

A Development Trajectory
of Bangladesh Agriculture

From Food Deficit to Surplus



Bangladesh Agricultural Research Council

New Airport Road, Farmgate, Dhaka-1215, Bangladesh

www.barc.gov.bd

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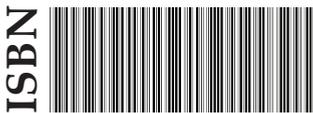
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DEDICATION

**Father of the Nation
Bangabandhu Sheikh Mujibur Rahman
and the martyrs of August 15, 1975**

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ



PRIME MINISTER
GOVERNMENT OF THE PEOPLE'S REPUBLIC OF
BANGLADESH

16 Magh 1429
30 January 2023

Message

It is indeed a great pleasure for me to learn that the Bangladesh Agricultural Research Council (BARC) is going to publish a book titled “*A Development Trajectory of Bangladesh Agriculture: From Food Deficit to Surplus.*” I congratulate BARC for this important publication.

Bangladesh, in her proud journey of fifty years since independence in 1971, has progressed steadily and firmly from the legacy of hunger and poverty of the pre-independence days to stand out today as the 35th largest economy in the world with new hopes for further development and prosperity in the days to come. One of the major achievements has been in the field of agriculture, which has made possible the transformation of the country from one of recurrent yearly food deficit to one of food security and surplus. In this regard, we may recall with great reverence, the historic address of the Father of the Nation, Bangabandhu Sheikh Mujibur Rahman on 20 February 1972, where he said, “We must work hard with our farmers to revolutionize agriculture, not even an inch of our land should remain untilled and unused”. This was Bangabandhu’s vision, which laid the foundation for future development of agriculture and food production in Bangladesh. Eventually, Bangladesh became self-sufficient in food for the first time in her history in 2000 during the 1996-2001 tenure of the Awami League Government.

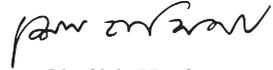
The present Awami League Government has been continuing with plans, strategies, and support for the last fourteen years for accelerated development of agriculture. In the last decade, there have been remarkable accomplishments in all sectors of agriculture like crops, fisheries, and livestock through concerted and dedicated efforts of agricultural researchers and extension experts, and toil and sweat of our hardworking farmers. Today, we can proudly say that we are self-sufficient in food grains, fruits, fish, meat, milk, eggs and are on the verge of self-sufficiency in vegetables. Indeed, Bangladesh is now a global example of fast growing development in agriculture and food production.

However, I firmly believe there is still scope for further development. Newer problems like diminishing land resources and escalating natural disasters caused by global climate change are emerging. Agricultural researchers and extension specialists will have to address the challenges of achieving higher agricultural productivity and profitability through the development of high-yielding resilient crop varieties,

livestock and fish breeds, climate smart production practices, sustainable farming systems, etc. Research and extension services will need to be oriented in line with Government policies, strategies and action plans envisioned in Vision 2041, 8th Five Year Plan, National Agriculture Policy 2018, National Agricultural Extension Policy 2020, National Agricultural Mechanization Policy 2020, Sustainable Development Goals 2030, Bangladesh Delta Plan 2100, etc. This will require new research and development programs. Furthermore, agricultural researchers, extension experts and farmers need to equip themselves with greater skills and expertise to keep pace with the Fourth Industrial Revolution using opportunities to grow and expand with new technologies and techniques.

I wish this book high acceptance of agricultural researchers and extension specialists, social workers and community leaders, government planners, and strategists as a useful resource and reference document.

Joi Bangla, Joi Bangabandhu
May Bangladesh live forever.



Sheikh Hasina



MINISTER
Ministry of Agriculture
Government of the People's Republic of
Bangladesh

Message

I am delighted to know that Bangladesh Agricultural Research Council (BARC) is going to publish a book titled “*A Development Trajectory of Bangladesh Agriculture: From Food Deficit to Surplus.*”

The greatest Bengali of all times, the father of the nation Bangabandhu Sheikh Mujibur Rahman dreamt of 'Sonar Bangla' by developing agriculture and farmers of the country. Therefore, he took many multidimensional and benevolent measures for the development of agriculture and the farmers just after independence. He also started the green revolution in the country. Due to various agri-friendly policies of the current Government, under the dynamic leadership of the Honorable Prime Minister Sheikh Hasina, Bangladesh is now a global example of a substantial food grain production. Government's strong political will and commitment, huge subsidies, right incentive for large scale demonstration of technologies and various institutional supports made an unprecedented success in agriculture and food security.

Although much progress has been seen in our country, the agricultural sector is encountered by many challenges, such as increasing population, declining crop land per person, land degradation and declining soil fertility, rapid urbanization, and climate change to ensure food and nutrition security. This book spells out what kind of future research and policy support is needed to address challenges, and future outlook and ways ahead which are magnificent.

I believe this book will be very helpful for researchers, planners, policy-makers, investors and other stakeholders. I do express my gratitude to BARC and the authors for their tremendous efforts to bring out this book.

I wish all the success of this book.

Joi Bangla, Joi Bangabandhu
Long live Bangladesh.

Dr. Muhammad Abdur Razzaque, MP



SECRETARY
Ministry of Agriculture
Government of the People's Republic of
Bangladesh

Message

I am very much happy to know that Bangladesh Agricultural Research Council (BARC) is going to publish a book titled “*A Development Trajectory of Bangladesh Agriculture: From Food Deficit to Surplus.*”

Bangladesh is now the 35th largest economy in the world. Bangladesh experienced significant food deficit as an independent nation in 1971. Soon after independence, Father of the Nation Bangabandhu Sheikh Mujibur Rahman realized the importance of agriculture and took drastic measures to take forward the Green Revolution concept for agricultural development.

Bangladesh became food surplus from food deficit during the 1996-2001 tenure of Awami League Government. Right now, Bangladesh is self-sufficient in grain food, fruits, fish, meat, milk, egg production and is on the verge of self-sufficiency in vegetable production. The country's agricultural development progress has set a global precedence following the path shown by the Father of the Nation.

Led by Honorable Prime Minister Sheikh Hasina, the present Government formulated Vision 2041, 8th Five Year plan, National Agriculture Policy 2018, National Agricultural Mechanization Policy 2020, Bangladesh Good Agricultural Practices Policy 2020, Sustainable Development Goals, Bangladesh Delta Plan 2100, Projections of Supply and Demand for Selected Food Crops in Bangladesh by 2030 and 2050. All these plans are made with a vision for attaining SDGs by 2030, particularly SDG 2 and have paved the way towards a developed and prosperous Bangladesh in 2041 and a safe delta in 2100.

Despite remarkable achievement in agricultural sectors, Bangladesh still faces formidable challenges in ensuring food and nutrition security for its growing population. In addition, shrinking arable land, land degradation and declining soil fertility, and climate change make our agriculture much more complex than even before.

In this book, the success stories of Bangladeshi agriculture are highlighted consistently in different chapters which explain how Bangladesh has become self-sufficient in cereals and has transformed from food deficit to food surplus, and what policies made this successful. Further, what kind of R & D is needed, which innovations can help to meet challenges, and what kind of investment in which areas are required to ensure food and nutrition security in future are also discussed in detail.

I believe that this book will be useful for policy makers, developments partners, academicians, research organizations and agri-business communities and other stakeholders. I also believe that it will serve as an informative book for the countries who are trying to develop their agriculture sectors.

Joi Bangla, Joi Bangabandhu
May Bangladesh live forever.



Wahida Akter



EXECUTIVE CHAIRMAN
Bangladesh Agricultural Research Council

Foreword

The Bangladesh Agricultural Research Council (BARC) is an apex organization of the National Agricultural Research System (NARS) working under the Ministry of Agriculture. BARC has been established with the vision of effective and efficient management of NARS institutes in the country spearheading agricultural research for productivity enhancement and diversification of Bangladesh Agriculture. As a result of the collective efforts of all, the Council is playing a unique role in the advancement of agriculture in Bangladesh through innovation and subsequent use of technologies in crops, livestock, and fisheries sub-sectors. Above all, the government's agri-friendly policies, enabling environment and continued support to R & D have contributed to today's incredible success in agriculture.

Bangladesh has made a remarkable progress in food production amidst many difficulties with a record of about 3.7 times higher rice production than that in 1971. Bangladesh now has got position among top 10 producers of rice, jute, jackfruit, mango, onion, tea, vegetables, potato, and farm fish in the global arena. Per capita fish, meat, and milk have increased considerably indicating diversity in the diet taking place. Nevertheless, under the situation natural resources (soil, water, and forests) are degrading, arable land is shrinking, climate change is negatively impacting, ensuring nutrition security for marginal and rural populations, increasing urbanization and significant changes in food habits for people's higher purchasing ability, the ever increasing population would require more food production with nutritious and safe food.

This prestigious BARC publication entitled "A Development Trajectory of Bangladesh Agriculture: From Food Deficit to Surplus" lucidly describes how Bangladesh turned from a food deficit country to a food surplus country in a short period of time. This book discusses and dissects the reasons behind the successes, especially in agriculture. This has been widely discussed how did the country become a food deficit to food surplus country amidst many formidable challenges? What kind of policy support was behind this success? What role did government institutions play in increasing agricultural productivity through market availability and farmers access to various inputs such as fertilizers, seeds, irrigation, etc? What type of subsidy system of the government made the agricultural production sustainable and profitable? How can the country achieve the SDGs, especially the SDG 2 (eradicate hunger) by 2030, and what kind of innovation and government policies are needed in future?

I sincerely believe that this book will serve as a valuable book for researchers, academicians, planners, policy makers, investors, and others stakeholders, as well as for other countries who want to transform their agriculture sector into a productive sector.

My heartfelt thanks are due to Dr. G M Panaullah, former Director, Bangladesh Rice Research Institute (BRRI) for his editorial assistance and guidance. Special thanks are extended to Prof. Dr. M Jahiruddin, former Dean, Faculty of Agriculture, Bangladesh Agricultural University (BAU) for his technical support and good encouragement. On behalf of BARC, I express my sincere thanks to Dr. Jiban Krishna Biswas, Executive Director, Krishi Gobeshona Foundation (KGF) for the financial support, without which this book would not have been possible to publish. Thanks are due to Mr. Mohammad Nazmul Islam, Graphics Designer, BARC for designing the cover and production of this publication. Finally, thanks go to all of my BARC colleagues for their nice help and cooperation in preparing this book.

Joi Bangla, Joi Bangabandhu
May Bangladesh live forever.



Dr. Shaikh Mohammad Bokhtiar

Preface

Bangladesh has fared commendably well in her momentous journey of 50 years since independence in 1971 moving away from the bane of poverty and despair to the boon of prosperity and high hopes today. The country has achieved unimaginable successes in recent years, under the visionary and dynamic leadership of the Honorable Prime Minister Sheikh Hasina, in raising incomes, poverty alleviation and improvement of other social indicators. A major success, widely recognized at home and abroad, has been in the remarkable development of the agriculture sector that transformed Bangladesh from a country of recurrent food shortages to one with self-sufficiency and even some surpluses in food. In the last decade, i.e., between 2012 and 2022, the per capita income of Bangladesh more than tripled rising from \$883 to \$2824 with an average GDP growth rate of 6.6%. Meanwhile, the country has graduated to the status of a “Lower Middle-Income Country” from that of a “Least Developed Country”, and, today, Bangladesh boasts being the 35th largest economy of the world, dubbed as the role model of development for nations striving for a better future.

In order to accelerate poverty alleviation and economic development, Bangladesh has diversified its economic endeavors giving due importance to the industries and services sectors, but agriculture has always remained a crucial undertaking as evidenced by an increased agricultural growth rate from an average of 2.68% during the 1970s to the 1990s to 3.77% during 2000-2010 and to 3.6% in the next decade. Food and agriculture are at the core of a country's civilization, development and prosperity. In Bangladesh, marginal and landless farmers are a significant part of the agricultural sector many of whom, unfortunately, live below the poverty line. Improving socioeconomic conditions of this section of the population and providing food and nutrition security for them have always been high on the nation building agenda of HPM Sheikh Hasina's Government. Of late, there have been some setbacks in this regard firstly due to the raging Covid-19 pandemic, secondly to the Russian-Ukrainian war and thirdly to the adverse effect of climate change, but Bangladesh and her people have always been known to be resilient fighters who at the end of the day have triumphed against seemingly unsurmountable odds, natural or man made!

This book discusses and analyses the reasons behind Bangladesh's resounding successes in agricultural development and food production, how the country became self-sufficient in food and accumulated surpluses in a short period of time facing many formidable challenges. The book details Government policy support and actions in subsidizing and facilitating timely and cost-effective supply of inputs like seeds, fertilizers, irrigation, machinery to the farming communities, in providing easy agricultural credit and improving market linkages for farmers' produce to make agriculture profitable, etc., that played a crucial role in markedly increasing agricultural productivity in the country. The book also describes how the NARS institutions, universities, the agricultural extension agency of the Government, NGOs, private enterprises acted in unison under the Government policy directives towards achievement of food security in as short a period as possible. The international development partners of Bangladesh like the World Bank, FAO, USAID, CGIAR research centers, etc., also played a very important role in this respect.

This book sketches out the critical lessons learned along the way of agricultural development in Bangladesh. Important among them are: Firstly, the Government's desire and strong political commitment to steer the country out of the malaise of food deficits and hunger to the realm of self-sufficiency and surpluses in food. In the last tenure of the present ruling party, the Awami League, had formulated the National Agriculture Policy 1996 which was instrumental in making the country almost self-sufficient in food. In the current tenure of the Government, a new policy was formulated known as the National Agriculture Policy 2013 which facilitated the achievement of self-sufficiency in food for the first time. To address current and future challenges of agriculture and overall national development, the Governments adopted a series of policies such as the National Agriculture Policy 2018, National Extension Policy 2020, National Mechanization Policy 2020, Bangladesh Good Agricultural Practices Policy 2020, Vision 2041, 8th Five Year Plan (July 2020 to June 2025) and Bangladesh Delta Plan 2100.

These policies emphasize, among other things, planned and accelerated development of the agricultural sector to realize the dream of a prosperous Bangladesh free from hunger and poverty. With Government policy support, Bangladesh is poised to enter an era of development of new crop varieties and livestock and fish breeds with the abilities to break through productivity barriers and modern, highly efficient and groundbreaking production technologies to not only sustain the gains made hitherto but also reach new heights of productivity. And, Secondly, the overwhelming importance of technological innovations and their quick and effective dissemination to the end users. Thirdly, Bangladesh has a strong institutional capacity to provide necessary services to the farmers such as, large scale adoption of technologies through efficient extension drives, farm mechanization, supply chain improvement and expansion of market linkages, export support, etc.

In fact, concerted efforts of forward-looking innovations, policy support and institutional capacity are imperative for the overall development of agriculture and allied sectors. The land, water, energy, and natural resources of the country will be greatly stressed by increasing demands for food, fiber and fodder. It is the right combination of Government policies, plans and strategies and dedicated efforts of academicians, researchers, extension specialists, other stake holders such as, food chain operators, processors, distributors and consumers, and above all, farmers that ensures sustainable agricultural production in the face of population growth, shrinking arable land, land degradation and declining soil fertility, shifting demand patterns and climate change.

In the context of the above, this book attempts to suggest the way forward to face the current and emerging challenges to agricultural R&D, productivity and production, and to achieve the SDGs, especially the SDG 2 by 2030.

We strongly believe that the issues presented and discussed in different chapters of this book, the opinions and suggestions given will generate interest among researchers, policy makers, development partners and all others who care to see Bangladesh move further ahead in achieving sustainable food and nutrition security and providing a better environment and a better life for her teeming millions, making sure that "no one nowhere is left behind".

Dr. S M Bokhtiar
Dr. Syed Samsuzzaman

ABBREVIATION

ACIAR	: Australian Centre for International Agricultural Research
ADP	: Annual Development Plan
AFACI	: Asian Food and Agriculture Cooperation Initiative
AIS	: Agriculture Information Service
ASTI	: Agricultural Science and Technology Indicators
AWD	: Alternate Wetting and Drying
AVRDC	: Asian Vegetable Research and Development Centre
BADC	: Bangladesh Agriculture Development Corporation
BAI	: Bangladesh Agriculture Institute
BAPA	: Bangladesh Agro-Processing Association
BAPTC	: Bangladesh Association for Plant Tissue Culture
BARC	: Bangladesh Agricultural Research Council
BARI	: Bangladesh Agricultural Research Institute
BAU	: Bangladesh Agricultural University
BBS	: Bangladesh Bureau of Statistics
BCIC	: Bangladesh Chemical Industries Corporation
BDP	: Bangladesh Delta Plan
BDT	: Bangladesh Taka
BFDC	: Bangladesh Fisheries Development Corporation
BFRI	: Bangladesh Fisheries Research Institute
BHWDB	: Bangladesh Haor and Wetland Development Board
BINA	: Bangladesh Institute of Nuclear Agriculture
BIRDEM	: Bangladesh Institute of Research and Rehabilitation in Diabetes, Endocrine and
BJRI	: Bangladesh Jute Research Institute
BLRI	: Bangladesh Livestock Research Institute
BMDA	: Barind Multipurpose Development Authority
BPC	: Bangladesh Planning Commission
BRAC	: Bangladesh Rural Advancement Committee
BRRI	: Bangladesh Rice Research Institute
BSMRAU	: Bangabandhu Sheikh Mujibur Rahman Agricultural University
BSRI	: Bangladesh Sugarcane Research Institute
BSS	: Bangladesh Sangbad Sangstha
BTRI	: Bangladesh Tea Research Institute
BWDB	: Bangladesh Water Development Board
BWMRI	: Bangladesh Wheat and Maize Research Institute
CA	: Conservation Agriculture
CARE	: Cooperative for Assistance and Relief Everywhere
CBFM	: Community Based Fisheries Management
CCTV	: Closed-Circuit Television
CDM	: Clean Development Mechanism
CDP	: Crop Diversification Program
CGIAR	: Consultative Group for International Agricultural Research
CHT	: Chattogram Hill Tracts
CIDA	: Canadian International Development Agency
CLP	: Char Livelihood Program
CNRS	: Center for Natural Resource Studies

COVID-19	: Coronavirus disease-2019
CRISPR	: Clustered Regularly Interspaced Short Palindromic Repeats
CSRP	: Cropping Systems Research Project
CVASU	: Chattogram Veterinary and Animal Sciences University
DAE	: Department of Agricultural Extension
DANIDA	: Danish International Development Agency
DAP	: Di-ammonium Phosphate
DFID	: Department of Foreign and International Development
DLS	: Department of Livestock Services
DoF	: Department of Fisheries
DTW	: Deep Tube Well
EEZ	: Exclusive Economic Zone
ELISA	: Enzyme-Linked Immunosorbent Assay
ESCAP	: Nations Economic and Social Commission for Asia and the Pacific
EU	: European Union
FAO	: Food and Agriculture Organization
FD	: Forest Department
FRSS	: Fisheries Resource Survey Systems
FSRD	: Farming Systems Research and Development
FSRP	: Farming Systems Research Program
g	: Gram
GBM	: Ganges-Brahmaputra-Meghna
GDP	: Gross Domestic Product
GHGs	: Green House Gases
GIFT Tilapia	: Genetically Improved Farmed Tilapia
GIS	: Geographic Information System
GOB	: Government of Bangladesh
GPS	: Global Positioning System
GSM	: Global System for Mobile communication
ha	: hectare
HRC	: Horticulture Research Centre
HRD	: Human Resources Development
HSTU	: Hajee Danesh Science and Technology University
HYV	: High Yielding Variety
ICAR	: Indian Council for Agricultural Research
ICLARM	: International Centre for Living Aquatic Resources Management
ICT	: Information and Communication Technology
IDA	: International Development Association
IDRC	: International Development Research Centre
IFAD	: International Fund for Agricultural Development
IPCC	: Intergovernmental Panel on Climate Change
IPM	: Integrated Pest Management
IPNS	: Integrated Plant Nutrition System
IPSA	: Institute of Post-graduate Studies in Agriculture
IRRI	: International Rice Research Institute
JICA	: Japan International Cooperation Agency
Kg	: Kilogram
KGF	: Krishi Gobeshona Foundation
LDN	: Land Degradation Neutrality
LIDF	: Livestock Insurance Development Fund

LPAP	: Livestock Policy and Action Plan
LV	: Local Variety
MDG	: Millennium Development Goals
Mha	: Million hectare
M Kg	: Million Kilogram
MoA	: Ministry of Agriculture
MoF	: Ministry of Finance
Mol	: Ministry of Industries
MoP	: Muriate of Potash
MSL	: Mean Sea Level
MT	: Metric Ton
NATP	: National Agricultural Technology Program
NCD	: Non Communicable Disease
NFNSP	: National Food and Nutrition Security Policy
NGO	: Non-government Organization
NNW	: North Northwest
ODA	: Official Development Assistance
OMS	: Open Market Sale
OP	: Open Pollinated
SAAO	: Sub Assistant Agriculture Officer
SAU	: Sylhet Agricultural University
SDG	: Sustainable Development Goals
SMEs	: Small and Medium Enterprises
SMS	: Short Message Service
SPF	: Specific Pathogen Free
SRC	: Spices Research Centre
SRDI	: Soil Resources Development Institute
SSE	: South Southeast
STW	: Shallow Tube Well
PP2041	: Perspective Plan 2041
PPR	: Pests des Petits Ruminants
PRSP	: Poverty Reduction Strategy Paper
PSTU	: Patuakhali Science and Technology University
R&D	: Research and Development
RDRS	: Rangpur Dinajpur Rural Service
TMR	: Total Mixed Ration
TSP	: Triple Superphosphate
T and V	: Training and Visit
UK	: United Kingdom
UNCCD	: United Nations Convention to Combat Desertification
UNEP	: United Nations Environment Program
UNFCCC	: United Nations Framework Convention on Climate Change
USA	: United States of America
USAID	: United States Agency for International Development
USD	: United States Dollar
VCF	: Village Community Forest
WB	: World Bank
WHO	: World Health Organization
WRC	: Wheat Research Centre
WTO	: World Trade Organization

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Chapter 1

Introduction

Resplendent with the greenery of extensive crop fields and vibrant fisheries, livestock and poultry farms, Bangladesh stands tall today in her proud journey of 50 years from grim deficits to a healthy provision of food and from the misery of hunger to the reprieve of food security. The country inherited a forbidding legacy of huge, recurrent yearly food deficits from the pre-independence times. Shortly after liberation in 1971, the Father of the Nation, Bangabandhu Sheikh Mujibur Rahman, in his historic address to the nation on 10 January 1972, declared, “All my life I have dreamed of freeing my people from the curse of hunger and poverty.....We must work hard to revolutionize agriculture, not even an inch of our land should remain untilled and unused....”. In recent times, the Honorable Prime Minister Sheikh Hasina, too, has repeatedly emphasized the need for continued efforts to boost agricultural production and achieve sustainable food and nutrition security for the people. Thus it is clearly visible that Bangabandhu’s commandments early on in our history and more recently, Honorable Prime Minister Sheikh Hasina’s fervent pleas have not gone in vain.

In the last decade, the agriculture sector in Bangladesh has grown substantially in spite of dwindling arable land area and intensifying natural adversities like climate change. Despite being small in size and burdened with an increasing population pressure over the past 50 years since its independence Bangladesh has managed to overcome all odds to clinch the envious position of being among the world’s top 10 in 13 sectors (Prothom Alo 2021) out of which 10 are directly related to agriculture. The contemporary story of agriculture in Bangladesh is a story of fast growth and spectacular accomplishments in all sub-sectors like crops, fisheries and livestock. The country now produces enough grains, vegetables, fruits, fish and livestock for domestic consumption and even has some surpluses for exports. At the world level, Bangladesh at present ranks third in the production of rice (staple food crop) and inland fish (source of protein) and is one of the top ten producers of potato, vegetables and fruits. The success stories of agriculture in Bangladesh, especially in achieving the long cherished goal of achieving food and nutrition security, owe greatly to the collective initiatives and efforts of agricultural researchers, extension workers and farmers. This success would not have been possible without congenial government strategies and policies for agricultural research and development in the light of the National Agricultural Policy 2018, Vision 2021, Vision 2041, 8th Five Year Plan, Sustainable Development Goals, Bangladesh Delta Plan 2100, etc.

Food deficit occurs when food supply within a bounded region does not provide the energy and nutrients needed by that region's population. Food

deficit is most easily conceptualized as a production problem, but constraints on importation as well as storage can also cause or contribute to food deficit. Food surplus occurs when the supply, availability and nutritional requirements of food exceeds the demand for it, and can take place at every stage of the supply chain from farms to households. With the global population set to soar up to nearly 10 billion by 2050, along with changing diets, the demand for food is expected to skyrocket, with some estimates projected to increase by 60%–110% between 2005 and 2050. To meet this rapidly increasing demand, the world's farming industries have adopted intensive farming methods that are capable of producing large quantities of food. Since 1961, food supply per capita has grown more than 30%, according to the 2020 IPCC Special Report on climate change.

Research and technology generation, dissemination and implementation by agricultural scientists, extension specialists and farmers coupled with Government policies targeted at achieving food and nutritional security have played key roles in Bangladesh's fifty-year battle against hunger. This book provides an interesting and exciting account of the country's triumphant march towards the achievement of food and nutrition security for her teeming millions. Especially, the authors have attempted to provide answers to such relevant questions as (a) is Bangladesh departing from food deficit and moving to food surplus, (b) what factors have helped transform the situation from deficit to sufficiency in food and how is this happening, (c) what is the trend of agricultural production towards the achievement of food surplus, (d) can Bangladesh move towards sustainable food surplus, and (e) what strategic investments are required to make Bangladesh a sustainable food surplus country addressing the emerging challenges in the 21st century?

1.1 Geographic and environmental features influencing agricultural production

Some of the geographical and environmental factors that influence agricultural production are (a) topography, (b) climate, and (c) agricultural land. Geographical factors play a vital role in agricultural development, in spite of the technological and scientific development. Bangladesh, covering an area of 147,570 sq km is situated in South Asia between India and Myanmar. It occupies the apex of the arch formed by the Bay of Bengal, which drains a large number of rivers and their tributaries crisscrossing the country and making it a very fertile delta. The country extends from 20'34N to 26'38N latitude and from 88'01E to 92'41E longitude with maximum extensions of about 440 km in the E-W direction and 760 km in the NNW-SSE direction. Bangladesh is bordered by the Indian States of West Bengal, Assam, Meghalaya and Tripura to the west, north and east respectively (Banglapedia 2021a), and is also bordered by Myanmar in the southeast (Fig. 1.1). The total length of the land border is about 4,246 km, of which 93.9% is shared with

India and about 6.1% with Myanmar. The length of the coastline of Bangladesh is more than 580 km and the territorial waters extend to 12 nautical miles (22.22 km). The exclusive economic zone (EEZ) of Bangladesh comprises an area of the Bay of Bengal beyond and adjacent to the territorial sea extending to a line every point of which is at a distance of 200 nautical miles from the nearest points of the territorial sea baselines/normal baseline of the nearest coastline (Banglapedia 2021a).

Agriculture has a strategic function in Bangladesh, because it is the main food supplier for the people, and it is by and large the agricultural sector that determines whether the country will have food deficit or surplus.



Fig. 1.1. Map of Bangladesh (Source: BARC)

The geographic location of Bangladesh provides a strategic advantage. Bangladesh has a balanced sharing of land and sea so the country can take advantage of land connectivity with India, Nepal, Bhutan and Myanmar. On the other hand, open waters of the Bay of Bengal to the south open the door for navigation across the world and the EEZ permits exploitation of blue economy which remains vastly untapped. Thus, Bangladesh can build its future as a hub of regional connectivity, attracting lucrative investments in infrastructure and communications. Only a few nations on earth enjoy such connectivity with thriving nations of Asia that include two emerging giants of the world: China and India. The demographic dividend of Bangladesh will be short-lived, but this geographic advantage will always be there making a difference for Bangladesh.

(a) Topography

The topographic configuration of a land surface includes its relief and contours, distribution of mountains and valleys, patterns of rivers and all other features, natural and artificial, that forms the landscape. Topography affects agriculture as it relates to soil erosion, ease or difficulty of tillage and transportation facilities. It also influences agricultural mechanization, machinery use being very difficult on undulating or hilly lands. In areas where the pressure on soil for crop production is great, even the slopes of mountains are terraced into small farms to provide agricultural land. Although Bangladesh is a small country, it has considerable topographic diversity. It has three distinctive features: (i) a broad alluvial plain subject to frequent flooding, (ii) a slightly elevated relatively older plain, and (iii) a small hill region drained by flashy rivers. On the south, a highly irregular deltaic coastline of about 600 km is fissured by many estuarine rivers and channels flowing into the Bay of Bengal (Banglapedia 2021a). The alluvial plain is part of the larger plain of Bengal, which is sometimes called the Lower Gangetic Plain. Elevations of the plains are less than 10m above the sea level declining to the near sea level in the southern coastal zone.

Most of the areas of Bangladesh lie within the broad delta formed by the Ganges and Brahmaputra rivers and are exceedingly flat, low-lying and subject to annual flooding. Much fertile, alluvial soil is deposited by the flood waters. The only significant area of hilly terrain, constituting less than one-tenth of the nation's territory, is the districts of Chattogram Hill Tracts in the narrow southeastern panhandle of the country. Small, scattered hills lie along or near the eastern and northern borders with India. There are eroded remnants of two old alluvial terraces, the Madhupur Tract in the north-central part of the country and the Barind Tract straddling the northwestern boundary with India. The soil here is much less fertile than the annually replenished alluvium of the surrounding floodplain. The hilly areas of the southeastern region of Chattogram, the northeastern hills of Sylhet and highlands in the

north and northwest exist at higher elevations. The Chattogram hills rise steeply to narrow ridgelines (average 36m wide), with elevation ranging between 600 and 900m above the mean sea level (MSL). Between the hilly ridges lie valleys that generally run north to south. To the west of the Chattogram hills is a narrow, wet coastal plain lying parallel to the shoreline (Banglapedia 2021a).

In the context of agricultural production, there are some fragile ecosystems in Bangladesh where normal agricultural practices do not bring about expected crop yields primarily due to uncongenial water regimes resulting from topographic features or unfavorable climate or soil and water salinity. Fragile ecosystems in Bangladesh include low-lying wetlands (*haors*), chars, drought-prone areas (Barind Tract), hill tracts, coastal areas, etc., which occupy quite a large part of the country. Notably, among the fragile ecosystems of the country, the flood-prone ecosystems (*haor*, *char* and coastal) accounts for roughly one-third of the land area and the coastal saline ecosystem alone covers about one-fifth of the land area. The adverse agro-ecological conditions and exposure to the vagaries of nature limit the productivity of crops, livestock and fisheries in most of these fragile ecosystems. It is evident that all these fragile ecosystems viz, *haor*, *char*, Barind, coastal and hill together occupy nearly 7,691,199 ha which is about 53.1% of the total area of Bangladesh, i.e., 14,486,269 ha (Table 1.1). Then, almost half of the total areas of Bangladesh, 6,795,070 ha (46.9%) have favorable agro-ecological conditions.

Table 1.1. Fragile ecosystems and their proportion to the total areas of Bangladesh

Ecosystem	Area (ha)	% of Bangladesh area
Fragile ecosystems	7,691,199	53.1
<i>Haor</i> ecosystem	873,524	6.0
<i>Char</i> ecosystem	916894	6.3
Barind ecosystem	755,155	5.2
Coastal ecosystem	3,309,021	22.9
Hill ecosystem	1,836,605	12.7
Favourable ecosystems	6,795,070	46.9
Bangladesh area	14,486,269	100

Source: BARC 2022, BBS 2021

Haor ecosystem: A *haor* is a vast low-lying land depression forming a deep basin which remains filled with water to various fluctuating depths during different seasons of the year. The *haors* are seasonally inundated and the region is interspersed with upland areas of 1-10 ha. The *haor* basin spread over Sunamganj, Habiganj and Moulvibazar districts and Sylhet Sadar upazila, as well as Kishoreganj and Netrokona districts outside the core *haor*

area (Banglapedia 2021b). The Sylhet Basin mainly comprises high river levees surrounding extensive basins (*haors*), the centers of which remain wet in the dry season. The lowest parts of the basin are less than five meters from MSL even though the basin is located some 300 km from the coast. The haors of these districts occupy nearly 873,524 ha which is about 6% of the total area of Bangladesh, i.e., 14,486,269 ha (Table 1.1).

Char ecosystem: Bangladesh, the largest river delta of the world, is crisscrossed by some mighty rivers, the Brahmaputra-Jamuna, the Ganges-Padma, the Meghna and the Tista.. Chars are essentially riverine islands formed through the accretion of alluvium carried by the rivers. They are often unstable, at least for the first few years, and as such often disappear as quickly as they appear. The meandering rivers may gradually or suddenly shift course drowning riverine islands, creating and re-creating chars in the process of erosion and accretion. The Brahmaputra river spreads into several districts of Rangpur and Dhaka divisions. The greatest spread of chars exists in the Jamalpur district, followed by the second largest chars in Kurigram district. On the other hand, Tista river crisscrosses several districts of Rangpur division and falls into the Brahmaputra river. The Brahmaputra river merges with the Jamuna river near Jamalpur-Gaibandha districts and then flows through several districts of Rajshahi and Dhaka divisions. The Jamuna river has contributed to the development of a significant number of chars in Sirajganj district of Rajshahi division, and Tangail and Manikganj districts of Dhaka division. The Jamuna, after crossing Tangail district, merges with the Padma river at the Manikganj-Rajbari-Pabna point. The Padma river has created a number of chars in Chapainawabganj, Rajshahi, Pabna and Rajbari districts. The river Meghna at its final approach to the Bay of Bengal traverses several districts such as Shariatpur and Chandpur developing many chars. The Bay of Bengal adjacent to several districts of Barishal and Chattogram divisions has also created significant char areas. The char areas of Barishal, Chattogram, Dhaka, Khulna, Mymensingh, Rajshahi and Rangpur divisions occupy nearly 9,16,894 ha which is about 6.3% of the total area of Bangladesh ie, 1,44,86,269 ha (Table 1.1).

Barind ecosystem: The Barind Tract is the largest Pleistocene physiographic unit of the Bengal Basin. Geographically, this tract occupies areas in Rajshahi, Chapainawabganj, Naogaon, Natore, Bogura, Joypurhat and Sirajganj districts of the Rajshahi division and Dinajpur, Rangpur, Gaibandha, Nilphamari and Thakurgaon districts of the Rangpur division. The Barind Tract is a relatively elevated, about 11-48 m above mean sea level (amsl) triangular wedge of landmass (Rashid et al. 2018). The eastern part of the Barind Tract has level topography with regional slopes towards southwest. The western part has undulating to rolling topography with regional slopes towards southeast and southwest, respectively. It covers 755,155 ha in 56 upazilas of 12 northwestern districts of Bangladesh occupying 5.2% of the total area of Bangladesh ie, 14,486,269 ha (Table 1.1).

Coastal ecosystem: The Ganges- Brahmaputra-Meghna (GBM) river system and the Bay of Bengal dominate the coastal zone of Bangladesh geomorphologically and hydrologically. The coastal zone of Bangladesh consists of three parts, (a) The eastern zone, (b) The central zone and (c) western zone (Ahmad 2019) depending on geographic features. The western region known as Ganges tidal plain, comprises the semi-active delta and is crisscrossed by numerous channels and creeks. The central region is the most active and continuous processes of accretion and erosion. Meghna river estuary lies here in this zone. The eastern region is covered by hilly area that is more stable. The coastal zone of Bangladesh has a low relief, 1.2-4.5 m above MSL (Banglapedia 2021c). The western coastal zone contains the Sundarbans; the average land elevation is 1.5 m above MSL (mean sea level) and suffers from severe tidal flooding and salinity intrusion (Karim and Mimura cited by Najnin 2014). The eastern zone contains the world's longest sea beach, the 120 km long Cox's Bazar sea beach. The coastal zone of Bangladesh consists of 19 coastal districts namely, Jashore, Narail, Gopalganj, Shariatpur, Chandpur, Satkhira, Khulna, Bagerhat, Pirojpur, Jhalakati, Barguna, Barishal, Patuakhali, Bhola, Lakshmipur, Noakhali, Feni, Chattogram and Cox's Bazar. The coastal zone occupies nearly 3,309,021 ha which is about 70.9% of the total area of 19 coastal districts (4,665,460 ha) and 22.9% of the total area of Bangladesh, i.e., 14,486,269 ha (Table 1.1).

Hill ecosystem: The hilly regions of the north-eastern and south-eastern parts of Bangladesh are situated in greater Sylhet, Chattogram and the Chattogram Hill Tracts (CHT). In Moulvibazar, Habiganj and north-eastern part of Sylhet, there are hills or hillocks covered with grasses and trees. Usually, these are situated at 30-60 meter (100-200 ft) above sea level. In the northern region of Chattogram there are some small hills situated along the seashore and are extended north to south. In the south, there are some small hilly ranges between Cox's Bazar and Teknaf. In general, slopes are very steep, and few low hills have flat summits. The Hill Tract area is mild to very steep ranging from 15% to over 70% slope, often breaking or ending in cliffs (SRDI 2018). High hills ranged from 200-1000 m and lower hills from 15-200 m above the mean sea level (Hossain et al. 2017). Of the two kinds of topography, (a) Low Hill Ranges (Dupi Tila and Dihing Formations) and (b) High Hill Ranges (Surma and Tipam Formations), Chattogram Hill Tracts comprise mainly the high hills. It is an almost parallel ridge running approximately north-south with summits reaching 300-1,000 m above the mean sea level and on steep slopes (generally >40%), and are often subject to landslide erosion. Hill Tracts occupy 1,836,605 ha which is 12.7% of the total area of Bangladesh ie, 14,486,269 ha (Table 1.1).

