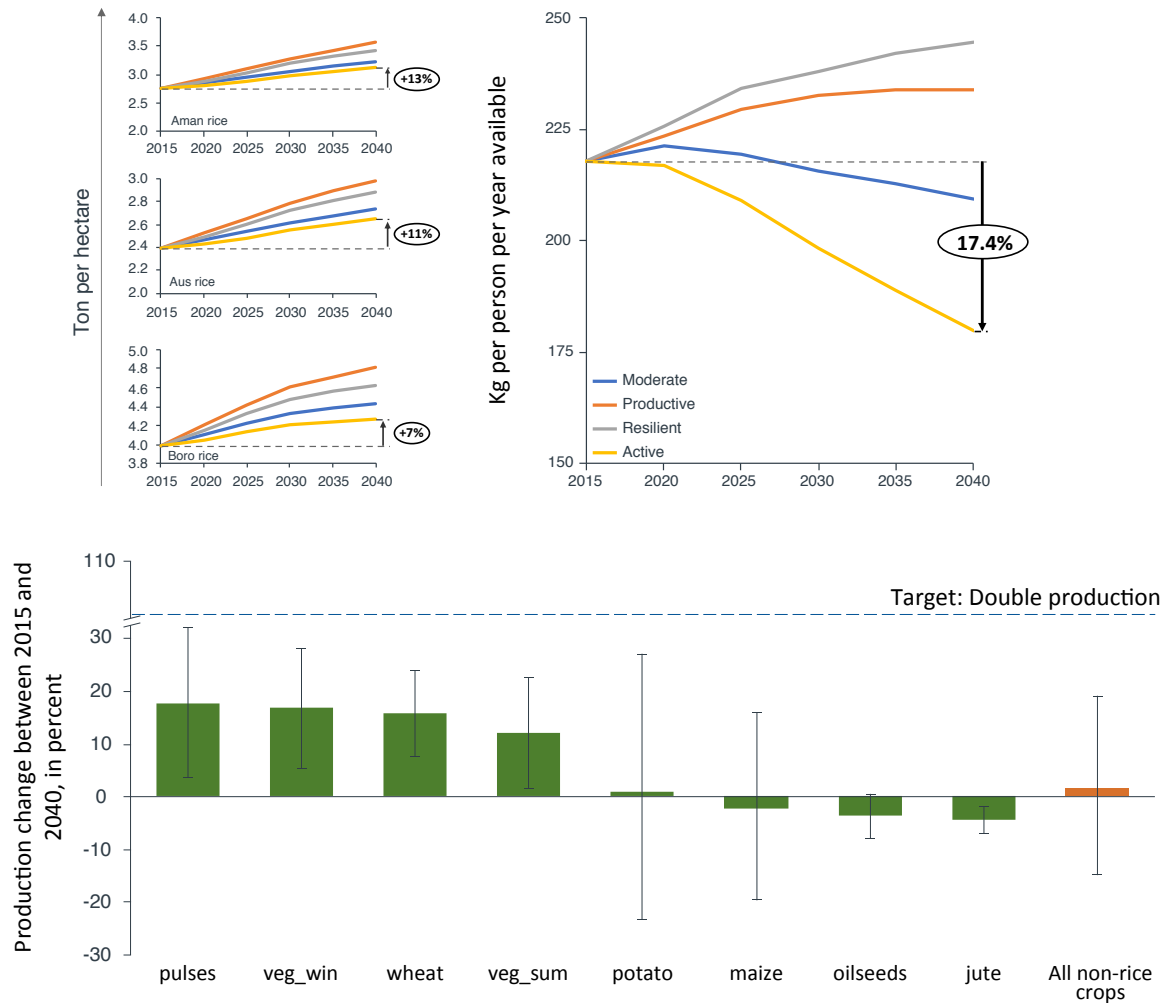
³⁶ World Bank. 2016. "Bangladesh: Growing the Economy through Advances in Agriculture." <http://www.worldbank.org/en/results/2016/10/07/bangladesh-growing-economy-through-advances-in-agriculture>.

³⁷ Raisuddin Ahmed, Steven Haggblade, and Tawfiq-e-Elahi Chowdhury, eds. 2000. *Out of the Shadow of Famine: Evolving Food Markets and Food Policy in Bangladesh*. Baltimore, MD: Johns Hopkins University Press.

³⁸ M. Matiur Rahman and Md Rafiqul Islam Mondal. 2010. "Agricultural Research Priority: Vision—2030 and beyond." Bangladesh Agricultural Research Council, Dhaka. http://s3.amazonaws.com/zanran_storage/www.barc.gov.bd/ContentPages/52596024.pdf.

increase in yield (tons per hectare) for this scenario is 7 percent for boro rice, 11 percent for aus rice, and 13 percent for aman rice. Given fast population growth in this scenario (28 percent between 2015 and 2040), per capita supply of rice risks falling to 17.4 percent below 2015 levels in the same period. Consequently, a yield increase of 17 percent is required beyond expected productivity growth rates to maintain today's level of rice self-sufficiency.

Figure 5.2 Yield gap to maintain rice supply at 2015 levels (based on BCSAIP Model results)



Because previous methods of intensification are seeing diminishing returns, new methods are necessary for innovation and intensification to continue. Only 4 percent of land remains fallow each year,³⁹ and arable land is decreasing at a rate of 1 percent per year.⁴⁰ Unlike other countries, Bangladesh does not have additional land area to expand into for agricultural production. At the same time, increased cropping intensity, now at approximately 185–200 percent nationwide and as high as 300 percent in some areas, has left soils depleted of nutrients and with little room to improve yield on the same land base.⁴¹ More than 60 percent of soils are in some way degraded.

³⁹ Bangladesh, Ministry of Agriculture. 1999. "Bangladesh National Agriculture Policy." http://dae.portal.gov.bd/sites/default/files/files/dae.portal.gov.bd/page/dd7d2be1_aeef_452f_9774_8c23462ab73a/NAP.pdf.

⁴⁰ M. Matiur Rahman and Md Rafiqul Islam Mondal. 2010. "Agricultural Research Priority: Vision—2030 and beyond." Bangladesh Agricultural Research Council, Dhaka. http://s3.amazonaws.com/zanran_storage/www.barc.gov.bd/ContentPages/52596024.pdf.

⁴¹ M. Matiur Rahman and Md Rafiqul Islam Mondal. 2010. "Agricultural Research Priority: Vision—2030 and beyond." Bangladesh Agricultural Research Council, Dhaka. http://s3.amazonaws.com/zanran_storage/www.barc.gov.bd/ContentPages/52596024.pdf.

The massive yield increases from the past from irrigation and fertilization have tapered off in the past decade, leaving Bangladesh in need of new solutions to continue to boost productivity. This has led to decreases in rice production growth, which slowed from 4.8 percent in 2007–11 to 0.7 percent in 2012–16.⁴²

Even when solutions exist, low rates of on-farm adoption limit the ability to reach scale. Relatively low adoption of existing technologies has limited the potential for these technologies to reach scale. Adoption has been low due to farmers' lack of knowledge, insufficient extension services, and the promotion of a limited number of varieties by research institutes. While 81 varieties of rice were developed by BRRI (25 boro, 36 aman, and 10 aus), and an additional 18 varieties were developed by the Bangladesh Institute of Nuclear Agriculture (BINA), more than 40 percent of rice production comes from one strain of boro rice.

Enabling Environment

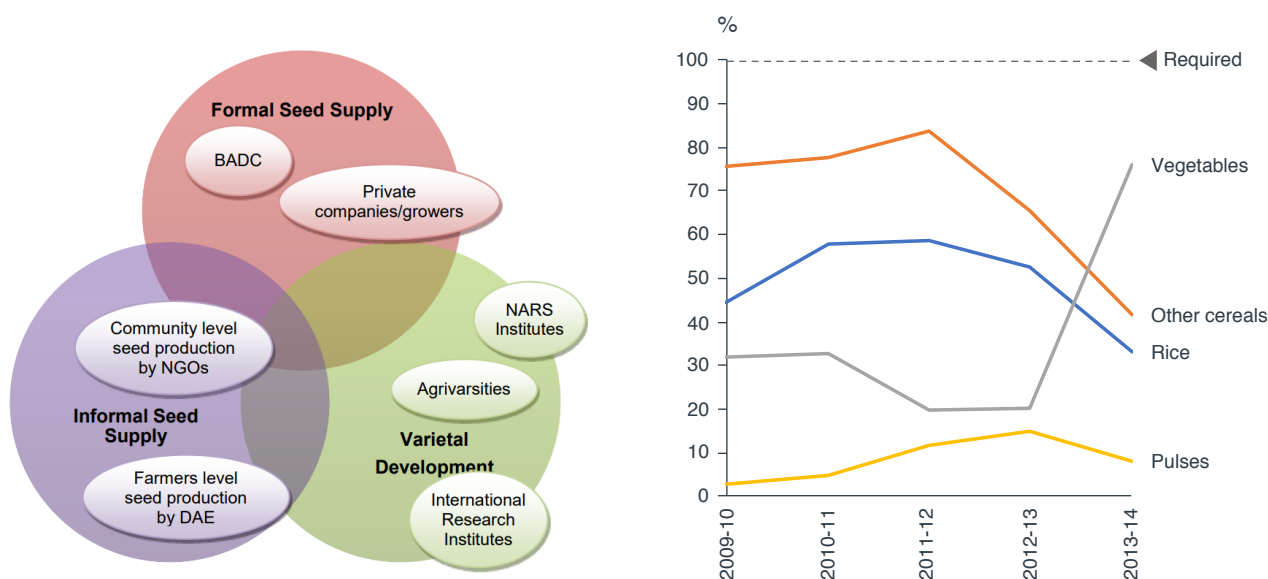
Since the 1970s, research-focused institutions and actors in Bangladesh have supported the importance of research and innovation. The principal actor is MOA, which houses BARC, six agricultural research institutes, the DAE, the Seed Certification Agency (SCA), the Agricultural Information Service, and the Department of Agricultural Marketing (DAM). BRRI serves as the host institute of the International Rice Research Institute (IRRI). BINA uses nuclear technologies to research the production of new varieties of crops, land and water management, technologies to improve crop quality and quantity, and methods for control of disease and insect pests. BARI is the largest multicrop research institution, housing 800 scientists. MOFL is responsible for increasing production, achieving self-sufficiency in protein, and conducting research and extension programs. The Department of Livestock Services (DLS) supports planning and implementation of extension activities. The Department of Fisheries (DOF) is responsible for all matters relating to fishing and fisheries. The Bangladesh Fisheries Research Institute (BFRI) is an autonomous research organization linked to MOFL to support fisheries development. The Palli Karma Sahayak Foundation (PKSF), which was established for sustainable poverty reduction through employment generation, works to enhance the capacities and resilience of the poor. The Bangladesh Academy for Rural Development (BARD) and the Rural Development Academy (RDA) operate to build capacities in rural development. The Horticulture Export Development Foundation was established by MOA to promote agribusiness. The Krishi Gobeshona Foundation (KGF) provides competitive research grants and technical support to researchers working for public sector agricultural research institutes. This list is nonexhaustive; there are many additional public and private stakeholders engaged in agricultural research and innovation in Bangladesh.

Research institutes alone are not enough to provide the innovation required to maintain and increase productivity growth rates. Investments in public research and development, extension, and education have shown high returns and pro-poor growth (or economic growth that benefits the poor). But these investments alone cannot meet the change of pace needed in Bangladesh. Innovation must occur through dynamic interactions between actors involved in the rice value chain, including growers, processors, packagers, distributors, and consumers. Agricultural innovation systems (AISs) represent integrated relationships and interactions between research organizations, extension services, and education actors. As shown in Figure, quality rice seed supply is currently around 40 percent of demand.

⁴² IFPRI (International Food Policy Research Institute). 2018. 2018 Global Food Policy Report. Washington, DC: IFPRI. <https://doi.org/10.2499/9780896292970>.

The enabling environment for this package can be strengthened with building blocks that already exist. A SWOT analysis from the second stakeholder workshop suggests that the low-capital/low-technology nature of this package is conducive to widespread adoption if private sector links are strengthened (figure 5.4). This can be accomplished by licensing farmer associations for research and development and gearing extension systems toward input supply chains and entrepreneurship among farmers. The following sections highlight several more opportunities to strengthen the enabling environment.

Figure 5.3 Schematic overview of national seed system in Bangladesh (left) and seed supply (BADC, DAE, and private companies) as a percentage of agricultural requirements (right)^a



Sources: Source: Mahabub Hossain, Abdul Bayes, and S. M. Fakhru Islam. 2018. "A Diagnostic Study on Bangladesh Agriculture." Agricultural Economics Working Paper, BRAC, Dhaka. <http://blog.brac.net/wp-content/uploads/2018/11/Agriculture-Report.pdf>.

Figure 5.4 SWOT analysis of Package 1 based on the second stakeholder workshop held in Dhaka, April 2018

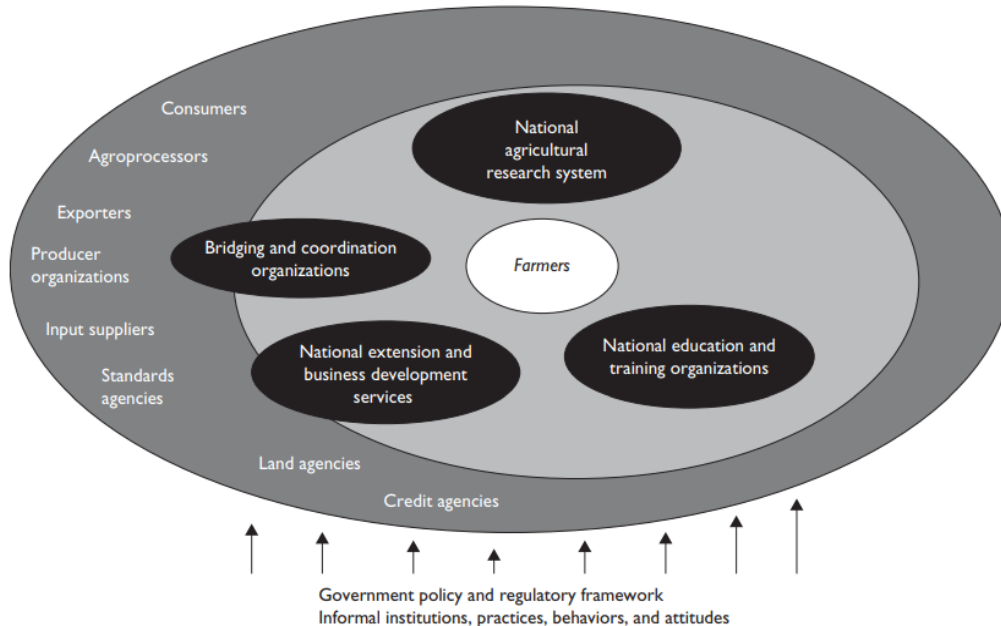
| | Helpful | Harmful |
|----------|---|---|
| Internal | <p>Strengths</p> <ul style="list-style-type: none"> • There are excellent rice research centers in Bangladesh. • Quick returns on the farm level promise rapid uptake. • Technologies are known and proven. | <p>Weaknesses</p> <ul style="list-style-type: none"> • Seed quality is not consistently high. • The private sector lacks interest in engaging in rice development. • There are high up-front costs and delays in return for the private sector. • There is a lack of land available for R & D. |

| | | |
|-----------------|--|--|
| External | <p>Opportunities</p> <ul style="list-style-type: none"> • Support formation of innovative farmer associations that contribute to R & D of improved seeds. • Support innovation platforms for information exchange along the entire supply chain. • Support the private sector to drive competitive, demand-based R & D and increase adoption of quality seeds. | <p>Threats</p> <ul style="list-style-type: none"> • There is resistance to delegating rice R&D to the private sector. • Farmer associations and the private sector lack capacity to take on R & D of adaptive varieties. • There are no adequate monitoring systems for seed and fertilizer quality. |
|-----------------|--|--|

Investment opportunities

An innovation system is defined as “a network of organizations, enterprises, and individuals focused on bringing new products, new processes, and new forms of organization into economic use, together with the institutions and policies that affect their behavior and performance.” It encompasses all relevant actors along the supply chain and seeks to increase the efficiency of each component through strong networks (figure 5.5). Innovation cooperatives (section 1.1.1.1), collaborative platforms (section 1.1.1.2) and a competitive private sector (section 1.1.1.3) are particularly relevant aspects of agricultural innovation systems in the context of improved varieties in Bangladesh. They are, however, not the only components necessary to implement an efficient AIS. Apart from strengthening the development of new varieties, an improved AIS can also benefit research in other areas that promise to enhance the sector’s capacity to adapt to climate change. Examples include the development and application of yield-boosting and cost-effective bio-pesticides and bio-fertilizers.

Figure 5.5 Schematic overview of an agricultural innovation system



1.1.1.1 Invest in innovation cooperatives

Stakeholder platforms are required to connect research and technological capabilities with farmers’ needs and market demand. Farmers are the linchpin in every AIS; every innovation has to

⁴³William M. Rivera, Gary Alex, James Hanson et al. 2006. “Enabling Agriculture: The Evolution and Promise of Agricultural Knowledge Frameworks.” In Proceedings of the Association for International Agricultural and Extension Education Annual Conference, 22nd Annual Conference, Clearwater Beach, FL. <https://www.aiaee.org/attachments/article/847/580.pdf>.

be understood, implemented, promoted, and improved by farmers. The disaggregated nature of the producer segment in Bangladesh's crop subsector calls for strong cooperatives or associations that communicate farmer demand upstream (researchers, extensionists, and seed producers) and gauge market dynamics of downstream actors (processors and wholesale buyers). While traditional farmer cooperatives have had mixed success in this role, three alternative organizational arrangements should be considered concrete investments in Bangladesh.⁴⁴ Examples from outside Bangladesh are summarized in Box.

1. **Traditional commodity-based farmers organizations**, such as the Kenya Tea Development Agency (KTDA) or India's dairy cooperatives, can manage input supply, output processing, and marketing, or these activities may be outsourced to private firms. Less attention goes to facilitating interactions and cooperation with potential partners in innovation. While the declared goal is usually the diffusion of technical innovations, successful commodity-based farmers organizations can coordinate large numbers of farmers. These organizations often sponsor their own research teams.
2. **Market-oriented farmers organizations** seek to improve market access through collaboration with key actors in the marketing chain (supermarkets or brokers). Often this kind of farmer organization is created with assistance from NGOs and/or externally funded projects (the Latin American farmers network Papa Andina is an example). Innovations are viewed as technical, commercial, and social processes to be addressed through participatory methods. Research capabilities reside in local and foreign universities or international research centers.
3. **Innovation-oriented farmers organizations focus** on developing technical innovations but can also develop commercial or organizational innovations or a combination of all three (a good example is South America's no-till farmer associations). These organizations may be created by farmers, NGOs, or public programs, and they may use public or private funds. They usually become the coordinating agent of a diverse network that includes research institutes, private firms, and public programs. Some focus mainly on farmer-developed innovations and seek to improve and/or diffuse them. Other farmers organizations that focus on innovation include farmers and researchers as equal partners. These farmers organizations use participatory methods to manage the innovation process and may combine top-down and bottom-up approaches.
4. **Farmers organizations that are service-oriented and networked**, such as Mexico's Produce Foundations, promote the emergence of local farmers organizations that form part of larger networks. Through collective action and participation in local and national forums, they establish partnerships with other actors in the AIS for the provision of services, including research, extension, training, credit and savings schemes, and lobbying (such as the Network of Peasant Organizations and Agricultural Producers in West Africa), or they develop value chains.

⁴⁴ R. Saravanan and B. Suchiradipta. 2017. "Agricultural Innovation Systems: Fostering Convergence for Extension." MANAGE Bulletin 2. National Institute of Agricultural Extension Management, Hyderabad, India. <https://www.manage.gov.in/publications/extnnext/June2017.pdf>.

Box 5.1 Examples of cooperatives around the world that evolved to support a larger AIS

The Kenya Tea Development Agency (KTDA) was created as a state company to regulate tea production by smallholders but evolved into a major corporation owned by small-scale farmers. It provides production and marketing services for members, successfully manages tea nurseries and 59 factories, and represents small-scale farmers in the Tea Board of Kenya. The agency grew output from about 2.8 million kilograms in 1970 to more than 700 million kilograms of green leaf in 2009, developed new tea products and new markets, accounted for 28 percent of Kenya's exporting earnings as the world's second-largest exporter of black tea, and developed and diffused sustainable production practices for small-scale farmers.

The Society for Elimination of Rural Poverty (SERP) in India helps farmers build an asset base, invest in procurement centers, and practice community-managed sustainable agriculture. High farmer debts in Andhra Pradesh led to a loss of 400,000 hectares in planted area between 1980 and 2005. SERP, an autonomous body established by the Government of Andhra Pradesh, implemented a program to mobilize self-help groups, each with 10–15 members, to engage in collective saving, lending, and other activities to build an asset base. These community groups also manage and invest in larger enterprises such as procurement centers for specific commodities, which provide grading, quality control, aggregation, and value addition. To date, 82 percent of communities managed to repay their debt, families increased their investments in productive assets and sustainable land and water management, communities saw greater business innovation and new livelihood opportunities, and food security improved.

Papa Andina in Latin America promotes innovation that leads to the development of market niches and value addition. Across the Andean region, small-scale farmers face the challenge of gaining access to dynamic new markets for high-value produce while remaining resilient amid the forces of climate change and globalization. The Papa Andina regional initiative, anchored in the International Potato Center (CIP), has two principal approaches to engage market chain actors: the participatory market chain approach (PMCA) and stakeholder platforms. PMCA builds interest, trust, and collaboration among participants, improves farmers' links to markets, and stimulates pro-poor innovation. Stakeholder platforms are spaces and events where public and private stakeholders interact, share reciprocal interests, build trust, and join in common initiatives.

South America's no-till farmer associations have significantly increased productivity of farmland in Argentina, Bolivia, Paraguay, and other countries in the region. These associations promote a transition from the European tilling model, which led to serious soil erosion, to a no-till regime. During the 1960s a group of innovative farmers came together to deal with the problem. Together, and with support from research institutions and universities, they opted to try the no-till approach, which at that time was still in experimental mode in the United States. In 1989, this informal group was organized into the Argentine Association of Direct Sowing Producers (AAPRESID), an open network of innovative agricultural farmers.

The West African Network of Peasants and Agricultural Producers (ROPPA) brings together farmers organizations from 10 West Africa countries to promote and defend sustainable and competitive farming practices. The network, which includes Benin, Burkina Faso, Côte d'Ivoire, Gambia, Guinea, Guinea-Bissau, Mali, Niger, Senegal, and Togo, advocates peasant-led agricultural production, builds solidarity between peasant producers of the region, and encourages the implementation of appropriate agriculture and rural development policies and programs. ROPPA projects include collaboration frameworks across farmers organizations to enhance dialogue among small-scale farmers, provide access to markets, understand the drivers of household vulnerability and resilience, tap into international finance, and inform regional agricultural policies.

1.1.1.2 Invest in platforms that allow intense collaboration among stakeholders and promise quick development, deployment, and evaluation of new varieties

AISs extend beyond research of new varieties to address demand, enterprises, and extension services. Agricultural innovations have had relatively limited adoption due to poor extension services, poor access to credit for farmers, erratic or poor commodity markets, and a policy atmosphere that does not sufficiently support innovation. Beyond research and innovation, AISs rely on government, private, and civil society organization actors to increase and ensure the sharing of information and technologies across people, enterprises, and institutions.⁴⁵ In accordance with these principles, Package 1 suggests strengthening interministerial collaboration and knowledge platforms in tandem with providing incentives for the private sector to share price and production information. Beyond being technical knowledge sharing devices, extension services can allow sharing of best practices between farms.

Improved seed varieties are an example of the potential of AISs to close yield gaps in key commodities. Of all the inputs required in production of rice (including fertilizer, pesticide, and irrigation), seed varieties play by far the largest role in yield increase. Quality rice seed alone can increase yield by 10 percent compared to other varieties. It is estimated that more than 2 million additional tons of rice can be achieved by using quality seeds.⁴⁶

Strong research institutions inside and outside of Bangladesh are continuing to develop new varieties. Bangladesh features several very well-capacitated and successful research institutes working at the intersection of seed development and associated agronomic technologies. For example, BRRI has developed 86 varieties, of which six are hybrids and the rest are high-yielding inbred varieties. In addition, BARI, BINA, and BRAC have all been instrumental in the intensification of rice production in the country and have earned international recognition for their achievements. Bangladesh also has a network of private sector actors involved in seed development in order to improve the quality of seeds. Currently, only a quarter of seeds used in Bangladesh are deemed high quality.⁴⁷ While the government formerly held restrictions on the use of new genetic materials, liberalization of the seed market in Bangladesh since the National Seed Policy of 1993 and the Seed Rules of 1998 opened up seed production to the private sector and NGOs.

Although varietal deployment can take 15–20 years from research to adoption, rapid breeding and varietal replacement are critical in the face of climate change. Despite strong research capacity and extension systems, development, deployment, and adoption at scale continue to be significant hurdles to large-scale adoption of new varieties. The average time to reach maximum adoption of BRRI released varieties in the past has been estimated at 16 ±3 years.⁴⁸ This adoption lag has a number of significant drawbacks. On the one hand, the foregone benefits of genetic gain are substantial.

⁴⁵ R. Saravanan and B. Suchiradipita. 2017. "Agricultural Innovation Systems: Fostering Convergence for Extension." MANAGE Bulletin 2. National Institute of Agricultural Extension Management, Hyderabad, India. <https://www.manage.gov.in/publications/extnnext/June2017.pdf>.

⁴⁶ Pradeep Man Tulachan, Md Khairul Bashar, Md Rafiqul Islam et al. 2013. "Value Chain Analysis of Rice Seeds in Bangladesh." SRSPDS Project under CSISA–Bangladesh, International Rice Research Institute, Dhaka. https://www.researchgate.net/publication/257984999_Value_chain_analysis_of_rice_seeds_in_Bangladesh.

⁴⁷ Salahuddin Ahmed, Mohammad Siddiqur Rahman, and Mohammed Moniruzzaman. 2012. "Integrated Seed Sector Status Paper: Bangladesh Perspective." Bangladesh Agricultural Research Institute. <http://q.datakultur.se/~svalofco/wp-content/uploads/2012/12/Bangladesh-Seed-Sector-Status-Paper1.pdf>.

⁴⁸ M. S. Kabir, M. U. Salam, A. Chowdhury et al. 2016. "Rice Vision for Bangladesh: 2050 and Beyond." Bangladesh Rice Journal 19 (2): 1–18. <https://doi.org/10.3329/brj.v19i2.28160>

Pandey et al. (1999)⁴⁹ estimate that the economic benefit from completing the breeding cycle of rice in northeast Thailand two years earlier was US\$18 million dollars over the useful life of the variety. On the other hand, climate change requires rapid development cycles that are adapted to local environments and stressors in order to maintain current yield levels.

Box 5.1 Examples of innovation platforms around the world that evolved to support a larger AIS

Examples around the globe show national and sectoral level innovation systems can be successful in increasing productivity and resilience. Effective coordination and organization of actors for agricultural innovation can be supported with different instruments, including building capabilities for innovation, joint priority setting or technology foresight exercises, and joint research and/or innovation programs, among others. Innovation councils and advisory committees involving different ministries can coordinate policies, joint priority setting, and technology foresight exercises, which are often supplemented with temporary stakeholder consultation arrangements. Innovation forums and market and technology intelligence can create common visions among agents, thus fostering coordination. The following examples, taken from the World Bank's AIS sourcebook, highlight the variety of activities that can contribute to increased coordination across stakeholders.^a

Uruguay: Producers help set the research agenda of the country's main agricultural research institute, the Instituto Nacional de Investigación Agropecuaria (INIA). Producers participate in identifying, prioritizing, and planning research as active members of the board of directors, regional advisory councils, and working groups. Specific mechanisms allow producers to articulate demands and to transfer technology, such as experimental units for validation and demonstration. Regional advisory councils capture local demands and host working groups to strengthen farmers' role in guiding research. These councils have become very useful in incorporating research planning and monitoring and in evaluating inputs. INIA also facilitates technology transfers, which provide feedback to reorient research.

Chile: To diversify its economy, Chile's government invested heavily in moving away from a commodity-based economy (agriculture and mining) toward a knowledge-intensive economy. For this purpose, the government created a national innovation fund for competitiveness (Fondo de Innovación para la Competitividad), advised by a national innovation council for competitiveness (Consejo Nacional de Innovación para la Competitividad) on how to allocate its resources with an interministerial committee on innovation (Comité de Ministros para la Innovación) responsible for implementation. Part of the new initiative was the formulation of a national innovation strategy that singled out five economic focal clusters for science, technology, and innovation (STI) investment: agro-food, aquaculture, mining, tourism, and global services. For each selected cluster, a strategic board with public and private representation developed cluster-specific priorities for which various STI funding agencies organized calls for proposals. Competitive funding schemes are used to promote cross-institutional collaboration between universities and research institutes and public-private partnerships in the form of technology consortia. Since the fund's creation in 2005, public STI investments in Chile have more than doubled in real terms, reaching US\$530 million in 2009, and are projected to grow by 10–15 percent per year over the next 10 years.

Source: World Bank. 2012. Agricultural Innovation Systems: An Investment Sourcebook. Washington, DC: World Bank. <http://documents.worldbank.org/curated/en/140741468336047588/Main-report>.

⁴⁹ Sushil Pandey and S. Rajatasereekul. 1999. "Economics of Plant Breeding: The Value of Shorter Breeding Cycles for Rice in Northeast Thailand." *Field Crops Research* 64 (1–2): 187–97.

1.1.1.3 Support a competitive private sector to accelerate research and development

Bangladesh recognizes the importance of the private sector in AIS, but the private sector is still in need of incentives to fully engage. The seventh five-year plan aims to intensify, diversify, and commercialize climate resilience and agricultural production through technological innovation and linking farmers to markets. The National Agricultural Policy of 2013 emphasizes a bottom-up approach for identifying research needs, setting research priorities, and equally promoting diversification. The National Livestock Development Policy of 2007 and the National Livestock Extension Policy of 2013 identify the need for livestock extension services. Other policies affecting innovation in the space include the New Agricultural Extension Policy of 1996, National Food Policy of 2006, National Fisheries Policy of 1998, National Water Policy of 1999, National Forestry Policy of 1994, and National Sustainable Development Strategy of 2013. Nonetheless, the private sector might not be fully incentivized to invest in the production and distribution of breeder seeds.⁵⁰ Successful AIS requires intense collaboration among stakeholders to mobilize and accelerate private sector engagement and to speed adoption of newly released technologies and inputs such as seeds. The currently insufficient support for agricultural research, adoption, and dissemination of new technologies and training in the country explains in part the declining productivity gains of Bangladesh's agriculture sector.⁵¹

To align private sector interests with development priorities, public-private links should be strengthened. The World Bank's project appraisal document for the Second Phase of the National Agriculture Technology Program Project for Bangladesh (NATP-2) asserts that "Public-private links are largely absent, and links between research entities public and private with the higher education sector are sparse and severely underexploited." Similarly, the 2016 scoping studies for the Capacity Development for Agricultural Innovation Systems (CDAIS) in Bangladesh show that although the private sector appears to be at the forefront of much agricultural innovation, "distrust is still voiced about their motivations and their profit focus." The existing personal links between private and public institutions must be intensified and institutionalized with clear and consistent incentive mechanisms and transparent pathways of competition (for example, predictable seed certification mechanisms, a level playing field of seed prices in wholesale markets, and short- to medium-term protection of intellectual property) to make the best use of private sector entrepreneurship and public sector capacity, reach, and experience.

Investments should focus on increasing the involvement of the private sector in demand-driven research. Perhaps the most pressing need is continued investment in demand-driven research and development. This need has been identified by the Government of Bangladesh in partnership with various development partners. Examples include the Agro-Based Industries and Technology Development Projects I and II (1996–2005), funded by the U.S. Agency for International Development (USAID), and the World Bank's National Agricultural Technology Project (since 2008). Both projects made strides to increase the competitiveness of the private sector through direct investments (such as investments in dryer and storage facilities) and through dedicated funds that support private sector innovation in the field. One interesting development in demand-driven research was

⁵⁰ Pradeep Man Tulachan, Md Khairul Bashar, Md Rafiqul Islam et al. 2013. "Value Chain Analysis of Rice Seeds in Bangladesh." SRSPDS Project under CSISA–Bangladesh, International Rice Research Institute, Dhaka. https://www.researchgate.net/publication/257984999_Value_chain_analysis_of_rice_seeds_in_Bangladesh.