(b) Climate

Bangladesh has a tropical monsoon-type climate, with a hot and rainy summer and a dry winter. The country experiences a hot summer of high

humidity from late March to late June, a somewhat cooler but still a hot and humid monsoon from late June through October and a cool dry winter from November to the end of February. However, January is the coolest month with low temperatures and April the warmest with high temperatures. Most rains occur during the monsoon (June-September) and little in winter (November-February). The groundwater provides adequate storage to compensate for annual variations in rainfall and stream flow. However, a dominant feature of life is the annual cycle of overabundance of water in the monsoon and its scarcity in winter. But the phenomenon changes dramatically during the winter months of November to May when the flows in the three major rivers, the Ganges, the Brahmaputra and the Meghna, decrease considerably and most of the streams and channels almost dry up leading to shortage of fresh water for use in agriculture, fishery, navigation and industries as well as for domestic use. Normal floods are regarded as highly beneficial for revitalizing the cropland. As it is situated in the tropic, the country is prone to cyclones associated with tidal surges, especially in the pre-monsoon and post-monsoon months. Because of high density of population in the flat deltaic coastal region, the loss of human lives in such cyclones has at time been very heavy. Devastating cyclones originate in the Bay of Bengal, during April to May and September to November. Often accompanied by surging waves, these storms can cause great damage and loss of life. Bangladesh experiences climate change and its consequences are flood, drought and salinity.

(c) Agricultural land

The fast spread of rural settlement including human housing and urban industrial factories is annually consuming about 0.24 percent of the country's agricultural land (Table 1. 2). Brammer (2016) concluded that a rapid population increase in Bangladesh is a greater immediate problem for development planning than the current rate of climate change in that country and that plans for feeding and employing the growing population deserve priority attention by the Government of Bangladesh. The shifting rate of agricultural land to non-agricultural use is said to be about 1% per year (Planning Commission, 2009), which is alarming in respect of the total crop production and food security in Bangladesh. If this data were correct, at least one quarter of the country's agricultural land would have been lost since independence. In this connection, the Soil Resources Development Institute (SRDI) estimated approximately 0.13% land transfer from agriculture to non-agriculture sector per year during the period 1963 to 1983 (Rahman and Hasan, 2003). Despite shrinking of agricultural land, Bangladesh has been moving from food deficit towards surplus due to advancement of technologies and policy support of the Government. However, the country needs to increase agricultural production further in pace with population growth as well as to generate employment opportunities outside agriculture.

Table 1.2. Changes in the areas of agricultural land during 1976–2021

Land use	1976*		2021**		Average annual rate of change during 1976–2021 (%)
	Area (ha)	%	Area (ha)	%	
Agricultural land	9,88,1300	67.6	8,833,198	61.0	-0.24
Forest	2,20,7400	15.1	2,576,113	17.8	0.37
Rural settlement	885,600	6.1	1,122,670	7.7	0.59
Urban + industrial	26,700	0.2	81,945	0.6	4.60
Other uses	1,606,000	11.0	1,872,343	12.9	0.37
Total	14,607,000	100	14,486,269	100	-0.02

Source: * Adapted from Hasan et al. (2013), ** BBS 2021

Note: 1. Agricultural land includes tea estates, 2. Forest includes mangroves and 3. Other uses include rivers and water bodies, salt pans, etc.

1.2 Agricultural production systems

The sub-sectors of Bangladesh agriculture, viz., Cultivation of crop, raising livestock and catching fish etc. are the main sources of livelihood of the vast majority population of the country. The crop sector is dominant among the three agricultural sub-sectors (crops, livestock, fisheries) in terms of land use and diversity. Crops are grown in three seasons – Kharif I (pre-monsoon), Kharif II (monsoon) and Rabi (winter). The main livestock assets of the farmers are cattle, which are used for meat and milk. The other domesticated animals influencing food production are buffaloes, goats, sheep, poultry and duck. Meat, milk, egg, curd and butter are important non-vegetable food items that come from animal. Cow dung is used both as fuel and manure, while the flesh and bones of the cows are used for manuring only. Fish constitutes an important item of the people’s diet. Local breeds and management technologies are generally used. However, intensive research has generated a large number of improved breeds and management technologies after the independence of Bangladesh.

The major food crops are rice, wheat, maize, sugarcane, pulses, oilseeds, potato, different kinds of vegetable and fruits, spices and condiments. Rice is the staple food crop.

Degradation of land and water resources and an excess use of toxic chemicals are threatening agriculture in Bangladesh. This has prompted the Government of Bangladesh to encourage adoption of sustainable agricultural methods to ensure environmental stability and economic profitability. Crop diversification, integrated farming systems, changes in cropping patterns and rotations, adoption of new crop varieties, modifying sowing dates, polyculture and crop rotations, and other modern cropping practices are all

being employed in this country to achieve self-sufficiency in food and ensure environmental sustainability. The Father of the Nation, Bangabandhu Sheikh Mujibur Rahman called for integrated farming systems to increase food production.

Bangabandhu Sheikh Mujibur Rahman said “We can't ensure our expected agricultural production. We must underscore integrated farming system to increase our food production. We must take measures to educate farmers about latest cultivation methods and authority concerned must share their experiences with the farmers. Then, we can achieve our intended success”

After the independence of Bangladesh in 1971, the Government took programs for accelerating agricultural production, especially food grain production through the adoption of modern seed-water-fertilizer technologies. The task of the procurement and distribution of irrigation pumps, fertilizers and improved varieties of seeds was entrusted to the Bangladesh Agricultural Development Corporation (BADC). As a result, application of chemical fertilizers, irrigation coverage and use of seeds of high-yielding varieties (HYV) of crops increased substantially. Simultaneously, the Bangladesh Agricultural Development Bank (BADB) also expanded the volume of short-, medium- and long-term institutional credits provided to the farmers. During the last five decades, farmers further increased the use of chemical fertilizers and good quality seeds of HYV crops, and irrigation facilities and acreage, too, expanded markedly. Expansion of irrigation systems and farm machinery in agriculture created huge employment opportunities for the rural youth and service providers.

BADC as a government organization and some private companies are involved in supplying inputs like seeds, fertilizers, irrigation, pesticides and agricultural machineries to the farmers. BADC arranges for production and distribution of certified seeds and procures chemical fertilizers and plant protection materials. Over the period 1972 to 2020, BADC sold, through dealers, 2.29 million MT (MMT) improved seeds and 339.4 million seedlings/saplings to the farmers. In addition, 10.63 MMT urea, 8.74 MMT TSP, 2.24 MMT DAP, and 5.18 MMT MoP fertilizers were sold to farmers through dealers (BADC 2021). The massive disbursement of quality seeds and fertilizers eventually contributed to desirable crop yield increases leading to enhanced food production. For example, the rice grain sharply increased from around 12 MMT in the late 1970s to 37.6 MMT in 2021 (BBS 2021), and today, Bangladesh is the third largest producer of rice in the world. Likewise, wheat showed good promise and contributed nearly 2 MMT to the annual food grain output in Bangladesh around the turn of the century, however, the wheat output declined to 1.1 MMT in 2021 (BBS 2021). Fish production annually has been growing at around 5% per annum over the last two decades (Asadduzzaman 2021).

After independence, policies regarding marketing of agricultural inputs have been changed drastically. Government controls were decimated and an open market economy ushered in encouraging private initiatives in the procurement and distribution of agricultural inputs and food grains. The government has been favoring export oriented industries to compete in the international market. Import policies for various inputs and equipment relating to poultry and dairy industries are meant to support local entrepreneurs. Policy changes also allowed and encouraged private sector participation in minor irrigation. Withdrawal of restrictions on imports, and innovations in open tendering for government procurement of wheat and rice helped private traders grow and flourish. Other major steps adopted to boost agricultural production have been disbursement of micro-credit, rescheduling of debt servicing by affected farmers, remission of land taxes for holdings up to 25 bighas (1 bigha=33 decimal), crop diversification programs and special programs for disaster-stricken farmers. These landmark policy changes and innovations played a crucial role in boosting staple food grain production in the country to about 37.6 MMT by 2021 (BBS 2021), matching the annual consumption requirement of a population of 166 million (World Bank 2022).

Bangladesh inherited many research institutes/stations/centers established in the pre-independence years. These institutions have been renamed, reorganized and modernized, further expanded and transformed into autonomous organizations with markedly enhanced R&D budgets of their own. Many new institutes like BARC (1973), BARI (1976), SRDI (1983), BFRI-Fish (1984) and BLRI (1984) were established. Currently, there are 13 research institutes dealing with crops, livestock, fisheries and forestry, coordinated by BARC under the National Agricultural Research Systems (NARS). Bangladeshi agricultural scientists introduced the first HYVs of rice and wheat in Bangladesh as early as 1972 and 1973, respectively creating a place of reputation for Bangladesh in the world arena of research and development. Systems research on cropping patterns and component technologies involving rice and sugarcane started in 1974 and continued through the Coordinated Cropping Systems Research Project (CSRP) from 1979. In 1985, the commodity research program was upgraded to the Farming Systems Research Program (FSRP) through integration of crop, livestock, fisheries, agro-forestry etc. On the other hand, a unified top-down extension approach viz., training and visit (T and V) was introduced in 1977. Through the T and V system, regular messages were given to the concerned groups of farmers for adoption of 'green revolution' technologies. It was, however, discontinued after at the end of the 1990s to be gradually replaced by the participatory approach. New and upcoming technologies were disseminated by different government organizations like DAE, DoF, DLS and private sectors. These initiatives and policies, new paradigms in the fields of technology development through research and dissemination through massive extension

drives have worked well. Their impacts can be easily seen today in a thriving agriculture and food scenario in Bangladesh.

1.3 Departing from food deficit – the development trajectory

A pertinent question looms large: Is Bangladesh departing from food deficit? Farming in Bangladesh is gradually transforming from subsistence to commercial production with an emphasis on agricultural diversification and intensification, a major focus being enhancement of incomes and improvement of livelihood for rural farming communities. Innovation has been a major factor for driving desired changes in the production systems as well as policies for sustainability in agriculture. The growth in the production system as formulated in the national policies continues to be the guiding principles of development. The visible impact of growth in agriculture has been reflected by all social, economic and livelihood indicators that resulted in a significant reduction of poverty. Adoption of new technologies by farmers in their crop fields and other farm enterprises as a result of effective extension work contributed significantly to improvement of these socioeconomic indicators, especially among the rural population. A brief account of production of various food items by Bangladesh in the world context follows, which bears testimony to Bangladesh's steady progress in moving away from the gloomy era of food deficits. Owing to the dedicated efforts of concerned stakeholders of the farming sectors, Bangladesh has moved up to the 3rd position in terms of global rice production, after China and India in 2020. Additional milestones achieved by Bangladesh in the frontiers of diverse food crops in global rankings are 6th in potato and 8th in mango and guava. Bangladesh also ranks 4th in the world in number of goats and meat production, 1st in hilsa fish catching, 3rd in inland open water fish catching and 5th in closed water fish catching (Source:<https://en.prothomalo.com/business/bangladesh-among-worlds-top-10-in-13-sectors>).

Commodity	Global Ranking in Production
Rice	3 rd
Mango and Guava	8 th
Potato	6 th
Vegetable	3 rd
Goats and Meat	4 th
Hilsa fish catching	1 st
Inland open water fish catching	3 st
Closed water fish catching	5 th

Third in rice production

Rice is the staple food of Bangladesh people. When the population was 75 million at the time of liberation in 1971 and in the 1970s there used to be recurrent food shortages in the country forcing the government to import

huge amounts of rice and other food grains at the cost of hard earned foreign currency. Now even though cropland has shrunk in area, Bangladesh is self-sufficient in rice production. According to BBS (2021), Bangladesh produced 37.6 MMT of rice in 2021, the third highest production in the world.

Third in vegetables

Bangladesh ranks third in vegetable production, producing 16 MMT annually. China is the top vegetable producer in the world and India is the second. This success in Bangladesh's year-round vegetable production has been possible due to the hybrid and quality seeds produced by the private companies. Presently 16.2 million farm families are involved in the production of 60 types of vegetables.

Sixth in potato

In the year before independence, the country produced only 0.9 MMT. Over the past 50 years potato there has been a 10-fold increased production to 9.9 MMT by 2021 (BBS 2021), and Bangladesh today is the sixth largest producer of this important tuber crop in the world. China produced 91.4 MMT followed by India with 49.7 MMT.

Second in jackfruit

Globally, 3.7 MMT of jackfruit are produced annually. Bangladesh is the second highest producer of this fruit, producing 1 MMT per annum. India produces the highest amount, 1.8 MMT. Indonesia and Thailand rank third and fourth, respectively.

Eighth in mango and guava

Mango is now cultivated all over Bangladesh. Previously, popular varieties like Himsagar, Gopalbhog, Langra and Fazli used to be grown exclusively in the two northern districts, Rajshahi and Chapainawabganj. Now, the mango variety Amrapalli being extensively grown in the southern and southwestern districts of the country. Bangladesh now ranks eighth in mango production with an annual output of 2.4 MMT. Ten years ago, with a production of 1.25 MMT, Bangladesh held the 10th position. India tops the list in mango production, producing 15 MMT.

Guava is mostly grown in the south and southwest districts of the country. Bangladesh produces 1.05 MMT of guava per annum, and presently is the eighth largest grower of this fruit in the world. India ranks first with 17.6 MMT and China second with 4.4 MMT. Previously, only low-yielding local varieties of guava were grown in Bangladesh, but the Thai and Kazi varieties of guava have brought about a revolution in guava production. The Germplasm Centre of Bangladesh Agricultural University (BAU) has come up with 10 varieties of guava.

Fourth in goat and goat meat

Bangladesh has made great progress in fish and in livestock production too, contributing substantially to nutrition security of the populace. Bangladesh is now self-sufficient in cows and goats. Bangladesh has clinched a position of repute in global livestock rearing. According to an FAO report, Bangladesh is steadily faring well in respect of goat number, goat meat and milk production. It ranks second in goat milk production, and fourth in the number of goats and goat meat production. The supplies and variety of livestock and poultry products have increased over time. The relative abundance of poultry meat and eggs is undeniable. There has been a major growth in commercial poultry farms for both meat and eggs (Asaduzzaman 2021). Various sources provide estimates of the number of eggs produced to be 20-33 million eggs/day. The number of cattle has increased and milk production has gone up substantially.

First in hilsa

Bangladesh produces 0.53 MMT of hilsa which is 86% of total hilsa catch of the world, and is poised to produce 0.7 MMT per annum in the near future. Even four years ago Bangladesh's share of the global hilsa catch was 65%. India ranks second in producing this fish and Myanmar third. Hilsa in small amounts is also found in Iran, Iraq, Kuwait and Pakistan.

Freshwater fish

Bangladesh ranks third, globally, in the production of freshwater fish. Despite the pitiful state of its rivers and streams, Bangladesh produces 10% of the world's freshwater fish. China ranks first with 16% and India second with 14%. Over the past 10 years, fish production in Bangladesh has gone up by 53% and fish export by 20%. According to FAO, by 2022 Bangladesh will be among the four countries in the world which is a great success in fish production. The other countries are Thailand, India and China.

Bangladesh agriculture responded favorably to global disasters and mishaps like the Covid-19 pandemic and the Russia-Ukraine war, ensuring adequate food production with generous support from the government machinery. According to a recent World Bank Report, there is no major food shortage in Bangladesh as of July 2022, although food price inflation remains at a multiyear as in other South Asian countries (<https://www.tbsnews.net/bangladesh/no-major-food-shortage-bangladesh-world-bank-479882>) despite blows from the COVID-19 pandemic and the Russia-Ukraine war. The government of Bangladesh had reduced rice import tariffs, increased the budgetary allocation to agriculture, increased fertilizer subsidies, and provided a cash incentive to exporters, the World Bank said. According to the report, food price inflation reached 8.3% in Bangladesh, 80% in Sri Lanka and 26% in

Pakistan. The Government of Bangladesh (GoB) took timely decisions to implement contingency marketing strategies across the country protecting the entire farming sector from the adverse effects of the pandemic and the war in Europe. This has, to a great extent, allayed the fear of food shortage. Political commitment to invest in developing modern technology based resilient farming systems paid good dividends in major food grain production. Nevertheless, investments have been so far insufficient for non-staple foods and non-crop sectors in agriculture which deserve immediate attention. Farming operations in Bangladesh are gradually transforming to digital agriculture relying on advanced ICT based tools to address challenges during the pandemic.

Technological advancement and input delivery systems

The NARS institutes in coordination with BARC, the apex body, have been working relentlessly for several decades to develop new HYVs of crops and modern production technologies. The research institutes are consistently developing HYVs and hybrids, nutrient fortified, insect and disease resistant, climate resilient (e.g., flood, drought, salinity, heat, cold tolerant) varieties of crops. Improved breeds of livestock and fish and fodder, agro-processing and management technologies are being developed. Agricultural research contributed to the development of 1,160 varieties/breeds and 1,167 management technologies for different crops, livestock, fish and forestry as of 2020. The technological progress was remarkable as evidenced by the release of 1160 HYV/breeds by the research institutes until 2020 in comparison with 505 HYVs/breeds until 2008 indicating a significant increase by 130% within 12 years (shown in the box). In addition to varietal improvement, research institutes developed 1167 management technologies until 2020 for better performance of HYVs/breeds in comparison with 576 until 2008 indicating a significant increase by 103% within the same period. These technologies contributed to increased productivity, intensification and diversification of farming systems.

Technology	Up to 2008	Up to 2020	Increase (%)
Variety/breed (no.)	505	1160	130
Management (no.)	576	1167	103
Total (no.)	1081	2327	115

Source: Websites of NARS institutes

Agricultural inputs are produced and sold by private companies through wide networks and distribution systems. They have contributed to rapid expansion of off-season maize, vegetable and poultry production. Moreover, private seed companies have contributed significantly to the spread of hybrid rice, maize, vegetables, etc., and markets have been created for the produce.

During 2020-21, farmers produced a total of 4.6 MMT hybrid rice from cultivation of 993,287 ha of land which constituted 8.48% of the total rice area (BBS 2021). Some private companies cultivate hybrid rice primarily for the purpose of selling seeds to the farmers. Considering yield increase of 1 t/ha of paddy (equivalent to 667 kg/ha of clean rice), hybrids introduced by the private companies contributed an additional 0.57 MMT to Bangladesh's annual clean rice production in 2019.

While high yielding varieties have continued to be in the priority list of research agenda viz, temperature stress, salinity, drought and water stagnation tolerant crops are under cultivation and many are in pipeline. Short duration varieties of crops are introduced in the cropping systems. Vegetables are now grown round the year unlike cultivated only during winter season in the past. Capture breeding techniques of different fresh water fish triggered the production of inland fisheries, where Bangladesh ranked third in the world.

Extension delivery to accelerate technology dissemination is supported by public departments. Public sector input delivery agency provides seeds, fertilizers and irrigation. NGOs also deliver extension services. Private actors are also involved in extension mechanism through their wide network and distribution systems. Bangladesh made a well-balanced regulatory environment for the agriculture sector with the international agreements in place. These include National Agriculture Policy 2018, National Agricultural Extension Policy 2020, National Agricultural Mechanization Policy 2020, National Food Policy 2013, The Food Safety Act 2013, GAP (Good Agricultural Practices) 2020 and other relevant documents. These policy instruments ensure safe and nutritious foods, minimize natural resource degradation, build skilled and capable institutions, crop diversification, value chain development, digitalization of agricultural operations and application of advanced ICT tools.

A scientifically developed and developing crop zoning system helps the growers select suitable crops for their lands and apply precise fertilizer applications using indigenously developed online apps. Village or mouza level GIS maps are now available for crop modelling. Bangladesh has successfully digitalized the entire country with enhanced communication using the Bangabandhu satellite. A digital revolution is in progress empowering farmers and other stakeholders to access extended market chain systems for greater profit margins and receive advisories and alerts.

The NARS institutions could foresee the impact of climate change in the country and, thus, started developing crops tolerant to salinity during the early eighties of the previous century. Salinity tolerant rice and heat tolerant wheat were developed during that period. Both processing and table varieties of potato particularly that are disease tolerant, offseason fruits availability

and some hybrid vegetables are recent products of advanced research. These varieties offer unique opportunity for location specific environment. HYVs of rice dominates the total agricultural production system in terms of area and volume in Bangladesh. However, similar investment is limited to the non-staple foods and deserve immediate attention particularly, in non-cereal and non-crop sectors in agriculture. Albeit, the productivity of many diversified crop has increased, it has not reached up to a larger scale of production due to competing land use.

Genetic engineering

Genome science is being used in the National Agricultural Research System (NARS) to explore the genetic potentials of plants and animals. Gene editing accelerated the development of crops. A genetically engineered pest resistant brinjal variety (Bt brinjal) has been developed by BARI and introduced in farmer's fields of Bangladesh complying with biosafety regulations and is considered the first of its kind in Asia. Bio-fortified crops rich in vitamins are under cultivation to address malnutrition and stunted growth in children.

Bangladesh is one of the major hotspots in the world for rich biodiversity and traditional knowledge of crops, livestock and fisheries germplasm. The BARC in partnership with different NARS institutes and universities is currently protecting the intellectual property rights of the precious germplasm along with the farmer's rights. These efforts are being recognized globally. A few important examples are traditional products/practices like floating agriculture in the flood plains, indigenous rice, fish and small ruminants. Bangladesh has become a partner in global negotiations on biosafety and Agreement on Agriculture (AoA) under WTO to conserve rights on products and services including trade.

Bangladesh agriculture took advantage of the global advancement of science since independence. In collaboration with the Consultative Group for International Agriculture Research (CGIAR) institutions, Bangladesh achieved genetic dividends through advanced breeding techniques and exchange of improved germplasm of staple food crops. IRRI, CIMMYT and other international research centers played a significant role in crop improvement for higher yields and knowledge sharing. Besides, organizations working under the umbrella of the United Nations along with multilateral/bilateral regional bodies are also contributing to institutional capacity building and development for advanced knowledge and skills. Bangladesh has, of late, also initiated knowledge sharing and collaborative R&D partnerships with reputed universities of USA, Canada and Australia.

Human resource development

Strengthening human resources of NARS institutes in agricultural research has made a significant contribution to increasing agricultural production to

the levels required to feed the country’s growing population. Additional efforts in agricultural research are being given to address emerging challenges like increasing weather variability, adaptation to climate change, water scarcity and increased price volatility in global markets. During 1981–2022, the total number of agricultural researchers in the country had increased from 1,240 in 1981 to 1,722 in 2022 (Fig. 1.2). Since 1981, the overall number of researchers grew by 39% during the last 42 years.

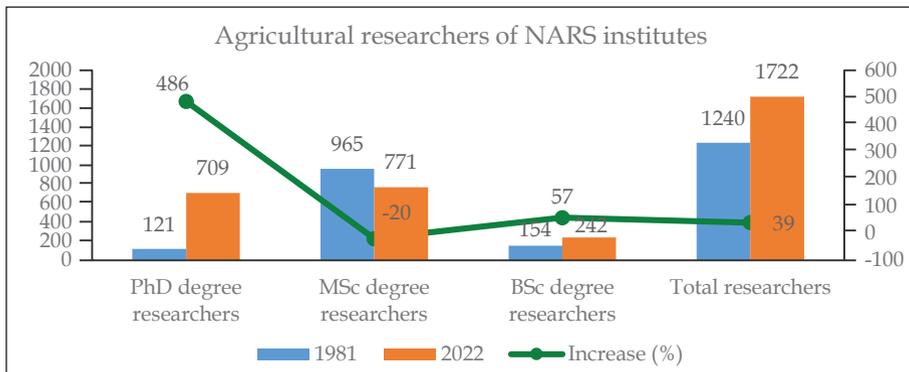


Fig. 1.2. Increase in the number of agricultural researchers with higher degrees
 Source: <http://www.asti.cgiar.org/>, http://www.asti.cgiar.org/pdf/Bangladesh_CB34.pdf
 BARC 2022

The average qualification levels of the agricultural researchers also improved considerably during 1981-2022. In 2022, 709 of the country’s agricultural researchers held PhD degrees compared to only 121 in 1981, indicating a 4.86% increase over the last 42 years (Fig. 1.2). However the number of researchers with Master’s degrees decreased from 965 in 1981 to 771 in 2022 (20% decrease). The number of researchers with the bachelor’s degree increased from 154 in 1981 to 242 in 2022 by 57%. The proportion of researchers with PhD degree increase from 9.8% in 1981 to 41.2% in 2022. Skilled manpower created by the agricultural universities has been employed in research institutes and extension organizations who have greatly contributed to the development and dissemination of improved technologies. However, despite this growing attention to the agricultural sector and positive impacts of agricultural research, Bangladesh, like many low- and middle-income countries continues, has to struggle with serious and deepening crises resulting from capacity shortcomings and funding constraints in agricultural research and higher education systems.

Despite an overall increase in the number of researchers since the turn of the millennium, more than 300 highly qualified researchers left the NARS institutes during 2000–2012 for settling overseas or for better opportunities elsewhere. To stop this, GoB took a series of measures including significant

salary increases, enhanced fringe benefits and incentives. Greater opportunities with funds from GoB and international development partners now exist to help young researchers pursue degree-level education both within the country and abroad. These measures, to quite a great extent, succeeded in checking the exit of qualified researchers from NARS institutions. Another important step to raise the retirement age for “outstanding” researchers from 59 to 65 is under process.

Reducing food deficits

Collective efforts of agricultural researchers, extension workers, farmers and other stakeholders Government policy makers and international development partners have successfully steered Bangladesh away from the bleak reality of hunger. Over the last five decades the country has experienced a marked expansion of the agricultural sector resulting in food production hike. Total domestic production of major food crops has increased by 4-20% annually over the last 50 years (Table 1.3) despite shrinking of agricultural land annually by 0.24%.

Table 1.3. Increase in production of major food crops during 1970-2021

Food crop	Production (MMT)		Rate of increase per year (%)
	1970	2021	
Rice	11.8	37.6	4.40
Wheat	0.10	1.10	20.0
Pulses	0.29	0.43	1.0
Oilseeds	0.30	0.99	4.60
Spices	0.39	3.60	16.50
Potato	0.90	9.90	20.0
Vegetables	0.90	4.60	8.20
Fruits	1.70	5.10	4.0
Total	16.38	63.32	5.70

Source: <https://ageconsearch.umn.edu/record/32668/files/wp010054.pdf>;
BBS 2021

The growth of cattle and buffalo, however, has not been very encouraging, the overall increase being only 0.40% per year on an average over the past 60 years (Fig. 1.3). The numbers of goat and sheep, however, soared increasing at an average annual rate of 6.6%. The growth in the livestock population mainly occurred in the poultry sector at an annual rate of 28.7% during the last 60 years, mainly due to a combined effect of GoB policy support and efforts of NGOs like BRAC, Proshika, RDRS, CARE-Bangladesh etc. to promote commercial poultry rearing involving mainly women.

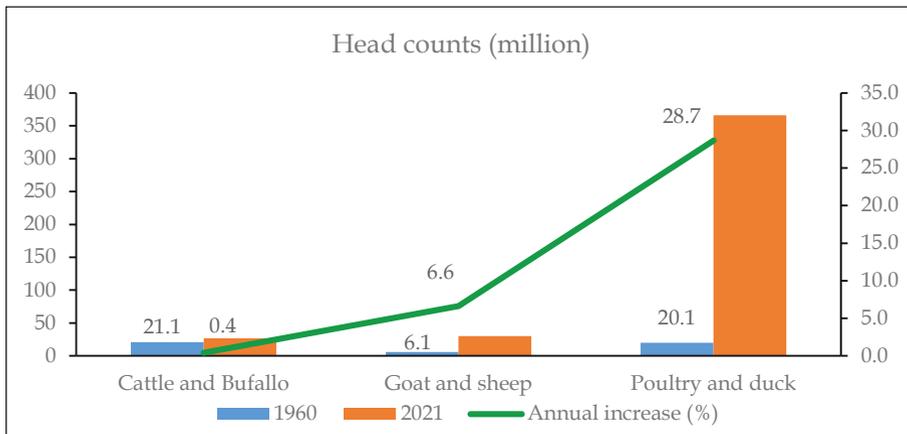


Fig 1.3. Increase in number of major livestock and poultry during 1960-2021

Source: <http://www.lrrd.org/lrrd26/10/rahm26173.html> ; BBS 2021

The production of meat and milk registered an impressive growth. During the last 50 years, meat and milk production have increased annually by 65.2% and 19.6%, respectively (Fig 1.4). However, milk production has showed a much lower annual growth compared to meat production during the same period. Egg production has also increased from 1,200 million in 1970 to 20,570 million in 2021 with an average annual growth of 32.3% over 50 years (<https://knoema.com/atlas/Bangladesh>, BBS 2021). Likewise, the production of total fish increased significantly over the last five decades, from only about 0.15 MMT in 1970 to 4.5 MMT in 2021, the average annual growth rate being 58% during the 1970–2021 period (Fig. 1.4).

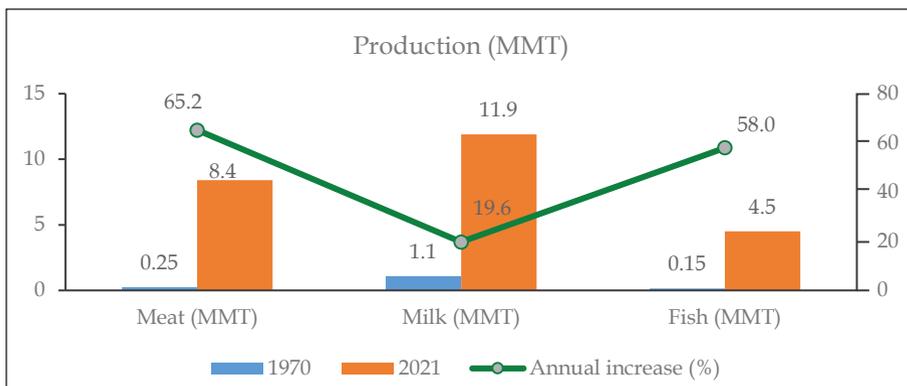


Fig 1.4. Increase in meat and milk production during 1970-2021

(Source: <https://knoema.com/atlas/Bangladesh>; <https://www.researchgate.net/publication/276440036>; <https://data.worldbank.org/indicator/ER.FSH.PROD.MT?locations=BD>; BBS 2021).

Agricultural R&D and implementation of various GoB policies and strategies ensured the achievement of food sufficiency in the country. A healthy and normal person needs to eat at least 496 g rice, 250 g vegetables, 63 g fish, 120 g meat per day and 104 eggs a year (FAO and WHO 2014), and 130 ml milk and 57 gm fruits per day (BIRDEM 2013). Considering a population of 166 million in 2021 (<https://www.worldometers.info/world-population/bangladesh-population/>), the per capita availability of rice, vegetable, fruits, fish, milk, meat, and egg has been increased to 620 g/day, 239 g/day, 84 g/day, 74 g/day, 196 ml/day, 138 g/day and 123 number/year, respectively (calculated as per production data base in 2021 given in the box). These data of per capita requirement and availability of the major food items indicate that Bangladesh by and large has left behind the gloomy days of hunger and malnutrition by reducing food deficit.

Commodity	Per capita requirement	Per capita Availability(base 2021)
Rice	*496 g/day	620 g/day
Vegetables*	250 g/day	239 g/day
Fruits	57 g/day	84 g/day
Fish	63 g/day	74 g/day
Milk	130 ml/day	196 ml/day
Meat	120 g/day	138 g/day
Egg	104/year	123/year

Source: FAO and WHO 2014, BIRDEM 2013
 * Per capita consumption
 ** includes potato

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Chapter 2

Food Production and Agricultural Economy

Agricultural production plays an important role in the overall economic development of Bangladesh. Agricultural operations and enterprises like crop cultivation, animal farming, fish farming, etc., not only produce food for the populace and also, to date, remain the main source of employment and livelihood for some 40% of labor force and contribute to the country's GDP. Agriculture is also a major source of a wide range of consumer demanded commodities in the domestic market. Bangladesh, since the first hour after independence in 1971, had to encounter the challenging task of developing and diversifying its economy with limited land and other natural resources and a growing population pressure and in the face of intensifying impacts of climate change. The Government of Bangladesh (GoB) promoted economic development based on high state involvement in both economic management and economic planning during the 1970s, 1990s and 2010s. The GoB economic policies were centered on 5-year plans (the first 5-year plan was launched in 1973), which aimed at country's development and public resource allocations. Achieving self-sufficiency in food has always been one of the avowed goals of the Government, and overall development of agriculture sector to attain this goal has been given the top most priority. To develop the agricultural sectors, the major steps taken by the GoB include production of improved quality and high-yielding varieties of seeds and breeds, their preservation and distribution, expansion of small irrigation facilities, reduction of waterlogging, increasing access to agricultural credit, etc.

Major progress has been made so far in the production of rice, the staple food grain making the country self-sufficient. Improvement and expansion of aquaculture have brought about remarkable production gains of fish, the major source of animal protein for the people. On the other hand, poultry farms supplying meat and eggs are a thriving enterprise now. Bangladesh aspires to transition into a developed country in the next two decades for which a sustainable, safe and profitable agricultural system needs to be built to ensure food security in accordance with Vision 2041, 8th Five Year Plan (July 2020-June 2025), National Agricultural Policy 2018, Sustainable Development Goals (SDG), Bangladesh Delta Plan 2100 (BDP 2100), etc. Agricultural research and development initiatives in Bangladesh are now geared to develop flood, drought, salinity, cold tolerant and short-duration varieties of crops, high-yielding, resilient breeds and broods of livestock and fish. Existing and upcoming technologies are expected to extend high-

yielding crop coverage to both favorable and fragile ecosystems, improve animal rearing, fish culture etc, and thereby increase food production manifolds in the future. Steps have been taken to scale up subsidies on agricultural inputs, ensure fair prices and supplies.

2.1 From food deficit to surplus: Major factors

Since independence, Bangladesh agriculture has experienced a steady transition from a low-productivity, subsistence level farming to a relatively high-productivity, surplus-produce oriented multi-faceted enterprise through the adoption of green revolution technologies. In the process the country has gone a long way towards elimination of hunger and alleviation of poverty. By increasing productivity of crops, fish and livestock the agricultural sector has freed a section of its underemployed labor force for other sectors such as manufacturing and services. These changes have expedited structural transformation of the Bangladesh economy. Even today agriculture remains crucial to the development of Bangladesh as agriculture and allied sectors continue to contribute to livelihoods, employment and incomes for a large segment of the rural population. The resultant effect is the transformation of food situation in Bangladesh from deficit towards surplus. The main drivers of this achievement have been i) increased allocation of revenues to agricultural ADP (Annual Development Plan), ii) agricultural policy reforms, iii) technological innovations, iv) increased access to agricultural inputs, and v) agricultural mechanization.

2.1.1 Increased allocation of revenues to agricultural ADP

Trend of revenues in agricultural ADP

The capacity of GoB to allocate funds for agricultural ADP increased in the recent past. GoB allocation in agricultural ADP increased massively by 5.6 times from BDT 7,901 million /year during the 2nd half of the 1970s to an allocation of BDT 44,500 million during 2022-23 (Fig. 2.1). There was a decline in GoB spending during 1980s, but it started increasing from the 1990s and has peaked in 2022-23. The GoB share of agricultural ADP initially declined from 80% in 1975-76 to 45% in 1994-95 and then it increased consistently to 81% in 2022-23. This increasing amount and share of GoB in the total agricultural ADP from BDT 7,901 million (45%) in 1994-95 to BDT 44,500 million (81%) in 2022 has helped Bangladesh depart from food deficit towards surplus.

Trend of agricultural research investment

The agricultural research investment in Bangladesh increased substantially by 5.9 times from BDT 1,120 million/year in 1981 to BDT 6,640 million/year in 2016 with a steady increase particularly from BDT 4,399 million/year in 2008 (Fig. 2.2). In fact, the country's agricultural research expenditures started

to increase since the turn of the millennium. This is mainly due to the Government's increased focus on agricultural sectors and funding from international development partners including the World Bank.