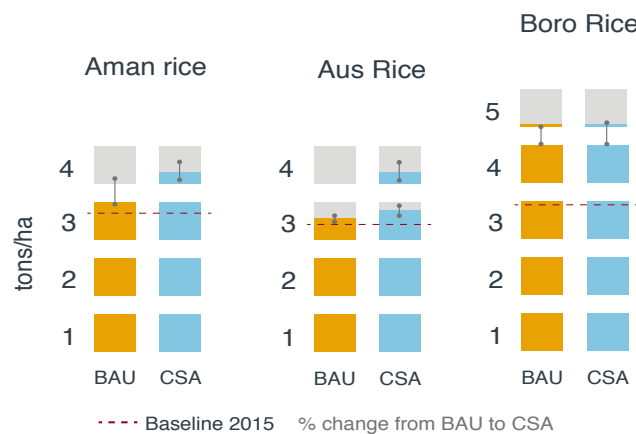
⁵¹ Unnayan Onneshan. 2014. "Recent Trends of Growth in Agriculture, Industry and Power." Bangladesh Economic Update 5 (3). [http://unnayan.org/reports/meu/MEU_March_2014/Final%20MEU\(Edited\)_29%20March14.pdf](http://unnayan.org/reports/meu/MEU_March_2014/Final%20MEU(Edited)_29%20March14.pdf).

Katalyst. Initiated by Swisscontact in 2000,⁵² the project focused on the competitiveness of small and medium enterprises and farmer-level market research to subsidy-independent private sector-driven innovations that increase corporate margins while reaching millions of farmers. One result of this process is Lal Teer’s mini seed packages, which allow smallholder farmers to buy affordable, quality seed. The minipackages are now used across the entire country.

Quantified estimate of impact

Yield and cultivated area increase with improved seeds. The most obvious change expected from higher-yielding varieties that are resistant to salty soils, droughts, and flooding is increased yield and increased feasible acreage. The model results suggest exactly that (Figure). By 2040, available cropland with higher-yielding stress-tolerant varieties under CSA will be 53 percent higher than at BAU for boro rice in Barisal, 87 percent higher in Chittagong, and 84 percent higher in Khulna. At a national level, yield will increase by 10 percent for aman rice, 8 percent for aus rice, and 1 percent for boro rice.

Figure 5.6 Isolated effect of improved rice seed varieties on yield and annual production (Based on CSAIP Model results)



Emission intensity stagnates and absolute emissions spike due to increased cropland available.

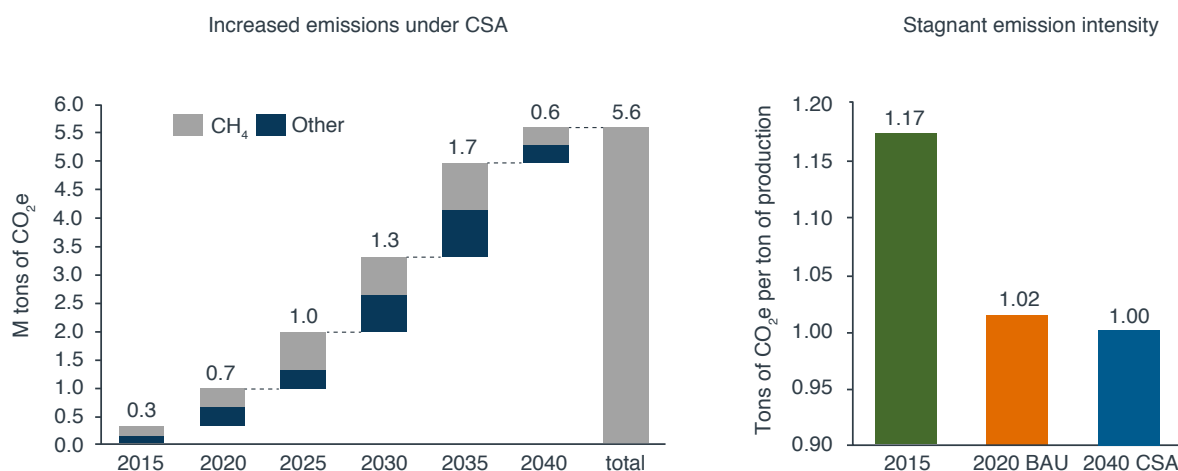
As shown in Figure 5.7, if no diversification away from rice were to be implemented, absolute emissions would increase by 5.6 million tons of CO₂e in 2040 under CSA even though emission intensity will remain almost unchanged compared to BAU. The driver of increased emissions is the ability of higher-yielding stress-tolerant varieties to thrive in areas that would otherwise remain fallow.

Improved varieties open pathways to sectoral change that increase resilience and decrease emissions.

The effect of higher-yielding stress-tolerant varieties on production, resilience, and mitigation cobenefits must be seen through the lens of increased efficiency. This technology allows Bangladesh to maintain rice self-sufficiency while freeing up cultivated land for other crops, thereby increasing profits, increasing resilience to weather and rice shocks, and decreasing overall emissions from the agriculture sector (see sections above).

⁵² DFID and SDC supported throughout the 15 years, while CIDA, SIDA, Dutch Embassy, and DANIDA supported different phases.

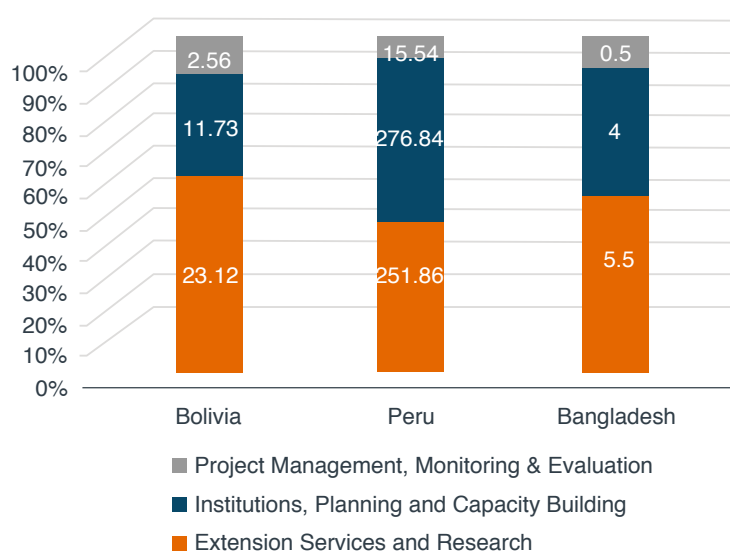
Figure 5.7 Isolated effect of improved rice seed varieties on emissions and emission intensity



Cost assessment Weather

Projects focusing on AISs have a large range of costs. Past World Bank projects with similar objectives range from US\$116 million to US\$256 million dollars (adjusted for 2017 PPP). Across projects, over 50 percent of the costs are made up of investments in extension services and research activities, followed by investments in institutions. Planning and capacity-building measures make up roughly 30 percent of costs. A closer look at these costs is revealing: in both components, the majority of costs are earmarked to build local capacities in research, technical knowledge, and extension and advisory services, as well as managing seed and genetic banks in an effort to strengthen national innovation services. After PPP adjustment, the costs per beneficiary in Bolivia and Peru were US\$37.41 and US\$544.23, respectively, as shown in figure 5.8.

Figure 5.8 Costs per beneficiary of two World Bank Projects in Bolivia and Peru and the proposed AIS package in Bangladesh



Note: Costs are shown in PPP 2017 US dollars.

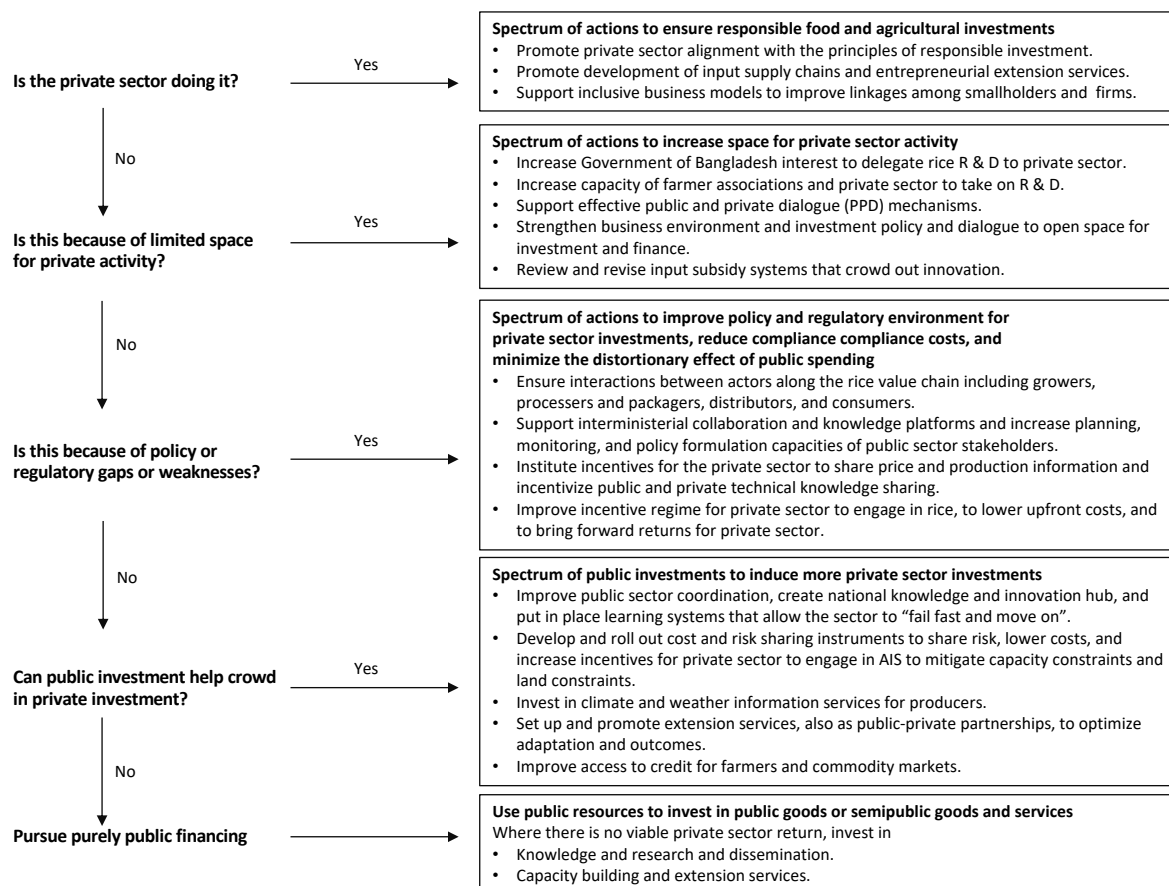
The estimated cost of Package 1 is US\$117 million, ranging from US\$111 million to US\$125 million (or US\$300 million, ranging from US\$285 million to US\$320 million, PPP 2017 US dollars). In order to assess the cost of implementation of Package 1, in addition to the World Bank project costs with similar objectives in other countries, the extent of the project activity to determine project costs also needs to be considered. As Bangladesh has a larger agriculture sector compared to Peru and Bolivia, costs related to extension services, research activities, and managing seed and genetic banks will be much higher. However, thanks to economies of scale, costs will not be proportionally higher. Considering all these aspects, the cost per beneficiary in Bangladesh will be around US\$10, as Bangladesh has a large number of potential direct AIS beneficiaries (around 60 million). In addition, there are other factors that need to be considered to assess the upper range of the costs. First, price level and inflation expectation in the country will have an important effect on assessing the cost of the projects. Second, the time value of money will be an important issue in identifying cost, as costs related to the implementation of the package over time need to be accounted for by including market rates of interest. Finally, the trend of the country's exchange rate will affect the cost assessment, as the cost is being estimated in terms of foreign currency. On the basis of these factors, final assessment shows that the cost of the package for Bangladesh is US\$117 million. The range of the cost of the package is US\$111–US\$125 million.

Results of Cost Benefit Analysis

A cost-benefit analysis for Package 1 shows an IRR of 24% and an ERR of 31%. This is higher than the median ERR of past World Bank projects. Relying on a regression analysis, the median ERR of World Bank projects in the agriculture and rural development sector between 1996 and 2008 is estimated at 23%. Based on the CBA, the NPV of Package 1 amounts to US\$ 67 million while the ENPV is estimated as high as US\$ 98 million. The CBA was based on the following assumptions. First, the sources of project benefits are linked to an increase in crop production, mainly from non-rice crops and lower losses from crop destruction. Second, the adoption rate of CSA will reach 50% over 20 years. Third, the adoption of CSA will increase yield and productivity of both rice and non-rice in the haor areas. Fourth, this package will increase production value annually by 4% due to an increase in both price and quantity. Fifth, this package will also foster benefits in non-agricultural sectors as enhanced food security will contribute to an increase in life expectancy and a reduction in health hazards.

Maximizing Finance for Development

Figure 5.9 Decision tree for maximizing finance for development for Package 1



5.3 Package 2: Gender-sensitive development of homestead production

Table 5.3 Overview of Package 2

| | |
|---|--|
| Subtitle | Strengthen resilience and boost inclusive growth of rural, women-run small-scale production of livestock and backyard pond aquaculture in southwest Bangladesh. |
| Context | <p>Southern Bangladesh is among the most climate-vulnerable places on earth. An economically marginalized rural population struggles to adapt to both gradual environmental changes (salinization, sea level rise) and intensifying extreme climate events (hurricanes, flooding). Women often run the country’s homestead production units (particularly pond aquaculture and livestock), though they lack access to information, capital, farm inputs, and markets—all of which are crucial to increase small-scale farm resilience to climate change. The productivity of aquaculture and livestock is driven by many factors. Key drivers of low aquaculture productivity include inadequate seed and feed quality, poor water management, and lack of technical knowledge of pond management. Similarly, livestock productivity is constrained by poor feed quality, and mortality is unnecessarily high due to a lack of veterinary services and missing emergency shelters. This package focuses on the most promising mechanisms to strengthen the resilience of homestead production units in southern Bangladesh. While this chapter focuses on the southwestern parts of the country, most findings are valid for other parts of the country.</p> |
| Investment opportunities | <ul style="list-style-type: none"> • Invest in gender-sensitive public-private extension services for disease control and prevention. • Invest in increased pond aquaculture productivity. • Invest in strong gender-sensitive nutrition education campaigns. • Invest in enhanced DRM approaches. |
| Potential impact | <ul style="list-style-type: none"> • Production will increase for crops (27%), livestock (19%), and pond aquaculture (30%), with strong gains in income resilience and nutrition security. • Emissions from crop cultivation will diminish by 8%; livestock emissions are projected to decrease by 12%. • There is a potential emission savings of up to 1.4 million tons of CO₂e per year if fish protein is used to substitute for meat proteins. |
| Cost of comparable World Bank projects | <ul style="list-style-type: none"> • 12 comparable country-level rural development projects across the world suggest project costs of US\$35–US\$360 million (PPP 2017 US dollars). • Dominant cost categories are (a) agro-industry, productive investments, and infrastructure and (b) marketing, trade, value chains, and finance. |
| Estimated cost in Bangladesh | <ul style="list-style-type: none"> • US\$ Nominal 2017: US\$125 million (Range: US\$117 to US\$133 million) • US\$ PPP 2017: US\$320 million (Range US\$300 million to US\$340 million) |
| Cost Benefit Analysis | <ul style="list-style-type: none"> • IRR: 27% • ERR: 34% • NPV: US\$ 87 million • ENPV: US\$ 126 million |

Context and problem statement

Southwest Bangladesh features highly productive agricultural systems. The coast of Bangladesh is home to approximately 46 million people and covers an area of 4.7 million hectares.⁵³ It can be divided into three zones: the southwestern coast comprises the coastal areas of the Ganges tidal plain, the south-central zone is the Meghna delta plain, and the southeastern zone is the Chittagong coastal belt. These southern regions (western, central, and eastern) differ greatly in geography, topology, economic performance, cultural setup, and agricultural systems but share the proximity to the coast and some of its associated vulnerabilities and opportunities. This chapter emphasizes the deltaic region of southwest Bangladesh, which stands out as particularly climate vulnerable. The entire landmass of the southwestern region is deltaic, low-lying, and fluviially dominated, with a varied landscape of mangrove forests, rice fields, ponds, lakes, and river systems. It is subject to major seasonal changes with successive periods of monsoon flooding and winter drying. The abundance of water, the annual deposition of rich alluvial silts, and extensive river and lake fisheries have traditionally provided a rich and productive environment capable of supporting significant populations and producing a range of food and other natural resource-based products.⁵⁴

Southwest Bangladesh is among the most climate-vulnerable agricultural landscapes in the world. Today, Bangladesh is considered one of the most vulnerable and exposed countries to climate change in the world.⁵⁵ There is evidence of prominent increases in the intensity and/or frequency of many extreme events such as floods, heat waves, tropical cyclones, intense rainfall, tornadoes, drought, and storm surges. In the coastal area, an increased acuteness of this vulnerability stems from the combined effects of topography, sea level rise, subsidence, changes of upstream river discharge, cyclone, and coastal embankments.⁵⁶ A few vulnerability aspects stand out in particular:

- **Sea level rise.** The topographic gradients are particularly low in southwest Bangladesh, with the majority of the region at less than 1 meter elevation.⁵⁷ Inundation will depend on the severity of climate change, but it is estimated that up to 1.7–2.2 million hectares of land will be inundated in southwest Bangladesh under scenarios of mean sea-level rise of 1–1.5 meters by 2100. Much of this inundation would take place in the low-lying deltaic region of southwest Bangladesh (Figure). For the period 2081–2100 (compared to 1986–2005), global mean sea level rise is expected to be 0.26 to 0.55 meters for representative concentration pathway (RCP) 2.6, 0.32 to 0.63 meters for RCP 4.5, 0.33 to 0.63 meters for RCP 6.0, and 0.45 to 0.82 meters for RCP 8.5.⁵⁸

⁵³ Md Golam Mahabub Sarwar. 2013. "Sea-Level Rise Along the Coast of Bangladesh." In *Disaster Risk Reduction Approaches in Bangladesh*, edited by Rajib Shaw, Fuad Mallick, and Aminul Islam, 217–31. Tokyo, Japan: Springer.

⁵⁴ CARE Bangladesh. 2006. "The Reducing Vulnerability to Climate Change (RVCC) Project: Final Report." CARE Bangladesh, Dhaka. http://www.carebangladesh.org/publication/Publication_4406527.pdf.

⁵⁵ Md Afjal Hossain, Sania Rahman, Md Imran Reza et al. 2012. "Climate Change and its Impacts on the Livelihoods of the Vulnerable People in the Southwestern Coastal Zone in Bangladesh." In *Climate Change and the Sustainable Use of Water Resources*, edited by Walter Leal Filho, 237–59. New York: Springer. https://www.researchgate.net/publication/226923239_Climate_Change_and_Its_Impacts_on_the_Livelihoods_of_the_Vulnerable_People_in_the_Southwestern_Coastal_Zone_in_Bangladesh.

⁵⁶ Md Afjal Hossain, Sania Rahman, Md Imran Reza et al. 2012. "Climate Change and its Impacts on the Livelihoods of the Vulnerable People in the Southwestern Coastal Zone in Bangladesh." In *Climate Change and the Sustainable Use of Water Resources*, edited by Walter Leal Filho, 237–59. New York: Springer. https://www.researchgate.net/publication/226923239_Climate_Change_and_Its_Impacts_on_the_Livelihoods_of_the_Vulnerable_People_in_the_Southwestern_Coastal_Zone_in_Bangladesh.

⁵⁷ World Bank. 2000. "Bangladesh: Climate Change and Sustainable Development." Report No. 21104-BD. Rural Development Unit, South Asia Region, World Bank. <http://documents.worldbank.org/curated/en/906951468743377163/Bangladesh-Climate-change-and-sustainable-development>.

⁵⁸ John A. Church, Peter U. Clark, Anny Cazenave et al. 2013. "Sea Level Change." In *Climate Change 2013: The Physical Science Basis; Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by Thomas F. Stocker et al., 1137–1216. New York: Cambridge University Press. https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter13_FINAL.pdf.

These projections will likely lead to SLR- driven migration of 0.7–2 million people by 2100.⁵⁹ The latter analysis considers mean sea level rise without normal high tides, so the results—both in terms of inundated area and displaced population—are conservative.

- **Saline intrusion.** The dry season saline front (2 deciSiemens per meter) is expected to move 30 to 50 kilometers north, assuming only 30 centimeters of sea level rise, affecting most of Khulna, Jessore, Barisal, Patuakhali, and Noakhali (greater) districts and parts of Faridpur and Comilla districts.⁶⁰ Saline intrusion affects soil chemistry and thereby has a number of effects on plant physiology (through osmosis, pH effect, and specific ion effect) that negatively impact agricultural productivity.⁶¹ In addition, livestock and fisheries are affected along the coastal belt.⁶² Due to the connectivity of agricultural products with human livelihoods, greater levels of gestational hypertension were found in pregnant women in the southwestern coast of Bangladesh compared with noncoastal pregnant women.
- **Waterlogging.** Key changes in recent decades have included the development of the Farakka Barrage in India, which greatly reduced upstream river flows through the Ganges-Brahmaputra river system; the development of major embankments; the obstruction of various channels and waterways due to road construction, minor embankments, and diversions; and the increase in shrimp farming. These developments have resulted in reduced drainage, causing vast areas of the southwest to be waterlogged and increasing saline intrusion from the Bay of Bengal due to reduced river flows.⁶³
- **Natural disasters.** Between 1980 and 2018, Bangladesh experienced more than 200 natural disasters, causing more than US\$16 billion in damage and costing hundreds of thousands of lives.⁶⁴ Particularly damaging are tropical cyclones that hit the country's coastal regions nearly every year in the early summer (April–May) or late rainy season (October–November). The strongest winds reach velocities of up to 220 kilometers/hour and lead to a tidal range of 3 meters up to 7 meters further west at the entrance of the Meghna estuary. Overall, Bangladesh bears about two-fifths of the world's total impact from storm surges, and the vulnerable area is expected to be 55 percent greater than under the baseline scenario, with an additional 2 meters of inundation depth.⁶⁵

⁵⁹ Kyle Frankel Davis, Abinash Bhattachan, Paolo D'Odorico et al. 2018. "A Universal Model for Predicting Human Migration under Climate Change: Examining Future Sea Level Rise in Bangladesh." *Environmental Research Letters* 13 (6): 064030. <https://iopscience.iop.org/article/10.1088/1748-9326/aac4d4>.

⁶⁰ Md Afjal Hossain, Sania Rahman, Md Imran Reza et al. 2012. "Climate Change and its Impacts on the Livelihoods of the Vulnerable People in the Southwestern Coastal Zone in Bangladesh." In *Climate Change and the Sustainable Use of Water Resources*, edited by Walter Leal Filho, 237–59. New York: https://www.researchgate.net/publication/226923239_Climate_Change_and_Its_Impacts_on_the_Livelihoods_of_the_Vulnerable_People_in_the_Southwestern_Coastal_Zone_in_Bangladesh.

⁶¹ Lubna Seal and Mohammed Abdul Baten. 2012. "Salinity Intrusion in Interior Coast: A New Challenge to Agriculture in South Central Part of Bangladesh." *Unnayan Onneshan: The Innovators, Centre for Research and Action on Development, Dhaka*. http://www.unnayan.org/reports/climate/Salinity_Intrusion_in_Interior%20Coast-A_New_Challenge_to_Agriculture_in_South_Central_part_of_Bangladesh.pdf.

⁶² Mohammad Zahangeer Alam, Lynne Carpenter-Boggs, Shishir Mitra et al. 2017. "Effect of Salinity Intrusion on Food Crops, Livestock, and Fish Species at Kalapara Coastal Belt in Bangladesh." *Journal of Food Quality*. <https://doi.org/10.1155/2017/2045157>.

⁶³ CARE Bangladesh. 2006. "The Reducing Vulnerability to Climate Change (RVCC) Project: Final Report." CARE Bangladesh, Dhaka. http://www.carebangladesh.org/publication/Publication_4406527.pdf; Bangladesh, General Economics Division, Planning Commission. 2017. "Bangladesh Delta Plan 2100 (Draft)." <http://www.lged.gov.bd/UploadedDocument/UnitPublication/17/624/Bangladesh%20Delta%20Plan%20100%20Draft%20Report.pdf>; Md Mahbubur Rahman and Muhammad Mizanur Rahaman. 2018. "Impacts of Farakka Barrage on Hydrological Flow of Ganges River and Environment in Bangladesh." *Sustainable Water Resources Management* 4 (4): 767–80.

⁶⁴ UNDP (United Nations Development Programme). n.d. "Bangladesh: Disaster Risk Reduction as Development." https://www.undp.org/content/undp/en/home/librarypage/poverty-reduction/supporting_transformationalchange/Bangladesh-drr-casestudy-transformational-change.html.

⁶⁵ Susmita Dasgupta, Mainul Huq, Zahirul Huq Khan et al. 2014. "Cyclones in a Changing Climate: The Case of Bangladesh." *Climate and Development* 6 (2): 96–110. doi:10.1080/17565529.2013.868335.

Figure 5.10 Projected inundation under different sea level rise scenarios^a



Source. Rekacewicz. 2009. Impact of sea level rise in Bangladesh. Maps, Grid Arendal, Vital Water Graphics. <http://www.grida.no/resources/5648>.

The homestead is a dominant feature in Bangladesh’s rural agricultural landscape. Bangladesh consists of almost 9,000 villages, each with a few thousand homesteads. Homesteads are the traditional cultural center of the rural Bangladeshi farming unit, a small family-run assemblage of housing structures that are typically mud- or clay-based. Homesteads feature a diverse agricultural operation, including crops, pond aquaculture, and livestock. According to Bangladesh’s *Census of Agriculture 2008*,⁶⁶ there were almost 28.6 million farm holdings across the country, 25.3 million of which were located in a rural setting. Of these, 11 million rural households (or 47 percent of all rural farm holdings) consisted of homesteads with no additional cultivated land to rely on. Another 10 million homesteads (35 percent) had cultivated land of up to 0.5 acres (0.2 hectares) (Figure). The 1977 and 1978 Land Occupancy Survey and a national survey on land occupancy carried out by the BBS in collaboration with USAID distinguished three categories of landless households:⁶⁷

- Landless I—Household with no land whatsoever
- Landless II—Those who own only homestead but no other land
- Landless III—Those who own homestead and 0.2 hectares of “other” land

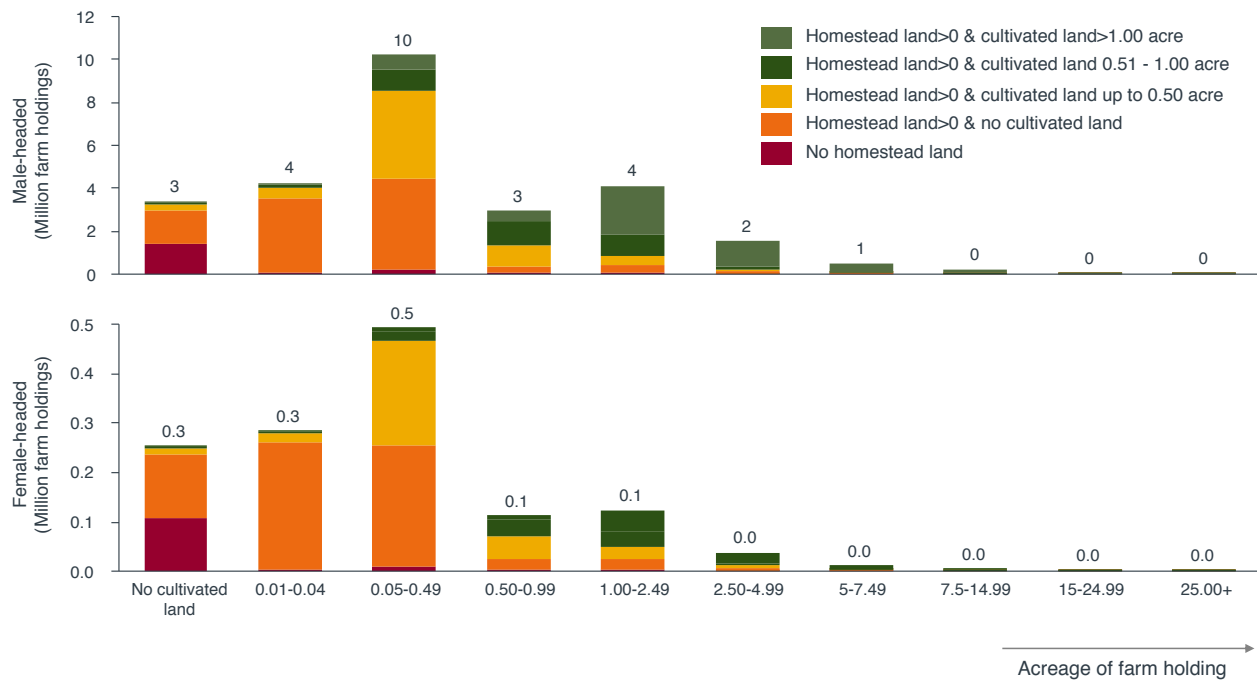
These 21 million landless homesteads make up a significant portion of the agricultural landscape in rural Bangladesh, occupying a total of 0.8 million hectares⁶⁸ and featuring diverse and seasonally varying production of agricultural products.

⁶⁶ Bangladesh, Statistics Division, Ministry of Planning. 2010. “Census of Agriculture 2008: Structure of Agricultural Holdings and Livestock Population.” Bangladesh Bureau of Statistics. http://www.fao.org/fileadmin/templates/ess/ess_test_folder/World_Census_Agriculture/Country_info_2010/Reports/Reports_3/BGD_ENG_REP_2008.pdf.

⁶⁷ FAO (Food and Agriculture Organization of the United Nations). n.d. “On Solid Ground: Addressing Land Tenure Issues Following Natural Disasters; Bangladesh.” <http://www.fao.org/3/i1255b/i1255b03.pdf>.

⁶⁸ Bangladesh, Statistics And Informatics Division, Ministry of Planning. 2018. Statistical Pocket Book: Bangladesh 2017. Dhaka: Bangladesh Bureau of Statistics. http://bbs.portal.gov.bd/sites/default/files/files/bbs.portal.gov.bd/page/d6556cd1_dc6f_41f5_a766_042b69cb1687/PocketBook2017.pdf.

Figure 5.11 Rural farm holdings in Bangladesh by gender of farm head, acreage of farm holding, and acreage of cultivated land



Source: Bangladesh, Statistics and Informatics Division, Ministry of Planning. 2018. Statistical Pocket Book: Bangladesh 2017. Dhaka: Bangladesh Bureau of Statistics. http://bbs.portal.gov.bd/sites/default/files/files/bbs.portal.gov.bd/page/d6556cd1_dc6f_41f5_a766_042b69cb1687/PocketBook2017.pdf.

Production in and around the homestead is geared towards subsistence, with surpluses an important part of household revenue. A typical homestead grows crops, vegetables, and trees; holds cattle, fowl, ducks, sheep, and/or goats; and services a small backyard pond with freshwater finfish or shrimp. Whereas the production system is geared toward subsistence, surplus production is marketed in order to earn additional income for the household. Fish and shrimp (and to a lesser extent cattle and fowl) are significant sources of income and sometimes make it onto the export market (particularly shrimp).

Rural households continue to suffer from malnutrition, which results from low production, cultural norms, and lack of information. Bangladesh has made significant improvements to diminish malnutrition. Infant mortality has drastically decreased over the past decades, as have stunting and deficiencies in vitamin A and Zinc. Despite these significant achievements, levels of stunting and underweight are still higher than the World Health Organization / Centers for Disease Control and Prevention threshold for emergency and are considered a severe public health problem.⁶⁹

Poverty and malnutrition remain a serious problem for one-fourth of the population who have few assets and are vulnerable to shocks from disease, economic crises, and extreme weather. Gender disparities are significant. Although 78 percent of employed women work in agriculture (compared to 53 percent of men), their contributions are not fully recognized because of cultural norms that value female seclusion and undervalue female labor. These norms also limit women's ownership of land in their own names (3.5 percent) and restrict access to and control over other productive assets.

⁶⁹ FAO (Food and Agriculture Organization of the United Nations) and WHO (World Health Organization). 2014. "Country Nutrition Paper: Bangladesh." International Conference on Nutrition 21 Years Later, Rome, November 19–21. <http://www.fao.org/3/a-at608e.pdf>.

Women-dominated agricultural practices have a high potential to contribute to household income, health, and education. Homesteads are family-run operations with all family members engaged in some part of the production and household system. Even children under 14 can be found working for large parts of the day on the homestead or in surrounding fields. Men and women typically have well-defined roles and responsibilities. Whereas men tend to work in the fields (mainly crops) or leave the house for labor work in the region, women are often in charge of rearing the livestock, managing the ponds, and growing vegetable gardens. What is more, women and men often separately control the revenues that spring from their respective areas of responsibility. Since women (often the mother-in-law) decide what is put on the table and send the children to school, homestead livestock, pond aquaculture, and vegetable gardens have an outsized influence on the nutrition and education of the entire family.