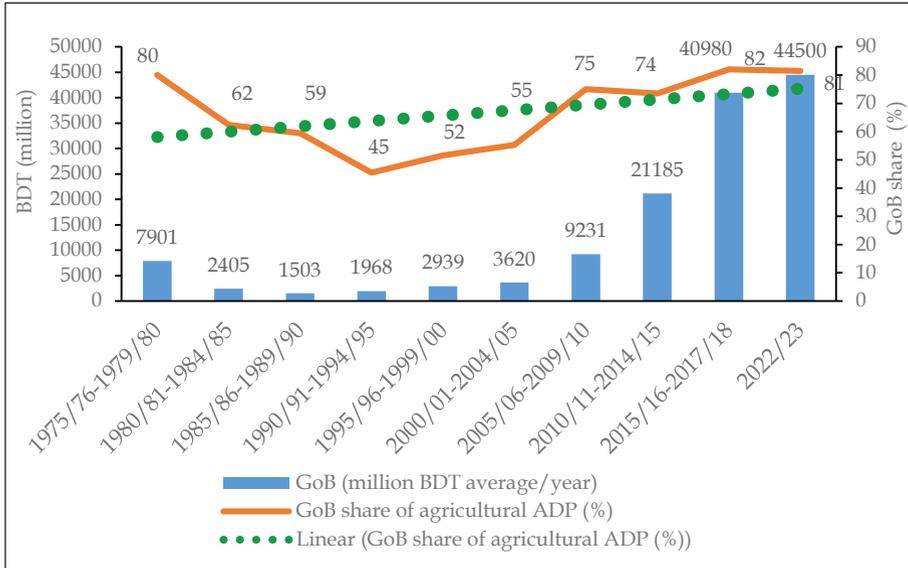


Fig. 2.1. Trend of GoB allocation in agricultural ADP

Source: ERD, <http://www.erd.gov.bd/>

The GoB share of research spending in total agricultural ADP is skewed. It was 34% in 1981, increased to 58% in 1986 and then declined again to 34% in 1996. Nonetheless, it rebounded to 64% in 2000 but declined once again steadily and massively to 14% in 2016 (Fig. 2.2). Compared with the proportions of agricultural research spending in total agricultural ADP expenditures, it appears that research had a higher share of agricultural ADP during 1986-1991 (about 55%) and during 2000-2004 (about 50%) but lost ground during subsequent years since 2008. This declining trend of agricultural research spending share in the total agricultural ADP in contrast with dramatic increase of research investment could be attributed to the special efforts given by the government for improving technology transfer, market development, capacity building etc., utilizing the increased growth of agricultural ADP. However, the decrease in total research expenditures, combined with a dwindling proportion of foreign aid in the development funds directed to agricultural R&D could be a cause for serious concern. Especially when Bangladesh has been vigorously championing poverty reduction and improving the competitive strength of its agricultural sector in an increasingly globalized market.

Despite increasing spending on agricultural research since the beginning of the MDG implementation (Fig. 2.2), the investment as a share of agricultural GDP on agricultural research is not pleasing being even below that in some neighboring countries. In 2016, the investment in agricultural research was only 0.38% of the country's agricultural GDP which was below that in Nepal (0.42%) and Sri Lanka (0.62%) but above India (0.30%). High-income countries invest, on an average, 2.7% of their agricultural GDP in agricultural research. Therefore, the country needs to invest more on agricultural research for addressing the merging multitude of challenges including rapid population growth, decreasing arable land and severe climate change impacts (<https://ebrary.ifpri.org/digital/api/collection/p15738coll2/id/133410/download>).

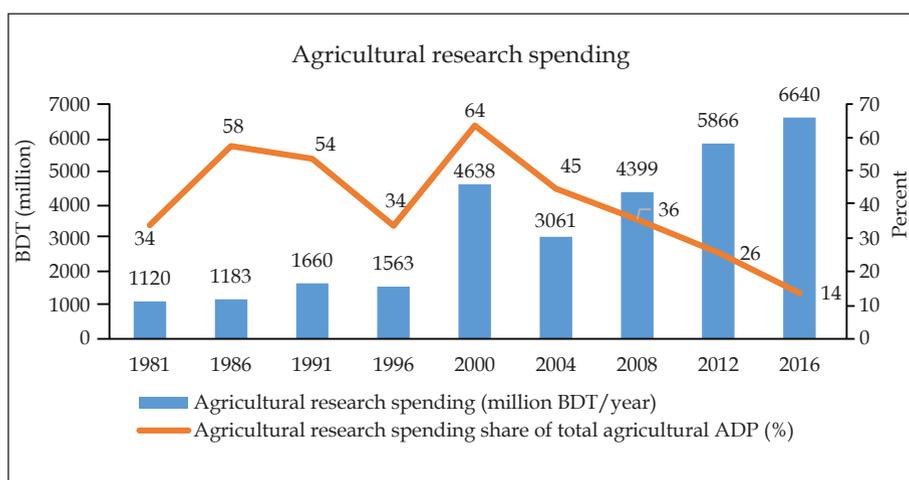


Fig. 2.2. Total agricultural spending on R&D

Source: Data from ASTI program database

Clear signs of the government's prioritization of agriculture and agricultural research include the prominence of agricultural research in the 8th Five-Year Plan (FYP 8). This support, however, needs to be enhanced and sustained into the future. Research is a long-term endeavor requiring sustained funding. Diversification of funding should also be promoted through a more enabling policy environment that stimulates private funding.

In Bangladesh, agricultural research is mainly performed by the public sector. Nonetheless, some prominent private seed companies also play an important role in introducing and popularizing hybrid seeds, especially of rice, maize, potato and some vegetables. Most of the research activities of these private companies are self-funded, although some are financed through research partnerships with multinational seed companies or international institutions

like International Rice Research Institute (IRRI). In addition to private Bangladeshi companies, multinationals like Bayer Crop Science and Syngenta also conduct in-country research aiming at improving seed quality for a number of crops. The private sector is currently the least source of sustainable financing for public-sector agricultural R&D in Bangladesh. Mobilizing private funding requires GoB to provide a more enabling policy environment through tax incentives, protection of intellectual property rights and regulatory reforms to encourage the spill-in of international technology.

2.1.2 Agricultural policy reforms and the impact

In the early to mid-1980s, the first wave of agricultural reforms took place where subsidies on inputs were cut back and domestic trading of inputs was liberalized. The second wave of reforms took place in late 1980s and early 1990s that included:

- i) liberalization of imports of inputs, private trading in grain markets both domestically and internationally, and
- ii) major reductions to longstanding programs for public distribution of grains.

The third wave of agricultural reforms occurred during the late 1990s-2000s where major emphasis was given on diversification of crop production, export-oriented poultry and fisheries production and also increase in forest coverage. The fourth wave of reforms happen in the early 2010s which included mainly improvement of HYVs, quality production, shrimp culture and sustainable increase in milk, meat, and egg production. During the late 2010s, GoB reformed agricultural policies by giving major emphasis on agricultural commercialization and mechanization, production of safe and nutritious food and participatory forestry management.

<p>Major Agricultural Policy Reforms</p> <p><u>Early to mid-1980s</u></p> <ol style="list-style-type: none"> i. Input subsidy cut back ii. Domestic trading of inputs liberalized <p><u>Late 1980s - early 1990s</u></p> <ol style="list-style-type: none"> i. Imports of inputs liberalized ii. Public grain distribution program drastically reduced <p><u>Late 1990s - 2000s</u></p> <ol style="list-style-type: none"> i. Diversification of crop production ii. Export oriented crop and fisheries production iii. Increase in forest coverage <p><u>Early 2010s</u></p> <ol style="list-style-type: none"> i. Improvement of HYVs ii. Quality production iii. Shrimp culture iv. Sustainable increase in milk, meat and egg production <p><u>Late 2010s</u></p> <ol style="list-style-type: none"> i. Agricultural commercialization and mechanization ii. Safe and nutritious food production
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Reforms during the early to mid 1980s

Reform measures were taken to privatize the input supply system, and to involve the private sector to support agriculture which was strengthened since the late 1990s by incorporating them in government programs. The government had cut its expenditure through institutional reform since the late 1970s. The subsidy on fertilizers was US \$83 million in 1979-80, which was reduced to only US \$0.6 million in 1992-93. Subsidy on tube well irrigation was reduced from US \$66.7 to US \$33million during 1979-80 through 1983-84, and almost the entire subsidy was eliminated in 1986 (Ahmed 1998).

The government continued to control the privatized fertilizer market and even increased its involvements in seed and agricultural credit supplies. The influences of evolving policies on the supply and use of inputs are described below taking various groups of farmers into consideration:

- (a) **Fertilizer:** The First Five-Year Plan (FYP 1) in Bangladesh allowed huge subsidies on fertilizers that motivated and enabled farmers to use greater amounts of all fertilizers during the 1975-1985 period. However, there was a negative impact of reform policies with a decrease in the supply of TSP fertilizer in the early 1990s. The farmers were cheated in buying low-nutrient SSP fertilizer due to almost the same color of TSP and SSP (Akanda et al. 1999). Lately, the government started importing TSP and MoP fertilizers to ensure their quality. The large and medium farmers, who were early users of fertilizers, were benefitted more from using greater quantities of fertilizers (Zohir 2001). Despite the subsidy cut down by GoB farmers still continued to use fertilizers at relatively high doses because of the returns they got in terms of higher yields of modern crop varieties. The share of the fertilized area to the total cropped area increased from 39% to 79% for small, from 35% to 78% for medium and from 32% to 75% for large farmers during 1983-84 to 1996 (BBS 1986 and 1999). However, fertilizer use per ha by large and medium farmers was higher than that by small farmers in HYV Boro rice farming in 1998 (Abedin et al. 1999).
- (b) **Seed:** Seed distribution by BADC increased from 19 to 30 thousand MT during 1981 to 1990 that continued to increase in view of the insufficient infrastructure for private seed production. The private sector and NGOs were also engaged in seed production after market liberalization in 1990. For example, seed production by the Grameen Krishi Foundation increased from 266 MT in 1993 to 781 MT in 1997 (Mondal 1999). The Seed Policy 1993 promoted a balanced development of public and private sector seed enterprises through education, training and financial support. This policy liberalization resulted in the engagement of more than 100 private seed companies in seed production. The large and medium farmers got access to improved seeds (Griffin 1974). The

land-poor and small farmers got little access to improved seeds because of the privatized distribution system and the involvement of NGOs.

- (c) **Agricultural credit:** Despite an increase in outstanding debts from US \$568 million (BDT 13,515 million) to US \$2,289 million (BDT 140,398 million), the government expanded its yearly credit flow from US \$285 million (BDT 6,786 million) in 1982-83 to US \$807 million (BDT 49,567 million) in 2004-05 (MoF 2006). However, 'overdue to outstanding debts' ratio of government loans declined and the ratio of 'recovery to due for recovery' increased since the early 1990s because of serious efforts of recovery with legal procedures and incorporating local elites in the Credit Committees (MoA 1999). The National Agriculture Policy (NAP) 1999 created an opportunity to introduce an appropriate institutional system of providing credit to ensure the availability of agricultural credit in time. Following this policy, the collateral-based traditional credit system of government banks used to help large and medium farmers but the land-poor farmers had no access to such help. However, the government launched some programs for small farmers. The DAE took several collaborative programs with NGOs to involve them in group formation, disbursement and recovery of micro-credit (DAE, 2006). It was notable that the NGOs started providing micro-credit, recovery of which was nearly 98%, to the landless and small farmers (Datta 2004).
- (d) **Irrigation:** The irrigated area had increased in the country due to easy availability of HYV seeds. Evidence indicates that the irrigated area, mechanized irrigated area, and the number of various mechanized irrigation devices in Bangladesh increased over time (Mandal, 2000). The number of STWs increased much since their adoption because of subsidized sale with credit support. The area under STWs was 10% of mechanized irrigated area in 1980-81, which increased to 35% in 1985-86. Irrigation coverage of STWs became nearly double during 1985-86 to 1990-01 and increased thereafter because of cheaper price of STWs after market reform (Mandal 2000). The number of DTWs and LLPs did not increase after 1996. The irrigation coverage by STWs accounted for 66% of mechanized irrigated area in 2004-05 (MoA 2006). The small farmer rarely owned STWs because of shortage of own capital and limited access to credit. Later, the STW ownership of small farmers increased significantly from only 8% in 1995 in a less irrigation-developed district to 76% in an irrigation-developed district (Mandal 2000). The irrigation market became competitive and the STW non-owner could use irrigation from any STW owner (Mandal 2000). The National Agriculture Policy 1999 and 2018 encouraged the farmers in providing supplementary irrigation during drought, which had a positive impact on increasing irrigated area coverage under crop production from 3.23 million ha in 2000 to 7.9 million ha in 2020 (BBS 2005, 2021).

- (e) **Agricultural machinery:** The government tried to introduce power tillers but there were only 27,000 power tillers found in 1983-84 (BBS 1986). The area under power tiller tillage grew at about 3.5% per year after its market liberalization in 1989 (MoA 2006). The number of power tillers reached to 141,000 in 1996 (BBS 1999) and then to 300,000 in 2004 ploughing nearly 70% of the cropped area. Many small farmers even owned power tillers as their income source because of low price. Meanwhile, locally made power tillers using STW engines became available in the market at a fairly low price. Due to the impact of NAP 1999 and NAP 2018, about 85% of land preparation was done mainly by a power tiller and to some extent by a tractor during the 2010s.
- (f) **Pesticides:** There was a slight decrease in the supply of pesticides in 1980 when responsibilities went to the private sector. The supply was, however, increased from 2,490 MT in 1980 to 17,392 MT in 2002 (MoA 2006). The NAP 1999 emphasized input supplies including pesticides to the farmers at fair prices in a competitive market, which contributed to this increase in the supply of pesticides. The policy reform was favorable for home production which was manifest in increasing gap between total pesticides use and imported amount. All types of farmers became indulged in pesticide use as pest attacks reduced production and even totally destroyed crops. Small farmers used pesticides unnecessarily at higher doses than medium and large farmers because of their lower literacy level.

The reforms in input subsidy cutback were successful in two dimensions. Firstly, GoB could save money from cutting subsidies on inputs, and, secondly, input dealers and farmers were benefitted which made green revolution a success. This allowed rice production to expand at a faster rate than the population growth rate which led to the country's domestic self-sufficiency in rice, the staple food grain. Most of these reforms are mainly related to the domestic support policies and input management. The opening up imports and abandoning rules for importing certain standard models reduced the costs of pumps and tube well equipment in the open market. This was a great step to sustain the agriculture sector during that period. The input market reforms accelerated the use of fertilizers and tube-well irrigation which facilitated the cultivation of Boro rice and boosted the rice output.

Reforms during late 1980s to early 1990s

The markets for both inputs and outputs had been almost completely liberalized relative to any time in the past. Domestic support and subsidies to agriculture shrank down but emphasis was given to public investment in agricultural research and extension, flood control and rural infrastructure development. Since the reforms, Bangladesh observed sustained increases in the production of rice, and decreases in the wholesale and retail prices of rice.

The government wound down control and shifted to an open market economy and encouraged private initiatives in the procurement and distribution of agricultural inputs and food grains. The Seed Policy 1993 emphasized making the best use of quality seeds of improved varieties of crops conveniently and efficiently available to farmers although these inputs were privatised. To support local entrepreneurs, GoB encouraged imports of various inputs and equipment relating to poultry and dairy industries, but not milk and other dairy products.

Formulated in 1992, the Livestock Development Policy (LDP) proposed various steps for the extension of poultry and animal husbandry as a means of self-employment as well as income-generation in rural areas. With a view to ensuring sufficient supply of protein to the common people's diet, the livestock policy laid emphasis on attaining self-reliance in the production of milk, meat and egg within the shortest possible time. The strategies that were underscored in the policy to achieve the objectives of importing high yielding breeds, improving local breeds through cross breeding, encouraging small-scale dairy and poultry farms, imparting training and providing all necessary inputs, including credit. As indicated in the policy, the Department of Livestock Services (DLS), through its field level offices, implemented various programs like artificial insemination, vaccination, treatment, feed and fodder production and training. Other governmental agencies, NGOs, people's representatives, and religious leaders were engaged in these programs.

Reforms during the late 1990s to 2000s

Policy changes also included allowing private sector participation in minor irrigation, withdrawal of restrictions on imports of wheat and rice by private traders, and innovations in open tendering for government procurement of rice. Disbursement of micro-credit, rescheduling of agricultural loans of indebted farmers, remission of land taxes for holdings up to 25 bigha (3.37 ha), crop diversification programmes and special programmes for disaster-stricken farmers were the other major steps adopted to boost agricultural production. These policy measures appear to have positively impacted the food situation in Bangladesh.

The NAP 1999 stressed on Crop Diversification Programs (CDP) for improving the nutritional status in the country. It also aimed at improving seed distribution program of BADC and ensuring fulfilment of at least 10% of the total demand by BADC supplies. In the light of the prevailing seed rules, the private sector will continue with their opportunities for production, import and marketing of seeds side by side with the public sector. Another reform was made through Fertilizer Dealer Recruitment and Fertilizer Distribution Based Coordinated Policy 2009, where recruitment of dealers was emphasized at union level and with introduction of retailer sellers or

dealers to expedite availability of fertilizers at the grass-root level in due time. This reform created an opportunity for recruitment of fertilizer dealers at the union level and farmers got easy access to fertilizers in their vicinity. This availability of fertilizer influenced the farmers to continue higher use of fertilizers as noticed through higher sale during 2010s indicating the positive impact of Fertilizer Policy 2009.

Introduction of Training and Visit (T and V) system in 1978 required extension workers to go to the farmers' fields on a regular basis. The government brought some mono-crop agencies under the fold of a single Department of Agricultural Extension (DAE) in 1982 for better coordination of extension programs (DAE 2006). The land-poor farmers, who were very late adopters, did not get access to the rice farming development-led extension service until the 'reform' policy phase (Siddiqui, 1998). The New Agriculture Extension Policy (NAEP) of 1996 was a milestone in targeting of the majority group of farmers that positively influenced crop diversification (MoA, 1996). Then the on-farm households (owner of <0.02 ha cultivable land not dependent on farming) were incorporated in agricultural projects which were not found earlier. The NAP 1999 positively impacted diversification of crops by supporting research and extension of different high-yielding varieties.

According to NAP 1999, distribution of fertilizers in the private sector continued, but the public sector imported fertilizers to ensure its supply and availability in time. Use of balanced fertilizers in order to maintain proper soil quality was highlighted. Moreover, emphasis was given to encourage farmers in providing supplementary irrigation during drought. Efforts were, therefore, made to increase irrigated area and reduce irrigation cost by promoting appropriate technology. The policy also expressed its commitment to provide credit facilities for the purpose. To ensure environment-friendly and sustainable agriculture, integrated pest management (IPM) was given priority in this policy for controlling pests and diseases. According to the National Integrated Pest Management Policy 2002, farmers were encouraged to grow healthy crops while improving the environment and community health following IPM methods.

To ensure fair prices for both growers and consumers, the improvement of marketing system was given priority in the NAP 1999. Agro-processing and agro-based industries were encouraged. Emphasis was laid on establishing a proper marketing network to facilitate timely marketing of farm produce. The policy also identified certain steps to reduce the control of middlemen and to ensure fair prices of crop produce for both growers and consumers. The reforms of agricultural policies influenced the agricultural industries of Bangladesh to increasingly focus on export markets.

The Livestock Development Policy (LDP) 1992 was revised to Livestock Policy and Action Plan (LPAP) 2005 with a greater emphasis on improving

small scale poultry farming and smallholder dairy. This policy incorporated new provisions of support for accelerating privatization of veterinary services, and establishing Livestock Insurance Development Fund (LIDF) to safeguard death loss of livestock and Livestock Credit Fund in the Bangladesh Bank for distribution of low interest credit to small scale livestock farmers through CBOs. Another reform was undertaken in the same policy through revision in 2007 to promote sustainable improvements in productivity of milk, meat and egg production including processing and value addition. In addition, this revised policy 2007 gave priority to facilitate increased private sector participation and investments in livestock production, livestock services, market development and export of livestock products and by-products. The National Poultry Development Policy (NPDP) 2008 brought out some reforms particularly in creating international market for poultry commodities and increasing export opportunities for earning foreign currency, and strengthening research programs in the poultry sector at the government and private sector levels.

The National Fisheries Policy (NFP) announced in 1998 emphasized the enhancement of fisheries production through scientific management of water bodies that included 1.4 million ponds and a large number of other seasonally submerged areas covering nearly 4.86 million ha and the 225 km long coastal area of the Bay of Bengal. Pointing out the potentiality of fisheries as a source of animal protein as well as in rural employment and poverty alleviation, the comprehensive policy laid emphasis on the availability of inputs like fish fries, feed and credit. Any private initiative in this regard, working in tandem with government efforts, was encouraged in the policy. Various acts were enacted for the development of fish resources including imposing restrictions on fishing with current nets, catching fish fries, and egg bearing fishes, and acquisition of fallow ponds. Under NFP 1998, the Government formulated strategies for inland capture fisheries and emphasized on fisher community participation in fisheries management, along with fish sanctuaries as a key management tool (DoF 2005).

The export from the fisheries sub-sector, although lower in volume compared with that of the crops sub-sector, contributed to the sectoral increase of income to BDT 53,294 million in 2021-22 from BDT 42,078 in 2006-07 as shown in Fig. 2.22 of the section 2.2.5. The NFP 1998 emphasized achieving economic growth through earning foreign currency by exporting fish and fisheries products. Similarly, NAP 1999 emphasized on promotion of agro-processing and agro-industries in the country. These policies eventually contributed to the above increase in exports of crop and fisheries products.

The NARS institutes were also influenced by agricultural policy reforms. Introduction of biotechnology and development of improved varieties and production technologies as a policy intervention of NAP 1999 and NAP 2013, Livestock Policy 2005, National Livestock Policy 2007 and National Poultry

Development Policy 2008, National Fishery Policy 1998 and National Shrimp Policy 2014. These policies provided a congenial atmosphere for the NARS institutes to deliver. These research centers developed HYVs of crops tolerant to abiotic stresses like floods, drought, salinity, high or low temperatures etc., and improved breeds of livestock and fish and agronomic management and agro-processing technologies. Outputs from the NARS institutes played a key role in Bangladesh's journey towards the achievement of food and nutrition security for the people.

Effective monitoring and evaluation of research programs since 1982 improved the accountability of the NARS institutes for need-based technological innovations. FAO along with two other international development partners started a vegetable development project. The Horticultural Research Centre (HRC) was built in 1989, which was a need-based institute in supporting vegetable and fruit production (FAO, 2005). Large and medium farmers got more benefits from research activities because they had greater access to new seeds of HYVs. Greater involvement of NGOs and the private sector helped extend technological innovations to the grassroots level (World Bank 2005).

Research, however, was reported to have suffered from fund shortage because of decreasing project aid by international partner agencies (World Bank 2005). The World Bank and many other agencies contributed to the implementation of agricultural projects including research in Bangladesh since the late 1970s. However, with the decrease in foreign aid, GoB funding increased which ultimately accelerated the research efforts resulting in the development of many varieties and production technologies that benefitted all farmer groups.

Reforms during early 2010s

The NAP 1999 was revised in 2013 and several of the reforms emphasized the development and dissemination of improved crop varieties and sustainable production technologies through research and training. It also created opportunities to continue competitiveness of agriculture through its commercialization, and promote effective initiatives to establish a self-reliant and sustainable agriculture that is adaptable to climate change and responsive to farmers' need.

The National Agricultural Extension Policy (NAEP) 2015 was in fact a draft policy, yet the Government implemented this draft policy until NAEP was finalized in 2020. The policy reforms especially prioritized decentralized, integrated and coordinated extension services and demand-led services to all categories of farmers with a view to increasing sustainable production and productivity. It gave due recognition of the need for empowering the grass-root agricultural workers to take decision on the transfer of technologies based on demands of farmers in coordination with different

stakeholders viz, agriculture, livestock, fisheries etc., integrating various components of farming, as needed.

Another reform was made in the Jute Policy 2012 where priority was given to increased production of jute and jute goods as environment friendly products for the domestic and international markets. In addition, emphasis was given to modernize machinery of jute industries and increase productivity of existing jute industries to diversify the use of jute products.

The National Livestock Extension Policy 2013 took into account for the first time the research-extension-farmers linkage and emphasis was given to mobilize, build and develop farmer groups and producer organizations for better access to technologies utilizing this linkage. An important reform took place through this policy in terms of strengthening health services, veterinary public health, diagnostic facilities, disease surveillance and reporting compared with the National Livestock Policy 2007.

Considering the huge export potential of shrimps, a separate National Shrimp Policy (NSP) 2014 was promulgated to promote shrimp culture. This policy encouraged shrimp production by applying environment friendly appropriate technologies complying with socio-economic, environmental, geo-natural and climate change standards. It also advocated an environment friendly integrated crop and shrimp culture through crop diversification and crop rotation with a view to creating a multiplier effect on the production of crops and fish on the same piece of land. Production of healthy, strong and disease-free fingerlings through specific pathogen free (SPF) brood stock was also encouraged.

Technological progress supported by different policy interventions eventually contributed to an increase in agricultural production. Double cropping along with the use of modern varieties and increased fertilizer application led to major increases in rice production. In 1992 Bangladesh produced between 20% and 32% more rice than it would have done had the reforms not taken place (Ahmed 1995). Rice yield increased from 1.77 MT/ha (paddy) in 1976-77 to 3.68 MT/ha in 2003-04 and further to 3.2 MT/ha in 2020-21 which took place mainly due to technological progress in HYV Boro rice farming, yield of which increased from 3.64 MT/ha in 1976-77 to 4.2 MT/ha in 2020-21 (MoA 2006, BBS 2021). However, the impact of policies differed among farmer groups because the small farmers did not have enough access to technology in the earlier years of adoption. The policy changes in extension and research activities were also found effective to raise income level of farmers because they got access to need-based extension service supported by NAEP 1996 and NAEP 2015. Akanda and Isoda (2006) in a study on the expansion of vegetable farming found that small farmers had relatively expanded the vegetable farming more than the large and medium farmers for getting more net returns from their limited crop areas along with

family nutrition. The need-based agricultural extension services from the DAE and efforts for smallholders' development by NGOs micro-credit were found to favor the small farmers.

Livestock and poultry policies positively influenced production of milk, meat and egg. The National Livestock Development Policy (NLDP) 2007 helped bring about sustainable improvements in the productivity of milk, meat and egg including processing and value addition. Similarly, the National Poultry Development Policy (NPDP) 2008 encouraged the production of safe and quality eggs and meat to meet the national demand for animal protein. Milk production increased from cross bred cows. The use of deep-frozen semen for artificial insemination significantly improved the cattle breeding program. Commercial chicken production in the country has developed at a faster rate.

Reforms during late 2010s

The NAP 2013 was revised in 2018 by incorporating further reform measures. Modernization of agricultural research, education, extension, input management and development of skilled manpower for the development of technologies suitable for commercialization was highlighted in NAP 2018. The necessity of producing nutritious, safe and demand driven foods was recognized. Other important reforms advocated in NAP 2018 were introduction of cost-saving farming systems through agricultural mechanization and commercialization through export oriented agricultural development. Production of climate resilient, environment friendly, safe, sustainable, nutrition rich and profitable crop production was prioritized in NAP 2018. This was also supported by the Good Agricultural Practices (GAP) 2020 document. The GAP also added health safety and security for the welfare of farmers and other agricultural workers and also of the consumers. HYV seed production increased, but the need for adaptation of the seeds to adverse situations like infestation of pests and diseases was felt. To address this, the National Seed Policy (2013) was revised as the Draft National Seed Policy 2018, which stressed the multiplication and distribution, on a timely basis, to all farmers sufficient quantities of quality HYV seeds that are resistant or tolerant to disease and insect pests.

Despite huge efforts, the country could not bring all potential areas under irrigation coverage and the situation has been exacerbated by rising costs of electricity and diesel and undesirable pressure on the underground water resources. Considering these issues, the Integrated Minor Irrigation Policy 2017 underscored lowering irrigation costs, improving farmers' skills in water use and using low-cost, water saving modern irrigation systems like the alternate wetting and drying (AWD) system developed by IRRI and adapted to the Bangladesh situation by BRRI in collaboration with IRRI. The AWD technology has been reported to reduce the number of irrigations by 25-30% without risking a yield decline of wetland rice.

The National Organic Agriculture Policy 2016 was formulated to check the decline of organic matter in soils of Bangladesh as a major objective. The policy supports the development and extension of organic agricultural production systems and making organically produced seeds easily available. The policy also emphasizes the identification of zones, locations and crops suitable for organic agriculture.

Farm mechanization has yet to be achieved up to the desired level while scarcity of farm labor in particular continued seriously affecting overall crop production. The National Agricultural Mechanization Policy 2020, therefore, suggests quick introduction of farmer-friendly agricultural machinery taking into account the socio-economic status of the farmers, small size of the farm and fragmented land and soil type. The policy also emphasizes accelerating agricultural mechanization, commercial and profit oriented agricultural enterprises.

To enhance utilization of jute, the Jute Policy 2012 was revised giving the name National Jute Policy 2018 which included reforms to promote jute and jute stick products and introduce them to the domestic and international markets. This policy also advocates attracting national and international investors with incentives and strengthening research for development of jute cropping and processing.

Surface water resources such as rivers, haors, beels etc., are not yet properly and fully utilized for fish culture, so far inland fisheries have received attention. Several years ago, fisheries scientists developed a technology to culture fish in cages set in open water bodies like haors and rivers, it has not been extensively utilized. The Cage Culture Policy 2019 prioritized extension of the cage culture technology to increase fish production in the rivers and other water bodies in a planned and environment friendly manner. The policy also provides directives for legal approval of the use of cage culture by farmers. Frozen shrimp and prawn are the most exported commodities of Bangladesh and they bring in appreciable amounts of foreign currency for the country. Policy reforms through the National Fishery Policy 1998 and National Shrimp Policy 2014 contributed to an increase in the total shrimp and prawn production, including capture and the production increased from 160,000 MT in 2002–03 to 270,114 MT in 2019–20 (BBS 2005, 2021). The supply of raw material for shrimp is limited and seasonal, so the average utilization rate of shrimp processing plants is generally low. High priority should be given to more efficient use of the existing capacity. The incentives, for example, could be tied to the performance of each processing plant. The private sector should be free to set up new plants, but it should also assume all the risks and benefits from investing in shrimp processing. The private sector was primarily dominated by small and medium enterprises (SMEs) with their strong linkage to the local production and high potential for processing, value addition and export. The National Fishery Policy 1998 and NAP 1999, 2013 and 2018 gave support for SMEs to develop.

Agricultural mechanization was influenced by policy reforms through NAP 1999, 2013 and 2018. The cropping intensity of 198% in 2019-20 (BBS 2021) could not have been achieved without mechanized tillage mainly by power tillers and to some extent by tractors. As pedal thresher proved to be inadequate to thresh large volumes of paddy, power threshers were developed and it is estimated that more than 60,000 are in use in the country.

Bangladesh has achieved self-sufficiency in food at least in terms of per capita calorie availability at the national level. Despite these impressive achievements of the past, Bangladesh still faces daunting challenges of ensuring safe and nutritious food for her current population of around 165.2 million (BBS 2022) projected to 183-199 million by 2031 (UNFPA 2014). Food safety is becoming an important issue due to increasing geographic separation of locations of consumption from the production centers as a result of urbanization. Growth of the middle and upper-income classes that increasingly rely on purchased food that may go through some degree of processing also makes food safety an important issue. Increasing incomes and urbanization have led to some dietary diversification but the rate has been slow, with cereals still accounting for 65-70% of the dietary energy intake. Diets have remained largely unbalanced with the diets of more than 50% of the population being deficient in Vitamin A, calcium, zinc and iron. There is also the need to avoid the “multiple burden of malnutrition” that can result in high incidences of obesity and non-communicable diseases (NCD). NAP 2013 and GAP 2020 emphasized ensuring sustainable production of safe and nutrition enriched foods. However, the progress so far has not been up to the mark. GAP policy 2020 presently in its first leg of implementation is expected to create a positive impact on safe and nutritious food production in the near future.

Food grain prices have been more volatile than usual, resulting in a rapid rise in the rice price in open market. Paddy growers were benefitted to some extent from the rice price hikes, but the net deficit farmers and wage laborers were hard hit especially during the lean period when the rice price went up while their stocks diminished. In summary, the impact of rising food grain prices was good for the rice traders, moderate for the growers and bad for the poor consumers. The weakest point in the major policy documents, i.e. NAP, Food Policy etc., was the inadequate attention given to an understanding of agriculture and food market development. The policy prescriptions, therefore, overlooked the implications of the low real rice price since 1999. The policy analyses prescribed liberalizing rice market looking at the poor urban consumers, rather than the rice producers whose incentives to invest in rice production eroded.

2.1.3 Technological innovations

Bangladesh agriculture emerged as a dynamic sector during the green revolution period. The use of modern technologies started in the mid-1960s

with the introduction of HYV rice and wheat varieties. Specifically, the rice HYV IR8, coupled with fertilizer-irrigation-pesticide-management technologies started the green revolution in the country. Side by side, significant progresses in agriculture infrastructure development were made and increased allocation of revenues in agricultural ADP including areas of research was done. Policy reforms including marginalization of government control on the research institutions allowing them to operate as autonomous organizations with their own work plans and budgets came into effect which provided impetus for accelerated R&D. The NARS institutes quickly developed high-yielding varieties/breeds of crops, livestock and fish and improved management technologies that paid off in the long run in sustained production increment.

Rice

The Bangladesh Rice Research Institute (BRRI) is the lead organization spearheading R&D for the staple food grain, rice in Bangladesh. Nevertheless, the contribution of some other organizations like Bangladesh Institute of Nuclear Agriculture (BINA), Bangladesh Agricultural University (BAU) and Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) are also appreciable. By 2021, BRRI had released 99 HYV and 7 hybrid rice varieties, BINA released 23 HYV, BAU came up with 3 HYVs and BSMRAU released 2 HYVs and 1 hybrid variety for different agro-ecological conditions (Table 2.1). Thus, the NARS institutions BRRI and BINA and two agricultural universities, BAU and BSMRAU have developed a total of 135 modern rice varieties in the last 50 years since the independence of Bangladesh.

Table 2.1. Season wise rice varieties developed by different institutes

Rice	Number of rice varieties				Total
	BRRI	BINA	BSMRAU	BAU	
Aus	13	2	-	-	15
Aman	42	13	2	-	57
Boro	44	8	-	3	55
Hybrid rice	7	-	1	-	8
	106	23	3	3	135

Source: BRRI, BINA, BSMRAU and BAU website, AIS 2022

The number of varieties released during 2011-2021 was very high (68) compared to 22 during 2001-2010, 20 during 1991-2000, 13 during 1981-1990 and 12 during 1970-1980 (Fig. 2.3). Similarly, the rice varieties developed for Aus, Aman and Boro season were the highest (8, 33 and 27, respectively) during the same period. The peak in the development of varieties during 2011-2021 could be attributed among other factors to intensive human resource development and allocation of generous financial assistance by GoB

for strengthening agricultural research. The increasing trend of modern rice varieties developed during the period from 1970 to 2021 strongly correlated with and contributed to increasing trend of rice production as both the parameters progress simultaneously showing positive linear growth (Fig. 2.3).

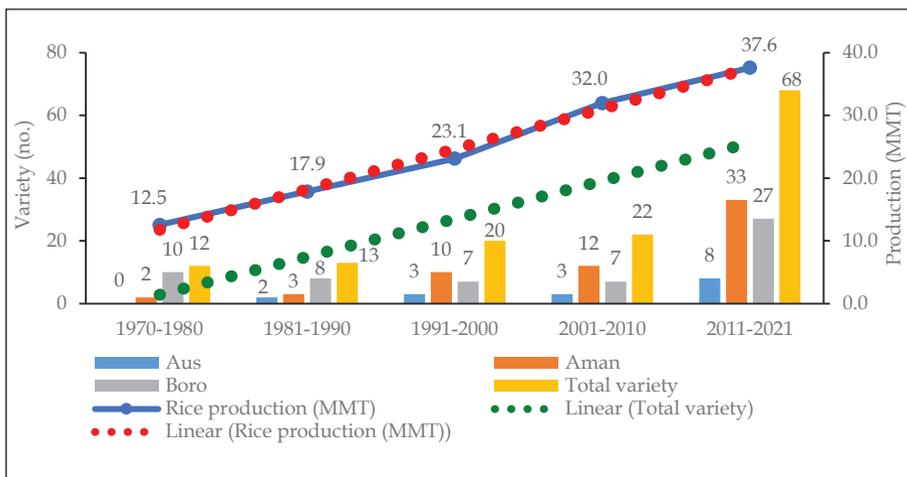


Fig. 2.3. Modern rice varieties (no.) developed by decade in Bangladesh
 Source: BRRRI and BINA website, AIS 2022

* Rice production figure is applicable for the last year of each period

Wheat and Maize

The development of improved wheat varieties increased from only 2 varieties during 1960-1970 to 10 varieties during 2011-2021 (Fig. 2.4). The number of maize varieties released during 2001-2010 was 4 times higher (12) than that (3) during 1981-1990. Later, 9 varieties were developed during 2011-2020. However, there was a sharp increase in development of both wheat and maize varieties by 400% and 100% respectively between the 1960s and 2010s. BARI and BWMRI developed 39 wheat and 28 maize varieties as of 2021 (see box).

BARI pioneered the development of hybrid maize and released more hybrid (17) than OP varieties (7) till 2021. However, wheat production could not keep pace with varietal development since 2000 (Fig. 2.4). Even though existing wheat varieties in Bangladesh are high-yielding, area coverage and production did not increase sufficiently to match the growth in human population. Moreover, in many areas wheat has been replaced by assorted Rabi crops such as, potato, Boro rice, maize and different short-duration vegetables.

Developed wheat and maize varieties (no.)			
	BARI	BWMRI	Total
Wheat	36	03	39
Maize	26	02	28
OP	07	-	07
Hybrid	17	01	18
Pop corn	01	-	01
Baby corn	01	01	02

Source: BARI and BWMRI website

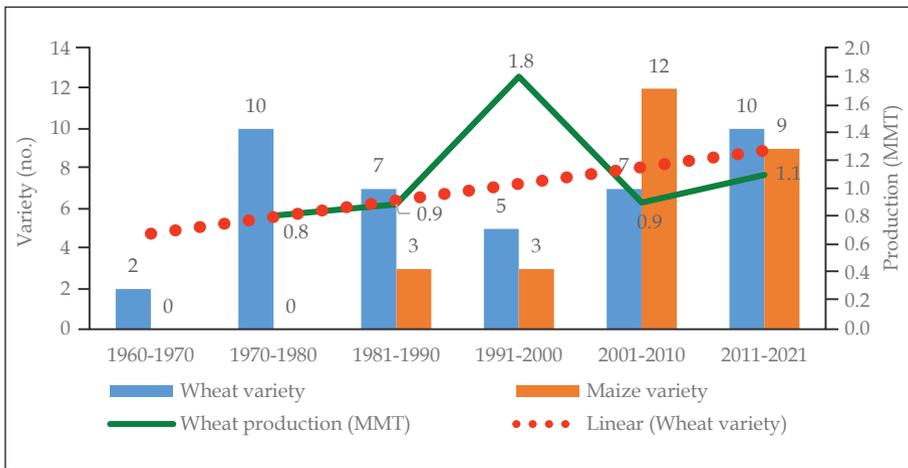


Fig. 2.4. Wheat and maize varieties developed in Bangladesh

Source: BARI and BWMRI website, AIS 2022

*Wheat production figure is applicable for the last year of each period

Jute and Sugarcrops

Development of high-yielding varieties was one of the main factors contributing to increased production of jute. So far, 44 jute varieties (27 white jute and 17 tossa jute) have been developed by BJRI since 1910. Improved jute variety development at the jute research institute started more than 100 years ago; 5 varieties were developed during 1910-1920, 8 during 1931-1960 and 7 during 2011-2021 (Fig. 2.5). Jute passed through a crisis due to low and unstable prices at the growers' level that led to low investments in variety development during the 1961 to 2010 period. During the recent years, however, jute has been on a comeback track in major jute producing countries of the world as demands for raw jute increased worldwide and there has been a continuous increase in the raw jute price in major jute producing

countries like Bangladesh. In addition, an increased awareness of environmental safety and diversified use of jute has contributed to the recent development of jute varieties for the last few years since 2011.

The Bangladesh Sugar Crop Research Institute (BSRI) has developed 48 varieties of sugarcrops (44 sugarcane, 2 sugar beet, 1 palm and 1 stevia) since 1961 to fight biotic and abiotic stresses. There has been a steady development of improved sugarcrop varieties from only 1 variety during 1961-1970 to 11 varieties during 2011-2020 (Fig. 2.5). The number of sugarcrop varieties released during 2011-2020 was 11 times higher than that during 1961-1970 while increased by 22% between the periods of 2001-2010 and 2011-2020 with an annual growth of 2.2% due to a significant effort given by the Government.

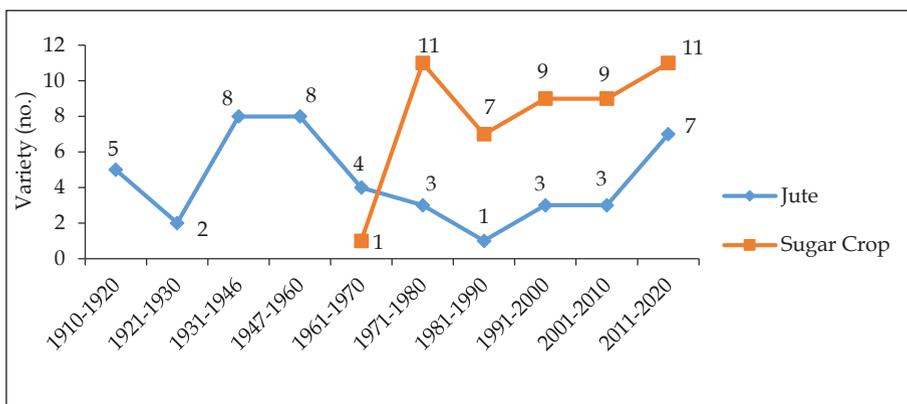


Fig. 2.5. Development of jute and sugarcrop varieties (no.) in Bangladesh

Source: BJRI and BSRI website

Genome sequencing of sugarcane has been achieved recently and sugarcrop scientists are trying to catch up with the pace of development of other major crops like rice and wheat. In the future, with rapid advances in sequencing techniques, bioinformatics tools, gene editing and with the strength of genome sequences from progenitor species, sugarcane transcriptomics is set to help meet the demands of different end users (<https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/sugarcane>).

Potato and Vegetables

Potato research and development in the then East Pakistan started in 1960, but varietal improvement work was limited to germplasm introduction and selection due to a lack of facilities until the year 2000. Potato plants usually do not produce flowers under short-day conditions. In recent years, BARI scientists used flower induction techniques in extended photoperiods which

opened the way to hybridization. Out of a total of 109 potato varieties developed so far, 103 came into effect after the independence of Bangladesh, 65 of them having been developed during the decade of 2011-21 (Fig. 2.6). Potato variety development underwent an enormous increase by 33 times from only 2 varieties released during 1950-1960 to 65 varieties during 2010-2021. About 4 times development of potato varieties occurred between 2011 and 2021 with an annual growth of about 33%.

Varietal development for vegetables like tomato, eggplant, chili pepper, okra, onion, garlic, radish, red amaranth, Indian spinach, kangkong, cabbage, Chinese cabbage, cauliflower, yard long bean, mungbean, vegetable soybean, peas, cucurbits and asparagus is remarkable in the country. Off-season production technologies have been developed for tomato, cauliflower and okra. Grafting technologies for tomato and watermelon are developed to control soil-borne diseases (AVRDC 2000). Since 1981, a total of 167 varieties of different vegetable crops have been developed in Bangladesh by BARI, BAU, BSMRAU and SAU during the last 40 years of which 135 varieties contributed by BARI, 27 by BSMRAU, 3 by BAU and 2 by SAU. The number of vegetable crop varieties released during 2011-2021 was quite high (78) compared with only 11 vegetable varieties during 1981-1990 (Fig. 2.6). The annual growth rate in vegetable variety development between 2011 and 2020 was 9.0%. The government had called for a departure from “rice-led” growth to a more diversified production base that includes several non-rice crops e.g., potato, vegetables, etc. This strategy of the government inspired the agricultural scientists, the result being an impressive annual growth of potato and vegetable variety development during the decade of 2010-2021. The trend of modern potato and vegetable varieties developed during each period from

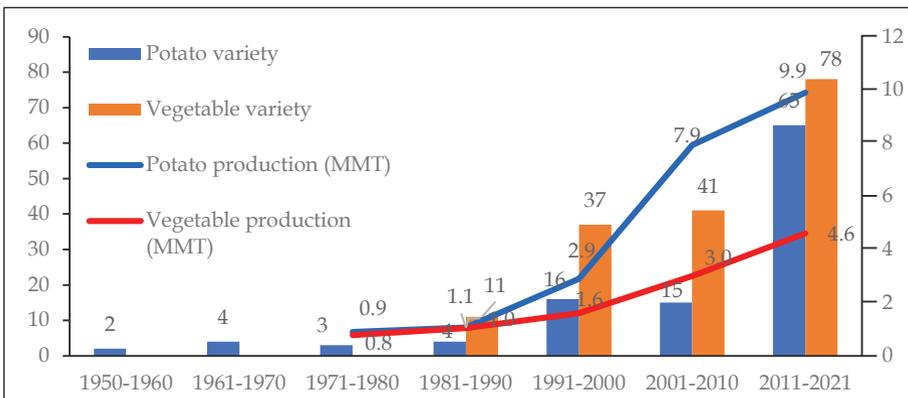


Fig. 2.6. Potato and vegetable varieties developed in Bangladesh

Source: BARI, BAU, BSMRAU, SAU (Sylhet) website, AIS 2022

* Potato and vegetable production figures are applicable for the last year of each period

1971 to 2021 demonstrated a positive linear growth and contributed to increasing trend of their production as both of their varietal development and production increased linearly (Fig. 2.6).

Out of 167 vegetable varieties developed as of 2021, the highest number was for OP (open pollinated) varieties (140) of which 110 were developed by BARI (Table 2.2). The OP varieties were developed for country bean (26), tomato (22), gourd (15), brinjal (13), leafy vegetables (13), aroid (11) and

Table 2.2. Numbers of vegetable varieties developed in Bangladesh during 1981-2021

Kind of vegetables	Number of vegetable variety						Total	
	BARI		BSMRAU		BAU	SAU	OP	Hybrid
	OP	Hybrid	OP	Hybrid	OP	OP		
Brinjal	13	9	-	-	-	-	13	9
Tomato	21	9	1	-	-	-	22	9
Country bean	15	-	9	-	-	2	26	-
Lady's finger	2	-	-	-	-	-	2	-
Palwal	2	1	-	-	-	-	2	1
Radish	5	-	3	1	-	-	8	1
Carrot			1	-	3	-	4	-
Cabbage	2	-	3	-	-	-	5	-
Cauliflower	3	-	1	-	-	-	4	-
Gourd	13	6	2	1	-	-	15	7
Aroid	11	-	-	-	-	-	11	-
Leafy vegetable	13	-	-	-	-	-	13	-
Others	10	-	5	-	-	-	15	-
Total	110	25	25	2	3	2	140	27

Source: BARI, BAU, BSMRAU, SAU (Sylhet) website, AIS 2022

radish (8) of which the most varieties were developed by BARI during 1981-2020. BSMRAU developed 25 OP varieties of different vegetables, 9 of which were for country bean. On the other hand, most of the hybrid vegetable varieties have developed for brinjal (9), tomato (9) and gourd (7) out of the 27 varieties during 1981-2020. The BARI deserves credit since the institutions have developed almost all of these hybrid varieties except that BSMRAU developed 1 hybrid for radish and 1 for gourd (Table 2.2). Considering the future need for commercial agriculture, efforts on development of hybrid varieties are still not adequate. It requires special attention to biotechnological advancement. Massive efforts are needed to expedite development of hybrid varieties for high-value vegetables such as pointed gourd, carrot, cabbage, cauliflower, leafy vegetables, lady's finger, etc., through biotechnological advancement.

Pulses and Oilseeds

Breeding for pulses was initiated at BARI during the mid-1970s and later on, BINA and BSMRAU also joined the venture. So far 83 pulse varieties have been released for cultivation in Bangladesh during 1971-2021 of which 42 were developed by BARI, 34 by BINA and 7 by BAU. Keeping in view the constraints in oilseed production, the research institutes have been pursuing commodity and non-commodity oriented research on oilseeds since 1974. A total of 77 HYVs of oilseed have been developed by BARI, BINA and BSMRAU during 1971-2021 of which 48 are developed by BARI, 27 by BINA and 2 by BSMRAU. Pulse production, however, did not increase as one would expect from the trend of varietal development since 2000 until 2010 before it

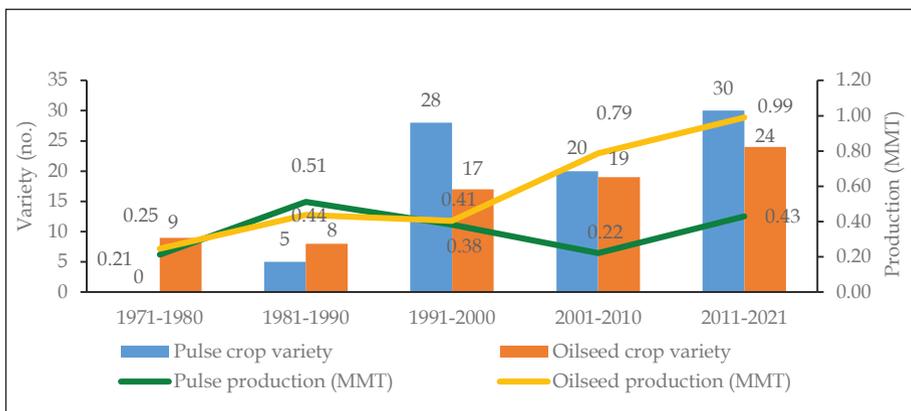


Fig. 2.7. Pulse and oilseed varieties developed in Bangladesh

Source: Website of BARI, BINA and BSMRAU

* Pulse and oilseed production figures are applicable for the last year of each period

turned up during 2011-2021. Most of the pulse varieties have been developed for mungbean (23), chickpea (21) and lentil (19) of which almost 50% varieties of these crops are developed by each of BARI and BINA during 1971-2021. However, BSMRAU developed a good number (6) of mung bean varieties.

The variety development of oilseed crop increased by 2.7 times from 9 varieties during 1971-1980 to 24 varieties during 2010-2021 (Fig. 2.7). Most of oilseed crop varieties have been developed for mustard (29), groundnut (21) and soybean (12) during 1971-2021 of which the maximum varieties of these crops are developed by BARI followed by BINA. The increasing trend of modern oilseed crop varieties developed during each period from 2000 to 2021 positively correlated with increasing trend of oilseed production. The constraints on pulse and oilseeds production in Bangladesh are related to climatic variability, competition with other crops, production and post-harvest management and market access. Massive efforts are also needed to expedite development of hybrid varieties for high-value and nutrient rich pulse and oilseed crops such as black gram, field pea, soybean, sunflower etc.

Fruits

Varietal development for fruits is being continued in Bangladesh mainly by BARI and a few agricultural universities including BAU and PSTU. BAU contributing the most among the universities. These organizations have developed so far 197 varieties of different fruit crops. The development of fruit varieties dramatically increased from only 1 variety during 1971-1980 to 78 varieties during 2011-2020 peaking to 93 varieties during 2001-2010 indicating a remarkable development of fruit varieties during the two decades from 2001 to 2020 (Fig. 2.8). Fruit production boosts in Bangladesh matched well with the pace of varietal development in the country.

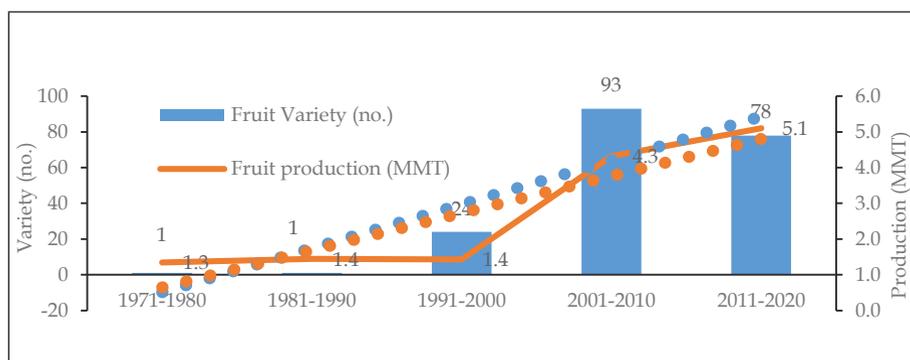


Fig. 2.8. Fruit varieties developed in Bangladesh

Source: Website of BARI, BSMRAU, BAU and PSTU, AIS 2022

* Fruit production figure is applicable for the last year of each period

Out of the 197 fruit varieties developed (Table 2.3), number of mango varieties is 42 (21%), of which BAU (25 varieties) outperformed BARI (17 varieties). This was also true for guava the varieties of which accounted for 8% (16) of the total fruit varieties with BAU having developed 10 of the 16 varieties. Lemon varieties occupied about 10% share of the total fruit varieties, BARI having developed 15 of the 20 varieties. Other fruit varieties were for litchi (9), banana (8) and jujube (8), and most of these varieties are developed by BARI.

Table 2.3. Numbers of fruit varieties developed during 1971-2021

Name of Fruit Species	BARI	BAU	BSMRAU	PSTU	Total
Mango	17	25	-	-	42
Jackfruit	3	1	-	-	4
Guava	4	10	2	-	16
Jujube	5	3	-	-	8
Lemon	15	4	-	1	20
Litchi	5	4	-	-	9
Banana	6	2	-	-	8
Papaya	1	-	2	-	3
Coconut	2	-	-	-	2
Orange	3	-	-	-	3
Malta	2	2	-	-	4
Jamrul	3	3	-	-	6
Safeda	3	4	-	-	7
Kamranga	2	3	-	2	7
Strawberry	3	1	-	-	4
Jambura	-	5	-	-	5
Dragon fruit	1	4	-	-	5
Water melon	2	-	1	-	3
Others	22	13	-	6	41
Total	99	84	5	9	197

Source: Website of BARI, BSMRAU, BAU and PSTU, AIS 2022

Spices and Condiments

Spices are common ingredients of assorted food items in the Bangladeshi food bowl. They are extensively used for nutritional merits, and too, add flavor and make food items tasty and also to preserve food. BARI, BAU and BSMRAU have developed 49 spice and condiment varieties during 1981-2021. BARI has the lead role. Only one variety has been developed

during 1981-1990, varietal development accelerated thereafter yielding 34 varieties during the 2011-2020 period. There was a 209% increase in variety development between 2010 and 2020, from 11 to 26 varieties with an annual growth of 20.9 % due to increased efforts and investments of BARI, BAU and BSMRAU. The increasing trend of modern spice varieties developed during each period from 1981 to 2021 strongly correlated with increasing trend of spices production as both varietal development and production increased linearly (Fig. 2.9). These 49 varieties developed by different organizations during 1981-2020 were for chili (10), garlic (9), onion (7) and turmeric (5) and most of these varieties have been developed by BARI, and BAU contributed appreciably to garlic variety development.

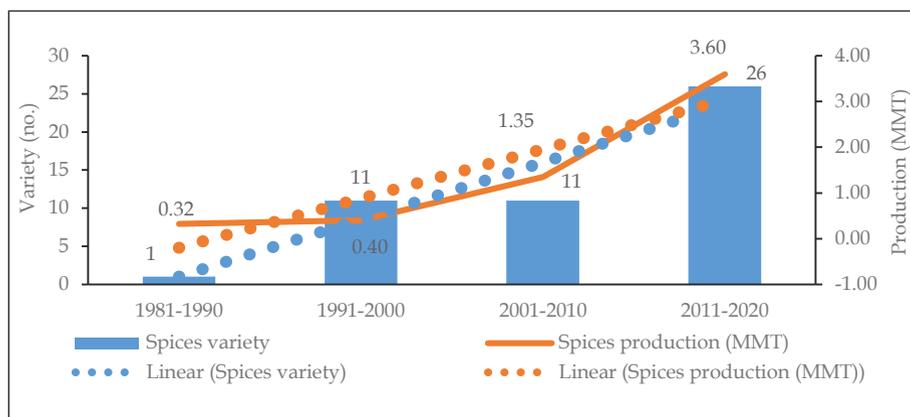


Fig. 2.9. Trend of spice varieties developed in Bangladesh

Source: Website of BARI, BAU and BSMRAU, AIS 2022

* Spices production figure is applicable for the last year of each period

Tea

Tea is one of the most consumed non-alcoholic as well as medicinal beverages in the world. At present, more than 58 countries around the world produce tea and Bangladesh ranks 10th among the tea growing countries (The Daily Star 2022). Tea is a major agricultural export commodity of Bangladesh but domestic consumption of tea is increasing so rapidly that export is coming increasingly under pressure, which has necessitated a rapid development of HYVs of tea and enhancement of the seed stock. The Bangladesh Tea Research Institute (BTRI) was established in 1957 with the main objectives of (i) producing seed stock for consistent production of seedling progenies of superior standard and (ii) selection of outstanding bushes and releasing them as vegetative clones. The BTRI has so far released 28 clones and seed stocks including 23 vegetative clones in the Bangladesh tea (BT) series (BT1 – BT23), four bi-clonal and one polyclonal seed stocks. Hybridization between clones was initiated at BTRI in the late 1960s with a view to developing bi-clonal seed

stocks combining the desirable characteristics present in different clones. Two bi-clonal seed stocks, BTS1 (BT1 X TV1) and BTS2 (B207/39 X TV1), were released for the establishment of bi-clonal seed baries in 1985. Tea clones increased from only 1 clone during 1960-1970 to 5 clones during 2011-2021 (Fig. 2.10) with a peak of 7 clones during 1991-2000. There was an abrupt increase in the periodic development of tea clones and seed stocks by 5 times during the last 61 years since 1960 indicating an annual growth of 6.6% in clone development. Meanwhile, the total tea production has also increased in the country (Fig. 2.10).

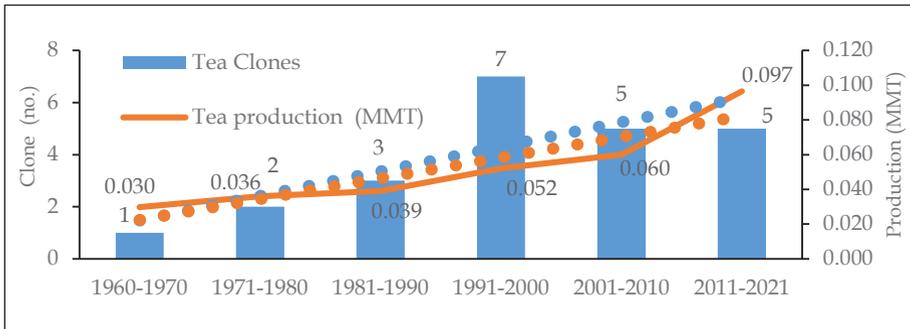


Fig. 2.10. Trend of tea clones and tea seed stock development

Source: BTRI website

* Tea production figure is applicable for the last year of each period

Livestock and Poultry

The Bangladesh Livestock Research Institute (BLRI) has developed as many as 71 technologies and packages related to livestock and poultry (Table 2.4). Chattogram Veterinary and Animal Sciences University (CVASU) started developing technologies in the early 2010s and released 5 management technologies related to livestock and poultry during 2011-2020. The BLRI has

Table 2.4. Number of major livestock and poultry technologies developed in Bangladesh

Period	Number of major livestock and poultry technology							Total
	Breed		Feed/Fodder		Disease management		Others	
	Livestock	Poultry	Livestock	Poultry	Livestock	Poultry		
BLRI	3	3	23	3	16	6	17	71
CVASU	1	-	1		1	-	2	5
Total	4	3	24	3	17	6	19	76

Source: Website of BLRI, CVASU

a pioneering role in conservation of 24 different farm animal and poultry species, and 43 fodder crop species of native and exotic origin. Some

examples of livestock technology developed are improved nutrition and feeding methods such as urea molasses straw (UMS), fresh and wet preservation of straw, green grass preservation, maize stover preservation etc. These technologies comprise mainly management of local and locally improved cross breeds of livestock and poultry for better health, nutrition, production and quality. Out of the 76 livestock and poultry technologies, the BLRI developed 71 and CVASU developed 5 technologies (Table 2.4). BLRI developed more breeds/varieties during 2011-2021 (3 poultry strains and 1 Napier grass variety as fodder), livestock feed management technologies during 2001-2010 (11) and livestock feed technologies during 1991-2000 (13) out of their total 71 technologies. Some new breeds/strains of poultry were developed during 2011-2021 e.g., Swarna breed, MCTC (Multi Color Table Chicken) etc., for layer and meat purposes, respectively. During the 1991-2000 period only 14 livestock and poultry technologies were available which increased to 76 by 2021 (Fig. 2.11) registering a 143% increase with an annual growth rate of 4.8%. The increasing trend of livestock and poultry technologies developed during each period from 1991 to 2021 strongly correlated with the trend of milk and meat production as the technology development, and production increased linearly.

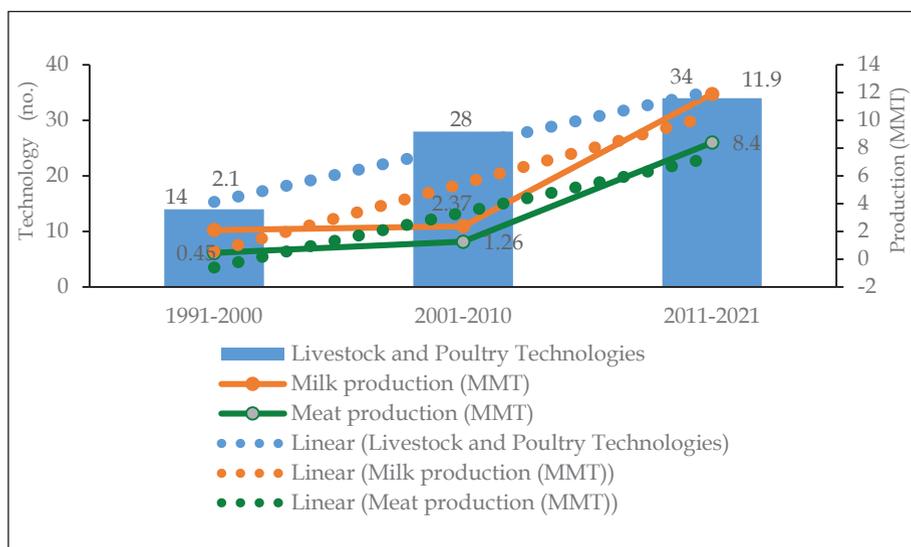


Fig. 2.11. Trend of livestock and poultry technologies developed in Bangladesh

Source: Website of BLRI, CVASU

* Milk and meat production figures are applicable for the last year of each period

Fisheries and Aquaculture

The Bangladesh Fisheries Research Institute (BFRI), since its inception, has been conducting research on diverse areas of fisheries including fish breeding, improved fish culture management and development policy issues. The most outstanding achievements were made on carp breeding under controlled conditions, improved hatchery and nursery system management, carp poly-culture mixing with local and exotic carps and prawn polyculture, culture of small indigenous species (SIS) under carp polyculture management system, hybrid progeny development of GIFT and silver barb with wild germplasm. The institute has impressive contributions to biodiversity conservation, and has successfully developed technologies for controlled breeding of the most threatened fish species namely, *mohashol* (*Tor sp.*), *aier* (*Mystus sp.*), *pangus* (*Pangasius pangasius*). The BFRI scientists have developed genetic progeny of quality seeds for tilapia, silver carps, carps, etc., through mass and family selection techniques.

Globally marine stocks are in decline and this is true for Bangladesh, too. Fisheries has reached their maximum sustainable yields. The scientists achieved notable progress in research and technology innovation for marine fisheries. Important achievements are as follows:

- Culture and brood development of sea bass (*Lates calcarifer*), mullets (*Mugil sp.*)
- Development of low-cost health friendly sun dryer for fish drying
- Development of improved device of *behundi* net (set-bag-net)

Recent research at BAU generated a few useful technologies related to fish handling and value addition to minimize post-harvest losses of fish. Technologies to prepare value added products such as fish fillets, frozen mince blocks, surimi, fish chatny, fish powder, fish soup, noodles, cookies, etc. from fresh fish have been developed (KGF 2021). Several useful, easy to handle, cheap fish handling and preservation tools have been developed such as, (i) manually operated ice crusher machine, (ii) self-powered aerator-cum-oxygen accumulator, (iii) portable folding SS-table, (iv) insulated tank ice box, (v) solid stackable plastic crates, and (vi) improved ice crushing petty with pestle to preserve fish quality during transport from landing centers to markets. In addition, the indigenous country fishing boat is redesigned with improved on-the-boat cold chain facilities equipped with TIB ice box in deck-hold, ice crushing petty, plastic crates, etc., for capture fishing and safe transport of fish.

The BFRI has developed a total of 61 technologies and CVASU developed 7 technologies for extension (Table 2.5). Among the listed technologies 30 are on fish breeding, 28 on fish culture and 10 related to fisheries management. BFRI developed breeding technologies (3–7 on carp and 1 each on GIFT *tilapia*, *pabda*, *gulsha* and *magur*), culture (20) and biotechnological (5) during 2009–2021 compared to those during 1986–2008.

Table 2.5. Number of major fishery technologies developed in Bangladesh

Institute	Number of major fisheries technologies								
	Breeding					Culture	Biotechno-logical	Others	Total
	GIFT Telapia	Pabda	Gulsha	Magur	Carp				
BFRI	2	1	1	2	3	35	7	10	61
CVASU						7			7
Total	2	1	1	2	3	42	7	10	68

Source: BFRI and CVASU website

The development of fisheries technology increased by 124% between the years 1986-2008 and 2009-2021 (Fig. 2.12). Considering 21 technologies developed by 2008, the annual growth of fisheries technology development stood 10.3% during the last 13 years, which was very impressive compared to the technological development in crop and livestock sub-sectors of Bangladesh agriculture resulting in massive fish production gains for the country (Fig. 2.12).

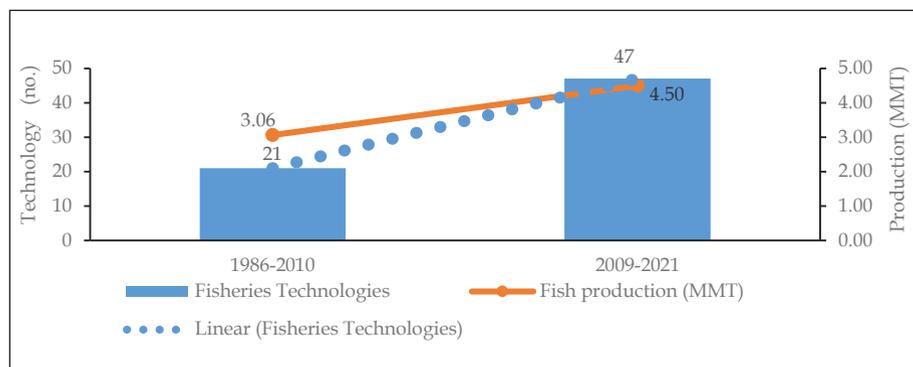


Fig. 2.12. Trend of fisheries technologies development in Bangladesh

Source: BFRI and CVASU website

* Fish production figure is applicable for the last year of each period

Agricultural management technologies

Research organizations and agricultural universities have developed a number of improved management technologies e.g., pest control methods, postharvest technologies, improved machines and devices, standardization of fertilizer dose and irrigation methods, livestock, poultry and fisheries etc., on the basis of different agro-ecological zones of the country. During the 2010-2021, total 1201 management technologies have been developed com-

pared with a total of 781 technologies up to 2009 after independence indicating a sharp increase by 54% with an annual growth of 4.48% (Table 2.6). The highest number of technologies was developed for crop management during both the periods (357 till 2009 and 462 till 2021) while the highest increase in technology development was for farming systems and socio-economics (129%) between these two periods. Efforts to increase technology development on insect pest management and farm machinery by more than 100% between 2009 and 2021 were overwhelming resulting in an increased food production and income. However, technology development in the fields of natural research (soil and water) management, post-harvest, livestock and poultry management needs to be enhanced further beyond the current trend of 19-25% between 2009 and 2021 to reduce the impact of climate change and to enhance food and nutrition security.

Table 2.6. Management technologies developed in Bangladesh

Research field	Management technology (no)		
	Till 2009	Till 2021	% Increase
Soil and crop management	357	462	29
Insect pest and disease management	109	229	110
Farm machinery	37	75	103
Irrigation and water management	40	50	25
Post-harvest technology	69	82	19
Farming systems and socio-economics	83	190	129
Fisheries management	23	34	48
Livestock and poultry management	63	79	25
Total	781	1,201	54

Source: Website of NARS institutes and agricultural universities.

Technologies to address climate change

Climate resilient varieties, cropping patterns, irrigation techniques, sustainable land management, etc., are necessary to adapt agriculture to climate change adversities. Effort is undertaken to develop strategies and technologies to survive and prosper against natural hazards like floods, droughts, tidal surges etc. The NARS researchers are innovating technologies that are resilient to climate change and that will ensure sustainable agricultural production and food security. Research on stress (salt, submergence, drought, high/low temperature) tolerant rice and wheat varieties can ensure food security by increasing yield of these crops. For example, BIRRI released salt-tolerant rice varieties like BIRRI dhan40, 41, 53 and 54, submerge-tolerant varieties BIRRI dhan51 and 52, drought tolerant

BRRRI dhan42 and 43, and salt-cold-drought tolerant BRRRI dhan56 and 57 using gene-marker technology. Short-duration rice varieties like BRRRI dhan33 by BRRRI and Binadhan-7 by BINA are being successfully cultivated to avert so called *monga* (seasonal famine) in northern Bangladesh. The BARI has developed heat tolerant wheat and tomato varieties.

Irrigation is crucial in the context of climate change. Introduction of the AWD irrigation technique was found to be promising in increasing water use efficiency for crop production. Besides, canal digging program is introduced by BADC and Water Development Board (WDB) to leach out salts from soil. In the comparatively dry Rajshahi and Rangpur divisions (Barind region), the Barind Multipurpose Development Authority (BMDA) ensures irrigation for rice. Both the BADC and BMDA are in pursuit of increasing irrigation coverage by taking newer projects and programs every year.

Sustainable Land Management Practices: Soil resources of the country are experiencing high pressure for increased crop production. Increasing cropping intensity and mineralization of soil organic matter exhausts the soil's capacity to support crops. The SRDI is generating periodically soil health data. The institute has prepared the Upazila Land and Soil Resources Utilization Guide for 459 upazilas of the country that would help determine appropriate doses of fertilizers based on the fertility status of the soil. The Ministry of Agriculture (MoA) is encouraging farmers to use organic fertilizers like compost, farmyard manure, etc., to safeguard soil health. Farmers are advised to use green manure and bio-fertilizers in addition to chemical fertilizers to sustain soil health. Agronomic practices like intercropping with leguminous crops, reduced tillage (conservative agriculture), alternate cropping, soil mulching, etc. are suggested to be used by the farmers to maintain soil fertility and crop productivity.

2.1.4 Agricultural Inputs

Rice HYV seeds has the highest increasing trend of sale from 1821 MT in 1971-72 to 160,403 MT in 2020-21 by 88 times followed by potato and maize while wheat has a fluctuating pitfall and increase during 50 years (Table 2.7). This increasing trend of HYV seed sale correlates well with the increasing production trend of major food crops as discussed earlier. The sale of vegetable seeds is poor and static due to open market sale through private companies.

TSP and MoP fertilizer sale have increased linearly from 1972 until they dropped to 2009-2010 and then again turned up to 2019-20 (Table 2.8). Notwithstanding this fluctuation, TSP and MoP sale increased enormously by 4.35 times and 23.86 times in 2020 from 60,140 MT and 13,932 MT from 1972 to 261,906 MT and 332,483 MT in 2020 respectively. Due to private sector involvement in selling of Urea and DAP, these fertilizers did not have good track of records in BADC and hence showed poor trend of sale with BADC.

Table 2.7. Trends of HYV seed sale from 1971-72 to 2020-21 (MT)

Year	Rice	Wheat	Maize	Potato	Vegetables
1971-72	1821	173	0	0	0
1979-80	2351	14022	0	3713	0
1989-90	5557	16952	0	7471	0
1999-00	14031	8473	214	6175	10
2009-10	62944	23429	6800	28000	1438
2020-21	160403	49826	10468	119348	2001

Source: BADC website, BBS 2012, 2021

Nonetheless, the increasing trend of TSP and MoP sale corroborates well with the increasing production trend of different HYV food crops in Bangladesh as discussed earlier.

Table 2.8. Trends of fertilizer sale by BADC from 1971-72 to 2019-20 (MT)

Year	Urea	TSP	DAP	MoP
1971-72	169771	60140	0	13932
1979-80	533314	205322	42157	45956
1989-90	355546	480670	0	118962
1990-91	104000	514000	0	147000
2009-10	0	169000	0	93000
2019-20	0	261906	627492	332483

Source: BADC website

The annual consumption of urea, TSP, MoP, gypsum and zinc fertilizers increased over 42 years since 1980 and their total consumption was increased by 434 % from 0.82 MMT in 1980-81 to 4.38 MMT in 2020-21 with an annual growth rate of 10.33% (Fig. 2.13). Use of urea fertilizer is always higher than that of TSP, MoP, gypsum and zinc fertilizers, and urea fertilizer alone

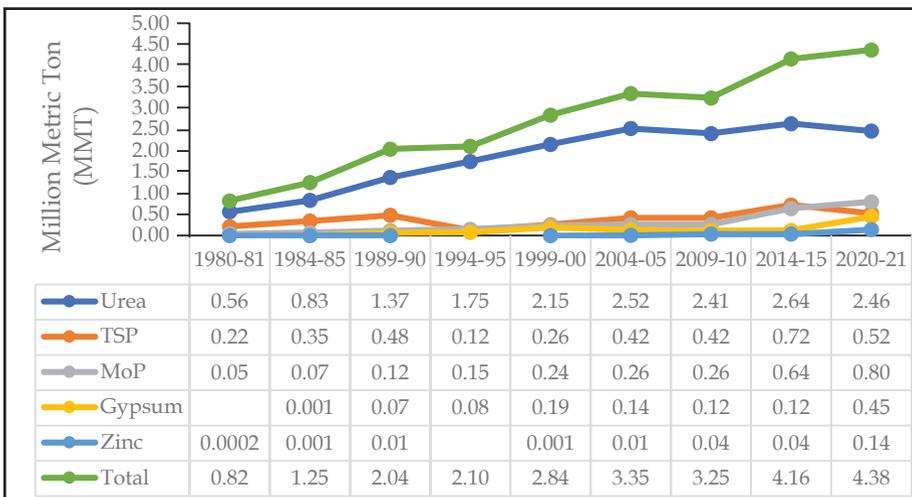


Fig. 2.13. Trends of fertilizers use in Bangladesh

Source: BBS 1980, 1985, 1990, 1995, 2000, 2005, 2010, 2015, 2021

constitutes 56.3% followed by MoP (18.3%), TSP (11.9%), gypsum (10.3%) and zinc (3.2%) in 2020-21.