But women are often not sufficiently empowered to increase their contribution to household earnings. Within vulnerable communities, women and children tend to be more vulnerable to environmental degradation and natural disasters. This is a result of poor socioeconomic and health status, roles, and responsibilities within the household, lack of mobility, and lack of access to information.⁷⁰ A 2013 assessment by USAID and IFPRI (the Women's Empowerment in Agriculture Index) showed that only 23 percent of women in southwest Bangladesh were empowered in the five domains of production, resources, income, leadership, and time⁷¹ and that the largest empowerment gaps were in leadership, resources, and income.

Past programs point at the need for continued education, simple technological solutions, and a strong supply chain. Because of the high poverty incidence in rural Bangladesh and its vulnerability to climate change, it has been on the receiving end of decades of development programs, both national and international (see BCSAIP Appendices, Appendix E). Most of the evidence from well-documented programs and projects is consistent: there has been a steady overall increase in welfare indicators, showing the effectiveness of Bangladesh's development programs, but challenges persist to achieving inclusive growth in rural parts of the country. Some of the most consistent lessons learned from programs focusing on gender-sensitive development in rural Bangladesh include the following:

- Nutrition security is closely linked to gender norms (empowering women to contribute to agricultural output), family dynamics (mothers-in-law wielding much power over dietary decisions), and nutritional and hygiene education (the importance of a diverse diet during pregnancy and for children under two years).
- Women often control livestock, backyard pond aquaculture, and vegetable gardens, each contributing an outsized amount to the diversity of nutrients; the empowerment of women can contribute to a significant increase in the productivity of these systems.
- Educational programs can be very effective at changing behaviors and increasing micronutrient intake of pregnant women and children under two years when the programs include all decision makers within the family and the village.

⁷⁰ CARE Bangladesh. 2006. "The Reducing Vulnerability to Climate Change (RVCC) Project: Final Report." CARE Bangladesh, Dhaka. http://www.carebangladesh.org/publication/Publication_4406527.pdf.

⁷¹ Esha Sraboni, Agnes R. Quisumbing, and Akhter U. Ahmed. 2013. "The Women's Empowerment in Agriculture Index: Results from the 2011–2012 Bangladesh Integrated Household Survey." International Food Policy Research Institute for USAID. <http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/127504>.

- Livestock productivity is largely constrained by high mortality rates, which can be addressed through a combination of infrastructure investments, species choices (for example, duck instead of chicken, buffalo instead of cow), improved feed quality, and accessibility of veterinary services.
- Pond aquaculture is a particularly effective way to increase family protein consumption, earn additional revenue for the family, and empower women (predominantly young unmarried women).
- Supply chains and market links continue to be underdeveloped, leading to high transaction costs for rural farmers seeking to sell surplus production from livestock and aquaculture.

Enabling environment

Institutional capacity and coordination should be improved to make livestock veterinary and health systems in southwest Bangladesh more effective. Livestock extension and advisory services (EASs) are dynamic and decentralized with many types of actors (public, private services providers, and NGOs). The public livestock EAS provider (DLS) has limited operational funds, with the majority of its budget used for salaries and capital costs (the estimated ratio of veterinary surgeons to farm animals and birds is 1:1.7 million).⁷² The situation leads to weak information and analytical capacity for evidence-based policy making, ineffective policy frameworks, and insufficient advisory and veterinary coverage (including diagnostic facilities) at local level.⁷³ Livestock services deployment from the central level is limited at the *upazila* level, and private sector services have low coverage, resulting in limited delivery of services to smallholder farmers. There is a need for coordination and incentive to facilitate collaboration among EAS actors and leverage private services providers to strengthen and drive success of livestock services delivery in the country.

Institutional capacity building and policy incentives could accelerate private sector engagement. The need for extended veterinary services is also identified in the 2007 National Livestock Development Policy, the 2013 National Livestock Extension Policy, and BDP2100. However, the livestock component of BDP2100 holds that “reformation in regulatory mandate is required due to NGO & Private sectors involvement.”⁷⁴ Challenges that stand out include the following: (a) no dedicated authority exists (or is functional) to certify and monitor the quality of vaccines; (b) no clear epidemic strategy exists for vaccinations against targeted and recurring diseases; (c) movement control and quarantine are not practiced during outbreak of contagious diseases and epidemics; and (d) prescription systems are not in place to limit the use of antibiotics, toxin-binders, protein concentrate, and other feed additives that are potentially harmful for human consumption.

⁷² Bangladesh, General Economics Division, Planning Commission. 2017. “Bangladesh Delta Plan 2100 (Draft).” <http://www.lged.gov.bd/UploadedDocument/UnitPublication/17/624/Bangladesh%20Delta%20Plan%202100%20Draft%20Report.pdf>.

⁷³ Livestock extension is poorly staffed and resourced. At the upazila level, staffing levels of 60–70 crop farming extension agents are in stark contrast with average levels of only three livestock extension agents. At the national level, institutional capacity for the promotion and regulation of the livestock subsector is also low, including with respect to quality assurance of inputs and products, research, regulatory oversight, market development, and so on.

⁷⁴ NGOs with livestock-related activities include BRAC, RDRS (Rangpur Dinajpur Rural Service), Proshika Concern, Practical Action, Uttaran, Sachetan, Pallisree, Ashray, Help Age, Asha, CCDB (Christian Commission for the Development of Bangladesh), PMUK (Padakhep Manabik Unnayan Kendra), UDDIPON (United Development Initiatives for Programmed Actions), BEES (Bangladesh Extension Education Services), GUP (Gono Unnayan Prochesta), Heed, TMSS (Thengamara Mohila Sabuj Sangha), PBK (Pally Bikash Kendra), PMK (Palli Mongal Karmosuchi), Swanirvar Bangladesh, VERC (Village Education Resource Center), Sajag, SSS (Society for Social Service), PPSS, ESDO (Eco-Social Development Organization), Coast Trust, VARD (Voluntary Association for Rural Development), among others.

Investments should focus on the development of community-based veterinary systems and mobile veterinary systems (ideally demand-driven with a wide range); the establishment of an oversight body to coordinate training programs, oversee registrations and licenses, and develop guiding principles for drug use and drug prescription; and the development of epidemic strategy plans that can be quickly executed, which requires information networks at community level.

Supply chain development for pond aquaculture requires a broad and strengthened enabling environment for businesses. The literature suggests that the major driver of pond aquaculture development in Bangladesh has been the investment of millions of farm households and small and medium enterprises, as opposed to NGO and government interventions.⁷⁵ As a result, policies and investments that support a broad enabling environment for a wide variety of businesses (for example, rural infrastructure development and minimization of regulatory constraints to enterprise start-up and growth) will generally be of greater importance than those that aim to solve sector- or segment-specific problems. This can include interventionist and noninterventionist policies (for example, not restricting conversions of agricultural land to ponds).

Although national policies acknowledge the role of women in agriculture, gender-sensitive extension services should be strengthened to support rural homesteads. Several important policies have gender components (for example, the National Agriculture Policy, the National Rural Development Policy, Poverty Reduction Strategy Papers I and II, the seventh five-year plan and two-year plan) or specifically create provisions to improve access to productive resources, services, and income-generating activities for women (for example, the National Women Development Policy 2011, the New Agriculture Extension Policy 2015). Of particular importance is the Bangladesh National Women Development Policy 2011, which makes comprehensive provisions for women's rights and empowerment through land ownership, earned property, health, education, training and technology, credit facilities, and income generation with a vision of improving nutrition. However, these policies face an implementation gap. The FAO evaluation of enabling conditions for its gender and rural advisory services suggests that "the use of a top-down approach, over-dependence on training and visit approach, limited front line human resources, limited policy guidelines and absence of proper feedback mechanism, lack of ICT use, inadequate training centers, lack of coordination and integration in different departments and ministries, and limited number of female RAS advisors, etc. hinder implementation."⁷⁶

⁷⁵ Ricardo Hernandez, Ben Belton, Thomas Reardon et al. 2017. "The 'Quiet Revolution' in the Aquaculture Value Chain in Bangladesh." *Aquaculture* 493: 456–68. https://www.researchgate.net/publication/317621591_The_quiet_revolution_in_the_aquaculture_value_chain_in_Bangladesh.

⁷⁶ M. Wakilur Rahman, Nishith Tanny, and M. Serajul Islam. 2017. "Piloting the FAO Gender and Rural Advisory Services Assessment Tool in Bangladesh Component: Enabling Environment." USAID and Feed the Future. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3022478.

Figure 5.12 SWOT analysis of Package 2 based on the second stakeholder workshop held in Dhaka, April 2018

| | Helpful | Harmful |
|----------|---|---|
| Internal | <p>Strengths</p> <ul style="list-style-type: none"> • Rapid knowledge transmission in homestead production systems • Minimal technological requirements; the highest impact comes from understanding and application of best practices with current crops and livestock | <p>Weaknesses</p> <ul style="list-style-type: none"> • Low access to capital in homestead systems • Risk-averse farmers wary of adopting new practices • Lack of available land for <i>killas</i> or other emergency shelters |
| External | <p>Opportunities</p> <ul style="list-style-type: none"> • Gender mainstreaming of extension systems • Supporting homestead pond aquaculture and livestock through investments in input supply chains • Ramping up nutrition education programs that put homestead production on the map to meet national food security goals • Investing in low-capital DRM approaches that focus on livestock | <p>Threats</p> <ul style="list-style-type: none"> • Low-profit homestead production not prioritized by the private sector • Livestock not seen as a priority in DRM |

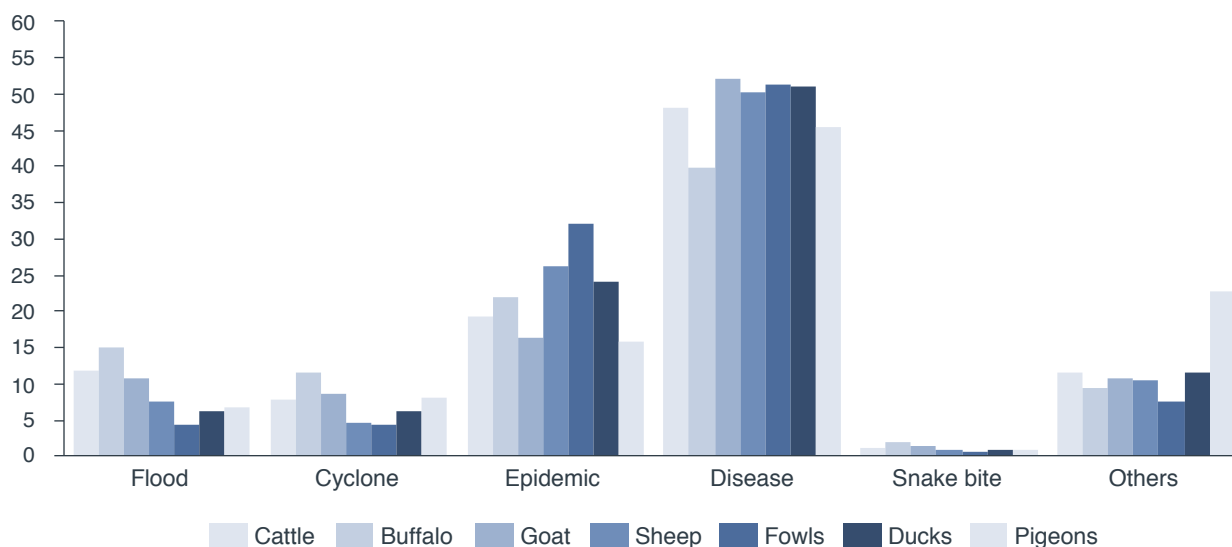
Investment opportunities

1.1.1.4 Invest in gender-sensitive public-private extension services for disease control and prevention

Increased productivity and decreased mortality of livestock could be achieved through a strengthened veterinary system. The 2008 agricultural census records the reasons for death for 47 million slaughtered animals in rural Bangladesh and reports that epidemics and diseases are responsible for about 70 percent across all species (Figure). Broadly speaking, poultry diseases are either bacterial in nature (such as salmonellosis, colibacillosis, fowl cholera, and necrotic enteritis) or virus-based (such as avian influenza, Newcastle disease, infectious bronchitis, and avian leukosis). In rural Bangladesh, the onset of the monsoon leads to high mortality given the lack of vaccination at the flock level. For cattle, diseases such as black quarter and foot-and-mouth disease often take their origin in inadequate diets and could be averted with the right dosage and schedule of simple vaccine programs. In the absence of an effective animal health care system, livestock owners must depend on informal health care providers for treatment of their animals. These treatment methods are too expensive and too generic to significantly reduce the risk of disease.

Figure 5.13 Cause of death for major livestock species in rural Bangladesh

Cause of death (in %)



Source: Bangladesh, Statistics Division, Ministry of Planning. 2010. "Census of Agriculture 2008: Structure of Agricultural Holdings and Livestock Population." Bangladesh Bureau of Statistics. http://www.fao.org/fileadmin/templates/ess/ess_test_folder/World_Census_Agriculture/Country_info_2010/Reports/Reports_3/BGD_ENG_REP_2008.pdf.

Public-private extension services for disease control and prevention could increase reach of public services while stimulating private sector engagement.

The DLS is not equipped to service rural homestead units at scale. Models as introduced by Solidaridad could be strengthened, whereby community members are trained as community livestock service providers to provide affordable services including deworming, regular health checkups, vaccination, and preventive and corrective measures.⁷⁷ Local government-certified private actors could increase the reach of DLS knowledge/standards while incentivizing private sector development in rural Bangladesh. Well-recognized and strictly enforced standards for vaccine prices, schedules, and best practices could minimize the despotism that farmers are subjected to. For example, uncertified "charlatan vets" exploit lack of information at the farmer level, drive up costs, and drive down effectiveness. The capacitation of community-based animal health workers (CAHWs) has been explored around the world with promising results. In Kenya, for example, the model has gained much traction since the 1990s and has become an important alternative channel for animal health delivery with the same effectiveness as professional veterinary practitioners.⁷⁸ The 2014 evaluation of the U.S. Office for Foreign Disaster Assistance CAHW support programs in the Horn of Africa also showed programs to have a strong and lasting effect on animal health, particularly when CAHWs were economically incentivized (for example, when they became independent business holders themselves).⁷⁹

⁷⁷ Consiglieri Private Limited. 2016. "An In-Depth Study on Farmer's Behavior Change, Drivers and Barriers as well as 'Spontaneous' Impact on Family and Neighbors of SaFaL." Solidaridad Network, Dhaka, Bangladesh. <https://www.solidaridadnetwork.org/sites/solidaridadnetwork.org/files/publications/Annex%20B-%20Study%20on%20Farmer%27s%20Behavior%20Change.pdf>.

⁷⁸ G. L. Mugunieri, P. Irungu, and J. M. Omiti. 2004. "Performance of Community-Based Animal Health Workers in the Delivery of Livestock Health Services." *Tropical Animal Health and Production* 36 (6): 523–35.

⁷⁹ Tim Leyland, Raphael Lotira, Dawit Abebe et al. 2014. "Community-Based Animal Health Workers in the Horn of Africa: An Evaluation for the Office of Foreign Disaster Assistance." Feinstein International Center, Tufts University, Somerville, MA, and Vetwork UK, Edinburgh. https://fic.tufts.edu/assets/TUFTS_1423_animal_health_workers_V3online.pdf.

1.1.1.5 Invest in increased pond aquaculture productivity

Homestead pond aquaculture significantly contributes to food security and household income.

Homestead pond aquaculture is prevalent throughout Bangladesh, where more than 4 million households feature ponds in the vicinity of the homestead, covering an area of 266,259 hectares in 2010.⁸⁰ The typical homestead pond (< 0.1 hectares) requires no more than one hour of work per day and contributes to up to 15 percent of household income and a substantial amount of daily protein for the family. Stocking density (animals per cubic meter) and growth rate are the primary drivers of productivity in pond aquaculture, but maximizing productivity is not always desirable. Depending on the species reared, financing available, energy experience, and skill level, strategies might vary. In the past, fish farming was extensive and subsistence in nature. Ponds were stocked with wild fry and fingerlings caught in rivers and cultured without the use of fish feeds. Following the introduction of technology for inducing carp to spawn in the late 1960s and the subsequent development of fishpond management technologies in the 1970s and 1980s, fish farming became widespread and market driven. Culturing various carp and exotic fish species in ponds and lakes became popular all over the country.⁸¹

Table 5.4 Characteristics of homestead carp culture in Bangladesh^a

| Characteristics of homestead carp culture in Bangladesh | | | |
|--|------------------------------|---------------------------|-------------------------------|
| Average pond size (ha) | Aquaculture as a % of income | Fish consumed at home (%) | Source |
| 0.1 | 2.8 | 41 | Thompson <i>et al.</i> (2006) |
| 0.09 | 3 | 37 | Thompson <i>et al.</i> (2006) |
| 0.08 | 13.2 | - | Winrock International (2004) |
| 0.1 | 10 | 26 | Khondker <i>et al.</i> (2010) |
| 0.1 - 0.2 | 15.5 | 47 | Karim (2006) |
| 0.04 | 10 | 29 | Hossain <i>et al.</i> (2010) |
| 0.06 | - | - | Thompson <i>et al.</i> (2006) |
| Approximate budgets for homestead pond carp culture, Phulpur Upazila, Mymensingh | | | |
| Item | Extensive | Improved-extensive | Semi-intensive |
| Extrapolated yield (Kg/ha) | 527 | 1860 | 2890 |
| Actual yield (kg/household) | 42 | 149 | 231 |
| Per unit farmgate value (\$/kg) | 1.44 | 1.44 | 1.44 |
| Operating costs (kg/household) | 58 | 163 | 216 |
| Actual cash equivalent gross income (kg/household) | 66 | 215 | 337 |
| Net cash income (kg/household) | 0 | 52 | 121 |
| Net fish consumption (kg/household) | 42 | 75 | 116 |

Source: B. Belton. 2013. "Small-Scale Aquaculture, Development and Poverty: A Reassessment." FAO Fisheries and Aquaculture Proceedings, 31: 93–108. http://pubs.iclarm.net/resource_centre/WF-3717.pdf.

⁸⁰ B. Belton. 2013. "Small-Scale Aquaculture, Development and Poverty: A Reassessment." FAO Fisheries and Aquaculture Proceedings, 31: 93–108. http://pubs.iclarm.net/resource_centre/WF-3717.pdf.

⁸¹ Madan M. Dey, Manik L. Bose, and Ferdous Alam. 2008. "Recommendation Domains for Pond Aquaculture. Country Case Study: Development and Status of Freshwater Aquaculture in Bangladesh." WorldFish Center Studies and Reviews No. 1872. WorldFish Center, Penang, Malaysia. http://pubs.iclarm.net/resource_centre/WF_1104.pdf.

Aquaculture productivity can be increased significantly through simple, cost-effective improvements. The majority of homestead ponds are “extensive,” meaning they have low stocking densities, minimal fertilizer use, and little additional feed inputs. A shift to “improved extensive” or “semi-intensive” management technologies can have tremendous impact on the productivity of ponds, with yield increases from 500 kilograms/hectare to 3,000 kilograms/hectare. This shift requires improved water management, the use of higher-quality fingerlings, higher-quality food, and basic knowledge about the use of inputs. Increasing pond productivity is neither trivial nor inexpensive, but the return on investment is so significant that adoption rates across the country have been higher than for almost any other agricultural technology in the last decade. Numerous governmental and nongovernmental programs have focused on increasing adoption of management technologies to increase productivity, most notably WorldFish, which has many decades of experience in Bangladesh and combines research and technical support in an effective way.

Input supply chains must be strengthened through private sector development. Commercialization of aquaculture has occurred quickly in Bangladesh. Increased productivity and increased marketability depend on an efficient, trustworthy supply chain, both upstream and downstream. Today, 75 percent of households sell fish. Strikingly, just five years prior the share of farms with a marketed surplus was only 57 percent, indicating that extremely rapid commercialization has occurred. It is not unusual for poor homestead production systems to feed into national and international supply chains. While access to markets is relatively well developed (for example, cool chains, transparency, and quality control), inexistent, inefficient, or untrustworthy input supply chains are the biggest hurdle to increased productivity at farm level (feed, fingerlings, water quality management). The following trends have developed in lockstep:

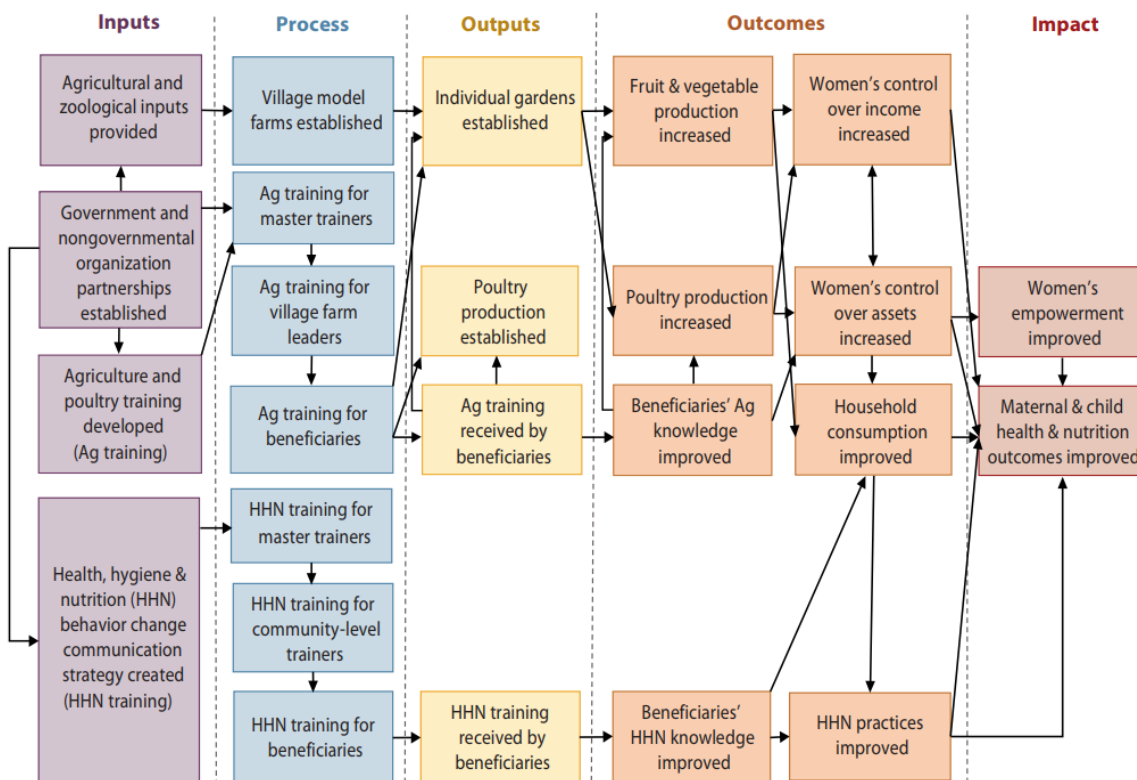
- **Commercialization of high-quality pellets.** Although commercialization is slowly increasing, high-quality pellets have not yet reached the most rural areas of the country. Where pellets can be purchased wholesale, suggested feeding quantities are often two or three times higher than necessary to increase consumption, thereby increasing nutrient overload in ponds and decreasing yields.
- **High-quality fingerlings.** Farmers have shifted away from trapping wild fish on their farms or buying locally available wild seed in the early 1990s to stocking hatchery-produced seed in the 2000s. By 2011, 98 percent of fish seed was produced by private hatcheries.⁸² Still, quality seedlings are in short supply, and ponds across the country suffer from high mortality rates.
- **Importance of water management.** Water management will increase in importance as stocking densities increase. Lime, antibiotics, salt, fungicides, insecticides, and feed additives such as vitamins have increased in line with higher stocking densities and feed use. This has occurred as the incidence of disease has increased and better management has become necessary to maintain water quality within the parameters required for fish survival and growth. As stocking densities increase further, water management will increasingly be a natural constraint to increased productivity.

⁸² Ben Belton and David C. Little. 2011. “Immanent and Interventionist Inland Asian Aquaculture Development and its Outcomes.” *Development Policy Review* 29 (4): 459–84. <https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1467-7679.2011.00542.x>.

1.1.1.6 Invest in strong, gender-sensitive nutrition education campaigns

Education campaigns are likely the most effective way to increase the productivity and resilience of women-controlled production systems. Increased homestead productivity (livestock, poultry, aquaculture, or vegetable gardening) is neither capital intensive nor does it require a highly technical understanding of agricultural processes. However, increased adoption rates require a strong understanding of the value proposition and risks involved, as well as the empowerment of family members to adopt and implement new technologies. In the context of gender-sensitive development, participatory education campaigns have proven particularly effective. A leader in this field is Helen Keller International, which combines homestead development with nutritional education. The main objectives of the program are to (a) increase the diversity and year-round production of fruits and vegetables by participating households; (b) increase the year-round production of meat, poultry, and eggs by participating households; (c) improve consumption of fruits and vegetables and animal source foods by members of households involved in the program through increased production and nutrition-related education; and (d) improve health and nutrition outcomes for women and children in participating households.⁸³ This program (and similar programs) have been very effective in terms of both outputs (adoption rates of improved homestead gardening technologies) and outcomes (decreased micronutrient deficiencies, increased household revenues).

Figure 5.14 Theoretical framework of Helen Keller International’s homestead food production program^a



Source: D. K. Olney, A. Dillon, M. T. Ruel et al. 2016. "Lessons Learned from the Evaluation of Helen Keller International's Enhanced Homestead Food Production Program." In *Achieving a Nutrition Revolution for Africa: The Road to Healthier Diets and Optimal Nutrition*, edited by Namukolo Covic and Sheryl L. Hendriks, 67–81. Washington, DC: International Food Policy Research Institute.

⁸³ A. Talukder, N. J. Haselow, A. K. Osei et al. 2010. "Homestead Food Production Model Contributes to Improved Household Food Security and Nutrition Status of Young Children and Women in Poor Populations: Lessons Learned from Scaling-Up Programs in Asia (Bangladesh, Cambodia, Nepal and Philippines)." *Field Actions Science Reports Special Issue 1 2010: Urban Agriculture*. <https://journals.openedition.org/factsreports/404>.

Three decades of experience in Bangladesh and beyond provide lessons about gender-sensitive development through education campaigns. Helen Keller International represents only one of many programs that have successfully deployed behavior change programs at the homestead level. Others include WorldFish, Feed the Future, Danida, CARE Bangladesh, IFPRI, and BRAC. Key lessons learned from these programs include the following:⁸⁴

- Reduce asymmetries of information, access to credits, property rights, and decision power between men and women in dual households.
- View agriculture as part of a wider set of rural development processes that include enterprise development and nonfarm employment.
- Couple technology transfer with other services relating to both the input and output markets.
- Employ more women extension staff, preferably female para-extension agents, to work closely with women groups.
- Understand that behavior change is most effective when the entire family partakes (or when it is cooperative-based) and when extension service is as much a conversation between actors as a training and/or education in a specific theme or technology.
- Address women's real needs through analysis of household-level information about their livelihoods, aspirations, and opportunities for sustainable income generation.
- Increase capacity and efficiency of extension service through a cascade structure whereby the trainee will cascade the knowledge to government extension and agribusiness officers at the local government levels and interested agribusiness entrepreneurs.
- Use extension agents as facilitator-building linkages between farmers and the private sector, NGOs, government programs, researchers, or others to address problems and stimulate rural innovation.

1.1.1.7 Invest in enhanced disaster risk management approaches.

Economic losses to the agriculture sector are estimated at US\$2.2 billion annually.⁸⁵ The Impact of Climate Change on Human Life Programme of the BBS estimates that US\$2.2 billion is lost annually due to environmental events exacerbated by climate change. The effect of floods and erosion stand out as major concerns, followed by cyclones and waterlogging. These costs are most relevant for homestead agriculture in southwest Bangladesh and therefore warrant considerable attention.

⁸⁴ Bjorn Van Campenhout. 2017. "Designing Gender Sensitive Agricultural Extension Information Campaigns. IFRI Blog, September 27. <http://www.ifpri.org/blog/designing-gender-sensitive-agricultural-extension-information-campaigns>; FAO (Food and Agriculture Organization of the United Nations). 2013. Convention on the Elimination of All Forms of Discrimination against Women: A Tool for Gender-Sensitive Agriculture and Rural Development Policy and Programme Formulation; Guidelines for Ministries of Agriculture and FAO. Rome: FAO. <http://www.fao.org/3/i3153e/i3153e.pdf>; Gary Alex, Willem Zijp, and Derek Byerlee. 2002. "Rural Extension and Advisory Services: New Directions." Rural Development Strategy Background Paper #9. Agriculture and Rural Development Department, IBRD/World Bank. <http://documents.worldbank.org/curated/en/871281468739519439/pdf/multi0page.pdf>.

⁸⁵ Md Rafiqul Islam. 2016. "Bangladesh Disaster-Related Statistics 2015." Impact of Climate Change on Human Life Programme, Bangladesh Bureau of Statistics, Dhaka. http://203.112.218.65:8008/WebTestApplication/userfiles/Image/National%20Account%20Wing/Disaster_Climate/Presentation_Realease_Climate15.pdf.

Table 5.5 Economic impact of weather events on agricultural subsectors in Bangladesh (in millions of US dollars)

| | Crops | Livestock | Poultry | Fishery | Land | Houses | Homestead & forestry |
|------------------------------|-------|-----------|---------|---------|------|--------|----------------------|
| Drought | 6.3 | 0.1 | 0.1 | 0.1 | 0.5 | 0.0 | 0.2 |
| Flood | 61.8 | 6.6 | 1.6 | 5.5 | 25.0 | 14.1 | 4.7 |
| Waterlogging | 9.1 | 0.7 | 0.2 | 2.6 | 1.6 | 1.9 | 0.8 |
| Cyclone | 7.8 | 5.8 | 1.4 | 3.9 | 0.0 | 20.0 | 13.6 |
| Tornado | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | 0.2 |
| Storm/tide surge | 1.9 | 0.6 | 0.3 | 2.7 | 2.7 | 1.5 | 0.7 |
| Thunderstorm | 1.8 | 0.3 | 0.1 | 0.0 | 0.0 | 4.4 | 1.2 |
| River/coastal erosion | 2.5 | 1.7 | 0.1 | 0.8 | 75.3 | 4.8 | 1.1 |
| Landslides | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Salinity | 0.9 | 0.1 | 0.0 | 0.0 | 1.1 | 0.0 | 0.4 |
| Hailstorm | 7.2 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 0.2 |

Source: Md Rafiqul Islam. 2016. "Bangladesh Disaster-Related Statistics 2015." Impact of Climate Change on Human Life Programme, Bangladesh Bureau of Statistics, Dhaka. http://203.112.218.65:8008/WebTestApplication/userfiles/Image/National%20Account%20Wing/Disaster_Climate/Presentation_Realease_Climate15.pdf.

Disaster risk management (DRM) has become a major focus of national governments and for multilateral donors. DRM is the application of disaster risk reduction policies and strategies to prevent new disaster risks, reduce existing disaster risks, and manage residual risks, contributing to the strengthening of resilience and reduction of losses.⁸⁶ It is hence an attempt to reduce the exposure and vulnerability of people, animals, and infrastructure to external hazards. Bangladesh is one of the major recipients of overseas development assistance. Throughout the past decade, US\$300 million has been committed in projects that are either already completed or still ongoing. The World Bank has a pipeline of projects amounting to US\$2.2 billion, either partly or wholly touching on DRM. This reflects the large and growing urgency for DRM in Bangladesh.

Two key DRM related interventions for the agriculture sector stand out:

First, killas are a simple way of saving the lives of farmers and livestock living close to the water. Killas are parcels of earth that are elevated 3–4 meters where people and livestock can quickly take shelter during storms and flooding. The sloping structure of killas opposite the water allows cattle and elderly people to climb them easily. The seaward face is straight to minimize the force of the cyclone or the tidal bore. The top of the killa is well vegetated to decrease erosion. Killas are not capital intensive and are often the first demand of villagers after cyclones strike.

Second the provision of Climate Services and Agriculture Information Services. Service provisions is currently being scaled up but the institutional capacity at national down to rural level would need to be strengthened and dissemination scale out further.

Floating gardens are an effective way to protect against the effects of flooding. As shown in box, floating gardens are an effective way to decrease the impact of floods and storms on household crop production.