2.1.5 Agricultural mechanization

Mechanization in irrigation

Bangladesh has achieved self-sufficiency in rice production, which could not be possible without farm mechanization of some of the important farm operations. There was a massive increase in irrigation coverage from 1.06 million ha in 1970 to 7.9 million ha in 2020 indicating an overall increase by 7.45 times during 50 years and an average annual growth of 12.9% (Fig. 2.14). The irrigation area has increased linearly without any decline during 1970 through 2020. About half of the total cultivated area/cropped area (49.1%) of the country has been brought under irrigation in 2020 while the share of the total cultivated area under irrigation was only 8.0 % in 1970. The major growth of cultivated area under irrigation occurred during 1990s (1.2%/year) and 2000s (1.3%/year) in comparison with the initial 20 years since 1970 (0.63%/year) and the recent 10 years since 2010 (0.4%/year). The lower growth of cultivated area under irrigation during 2010s could be attributed to the combined effect of reaching near the potential of land area for irrigation and of the HYVs/technologies available with low water requirement in support of reducing pressure on underground water. However, the increasing trend of irrigation coverage occurred during each period from 1970 to 2020 and it strongly correlated with increasing trend of food production (Fig. 2.14).

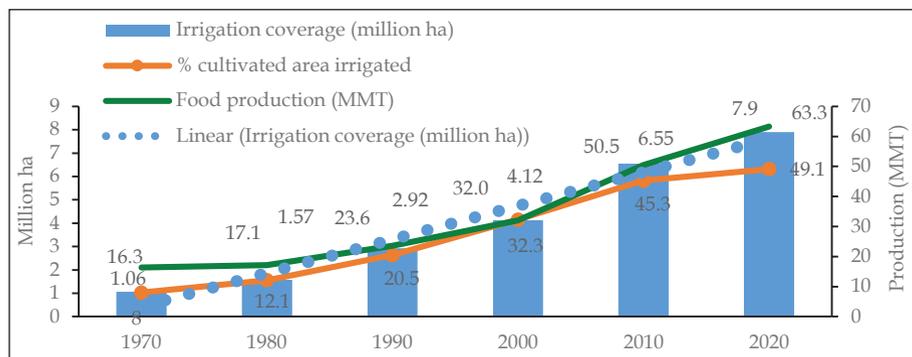


Fig. 2.14. Trend of irrigation coverage in Bangladesh

Source: <https://knoema.com/atlas/Bangladesh/topics/Water/Irrigation-Area-Equipped-for-Irrigation/Cultivated-area-equipped-for-irrigation>
<https://www.researchgate.net/publication/259951473>
 BBS 2011, BBS 2021

Other machineries

For threshing rice, Japanese type pedal threshers and for weeding in wetlands, weeders were introduced to a limited scale. Tillage was the next

operation that was mechanized. Tractors and power tillers were introduced in 1970. At present about 85% of land preparation is done mainly by power tillers and to some extent by tractors. As pedal thresher proved inadequate to thresh bulk production of rice, power threshers were used. Entire maize shelling is done by power corn sheller. Total number of agricultural laborers now engaged in farming has more than doubled in comparison to what it was in 1950s. Yet, labor shortage becomes acute during sowing/planting and harvesting seasons. These two operations need immediate mechanization. Wages of agricultural laborers were so high that use of imported rice transplanters, reapers and combine harvesters became cost effective and farmers are using these implements in limited areas. It is expected that these two operations would be mechanized shortly throughout the country. Bangladesh also has a long history of small-scale rural mechanization in which small engines in rural areas have powered boat and road transportation, pump-sets, and two-wheel tractors, among other usages. Before independence, the irrigation policy in Bangladesh concentrated on large-scale canal systems and deep tube wells but at least half of the land used to be irrigated by local small-scale tools such as, swing buckets and dhones.

2.2 Food production and economic growth

Agricultural sectors contribute to economic growth of Bangladesh mainly through food production and job creation and intricately linked with the rest of the economy. Consequently, agriculture is also a key player in poverty alleviation. The economy of Bangladesh was largely dependent on the rural sector which, before the 2000s, was almost synonymous with agriculture as more than 70% of Bangladesh's population was engaged in agricultural activities including livestock and fishing. Agriculture accounted for 54.6% of the GDP in 1970 which went down to 12.07% at constant price in 2021 (BBS 2021). This decline has been in relative terms but in absolute terms it increased from BDT 23.6 billion in 1970 to BDT 4,110 billion in 2021 (<https://data.worldbank.org/indicator/NV.AGR.TOTL.KN?locations=BD>). Agriculture will continue to remain an important sector in the economy of the country in terms of provision of raw material for industries, export earning, employment and food security despite the declining trend of the agricultural share in the GDP.

2.2.1 Agricultural production and GDP

The GDP of a country is the market value of all final goods and services produced within that country in a given time period (generally one year). GDP from food production by the agricultural sub-sectors can be calculated in a way, for example, if there are 100 tons each of rice and potato, the total GDP from these two products is 100 tons of rice x market price of every ton of rice + 100 tons of potato x market price of every ton of potato. Bangladesh's GDP on account of agricultural production increased from BDT 23.6 billion in

1970 to BDT 4,110 billion in 2021 (Fig. 2.15) indicating a sharp increase by 174 times during the last 50 years (average 346%/year). Food production (rice, wheat, pulses, oilseeds, spices, potato, vegetables, fruits, milk, meat, eggs, fish etc) from different agricultural sectors (crop, livestock and fisheries), which contributes directly to GDP, also increased from 17.8 MMT in 1970 to 88.1 MMT in 2021 indicating a tremendous increase by 4.7 times with an annual growth of 7.4% (Fig. 2.15). Both the agricultural share of GDP and total food production from agricultural sub-sectors registered linear growths during 1970-2021 indicating that the agricultural share of GDP is correlated well with the total agricultural production. The linear increase and correlation of agricultural production with the agricultural share of GDP may be attributed to price escalation of agricultural produce coupled with the increase of production.

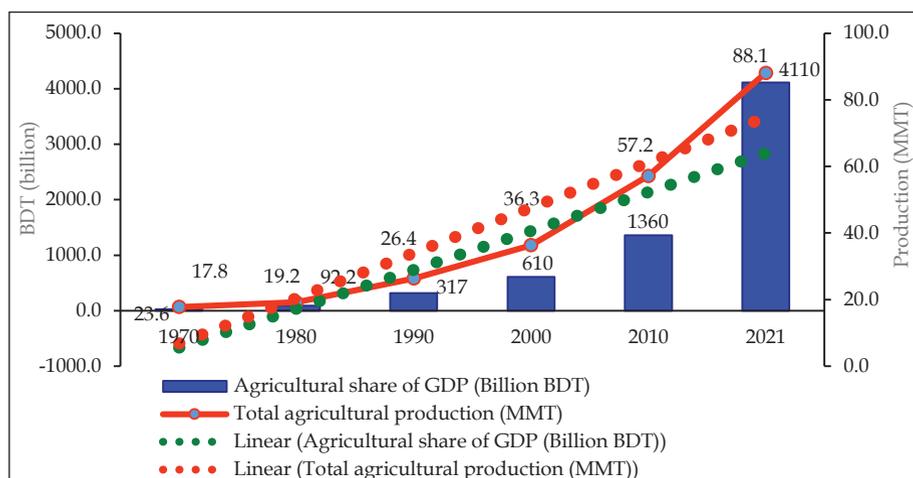


Fig. 2.15. Trend of GDP from agriculture as influenced by total agricultural production

Source: <https://data.worldbank.org/indicator/NV.AGR.TOTL.KN?locations=BD>
BBS of different years

The Government was able to increase agricultural share of GDP (BDT 23.6 billion) in 1970 to BDT 92.2 billion in 1980 with an annual average growth rate of 29.13% despite war ravaged situation of Bangladesh after her independence in 1971 (see box). This improvement of the GDP share from agriculture was attributed to an annual increase of agricultural production by 0.77%. This production increase was influenced by the direct initiatives of GoB during the early 1970s through expansion of high-yielding varieties of rice and other crops together with subsidies for irrigation and agricultural inputs viz, seeds, fertilizers, irrigation equipment etc. There was a decline in annual average growth rate of the agricultural share to GDP during 10 years from 1980 to 1990 (24.39%) despite a significant annual growth of agricultural

Annual Growth Rate of Agricultural GDP and Food Production		
Period	Annual increase of agricultural GDP (%)	Annual increase of agricultural production (%)
1970-1980	29.13	0.77
1981-1990	24.39	3.74
1991-2000	9.24	3.79
2001-2010	12.30	5.73
2011-2021	18.38	4.20

Source: Data calculated from Fig 2.15

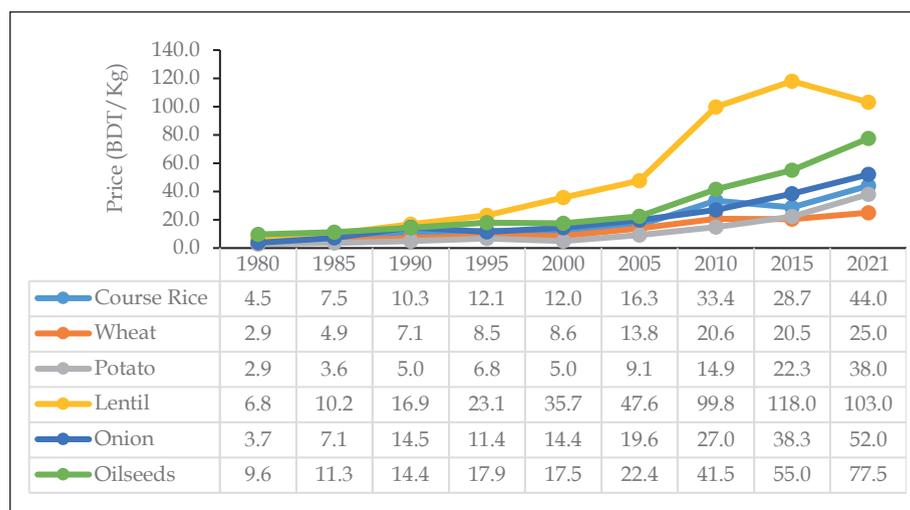


Fig. 2.16. Trend in price (BDT/kg) of major food crops

Source: BBS of different years

production (3.74%) as evident from the same source. This declining annual growth of agricultural GDP could be due to a price fall of agricultural produce. The annual average growth rate of agricultural share again declined up to 12.3% during 2001-2010 despite increasing trend of annual growth of agricultural production (5.73%) primarily due to price reduction of agricultural produce and poor support from Government price regulation. Nonetheless, annual growth of agricultural GDP stood up to 18.38% during 2011-2021 even though the annual increase of agricultural production got down to 4.20% during the same time from the previous period (2001-2010). Price escalation of different agricultural produces over time (Fig. 2.16 and 2.17) coupled with the increase of their production contributed to increasing agricultural share of GDP, especially during 2011-2021. The Government took intensive measures for strengthening agricultural research, extension, education and related areas of agriculture during 2011-2021. Further, the Government took initiatives for regulation and management of market

prices of agricultural products through procurement of food grains after harvest and their distribution through open market sale (OMS) during peaks of market price escalation. This system created favorable market prices of agricultural products reducing large price gaps over a period of time and eventually helped increase the agricultural share of GDP.

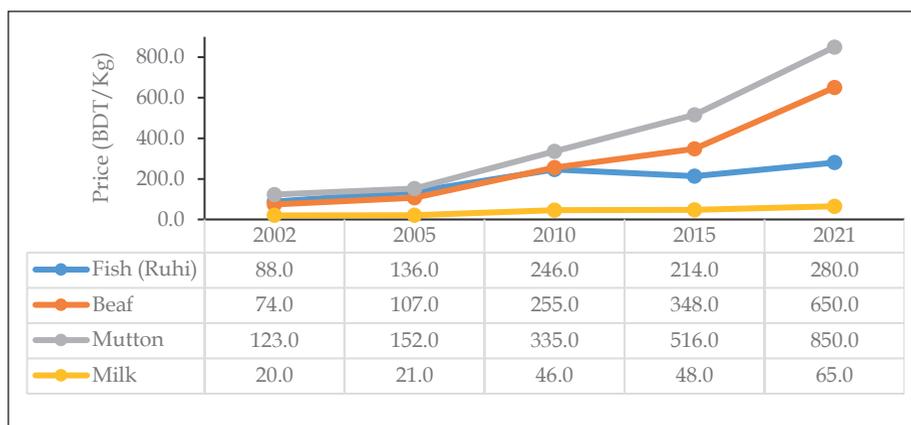


Fig. 2.17. Trend in price (BDT/kg) of major livestock and fisheries products

Source: BBS of different years

Among the agricultural sectors (crops, livestock, fisheries and forestry), the crop sub-sector alone contributed a 57.1% share of agricultural GDP in 2002-03, 56.2% in 2005-06, 58.7% in 2009-10, 54.4% in 2015-16 and 47.2% in 2020-21 followed by the fisheries sub-sector (Table 2.9). The increase in share of GDP by sub-sectors was also substantial as the forestry sub-sector increased by 1009% during 2003 to 2021 (18 years) followed by fisheries (500%), livestock (706%) and crops (406%). The impact of agricultural growth on rural wages is also an important element in the process because of the poor households, a major share of income originates from labor wage in agricultural operations. The crop diversification program, credit, extension and research and input distribution policies pursued by GoB are yielding positive results.

Table 2.9. GDP from agricultural sub-sectors at constant prices (Billion BDT)

Agricultural Sector	2002-03	2005-06	2009-10	2015-16	2020-21
Crop	307	336	625	708	1554
Livestock	67	80	119	141	540
Fisheries	120	133	216	310	720
Forestry	43	49	105	143	477
Total	537	598	1065	1302	3291

Source: BBS 2011, 2021

The livestock and fisheries sub-sectors experienced substantial increase in physical output, as well as favorable prices compared with the crops sub-sector in 2000. Fisheries grew by 7.8% in 2000 but a substantial decline to 4.60% occurred in 2010 and 4.11% in 2021 (Table 2.10). Livestock growth increased at a robust rate of 7.3% in 2000 compared to that in 1973 (5.2%), and then fell in 2010 (2.51%) and 2.94% in 2021. Only the forestry sub-sector grew at a moderate rate of about 4.0% per year till 2000 and continued to grow at a higher rate during 2010 (5.34%) and 2021 (4.98%).

Table 2.10. Long-term growth (percent) of agricultural sub-sectors at constant price

Sector	1973	2000	2010	2021
Agriculture	2.6	3.3	6.55	3.17
Crop and horticulture	1.7	2.5	7.57	2.29
Forestry	3.8	3.8	5.34	4.98
Livestock	5.2	7.3	2.51	2.94
Fisheries	2.3	7.8	4.06	4.11

Source: BBS 1986, 2011, 2021

2.2.2 Growth of agricultural income

Agricultural growth stimulates economic growth in the non-agricultural sectors, too, which, in turn, results in increased employment and reduced poverty. This stimulates demands for agricultural commodities, acting as a growth multiplier in the agricultural sector. The limited availability of new land in Bangladesh, however, means that agricultural intensification as the key to poverty alleviation entails increasing the productivity of land already under cultivation. Agricultural growth shall, in the future, be the sine qua non for alleviation and eradication of rural poverty and hunger in countries that have not yet fully achieved their broad-based growth. This is particularly so in Bangladesh, where the numbers of rural poor - including the land-less and those farming sub-marginal holdings - are so large. Moreover, the small size of most Bangladeshi farm holdings, and the low-income elasticity and high price elasticity of agricultural produce, together dictate that future agricultural growth shall need to diversify beyond its current emphasis of cereals.

During 1970-2021, the annual growth of agricultural income in Bangladesh declined from 5.4% to 3.2% including ups and downs in different periods but showing a negative linear growth while the annual growth of agricultural production increased from 0.77% to 4.20% showing a positive linear growth (Fig. 2.18). After the independence of Bangladesh, an impressive growth rate of annual agricultural income occurred in 1974 (6.4%) primarily due to massive expansion of HYVs of crops and irrigation facilities. This income growth rate then sharply declined to 3.3% each in 1981 and 1986 followed by

a rapid increase in 1990 (9.2%) with a modest annual growth rate of agricultural production (3.74%) and a further decline in 1996 (3.0%). Massive drives in the areas of agricultural research and extension could be a reason for the agricultural growth rate to the peak of 7.4% in 2000 influenced by annual increase of production (3.79%) and 6.2% in 2010 being highly influenced by annual increase of production (5.73%). After a drop to 5.6% in 2006, the country maintained a steady annual growth rate of agricultural income by 3.3% in 2015 and 3.2% in 2021. Since 2010, annual growth of agricultural production strongly correlated with and influenced annual growth of agricultural income as both the linear curves meet each other and progress closely. However, food production from the agricultural sub-sectors did not correlate with the agricultural income until 1990 but after that food production gradually contributed to the growth of agricultural income and became the significant contributor since 2010 (Fig. 2.18). Thus, food production influenced agricultural economy of Bangladesh through contributing to agricultural income.

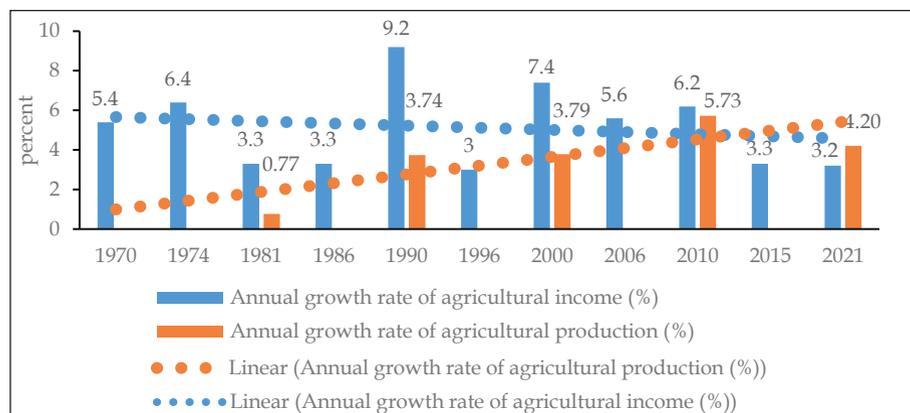


Fig. 2.18. Annual growth rate of agricultural income (%) as affected by annual growth rate of agricultural production

Source: <https://data.worldbank.org/indicator/NV.AGR.TOTL.KN?locations=BD>
BBS of different years

2.2.3 Employment and food security

After independence of Bangladesh, the share of employed agricultural labor force in the total labor force had been initially increasing to 63.5% in 1984 and 69.5% in 1991, and then eventually declining to 64.8% in 2000, 57.2% in 2003, 48.1% in 2006, 47.3% in 2010, 42.7% in 2016 and 37.8% in 2020 (Fig. 2.19). Nonetheless, the share of agriculture labor force has been still higher than that in the non-agricultural sectors e.g., industry and service sectors.

The demand for hired labor increased substantially when the modern rice HYVs were introduced, but over time labor use in rice cultivation has declined with the spread of agricultural mechanization in land preparation,

irrigation and post-harvest processing. However, an impressive development in the rural road network in the 1990s coupled with the increase in marketed surplus of rice, vegetables and fruits has created employment opportunities in transport operation and petty trading. The increase in the numbers of shallow tube wells, pumps, power tillers, rickshaw and rickshaw vans created jobs to look after their operation, repair and maintenance. Many marginal land-owning households with some skills for utilizing capital were able to generate self-employment in livestock and poultry raising, petty trading, and various kinds of personal services with the vast increase in micro-credit supplied by the NGOs.

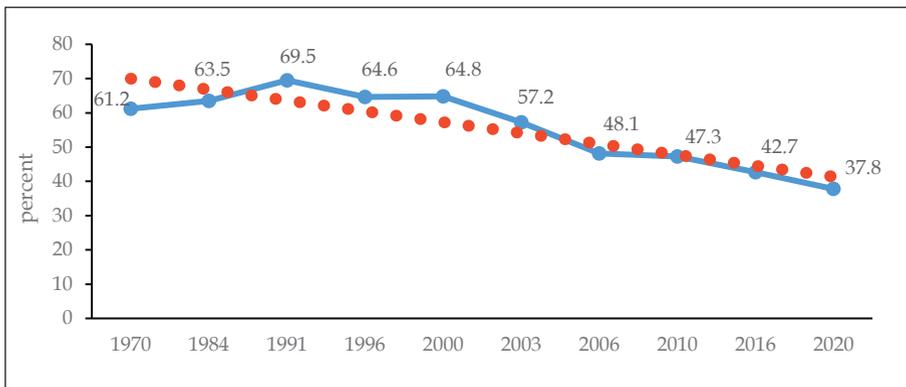


Fig. 2.19. Share (%) of employed agricultural labor force in the total labor force

Source: <https://core.ac.uk/download/pdf/38916062.pdf>

<https://data.worldbank.org/indicator/SL.AGR.EMPL.ZS?locations=BD>

The largest share of all employed persons was still in the agriculture sector ranging from 37.8% (lowest) to 69.5% (highest) during 1984 through 2020 despite declining trend of employed agricultural laborer in recent years (Fig 2.20). The services sector emerged as the second largest sector where the share of employed persons ranged from 16.9% to 40.6%, which was followed by the industries sector with the share ranging from 9.3% to 21.7% during the same period.

Agricultural development has contributed to poverty reduction in an indirect way. Agriculture produces food for the people. The increase in the supply of food faster relative to demands has helped keep food prices within affordable limits of the low-income people which has contributed to achieving food security. The amount of food the poor can buy from the market depends on the price of food. Since the early 1980s the food grain prices have increased at a much slower rate than the general price index, due to favorable growth in agriculture in general and rice production in

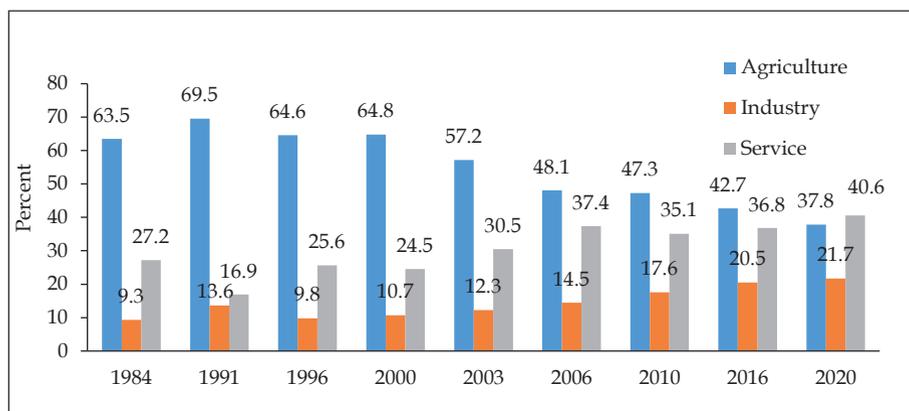


Fig. 2.20. Share (%) of employed labor force in agriculture, services and industries sectors

Source: <https://data.worldbank.org/indicator/SL.AGR.EMPL.ZS?locations=BD>

particular. Large farmers have been hurt by the decline in the real rice price, but the landless have gained. An agricultural wage-laborer could buy 2.43 kg of rice with their daily wage in 1981. The rice-equivalent wage was 5.37 kg in 2010, an increase of 4.16% per year during 1980-2010 while the rice-equivalent wage increased to 9.1 kg in 2021 by 6.9% per year during 2010-2021 (Table 2.11). It was recognized that the growth of rice price would hardly affect the poor, especially in the rural areas as it was also evident from agricultural wage rate and rice price dynamics over time as shown in Table 2.3. The daily nominal wage rate (without food) of agricultural laborers increased from Tk. 13.97 in 1981 to Tk. 400.00 in 2021 implying an annual growth of 69.1% during 40 years. In contrast, the price of coarse rice per kg increased from Tk. 5.74 to Tk. 44.0 during the same period implying annual growth of 16.7%. Given that the average rate of wage rate inflation during the period stood more than 4 times than the real price of rice throughout the period. So, agriculture contributed to maintaining the supply of food at least at a rate at which the demand has been growing, thereby keeping the food prices stable and within affordable limits of low-income households markedly improving their food security situation.

Table 2.11. Changes in the real wage for agricultural workers

Indicator	1981	2010	2021
Wage rate (Tk/day)	13.97	179.83	400.00
Rice price (Tk/kg)	5.74	33.48	44.00
Real wage (kg of rice)	2.43	5.37	9.1

Source: BBS 1986, 2011, 2021

http://fpmu.gov.bd/agridrupal/sites/default/files/12_Paul_Dorosh_Price_Stabalization.doc

2.2.4 Agricultural production and industrial development

Agricultural production has so far greatly contributed to the economic development and wellbeing of the nation. In fact, it can be said that the sector has not only been a major driver of economic growth of the country but also laid the foundation for the country's drive towards industrialization. The share of agricultural production in the country's GDP has declined from its peak at 61.9% in 1975 and 54.6% in 1970 to about 11.6% in 2021 while GDP share from industry increased from 8.7% to 33.3% during the same period (Fig. 2.21). However, the decline of GDP from agricultural sector is otherwise an indicator of the country's progress from an agriculture-based to an export-oriented economy. The contribution of agricultural production to the country's GDP is declining but its absolute value is increasing, and its economic and socio-political significance in terms of export earnings, employment and food security cannot be overlooked.

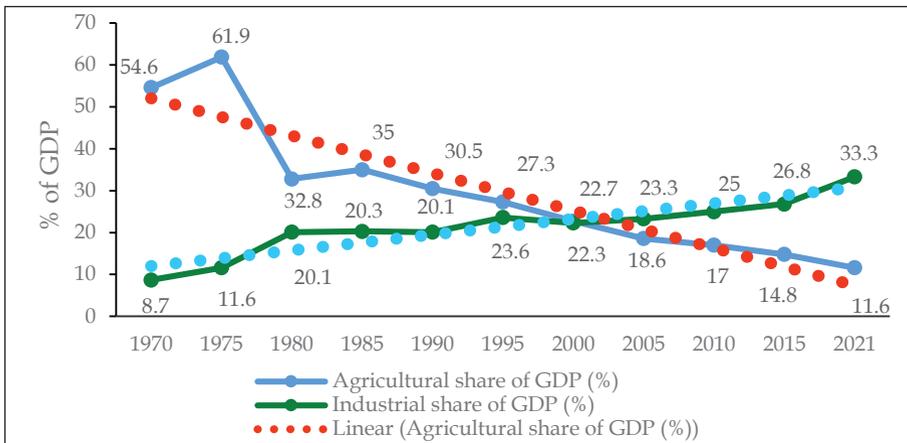


Fig. 2.21. Agricultural share of GDP (%) during 1970-2021

Source: <https://data.worldbank.org/indicator/NV.AGR.TOTL.KN?locations=BD>

The agricultural sectors are the sources of raw materials in the backward and forward linkages for agro-based industries. Except readymade garments, a large part of the manufacturing sector relies on the processing of agricultural commodities (e.g. jute, tea, sugarcane, hides and leather, shrimp, rice and wheat). Some agro-based industries (e.g., jute industry) in Bangladesh fully depend on agricultural output for their raw materials. An important part of the manufacturing sector in Bangladesh is the industry, which now accounts for about 20% of the GDP of the country. About 8.0% of the manufacturing output (1.7% of GDP) is now contributed by the agro-food processing industry.

(Source: <https://www.thefinancialexpress.com.bd/views/agro-food-processing-industry-in-bangladesh-an-overview-1572707863>).

According to FAO, agro-processing involves the transformation of products originating from agriculture, forestry and fisheries. The primary inputs for the industry include crops, poultry and livestock, fishery and some forestry products. This industry now employs about 2.2% of the total workforce of the country. Its share of total exports now stands at around 1.5% while as a part of the manufacturing sector the agro-food processing industry remains closely integrated with the agriculture sector. More importantly, the industry remains at the centre of all economic activities within the complex food system to ensure food supply for the population using mostly the market mechanism.

2.2.5 Agricultural globalization

The agro-food processing industry in the country is primarily dependent on agro products and is heterogeneous in nature with a great diversity in size, technology application, quality of products, processing, preservation and marketing and distributions systems. The agro-processing sector accounted for over 22% of all manufacturing production and employed about 20% of labor forces and accounted for about 2% of the GDP (MoI, 2012). In recent times the agricultural industry of Bangladesh has been increasingly focusing on export markets.

There were nearly 700 processed food-manufacturing enterprises in the country including homemade processing units of which, at least 30 enterprises were processing fruits and vegetables. The food-processing sector included processing of cereals, pulses and oilseeds, bakery and confectionery, fruits and vegetables, dairy, carbonated beverages and noncarbonated fruit juices, drinks, other beverages and various other food items. Bangladesh itself possesses a huge domestic market for processed food. There are currently 479 members in Bangladesh Agro-Processing Association (BAPA) of which 244 are exporters and 235 are manufacturers of agro-processing products. Collectively, members of the association export around \$500 million annually to 144 countries (<http://bapabd.org/>). The major agro-product manufacturing companies are Pran Exports Ltd., Pran Agro Ltd., Pran Foods Ltd., Ibco Food Industries Ltd., Agricultural Marketing Co Ltd., Eurasia Food Processing (So) Ltd., M/s Azmi Foods Ltd., Square Consumer Products Ltd.; Pran Dairy Ltd.; Alin Food Products Ltd. Foreign companies have also showed considerable interest in entering the market through FDIs. Bangladesh is currently exporting its agro-processed products to more than 144 countries in all continents of the world, 81% of the exports going to Asian countries followed by 8% to those of Europe. The major export destination of Bangladesh for her agro-processed products in terms of value was the Kingdom of Saudi Arabia (KSA) followed by United Arab Emirates (UAE) and India. In terms of quantity, India has been the major destination of exports followed by UAE and KSA (file:///C:/Users/user/Downloads/A-

gro-industrial development and sustainability in Bangladesh-As-tudy%20(3).pdf). GoB provides both tax holidays and cash incentives for exporting processed food.

Bangladesh exported agricultural-industrial products worth BDT 282.3 billion in 2021-22 which was 272% increase from BDT 75.8 billion in 2006-07 (Fig. 2.22). This export included different live/frozen and dried products of fisheries and agriculture products, jute and jute goods. The crop sector products consisted of potato, vegetables, pulses, oilseeds, spices, fruits, tea, nuts, seeds, tobacco, dry foods etc. Jute and jute goods, dominated the export consignments. These exports were valued at BDT 112.8 billion in 2021-22 registering a 278% increase over BDT 29.9 billion in 2006-07. The export from agriculture products contributed enormously to its sectoral income by 2,892% increase from 2006-07 (BDT 3.9 billion) to 2021-22 (BDT 116.2 billion). However, the export from fish products remained almost static over these years ranging from BDT 42.1 billion in 2006-07 to BDT 53.3 billion in 2021-22.

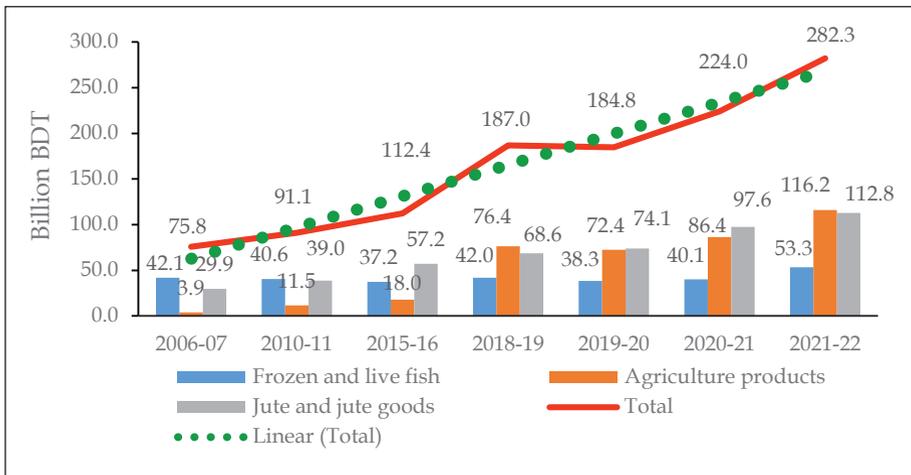


Fig. 2.22. Trend in export of major agricultural products from Bangladesh

Source: BBS 2011 and 2021; Export Promotion Bureau, Bangladesh

(http://epb.gov.bd/site/view/epb_export_data/)

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Chapter 3

Journey from Food Deficit to Food Surplus

Since independence in 1971, food production issue in Bangladesh has been amongst the highest priorities on the government's agenda. Today, as Bangladesh celebrates the Golden Jubilee of Independence, the country can boast major successes in a forward journey away from bleak days of food shortages and abject poverty of the past. Bangladesh now produces enough rice, the staple food, to meet the demands of a population that has more than doubled in the last five decades. There have been manifold increases in the production of vegetables and fruits. The fisheries sector has huge production boom especially from aquaculture. Poultry farms supplying meat and eggs now abound across the country. There is, however, still room for complacency since the desired and targeted level of food and nutrition security is yet to be achieved. Food production and households' access to food in Bangladesh still remain vulnerable due to a number of demographic, socioeconomic and ecological challenges, e.g. soil and river water salinity, arsenic contamination etc. These are complicated further by climate change, including the consequences of a projected sea level rise. While food and nutrition security in its fullest sense is yet to be achieved, major progress has been made and in the case of rice, fish, meat, and egg, the country is self-sufficient. Bangladesh has a vision to graduate to a developed country in another 20 years. Achieving true food and nutrition security for a populace that would surge to some 200 million by that time will be a major challenge and the battle against all odds must be won. Long-term planning based on science and technology and coordinated efforts will be needed to achieve this goal. From this perspective, the Government of Bangladesh (GoB) had taken up a number of policies, including Vision 2021 and the related Perspective Plan recognizing the risks. Achieving food surplus is also a key objective of the country's poverty reduction strategy and has been recognized to be the highest risk identified in the Bangladesh Climate Change Action Plan, 2009.

For agricultural development and boosting food production to achieve self-sufficiency and surplus, Bangladesh took some revolutionary steps for moving from food deficit to food surplus such as:

- a) reinforcing Green Revolution,
- b) innovations in agricultural education, research and extension,
- c) innovations in agricultural input supply systems,
- d) moving ahead from Green Revolution to Gene Revolution and from subsistence farming to commercial farming.

3.1 Green Revolution period in Bangladesh

The Green Revolution ushered in an era of development of crop production technologies comprising high-yielding variety (HYV) seeds, pesticides, fertilizers and irrigation and their dissemination to farmers which resulted in dramatic increases in crop production. Dr Norman E Borlaug dreamt of and led the Green Revolution, a long journey from traditional to technology-based agricultural practices. He started this journey from a solitary wheat field in Mexico in the 1940s. The miraculous semi-dwarf HYV was developed within two decades of rigorous hybridization since 1940 culminating in the Green Revolution harvests in the late 1960s. This promising variety was popularly named as "miracle wheat" for its exceptional yield potential and disease resistance. Taking cue from Dr. Borlaug and using similar research protocols, rice HYVs were soon developed by the scientists of the International Rice Research Institute (IRRI) based in the Philippines. The rice HYVs spread over the countries of south and southeast Asia. The spectacular increases in wheat and rice production in the late 1960s, known as the Green Revolution, brought about a revolution in global food production.

The golden rays of the Green Revolution touched the soil of Bangladesh immediately after its liberation in 1971. The Father of the Nation, Bangabandhu Sheikh Mujibur Rahman, responded to the Green Revolution very quickly and appealed for an agricultural revolution in the new-born country. The Government of Bangabandhu Sheikh Mujibur Rahman gave the top most priority to agricultural development and increasing agricultural production. He took effective policy measures with the slogans "Sabuj Biplab" (Green Revolution) and "*Krishak Banchhe Desh Banchhe*" (the country will survive, if the farmers survive) for modernizing agriculture with accelerated agricultural research and extension to reap the benefits of the Green Revolution. In those initial days of Bangladesh, Bangabandhu's policy priorities paved the way for the transition of Bangladesh from a country of recurrent food shortages to one soon to be a land free from hunger and poverty.

The Green Revolution spread rapidly in the country from the 1970s to the 1980s. Throughout the Green Revolution, agricultural research in Bangladesh primarily focussed on the main crops, rice and wheat. Rice research has been very successful, the annual rice output has increased dramatically. Many HYVs of rice suited to diverse agro-ecological situations have been developed including specialized HYVs tolerant of assorted ecological stresses like salinity, submergence and temperature extremities.

3.1.1 Rice production

Immediately after independence of the country, the main focus of the Government was to increase food production. In this backdrop, the Bangladesh

Rice Research Institute (BIRRI) geared its breeding program to quickly develop rice HYVs with germplasm from home and abroad. Until 1990, BIRRI plant breeders had mainly conducted germplasm evaluation, selection and adaptation trials with exogenous varieties/breeding lines in close collaboration with IRRI and during this period 24 HYVs were released for cultivation in Bangladesh. (Table 3.1). During the period, the most important achievement of BIRRI was the development and release of BR3 and BR11, two mega rice varieties, an all-season rice and a T. Aman rice, respectively. In the mid 1970s, the “miracle rice” IR8 was developed by IRRI and the revolutionary year-round rice variety BR3 (Biplob), developed by BIRRI, brought about the first breakthrough in food production of Bangladesh. It was during this period that the farmers of Bangladesh began to derive benefits of the Green Revolution coming from locally adapted and consumer friendly modern rice varieties and production technologies. The BIRRI soon began to emphasize research on HYV rice and improved production technology development for diverse agro-ecological regions and biotic and abiotic stress situations. The Modern varieties (MV) of rice developed by BIRRI and other organizations of Bangladesh are classified into three broad groups:

MV1: First generation varieties released in the 1970s with high yield but low resistance to insects and diseases.