⁸⁶ UN–SPIDER (United Nations Office for Outer Space Affairs). "Disaster Risk Management." Accessed September 2018. <http://www.un-spider.org/risks-and-disasters/disaster-risk-management>.

Box 5.3 Floating gardens: a case study of increased smallholder production and nutrition security

Floating gardens

Climate change impacts

Evidence of climate change in Bangladesh can be seen in an accumulation of heavy rains, frequent storms, and rising sea levels that result in severe flooding. Due to continuously waterlogged conditions, crops are often lost, and land for agriculture has become scarce. The low-lying areas of the southern coastal and south-central districts of Bangladesh remain submerged for six- to eight-month periods every year, especially during monsoon season. As a result, crop cultivation is not possible on land. In these circumstances, adaptation and resilience measures to climate change have become a priority for improving the flood security of the nation's vulnerable people.

The study

In 2015 FAO conducted a study on a successful climate-smart production system in the lowlands of Bangladesh that was based on the knowledge of local farmers. These farmers had converted the prolonged flooding season into an opportunity to create floating gardens, or floating plots made from local organic material on which diversified vegetables are grown or seedlings are raised for marketing. The FAO study examined how these floating garden production systems are constructed and how they contribute to resilience and livelihoods in these communities. The study was conducted at three floating vegetable cultivating districts: Pirojpur, Barisal, and Gopalganj. The practitioners, local extension providers, input suppliers, and local government officials were all consulted. (There are only a handful of other studies on the floating garden production system.)

Farmers prepare the rectangular-shaped beds during June and July and sow/transplant seeds eight to 10 days after the last stacking to the garden bed. Around 30 species of vegetables, spices, and other crops or seedlings are grown in this water-based production system. The major vegetable crops are okra, ribbed gourd, Indian spinach, brinjal, cucumber, red amaranth, stem amaranth, wax gourd, and in winter, turnip, papaya, cabbage, cauliflower, and tomato. The spices turmeric and chili are also grown. Mixed intercropping is the most prevalent system.

The results

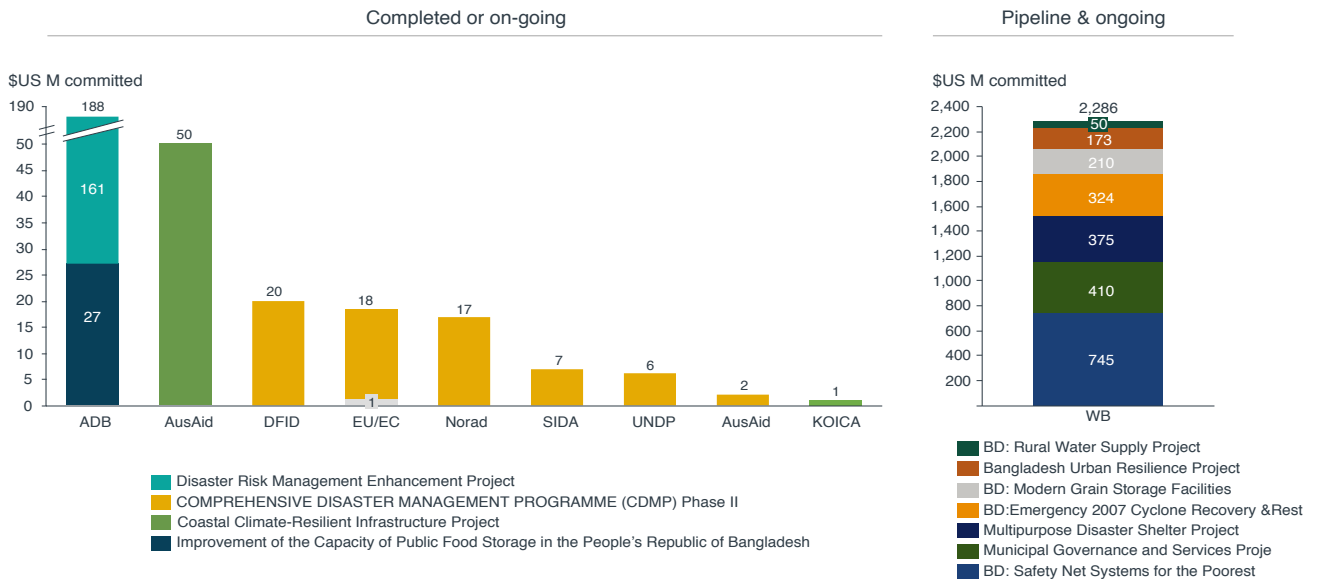
The results of the study demonstrate that floating gardens have several advantages:

- The fallow waterlogged area can be cultivated, and the total cultivatable area is increased.
- The area under floating cultivation is more fertile than the land on the plains.
- No (or minimal) fertilizer or manure is required, unlike in the conventional agricultural system.
- After cultivation, the biomass generated can be used as organic fertilizer in the field, and it conserves natural resources.
- During floods, floating gardens can be used as shelters for poultry and cattle. Fishers can cultivate crops and fish at the same time since the gardens are built on beds made of plant material and bamboo. This allows the plot to rise and fall with the river water levels, and it does not wash away no matter how long the floods last.

Floating gardens are environmentally friendly while contributing to food security and nutrition. The organic production of vegetables is important for local, urban, and export markets. There is scope for improving productivity, profitability, and marketing, as well as opportunities for value addition through research and development programs.

Source: FAO (Food and Agriculture Organization of the United Nations) 2018. Climate-Smart Agriculture Case Studies 2018: Successful Approaches from Different Regions. Rome: FAO. <http://www.fao.org/3/CA2386EN/ca2386en.pdf>.

Figure 5.15 Major disaster risk management programs and projects funded by Official Development Assistance (ODA) in Bangladesh^a

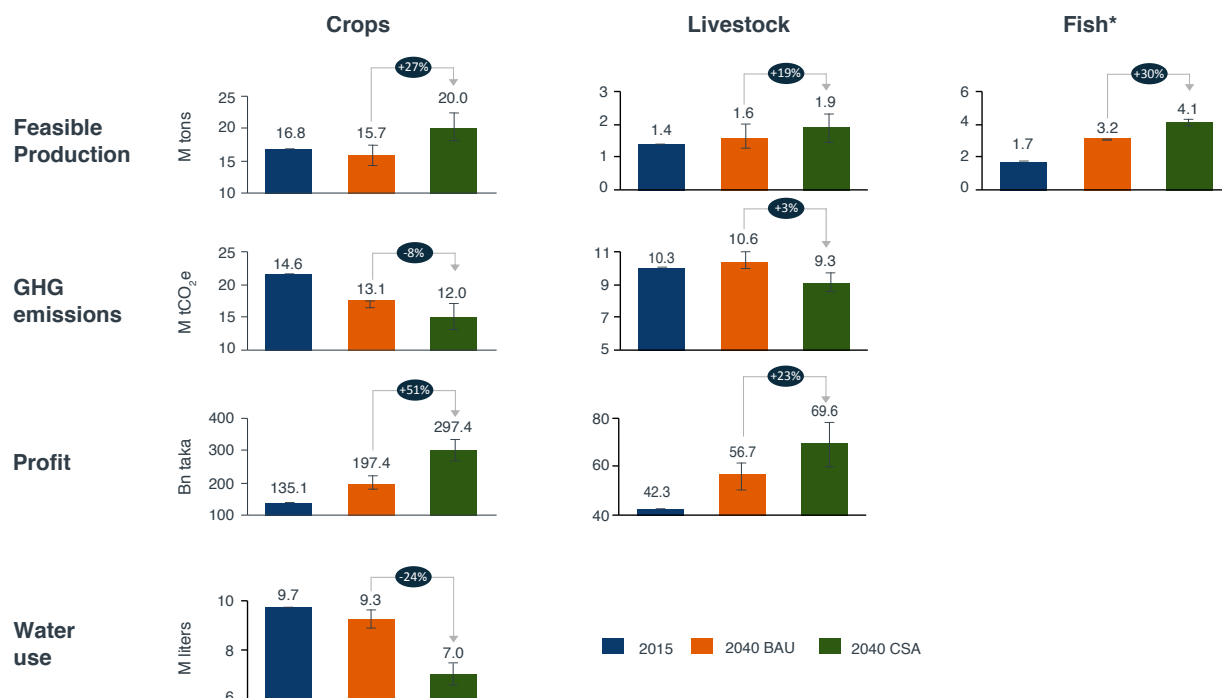


D. K. Olney, A. Dillon, M. T. Ruel et al. 2016. "Lessons Learned from the Evaluation of Helen Keller International's Enhanced Homestead Food Production Program." In *Achieving a Nutrition Revolution for Africa: The Road to Healthier Diets and Optimal Nutrition*, edited by Namukolo Covic and Sheryl L. Hendriks, 67–81. Washington, DC: International Food Policy Research Institute.

Quantified estimate of impact

CSA promises to increase production, decrease GHG emissions, and increase resilience in southern Bangladesh. CSA technologies explored in the CSAIP model are projected to have a strong effect on production across commodities compared to the BAU scenario. Most significantly, fish production is projected to rise by around 30 percent, reflecting significant productivity boosts and an expansion of homestead aquaculture. Total crop yields could increase by 27 percent and livestock production by 19 percent, providing higher incomes, better job opportunities, and greater food security. Importantly, associated profits for crops and livestock are projected to rise by 51 percent and 23 percent, respectively, creating an important buffer against environmental and price shocks. While these figures include larger-scale production systems in the region, the overall trend can be expected to hold for small-scale production systems typical of homestead production, such as vegetables, cattle, poultry, and fish. The following paragraphs deviate from the CSAIP model and introduce a few simple calculations to estimate homestead-level benefits that are more closely associated to investment opportunities discussed above.

Figure 5.16 Effect of CSA on key indicators in southern Bangladesh (Barisal, Khulna, and Chittagong)
(Source: BCSAIP Model Results)



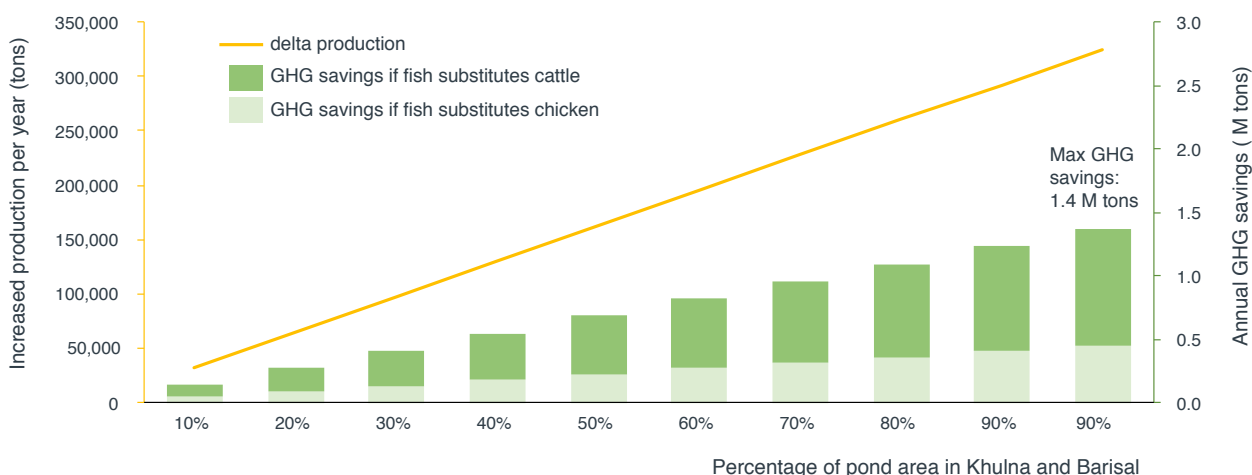
Note: Model projections for fish values are very preliminary and should be interpreted with caution.

Improved veterinary systems and DRM could significantly drive down mortality, decrease variability of income throughout the year, and decrease GHG intensity. For simplicity, it is assumed that all farm holdings in Khulna and Barisal that are smaller than 2.5 hectares (a total of 2.9 million farm holdings) are generally in the scope of this package. Based on 2008 census data, the following estimates can be made:

- If DRM interventions decrease livestock mortality from environmental hazards by 25 percent and if improved veterinary services decrease livestock mortality from diseases and epidemics by 25 percent, a total of 2.5 million fowl and 40,000 cattle could be saved.
- Veterinary systems can further increase the productivity of cattle, thereby boosting the dairy and fattening process.
- The highest mortality rates (particularly of fowl) are during the monsoon season, when flooding and rain weakens the immune system of poorly adapted flocks; improved veterinary services ensure year-long income streams from livestock.

Improved pond aquaculture practices could increase productivity threefold and decrease the GHG footprint of protein consumed. Pond aquaculture productivity could theoretically be increased 400–500 percent, assuming strong water quality management, quality feed, and quality fingerlings. This is especially true for fast-growing saline and brackish-water species such as shrimp; productivity can be increased by a factor of at least 10 compared to Thailand. Realistically, however, homestead ponds can transition from current productivities of 500 kilograms/hectare/year to 1,800 kilograms/hectare/year. Given a total homestead pond area of approximately 250,000 hectares in Khulna and Barisal, Figure provides an overview of feasible impacts (tons and GHG mitigation) based on different assumptions on project reach and/or effectiveness.

Figure 5.17 Potential impact of increased homestead pond productivity in Khulna and Barisal (Source: BCSAIP Model Results)



Cost assessment

Projects focusing on rural development and resilience have a large range of costs. Past World Bank projects that are similar in their objectives to this package range from US\$35 million to US\$360 million (Figure). Counting all phases and components of the Philippine Rural Development Project, costs exceeded US\$520 million. For comparison and simplification, the costs are divided into six component categories. Across projects, 50 percent of the costs are made up of investments in the agro-industry, productive assets, and infrastructure, followed by investments in marketing, trade, value chain, and finance. A closer look at these costs reveals that in both components, the majority of costs are earmarked to develop supply chains, improve market links, and build local capacities to increase the efficiency of existing infrastructure structures such as markets and cooperatives.

Extension services should be made a priority. As shown in the Figure, only 1 percent of costs across comparable World Bank projects have been earmarked to extension services and research, though the importance of extension services and research for agricultural productivity is well recognized. In Bangladesh, extension services and research receive much attention in the commercial crop and livestock subsectors. Promoting this aspect of sector support in rural development programs should be a central focus of future investments.

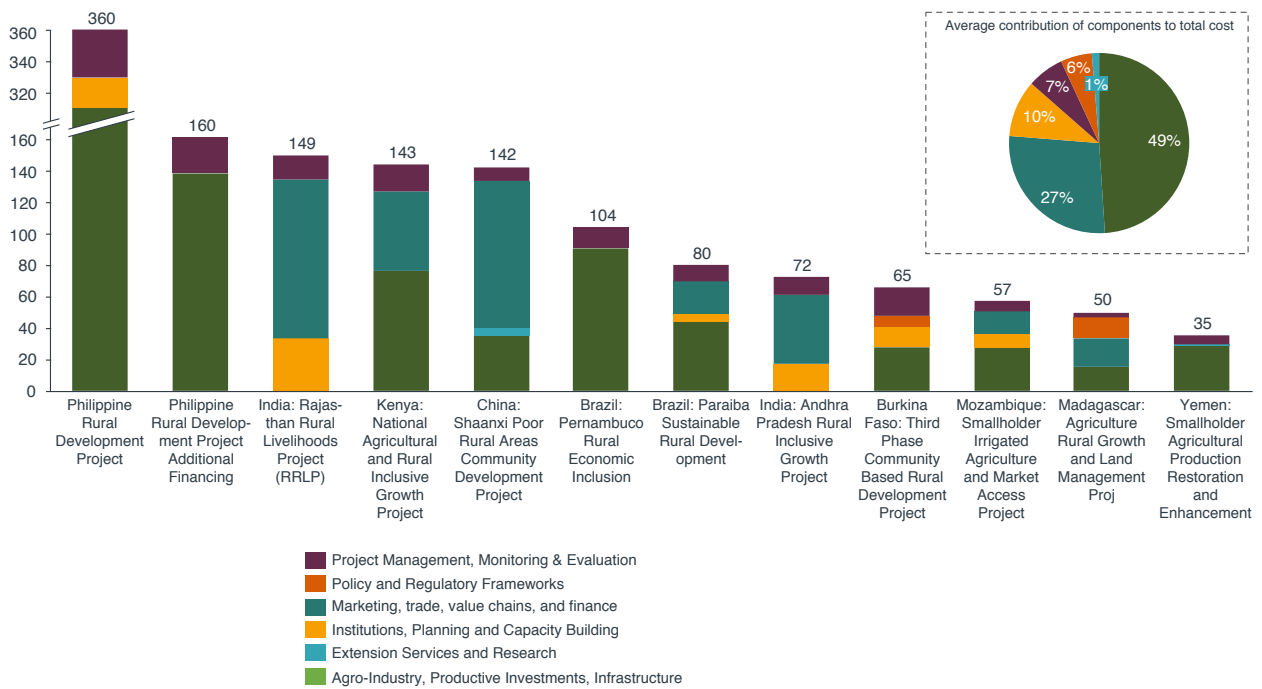
The estimated cost of Package 2 for southern Bangladesh is US\$125 million, ranging from US\$117 million to US\$133 million (or US\$320 million, ranging from US\$300 million to US\$340 million, PPP 2017 US dollars). In order to assess the cost of Package 2 in Bangladesh, the number of beneficiaries in the southern region of the country was estimated at 1 million households. Comparable projects of other countries were also taken into consideration. Following the cost per beneficiary of Philippines as standard for Bangladesh, the estimated cost of this package is US\$125 million. However, considering the different scenarios of inflation, time value, and exchange risk, the range of estimated package cost is from US\$117 million to US\$133 million.

Results of Cost Benefit Analysis

The results of a cost-benefit analysis for Package 2 show an IRR of 27% and an ERR of 34%. This is higher than the median ERR of past World Bank projects. Relying on a regression analysis, the median ERR of World Bank projects in the agriculture and rural development sector between 1996 and 2008 is estimated at 23%. Based on the CBA, the NPV of Package 2 amounts to US\$ 87 million

while the ENPV is estimated as high as US\$ 126 million. The CBA for Package 2 was based on the following assumptions: First, crop production will increase by 27%, livestock by 19% and fish from pond aquaculture by 30% as estimated by the Bangladesh CSAIP model due to package implementation. Second, it is assumed that at least 40% of these increases will materialize in the most conservative scenario. Third, southwest Bangladesh will be the part of the country that is most affected by climate change. Fourth, in line with historical growth rates, production will increase by 3% annually. Fifth, non-agricultural benefits caused by positive externalities such as a reduction in health hazards and an increase in life expectancy will account for 10% of total package benefits.

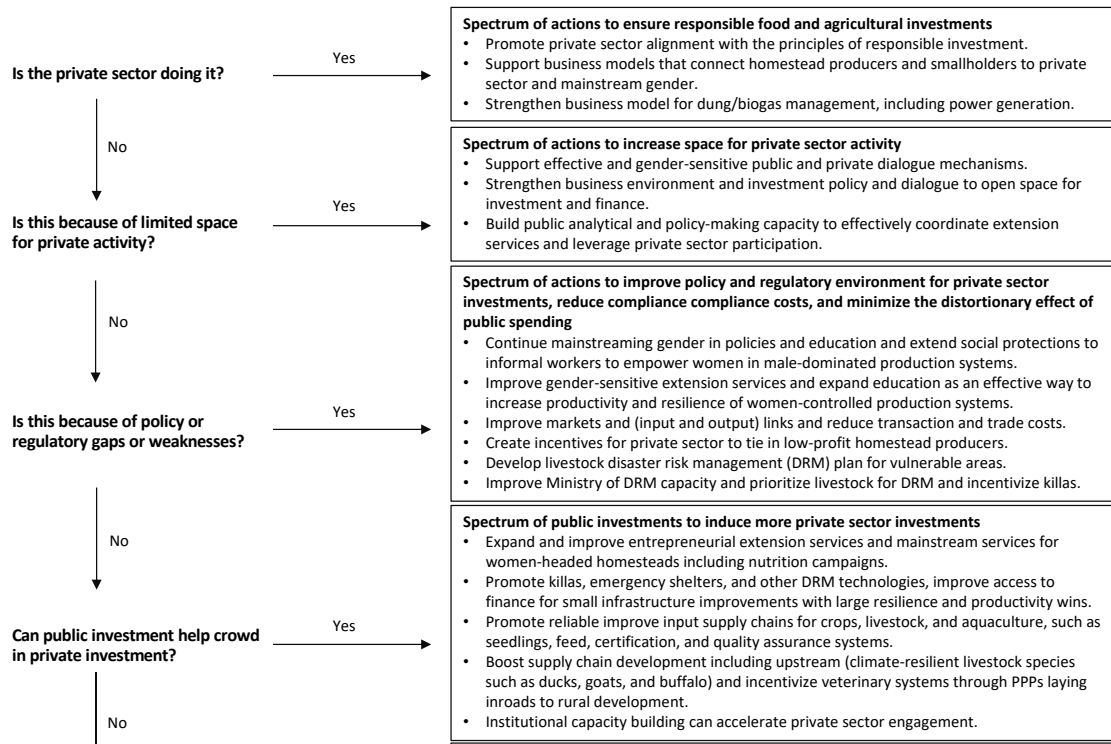
Figure 5.18 Cost of World Bank projects with objectives comparable to those of Package 2 (Source: World Bank Project Appraisal Documents))



Note: Costs are shown in 2017 PPP US dollars.

Maximizing Finance for Development

Figure 5.19 Decision tree for maximizing finance for development for Package 2



5.4 Package 3: Resilience through diversification

Table 5.6 Overview of Package 3

| | |
|---|---|
| Subtitle | Secure higher and more resilient income streams for farmers in northern Bangladesh through crop diversification, especially during the boro season. |
| Context | High-yielding boro rice is one of the most prominent crops in northwestern Bangladesh, an area prone to moderate-to-severe droughts across all seasons and moderate-to-severe river flooding along the river banks. Cultivating rice at high cropping intensities (up to 300 percent across three seasons—aus, aman, and boro) with high use of synthetic fertilizers and pesticides has acidified the soil. The expansion of rice cultivation, especially of irrigated boro rice, over the past decades has led to increasing pressure on already scarce water resources, resulting in rapidly declining groundwater levels. Crop diversification away from highly water-intensive boro cultivation is widely seen as a necessary step to increase the resilience of both farmland and farm income. However, past attempts to diversify crops have seen poor adoption rates due to lack of technological know-how at the farm level and lack of robust supply chains (seed supply, postharvest and storage facilities) and markets (poor demand). This package focuses on the key ingredients necessary to make alternative crops an attractive value proposition for farmers in northwestern Bangladesh and spur the uptake of diversified crop production. |
| Investment opportunities | <ul style="list-style-type: none"> • Invest in targeted supply chain improvements. • Invest in improved high-yielding restorative non-rice crop systems. |
| Potential impact | <ul style="list-style-type: none"> • Rice production will remain constant at 2015 levels with massively increasing profits. • Non-rice crop production will increase by 94%; profits will increase by 77%. • Water use will drop by 10 million liters a year by 2040 (compared to BAU), and GHG emissions will drop by 8 million tons of CO₂e per year. |
| Cost of comparable World Bank projects | <ul style="list-style-type: none"> • Comparable country-level AIS projects in Burkina Faso and Benin had costs ranging from US\$160 million to US\$184 million. • Dominating cost categories are (a) agro-industry, productive investments, and infrastructure and (b) marketing, trade, value chains, and finance. |
| Estimated cost in Bangladesh | <ul style="list-style-type: none"> • US\$ Nominal 2017: US\$196 million (Range: US\$186 to US\$205 million) • US\$ PPP 2017: US\$500 million (Range US\$475 million to US\$525 million) |
| Cost Benefit Analysis | <ul style="list-style-type: none"> • IRR: 25% • ERR: 31% • NPV: US\$ 79 million • ENPV: US\$ 101 million |

Context and problem statement

Rice intensification has led to self-sufficiency in food production but comes at an economic and ecological price. Since the 1960s, rice has been grown on more than three-quarters of Bangladesh's arable land area.⁸⁷ Boro rice alone is responsible for more than half of Bangladesh's overall rice production in the past decade and is even higher in the northwestern province of Rajshahi, where boro comprises nearly two-thirds of rice production.

⁸⁷ FAO (Food and Agriculture Organization of the United Nations). 2016. "Country Fact Sheet on Food and Agriculture Policy Trends." <http://www.fao.org/3/a-i5890e.pdf>.

Rice intensification and monocropping have resulted in a tripling of rice production since the 1970s but have left soils depleted and harvests vulnerable to pests and diseases. From a nutritional perspective, reliance on rice satisfies national calorie demand but has not closed the national nutritional gap for essential nutrients. Economically, farmers are dependent on single markets, which can fluctuate, and the large national production of rice at scale diminishes individual farmers' margins.⁸⁸ As a result, crop diversification has been an often-cited opportunity to address nutrient deficiencies and rural poverty.

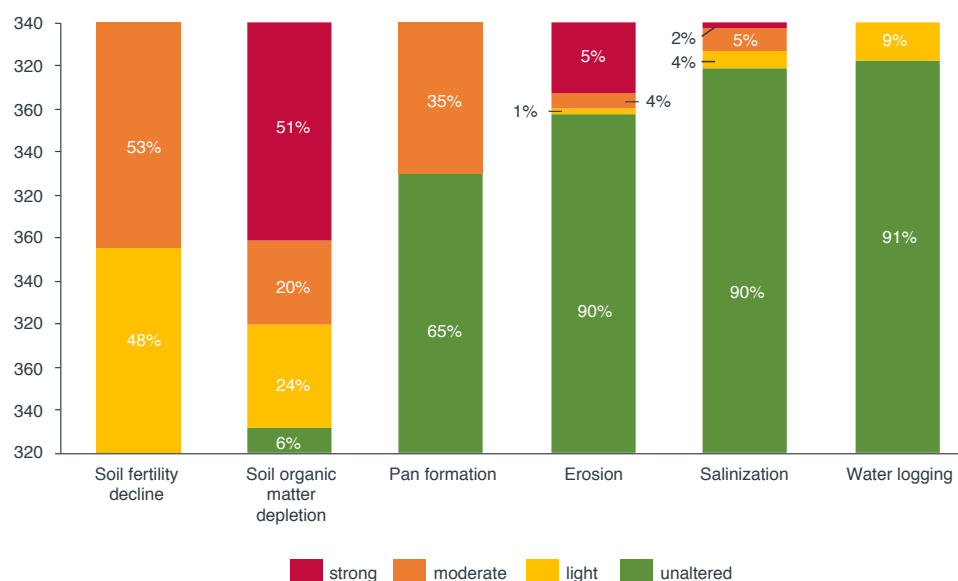
Boro rice increases pressure on water resources in an already drought-prone area. High-yielding boro rice was developed for cultivation in waterlogged areas in Bangladesh. With increased irrigation capabilities across the country, it has become the most productive paddy in the country and has contributed considerably to Bangladesh's rice self-sufficiency achievements. Boro is grown in the rabi season, off-season from the annual monsoons, when water is scarcer. As a result of climate change and large infrastructure projects in India, water availability is projected to decrease even further due to decreased river volumes (mainly dams in India), decreasing and more erratic rainfall, and falling water tables. As a result, farmers face increasing risk of crop failure and spiking irrigation costs.

While southern Bangladesh struggles with land loss, northwestern Bangladesh is concerned with declining soil quality. All of the soils used for agricultural productivity are experiencing a decline in fertility, with nearly all (7.6 out of 8 million hectares) experiencing a decrease in soil organic matter (figure 5.20). More than half of the country's soils are severely depleted of organic matter. Other key soil nutrients, such as phosphorus, nitrogen, and potassium, are all declining significantly across the country from multiple years of rice-rice and rice-wheat cultivation, particularly where fertilization has not been used to replenish soil nutrients. Cropping intensities in the north are among the highest in the country (up to 300 percent including all crop varieties).⁸⁹ Crops that have the capacity to fix nitrogen and help to improve soil quality are grown on less than 2 percent of land area. Beyond intensification, the soils are threatened by a number of factors such as erosion, salinization, waterlogging, and hardpan (the removal of a top layer of soil).

⁸⁸ Mohammad Monirul Islam and Md Elias Hossain. 2016. "Crop Diversification in Bangladesh: Constraints and Potentials." <http://bea-bd.org/site/images/pdf/057.pdf>.

⁸⁹ M. K. Hasan and A. K. M. Ashraful Alam. 2006. "Land Degradation Situation in Bangladesh and Role of Agroforestry." *Journal of Agriculture and Rural Development* 4 (1): 19–25. https://www.researchgate.net/publication/250212433_Land_Degradation_Situation_in_Bangladesh_and_Role_of_Agroforestry.

Figure 5.20 Land degradation in Bangladesh as a percentage of total arable land



Source: Hasan, M. K., and A. K. M. Ashraf Alam. 2008. "Land Degradation Situation in Bangladesh and Role of Agroforestry," *Journal of Agriculture and Rural Development* 4 (1): 19–25. https://www.researchgate.net/publication/250212433_Land_Degradation_Situation_in_Bangladesh_and_Role_of_Agroforestry.

Enabling Environment

Although agricultural policies are focused on rice self-sufficiency, diversification has become a highly recognized driver for resilience and nutrition security. As discussed above and detailed in BCSAIP Appendices, Appendix A, current policy instruments primarily focus on self-sufficiency as a development goal of the agriculture sector. However, resilience to environmental and market shocks has long been considered an important policy goal. Most prominently, the goal of diversification is highlighted in the seventh five-year plan, which envisions that Bangladesh will "attain and maintain self-sufficiency in staple food (rice) production and meet the nutritional requirement of the population through supply of an adequate and diverse range of foods. Production and consumption diversification with high value crops including vegetables, fruits, has to be the ideal target for food production in the country."⁹⁰

Several crop diversification programs in Bangladesh point to important lessons learned. Bangladesh has long promoted crop diversification with significant financial commitments, such as for the 1989 Crop Diversification Programme. The program's objectives included achieving self-sufficiency in food grain production, increasing household-level incomes, promoting adoption of modern agricultural practices in dry land, and ensuring sustained agricultural growth through more efficient and balanced use of land, water, and other resources. Since then, several attempts have been made to diversify production and shift away from dependence on rice. In 2000, the Asian Development Bank approved the Northwest Crop Diversification Project (\$46.3 million loan) to help increase the income of small and marginal farmers by cultivating high-value crops and adopting appropriate modern production technologies and improved marketing. Throughout the program's lifetime (2001–09), it disbursed US\$36 million in credits to 260,000 farmers seeking to buy high-value non-rice varieties (HVCs), trained almost 400,000 farmers in modern cultivation technologies around HVCs, and constructed 76 markets at the grower, district, and central levels.

⁹⁰ Bangladesh, General Economics Division, Planning Commission. 2015. "Seventh five-year plan, FY2016–FY2020: Accelerating Growth, Empowering Citizens." https://www.unicef.org/bangladesh/sites/unicef.org/bangladesh/files/2018-10/7th_FYP_18_02_2016.pdf.

As a result, 4 million farmers, of whom 57 percent were women, increased their income by 21–56 percent, with a loan repayment rate of nearly 100 percent.⁹¹ The project provides important lessons that should be considered in follow-up projects. Judging from a large body of evaluation literature and expert opinions, key constraints typically entail the following:

- The most productive land continues to be used for high-yielding boro rice, and risk-averse farmers are not incentivized pivot to crops with potentially lower yields and less developed markets.
- Most crops (except pulses, maize, and some vegetables) require irrigation during the dry season, but subsistence farmers can hardly afford to irrigate crops other than rice.
- A large quantity of pulses, oilseeds, and edible oils are imported every year, and imports bring down the local price for pulses, exposing local producers to competition from world market prices.
- A lack of storage facilities leads to sudden spikes of regional supplies, thereby decreasing prices to unprofitable levels.

Figure 5.21 SWOT analysis of Package 3 based on the second stakeholder workshop held in Dhaka, April 2018

| | Helpful | Harmful |
|----------|---|--|
| Internal | <p>Strengths</p> <ul style="list-style-type: none"> • Increased profitability sets in quickly (off-season price surges). • Northern Bangladesh is a priority region for development by the Government of Bangladesh. • The microfinance ecosystem is strong. | <p>Weaknesses</p> <ul style="list-style-type: none"> • Low demand for non-rice crops • Limited farm-level know-how • Inadequate access to finance • Risk-averse farmers |
| External | <p>Opportunities</p> <ul style="list-style-type: none"> • Developing clear market access for non-rice crops to ensure profitability for diversifying farmers • Policy push for diversification (in the eighth five-year plan) • Blended finance vehicles to make early investments less risky and strengthen the supply chain • Learning from farmer associations inside and outside of Bangladesh • Digitization of government procurement | <p>Threats</p> <ul style="list-style-type: none"> • Market access or rural communities might not be economical for producers. • Low-quality products decrease interest of private sector. • Food systems are informal and market links are weak. • Hoarders and middlemen who control market segments and dilute profits for farmers arbitrage the value chain. |

⁹¹ Asian Development Bank. 2011. "Bangladesh Project Brief: Northwest Crop Diversification Project." <https://www.adb.org/sites/default/files/publication/29400/brief-ncdp-2.pdf>.

Investment opportunities

1.1.1.8 Invest in targeted supply chain improvements

Develop clear market access to ensure profitability for farmers. Boro rice is perceived as more favorable than other crops due to its importance to household-level food security, high yields, and secure market pathways. Although a shift to non-rice crops can provide important benefits to farmers (such as off-season income streams, a diversified diet, and reduced water costs), these benefits must be tangible from the onset. This requires (a) a high level of collaboration among farmers on a regional level to build cooperatives and markets, (b) increased transparency of the government's rice/wheat procurement system to help farmers plan production cycles, and (c) access to low-risk finance (potentially microfinance) that is made less risky through climate adaptation funds (both debt and equity). Marketing of crops is a key limitation of previous crop diversification projects in Bangladesh, with only half of the marketplaces established through other development mechanisms in regular use.⁹² Developing effective, functioning cooperative systems with a physical marketplace that can be used is critical to the success of future diversification projects.

Market access is key to incentivizing diversification, but top-down creation of supply chains could lead to inefficiencies. Past market development programs have suffered from simple design issues that only became apparent in retrospect. One example is that the throughput of products gets overestimated, resulting in excessively large marketplaces that end up being used under capacity, leading to economic inefficiencies with serious long-term repercussions for sustainable finance. Another example is the holdup of marketplace construction and inauguration when new markets replace older marketplaces that benefit local political and commercial actors. Hence, technicalities such as location, size, and governance of market halls should be developed in close coordination with local governments, NGOs, and the private sector.

Development of cold storage is critical to ensuring that vegetables and non-rice commodities reach market. Currently, lack of adequate systems to store perishable non-grain commodities limits farmers' ability to bring them to market, particularly in the northwestern portion of Bangladesh, which is far from the population hub of Dhaka. While BARI provides recommendations for few postharvest technologies on litchi, mango, and tomato, refrigerated storage systems help to ensure that these commodities can be sold by smallholder farmers in Bangladesh. Creating this system of refrigerated units will require access to microfinance mechanisms that have been made sufficiently less risky using climate adaptation funds and other mechanisms. Currently, farmers are constrained by a lack of physical collateral from accessing these kinds of loans. Furthermore, most cold storage units are beyond the investment scale of most individual farmers. In India, climate finance has been used to provide as much as 60 percent of the capital needed to fund these initiatives.⁹³

1.1.1.9 Invest in improved high-yielding, restorative non-rice crop systems

Provide improved seeds of high-value non-rice crops. Promising non-rice crops include pulses, maize, and vegetables that require less water and are better suited for the environmental conditions of northwestern Bangladesh. Of particular interest are improved varieties, such as dwarf maize, which allows an early harvest and is only marginally vulnerable to wind; heat-tolerant wheat varieties that are suitable for late planting; and high-yielding drought-tolerant chickpea varieties. These crops offer higher profit margins and labor productivity than rice, which is labor intensive to harvest and provides only limited profits to farmers.

⁹² Eusuf and Associates. 2010. Impact Evaluation of Northwest Crop Diversification Project. Dhaka: Implementation Monitoring and Evaluation Division, Ministry of Planning, Government of Bangladesh.

⁹³ Marc Peter Sadler, Alberto Millan Arredondo, Stacy A. Swann et al. 2016. "Making Climate Finance Work in Agriculture." Discussion Paper. World Bank Group, Washington, DC. <http://documents.worldbank.org/curated/en/986961467721999165/Making-climate-finance-work-in-agriculture>.

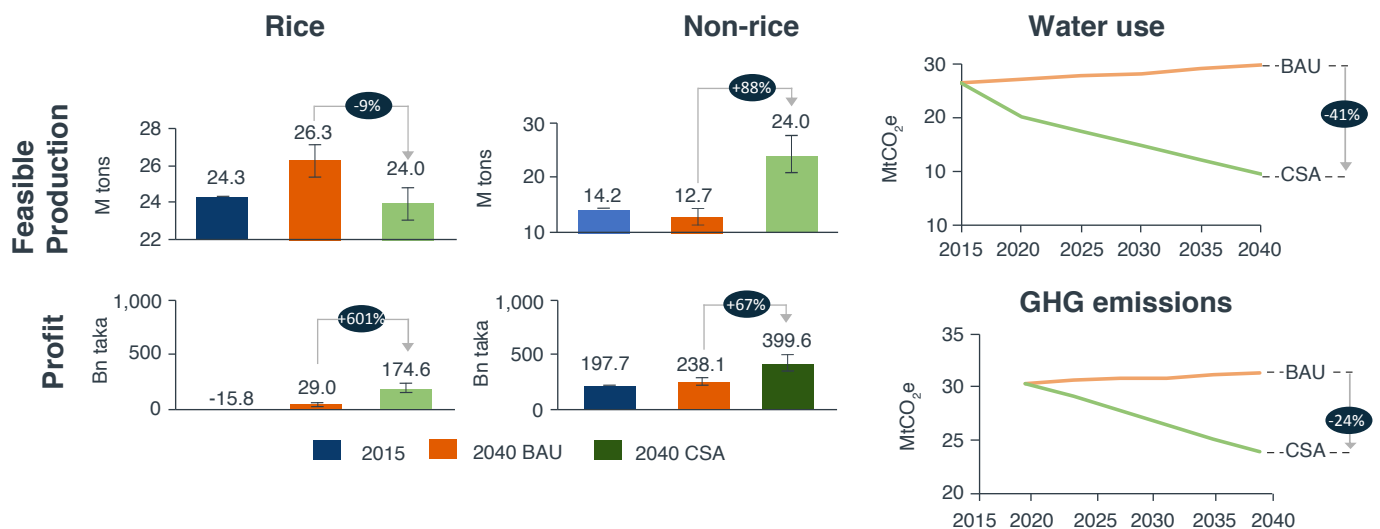
Research institutions such as BARI are critical to the development and distribution of high-quality seed development, and previous attempts at crop diversification in Bangladesh have fallen short of their target due to a lack of support from BARI to develop these varieties and collaborate with extension workers on distribution.

Improving soil quality and promoting alternative cropping patterns requires coordinated, well-funded support from extension workers. The National Agricultural Extension Policy (NAEP) was most recently updated in 2012 and contains a variety of modern and practical measures, including use of information and communications technology for linking marketing and production systems and linking data down to the upazila level. While Bangladesh has a significant number of extension workers at the public, private, NGO, and multilateral levels, these workers are generally not well coordinated, and public sector extension workers have historically been underfunded.⁹⁴ Furthermore, public extension workers have traditionally been funded at the project level but are responsible for as many as 2,000 families per extension worker. This package requires the coordination of extension workers across multiple sectors to work under the coordinated framework of NAEP in the northwestern region. This will facilitate the delivery of seeds and education on alternative cropping patterns to enable the planting of new crop types.

Quantified estimate of impact

Diversification, linked with CSA technologies, has one of the largest effects on key indicators of all packages. As discussed above, CSA has the ability to keep rice production constant while significantly increasing non-rice crop production, value, and profitability and decreasing overall GHG emissions. Figure shows the high-level impact of diversification (combined with other CSA technologies) on key indicators of interest. Most importantly, non-rice crop production is projected to almost double while profitability rises by 67 percent. Simultaneously, the decreased cultivation of boro rice in the rabi and kharif 1 season, as well as the increasing adoption of solar irrigation, buried pipe irrigation, and AWD technologies, is expected to have strong negative effects on water use (projected to decrease by 10 million liters) and GHG emissions (projected to decrease by 8 million tons of CO₂e) per year. Strikingly, decreased fuel costs used for irrigation will see profits for rice cultivation rise sixfold.

Figure 5.22 Effect of CSA on key indicators in northern Bangladesh (Dhaka, Rajshahi, Rangpur, and Sylhet)

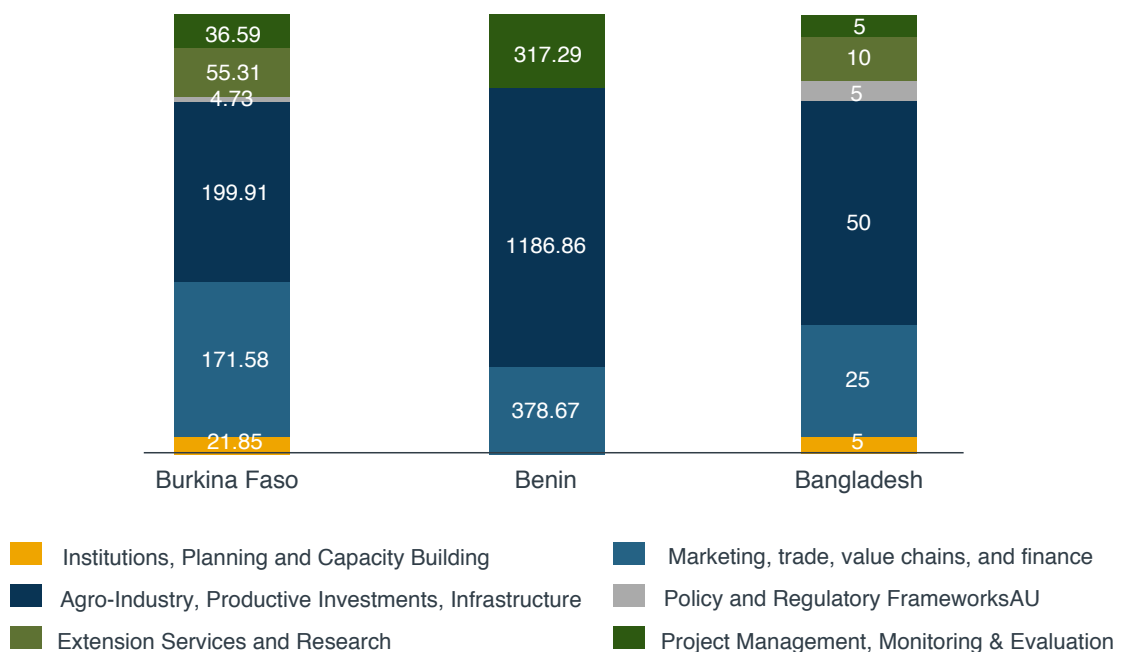


⁹⁴ USAID (United States Agency for International Development) and IFPRI (International Food Policy Research Institute). 2017. "Bangladesh: Desk Study of Extension and Advisory Services." Developing Local Extension Capacity Project, USAID. . <http://www.digitalgreen.org/wp-content/uploads/2017/09/Bangladesh-Desk-Study.pdf>.

Cost assessment

The two World Bank projects that most closely resemble a national or subnational diversification program suggest costs of US\$160–US\$184 million. Programs in Burkina Faso and Benin focusing on agricultural diversification and market access suggest that the largest costs include productive investments and infrastructure (such as roads, processing facilities, and storage facilities), as well as aspects of marketing, value chain development, and finance. This is consistent with problem identifications in the seventh five-year plan and lessons learned from past diversification programs in Bangladesh (see above). After PPP adjustment, the costs per beneficiary in Burkina Faso and Benin were US\$489.96 and US\$1,883.00, respectively, as shown in figure 5.23.

Figure 5.23 Costs per beneficiary of two World Bank projects in Burkina Faso and Benin and the proposed package on resilience through diversification in the northwestern region of Bangladesh



Note: Costs are shown in PPP 2017 U.S. dollars.

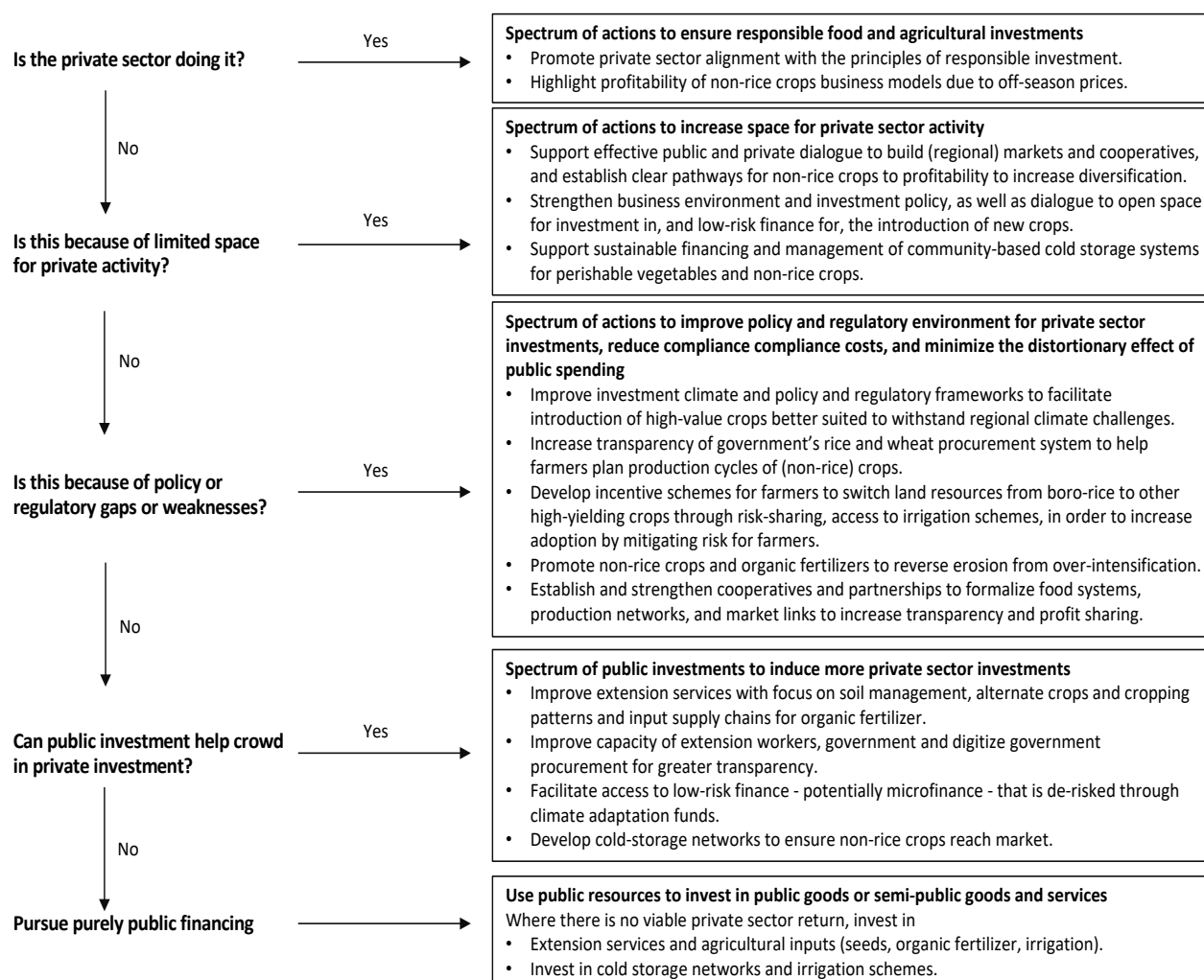
The estimated cost of Package 3 for northern Bangladesh is US\$196 million, ranging from US\$186 million to US\$205 million (or US\$500 million, ranging from US\$475 million to US\$525 million, PPP 2017 US\$). In order to assess the cost of Package 3, the number of beneficiaries in the northwestern region of the country was considered, as was the benefit of scaling up the package activities, which is reflected in the lower cost per beneficiary of Burkina Faso compared to Benin. The benefit of scale is much less in Package 3, however, as infrastructure development is included. Considering all these aspects, the cost per beneficiary in Bangladesh is US\$100 (PPP 2017 US\$), although this package has a large number of direct beneficiaries (around 10 million people) in the northwestern region of the country. Considering inflation, time value, and exchange risk, final assessment shows that the estimated cost of this package is US\$196 million. However, under different scenarios of inflation, time value, and exchange risk, the range of costs is from US\$186 million to US\$205 million.

Results of Cost Benefit Analysis

The results of a cost-benefit Analysis for Package 3 suggest an IRR of 25% and an ERR of 31%. This is higher than the median ERR of past World Bank projects. Relying on a regression analysis, the median ERR of World Bank projects in the agriculture and rural development sector between 1996 and 2008 is estimated at 23%. Based on the CBA, the NPV of Package 3 amounts to US\$ 79 million while the ENPV is estimated as high as US\$ 101 million. The CBA for Package 3 was based on the following assumptions: First, non-rice crop production will increase by 94% as estimated by the Bangladesh CSAIP model due to package implementation. Second, in the most conservative scenario, it is assumed that 50% of the projected increase will materialize. Third, this package concerns the northwestern areas of Bangladesh. Fourth, in line with historical growth rates, production will increase by 3% annually. Fifth, benefits caused by positive externalities will account for 10% of total benefits.

Maximizing Finance for Development

Figure 5.24 Decision tree for maximizing finance for development for Package 3



5.5 Package 4: Livestock Upstream Value Chain Development

Table 5.7 Overview of Package 4

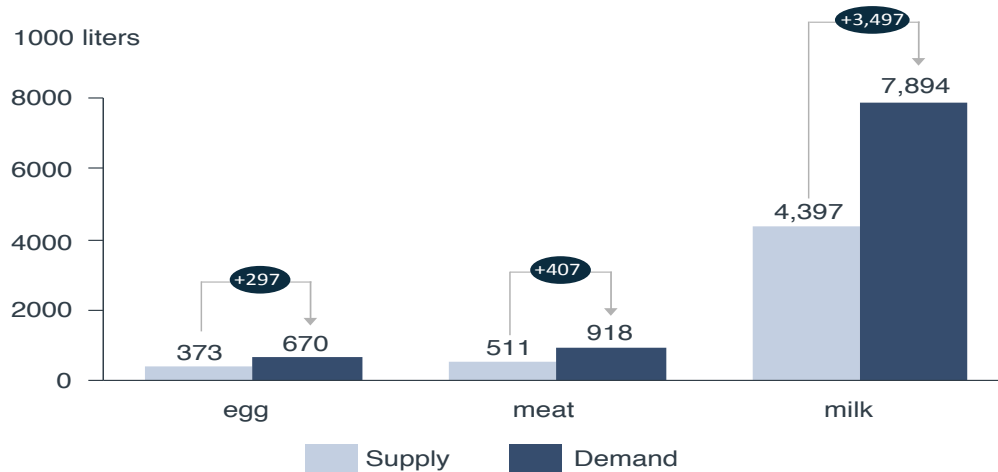
| | |
|---|---|
| Subtitle | Boost productivity of the (semi-) commercial livestock sector through high-quality feed and value chain development of dairy farming. |
| Context | As Bangladesh's middle class grows, so does demand for high-value products including—most prominently—protein. Although 70 percent of farmers in Bangladesh are engaged in livestock production, it remains a slow-growing, low-efficiency sector constrained by disease and poor fodder quality. Two major factors constrain efficiency growth and disease prevention: poor fodder quality and inefficient supply chains. This package focuses on the increased productivity and profitability of semicommercial dairy farms to ensure that the increasing demand for milk is met. Two potential investments are explored: (a) cross-sectoral interventions that enhance supply of quality, cost-effective feed and (b) strengthening the supply side of dairy value chains. |
| Investment opportunities | <ul style="list-style-type: none"> • Invest in the establishment of a national dairy development board. • Make targeted investments in critical production inputs and extension services. • Advance diversification into other livestock supply chains (e.g. poultry) |
| Potential impact | <ul style="list-style-type: none"> • Increase production volume and value by 17% (high ranges of uncertainty). • Reduce GHG emissions and GHG intensity of production by 18%. |
| Cost of comparable World Bank projects | <ul style="list-style-type: none"> • US\$16 million–US\$1.3 billion (PPP 2017 US\$) • Dominating cost categories are (a) agro-industry, productive investments, and infrastructure; (b) marketing, trade, value chains, and finance; and (c) extension services and research. |
| Estimated cost in Bangladesh | <ul style="list-style-type: none"> • US\$ Nominal 2017: US\$254 million (Range: US\$243 to US\$266 million) • US\$ PPP 2017: US\$650 million (Range US\$620 million to US\$680 million) |
| Cost Benefit Analysis | <ul style="list-style-type: none"> • IRR: 24% • ERR: 30% • NPV: US\$ 32 million • ENPV: US\$ 62 million |

Context and problem statement

As Bangladesh grows in population and income, projected demand for livestock products (meat, milk, and eggs) is expected to grow dramatically. Bangladesh has a growing livestock market that has struggled to keep up with growing demand. As both population and GDP grow, so does appetite for meat, milk, and eggs. In order to supply enough of these products, the livestock sector must double in size by 2021. Whereas poultry is a poster child of private sector-driven agricultural development, cattle has been very slow to meet quickly increasing demand. This is reflected in low productivity and inefficient supply chains. Cattle in Bangladesh are approximately 25–35 percent smaller than Indian cattle and produce less than a third of cow's milk in Pakistan. In fact, Bangladesh has the smallest per capita milk consumption of any South Asian Association for Regional Cooperation (SAARC) country and must make up the majority of its demand deficit for milk with imported powdered milk. Between 2011 and 2013, the livestock sector contributed approximately 2.5 percent to GDP (with significant potential to increase GDP contribution).

The supply and demand gap will be widest for milk. As average national incomes increase, demand is growing for all animal products, including milk, meat, and eggs. By far the greatest demand (in terms of absolute production) will be for milk, with an annual supply and demand gap of 3.5 million liters in 2040 (Figure).

Figure 5.25 Supply and demand of major livestock products by 2040 under BAU model



Most dairy farms are small- to medium-scale operations whose development is slowed by inefficient supply chains and climate-related risks.

- Low productivity and high mortality.** The most significant constraint on Bangladesh’s dairy sector is quality feed. Dairy cows require five major classes of nutrients: energy, protein, minerals, vitamins, and water. While all are essential for normal health and productive purposes, a pregnant or lactating cow needs additional energy for building fetal tissues and manufacturing milk. A cow’s reaction to nutrition shortage (in terms of milk production) is quick and dramatic.⁶³ In Bangladesh, the availability of feed and fodder is a major constraint on developing the full potential of the livestock sector. Chronic shortages of feed and fodder, together with the poor nutritive value of available feeds, have lowered the productive capacity and fertility of Bangladesh livestock and make cattle prone to disease. Heat waves, floods, and cyclones diminish cows’ health, driving up mortality rates. Finally, as discussed above, veterinary services are not sufficiently equipped to service a growing number of dairy farm operators.
- Inefficient supply chains.** Milk production is a disaggregated sector with opportunistic and instable market links between suppliers, producers, and buyers. The fast growth of demand for fresh milk has not yet been reciprocated with development in supply goods and services. This includes lack of on-farm cooling chambers; a weak “milk grid,” which would allow clusters of farms to be connected to major buyers in a planned and efficient fashion; veterinary services; and marketing services, to name a few.
- Poor cross-sectoral planning.** Livestock production (particularly dairy) requires a well-coordinated planning network consisting of public and private actors who support the supply, production, marketing, and distribution of a product (such as milk) that requires high-quality

⁶³ A. K. Shamsuddoha and Geoff W. Edwards. 2000. “Dairy Industry in Bangladesh: Problems and Prospects.” Paper for Australasian Agricultural and Resource Economics Society 2000 Conference.

inputs (such as feed, artificial insemination, disease prevention, information, and cool chains). While major public and private organizations have driven the development of the dairy system for decades (for example, the DLS since 1955), the actors in the system are not well coordinated or connected. These actors are neither working in silos nor coordinating under the same umbrella.

Livestock development has been the focus of at least five major collaborations between the World Bank and the Government of Bangladesh. The government is pursuing multiple projects to develop its livestock subsector as part of its strategy for economic growth and development emphasizing agriculture and livestock as a key driver of GDP growth and poverty reduction. The livestock subsector is an engine of shared growth and prosperity, providing business opportunities for producer organizations; micro, small, and mid-sized enterprises; and service providers. Over 70 percent of rural households are engaged in livestock production, which contributes a large share to smallholder and landless farmers' livelihoods. Given the challenges in the sector, the government is pursuing multiple, parallel efforts to improve the livestock sector in Bangladesh. As such, these projects will benefit significantly from an in-depth study of development opportunities in Bangladesh's livestock sector. On the one hand, the sector is uniquely positioned to meet the milk and protein demands of a growing middle class and to diversify commodities (production and adaptation to climate change). On the other hand, the continued development of this sector increases the country's challenges to meet its intended NDCs for reduction in GHGs. The following are CSA opportunities for the livestock sector, assessed in terms of their feasibility and contextualized in the broader literature on Bangladesh's agricultural policy:

- **Livestock and Dairy Development Project (LDDP).** LDDP includes among its objectives the promotion of resilient productivity growth and support for climate-smart production systems. Currently in the project preparation phase, LDDP aims at fostering market-led transformation of livestock production while ensuring that the supply response to growing demand is sustainable, inclusive, safe, and environmentally conscious. To this end, the project will improve the ecosystem for value chain development by financing key infrastructures, including markets and access to markets; insurance and financial products and services; capacity building; and knowledge. Resilient livestock production systems are developed through the promotion of appropriate CSA practices addressing feeding strategies, animal health and welfare, animal husbandry and breeding, manure and waste management (including production of energy), and improved storage and processing.
- **Second Phase of the National Agriculture Technology Program Project for Bangladesh (NATP-2).** NATP-2 aims to improve the productivity and market access of smallholder farmers, with an emphasis on crops as well as livestock and fisheries. This project is primarily focused on rural infrastructure, technology diffusion, and market development and is in collaboration with the Government of Bangladesh, World Bank, IFAD, and USAID.
- **Sustainable Enterprise Project.** The Sustainable Enterprise Project seeks to increase the adoption of environmentally sustainable practices through microloans in Bangladesh. While not limited to the livestock sector, microloans are distributed through the Palli Karma-Sahayak Foundation (PKSF) for practices in line with CSA principles and include adoption of CSA technologies and practices.
- **The Bangladesh Delta Plan 2100 (BDP2100).** BDP2100 is a multisectoral planning and investment process focused around water and agricultural resilience in the Bangladesh Delta through 2100. This significant undertaking anticipates climate-related risks such as flooding and drought, water

property rights with neighboring India, and risks posed by Bangladesh's multiple rivers to land and infrastructure. While the focus of the plan is the problem of too much water during wet months and too little water during dry months, the benefits to CSA include irrigation, aquifer replenishment, and flood and cyclone shelters.

Enabling Environment

The past 12 years of agricultural policy and planning have increasingly prioritized livestock development as an engine of GDP growth, poverty alleviation, and food security. Bangladesh's agriculture sector stands to benefit from decades of solid forward-looking planning and policy making. The past 12 years show no shortage in detailed, fact-based policy-frameworks and recommendations to boost production, increase sector resilience, and even achieve mitigation cobenefits. Past and current planning frameworks represent an ideal starting point for the CSAIP approach, which builds on existing planning frameworks to devise a long-term decision-making tool for prioritized investments in the agriculture space that promise to achieve the goals of a highly productive, resilient, and low-impact sector:

- **The National Adaptation Programme of Action (NAPA, 2005)** aims at reducing adverse effects from the impact and fluctuation of environmental conditions induced by climate change. Major livestock-related challenges identified by NAPA include insufficient integration of climate change risk assessments into livestock sectoral planning and lack of shelters to protect against flooding and cyclones. Livestock-specific aspirations include improved DRM infrastructure, improved early warning systems, improved knowledge management practices, and the implementation of livestock insurance programs.
- **Bangladesh Vision 2021 (2007)** reiterates challenges identified in NAPA and aims at increasing livestock productivity through increased agricultural diversification.
- **The National Livestock Development Plan (2007)** is the most comprehensive development strategy to date and identifies 10 critical areas for policy issues: dairy development and meat production, poultry development including duck, veterinary services and animal health, feeds and fodder management, breeds development, hides and skins, marketing of livestock products, international trade management, access to credit and insurance, and institutional development for research and extension.
- **The National Poultry Development Policy (2008)** emphasizes four issues of poultry development, namely poultry production, entrepreneurship development, extension and research, and quality control. The policy has not yet been supported by an elaborate action plan.
- **The Bangladesh Climate Change Strategy and Action Plan (BCCSAP) (2008)** rests on the six pillars of food security, health, disaster management and preparedness, low carbon development, and the capacity of people and infrastructure to respond to climate change-related shocks. BCCSAP envisions a strong, resilient livestock sector that improves food security and health for the poorest and most vulnerable members of society. Development priorities for livestock include strengthened supply chains, reduced mortality rates, and increased farmer access to services (such as veterinarians and credit).
- **The Bangladesh Country Investment Plan (2011)** is a planning, fund mobilization, and alignment tool that supports increased effective public investment to increase and diversify food availability, accessibility, and security. It identifies livestock as a sector that could boost national incomes and nutrition through stronger productivity and market access (with a focus

on poultry and dairy).

- **The National Agricultural Extension Policy (2012)** envisions a livestock sector that can meet the food demand of Bangladesh's entire population as well as competitively produce high-value products for global markets. Challenges include the preponderance of smallholder farms, poor mechanization, and a shortage in working capital. The NAEP aims to respond through improved access to extension services (e-agriculture, contract farming, input support, subsidies, and decentralized demand responsiveness). It also stresses the importance of decentralized, bottom-up planning and the need to recognize farmers as development partners.
- **The seventh five-year plan (fiscal years 2016–20) (2015)** envisions increased commercialization of the livestock sector through technological innovations and use, strengthening of the research and extension system, development of supply chain extension, value addition for agricultural products, and linking the farming community with markets, local and global. Priorities include incentivizing the integration of climate risks in national and regional planning and increased commercialization of semisubsistence systems, partly through access to credit for rural smallholder farmers.
- **Intended Nationally Determined Contributions (2015)** envision a resilient, low-carbon livestock sector that provides food and livelihoods for Bangladeshis without significantly contributing to climate change. Adaptation priorities include "stress tolerant (salinity, drought and flood) variety improvement and cultivation." Specific mitigation commitments for the agriculture sector (as related to livestock) include a 50 percent reduction in draft animals compared to BAU.
- **The Bangladesh Delta Plan 2100 (2017)** is a long-term, integrated, holistic vision of water, land management, and development throughout Bangladesh. BDP2100 states that the livestock sector must adapt to the impacts of climate change to improve the resilience of food production systems in order to feed a growing population. It stresses the lack of institutional coordination (policy, research, extension) and highlights the need for a more strategic support of livestock supply chains.
- **The Draft Integrated Livestock Manure Management (ILMM) Policy (2019)** was drafted by Bangladesh Livestock Research Institute under a project of SEI-Asia Centre supported by CCAC and UNEP. The policy draft has recently been accepted by the Ministry of Fisheries and Livestock and is currently proceeding for approval by the cabinet. It aims to change traditional practices into demand driven, market oriented, value added utilization of livestock manure as well as to generally increase the sustainability of livestock production. In this way, the policy also addresses the need to reduce pollution, to protect public health and to create new business opportunities.

These policy frameworks enable and support almost all critical aspects of livestock development and mechanization. However, a comprehensive policy focusing on supply chain development is still missing. Increasing supply chain efficiencies requires specific and dedicated policies that regulate technology support services across value chain segments, introduce clear financing guidelines, and put in place comprehensive regulations for biofertilizer certification system, among others.

There are three major public sector institutions for livestock-related activities. The DLS is responsible for all livestock-related activities in the country, including extension and regulatory functions. BLRI focuses on research. Bangladesh Agricultural University and a few other universities are dedicated to livestock-related education and research. However, coordination among extension,

research, and educational institutions is almost nonexistent. The mandates of DLS and BLRI require reform to meet the requirements of private sector and NGO involvement in livestock development activities.