MV2: Second generation varieties released during 1980s with greater resistance to pests and diseases and better grain quality, without appreciable yield advantage over the first generation.

MV3: Third generation varieties released since 1990 with a higher yield potential than the first generation MVs and also with improved grain quality where possible.

Table 3.1. HYV rice varieties developed by BIRRI and other organizations of Bangladesh during Green Revolution era (1970-1990)

Period	Variety (no.)	BIRRI	BINA
1970-1980	12	Aman season (2): BR10 (Progoti) and BR11 (Mukta). Boro/Aus season (9): BR1 (Chandina), BR2 (Mala), BR3 (Biplob), BR4 (Brishail), BR5 (Dulabhog), BR6, BR7 (BIRRI Balam), BR8 (Asha) and BR9 (Sufola)	Boro season (1): Iratom-24
1981-1990	12	Aus season (2): BR20 (Nijami) and BR21 (Niamot) Aman season (2): BR22 (Kiron) and BR23 (Dishari) Boro season (7): BR12 (Moyna), BR14 (Gazi), BR15 (Mohini), BR16 (Shahibalam), BR17 (Hasi), BR18 (Shahjalal), BR19 (Mongal).	Aman season (1): Binashail
Total (1970-1990)	24	Aus season (2), Aman season (4) and Boro/Aus season (16) = Total 22	Aman season (1) and Boro season (1) = Total 2

Source: BIRRI and BINA website, AIS 2022

Almost half of the varieties released by BRRI for the dry season during the 1970-90 period were in fact advanced lines developed at IRRI or other NARS institutes and found suitable for Bangladesh after multi-location trails under the International Network for Genetic Evaluation of Rice (INGER) program launched by IRRI. However, the crosses for most of the varieties in the wet season were done by BRRI plant breeders. It indicated that for the irrigated ecosystem, a country could depend on an international spillover of technologies (Evenson and Douglas 1997) as good water control made the varieties widely adaptable. However, for the less favourable rain-fed ecosystem, breeding needed to be done locally to take care of location-specific agro-ecological and climatic conditions. Breeders looked for traits other than yield, such as resistance to insects and diseases, grain quality, plant height and growth duration before deciding to release a new variety (Miah 1989). Varieties released in the 1970s had medium resistance to the rice Tungro virus (RTV), but were susceptible to most other diseases and insects. The varieties released in the 1980s had better resistance to the yellow stem borer (YSB) insect and diseases like bacterial leaf blight (BLB) and blast. They also had a mild resistance to the brown plant hopper (PBH) insect and the sheath blight disease (Miah 1989; Shahjahan 1993; BRRI 2003). The highest yielding early variety for the dry season was BR3 which was released in 1973. The yield potential of this variety was surpassed only by BRRI dhan29 developed and released later in 1994 by BRRI, which yielded 7.5 MT/ha on an average in multi-location trials across Bangladesh.

A massive improvement was achieved in irrigation coverage during Bangabandhu's rule (1972-1975), i.e., during the initial stage of the Green Revolution in Bangladesh which provided impetus for the expansion of wetland transplanted rice in the dry winter season (Boro) which eventually contributed most to an increase in the country's rice output. Development of irrigation facilities comprised surface water utilization by low-lift pumps (LLP) and through major surface water irrigation projects, major gravity irrigation schemes, of the Bangladesh Water Development Board (BWDB) some of which were double lift schemes using LLPs. These schemes and projects had been a significant factor in the development and expansion of irrigation in the country. Exploitation of groundwater for irrigation began with the sinking of deep tube wells (DTWs) and shallow tube wells (STWs) in northern Bangladesh in the mid-1960s under the aegis of BWDB and became an important factor due to the expansion of DTWs starting with the Boro season of 1972-73. By the end of 1972, farmers were provided with 40,000 LLPs, 2900 DTWs and 3000 STWs at reduced prices. During three and a half-year rule of Bangabandhu, the number of LLPs increased significantly by 47% to 35,534 (Boro, 1974-75) from 24,243 (Boro, 1971-72) (Fig. 3.1), increase being by an abrupt 36% (32,917) in the very first of this period compared with 24,243 in 1971-72. Similarly, the number of DTWs increased linearly being 906, 1236, 1494 and 2699 in 1971-72, 1972-73, 1973-74 and 1974-75, a 198% over

that in 1971-72 (Fig. 3.2). Bangabandhu also ordered to make the Ganges-Kapotakhkha Irrigation Project work in full swing within eight months in 1973.

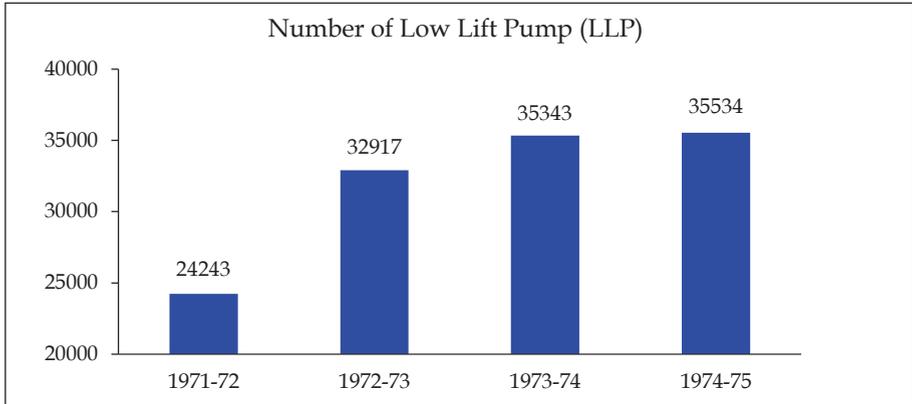


Fig. 3.1. Trend of LLPs provided during Bangabandhu's rule
Source: BBS 1980

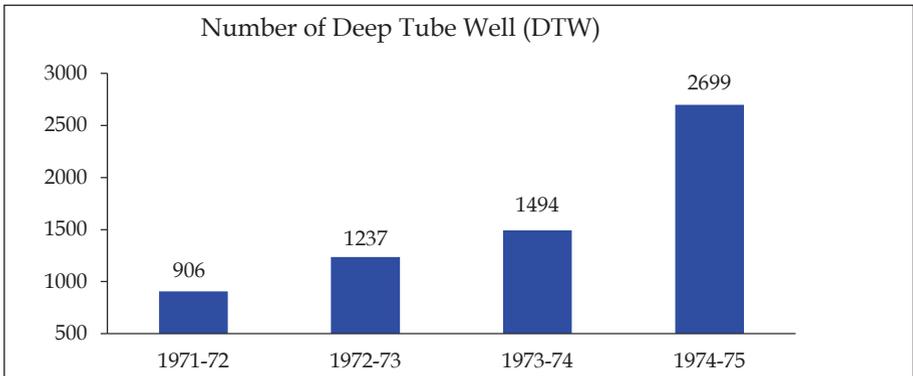


Fig. 3.2. Trend of DTW provided during Bangabandhu's rule
Source: BBS 1980

These initiatives in the development of irrigation facilities taken by Bangabandhu's government bore fruit in terms of irrigation coverage. Irrigated land area under LLPs expanded to 526,521 ha in 1974-75, registering a 47% increase over 357,871 ha in 1971-72 (Fig. 3.3) of which 38% came in only one year (357,871 ha in 1971-72 and 493,428 ha in 1972-73). Similarly, the irrigated area under DTWs increased linearly from 11,874 ha during 1971-72 to 47,714 ha in 1974-75, a 302% increased over that in the base year (1971-72) (Fig. 3.4).

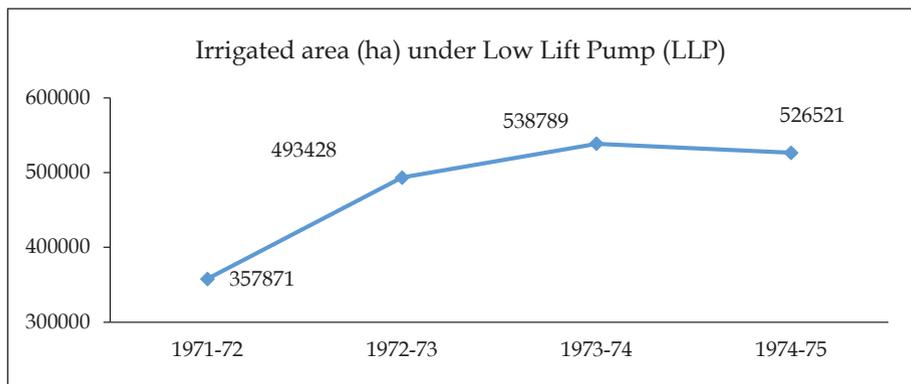


Fig. 3.3. Expansion of irrigated area during Boro season under LLP
Source: BBS 1980

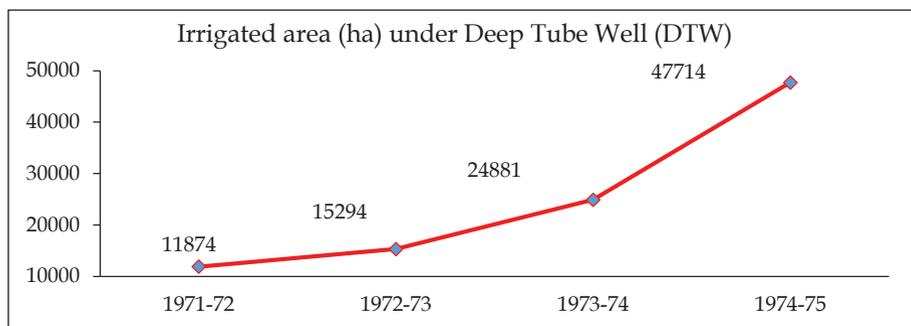


Fig. 3.4. Expansion of irrigated area during Boro season under DTW
Source: BBS 1980

Alongside the development and expansion of irrigation facilities, 17,616 tonnes of HYVs rice, jute and wheat seeds were distributed among the farmers in 1972 alone. Rice farmers were provided with seeds of the HYV IR 8 brought from IRRI, Philippines and wheat farmers with seeds brought from CIMMYT (International Maize and Wheat Improvement Center), Mexico. Bangabandhu was also conscious about the complementary roles of the agricultural and industrial sectors in the overall development of the nation. For example, fertilizers are a critically important agricultural input and so he prioritized the establishment and functioning of fertilizer factories across the country. Besides, Bangabandhu's government ensured a supply of fertilizers to farmers at subsidized prices. These agriculture-friendly steps boosted the use of chemical fertilizers by 70%, pesticides by 40% and HYV seeds by 25%.

Distribution of huge HYV seeds of rice, the staple food of Bangladesh, coupled with expansion of irrigation facilities and fertilizers and pesticides

usage, resulted in a substantial increase in the area and production of HYV Aus, T. Aman and Boro rice during Bangabandhu’s rule. The areas under HYV Aus, T. Aman and Boro rice generally experienced a significant linear rise (Fig. 3.5), the HYV Aus rice area increased by 17 times from 17,000 ha in 1969-70 to 283,000 ha in 1974-75, HYV T. Aman rice area by 42 times from 12,000 ha in 1969-70 to 501,000 ha in 1974-75 and HYV Boro rice area by 2.8 times from 235,000 ha in 1969-70 to 659,000 ha in 1974-75. It is evident that significant increases in areas of HYV Aus, T. Aman and Boro also occurred by 5.8, 1.98 and 2.0 times, respectively in 1974-75 compared with that in 1971-72 (Fig. 3.5).

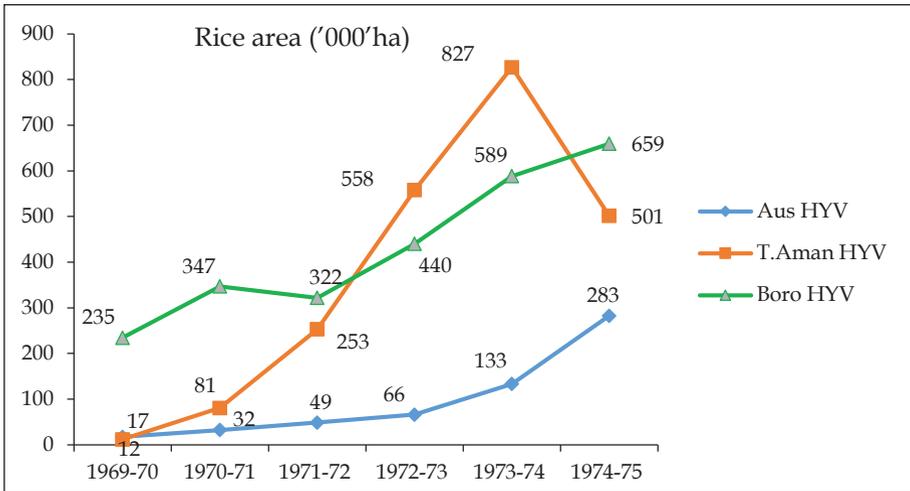


Fig. 3.5. Trend of area coverage (ha) under HYV Aus, T. Aman and Boro rice
Source: BBS 1980

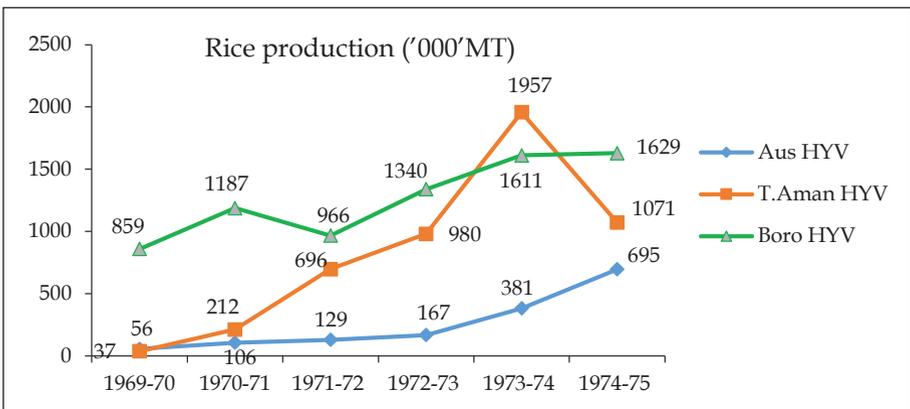


Fig. 3.6. Trend of production (MT) of HYV Aus, T. Aman and Boro rice
Source: BBS 1980

Commensurate with an increase in the area coverage, HYV Aus, T. Aman and Boro rice outputs increased linearly (Fig. 3.6). HYV Aus rice production increased by 12 times from 56,000 MT in 1969-70 to 695,000 MT in 1974-75, HYV T. Aman rice production by 29 times from 37,000 MT in 1969-70 to 10,71,000 MT in 1974-75 and HYV Boro rice production by 1.9 times from 859,000 MT in 1969-70 to 16,29,000 MT in 1974-75. It is evident that significant increases in the production of HYV Aus, T. Aman and Boro occurred by 5.4, 1.5 and 1.7 times, respectively during Banganadhu's rule (Fig. 3.6).

The total HYV rice area also increased by 5.5 times from 264,000 ha in 1969-70 to 14,44,000 ha in 1974-75 (Fig. 3.7) while the total HYV rice production increased by 3.6 times from 953,000 MT in 1969-70 to 33,94,000 MT in 1974-75 (Fig. 3.8). A substantial increment in area (2.3 times) and production (1.9 times) of HYV rice was noticed in 1974-75 when compared to that in 1971-72 (Fig. 3.7 and 3.8). This massive increase in area and production of HYV rice was primarily attributed to the huge distribution of HYV seeds, fertilizers, pesticides, irrigation facilities, etc., by Bangabandhu's government in 1972. Bangladesh experienced a structural shift in its rice production from a largely weather influenced crop to an irrigated crop starting from Bangabandhu's rule.

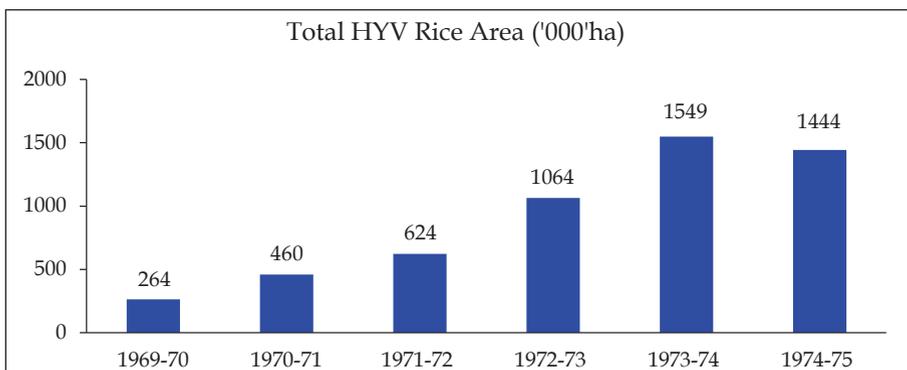


Fig. 3.7. Trend of total HYV rice area
Source: BBS 1980

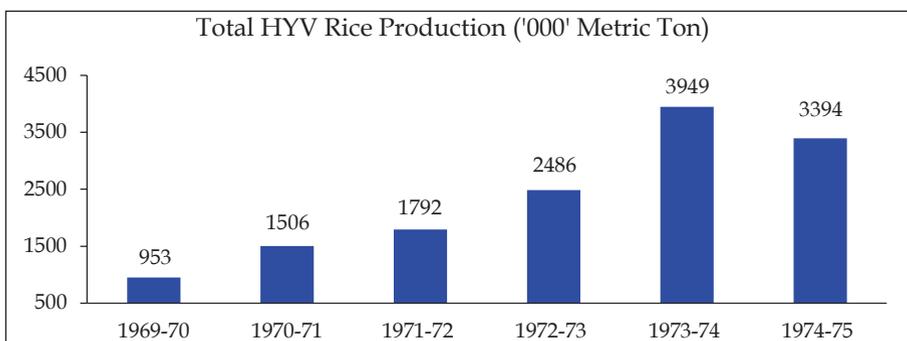


Fig. 3.8. Trend of total HYV rice production
Source: BBS 1980

Bangabandhu's vision of a hunger-free Bangladesh began to take shape with the continuation of his initiatives and programs. The total yearly rice output increased linearly by 1.8 times from 9.93 MMT in 1972-73 to 17.86 MMT in 1989-90 indicating an annual growth rate of 4.44% (Fig. 3.9). In effect, rice deficit had decreased abruptly by 6.9 times from 2.02 MMT in 1972-73 to only 0.29 MMT in 1989-90 considering the total rice consumption of the people (Fig. 3.9). The increasing trend of rice production from 1972-73 to 1989-90 strongly correlated with and contributed to a decreasing trend of rice deficit as the magnitude of rice deficit declined linearly while rice production had a positive trend (Fig. 3.9).

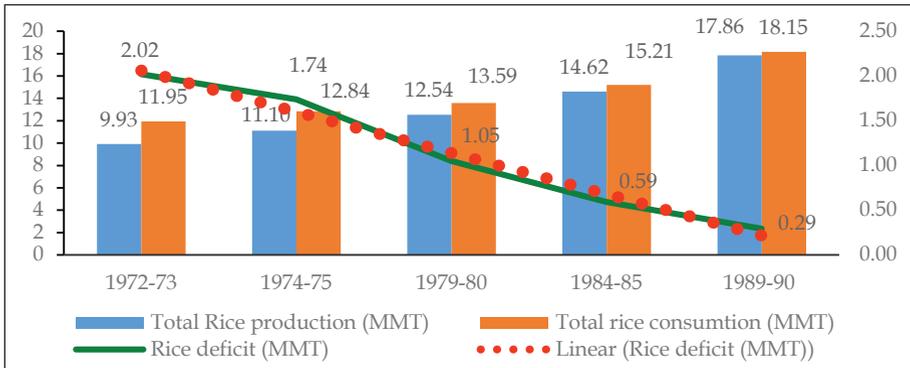


Fig. 3.9. Rice deficit as impacted by the green revolution during 1972-1990

Source: BBS 1980, 1985 and 1990

<https://www.indexmundi.com/agriculture/?country=bd&commodity>

The Green Revolution positively impacted HYV rice production, which in turn contributed to an increase in total rice production. HYV rice production increased linearly by 4.1 times from 2.5 MMT in 1972-73 to 10.3 MMT in 1989-90 while local variety rice production remained almost static ranging from 7.4 to 8.2 MMT during the same period (Fig. 3.10).

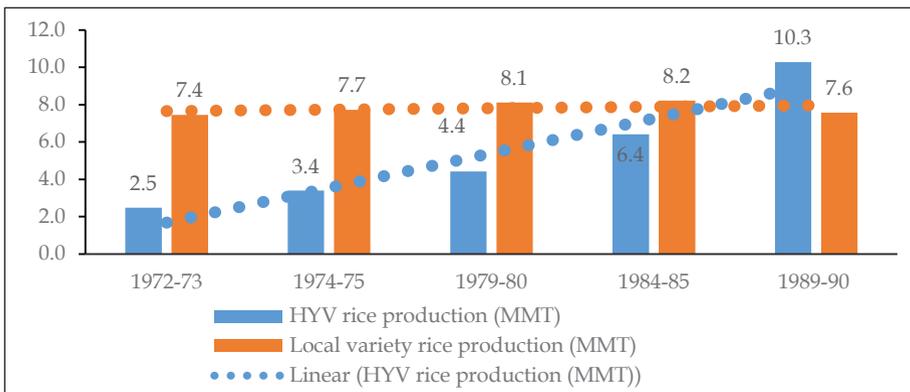


Fig. 3.10. HYV and LV rice production during 1972-1990

Source: BBS 1980, 1985 and 1990

The HYV rice growing area increased from 1.06 million ha (Mha) in 1972-73 to 4.34 Mha in 1989-90 with a total increase of 4.1 times (Fig. 3.11). On the other hand, local rice variety (LV) area decreased linearly from 8.57 to 6.15 Mha during the same period indicating that a massive introduction of HYVs had LV in the rice growing areas. This expansion of HYV rice growing areas eventually helped maintain an increasing trend of total rice areas from 9.63 to 10.48 Mha over the same period and acted as the push factor for increasing total rice production.

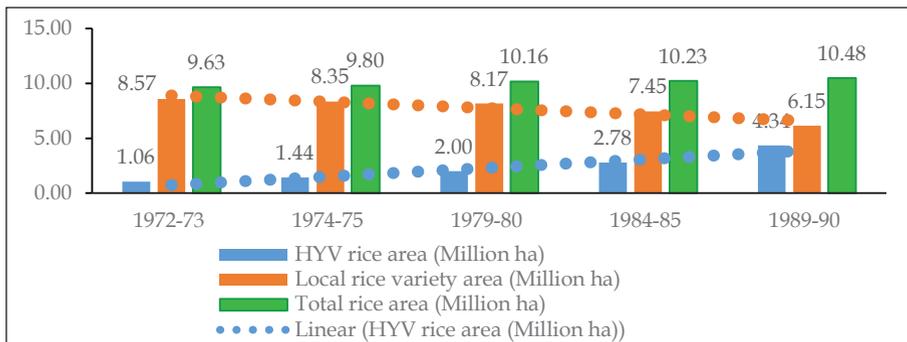


Fig. 3.11. HYV and LV rice area coverage during 1972-1990
Source: BBS 1980, 1985 and 1990

Introduction of HYVs markedly influenced rice yield. HYV rice yield ranged from 2.33 to 2.37 t/ha, much higher than the LV yield level of 0.87 to 1.23 t/ha although the HYV rice yield remained stagnant during 1972-73 through 1989-90 (Fig. 3.12). However, the combined effect of HYV and LV yield was in increasing trend of all-variety rice yield from 1.03 to 1.70 t/ha during the same period which contributed to the total rice production.

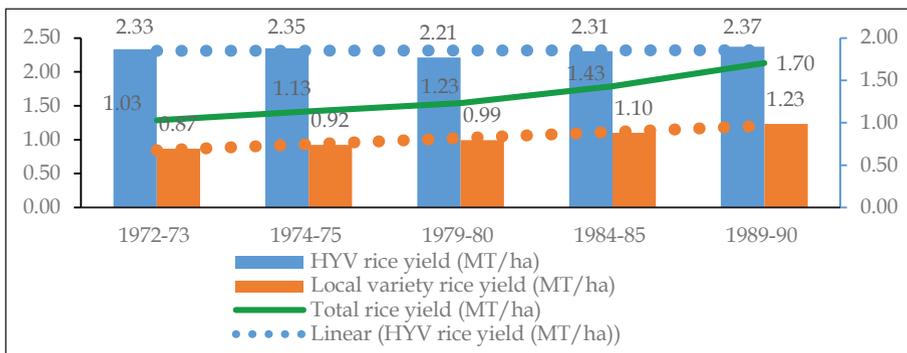


Fig. 3.12. HYV and LV rice yields during 1972-1990
Source: BBS 1980, 1985 and 1990

3.1.2 Wheat production

Several Mexican varieties, especially ‘Sonora 64’ and ‘Kalyansona’, were successfully introduced in collaboration with CIMMYT in the then East Pakistan in late 1960s. During 1970s and 1980s, the Bangladesh Agricultural Research Institute (BARI) developed 17 HYVs of wheat (Table 3.2). After independence of Bangladesh, the release of ‘Sonalika’ in 1972 created a true breakthrough in wheat production during the Green Revolution period. This variety became very popular among wheat growers due to its relatively short duration, high yield (2 MT/ha) and the ability to adapt well to different production environments. Sonalika was adopted in 80% of the wheat area by the early 1980s (WRC 2009). In 1983, the Wheat Research Centre (WRC) of BARI released four more high-yielding (2–3 MT/ha) varieties (Ananda, Kanchan, Barkat and Akbar). Among these, Kanchan proved to be particularly adaptable and gradually replaced ‘Sonalika’ to become the predominant wheat variety in Bangladesh by the early 1990s. The other high-yielding variety, Agrahayani was recommended by the Bangladesh National Seed Board in 1987. This variety was able to grow well in a wide range of weather conditions as well as responded well to fertilizers, irrigation and intercultural operations.

Table 3.2. Wheat varieties developed in Bangladesh during 1970-1990

Period	Variety (no.)	Variety name
1970-1980	10	Mexi-65, Norteno-67, Inia-66, Sonalika, Tanori-71, Jupateco-73, Noori-70, Balaka, Doel, Pavon-76
1981-1990	7	Akbar, Kanchan, Agrahayani, Ananda (BAW 18), Barkat, Seri-82, Nacozari-70

Source: Bangladesh Agricultural Research Institute (BARI) website

Wheat in this country within a decade after independence got the position of the second staple food crop as popular acceptance, its consumption and imports as a food item increased fast. In the wake of the 1974 famine, farmers rapidly increased the area of wheat (Chowdhury 1993). Taking cue from the farmers, government policymakers decided to encourage domestic production, partly to reduce reliance on wheat imports and partly to diversify domestic foodgrain supply away from rice. Efforts to promote wheat production began in the mid-1970s which led to a rapid expansion in the wheat area, much of it concentrated in the northern and western parts of the country.

The wheat deficit decreased by 15.8% from 1.58 MMT in 1972-73 to 1.33 MMT in 1989-90 considering the total wheat consumption of the people (Fig. 3.13) which is strongly correlated with the wheat production trend.

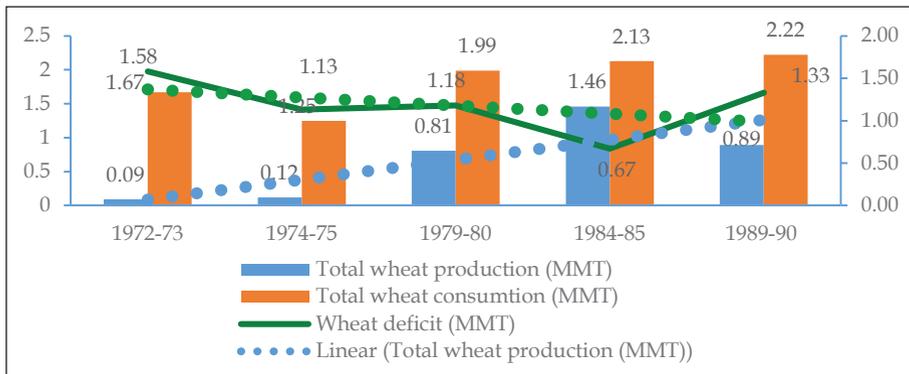


Fig. 3.13. Wheat deficit as impacted by then Green Revolution during 1972-1990

Source: BBS 1980, 1985 and 1990

<https://www.indexmundi.com/agriculture/?country=bd&commodity>

The surge in wheat production was confined to the period from the 1970s to 1980s, coinciding with the government's campaign to promote the crop (Fig. 3.13). This impressive growth later slowed down dramatically during the late 1980s. Although the reasons for the slowdown are still debatable, two factors are frequently cited as having contributed to the deceleration in the expansion of wheat area and the stagnation of wheat yields. Firstly, increased access to irrigation (resulting from government programs to develop irrigation infrastructure) encouraged many wheat growers to divert resources to irrigated Boro rice. Secondly, the late 1980s corresponded to the period when subsidies were removed from many inputs; sudden sharp increases in input prices may have led wheat growers to cut back on their use.

Over the 18-year period (1972-90), the area planted to wheat increased at a rate of 19.7% per year from a small area of 0.13 Mha in 1972-73 to 0.59 Mha in 1989-90 (Fig. 3.14). Wheat yield doubled from 0.71 MT/ha in 1972-73 to 1.50 MT/ha in 1989-90 and having peaked at 2.16 MT/ha in 1984-85 (3.14). After this peak in 1984-85, wheat yield declined but still maintained a positive growth over that in the base year. As one of the world's largest recipients of international food aid in those days, much of which was given in the form of wheat, Bangladesh has been a consistent wheat importer. Although most Bangladeshi consumers exhibit a strong preference for rice, wheat imports have been frequently relied upon to help overcome rice production shortfalls. Wheat is well suited for this purpose because it is reliably available in world markets, often at concessional prices due to chronic overproduction in the major exporting countries. The expansion in wheat area and the growth in wheat yields realized during the late 1970s and early 1980s fueled manifold increases in wheat production and led to a sharp reduction in the level of dependence on imports. This was a clear sign of the impact of HYV wheat

developed during the Green Revolution in Bangladesh on wheat production, which helped reduce food deficit largely, especially in 1984-85 (Fig. 3.13).

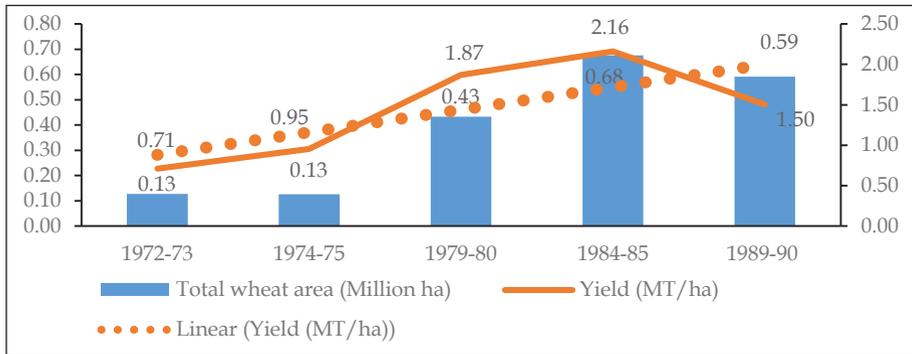


Fig. 3.14. Wheat area coverage and yield during 1972-1990

Source: BBS 1980, 1985 and 1990

3.1.3 Potato and vegetables production

A few varieties of potato (8) and vegetables (11) were developed during 1971-1990. In fact, development of vegetable varieties started only during 1980s, i.e., in the last leg of the Green Revolution era in Bangladesh (Table 3.3). Varietal improvement of potato and vegetables was limited due to lack of facilities in NARS institutes during 1971 to 1980.

Table 3.3. Potato and vegetable varieties developed during 1971-1990

Period	Potato	Vegetables
1971-1980	Total - 3 Mirka, Kronia, Ukama	-
1981-1990	Total - 5 BARI Alu-1 (Hera), BARI Alu-2 (Morene), BARI Alu-3 (Origo) Other - 1 Elivira	Total - 11 Leafy vegetable - 4 BARI Puishak-1 (Chitra), BARI Gimakalmi, BARI Chinashak-1, BARI Batishak-1 Cabbage - 1 BARI Badhacopy-1 (Provati) Brinjal - 1 BARI Begun-1 (Uttara) Tomato - 2 BARI Tomato-1 (Manik), BARI Tomato-2 (Ratan), Aroid - 2 BARI Mukhikachu-1, BARI Panikachu-1 Radish - 1 BARI Mula-1 (Tasaki)
Total (1971-1990)	All varieties - 8	All Varieties - 11

Source: Bangladesh Agricultural Research Institute (BARI) website

Vegetable production including potato increased from 1.43 MMT in 1972-73 to 2.12 MMT in 1989-90 (Fig. 3.15) but had an almost static growth of around 1.6-1.7 MMT during 1972 through 1985 preceding a breakthrough with a sharp increase in 1990. The overall increase was 48.3% with an average annual growth rate of 2.7% over 18 years. In Bangladesh, the recommended per capita daily vegetable intake requirement is 250 g/day (FAO and WHO 2014). Considering this vegetable intake requirement, vegetable (including potato) deficit increased by 52% from 4.65 MMT in 1972-73 to 7.07 MMT in 1989-90 despite an increase in vegetable production (Fig. 3.15). This indicates that the Green Revolution had little impact on the reduction of vegetable deficit as vegetable production could not pace with the intake requirement level. However, the annual vegetable deficit had decreased from 3.2% in 1979-80 to 2.5% in 1989-90.

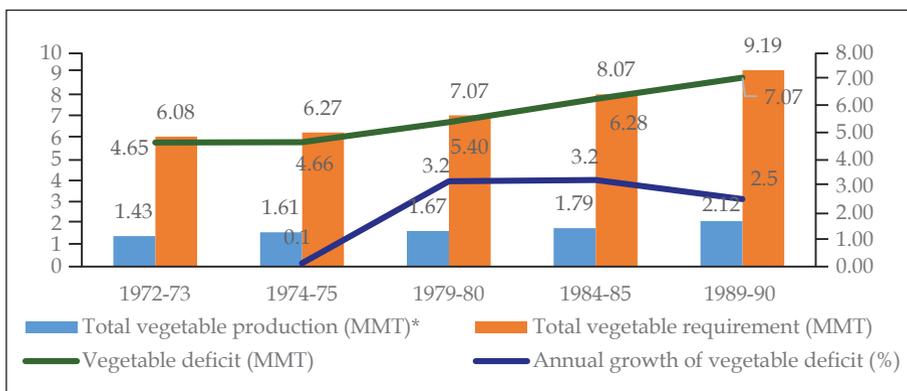


Fig. 3.15. Vegetable (including potato) deficit as impacted by the Green Revolution during 1972-1990

Source: BBS 1980, 1985 and 1990, FAO and WHO (2014)
*includes potato

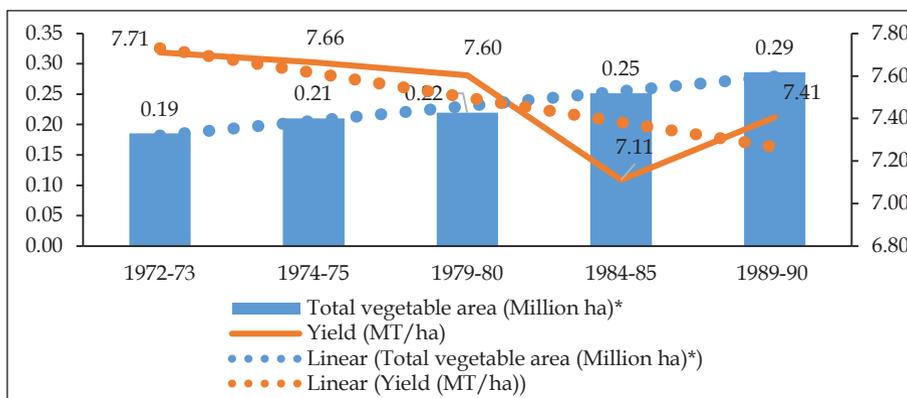


Fig. 3.16. Vegetable (including potato) area coverage and yield during 1972-1990

Source: BBS 1980, 1985 and 1990

Although varietal development of vegetables started in the late 1980s, their area coverage increased by 52.6% from 0.19 Mha in 1972-73 to 0.29 Mha in 1989-90 (Fig.3.16). Vegetable yield decreased by 3.9% from 7.71 MT/ha in 1972-73 to 7.41 MT/ha in 1989-90 with a pitfall in 1984-85 (7.11 MT/ha). During the late 1980s, subsidies were removed from many inputs and the vegetable growers may have cut back on the use of inputs that could have resulted in yield decline.

3.1.4 Pulses and oilseeds

Pulse breeding started in the late 1980s in a low-profile manner. BARI developed only a few pulse and oilseed varieties during 1971-80 and 8 HYVs during 1980-90 (Table 3.4). NARS institutes were able to develop more mungbean (3) than the other pulse crops and develop more mustard varieties among the other species of oilseed crops.