Figure 5.26 SWOT analysis for Package 4 based on the second stakeholder workshop held in Dhaka, April 2018

| | Helpful | Harmful |
|----------|---|---|
| Internal | <p>Strengths</p> <ul style="list-style-type: none"> • Knowledge base in place • Fodder production profitable in dairy clusters • Strong private sector in livestock • Establishment of farmers information and advisory centers (FIACs) • Availability of underutilized manure for improved manure management | <p>Weaknesses</p> <ul style="list-style-type: none"> • No single or dominant source of protein available to fill protein gap • Most rumen balancing strategies complicated and expensive • Limited land availability for additional fodder production |
| External | <p>Opportunities</p> <ul style="list-style-type: none"> • A national-level coordinating body to prioritize investments in dairy supply chain • Targeted investments in input supply chain | <p>Threats</p> <ul style="list-style-type: none"> • Land use conflicts between fodder and food crops • Weak extension service • Insufficient rural infrastructure to support efficient milk grids |

Investment opportunities

1.1.1.10 Invest in the establishment of a national dairy development board

Public and private organizations are slowly becoming a well-capacitated group of actors. Public and private actors have increasingly built the capacity to provide services that are crucial for sector development. The following are among the public institutions involved:

- MOFL has control over all public agencies involved in the livestock production, extension, research, and livestock-related services.
- DLS is the executing agency and regulatory body responsible for all public livestock-related service activities in the country, including veterinary health services, disease prevention and curative services, registration, licensing training, and others.
- BLRI is responsible for carrying out livestock- and poultry-related research, including on production, disease prevention and control, and vaccines for animal and poultry diseases.
- Agricultural universities, veterinary universities, training institutes, and government-owned farms offer education, training, research, livestock input production, and service providing activities.
- Other ministries and public sector organizations/agencies are involved directly or indirectly in livestock development. These include the MOA; Ministry of Local Government, Rural Development and Cooperatives; Ministry of Industries; Ministry of Commerce; Ministry of Finance; Ministry of Health and Family Welfare; Ministry of Law, Justice and Parliamentary Affairs; DOF; DAE; Department of Youth Development; Bangladesh Rural Development Board; DAM; and financial institutions such as PKSF.

- In addition, some private actors have emerged as important players, particularly in the production of semen and artificial insemination services and the collection of fresh milk:
 - Milk Vita (Bangladesh Milk Producers' Co-operative Union Limited), the largest dairy cooperative in Bangladesh, started dairy business based on genetic improvement of dairy cattle through artificial insemination services of their cooperative farmers in 1972. Milk Vita holds 50 percent of the fresh milk market share.
 - BRAC, an international NGO cattle breeding program with artificial insemination services using liquid semen from government origin, began in 1985. The organization has trained 2,523 artificial insemination technicians and operates artificial insemination services in 61 districts (440 upazila) out of 64 districts.
 - Lal Teer Livestock is a sister concern of the country's largest seed company, Lal Teer Seed. The organization started a major cattle and buffalo improvement program in 2009. Along with Beijing Genomics Institute, Lal Teer has decoded the buffalo genome, promising productivity increases in the near future.
 - Programme for Rural Advancement Nationally (PRAN) Dairy and Gentec International import semen from World Wide Sires.

More recently, both larger and smaller entrepreneurs have started to engage in the production, sourcing, distribution, and marketing of cattle feed. While the poultry sector has driven industrial concentrate production, the sourcing of roughage and dry forages has remained small scale.

But these actors tend to work in silos and could improve their collaboration. Most business links in the cattle supply chain are opportunistic and not sufficiently coordinated. At the farm level, even semicommercial farmers have very limited information about, for example, feed requirements, availability, cost of input services, and the implications of higher-quality feed and vaccines on productivity and mortality rates. Although farmers are sometimes organized into cooperatives, these cooperatives are not efficiently linked into milk grids, are not represented at the national level, and do not provide sufficient services to their members. At the institutional level, the level of coordination between related policies, research institutes, and extension services should be increased. Furthermore, livestock development plans are not fully integrated with other relevant plans such as crop agriculture or infrastructure development.

The Indian National Dairy Development Board is a promising model for Bangladesh. In 1946, a group of farmers in Gujarat, India, were so angered by the arbitrariness of middlemen in setting milk prices that they formed a producer cooperative called the Kaira District Co-operative Milk Producers' Union Limited (KDCMPUL). With the support of Morarji Desai, who would later become India's prime minister, the union set up small cooperatives in every village of the region to collect and process milk for farmers, who each supplied 1–2 liters per day. By June 1948, the KDCMPUL had begun pasteurizing milk for the Bombay Milk Scheme. Within a decade, the model spread to five other regions, and Anand Milk Union Limited (Amul) was created. Amul inspired the establishment of India's National Dairy Development Board in 1965 and spurred India's white revolution, which made the country the world's largest producer of milk and milk products. The dairy board's Operation Flood contributed significantly to this success. Launched in 1970, the program created a national milk grid linking producers throughout India with consumers in over 700 towns and cities, reducing seasonal and regional price variations while ensuring that the producer received a major share of the price consumers paid by cutting out middlemen. The bedrock of Operation Flood has been village milk producers' cooperatives, which procure milk and provide inputs and services, making modern management and technology available to members.

Bangladesh is considering launching a dairy development board to promote production of milk and dairy products and develop entrepreneurship. Such a board could become the connecting platform of policy, the private sector, and extension services for an efficient innovation system in dairy production. The board would not replace existing actors such as DLS, BLRI, or private sector organizations; rather it would facilitate knowledge exchange, prioritize budgeting processes, stimulate innovation-focused research conducted in collaboration with farmer cooperatives, and make credits available for farmers seeking to adopt prioritized technologies.

In a dairy innovation system, farmers should be at the center of the network. Farmers were at the center of the white revolution in India. Region-specific challenges were assessed in close collaboration with local farmers, which allowed dedicated extension teams to test and evaluate technologies, breed types, and feed composition and mechanisms. The learning curve consisted of three steps: learning to be effective (identifying what works), learning to be efficient (training and educating producers), and learning to expand (adopting solutions to different regions and contexts).

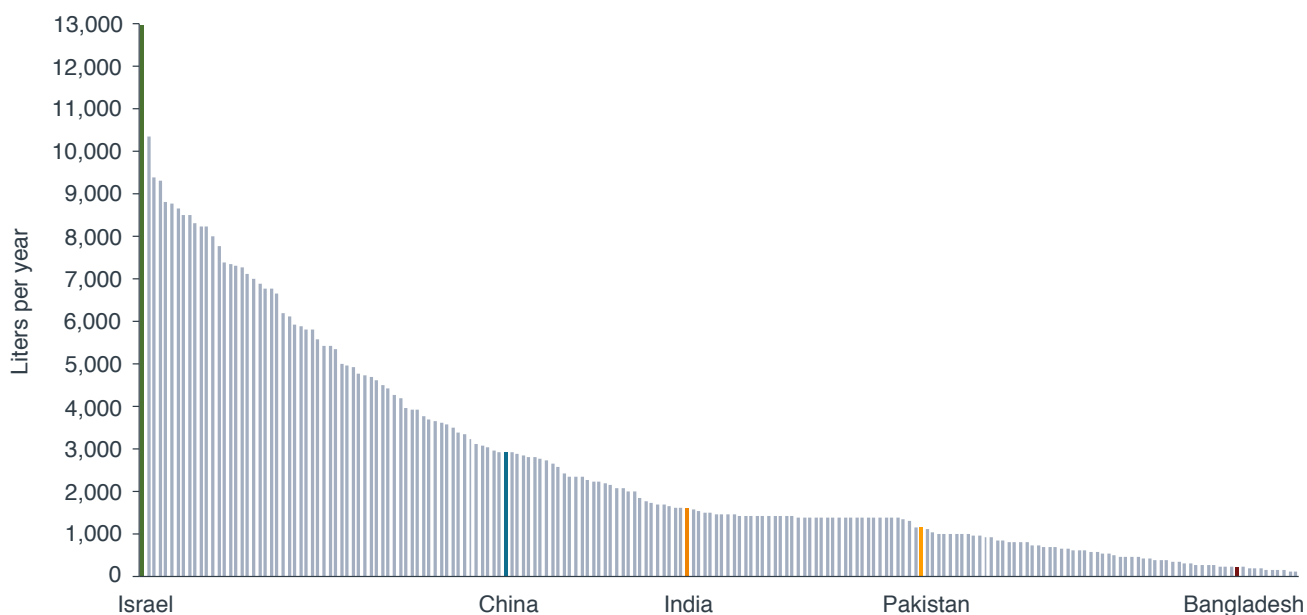
Policies that decentralize research, extension, and private sector investments would help in establishing an effective dairy board. The organizational unit for transformative dairy development is the cooperative, which must be represented at the regional and national levels through effective unions that translate local need assessments into policy action, budgetary priorities, and private sector partnerships. Supportive legislation must strengthen a bottom-up approach to planning that is responsive to the diverse needs of region-specific producers. MOFL has already finalized a draft of the Bangladesh Dairy Development Board Act of 2017 to facilitate formation of the board. The board would be a statutory and autonomous body run by a board of directors from public and private institutions and headed by a fisheries and livestock minister or state minister as chairman. The implementation of this act through capacity building, regional pilots, and the establishment of efficient public-private partnerships could be a prioritized CSA investment.

1.1.1.11 Targeted investment in critical production inputs and extension services

The productivity of Bangladesh dairy farms is one of the lowest in the region, owing to poor genotype and lack of quality feed. According to the baseline survey of the recently approved Livestock and Dairy Development Project by the World Bank, the average milk productivity of smallholder households was as low as 3.26 kilograms fat and protein corrected milk per cow per day. An average cow in Bangladesh produces 440 liters of milk per year, with some regional variation due to a number of factors. Depending on the farming system, the annual production of a typical cow in Bangladesh is 600–700 liters in traditional subsistence rural settings and 1,000–1,800 liters per year in intensive Bathan peri-urban settings.⁹⁶ Whereas rural cattle are mainly local breeds, peri-urban and cooperative rearing uses mainly crossbreeds. Based on FAOSTAT, the average yield per cow is only 205 liters per year in Bangladesh, compared to 1,100 in Pakistan, 1,600 in India, and 3,000 in China. Compared to crossbreeds that yield 2,200 liters per year in India and Pakistan, Bangladeshi cows reach only 1,800 liters a year (figure 5.28). This means that there is tremendous potential for increased yield. According to recent assumptions made in the context of the Livestock and Dairy Development Project, a 100 percent gain in milk productivity throughout the project is considered realistic.

⁹⁶ M. M. Uddin, M. N. Sultana, O. A. Ndambi et al. 2011. "Milk Production Trends and Dairy Development in Bangladesh." *Outlook on Agriculture* 40 (3): 263–71. https://www.researchgate.net/publication/272212553_Milk_production_trends_and_dairy_development_in_Bangladesh.

Figure 5.28 Average yield of milk per cow in 2016 by country



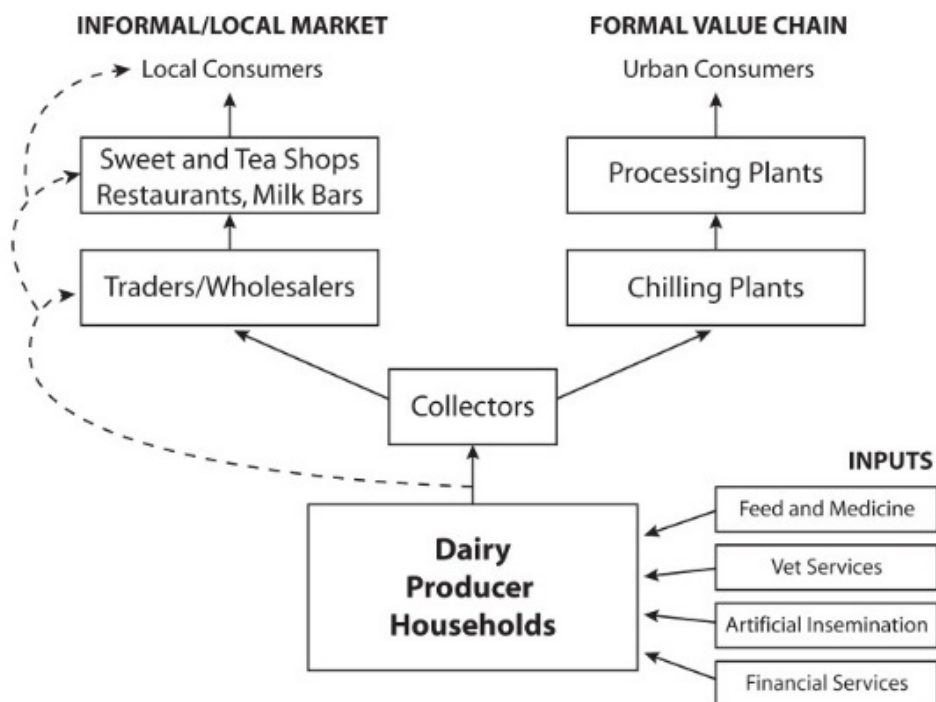
Source: FAO (Food and Agriculture Organization of the United Nations). 2017. "FAOSTAT: Bangladesh; Food Utilization." www.fao.org/faostat/en/#country/16.

Dairy farms still produce at comparatively low profit margins due to underdeveloped cool chains and low fat content in milk. Beyond low production, profitability suffers due to low feed quality and supply chain inefficiencies. On the one hand, milk prices are based on fat content. Fresh milk with 3 percent fat content yields half the price of milk with 6 percent fat content.⁹⁷ The fat content, in turn, is directly correlated with the feed composition and health of the animal. On the other hand, a substantial amount of production (20–25 percent) is processed into sweets to avoid spoilage. Typically, the milk supply chain follows a simple structure (Source: CARE Bangladesh. 2006. "The Reducing Vulnerability to Climate Change (RVCC) Project: Final Report." CARE Bangladesh, Dhaka.⁹⁸ Fresh whole milk production is collected by local entrepreneurs who supply both the informal local market (mainly sweatshops and tea shops) and the formal market (chilling plants and processors). However, the formal supply chain is limited in its reach as the economics of procurement do not work for chilling plants and processors in highly disaggregated supply chains where hundreds of thousands of small-scale farmers supply few liters of milk.

⁹⁷ Ashoke Kumar Ghosh and Keshav Lall Maharjan. 2002. Milk Marketing Channels in Bangladesh: A Case Study of Three Villages from Three Districts." *Journal of International Development and Cooperation* 8 (2): 89–101. https://www.researchgate.net/publication/32115838_Milk_Marketing_Channels_in_Bangladesh_A_Case_Study_of_Three_Villages_from_Three_Districts_Article.

⁹⁸ CARE Bangladesh. 2006. The Reducing Vulnerability to Climate Change (RVCC) Project: Final Report. http://www.carebangladesh.org/publication/Publication_4406527.pdf

Figure 5.29 SWOT analysis for Package 4 based on the second stakeholder workshop held in Dhaka, April 2018



Source: CARE Bangladesh. 2006. "The Reducing Vulnerability to Climate Change (RVCC) Project: Final Report." CARE Bangladesh, Dhaka. . http://www.carebangladesh.org/publication/Publication_4406527.pdf.

Targeted investments promise to increase both productivity and profitability at farm levels, thereby driving innovation.

- **Improved feed.**⁹⁹ Both feed quality and feed quantity constrain the production and productivity of dairy farmers. Poor productivity of cattle in general and dairy in particular could be overcome by the supply of high-quality feed, including most importantly high-protein feeds. Although numerous protein crops have been identified as suitable in Bangladesh (such as napier grass, moringa, and maize) and demand would be high, crop farmers have not yet transitioned to high-volume production of these crops. This might have a number of reasons, including lack of information, risk-averse producers, and land-budgeting of small-scale farmers. In other words, rice has priority over other crops for self-sufficiency and as a secure source of cash. Also, the links between crop farmers and livestock farmers is not well established and has mainly evolved opportunistically. Knowledge platforms, transparent market places, and transitional crop insurances might be ways to incentivize crop diversification.
- **On-farm cooling units.** In order to meet growing milk demand, farmers must be supported by strong input supply chains. One of the major constraints of milk marketing is the quality (and trust in quality) of fresh milk. The disaggregated nature of rural production units makes it difficult for farmers to supply to chilling plants. The development of a milk

⁹⁹ In the most general terms, cattle require roughage, concentrate, protein, and vitamin supplements for a balanced diet. Roughage is fibrous feed with high cellulose levels; it has low energy levels and is difficult to digest. Concentrates are high in energy, low in fiber, and usually highly digestible; they typically consist of cereal grains (corn, milo or sorghum, wheat, oats, barley) or oil meals (soybean, cottonseed, linseed). Feeds containing more than 20 percent protein or protein equivalent are called protein supplements.

and profitable market. One technological solution that would promise increased production and supply across the country is solar panel–driven cooling units that have the capacity to store a few dozen gallons, just enough for a semi commercial farmer to keep milk fresh for two to three days, thereby increasing the financial viability for collectors.

- **Cooperative formation and training.** Dairy farming is a risky and technically complex business. Diseases, price fluctuations, and the perishable nature of milk pose considerable risks for farmers investing in the growth of a dairy business. As a result, the majority of dairy production is highly disaggregated, with just a few animals per family ruminating in the homestead. Commercialization of dairy systems requires knowledge, negotiation power, purchasing power, and strong networks. Cooperatives allow exactly that. In Bangladesh, the cooperative model in peri-urban areas is already starting to prove successful for dairy farmers. Building on lessons learned to translate such models to the rural context can support the commercialization of more remote farmer collectives.
- Value added use of manure. This will not only increase farm profitability but will also contribute to reducing methane emissions and decreasing pollution. Furthermore, manure can be used for renewable energy production and for making livestock production more energy efficient.

Quantified estimate of impact

There is strong potential for increased productivity. At the national level, the CSA technologies included in the CSAIP model project average increases of 17 percent for both production and value across milk and beef production. Given the low baseline yield compared to that of other countries, livestock interventions are arguably among the most impactful in the agriculture sector, and model results likely underestimate the real production potential. On the one hand, feed is a constraining factor in the model. For example, the amount of available crop by-products determines roughage availability and therefore limits projections of livestock production. On the other hand, the model has no way to estimate the influence of supply chain improvements on efficiency gains. If, for example, the constraining factor of milk production is the nonexistence of affordable cool chains for semicommercial farmers, such investments might be more disruptive than a linear model could predict.

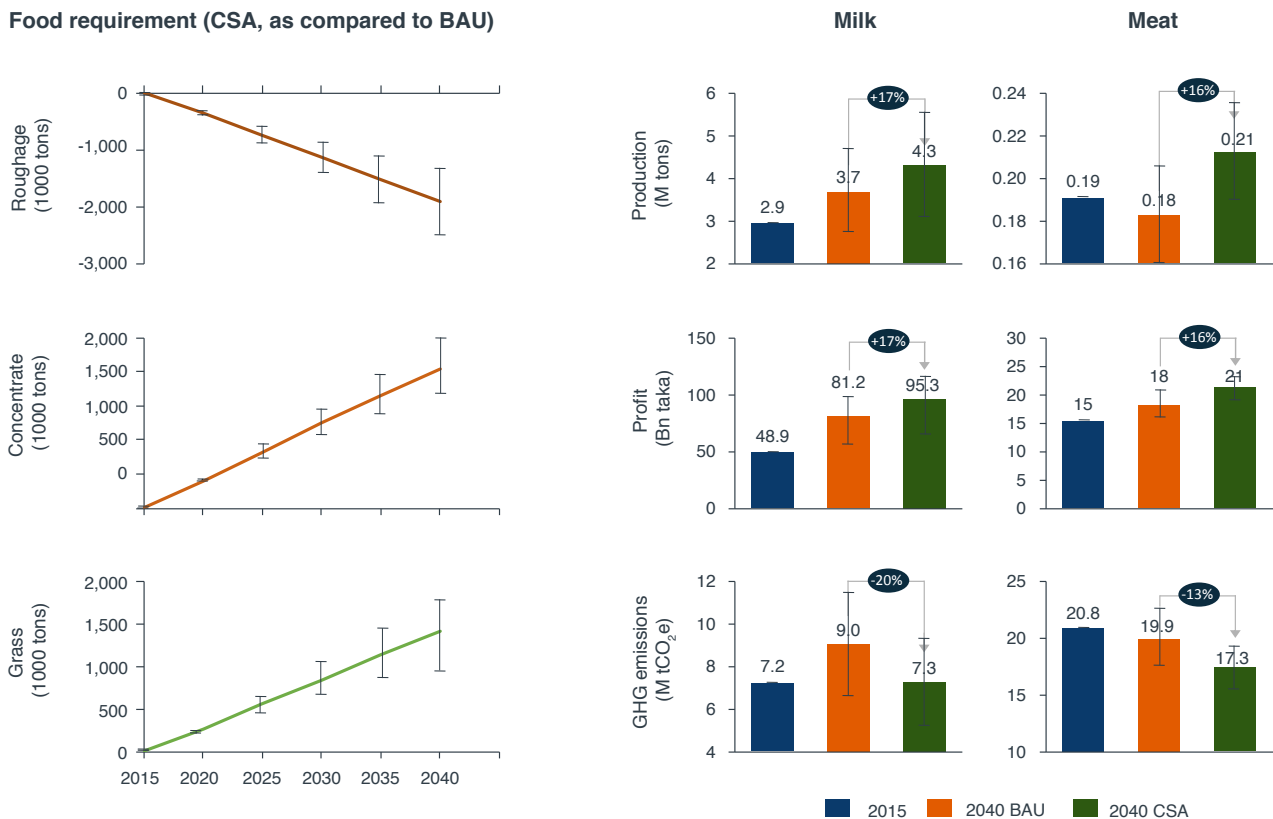
Increased productivity requires increased concentrate use. A large portion of yield increase (as assumed by the model) is a shift in dietary composition toward a more protein-rich feed. Increasing milk and beef production by 17 percent (as compared to BAU), would require increased concentrate production of 700,000 tons (an almost 10 percent increase from today's concentrate availability).

There is high mitigation potential linked to productivity increases. Importantly, better feed and higher yield per animal make for an overall decrease in GHG emissions in the sector compared to a BAU scenario (an average 20 percent for milk and 13 percent for meat production), even if uncertainty ranges are large. The modeled mitigation potential is underscored by projections of substantial GHG emission intensity gains between 16 percent (low productivity increase scenario) and 30 percent (high productivity increase scenario) in the context of the Livestock and Dairy Development Project, which targets 2 million livestock producers. These substantial emission intensity decreases correspond to emission reductions between 2.47 and 5.39 million tons CO₂e.

Milk and beef production are highly sensitive to both climate change and economic development. The error bars indicate the high variability in projected values across indicators. Milk production, for

example is projected to be anywhere between 3 million and 5.5 million tons in 2040 under a CSA scenario. In other words, production may remain stagnant or increase by 90 percent in the next two decades. This high sensitivity is in part due to the potentiation of various uncertainties. On the one hand, milk and beef yields vary across climate change and economic development scenarios. On the other hand, overall production is constrained by feed availability, which in turn depends on crop production. As shown above, crop production is highly sensitive to these scenarios.

Figure 5.30 Effect of CSA on production indicators of milk and meat (cattle only) at the national level



Cost assessment

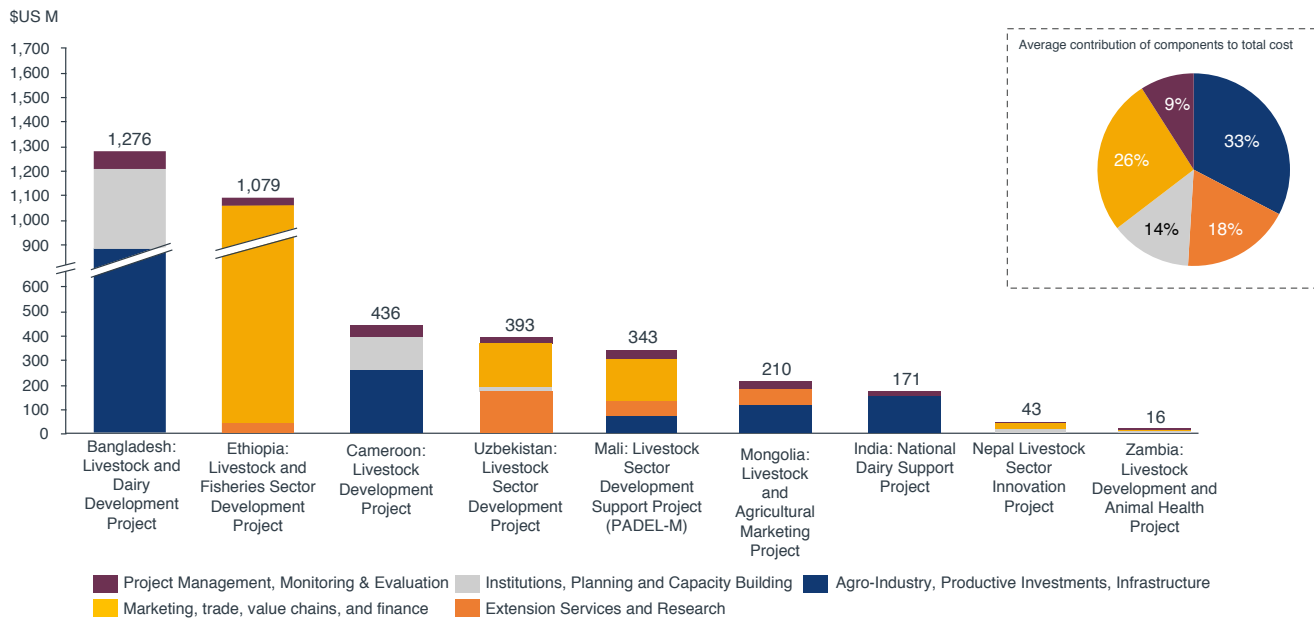
Dairy and livestock development projects can have highly divergent costs depending on the scale and scope of the project. The 10 World Bank projects whose general project objective was comparable to Package 4 and for which cost data were available suggest that project costs can vary from US\$16 million (Zambia) to US\$1.3 billion (Bangladesh), PPP 2017, as shown in Figure 5.31. Note: The composition of costs varies by the size of the project. Larger projects tend to invest most resources into industry development and institutions, whereas smaller projects spend more on extension services and marketing.

The Livestock and Dairy Development Project closely resembles activities proposed in Package 4. The cost of the project is US\$500 million (US\$1,275 million, PPP 2017). The project targets 2 million people, principally through infrastructure development and capacity building. Additional finance is required in order to facilitate the activity of value chain related finance and research as well as the establishment of a national dairy board. It is estimated that the an additional US\$254 million is required for these activities, ranging from US\$243 million to US\$266 million depending on price escalation (US\$650 million, ranging from US\$620 million to US\$680 million, PPP 2017 US\$).

Results of Cost Benefit Analysis

A cost-benefit analysis for Package 4 suggests an IRR of 24% and an ERR of 30%. This is higher than the median ERR of past World Bank projects. Relying on a regression analysis, the median ERR of World Bank projects in the agriculture and rural development sector between 1996 and 2008 is estimated at 23%. Based on the CBA, the NPV of Package 4 amounts to US\$ 32 million while the ENPV is estimated as high as US\$ 62 million. The CBA for Package 4 was based on the following assumptions: First, livestock production will increase by 17% as estimated by the Bangladesh CSAIP model due to package implementation. Second, the climate-smart technology proposed by Package 4 will be adopted within 7 years.

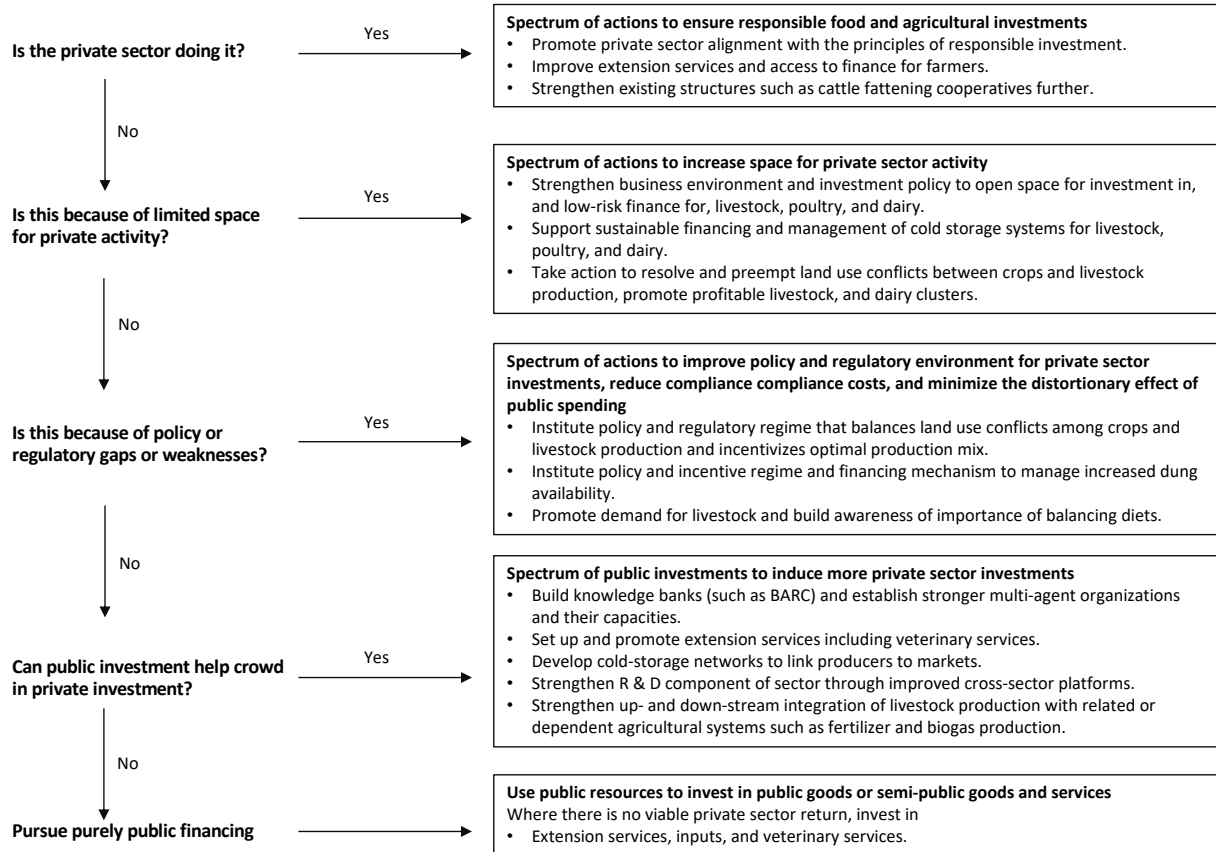
Figure 5.31 Cost of World Bank projects with objectives that are comparable to Package 4



Note: Costs are shown in PPP 2017 US\$.

Maximizing Finance for Development

Figure 5.32 Decision tree for maximizing finance for development for Package 4



5.6 Package 5: Climate-resilient agri-livelihood development in haor areas

Table 5.32 Overview of Package 5

| | |
|-------------------------------------|---|
| Subtitle | Develop climate-resilient agri-livelihood in haor areas through climate-smart intensification of rice cultivation and diversification into non-rice crops using a homestead-based farm development approach combined with fish sanctuaries and supply chain development. |
| Context | <p>Haor plays a catalytic role in the livelihood of the people of Bangladesh's seven northeastern districts:</p> <ul style="list-style-type: none"> • The area covers 13 percent of the country and accommodates about 20 million people. • Haor areas contribute significantly to Bangladesh's rice and fish production. Boro-fallow-fallow is the dominant cropping pattern, leaving significant scope for increased cropping intensities. • Natural disasters, especially flash floods, frequently challenge crop and livestock production in the area. Haor areas are rich in aquatic biodiversity, particularly fish. Destruction of swamp forests leads to a reduction in fish production and biodiversity, as observed particularly with regard to the waterfowl population over the past years. While measures have been taken to protect crops and preserve ecosystem diversity, greater efforts are necessary to effect meaningful impact. |
| Investment opportunities | <ul style="list-style-type: none"> • Invest in research on short-lived and flood-tolerant rice varieties linked to Package 1. • Invest in improved high-yielding restorative non-rice crop systems. • Invest in homestead-focused farm development (gardening, floating gardens and duck rearing). • Establish beel nurseries and fish sanctuaries. • Invest in specific high-potential supply chains. |
| Potential impact | <ul style="list-style-type: none"> • Significant additional income generation opportunities from diversification into additional crops. • Increased resilience of agriculture production driven by the use of flood-tolerant varieties and diversification away from overreliance on rice production. • Significant emission savings where rice crops are substituted with the production of other crops. |
| Estimated cost in Bangladesh | <ul style="list-style-type: none"> • US\$ Nominal 2017: US\$117 million (Range: US\$110 to US\$129 million) • US\$ PPP 2017: US\$300 million (Range US\$280 million to US\$330 million) |
| Cost Benefit Analysis | <ul style="list-style-type: none"> • IRR: 30% • ERR: 39% • NPV: US\$ 113 million • ENPV: US\$ 138 million |

Methodology

The development of this package was based on a desk review undertaken to identify the context of the current development of haor areas, the institutional framework, and the framework of existing policies, as well as planned policies, programs, and plans. A small survey was conducted remotely for the three major haor districts (Sunamganj, Kishoreganj, and Netrokona) among the district agriculture, fisheries, and livestock officers and NGO activists. Each respondent was asked to provide a set of five interventions in each agriculture subsector (crop, livestock, and fisheries), the implementation

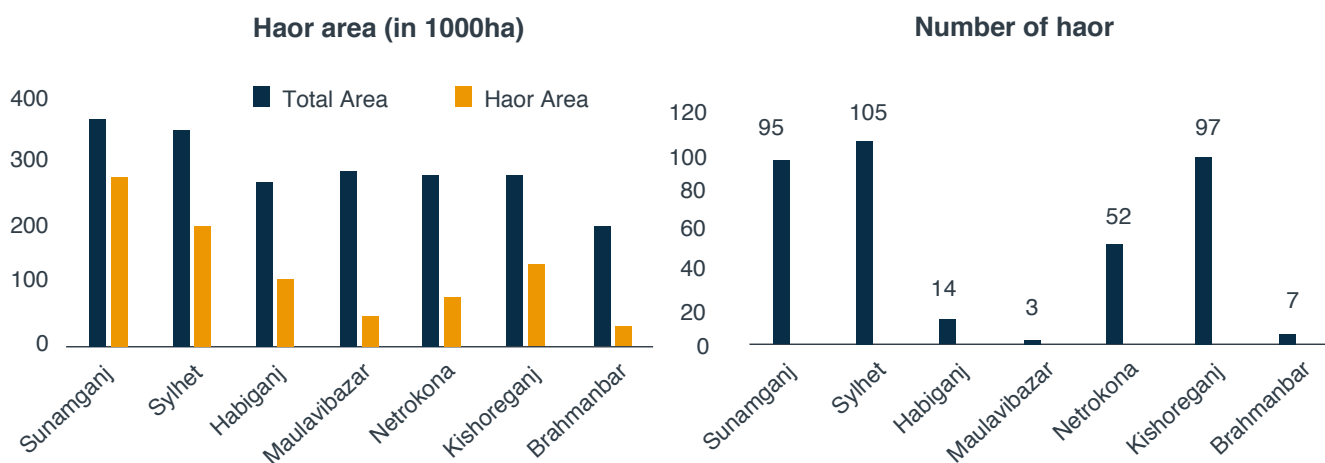
of which would contribute to climate-resilient agri-livelihood development in the haor area. After compiling all interventions, consultations with local climate change and haor experts guided the finalization the elements of the investment package. Absent comparable World Bank projects, the cost of the package was calculated based on information obtained from survey participants and a literature review.

Context and problem statement

The haor area covers 13 percent of the country and accommodates about 20 million people. There are 373 haors/wetlands located in the districts of Sunamganj, Habiganj, Netrokona, Kishoreganj, Sylhet, Moulvibazar, and Brahmanbaria, covering about 43 percent of the haor region (figure 5.33). Haor is featured with a mosaic of wetland habitats including rivers, streams, canals, and large areas of seasonally flooded cultivated plains and beels. People of the haor area are poorer than the rest of the country. According to the 2016 Household Income and Expenditure Survey, more than 28 percent of the total haor population lives below the lower poverty line.

Haor areas contribute significantly Bangladesh’s rice and fish production. Agriculture and fisheries are the main bases of the diversified economic resources of the area. The haor region is famous for boro rice and inland fish production. Haor districts constitute about 16 percent of the total rice cultivation area and produce 18 percent of the total rice production of the country under the disaster-free condition. These regions contribute nearly 20 percent of the country’s total inland fish production. In recent years, however, their enormous potential has been overshadowed by climate vulnerability, particularly to flash floods.

Figure 5.33 Haor area and number by district



Source: Bangladesh, Ministry of Water Resources, Bangladesh Haor and Wetland Development Board. 2012. "Master Plan of Haor Area." Vol. 1: Summary Report. Center for Environmental and Geographic Information Services (CGIS), Dhaka.

Boro-fallow-fallow is the prevalent cropping pattern in the haor areas, which leaves room for productivity increases. In haor areas, crops are grown only in the rabi season from November to April, meaning the land remains fallow during the aus season between April and July and the aman season from July to November. The boro-fallow-fallow cropping practice allows only winter crops to grow. Farmers mostly cultivate one rice crop per year and prefer modern improved varieties over local varieties. Roughly 10–40 percent of land in the haor areas is elevated and locally referred to as kanda. Water recedes from these kanda lands 30 to 45 days earlier than in the low-lying rice fields and makes the kanda ready for crop production. Despite this advantage, kanda lands are mostly kept fallow

throughout the year because of lack of irrigation infrastructure.

Natural disasters, especially flash floods, frequently challenge the agriculture potentials of the region. Between 1993 and 2010, major crop losses occurred in four years, during which about 70 percent of crop areas were damaged, resulting in the loss of 2.44 million tons of rice, 64,000 tons of jute, and 40,000 tons of other crops to floods. Haor is mainly a single-cropped region with boro production. In 2017, a devastating flash flood hit the region, resulting in a loss of 90 percent of boro production and 903 tons of fish production. The region's agricultural potential remains under constant threat from flash floods. Annual rainfall ranges from 2.2 meters along the western boundary to 5.8 meters in its northeast corner and as high as 12 meters in the headwaters of some catchments extending to India. The region receives water from the catchment slopes of the Shillong Plateau across the borders in India to the north and the Tripura Hills in India to the southeast. Excess rainfall in the upstream hilly areas and the subsequent runoff, river sedimentation, unplanned road and water infrastructure, deforestation, improper drainage, and increased rainfall variability due to climate are the main causes of flash floods.

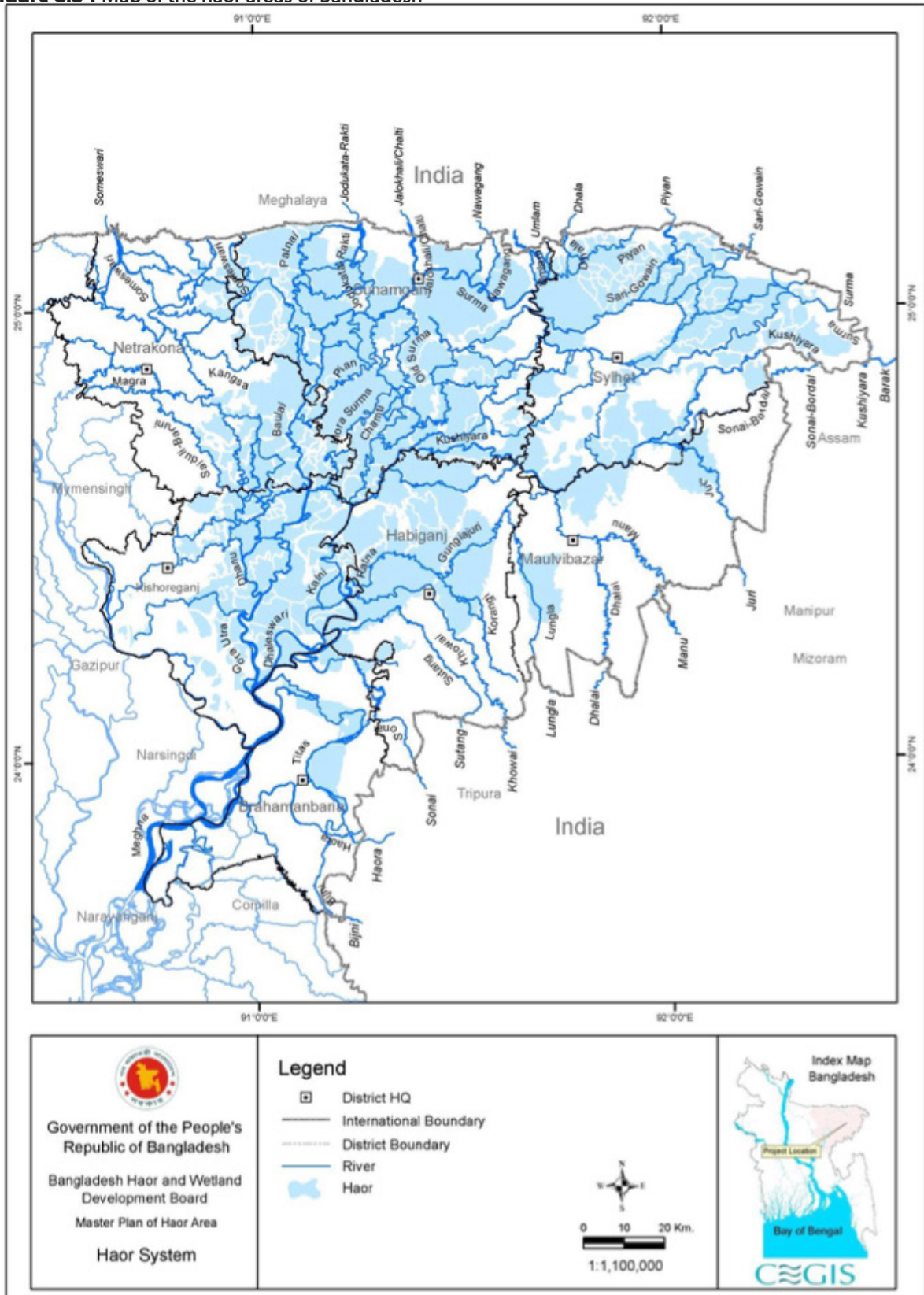
Haors are rich in aquatic biodiversity, with 140 species of fish and thousands of migratory birds. The area is steadily becoming a popular tourist attraction in Bangladesh. Fish culture is an important economic activity in the haor area. The fishermen face economic, social, and technical constraints in pursuing their occupation. They are relatively poor and often cannot meet their basic needs from existing fisheries management practices. Over the years, many species of fish have become rare or have decreased significantly due to overfishing and habitat destruction. Again, sedimentation in rivers, canals, and other bodies of water creates disturbance in the local ecology in terms of disruption of fish breeding cycles and migration routes. These all lead to a reduction in fish population, productivity, and production. Moreover, degradation of the conditions and declining of swamp forests have led to a reduction in fish production, animal diversity, and waterfowl population over the past several years.

Several measures are being implemented to protect crops and preserve ecology, but more needs to be done. Submersible embankments have been built up along the banks of rivers and canals to control the influx of premonsoon flash floodwater into the haor for a certain period so that farmers can manage the safe harvest of their only crop, boro. The Bangladesh Water Development Board constructed 1,826 kilometers of submersible embankments in 46 project areas under six districts (Sunamganj, Sylhet, Moulvibazar, Habiganj, Netrokona, and Kishoreganj) in the northeast region to protect the boro rice crop from premonsoon flash floods. The earthen embankments become submersed every year in monsoon and encounter severe waves. Therefore, they require regular repair and maintenance. The reported reason for the devastating impact of flash floods in 2017 was improper management of submersible embankments. Measures have been taken to preserve and regenerate the swamp forest but at a small scale.

Enabling Environment

The Bangladesh Haor and Wetland Development Board has been set up to strengthen development focus on the haor region. The multiple dimensions of the issues of haor ecology require the coordination of a number of public departments. In order to coordinate the activities and formulate projects following a holistic development approach to Bangladesh's haors and wetlands, Bangladesh established the Bangladesh Haor and Wetland Development Board (BHWDB) in 2000. In order to strengthen the development activities of the haor areas, the board was elevated to the status of a department in 2016, but the department did not operate with full functionality until several years later. In addition, the local departments at the district and subdistrict levels are actively involved with implementing the dedicated projects. Moreover, both district and subdistrict administrations are deeply engaged with managing the haor areas of that region.

Figure 5.34 Map of the haor areas of Bangladesh



Source: Bangladesh, Ministry of Water Resources, Bangladesh Haor and Wetland Development Board. 2012. "Master Plan of Haor Area." Vol. 1: Summary Report. Center for Environmental and Geographic Information Services (CGIS), Dhaka.

A longitudinal integrated development plan has been adopted for the haor areas. In order to consolidate the development potentials of the haor area, BHWDB prepared a master plan in 2012. The plan is consistent with other national development plans, such as Vision 2021 and the five-year plan. Through these policies and plans, the Government of Bangladesh aims to promote the welfare of its inhabitants by ensuring living standards, social services, and equitable distribution of income and property. The 20-year master plan is a framework plan that will be implemented on a short-, medium-, and long-term basis. Specifically, integrated development would comprise mainly flood management, environmental sustainability, production of crops, fisheries and livestock, expansion of education, settlement and health facilities, road communication, navigation, water supply and sanitation, industry, afforestation, and power generation and energy. Planned investment portfolios have been prepared for 17 sectors, including water resources, agriculture, fisheries, livestock, and forest. This plan has envisaged multiorganizational involvement and community participation as key to successful implementation; development partners and the private sector will participate vigorously.

Some projects dedicated to the haor area have been implemented, but they are mainly infrastructure related. The haor development department has implemented six projects, two of which are small-scale infrastructure development projects. The other four are mainly technical studies. At present, the haor department is implementing three technical studies at a cost of 730 million Bangladeshi taka. The department has 11 proposed projects focusing mainly on water management and flood protection in the haor areas. The BWDB is implementing the Haor Flood Management and Livelihood Development Project to reduce the damage to boro crops from premonsoon floods, improve access to basic infrastructure, and increase agriculture and fishery productivity in the haor areas in the upper Meghna river basin. This project mainly focuses on the construction of submergible embankments and canal/river excavation in haor area of the 32 subdistricts and includes small-scale agriculture and fishery promotion activities, including adaptive trial of new varieties and field demonstration of improved agricultural practices. The local government and engineering department is implementing the Haor Infrastructure and Livelihood Improvement Project in 28 upazilas of the haor areas, mainly to develop rural road infrastructure.

Development partners and NGOs are actively engaged in developing the haor areas. As a Ramsar site, the Tanguar haor has the government's commitment to conserve its biodiversity. The International Union for Conservation of Nature (IUCN) is implementing a project for the period of 2006–16 for the conservation, stabilization, and sustainable use of the natural resources of the Tanguar haor to generate significant improvements in the livelihood of rural communities with the financial assistance of the Swiss Agency for Development and Cooperation. The Center for Natural Resource Studies has studied the vulnerabilities of the haor areas by focusing the challenges of the sustainable livelihood of the haor communities. Oxfam has also conducted assessments on early flash floods in haor areas. Care Bangladesh, with assistance from USAID, is implementing Strengthening Household Ability to Respond to Development Opportunity (SHOUHARDO) as an integrated multisectoral program to ensure food security, maternal and child nutrition, women and youth empowerment, improved governance, and disaster resilience for the poor and extreme-poor households in haor areas.

Upon consultation with a large body of reports, papers, and expert opinions, key agricultural constraints in the haor area have been identified:

- The haor area is producing a monocrop, boro, whose harvest is frequently disturbed by flash

- floods.
- The raised land (kanda) remains fallow because of lack of irrigation.
- Human activities endanger fish habitats by destroying the biodiversity of the wetlands.
- Poor information and communications technology infrastructure and other structural barriers put constraints on farmers’ access to the market.

Figure 5.35 SWOT analysis of Package 5 in consultation with the haor stakeholders

| | Helpful | Harmful |
|----------|---|--|
| Internal | <p>Strengths</p> <ul style="list-style-type: none"> • Increased profitability sets in quickly • Northeastern Bangladesh is a priority region for development according to the Government of Bangladesh • Some interventions are already there | <p>Weaknesses</p> <ul style="list-style-type: none"> • Low demand for non-rice crops • Limited farm-level know-how • Poor farming practices • Inadequate access to finance • Risk-averse farmers |
| External | <p>Opportunities</p> <ul style="list-style-type: none"> • Developing clear market access for rice and non-rice crops to ensure profitability for diversifying farmers • Policy push for diversification • Blended finance vehicles to make early investments less risky and strengthen the supply chain • Learning from farmer associations inside and outside of Bangladesh • Digitalization of government procurement | <p>Threats</p> <ul style="list-style-type: none"> • Market access or rural communities might not be economical for producers • Low-quality product decreases interest of private sector • Food systems are informal and market links are weak • Hoarders and middlemen who control market segments and dilute profits for farmers engage in value chain arbitrage |

Investment opportunities

1.1.1.12 Invest in research of short-lived flood-tolerant rice varieties with intense collaboration among stakeholders and promise quick development, deployment, and evaluation of new varieties linked to CSA Package 1

Improved seed varieties with short-lived and flood-tolerant features can help haor farmers harvest before a flash flood. Short-lived rice varieties will help the farmers escape flash floods, while the flood-tolerant nature of the rice will strengthen the plants to survive. It is estimated that if the loss of rice due to flash floods can be avoided, farmers can save up to 80 percent of the rice production of the haor areas. Bangladesh has several very well-capacitated and successful research institutes working for seed development and associated agronomic technologies, including BIRRI, BARI, and BINA. BRAC, a leading NGO of the country, is also actively involved with seed varietal development. In spite of the efforts of these organizations, only a quarter of seeds used in the country are deemed high quality.

AISS encompass intense collaboration among stakeholders and promise quick development, deployment, and evaluation of new varieties. Intense collaboration among stakeholders will not only develop new varieties quickly but also reduce the new variety adoption lag time that the country has seen with new rice varieties in the past. Setting up a knowledge platform among the key haor

stakeholders will ensure technical knowledge is shared and the changing needs for agricultural extension services in the haor areas are met.

1.1.1.13 Investment in improved high-yielding restorative non-rice crop systems

Providing improved seeds of high-value non-rice crops and agriculture machines can boost profits and productivity. Promising non-rice crops include maize, mustard, ground nut, and vegetables that require less water and are better suited for the environmental conditions of northeastern Bangladesh. These crops can generate higher profit margins and labor productivity than rice, which is labor intensive to harvest and provides only limited profits to farmers. Moreover, mechanized agriculture needs to be introduced in the haor area to reduce the labor cost of crop production. Research institutions in the country can play a crucial role to facilitate new non-rice varietal development, and collaboration among the stakeholders expedites the adoption of the new non-rice varieties.

Bringing kanda lands under crop cultivation requires irrigation facilities and extension services.

Coordinated support from extension workers is required to motivate and train the people to bring kanda lands under cultivation. Since kanda lands have no irrigation facilities, crops that require less irrigation can bring vast fallow land under production. Alternative rabi crops can be grown here—for example, pulses, oil seeds, cereals, and vegetables. Reliable and affordable solutions for expanding irrigation facilities to the kanda lands need to be investigated. Establishment of deep tube wells can be a way to provide irrigation facilities on kanda land.

1.1.1.14 Development of home-based composite farms with vegetable gardening, floating gardens and duck rearing

Development of home-based composite farms with vegetable gardening and duck rearing will help farmers generate higher incomes through greater agricultural productivity. Agricultural extension services can be provided to the farmers to choose the right kind of varieties for gardening. New types of climate change–tolerant cultivation technologies can be applied in the homestead so that they will not be damaged by flash floods or other natural disasters. Farmers can apply hydroponic cultivation methods, which are not vulnerable to floodwater. Rainwater harvesting can be integrated with hydroponic cultivation instead of irrigation. The United Nations Development Programme (UNDP), with the help of the union parishads, is implementing a climate-resilient alternative livelihood development project in Deluti Union Parishad of the Paikgacha subdistrict of Khulna District, where a demonstration of hydroponic cultivation integrated with rainwater harvesting has been conducted. This type of model can be tested and replicated in the haor areas. In addition, other types of climate change–tolerant cultivation, such as floating gardens, can be replicated in the haor areas with effective agriculture extension services.

Livestock potentials in haor areas can be leveraged by duck rearing. Households living near or beside haors can rear duck at a large scale that will help poor households emerge from poverty. Ducks are more climate change tolerant than chickens. Extension services can be provided by livestock offices and qualified NGOs to protect ducks from diseases and other potential threats.

1.1.1.15 Establishment of fish sanctuaries and beel nurseries

Establishment of fish sanctuaries in the large haors will significantly contribute to enhance fish production. Fish habitats in the haor area have narrowed over the years due to the decline of swamp forest, which leads to a reduction in fish production. Regeneration of swamp forest and its preservation will help to grow the fish properly. Moreover, it will enhance the ecological resources of haor areas. Additionally, local technologies to create fish sanctuaries, such as keeping bamboo and tree branches in the haor water, will increase fish production significantly. Maintenance and

surveillance are essential to protect the fish sanctuary from frequent human disturbances.

Creation of beel nurseries in haor areas will protect rare species of fishes. Over the years, overfishing and habitat destruction have significantly reduced the population of many species of fish, bringing them to the brink of extinction. Beel nurseries can protect nearly extinct fish species and in turn sustainably increase fish production. Moreover, sedimentation in rivers, canals, and other bodies of water creates disturbance in the local ecology in terms of disruption of fish breeding cycles and migration routes. These all lead to a reduction in the fish population, productivity, and production. River and canal re-excavation are essential to protect fish breeding cycles and migration routes.

1.1.16 Invest in targeted supply chain improvements

Setting up effective market mechanisms is crucial to ensure profitability for farmers. Frequently, boro rice production is not economical to farmers who cannot achieve cost-covering prices. Intensification of boro rice production and a shift to non-rice crops cannot be fully implemented unless market inefficiencies are removed. An effective market mechanism requires a high degree of collaboration among farmers on a regional level to build cooperatives and markets, increased transparency of the government's rice/wheat procurement system to help farmers plan production cycles, and access to low-risk finance. Promoting effective and functioning cooperative systems with a physical marketplace will be critical to the success of crop diversification. Moreover, technicalities such as location, size, and governance of market halls should be developed in close coordination with local governments, NGOs, and the private sector. Along with developing physical markets, road communication needs to be developed to smooth access to markets.

Cold storage systems and networks are essential to ensure the supply of vegetables and non-rice commodities to market. Haor areas are located in the northeastern region of the country, which is not well-connected with the main hub of Dhaka. In some cases, remote haor areas are not even connected with district headquarters. Therefore, a reliable storage system should be developed to store produce. Because cold storage is beyond the financial capacity of individual farmers, the public and private sectors need to collaborate to establish cold storage in the haor areas.

Cost Assessment and Financing Strategies

To assess the costs of the haor package, a direct cost estimation was conducted for each investment strategy, with consideration of the number of beneficiaries in northeastern Bangladesh and the cost of other similar CSA investment packages (table 5.9). For each investment strategy, the cost of the interventions was considered at the field level and cross-checked with local experts on haor. For different interventions, respective assumptions were set to assess costs. For instance, for development of home-based composite farm development, agri-households living in extreme poverty in the haor area were considered beneficiaries (around 500,000). In the case of establishing beel nurseries and fish sanctuaries, 300 beel nurseries and 300 fish sanctuaries were accounted for.

Table 5.33 Cost of hoar agriculture investment strategies with suggested financing strategies

| Investment strategy | Cost (US\$ millions) | Financing strategies |
|--|----------------------|---|
| Research on short-lived and flood-tolerant rice varieties | \$20 | Public sector led, with private sector participation |
| Improved high-yielding restorative non-rice crop systems | \$40 | Public sector led, with private sector participation |
| Home-based composite farm development (gardening and duck rearing) | \$160 | Public-private partnership with the assistance of development partners, the Green Climate Fund, other dedicated climate funds, and local government funds |
| Establishment of beel nurseries and fish sanctuaries | \$30 | Public sector led, with the assistance of development partners, the Green Climate Fund, other dedicated climate funds, and local government funds |
| Targeted supply chain improvements | \$50 | Public-private partnership with the assistance of development partners |
| Total | \$300 | |

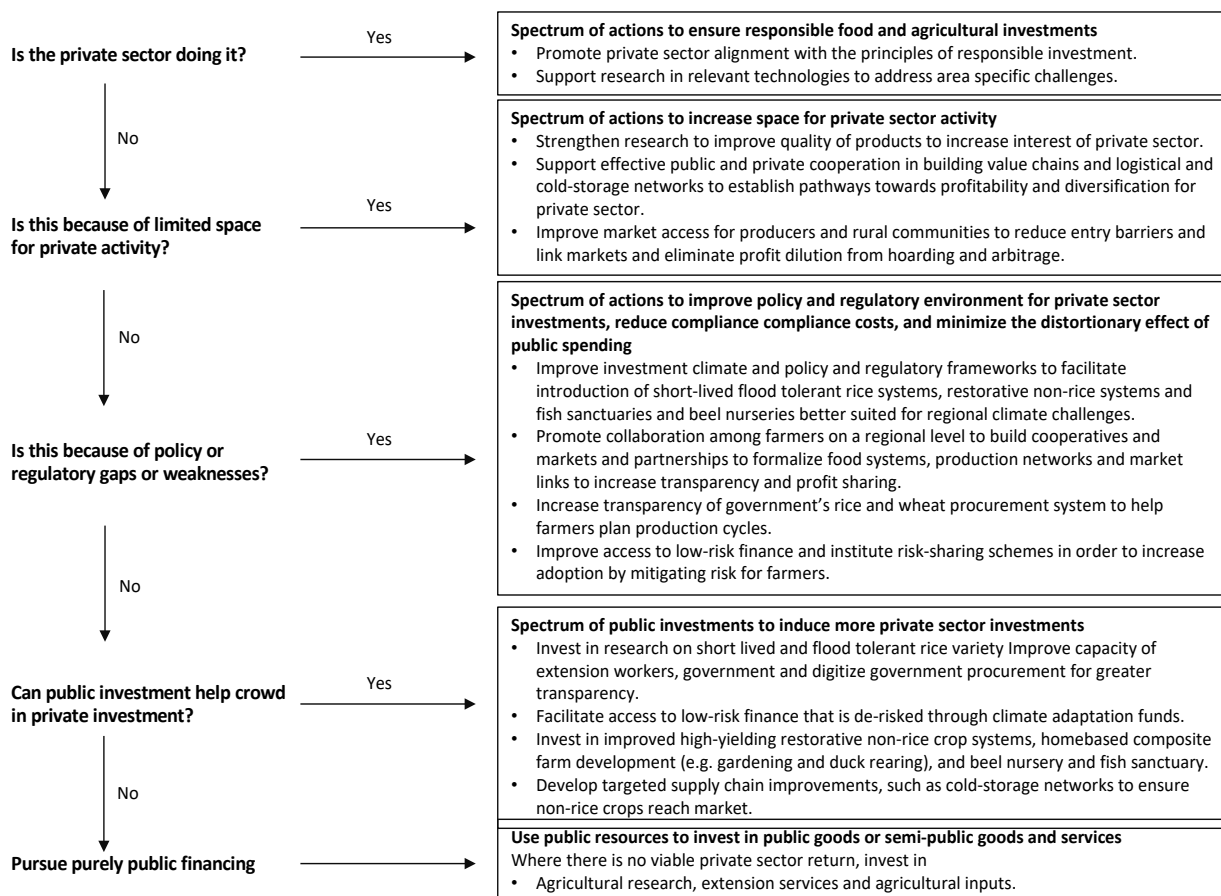
The estimated cost of this package is US\$117 million, ranging from US\$110 million to US\$129 million (or US\$300 million, ranging from US\$280 million to US\$330 million, PPP 2017 US\$).

Results of Cost Benefit Analysis

A cost-benefit analysis for Package 5 suggests an IRR of 30% and an ERR of 39%. This is higher than the median ERR of past World Bank projects. Relying on a regression analysis, the median ERR of World Bank projects in the agriculture and rural development sector between 1996 and 2008 is estimated at 23%. Based on the CBA, the NPV of Package 5 amounts to US\$113 million while the ENPV is estimated as high as US\$ 138 million. The CBA for Package 5 was based on the following assumptions: First, crop losses from flash floods will decrease due to package implementation. Second, crop losses will be reduced by 20% in the first year and by 5% annually through innovations such as new varieties. Third, adopting CSA technologies will increase yield and productivity of both rice and non-rice crops in the haor areas. Fourth, this package will reduce crop losses from flash floods by 70% in the final year of package implementation. Fifth, the same production growth rate of non-rice crops as in package 3 is assumed. Sixth, this package will also foster benefits in non-agricultural sectors as enhanced food security will contribute to an increase in life expectancy and a reduction in health hazards.

Maximizing Finance for Development

Figure 5.36 Decision tree for maximizing finance for development for Package 5



5.7 CSAIP Financing

Climate finance in general refers to all financial flows that help achieve climate change adaptation and mitigation objectives. It can be instrumental in supporting the agriculture sector by accomplishing the following:

- **Meeting the financing gap.** Climate finance could be used to meet the shortfall in financing or increase the attractiveness of an investment to catalyze financing from other sources.
- **Managing risk.** Climate finance could be structured to reduce risks associated with an agriculture project, either by reducing the overall financing requirement or by providing climate finance in the form of risk mitigation instruments such as guarantees.
- **Reducing transaction costs.** Climate finance could be deployed programmatically to finance interventions that systematically reduce the costs associated with CSA at the sector level.

For climate finance to be effective in achieving these goals, strengthening the link between financial institutions and farmers is key. Broadly, two types of financing approaches in climate finance exist: upfront financing and results-based financing (RBF). Upfront climate financing is typically made available at the early stages of the project cycle—for example, through grants, low-cost debt (concessional loans), equity, guarantees, and so on. By contrast, RBF disburses funds to a recipient upon the achievement and independent verification of agreed-upon results. RBF flows are similar to an additional revenue stream at the project level.

Sources can be public, bilateral, or private. Climate finance may be raised from public sources, such as government budgets, public sector companies, or public financial intermediaries such as bilateral aid agencies, climate funds, and development finance institutions, including national, bilateral, and multilateral development banks. Climate finance may also be raised from private sources such as financial institutions, venture capital funds, private equity, institutional investors, and project developers. Climate finance may include some element of concessionality, or financing offered on terms that are more attractive than those offered by the markets, though this is not always the case. Some sources of upfront climate finance from the public sector that support climate-smart investments in agriculture are outlined below. Each fund has different eligibility criteria and access modalities for reviewing and approving funding requests:

- **Adaptation Fund.** The Adaptation Fund was created through a 2 percent levy on projects under the UN Clean Development Mechanism. The fund supports concrete adaptation projects and programs in developing countries that are particularly vulnerable to the adverse effects of climate change with a focus on climate adaptation and resilience activities. Projects are selected based on countries' needs and priorities.
- **Global Environment Facility (GEF).** The World Bank is a trustee of the GEF, which provides financing to developing economies and economies in transition to meet international environmental conventions and agreements covering the incremental costs for such measures. Projects should be driven by national entities and demonstrate alignment with national priorities. By the end of 2015, the GEF had invested in 1,000 climate mitigation projects, including 380 projects that support sustainable forest management and US\$1.3 billion to help communities adapt to climate change.
- **Green Climate Fund (GCF).** GCF was set up in 2010 by the 194 countries that are parties to the UNFCCC as part of the convention's financial mechanism. GCF aims to deliver equal amounts of funding to mitigation and adaptation in developing countries through its accredited entities. GCF offers a wide range of instruments to both the public and private sectors, with a focus on vulnerable communities.
- **Special Climate Change Fund (SCCF).** The SCCF supports adaptation and technology transfer in all developing country parties to the UNFCCC, supporting both long-term and short-term adaptation activities in sectors such as water resources management, land management, and agriculture.
- **Least Developed Countries Fund (LDCF).** LDCF addresses the special needs of the 51 least developed countries that are especially vulnerable to the adverse impacts of climate change. It focuses on reducing the vulnerability of resources that are central to development and livelihoods, such as water, agriculture, and food security.

- **Pilot Program for Climate Resilience (PPCR).** PPCR provides concessional and grant funding to projects in vulnerable countries to implement national plans and pilot innovative public and private sector solutions for adaptation and resilience.
- **Climate Investment Funds (CIFs).** CIFs provide financing to developing and middle-income countries to manage the challenges of climate change and reduce GHG emissions. CIFs offer concessional financing to test new business models and approaches, build track records in unproven markets, and boost investor confidence to unlock additional finance from other sources, particularly the private sector and multilateral development banks.
- **Other funds.** Different international and national companies, predominantly financial institutions, mobilize funds as their corporate social responsibility for climate change adaptation activities. At the same time, philanthropic organizations also participate in climate actions in developing countries. Moreover, sometimes communities generate funds to implement climate actions.

Results-based climate finance (RBCF) is typically provided against the achievement of specific climate outcomes, typically emission reductions measured in tons of CO₂e. RBCF is provided when emission reductions are delivered because of project operations. Typically, such funds specify accepted methodologies for estimating or quantifying emission reductions. A design document with this estimate and the system for monitoring, reporting, and verifying the result parameters is submitted to the fund for review. The financing is disbursed at agreed-upon intervals upon completion of verification by an independent consultant, thereby monetizing the climate asset generated by the project. Sources of results-based climate finance that could be used for CSA projects include the following:¹⁰⁰

- **Transformative Carbon Asset Facility (TCAF).** TCAF supports purchase of emission reductions from transformative mitigation programs to generate outcomes at a large scale, such as projects that deliver sectoral results or lead to policy reform.
- **Forest Carbon Partnership Facility (FCPF).** The FCPF supports countries in achieving emission reductions from deforestation and forest degradation projects by providing a combination of financial and technical assistance. FCPF pilots performance-based payments to promote large-scale incentives for REDD+ and disseminate knowledge. It also focuses on sustaining livelihoods of local communities and conserving biodiversity.
- **BioCarbon Fund (BioCF).** BioCF focuses on afforestation and reforestation projects. It seeks to demonstrate land-based activities that can generate high-quality emission reductions while creating cobenefits for local communities.