Table 3.4. Pulse and oilseed crop varieties developed in Bangladesh by decade

Period	Pulses	Oilseeds
1971-1980	-	<p>Total - 9</p> <p>Mustard - 5 BARI sarisha-1 (Tori-7), BARI sarisha-2 (Rai-5), BARI sarisha-3, Kalyania (TS-72), Sonalisorisha (SS-75)</p> <p>Groundnut - 2 Maizchar Badam (Dhaka-1), Dhaka-4 (Groundnut),</p> <p>Sesame - 2 T-6 (Sesame), Til-58077 (Sesame)</p>
1981-1990	<p>Total - 5</p> <p>Mungbean - 3 Mubarik (mungbean), BARI mung-1, BARI mung-2,</p> <p>Chickpea - 1 BARI Chola-1</p> <p>Black gram - 1 BARI mash-1</p>	<p>Total - 8</p> <p>Mustard - 1 BARI sarisha-5 (Daulot)</p> <p>Groundnut - 3 BasantiBadam (DG-2), Tridana Badam (DM-1), JhingaBadam</p> <p>Sesame - 1 Shova (GorjonTil),</p> <p>Soybean - 2 Brag (Soyabean), Davis (Soyabean)</p> <p>Other - 1 BARI Tishi-1 (Nila)</p>
Total (1971-1990)	All varieties - 5	All Varieties - 17

Source: Bangladesh Agricultural Research Institute (BARI) website

Pulse production remained static until 1980 with an annual output of about 0.22 MMT but increased thereafter to 0.512 MMT in 1989-90 (Fig. 3.17). The overall increase was 131.7% with an average annual growth rate of 7.31% over 18 years. Nevertheless, pulse deficit increased by 84.9% from 0.994 MMT in 1972-73 to 1.838 MMT in 1989-90 despite increase in pulse production considering the recommended intake requirement (Fig. 3.17). Green Revolution technologies had a little impact on the reduction of pulse deficit although pulse production was positively influenced.

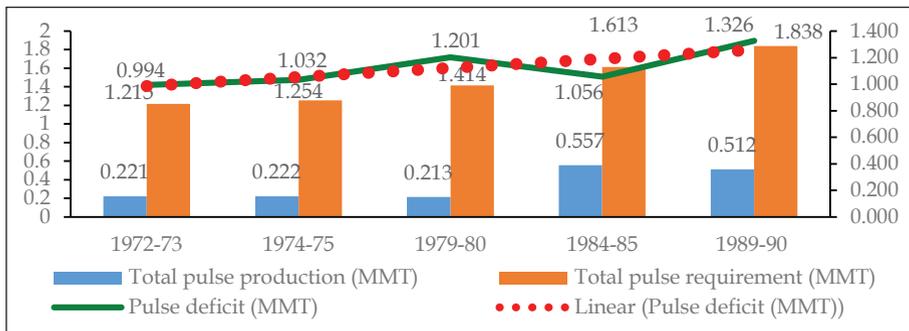


Fig. 3.17. Pulse deficit as impacted by Green Revolution during 1972-1990

Source: BBS 1980, 1985 and 1990, BIRDEM 2013.

<http://www.hortex.org/Avarage%20Per%20capita%20per%20day%20food%20intake%20260813.pdf>

The area coverage of pulse crop increased linearly by 2.38 times from 0.31 Mha in 1972-73 to 0.74 Mha in 1989-90 (Fig.3.18) with a peak of 0.78 Mha in 1984-85 from 0.33 Mha in 1979-80 when BARI pulse breeders started to develop HYVs. However, pulse yield decreased from 0.71 MT/ha in 1972-73 to 0.69 MT/ha in 1989-90 with an all-time low of 0.64 MT/ha in 1979-80 (Fig. 3.18).

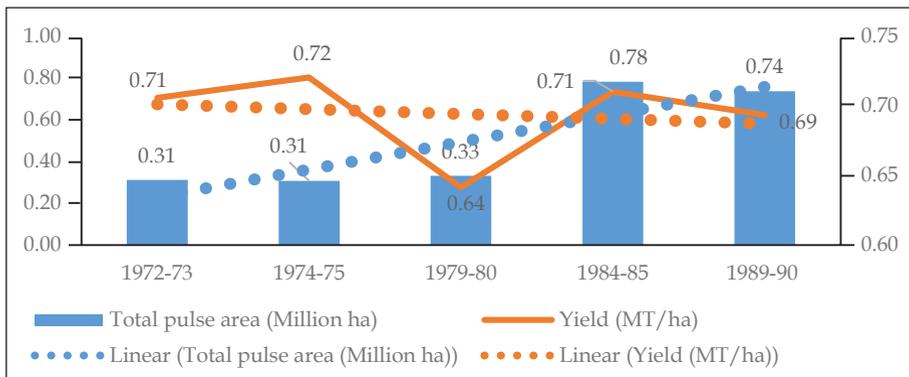


Fig. 3.18. Pulse area coverage and yield during 1972-1990

Source: BBS 1980, 1985 and 1990

This yield decrease accounted for the insignificant increase in pulse production over 18 years from 1972 despite an increase in the area under pulse cultivation. Removal of subsidies from many inputs during the late 1980s may have been major cause of this as farmers were forced to cut back on the use of inputs.

Oilseed production also remained static until 1980 within about 0.23 MMT but increased thereafter to 0.438 MMT in 1989-90 (Fig. 3.19). The overall increase was 92% with an average annual growth rate of 5.1% over 18 years. However, oilseed deficit, considering the recommended intake requirement, increased by 46.4% from 1.96 MMT in 1972-73 to 2.87 MMT in 1989-90 despite an increase in oilseeds production (Fig. 3.19). Therefore, the green revolution did not influence reduction of oilseed deficit although it had impact on their production.

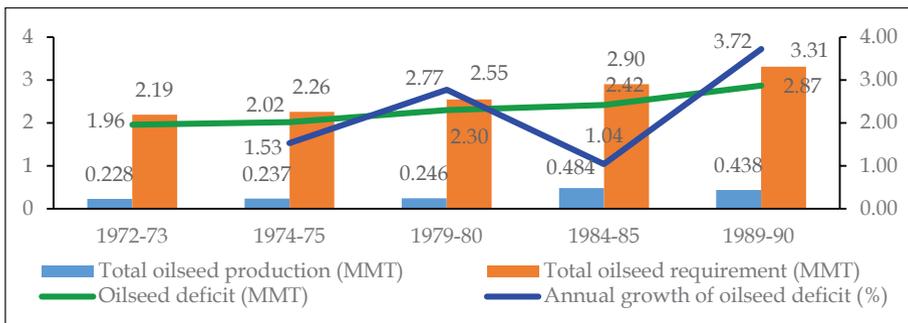


Fig. 3.19. Oilseed deficit as impacted by the green revolution during 1972-1990

Source: BBS 1980, 1985 and 1990, BIRDEM 2013

<http://www.hortex.org/Avarage%20Per%20capita%20per%20day%20food%20intake%20260813.pdf>

The oilseed crop area increased by 1.9 times from 0.301 Mha in 1972-73 to 0.574 Mha in 1989-90 (Fig. 3.20) with a peak of 0.599 Mha in 1984-85. Oilseed crop yield also increased from 0.757 t/ha in 1972-73 to 0.763 t/ha in 1989-90 peaking to 0.809 t/ha in 1984-85 (Fig. 3.20). Increases in both cultivation area

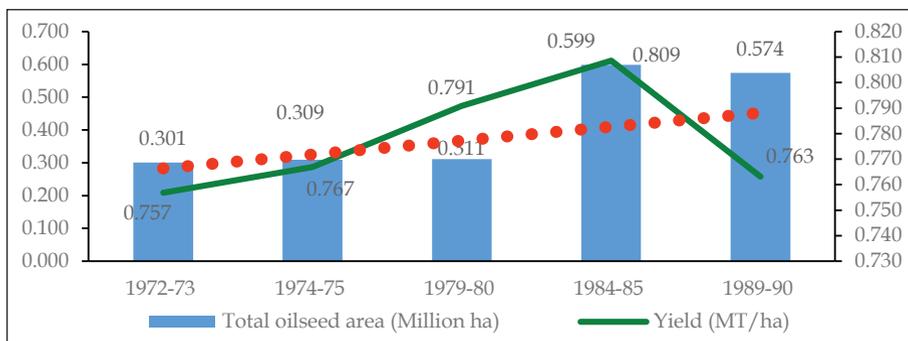


Fig. 3.20. Oilseed area coverage and yield during 1972-1990

Source: BBS 1980, 1985 and 1990

coverage and yield contributed to oilseed production increases over 18 years from 1972.

3.2 Innovations in agricultural research, extension and education

3.2.1 Agricultural research

Structural development

The farmers of Bangladesh, through many generations of practical trials and errors, developed cropping patterns that make the best use of their resources. However, they require new knowledge, skills and resources from modern agricultural research for transforming their traditional agriculture. Agricultural research systems have been developed to fulfill this requirement. On-farm research started in 1957 with fertilizer trials mainly to encourage farmers to use fertilizers (Jabbar and Zainul Abedin 1989). On-farm research on wheat was initiated in 1973 to select location specific varieties. Systems research started in 1974 with trials on cropping patterns and component technologies involving rice and sugarcane. In 1979, a National Coordinated Cropping Systems Research Project (CSRP) was initiated by Bangladesh Agricultural Research Council (BARC) with the participation of several NARS institutes, Bangladesh Agricultural University (BAU) and Bangladesh Water Development Board (BWDB). Experiences gained from CSRP suggested that crops alone could not improve farm productivity to the desired levels. Other components of the farming systems like livestock, poultry, fisheries, and forestry, needed to be integrated to improve the farm production system as a whole. In 1985, CSRP was succeeded by the Farming Systems Research Program (FSRP). The program was expanded to encompass homestead vegetable production, livestock, fisheries and agro-forestry in addition to crops.

Later on, in 1989 FSRP was renamed as the National Coordinated Farming Systems Research and Development (FSRD) Program. In this program, there was a development component comprising technology demonstration, field days and farmers' training by extension service providers including NGOs to expedite the technology transfer process. FSRD has now become an integral part of the research programs of NARS institutes under which a holistic approach integrating commodities and search for intertwined factors is being pursued.

Advances in technology generation have been the main driver of agricultural productivity growth and will remain as the most important factor in the country's efforts to achieve food security and address poverty. Agricultural research has been an important contributor to substantial growth in the production of rice, wheat, potatoes, vegetables, forestry, livestock, poultry,

Structural changes in agricultural research

1973

On-farm research on wheat initiated

1974

Systems research started on cropping pattern and component technologies involving rice and sugarcane

1979

National Coordinated Cropping Systems Research Project (CSRP) initiated

1985

CSRP was succeeded by Farming Systems Research Program (FSRP)

1989

FSRP was renamed as the National Coordinated Farming Systems Research and Development (FSRD) Program

From 1989 to 2020

FSRD became an integral part of research programs across NARS institutes taking into account commodities and interdependence

fish, etc. Many agencies are involved in agricultural R&D in Bangladesh, including agricultural research institutes, universities and other organizations.

Infrastructure development

BARI, the largest agricultural research institutes of the country, was established and developed during two decades following independence in 1971. The journey of BARI began with a skeleton physical infrastructure of old Laboratory buildings in Dhaka and a few research substations at Ishurdi (Pabna), Jashore, Hathazari (Chattogram), Rahmatpur (Barishal) and Jamalpur belonging to the erstwhile Directorate of Agriculture. With financial support of USAID and other international development agencies, BARI established its major laboratories and headquarters at Joydebpur (Gazipur). These international agencies also helped BARI improve physical facilities, laboratories and experimental farms at the BARI HQ and regional stations.

For some years after its establishment, BARI shouldered the responsibility of running the Bangladesh Agricultural Institute (BAI), the oldest agricultural institution in the region for higher education in agriculture, which in later years turned into a university, currently known as the Sher-e-Bangla Agricultural University, situated at Sher-e-Bangla Nagar, Dhaka. In addition, BARI established the Institute of Postgraduate Studies in Agriculture (IPSA) with financial and technical assistance of the Japanese International Cooperation Agency (JICA). The establishment of IPSA, which began independent academic programs at the postgraduate level, was a milestone in

the field of higher agricultural education and research in Bangladesh. JICA provided financial and technical assistance to IPISA to build capacity for basic and applied and adaptive research at the NARS institutes. IPISA brought about a qualitative change in higher agricultural education in Bangladesh by instituting a research-based academic program up to the MS and PhD levels. The major physical infrastructure of IPISA was developed through Japanese Grants-in-Aid, followed by a long-term technical assistance project supported by USAID. A useful partnership was developed between the JICA experts and their Bangladeshi counterparts which contributed substantially to the building of strong leadership in Bangladesh in respect of research planning and implementation in the agricultural research arena of Bangladesh.

In the meantime, BRRI was established at Joydebpur, Gazipur and research facilities and physical infrastructure were developed with foreign development assistance. The Agricultural Research Project (ARP) largely funded by USAID contributed greatly to infrastructure development of BARC, BARI, BRRI, Bangladesh Jute Research Institute (BJRI), Bangladesh Sugarcane Research Institute (BSRI), Bangladesh Livestock Research Institute (BLRI) and Bangladesh Fisheries Research Institute (BFRI).

Human resources development

Understanding the importance of developing manpower as a part of capacity enhancement, NARS institutes invested heavily on training of scientists at different levels despite facing challenges in acquiring resources. IRRI gave formal training on aspects of agricultural research to 1,184 scientists of BRRI and other organizations during 1964 to 2019. It is conceivable that the scientists with their enhanced skills and productivity were critical to scientific advancement and productivity of BRRI.

There were a few scientists (121 in 1981; see chapter 1) having higher degrees (PhD) and scientists with BS degree dominating in most of the NARS institutions during the 1970s and early 1980s. But in 2022, scientists with PhDs dominated as they (709) outnumbered BS degree holders (242). This empowered NARS institutes in terms of knowledge and technical skills. In addition to assistance for PhDs and MS degree programs, international collaboration in various forms supported a good number of researchers to prepare for leadership through training and post-doctoral fellowship programs at various international research centers and overseas universities. In addition, participation of Bangladeshi agricultural scientists in international seminars, symposia, short training courses, study tours, etc. sponsored by international collaborators enabled them to learn from their international peers and share knowledge and experience contributed markedly to an improvement in their research skills and expertise.

Technological advancement

Out of the 135 rice varieties so far released in Bangladesh, BRRI in partnership with IRRI contributed to the development of 99 inbred HYVs and 7 hybrid rice to date. IRRI contributed to the release of about 70 rice varieties by providing at least a parent from the IRRI germplasm resources. The BRRI varieties are being cultivated in about 80% of the total rice area having contributed almost 91% of the total rice output of the country (BRRI 2014).

In the initial years following independence in 1971, Bangladesh received foreign assistance mainly as relief or bilateral commodity aid with little technical assistance. Later on, from the late 1970s, Bangladesh started receiving development assistance in the form of project aid and technical assistance addressing economic development issues including agriculture. Since then, Bangladesh has been receiving development assistance for agriculture mainly from such international agencies as USAID, Canadian International Development Agency (CIDA), Official Development Assistance (ODA) of UK, JICA, European Union (EU), and Australian Agency for International Development (AusAid) through the Australian Centre for International Agricultural Research (ACIAR).

Apart from the formal bilateral or multilateral development assistance programs, an ad-hoc consortium of government and non-government organizations, foreign aid agencies, UN agencies and the Consultative Group for International Agricultural Research (CGIAR) actively collaborate with IARC and NARS institutes in technological advancement. Collaboration between CGIAR centres and NARS institutes apparently constitutes a multilateral assistance providing guidance and technical support promoting technology transfer from developed institutions to developing recipient research institutions of Bangladesh. CGIAR and Bangladesh have had a special type of research collaboration since the mid-1960s (Pray and Anderson 1985). It started in 1966 with the beginning of IRRI's relationship with the Directorate of Agriculture prior to the establishment of BRRI. The number of collaborative crop research projects expanded gradually to include wheat, maize, potato and some pulse and oilseed crops. Important aspects of this collaboration were posting of researchers of international CGIAR research centres such as, IRRI, CIMMYT in Bangladesh to work with local researchers on local problems, organizing training programs for Bangladeshi researchers at the centres, implementing joint programs of germplasm testing and publishing research findings.

Besides generating knowledge and technologies (improved varieties and production practices), BRRI improved its institutional capacity (infrastructure and human resources) while implementing more than 130 projects in partnership with international centres of excellence like IRRI. BRRI's research and developmental activities can be gleaned from the development and release

of 106 modern varieties (MV) of rice and their large-scale cultivation throughout the country. The adoption of MVs has been driven largely by the subsistence demands of households and supplemented with systematic agricultural extension efforts. The small farmers have adopted MVs more readily than the large ones. The privatization of STW irrigation contributed to the country's wide adoption of rice MVs as did the development of infrastructure such as, rural roads, bridges and electrification. However, households in flood-prone and coastal areas were somewhat bypassed where the adoption of MVs so far proved to be difficult.

Bangladeshi farmers have been growing rice as the single most important cereal crop for ages. After the liberation of Bangladesh, wheat began to gain importance as a second staple cereal. The government's initiative to promote wheat got momentum after the famine of 1974. BARI strengthened its wheat research program in collaboration with CIMMYT which provided some core funds. BARI's partnership with CIMMYT contributed to the development and release of 41 varieties of wheat (see chapter 2) making it the second staple cereal crop in the country. Likewise, BARI in partnership with CIMMYT developed and released 27 varieties of maize in Bangladesh establishing it as a major crop for the first time. BARI-CIMMYT collaboration also contributed to the development of improved farm machinery for crop establishment, harvesting and post-harvest operations for wheat and maize. This collaboration helped disseminate modern production technologies for wheat and maize and also triticale as a fodder crop in Bangladesh (Anonymous 2008).

Bangladesh Fisheries Research Institutes (BFRI) has made significant contributions to fisheries and aquaculture development in the country since its establishment in 1984. The institute received grants/loans from various sources including International Development Association (IDA)-World Bank, International Development Research Centre (IDRC), USAID/International Centre for Living Aquatic Resources (ICLARM), ACIAR, International Fund for Agricultural Development (IFAD) to establish research facilities and human resource development. Hilsa research in Bangladesh was initiated with IDRC grants.

Bangladesh Livestock Research Institute (BLRI) has been contributing markedly to livestock and poultry development in the country since 1986. The institute received grants/loans from various sources including JICA, Asian Food and Agriculture Initiative (AFACI), International Livestock Research Institute (ILRI) to establish research facilities and human resource development. JICA funds facilitated poultry research in the country.

3.2.2 Agricultural extension

The history of agricultural extension services in Bangladesh dates back to 1870 during the British colonial rule (Karim et al. 2009; Halim and Kaida

Structural changes in agricultural extension in Bangladesh

1914

Extension work formally initiated through farm demonstration – 1st generation extension.

1947

Provincial Directorate of Agriculture (a. Research and Education; b. Extension and Management) was generated.

1953

VAID project was initiated to establish livestock, fisheries and marketing directorates and various trials/experiments were performed.

1960

Commodity-based extension services followed by green revolution were started – 2nd generation of extension.

1977

Training and Visit (T and V) system was introduced as ‘unified top-down extension approach - 3rd generation of extension’ system.

From the end of 1990’s

Participatory approach gradually replaced the top-down approach of T and V system – 4th generation of extension.

From 2012 to 2022

Farmers Information and Advice Center (FIAC) housed in Union Parishad is operational.

2001). Several departments (e.g., Jute Regulation Department) were established in 1906 and the extension work was formally initiated through farm demonstrations in 1914 (Karim et al. 2009). This period was linked to the 1st generation of extension services in south Asia and is popularly known as ‘colonial agriculture extension’. Many experimental stations were set up by the British-Indian government giving priority to export crops like rubber, jute, tea, cotton, and sugar. Large landowners were the recipients of technical support while small farmers were left out (Uddin 2008). After the independence of India and Pakistan in 1947, the Provincial Directorate of Agriculture (PDA) with a Research and Education wing and an Extension and Management wing was created and the Jute Regulation Department (JRD) was merged with PDA. Various trials/experiments were performed by PDA staff during the 1950s. For example, the VAID (Village Agricultural and Industrial Development) project was initiated in 1953 to establish livestock, fisheries and marketing directorates (Karim et al. 2009). Commodity-based extension services were started in the 1960s which in effect laid the foundation for the present extension system (Karim et al. 2009; Halim and Kaida 2001). This type of extension service is also known as ‘diverse top-down extension’ or ‘2nd generation of extension’ in south Asia.

After the independence of Bangladesh in 1971, the agricultural sector continued to develop and the agricultural extension system was considered for further

reform. The Directorate of Agriculture (Research and Education) was given the responsibility to perform research activities (Karim et al. 2009) and Training and Visit (T and V) system was introduced in 1977 as 'unified top-down extension approach or 3rd generation of extension' system with financial support of World Bank (Uddin 2008). Regular messages were given to groups of farmers through the T and V system for promoting the adoption of 'Green Revolution' technologies.

By the end of the 1990s some weaknesses of the T and V system began to surface, e.g., most of farmers were not covered. Also, T and V activities were hampered due to a lack of financial support from international development partners. The participatory approach to extension gradually replaced the top-down approach of the T and V system because of growing concerns for equity and sustainability. This kind of extension system is also known as 'diverse bottom-up extension' or '4th generation of extension' in south Asia (Uddin 2008). Complying with the National Agriculture Extension Policy (NAEP) 2012 and 2020, DAE has been mobilizing inclusive farmer groups and their apex organizations and linking them with Farmers Information and Advice Center (FIAC) housed in Union Parishad where the field extension personnel provide one stop integrated services for different categories of farmers.

3.2.3 Agricultural education

Agricultural education involves the production of manpower equipped with knowledge and skill in crop cultivation, animal husbandry, forestry, fisheries and allied disciplines (Hossain 1983). Empirical knowledge passes from one farmer to another. Farmers are the primary teachers and researchers who are continually involved in experimenting and evolving new knowledge and technologies for disseminating among the farmers. Innovative farmers usually play role of generating knowledge (Halim and Hossain 1980). The Government of Bangladesh (GoB) provides funds for training and skill development in agriculture, livestock and fisheries to interested persons under 2-3 months long courses at the Youth Development Centers across the country. These training centers are controlled by the Youth Development Ministry. Recently GoB introduced agriculture as a compulsory subject in the course curricula at the secondary level so that the students get some basic orientation about agriculture. One full paper carrying 100 marks (75 marks for theory and 25 for practical) mostly highlights principles of crop production, crop production technologies, poultry and livestock raising practices, poly-culture of major carps and major diseases of agronomic and horticultural crops. Agriculture discipline courses are also available at the intermediate level (post-secondary level) in many colleges. The students enrolling for agricultural science at the intermediate level acquire knowledge broadly on agronomy, soil science, entomology, horticulture, plant diseases and post-harvest technologies.

Agriculture Training Institutes (ATI) have been established in most of the greater districts of Bangladesh. There are about 175 ATIs in the country out of which 15 are under DAE. These institutes offer 4-year diploma courses on agricultural subjects. The diploma holders are recruited by DAE to work as Sub-Assistant Agriculture Officer (SAAO). Likewise, there are two fisheries training institutes in Bangladesh where the students can enroll for 4-year diploma courses in fisheries and aquaculture. The diploma holders from these institutes are employed in the Department of Fisheries (DoF) as Assistant Fisheries Officers (AFO) at the Upazila level. The Bangladesh Open University (BOU) offers the bachelor's degree in agricultural science known as B. Ag through a distance learning program. The Bangladesh Agricultural University (BAU) situated in Mymensingh is the oldest one among the seven public agricultural related universities, which has adequate academic and research facilities with a core group of highly skilled teaching staff for offering high quality agricultural education in Bangladesh. The seven public agricultural related universities (BAU, BSMRAU, CVASU, SAU, SAU Sylhet, HSTU and PSTU) have produced 93,511 graduates including 62,305 Honors, 29,922 MS and 1,284 PhD until 2020 (Source: Data provided by the respective university).

3.3 Innovations in agricultural input supply system

3.3.1 Marketing and distribution

Immediately after independence in 1971, Bangladesh is following a public-sector led growth strategy in all sectors of the economy. In the agriculture sector, Bangladesh Agricultural Development Corporation (BADC) was given monopoly power for the procurement and distribution of subsidized agricultural inputs such as seed, fertilizer, irrigation equipment etc. However, in the 1980s, as part of the Structural Adjustment Programs (SAPs), advocated by the World Bank and IMF, the private sector was allowed to procure and distribute inputs, import food grains and the subsidies were gradually withdrawn. This liberalization and privatization policy of the government was blamed for the adverse effect on the poor and marginal farmers (Titumir and Sarwar 2006). It was claimed that the ultimate beneficiaries of this liberalization policy were the local elites, rich landlords and the multinational companies.

3.3.2 Seed production, quality control and marketing

The seed system in Bangladesh may be classified as traditional or informal, semi-formal and formal. In the informal system, farmers themselves save seeds for the next season from their current season harvest or acquire seeds through informal trade and exchange. In this system quality control measures are informal, inherited from their ancestors and improved from their experience. It is the major source of supply but quality is lower than the

formal system. ARIs, universities and others involved in crop variety development, supply of breeders' seeds to BADC and private sector and NGOs for production of foundation seeds and certified seeds (Razzaque 2007). According to Talukder (2011), 14 private sector companies and NGOs were involved in producing and importing hybrid seeds in Bangladesh. The private sector driven by profit motives is mainly interested to supply and produce hybrid seeds that ensure a higher return on investment for them. In addition, in absence of organized seed producing enterprises within the country many seed traders entered into the market. According to Razzaque (2007) these traders often supply seeds of unknown origin and of unknown quality. Simultaneously multinational companies made easy inroads to the seed business of the country, mostly through importation. These activities are considered a threat to plant genetic resources in Bangladesh agriculture. BADC has also some capacity to provide services to private sector including seed drying, cleaning, grading, storing, germination, moisture and purity test, and training. However, the services are not enough according to the requirement. In case of the distribution system, there are seed dealers of BADC in every union. The dealers buy seeds from BADC and sell them to seed retailers. The retailers then sell them to the farmers.

In accordance with the National Seed Policy (NSP) of 1993 and Seed Rules of 1998, following measures were taken to improve seed quality:

- First, any variety whether imported or domestically developed, must be registered with the National Seed Board (NSB).
- Second, all private dealers involved with seed import, registering new seed variety and packaging seeds in labelled containers, must be registered.
- Finally, all varieties of seed must be certified by the Seed Certification Agency (SCA).

A field survey (Hossain and Jaim, 2009) revealed that farmers used Bangladeshi MV seeds of rice in about two-thirds (64%) of rice fields, Indian MV seeds in about 10% fields hybrid seeds were used in less than 2% fields. On the other hand, LV rice seeds were used by about a quarter (24.36% of the rice farmers. In the case of Bangladeshi MV, the main source of seed was found to be own harvest (52%) followed by BADC/DAE (25%), neighbors (14%), dealers (9%), etc. Therefore, Government sources like BADC/DAE have an important role in supplying MV seeds to the farmers.

3.3.3 Fertilizer marketing and distribution

The supply of fertilizers used to be completely controlled by public sector organizations until the 1970s. The system was known as the Old Marketing System (OMS). Policy instruments used under this monopoly system were fertilizer subsidy, regulated trade and controlled prices. The OMS was considered to be inefficient and unsuccessful. So, the New Marketing System

(NMS) was set up in around 1977-78. The implementation of the privatization policy under the NMS began in the early 1980s (Ahmed 1995, Ahmed et al. 2000). The Subsidies on fertilizers were withdrawn completely by 6 December, 1992 and the fertilizer trade was privatized, the import and distribution of fertilizers were entrusted with the private sector.

Prior to 2007, fertilizers were sold and distributed by some 4,500 dealers registered with the Bangladesh Chemical Industries Corporation (BCIC). In order to make the fertilizer distribution system easier and fruitful, GoB appointed some sub-dealers at the union level all over the country in 2007. The Government also introduced a system called the slip system and allotment slips were issued to the farmers by the chairman, members and SAAOs of DAE in their respective unions. The slips system allotments were discriminatory because some farmers managed to collect more slips and so got more fertilizers. Thus, some others were deprived of getting required amount of fertilizers as they were not accessible to the allottees of slips. GoB then introduced a new system in Boro 2009 season, where SAAOs conducted household surveys and prepared 'Farmers Registers' with data of each household including their cultivating crops and areas by season. In addition, each household has been provided with a printed 'Fertilizer Distribution Card' with records of their crops and cultivation area by season. Fertilizer distribution was made on the basis of information recorded and recommendations of the SAAOs. On the day of distribution each farmer was obliged to go to dealers' shops where SAAO checks into the 'Fertilizer Distribution Card' and farmer's 'Fertilizer Distribution Register' lying with the dealer and gives allotment of fertilizers to the farmers on the spot. The new system is more objective than the previous systems; farmers cannot purchase fertilizer in excess of their requirements. The prices were fixed by the Government and selling fertilizer outside the union was prohibited.

Although the mechanism greatly facilitated the availability of fertilizer to all farmers, the system is time consuming and may be expensive too. The farmers have still expressed their aversion to the system as they are required to spend a long time in the registering process. Farmers prefer to purchase fertilizers from the open market. In the above circumstances, the fertilizer distribution system was again changed. According to the current distribution system of fertilizers, the distribution systems for urea and non-urea fertilizers are different. There are fertilizer dealers in every union of the country (one dealer for each union). The dealers buy urea at fixed Government prices from BCIC. There are quotas for the dealers regarding the quantity of urea they can buy. Then they sell the urea to sub-dealers according to their requirements. There is one sub-dealer in one ward (nine for each union). The sub-dealers then sell urea to the farmers. There is no fixed quota or quantity for selling urea to the farmers but the price is fixed by the Government. Some other traders/retailers also buy urea from the dealers and sell in the open market. In the case

of other fertilizers, the dealers buy fertilizers from the open market and sell them to sub-dealers and retailers. The sub-dealers/retailers sell fertilizer to the farmers in the open market at market price. There has not been any reported fertilizer crisis after introduction of the open market system.

3.3.4 Irrigation

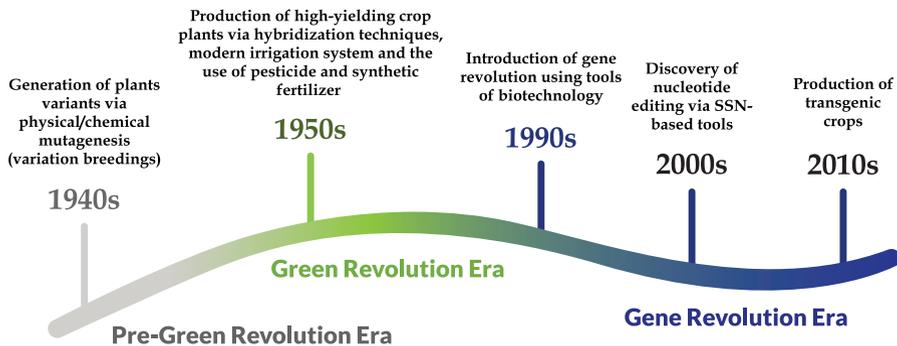
The adoption of Green Revolution technologies in Bangladesh necessitated the development and expansion of irrigation facilities to ensure adequate water supply for crops. Initially, large irrigation systems were established in south-western, northern and north-eastern Bangladesh (for example the Ganges-Kobadak Irrigation Project). Minor irrigation was spread gradually all over the country. The Thana Irrigation Project (TIP) of GoB and BADC's own program initially LLPs for surface water irrigation and DTWs for groundwater irrigation. Thereafter STWs to exploit groundwater for irrigation were adopted which rapidly spread across the country in the irrigated areas. DTWs and LLPs were rented out seasonally to cooperatives and a variety of informal farmers' groups with relatively low rental charges, involving substantial subsidy. DTWs were installed in response to demands by farmers groups after site inspection by BADC, and rented on an annual basis to the group. STWs were sold to private individuals or groups at prices which contained virtually no subsidy but they were provided with subsidized credit from nationalized banks subject to controls on their installation at a site sanctioned by BADC. In the first five-year plan (1973-1977) after the independence of the country, the state heavily invested in irrigation facility in order to increase the production of modern variety of rice. In the late 1970s and early 1980s the Boro rice production grew considerably due to various projects to support sale of STW and to a lesser extent DTW (Palmer-Jones 1992). During the early years of Bangladesh BADC selected technologies, imported standardized equipment, and regulated its location in the fields. The operation of all types of irrigation equipment including private STWs was subject to regulatory control by BADC. Thus, the BADC handled the procurement, marketing and distribution of irrigation equipment in Bangladesh until extensive changes in agricultural input sector took place.

3.4 The turning point

3.4.1 From Green Revolution to Gene Revolution

In the 1970s and 1980s, for instance, the insect pest, BPH (Brown Leaf Hopper), which carries the grassy stunt virus, caused widespread damage to IR8 rice in Bangladesh. As a result, poor farmers, who are necessarily risk minimizers, were very reasonably reluctant to adopt varieties that were so vulnerable. Combating such vulnerability required frequent applications of pesticides at high doses with potential human health and environmental hazards. In the 1990s there was a realization that the traditional breeding

methods, which had been the basis of the Green Revolution, were nearing their capacity to deliver breakthroughs in crop production. Yield growth had slowed due to groundwater exhaustion, micronutrient depletion and buildup of pests to which conventional plant breeding had no answer. Crop scientist began to observe the impacts of biotechnology, where micro-biological techniques were used to manipulate crop characteristics in the 1990s. This heralded a R&D paradigm shift from the 'Green Revolution' to the 'Gene Revolution'. The journey from the Green Revolution to Gene Revolution is sketched below:



The Green Revolution varieties had characteristics that were inappropriate for some ecosystems. In Bangladesh, for instance, there are regions that are flooded to a considerable depth every year. Here a long stemmed, or even a floating variety, is better adapted than a short-stature HYV. Also, some Green Revolution varieties were unacceptable to the consumer because they did not mill or cook satisfactorily.

In 1990, the Bangladesh Association for Plant Tissue Culture (BAPTC) was formed which organized several international conferences since its inception. In September 1993, GoB formed a National Committee on Biotechnology Product Development to select potential biotechnological projects which could be leased out for commercialization. In collaboration with BAPTC, the Ministry of Science and Technology organized a workshop on Biosafety Regulation in 1997, after which a task force was formed to formulate biosafety guidelines and biosafety regulations in the light of the regulation of the workshop. In the late 1990s, Bangladesh became a member of the International Centre for Genetic Engineering and Biotechnology (ICGEB). In 1999, the National Institute of Biotechnology was established as the center of excellence in biotechnological education (Chaturvedi 2004). To accelerate multidimensional biotechnological research, GoB adopted the national policy guidelines on biotechnology in 2006 which was approved by the National Task force on biotechnology (Bdnews24.com 2013). In 2012, the cabinet approved the draft of the National Biotechnology Policy, 2012 which aimed at eradicating poverty through increasing productivity in agriculture and industrial sectors (The Financial Express 2013, BSS 2013).

Genetic engineering in crops

Genetically modified (GM) crops and foods have been a strongly debated issue over the last few years in Bangladesh. This issue surfaced for the first time drawing the attention of the Bangladeshi people following an agreement between Monsanto and Grameen Bank in 1998. On 30th October 2013, GoB through a gazette notification approved the cultivation of GM crops which made Bangladesh the first nation in south Asia with the legality of growing a GM food crop (Ahmed 2013). The promoters of GM crops or foods argue that, Bangladesh's population is increasing rapidly but cultivable land is decreasing, agriculture is also threatened by adverse impacts of climate change (i.e., salinity, drought, flood, storm), insect and disease infestation where high-yielding, stress tolerant GM crops could be a useful tool to meet increasing demands for food.

The first GM crop in Bangladesh, a brinjal crop, (BARI Bt Brinjal-1), was released to farmers in 2013 (Ahmed 2013), and with this, Bangladesh became the 29th nation to grow a GM crop. Thereafter in the same year (2013) BARI Bt Brinjal-2, BARI Bt Brinjal-3 and BARI Bt Brinjal-4 were released following approval from the GoB biosafety regulator. In keeping with the growing interest of smallholder farmers in Bangladesh, BARI produced breeder seeds of varieties namely BARI Bt begun-1 (Bt Uttara); BARI Bt begun-2 (Bt Kajla); BARI Bt begun-3 (Bt Nayantara); BARI Bt begun-4 (Bt Iswardi or ISD006). In total, BARI produced 90 kg of breeder seeds in 2014-15, 875 kg in 2015-16 and around 1,500 kg in 2016-17 (ISAAA 2016). The vegetable has been modified to be resistant to its most common pest, fruit and shoot borers, which have the potential of destroying 50-70% of a brinjal crop (Ahmed 2013). In order to control the late blight (LB) disease, BARI's Tuber Crop Research Center (TCRC) has developed a late blight resistant (LBR) potato variety namely BARI Potato-8 popularly known as Diamant by introducing RB gene sourced from *Solanum bulbocastanum* in 2007. BARI conducted backcrossing, contained and confined multi-location field trials of LBR potato over the last several years (Rashid et al. 2020). The BARI has developed some banana varieties viz., BARI Kola-1, 2, 3, 4 using tools of biotechnology. Research on leaf curl resistant tomato, shoot and fruit borer resistant brinjal and pulse crops, is going on (BARI website).