¹⁰⁰ World Bank. 2018. Carbon Markets for Greenhouse Gas Emission Reduction in a Warming World: An Evaluation of the World Bank Group's Support to Carbon Finance. IEG (Independent Evaluation Group). Washington DC: World Bank. ieg.worldbankgroup.org/evaluations/carbon-finance.

Climate Financing Instruments

The following are commonly used instruments for providing climate finance:

- **Grants.** Climate finance, particularly when raised from public sector sources, may be offered in the form of grants at the project or program level to address a specific barrier or reduce overall cost.
- **Project equity.** Equity offers long-term capital and may offer an opportunity to leverage investors' expertise, in addition to financing. Climate finance in the form of early-stage equity investment may be raised from venture capital funds focused on impact investments from or private equity funds. Public sector sources such as the GCF also make equity investments.
- **Debt.** Project debt may be low-cost or market-rate, depending on the type of project and source of financing. For example, debt financing from public sector sources may include some element of concessionality. Debt may also be raised on various terms (for example, senior or mezzanine financing). Debt may be raised directly from financial institutions. It may also be raised from institutional investors, such as through issuing green bonds.
- **Risk mitigation instruments.** Risk mitigation instruments are off-balance sheet financing instruments that strengthen the project in order to raise financing from other sources. For example, a partial loss guarantee could offer coverage for part of a project's debt repayments, thereby increasing the availability or reducing the cost of commercial finance.

Several other instruments, such as aggregation vehicles or funds, may also be used depending on project design, the nature of financing required, and the investment objective to be met.

CSA Finance in Bangladesh

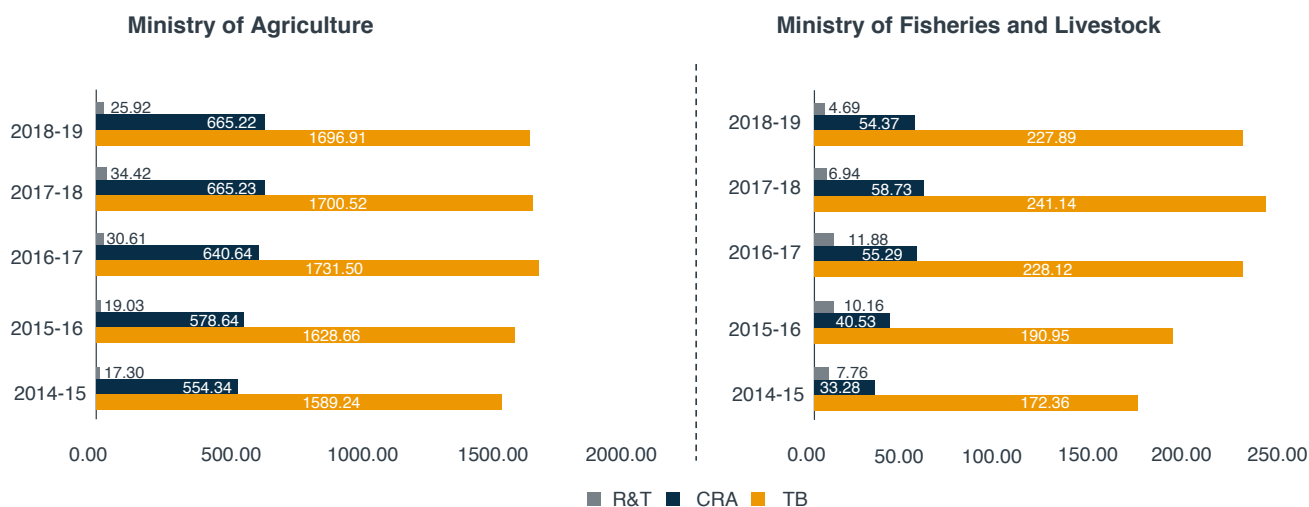
Financing for agriculture in Bangladesh takes many shapes and involves many different actors. The public sector, development partners, NGOs, financial institutions, and the private sector all assume specific roles in channeling funding into agriculture. In the public sector, MOA and MOFL typically take the lead, but other ministries such as the Ministry of Local Government, Rural Development and Cooperatives; the Ministry of Food and Disaster Management; the Ministry of Social Welfare; and the Ministry of Finance also play a role in financing agricultural projects and agricultural infrastructure across the country. Development partners have been pivotal sources of finance for Bangladesh's agriculture sector, on the one hand providing grants and concessional loans as on-budget support for agricultural development to the public sector and, on the other, providing off-budget support to NGOs that channel these funds into microfinance schemes for agricultural development. Bangladesh is home to one of the most established microfinance industries in the world. Largely run by NGOs, microfinance schemes are widespread across the country and have enormous reach. Besides receiving third-party financial support for their operations, microfinance NGOs generate revenues from lending out deposited microsavings of households, in turn expanding their microfinance schemes, frequently for agricultural development. Microfinance aside, traditional financial institutions, particularly state-owned banks, have been central to agricultural development in Bangladesh, particularly in offering credit to small farmers to commercialize their operations. Finally, the private sector itself is gradually evolving as a financier of agricultural businesses, particularly in areas of professionalized agriculture, such as mechanized agriculture and formalized value chains. Overall, however, to boost agricultural development in Bangladesh, the private sector needs to assume a larger role in funding agricultural

development, from research through all steps of agricultural value chains. One additional source of funding, whose importance may only increase in the future, is climate finance.

The importance of public funding for CSA development in Bangladesh is evidenced by the significant climate cobenefits it generates. Of all ministries' budget allocations, the MOA's budget allocations generated the largest share of climate cobenefits, accounting for 28.79 percent of total allocations eligible for climate cobenefits in fiscal year 2018–19. Of the MOA budget earmarked for agricultural development, 44.15 percent qualified for climate cobenefits due to being dedicated to climate change–related interventions in fiscal year 2018–19. In contrast, in fiscal year 2014–15 this share was a mere 8.83 percent, demonstrating how the government prioritizes climate change in its planning. Over the same time span, climate change–related MOFL development budget allocations increased from 12.79 percent to 20.97 percent. To address climate change risk, Bangladesh set up the Bangladesh Climate Change Trust Fund in 2010, which funds programs and projects from the national budget to help communities recover and become resilient to climate change impacts. Until 2018, MOA had claimed around 5 percent of the fund's allocations.

Funding for research in CSA is led primarily by the public sector, but better incentives are needed for the private sector to close the gap. MOA and MOFL allocate less than 10 percent of their respective budgets to research and capacity building, despite how essential both are to countering the climate vulnerabilities of Bangladesh's agriculture sector (figure 5.36). This low prioritization, particularly of research, is striking, as MOA alone has eight dedicated research institutions dealing with agriculture's different subsectors. Additionally, some of the country's higher education institutions receive funding for CSA research from the Ministry of Education. Nevertheless, overall engagement is low, particularly from the private sector. Instead, given the country's sizeable seeds market, many NGOs have been involved in seed research in recent years. However, no concrete figures of the levels of NGO-funded research in Bangladesh exist, which further demonstrates the inadequacy of the enabling environment with regard to agricultural finance. Given Bangladesh's large agriculture sector, however, CSA research could, and indeed should, be profitable for the private sector. This shortfall of private funding for CSA research is due to insufficient incentive schemes for private sector participants and can be countered through grants, licensing, or risk-sharing schemes and the formalization of agricultural markets. To this end, the government established the Bangladesh Krishi Gobeshona Endowment Trust in 2008 as an entity under MOA with around US\$50 million to foster an enabling environment to advance agricultural development through support of agricultural research and related activities. In another initiative, the World Bank supplemented the Government of Bangladesh with funds for agriculture research through the first phase of its National Agriculture Technical Project (NATP) and is currently starting NATP-2 with an investment of US\$200 million over five years.

Figure 5.37 Public finance in broad agriculture in Bangladesh (in US\$ million)



Note: R & T = Research and training, CRA = climate-related allocation, and TB = total budget.
 Source: Bangladesh, Ministry of Finance, Finance Division. 2018. "Climate Financing for Sustainable Development: Budget Report 2018–19." Ministry of Finance, Government of Bangladesh, Dhaka. <https://www.undp.org/content/dam/bangladesh/docs/Projects/IBFCR/Climate%20Financing%202018-19.pdf>.

NGOs are well placed to fill some gaps in facilitating CSA practices in Bangladesh. Bangladesh is host to some 1,500 NGOs, as well as to numerous government- and donor-sponsored microfinance projects and programs, such as the Bangladesh Rural Development Board, Swanirvar Bangladesh, and RD-12. Many of these institutions provide microfinance for agricultural ventures and due to their enormous reach can and should be tied to establishing CSA practices. At the same time, most NGOs are not able to provide the levels of funding needed to facilitate larger-scale investments, which help transition the agriculture sector from subsistence farming to sustainable commercialized agriculture. Besides the microfinance space, many NGOs have been involved in CSA research and can continue to play a role. Given the importance and size of agriculture in Bangladesh, funding of CSA research should not rest with the public sector and NGOs alone but with the private sector as well, as it contains an inherent value proposition from which the private sector stands to benefit.

Credit to the Bangladesh agriculture sector is policy-driven and inclusive and has been robust for years, but it needs to be made conditional on CSA adoption. Financial institutions, particularly state-owned banks, have programmatically provided agriculture credit to farmers in the country. In the first half of fiscal year 2018–19, Bangladesh’s state-owned and private banks disbursed around US\$1 billion to the agriculture sector. Around 3.4 million farmers are the beneficiaries of agriculture loans, 1.4 million of whom are women. Given the direct influence the Government of Bangladesh wields over many players in the country’s financial sector, policies to offer credit to agriculture ventures should be amended to incentivize the adoption of CSA practices of borrowers. In addition to offering traditional funding, in 2011 the central bank of Bangladesh launched a revolving fund of 1 billion Bangladesh taka to boost agroprocessing, particularly in rural areas, which was gradually increased to 4.5 billion Bangladesh taka by 2015 in response to high demand. By the end of June 2016, 8.8 billion Bangladesh taka had been disbursed under this scheme on a revolving basis to 2,312 enterprises. Like traditional agricultural credit, however, this fund does not feature a mechanism to ensure the climate smartness of the ventures it supports. This offers an opportunity to introduce agriculture businesses to the concepts of CSA and to anchor CSA considerations in large-scale agriculture projects, financing of which is beyond the scope of microfinance institutions.

Given Bangladesh’s sizeable vulnerabilities as a climate hot spot, the country may have access to tremendous resources of international climate finance. According to the Bangladesh Climate Public Expenditure and Institutional Review 2012, 25 percent of Bangladesh’s climate funding comes from development partners. These funds are channeled through different climate change–related funds, such as the Bangladesh Climate Change Resilience Fund, the LDCF, and the SCCF. By April 2018, Bangladesh had received approximately US\$328 million from climate finance sources. This source of funding may become increasingly important in the coming years; the GCF in particular could be a major climate finance source to implement CSA projects in Bangladesh. Already the GCF has recognized the PKSf and the Infrastructure Development Company Limited (IDCOL) as nationally accredited entities for climate finance projects through the Economics Relations Division of the Ministry of Finance, which acts as the national designated authority for the GCF. Thus far, the GCF has approved funding of US\$85 million for three projects, with a total project volume of US\$195.2 million in the water, energy, and infrastructure sectors of Bangladesh. Despite its potential, no CSA sector has received funding from GCF thus far. To facilitate the adoption of CSA practices in the country, CSA projects should be brought into the pipeline for GCF approval. The GEF, by contrast, has funded 43 projects in Bangladesh focused on climate change, land degradation, biodiversity, and marine life, providing over US\$150 million in grant funding and raising more than US\$1 billion in cofinancing.

Financing Strategies for the Bangladesh CSAIP

CSA projects may also benefit from the use of blended finance—that is, the use of public sector finance to crowd in or scale up private investment in a project or program. Blended finance can be particularly effective when catalyzing investments in sectors where perceived risk is higher than actual risk, which is especially true for new sectors and projects with which investors are unfamiliar. Blended finance can also help deliver enhanced development impacts. In the case of four chosen CSA packages, blended finance would be the most preferred method of financing (table 5.10).

Table 5.34 Financing strategies for the four main packages

| Package 1 | Agriculture Innovation System |
|-----------------------------|--|
| Subtitle | Strengthen the agricultural innovation system to provide the required research and development advances to maintain yield growth in the face of climate change by building adaptive capacity, particularly through adaptive varietal development. |
| Financing strategies | Public sector finance can help boost the development of platforms that allow intensified collaboration among stakeholders in Bangladesh to research, develop, and deploy new climate-resilient crop varieties. Grants from dedicated international funding sources such as the GCF can be a major source for both the private and public sectors to support such CSA research. Alongside multilateral development partners, PKSf and IDCOL have been approved as national implementing entities (NIEs) for the GCF. The private sector can access GCF funds through these NIEs. Further, advances can be made by introducing contract farming methods to ensure agreed-upon specifications of agricultural products. Financial institutions can provide credit to producer cooperatives that engage directly with seed distributors and research institutions to adapt the development and deployment of seeds to local environmental conditions. In this context, NGO finance can be mobilized as well, as many have been engaged in climate-adaptive seed research, development, and distribution. Bilateral and multilateral financing can be mobilized, including in the form of grants, for purposes of capacity building and exchanging technical know-how on seed research and development. A public-private partnership finance framework specifically catering to agricultural production systems and value chains may help mobilize additional private sector funds. |

| | |
|-----------------------------|--|
| Package 2 | Gender-sensitive development of homestead production |
| Subtitle | Strengthen resilience and boost inclusive growth of rural, women-run small-scale production of livestock and backyard pond aquaculture in southwestern Bangladesh. |
| Financing strategies | <p>Microfinance is the most widely accessible, and therefore suitable, funding mechanism to facilitate small-scale production of livestock and backyard pond aquaculture in southwestern Bangladesh. As most small agricultural households in rural Bangladesh lack the collateral necessary for traditional financing options, group and peer-based microfinance can help them gain access to credit. Women-targeted microfinance can provide the opportunity for women to run homestead enterprises of small-scale production of livestock and backyard pond aquaculture. The public sector jointly with bilateral and multilateral financing sources can inject funds through NGOs to boost the growth of these home-based enterprises. State-owned and private banks can support these enterprises in a coordinated manner. Local government institutions, particularly the union parishad, can play an important role in mobilizing local funds to facilitate CSA practices at the local level. Insurance schemes can help mitigate risk on a small scale. The public sector can finance—and development partners can provide grants for—gender-sensitive extension services for disease prevention and control, nutrition education, and enhanced DRM approaches. Lastly, many possible interventions under this package may qualify for international climate finance sources, such as the GCF.</p> |
| Package 3 | Resilience through diversification |
| Subtitle | Secure higher and more resilient income streams for farmers in northern Bangladesh through crop diversification, especially during the boro season. |
| Financing strategies | <p>To alleviate challenges caused by the remoteness of agricultural households, public finance continues to play an important role in Bangladesh. Local government institutions can finance the development of local infrastructure with the aid of development partners in the form of concessional loans or grants. Additionally, community financing or funding from philanthropic organizations can be relied on to develop small-scale infrastructure at the local level. Financial institutions can provide credit to producer organizers that foster the adoption of high-yielding restorative non-rice crop systems. Leasing and factoring methods can additionally encourage farmers to adopt high-yielding restorative non-rice crop systems.</p> |
| Package 4 | Livestock upstream value chain development |
| Subtitle | Boost productivity of the (semi-) commercial livestock sector through high-quality feed and value chain development of dairy farming. |
| Financing strategies | <p>The private sector can take the lead in investing in critical input goods and services for the livestock upstream value chain. To this end, the public sector should ensure an enabling environment that allows the private sector to fully leverage funding along the entire upstream value chain of Bangladesh's livestock sector. State-owned and private banks can offer structured credit products to funnel additional funding to the livestock sector in order to realize the substantial demand for inputs and outputs. Given the potential for profitability of businesses producing inputs for the livestock sector, as well as businesses processing outputs such as dairy products, equity funding may be raised from venture capital or private equity funds.</p> |

Aligning Climate Finance with the Maximizing Finance for Development Framework

The World Bank Group and other MDBs will play a critical role in reducing the costs and risks of climate finance investments and in building the country's institutional capacity. Funding can be scaled up by working with other public sources, including governments, bilateral aid agencies, CIFs, the GEF, and the GCF to provide risk-sharing measures aimed specifically at catalyzing private finance. Maximizing finance for development (MFD) is a framework to guide the World Bank's efforts to help countries maximize their development resources by drawing on private financing for growth and sustainable development. In the context of climate change, the World Bank's Concessional Finance Strategy for Climate Change applies the MFD approach to climate mitigation and adaptation.¹⁰¹ A key principle is development finance institutions to mainstream climate change in all development financing and prioritize concessional resources where there is the greatest climate-related risk and where commensurate capacity and resources to respond to climate change are most limited.

The strategy for crowding in private sector finance focuses on three main areas:

- Strengthening investment capacity and policy frameworks at the national and subnational levels
- Enhancing private sector involvement and prioritizing commercial sources of financing
- Making use of the catalytic role of the World Bank

¹⁰¹ World Bank Group. 2017. "Maximizing Finance for Development: Leveraging the Private Sector for Growth and Sustainable Development." Paper prepared for Development Committee, World Bank, Washington, DC. http://siteresources.worldbank.org/DEVCOMMINT/Documentation/23758671/DC2017-0009_Maximizing_8-19.pdf.

Table 5.35 Answers to questions about maximizing climate finance for development

| Question | How climate finance will be applied |
|---|---|
| Can commercial financing be cost-effectively mobilized for sustainable investment? | Public sector climate finance is typically provided for low-carbon infrastructure projects that are not commercially viable. For example, concessional or grant-based climate finance reduces the overall cost of capital, while the purchase of emission reductions through the public sector provides an additional revenue stream. The intention of the program is to improve the financial viability of projects and to attract private investment in the sector by demonstrating market demand for the climate cobenefits produced by the project. |
| Can upstream reforms be put in place to address market failures? | By building up institutional capacity and ensuring stakeholder engagement, CSA programs seek to facilitate an enabling environment for such initiatives to improve access to traditional sources of finance over time. |
| Can risk instruments and credit enhancements effectively cover remaining risks? | Where necessary, climate finance may be structured in a manner that minimizes the use of scarce public resources and mitigates risks associated with a project. In the case of projects that are financially viable in the absence of climate finance, revenues from the purchase of emission reductions may be used toward other development activities. |
| Can development objectives be resolved with scarce public financing? | The use of climate finance effectively helps “price” the positive externality generated by projects in the form of emission reductions or increased climate resilience. In the long term, public climate finance is intended to provide a market signal of demand for climate mitigation and adaptation cobenefits, thereby encouraging private investors to include climate as a variable in their assessment of investment opportunities. |

Section

6

Conclusion

Summary

Implementation of CSA technologies and policies could shift Bangladesh's agriculture sector onto a more productive, climate-resilient, and low-emission growth path. Model projections for 2040 indicate significant production, resilience, and mitigation cobenefits that can be achieved through CSA technologies. Widespread implementation of CSA technologies will likely allow Bangladesh to remain self-sufficient in rice production while diversifying and increasing non-rice crop production by 90 percent, livestock production by 17 percent, and fish production by 100 percent over BAU estimates. Increased cultivation of salt-resistant rice and wheat varieties under CSA is likely to decrease farmers' vulnerability to rising sea levels as model projections predict a 9 percent gain in cropland availability compared to BAU. This is driven by increased cropping intensities and salt-tolerant varieties that enable the use of salinized land. At the same time, crop diversification and reduced fuel use thanks to technologies such as solar irrigation are modeled to improve farmers' profits in the crop sector by 80 percent. Diversification away from rice, a more widespread application of AWD techniques, and drastically improved livestock productivity are likely to help Bangladesh achieve its unconditional GHG mitigation goals.

The Bangladesh CSAIP prioritizes five investment packages using a stakeholder- and evidence-driven process. To develop the packages, the CSAIP relied on three methodological building blocks. First, the CSAIP developed a vision for the agriculture sector in 2040 underpinned by specific quantitative targets across the three CSA dimensions. Second, the CSAIP Bangladesh developed four scenarios of plausible future states of the world along two uncertainty drivers: the intensity of climate change and the degree of economic development. Using the scenario technique allowed identification of CSA packages whose impacts would be robust to a wide range of uncertain outcomes. Third, a quantitative model was custom built for the CSAIP to allow decision makers to explore the impacts of and trade-offs across CSA investment options. The model used to validate the packages covers the most important agricultural products and is disaggregated at the division level.

CSA investment recommendations

The five major CSA investment packages have a total volume of US\$809 million (US\$2 billion, PPP).

- **Package 1: Agricultural innovation system.** Investments in stakeholder collaboration platforms, producer cooperatives, and enabling environments for the private sector are proposed to accelerate research and development of high-yielding stress-tolerant rice varieties and seeds. The investment in high-yielding stress-tolerant seeds is projected to increase yield by up to 10 percent. The increased productivity allows for the current rice land to be freed for non-rice crops, thereby decreasing emissions and water use and increasing farmer-level profitability.
Total investment volume: US\$117 million (US\$300 million, PPP)
- **Package 2: Gender-sensitive development of homestead production.** To strengthen the resilience of homestead production units in southern Bangladesh, it is suggested to invest in gender-sensitive public-private extension services, aspects of livestock disease control and prevention, pond aquaculture productivity improvement, nutrition education campaigns, and DRM. This package is projected to increase crop production by 27 percent compared to BAU, while GHG emissions are projected to decrease by 8 percent. According to model estimates, production of fish can be expanded from 1.7 million tons in 2015 to 4.1 million tons in 2040, thereby boosting homestead nutrition security.
Total investment volume: US\$125 million (US\$320 million, PPP)
- **Package 3: Resilience through diversification.** Investments in high-yielding restorative non-rice crop systems and related supply chains are proposed to secure higher and more resilient income streams for farmers in northern Bangladesh. Resilience through diversification will, according to model projections, increase non-rice crop production by 88 percent, with profits raised by 67 percent. Water use is estimated to decrease by 10 million liters a year (compared to BAU in 2040), and GHG emissions will fall by 8 million tons CO₂e per year.
Total investment volume: US\$196 million (US\$500 million, PPP)
- **Package 4: Livestock upstream value chain development.** This package proposes investing in the establishment of a national dairy board and the supply side of dairy value chains to increase the productivity and profitability of semicommercial dairy farms. This package will increase milk production by 17 percent and beef production by 16 percent, with GHG emission decreases by 20 percent and 13 percent, respectively.
Total investment volume: US\$254 million (US\$650 million, PPP)
- **Package 5: Climate-resilient agri-livelihood development in haor areas.** To promote climate-resilient livelihoods in haor areas, it is proposed to promote climate-smart intensification of rice cultivation and diversification to non-rice crops using a homestead-based farm development approach. Furthermore, it is suggested to combine this with the establishment of fish sanctuaries and investments in supply chain development.
Total investment volume: US\$117 million (US\$300 million, PPP)

The next step in the CSAIP process is investor identification. Several entry points have been identified. CSAIP development took place in coordination with BDP2100, which was recently approved and will be mainstreamed into five-year plans. The CSAIP is tailored to strengthen the agricultural aspects of BDP2100. The model and results are also ideally suited to inform the next iteration of the NDCs. Finally, the World Bank is in the process of supporting the development of an updated agricultural development strategy for which the CSAIP will provide critical inputs. A broader dissemination and outreach strategy will be selected in order to engage with private sector investors and climate finance sources.

Lessons Learned

CSAIP implementation needs to be geographically specific, as regions within Bangladesh face very different challenges. For example, in northern Bangladesh, boro rice increases the pressure on water resources in an already drought-prone area. Accordingly, Package 3 is designed to reduce reliance on this limited resource in northern Bangladesh. Conversely, in the south, water is abundant and agricultural production is constrained by diminishing land availability and more frequent extreme weather events. Therefore, Package 2 provides increased support for landless households as well as DRM.

Participatory methods may facilitate implementation and effectiveness of the investment plan. Participants provided input to identify technologies, policies, and market-based mechanisms that promise to reach specific, measurable goals. Employing participatory processes might enhance stakeholders' awareness of CSA and create a more enabling environment for adoption of CSA practices.

The Bangladesh CSAIP model promises to become a valuable tool for the nation's policy makers. As discussed in the report, the model to date serves as a tool to ask what if questions, not to make fully fledged policy impact assessments. It is the first analytical tool that covers the three dimensions of CSA for all the nation's agriculture subsectors. This broad scope and the ease of its use (being Excel based) come at the price of lack of detail and inability to simulate dynamic processes. Uncertainty bands around results continue to be large due to data limitations and the inherently difficult nature of modeling the future. The model reflects extreme events through their impact on average yields under climate change over time. A function that would allow the modeling of the impact of individual extreme events would be desirable to better reflect policy options around resilience.

Annex A: List of Engaged Stakeholders

| Name | Organization |
|---------------------------------|--|
| Ishrat Jahan | Accelerating Agriculture Productivity Improvement (AAPI) project |
| Khan Faisal Ahmed | Bangladesh Agricultural Development Corporation (BADC) |
| Dr. Md. Kabir Ikramul Haque | Bangladesh Agricultural Research Council |
| Abu Hena Sorwar Jahan (Belal) | Bangladesh Agricultural Research Institute (BARI) |
| Abul Kalam Azad | Bangladesh Agricultural Research Institute (BARI) |
| Jalil Uddin | Bangladesh Agricultural Research Institute (BARI) |
| Mohamed Amiruzzaman | Bangladesh Agricultural Research Institute (BARI) |
| Dr. Md. Alimur Rahman | Bangladesh Agriculture Research Institute (BARI) |
| Md. Atiqur Rahman | Bangladesh Agriculture Research Institute (BARI) |
| Dr Md. Harunor Rashid | Bangladesh Agriculture Research Institute (BARI) |
| Dr. Md Abdul Aziz | Bangladesh Agriculture Research Institute (BARI) |
| Dr. Md. Abu Hena | Bangladesh Agriculture Research Institute (BARI) |
| Amir Hossain | Bangladesh Bureau of Statistics (BBS) |
| Dr. Atiq Rahman | Bangladesh Center for Advanced Studies (BCAS) |
| Dr. Samarendra Karmakan | Bangladesh Center for Advanced Studies (BCAS) |
| Md. Ashraful Kabir | Bangladesh Center for Advanced Studies (BCAS) |
| Dr. Abu Syed | Bangladesh Center for Advanced Studies (BCAS) |
| Shakila Yasmin | Bangladesh Climate Change Trust |
| Dr. Giasuddin Choudhury | Bangladesh Delta Plan (BDP 2100) |
| Khan Ahmed Sayeed Murshid | Bangladesh Institute of Development Studies |
| Md. Al-Arafat Tapu | Bangladesh Institute of Nuclear Agriculture (BINA) |
| Mohammad Fazle Reza Sumon | Bangladesh Institute of Planners (BIP) |
| Dr. AKM Abul Kalam | Bangladesh Institute of Planners (BIP) |
| Yearuddin Sarker | Bangladesh Jute Research Institute (BJRI) |
| Nathuram Sarker | Bangladesh Livestock Research Institute (BLRI) |
| Dr. Khan Shahidul Huque | Bangladesh Livestock Research Institute (BLRI) |
| Sarda Mohammad Amanullan | Bangladesh Livestock Research Institute (BLRI) |
| Imrul Hasan | Bangladesh Ministry of Agriculture |
| Md. Abdul Jalil | Bangladesh Ministry of Land |
| Dr. Golam Rabbani | Bangladesh Ministry of Livestock and Fisheries |
| Abdur Rauf | Bangladesh Ministry of Local Government, Rural Development and Cooperatives, Local Government Division |
| Mantu Kumar Biswas | Bangladesh Ministry of Water Resources |
| Mohammad Ali Khan | Bangladesh Ministry of Water Resources |
| Md. Raisul Alam Mondal | Bangladesh Ministry of Fisheries and Livestock |
| Dr. Md. Ibrahim | Bangladesh Rice Research Institute (BRRI) |
| Dr. Md. Shahidul Islam | Bangladesh Rice Research Institute (BRRI) |
| Dr. A.S.M. Mahbubur Rahman Khan | Bangladesh Rice Research Institute (BRRI) |
| Dr. BR Bonik | Bangladesh Rice Research Institute (BRRI) |
| Abdul Gofran | BBDF |
| Muhainur Ilhan | Better Stories Ltd. |
| Ainun Nishat | BRAC University |
| Shahnawaz Mamtaz | Building Resources Across Communities (BRAC) |

| | |
|------------------------------------|--|
| Sirajul Islam | Building Resources Across Communities (BRAC) |
| Tania Sharmin | CARE |
| Md Harun-or-Rashid | CARE Bangladesh |
| Cyril Antonius Freiherr von Gagern | CEA Consulting |
| Michael Berger | CEA Consulting |
| Engr. Md. Wajiullah | CEGIS |
| Dr. Md Abdul Mazid | Center for Agri-research and Sustainable Environment & Entrepreneurship Development (CASEED) |
| Mia A. Rashid | Center for Agri-research and Sustainable Environment & Entrepreneurship Development (CASEED) |
| Moklesur Rahman | Center for Natural Resource Studies (CNRS) |
| Luis Molina Carpio | CIAT |
| Godefroy Grosjean | CIAT-Vietnam |
| Felicitas Röhrig | CIAT-Vietnam |
| Dr. Ghulam Hussain | CIMMYT |
| Dr. Khurshed Alam | Community Development Centre (CODEC) |
| Mohammad Abdul Qayyam | Comprehensive Disaster Management II (CDMP II)-UNDP supported |
| Muhaimin Khan | Better Stories |
| Dr. M Shahal Uddin | Department of Agricultural Extension (DAE) |
| Dr. Abu Wali Raghieb Hassan | Department of Agricultural Extension (DAE) |
| KBD Mohammed Mohsin | Department of Agricultural Extension (DAE) |
| Dr. Sultan Ahmed | Department of Environment |
| Dr. Hossan Mohammad Salim | DLS |
| Dr. Syed Ali Ahasan | DLS |
| Dr. Muklesur Rahman | DLS |
| Dipak Ranjan Roy | DLS |
| Dr. Md. Rabigul Islam | DLS |
| Ahmadul Hassan | Environment & Infrastructure Management Solution (EIMS) |
| Anatoli Poultouchidou | FAO |
| Rebekah Bell | FAO |
| David W Doolan | FAO |
| Imanun Nabi Khan | FAO |
| Gopal Chandra Mondal | Farmer organization |
| Md. Wahidul Amin | Harvest Plus |
| Dr. Md. Khairul Bashar | Harvest Plus |
| Kbd. Md. Afzal Hossain Bhuiyan | IDE Bangladesh |
| Benoit Thierry | IFAD |
| Yam Haihre | IFDC |
| Mainul Ahsan | IFDC Asia - Bangladesh |
| Craig Meisner | IFPRI |
| Dr. Md. Abdul Mazid | IFPRI |
| Hazrat Ali | Institute of Water Modeling (IWM) |
| Zahirul Haque Khan | Institute of Water Modeling (IWM) |
| Tarikul Islam | IRM division |
| Dr. Z Karim | MFSP |
| Hasib Ahsan | mPower-Social Enterprises Ltd. |
| Sheikh Nazrul Islam | Planning Commission, Water Resources & Rural Institution Division |
| Sadiq Ahmed | Policy Research Institute of Bangladesh |
| Taibur Rahman | Renewable Sustainable Energy Power Generation Project |
| Samir Kumar Sarkar | Rural Development Academy (RDA) |

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| Altaf Uz Zaman | SEAF Ventures Management LLC |
| Ashikur Rahman | Shere Bargla Agricultural University Dhaka |
| Dr. K.B.M. Saiful islam | Shere Bargla Agricultural University Dhaka |
| Ziaul Hasan | Space Research and Remote Sensing Organization (SPARRSO) |
| Nasrin Sultana | Space Research and Remote Sensing Organization. (SPARRSO) |
| Md Elias Hossain | Supreme Seeds |
| Abu Wali Raghieb Hassan | University of Dhaka, Department of Geography and Environment |
| Professor Khairul Islam | WaterAid |
| Jinia Soltana | World Bank |
| Abu Mostafa Kamal Uddin | Winrock International |
| Md. Emdad Hussein | Worldfish |

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