On the other hand, BRRI in collaboration with BSMRAU released the first biotech rice BRRI dhan62 which is a zinc enriched variety in 2013. Later, in 2017, BRRI released the biotech variety BRRI dhan86 using another culture technology. BRRI has released three other biotech HYVs viz., BRRI dhan87, BRRI dhan89 and BRRI dhan92. Through molecular marker assisted backcrossing method bacterial blight resistance genes pyramided BRRI dhan29 rice lines have been developed. Efficient *Agrobacterium*-mediated genetic transformation protocol was established for Bangladeshi rice

genotypes resulting in the development of some salt tolerant putative transgenic rice lines. Gene cloning work has also been initiated at BRRI and already one salt tolerant gene PVAI has been cloned from a wild rice. Biotechnological research is ongoing at BRRI to develop anti-oxidant enriched black rice and low glycaemic index (GI) rice for human health benefits (Haque et al, 2019). Meanwhile, scientists of BRRI reported that on completion of a successful experiment with the genetically engineered “Golden Rice” at its transgenic screen house, they very recently initiated confined field trials of biotech rice GR-2 E BRRI dhan29. As follow-up steps, open-field and multi-location trials will be conducted, paving the way for the last stage of the process for its release to farmers. Along with two other rice varieties, IR-64, a variety developed by IRRI and RC-28, a Filipino variety, BRRI dhan29, one of Bangladesh's most productive mega rice varieties, has been genetically engineered to produce beta carotene (also known as pro-vitamin A). This has been widely publicized as Golden Rice for its yellowish color. Consumption of only 150 g of Golden Rice a day is expected to supply half of the recommended daily intake (RDA) of vitamin A for an adult (Haque et al. 2019).

Since its inception in 1971, BINA has so far released 9 improved varieties of rice through the induced mutation technique. Of the 9 varieties ‘Iratom-24’ and ‘Iratom-38’ were developed by irradiating the seeds of the rice variety IR 8 and released by NSB in 1974 for Boro and Aus seasons. The mutated characteristics of these varieties are shorter crop duration, resistance against bacterial leaf blight (BLB) and medium fine grains. ‘Binasail’ was also developed by irradiating the seeds of ‘Naizersail’ and released in 1987 for the T. Aman season with mutated characters like long panicles, a greater number of grains, medium fine grains with higher weight, early maturing with photo-insensitivity and higher grain and straw yields. ‘Binadhan-4’ for Aman, and ‘Binadhan-5’ and ‘Binadhan-6’ for Boro season have been developed by irradiating F2 seeds of the parents ‘BR-4’ and ‘Iratom-38’ and released in 1998. ‘Binadhan-7’ was developed from M3 seeds of the cv. ‘Tai Nguen’ of Vietnam. This variety was released in 2007 for Aman season with earliness, long fine grain and high yield. Early maturing character of this variety helps escape drought and insect attack during flowering and dough stages. Moreover, it helps increase cropping intensity by facilitating timely cultivation of the following winter crops. ‘Binadhan-9’ was developed by hybridizing between the local cv. ‘Kaloziira’ and an exotic mutant line Y-1281. It was released in 2012 for Aman season and also can be grown in Boro season. Unlike the parent ‘Kaloziira’ it has short duration, long and slender grains with slight aroma (Azad et al. 2012). NARS institutes have been working on major biotic and abiotic stresses, and contributing towards food self-sufficiency.

Genetic engineering in the livestock sector

In animal biotechnology, the BLRI and BAU have initiated modern biotechnology programs. These include embryo transfer technology, multiple ovulation embryo transfer and artificial insemination program. But, the program of animal gene transfer through genetic engineering technique has yet to be started. However, livestock biotechnology produced 11 types of veterinary biologics for the treatment of infectious diseases in livestock and poultry, vaccines for foot and mouth disease and pest. Biotechnology in fisheries induces spawning in carp, pabda, catfish, koi and others. With this technology 50,000 kg of different fish species can be produced annually (Zaman 2012).

Hybrid breeding

Concentrations have been focused onto the following cases-

- BLRI cattle breed-1
- Improvement of Red Chittagong cattle, Goyal and Buffalo by selective breeding
- Selective breeding of Black Bengal Goat
- Open nucleus breeding system (ONBS).

Marker assisted breeding

The idea behind marker assisted selection is that there may be genes with significant effects that may be targeted specifically in selection. Some traits are controlled by single genes (e.g. hair color) but most traits of economic importance are quantitative traits that most likely are controlled by a fairly large number of genes. However, some of these genes might have a larger effect.

Resistance against disease

Several vaccines have been developed locally or have been improved for local varieties. For example:

- Foot and mouth disease vaccine
- NDV4HR for poultry disease Ranikhet
- Antiserum Antibiotic against Goat and Sheep plague/PPR (Pests des Petits Ruminants)
- Vaccine against Goat Pox (capripox)
- Mastitis vaccine
- Black quarter (BQ) vaccine
- Hemorrhagic septicaemia (HS)

Myiasis molecular characterization or diagnosis has been successful in-

- H1N1/ avian influenza virus of duck and hen by post mortem data by PCR
- Phylogenetic analysis of HPA1 virus isolates
- ELISA based technique to diagnose Foot Mouth Disease (FMD).

Poultry hybrid

Intensive poultry farming techniques have not yet been fully adopted. Thus, efforts have been made for developing a breed or strain suitable for scavenging and semi-scavenging systems of rearing. Of the six distinct types of pure native chicken, native Naked Neck, native Dwarf and Hilly were found to have better production potentialities than others. Among different combinations of native and exotic chickens, RIR x Fayoumi, NN x RIR and NN x Fayoumi had better performances under semi-scavenging conditions. In all cases productivity under scavenging conditions was lower than under intensive systems largely due to poor nutrition. Supplemental feeds, especially protein sources increased the productivity of scavenging and semi-scavenging chicken.

Genetic engineering in the fisheries sector

- Development of improved rohu fish (*Labeo rohito*) stock through cross breeding among the broods collected from noturoj stock of different river systems. This cross-bred rohu is 17% higher growth performer than the existing stock.
- Development and production of BFRI super GIFT tilapia which is 49% higher and BFRI Rajputi which is 30% higher than that of the existing stocks of the respective fish population.
- Development of induced breeding and seed production techniques of six endangered species of corps viz. *Labeo bolo*, *Puntlus sorono*, *Chlrhlnus rebo*, *L. cofbosu*, *L. gonlo* and *Torpufitoro* and five species of catfish viz, *Mystus seengola*, *Ompok pobdo*, *Myslus cavosius*, *Heteropneustes fossilis* and *Ctorius botrochus*.
- New pure stocks of Thai pongosius (*Pongosius hypophtholmus*) and Thoi koi (*Anobos testudineus*) have been imported from Thailand and are being reared under stock development program. Research for development of pure line of these species has been in progress.

There are concerns over the inadvertent effects, such as the creation of food that can cause an allergic reaction, GM that can cause harmful genetic effects, and genes moving from one species to another that is not genetically engineered. It has been shown that GM crop plants can pass the beneficial gene along to a wild population. An example is the sunflower genetically-engineered to fend off certain insects. They were observed to have transferred the gene to their weedy relatives. Nature is an extremely complex interrelated chain. Some scientists believe that introducing genetically-modified genes may have an irreversible effect with consequences yet unknown.

Genome editing technology

In the late twentieth century, advances in biotechnology, hybridization, mutation, and transgenic technologies paved the way toward developing

genetically improved crop varieties. These technologies, combined with improved agronomic practices, significantly enhanced crop productivity in the last 5–6 decades. By the mid-1990s, genome modification via mutation and transgenic breeding approaches and transformation technologies improved plant traits and generated high-yielding crop varieties. Transgenic breeding for resistance to insects and herbicides has been widely adopted. Although transgenic varieties have significantly reduced insecticides' application (insect-resistant varieties) and soil tillage (herbicide-resistant varieties), they need vigilant supervision to limit the natural selection of insect pests and weeds with tolerance to the engineered traits. In addition, issues related to cost, efficiency, bioethics, regulation, and public acceptability of genetically modified plants have limited applying these techniques in crops (Mackelprang and Lemaux 2020). Therefore, these technologies may not be sufficient to meet increasing food demand; indeed, the UN recently stated that it would be harder to achieve SDG2 by 2030 if the world does not change its strategy regarding crop improvement and development. In this regard, recent advances in genome editing technologies, mainly the CRISPR-Cas technology, make the targeted and precise genetic manipulation of crops more feasible and accelerate the transition toward precision breeding for crop improvement (Ahmad et al. 2020).

Bangladesh's rice scientists pursued frontier science–genome editing (commonly referred to as gene editing) to gain different stress and disease-tolerant traits in a short period of time, thereby increasing the productivity of some of the existing best rice breeds. Scientists of BRRI have attained early success in developing some of the country's first-generation gene-edited rice lines, which are expected to effectively fight against diseases like blast, insect-like brown planthopper (BPH) and the climatic stress of high salinity. Together with the problem of salinity, fungal disease blast and insect BPH, are the key factors holding back Bangladesh from achieving further growth in rice yields. By applying the CRISPR/Cas9 tool, BRRI scientists have identified and extracted a few targeted genes from some of its most productive rice varieties in pursuit of gaining new traits, which will effectively fight against blast, BPH and salinity. CRISPR/Cas9 is a unique technology that enables scientists to edit parts of the genome by removing, adding or altering sections of the DNA sequence. Bangladesh needs to understand that pursuing a conservative approach, as the country does in the case of GM technology (genetic modification), would be counterproductive if applied in the case of gene-editing technology. Gene editing has been applied in some of Bangladesh's most productive rice varieties i.e., BRRI dhan28, BRRI dhan63, BRRI dhan67, BRRI dhan81 and Bangabandhu dhan100 (<https://www.dhakatribune.com/bangladesh/2021/12/18/rice-sciences-graduation-to-gene-editing-technology>).

3.4.2 Subsistence to Commercial Farming

Most agricultural production in Bangladesh is characterized as traditional subsistence farming. Bangladesh produces a variety of agricultural products such as rice, wheat, corn, legumes, fruits, vegetables, meat, fish, seafood, and dairy products. Rice is the main staple food in the Bangladeshi diet. Lack of arable land and limited natural resources increases the importance of developing new agricultural technologies, such as salt tolerant or submergence tolerant crop varieties, to help increase productivity and meet future demand. Floods, cyclones, and biotic-abiotic stress can also affect agricultural productivity levels and incomes. With the introduction of modern technologies and provision of various support from the government authorities, agricultural production system in many developing countries is turning to be a commercialized system. In Bangladesh also agricultural production system has gradually been transforming from subsistence farming to commercial agriculture (Razzaque and Hossain 2007). It is observed that the importance of traditional cash crops such as jute, sugarcane, tobacco, etc. has been diminishing to the farmers of Bangladesh over time. Considering their opportunities, farmers are now turning towards food crops like rice, wheat, fruits and vegetables for commercial production and for gaining more profit (Razzaque and Hossain 2007). Commercialization of agriculture can be achieved by promotion of value addition to agricultural commodities, particularly horticultural and dairy products which supports to agri-businesses and links farmers with local and international markets (World Bank 2009). National Agricultural Technology Project (NATP) of BARC funded by WB and IFAD, integrates small and marginal farmers who produce rice, maize, fruits, vegetables, livestock, fisheries, etc., into value chains, so that farmers can produce more products to meet the domestic demand and can export some portion of their products in other countries in the world (MoA 2014).

Commercial vegetable farming

Farmers who are engaged in the production of vegetables often earn higher incomes than those engaged in the production of cereal crops alone. Vegetables like eggplant, radish, cabbage, cauliflower, tomato and pumpkin gave returns at least three times higher than rice (Ateng 1998). In addition, the economic returns in terms of domestic resource cost at export parity also indicate that there is a comparative advantage in the production of vegetables in Bangladesh (Shahabuddin and Dorosh 2002). For instance, pumpkin, cauliflower and tomato cultivation areas have increased incredibly by 274%, 320% and 269% from 8,000, 5,400 and 8,000 ha in 1974-75 to 29,900, 22,700 and 29,500 ha in 2020-21, respectively (Fig. 3.21). This huge expansion of cultivation area demonstrates that pumpkin, cauliflower and tomato growers have shifted their subsistence farming to commercial farming. It is

particularly evident from 2014-15 when the area coverage of each vegetable raised to the maximum level closer to that in 2020-21 (Fig. 3.21).

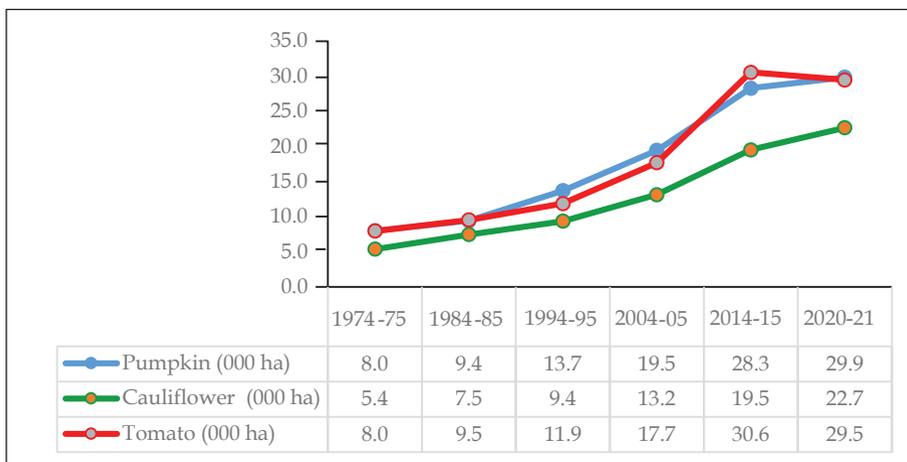


Fig. 3.21. Growth of pumpkin, cauliflower and tomato during 1974-2021

Source: BBS 1980, 1985, 1997, 2005, 2015 and 2021

Commercial fruit orchards

The high-return investment in fruit orchards has attracted many people in Bangladesh, who are now moving away from the traditional subsistence growing of fruits to commercial farming. For instance, mango and jackfruit cultivation areas have increased abruptly by 363% and 98% from 25,055 and 9,145 ha in 2004-2005 to 116,123 and 18,068 ha in 2020-21, respectively (Fig. 3.22). This huge expansion of mango and jackfruit cultivation areas have

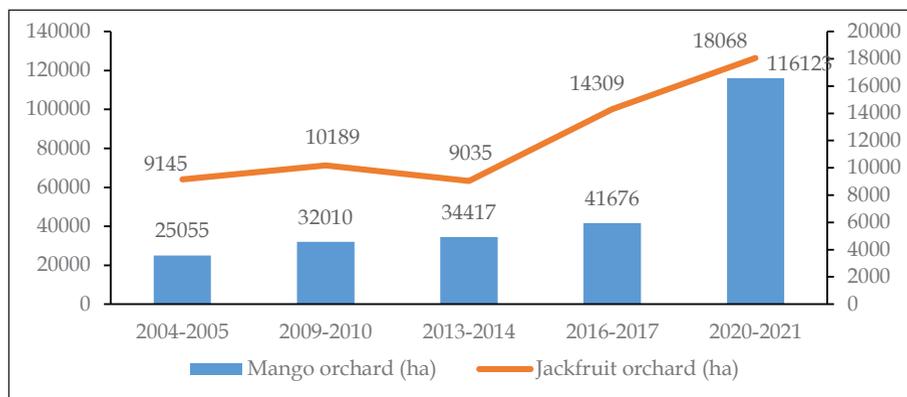


Fig. 3.22. Growth of mango and jackfruit orchards during 2004-2021

Source: BBS 2011, 2015, 2017 and 2021

made the respective farmers shift from subsistence farming to commercial farming. It particularly happened between 2017 and 2021 when the area coverage of each fruit orchard raised to a maximum level in 2020-21 (Fig. 3.22).

Commercial poultry farm

Historically, backyard farming provided the sole source of chicken meat and eggs in Bangladesh. Chickens are reared to meet family demands and productivity level was low. The modernization of the poultry sector started around 1960 with the import of modern breeds and equipment and improvement of marketing systems. From that point onwards, the Bangladeshi poultry sector gradually shifted towards a commercial industry (Rahman et al. 2017).

Before 2000, commercial broiler and layer farms were dependent on imported parent stock (PS). At the beginning of the new millennium, several local companies started their parent and grandparent (GP) operations to meet the country's demand. The most commonly available broiler strains are Cobb 500, Ross 308, Indian River, Tiger Sasso, Hubbard and Arbor Acres, whereas the most reared layer strains are Novogen Brown/White, Hyline Brown/White, Shaver 579, ISA Brown/White and Bovine White (Hamid et al 2017). Starting from the 1990s, the poultry sector experienced a significant growth of approximately 15-20% annually, until the outbreak of AI in 2007. In 2007-2008, 60% of the poultry farms and 70% of the hatcheries and breeding farms were closed due to this outbreak (Mamun 2009).

Poultry industry includes both the layer farms and broiler farms in the country. Large numbers of farms in different sizes are operating all over the country. The poultry industry was hit by bird flu in 2007, 2009 and 2011. The number of firms reduced to 55,000 in 2010 from 1,47,000 in 2007 due to outbreak of diseases along with some other problems (Fig. 3.23).

The transition towards efficiency can be derived from Fig. 3.23, which displays a significant decline in the number of commercial farms after the outbreak before it went up to the peak of 150,000 in 2017 and then to 110,000 in 2021. Table 3.5 confirms the transition towards more efficiency; the number of commercial hatcheries had declined after the flu outbreak, whilst production increased.

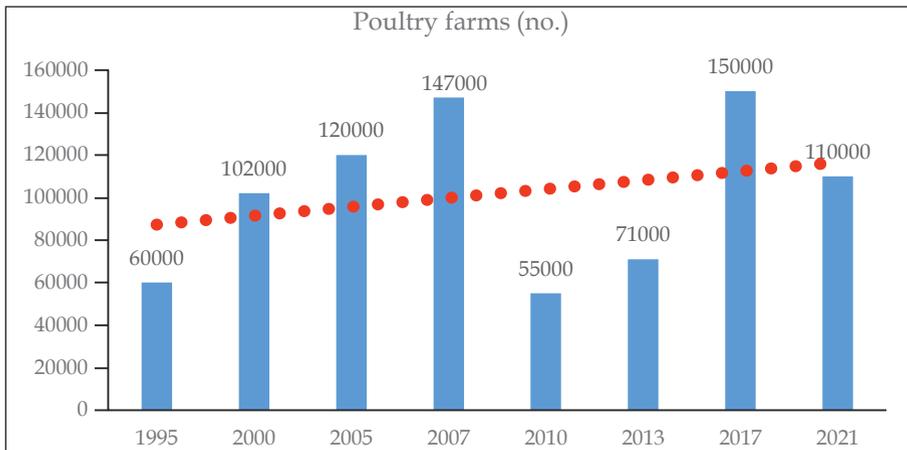


Fig. 3.23. Growth of commercial poultry farms in Bangladesh during 1995-2021

Source: DLS 2013, Hamid et al 2017

<https://www.tbsnews.net/economy/poultry-growth-data-odds-reality-294226>

<https://www.onehealthpoultry.org/where-we-work/bangladesh/poultry-in-bangladesh/>

https://en.wikipedia.org/wiki/Poultry_farming_in_Bangladesh

Table 3.5. Growth of commercial poultry industry during 1984-2011

Description	1984-85	1991-92	2000-02	2003-04	2004-05	2005-06	2008-09	2010-11
No. of hatcheries	2	6	130	130	130	130	80	84
Broiler parent stock (x 1,000)	5	30	1,550	1,990	2,454	3,225	3,128	3,374
Day old broilers per year (x 1,000)	600	3,540	126,000	186,264	237,432	301,912	297,200	320,500
Broiler meat production per year (x1,000 MT)	0.48	4.54	170	217	276	320	297	320
Layer parent stock (x 1,000)	2	22	236	345	212	400	609	1,523
Day old layers per year (x 1,000)	160	2,025	21,240	30,960	19,080	25,380	42,600	106,600
Egg production (x 1,000,000)	48	610	3,430	4,780	5,623	5,422	5,653	6,078

Source: Kabir, 2013

Along with transformations in the commercial poultry sector, backyard poultry rearing is similarly subject to significant changes. Backyard farming is associated with more high yielding breeds and crossbreeds such as Sonali and Deshi. The Sonali is a cross-breed of Rhode Island Red cocks and Fayoumi hens and has a similar phenotypic appearance to that of local chickens. Deshi

chicken is the free ranged, naturally hatched traditional/rural backyard scavenging local chicken (i.e. no professional breeder farms and hatcheries). The backyard sector is gradually transforming from traditional family (subsistence) farming towards more professional farming practices that involve more capital, productivity and profitability (Rahman et al. 2017).

Dairy and goat farms

The majority of the dairy cattle farms in the country are private which can be categorized into five different groups:

a) Dairying for home consumption

The large and medium size farmers keep 1-3 cows to meet primarily their household demand for milk products, and the surplus being sold in the local market.

b) Rearing of cows for dual purposes (draught and milk)

Households depending mainly on draft power for cultivation usually keep 2-6 cows including both bulls and dairy cows and often have to use their dairy cows for ploughing. During the off season when cows are free from agricultural farm use, they produce milk which is usually sold in the market. However, ploughing by draft power has almost gone off.

c) Small-scale dairy farming

The small and medium sized households with financial and technical support from the government, NGOs and cooperatives manage to rear 2-5 cows. They usually sell all their milk and milk products in the market.

d) Medium sized commercial dairy farming

The medium sized household receiving mostly government incentives or cooperative support established dairy farms where they usually rear 6-25 cows for market sale of milk and milk products.

e) Private large commercial dairy farms

These commercial operations establish modern dairy farms and keep 26+ cows (Halder and Barua 2003).

Many people in Bangladesh are now moving away from the traditional subsistence farming of livestock to commercial farming. For example, number of dairy and goat farms increased abruptly by 1542 times and 2.7 times from 227 in 1979-80 and 104,200 in 1997-98 to 350,000 and 281,000 in 2019-20 and 2009-10 respectively (Fig. 3.24). There is a colossal expansion of dairy farms in Bangladesh over 40 years since 1980. Due to huge expansion of dairy and goat farms, the country has been achieving self-sufficiency in milk and meat

production. It particularly happened between 2010 and 2020 when the number of dairy and goat farms raised to a maximum level (Fig. 3.24).

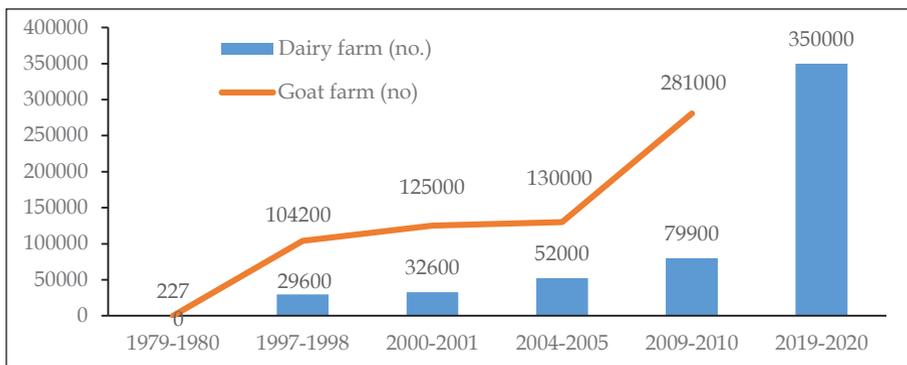


Fig. 3.24. Growth of commercial dairy and goat farms in Bangladesh 1979-2020

Source: https://www.researchgate.net/publication/292624109_Role_of_private_sector_in_the_development_of_dairy_industry_in_Bangladesh
<https://archive.dhakatribune.com/business/2020/03/25/coronavirus-dairy-farmers-seek-govt-immediate-support>

Pond fish farming has been proved to be a more profitable business than rice cultivation. So, many farmers in rural areas are converting their rice fields into fish ponds. Many pond fish farmers in rural areas have taken fish farming activities as their secondary occupation and most of the people involved in fish farming improved their socio-economic condition through pond fish farming. Due to the expansion of pond fish farming, the commercial nursery farms have been growing tremendously to support the demands of fish farmers for fry/fingerlings. Especially, most of the people of southern area of Bangladesh are directly engaged with commercial fish farming or fish farming related business. Khulna, Barisal, Bagerhat and Satkhira. are considered as the best places for commercial fish farming in Bangladesh. For example, the number of fish nursery farms increased linearly by 57% from 8,824 in 2008 to 13,885 in 2015 (Fig. 3.25). This expansion of nursery farms triggered production fish fry with a massive increase from 6239 million in 2008 to 9617 million in 2020, the growth was 54% over 12 years (4.5%/year). Due to huge expansion of nursery farms and thereby fry production, the country has been achieving self-sufficiency in fish production.

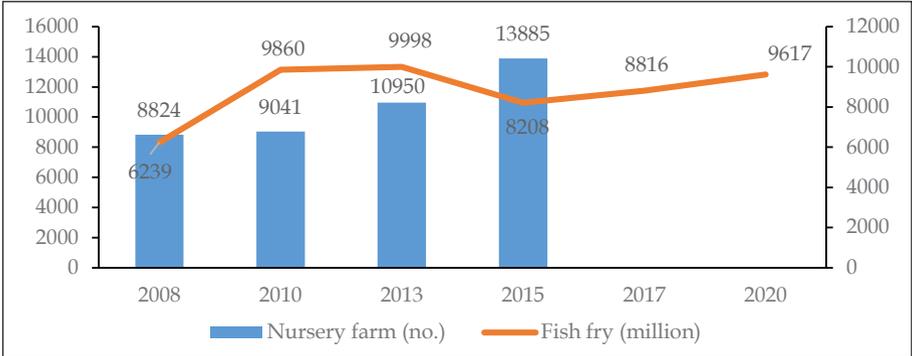


Fig. 3.25. Growth of commercial fish nursery farms and fry production during 2008-2020

Source: DoF 2010, 2015 and 2020

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Chapter 4

Trend in Agricultural Production towards Food Surplus

The use of modern production technologies comprising high-yielding varieties (HYV), fertilizers, irrigation and pest management since the Green Revolution days has accelerated agricultural development in Bangladesh over the past decades. The Green Revolution paved the way to technological progress in Bangladesh agriculture as evidenced by the release of many HYVs of various crops and plant breeding techniques transforming gradually from conventional breeding to genetic engineering. The NARS institutes, agricultural universities, NGOs, private enterprises, etc., have been the major drivers of this technological advancement. Agricultural extension organizations in Bangladesh are mainly responsible for technology transfer contributing to increased agricultural production in a journey towards food surplus. Technological information usually flows from researchers to extension agents and from extension agents to farmers in one direction and from farmers to extension agents and then to the researchers in the opposite.

The Government's agricultural extension organizations viz, i) Department of Agricultural Extension (DAE), ii) Department of Livestock Services (DLS), iii) Department of Fisheries (DoF), and iv) Forest Department (FD) are mainly involved in technology transfer. The principal public organization involved in selling HYV seeds, fertilizers, irrigation inputs, etc., is the Bangladesh Agricultural Development Corporation (BADDC), and nonetheless the private sector is also playing good role in this respect. These organizations and enterprises are contributing largely to increasing the production of crops, livestock, poultry, fisheries and forestry through information, technology transfer, input distribution, market chain development, etc. This chapter presents the trend of agricultural production over the years which shows the country's steady march from food deficit to food surplus.

4.1 Crop production trend

4.1.1 Rice

Food crops alone account for about 75% of the total agricultural output. Rice is the major crop that covers most of the total cropped area and accounts for the lion's share of the value of total crop output. Wheat, maize, potato, vegetables, pulses and oilseeds are the other principal food crops. In fact, the entire growth in food grain production towards achieving a food surplus can

be explained by the growth in the rice area coverage and production. The total yearly rice production has increased by 3.8 times from 9.93 MMT in 1972 to 37.6 MMT in 2021 indicating an annual growth rate of 5.57% (Fig. 4.1), which surpassed that in the green revolution era (annual growth rate 4.44% as shown in Chapter 3). Due to an increase in population, rice consumption has increased by 2.53 times from 12.06 MMT in 1972 to 30.05 MMT in 2021. Today, Bangladesh stands out as the 3rd largest producer of rice in the world. The country has become self-sufficient in rice since 2000 and accumulated surpluses in rice grain in 2005 by 0.37 MMT to in 2021 by 7.55 MMT (Fig. 4.1). The increasing trend of rice production during 1972 to 2021 correlated well with increasing trend of rice grain surplus since 2000, which came up from the decreasing trend of rice deficit from 1972 to 1995 and reached zero deficit in 2000 (Fig. 4.1).

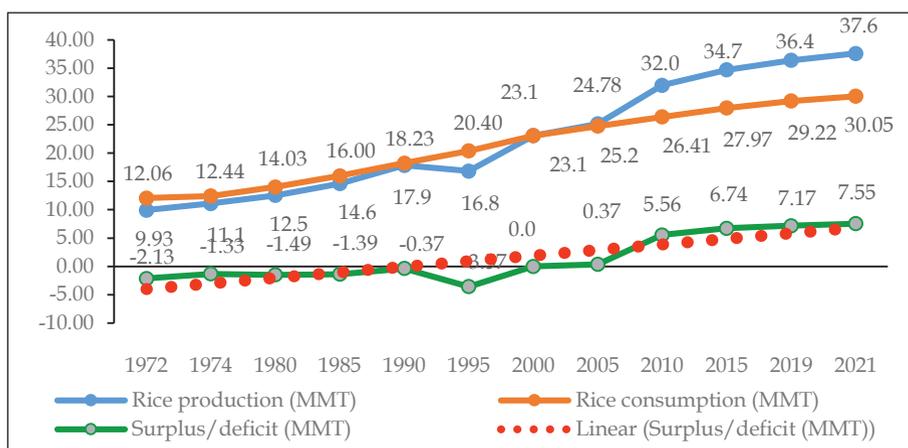


Fig. 4.1. Trend of Rice production from deficit to surplus over the years

Source: BBS 1980, 1985, 1990, 2000, 2005, 2011, 2015, 2019, 2021

<https://www.indexmundi.com/agriculture/?country=bd&commodity>

Since rice is the staple food crop, progress in rice production has a significant impact on the agriculture sector's performance. Major shifts in crop diversification are expected to be limited as long as rice remains as the most important food item in the country. Within the domain of rice, however, there is a great diversity to the varieties (HYV and local varieties) and to the growing season (Aus, Aman and Boro). Food production has increased substantially over the years following the introduction of HYVs and application of modern inputs, but the results fluctuated due to climate change. In 1995, rice production declined as a result of natural disasters, particularly flood and drought in the northwestern region, which has become now a surplus grain production region. Rice production during 1995 dropped to 16.8 MMT from 17.9 MMT during 1990 (Fig. 4.1). The decline in rice production also reflected farmers' response to a fall in rice price in the

preceding year. However, this trend started improving consistently from the succeeding periods.

Boro HYV has been far from the most important contributor to rice production over the years, the Aman HYV and Aus HYV being the next in order. With the expansion of irrigation facilities, Boro HYV rice became more important than traditional Aus and Aman rices in the country. However, the production of HYV rice during each season (Aus, Aman and Boro) increased manifold (Fig. 4.2). Boro HYV rice production increased from 1.3 MMT in 1972 to 19.83 MMT registering a staggering 15.3 times boost over the last 50 years. During the same period, Aman HYV rice grew astonishingly in production from 0.98 MMT to 12.93 MMT while Aus HYV rice production increased gradually from 0.17 MMT to 3.10 MMT.

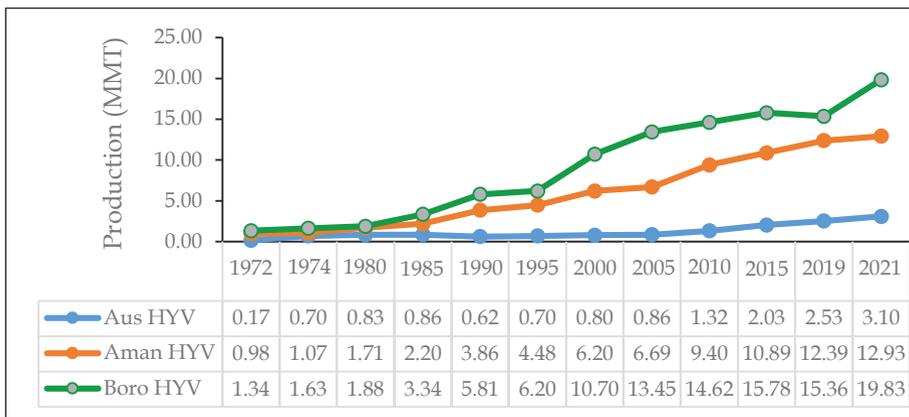


Fig. 4.2. Trend of HYV rice production in the Aus, Aman and Boro seasons over the years

Source: BBS 1980, 1985, 1990, 2000, 2005, 2011, 2015, 2019, 2021

One of the major contributors to increasing rice production is the rice growing area, which increased from around 10.3 million ha in 1970 to 11.7 million ha in 2021 with a total increase by 13.6% in 52 years (Fig. 4.3). However, declines in 1975, 1995 and 2004-05 occurred, but the increasing trend resumed in the immediately following years so that the overall increase in the 50-year was not significantly affected. Despite a relatively slow growth rate of total rice area increase can be attributed mainly to losses of agricultural land to non-agricultural land uses. A massive growth in rice production was made possible by a rapidly expanding HYV coverage and use of improved management practices comprising inputs like irrigation, seeds, fertilizers, pesticides, credit assistance etc. In effect, the HYV rice area increased remarkably with a linear growth from 0.3 million ha in 1970 to 10.5 million ha in 2021 and the increase was 35 times during the last 52 years with a 65% annual growth rate (Fig. 4.3). On the other hand, local rice variety (LV) area

declined sharply by 8.8 times from 8 million ha in 1970 to 0.9 million ha in 2021 with a negative growth rate of 1.7% per annum during the same period.

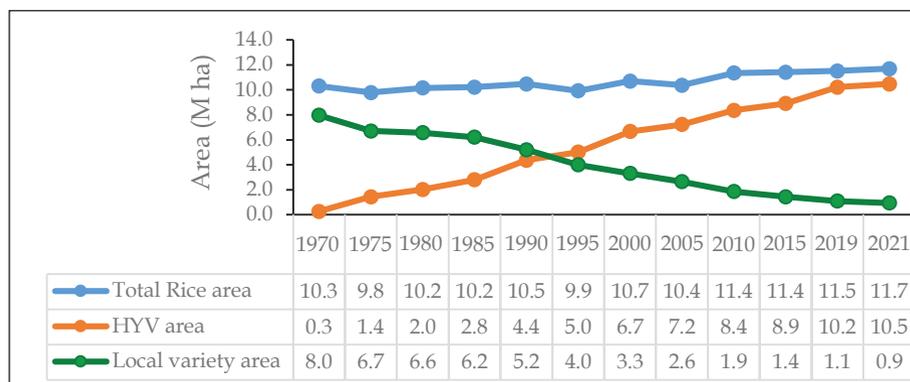


Fig. 4.3. Trend of land area under rice cultivation over the years

Source: BBS 1980, 1985, 1990, 2000, 2005, 2011, 2015, 2019, 2021

There was a massive expansion of Boro HYV rice area from 0.24 million ha in 1970 to 4.7 million ha in 2021, the increase being manifold, i.e., 19.5 times over the last 52 years indicating an average annual growth rate of 35.7% (Fig. 4.4). The Aman HYV area had a commensurate increase from 0.01 million ha in 1970 to 4.6 million ha in 2021, an overall increase by 460 times during the same period. The Aus HYV rice area increased from 0.02 million ha in 1970 to only 1.2 million ha in 2021 indicating an overall increase by 60 times during the same period, the increase being not marked as that in case of Boro or Aman rice. Overall, 4.46 million ha area was increased for Boro HYV rice followed by 4.59 million ha by Aman HYV rice while only 1.18 million ha was increased for Aus HYV rice over the last 52 years.

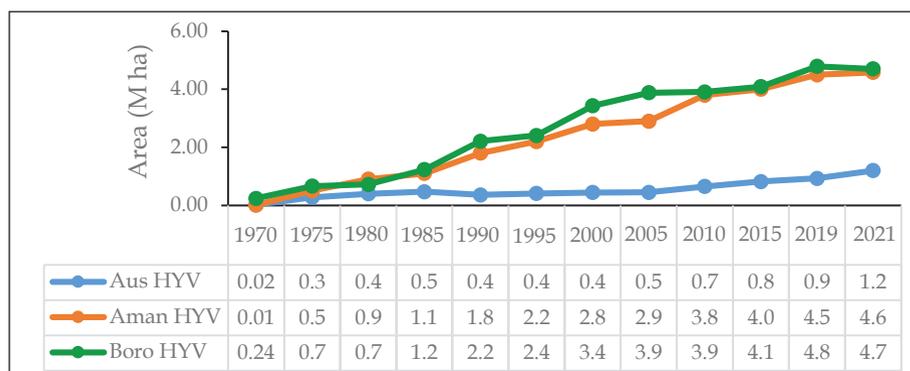


Fig. 4.4. Trend of HYV area expansion in Aus, Aman and Boro seasons over the years

Source: BBS 1980, 1985, 1990, 2000, 2005, 2011, 2015, 2019, 2021

The continuous development of HYVs by BRRI coupled with enhanced availability of irrigation, seeds, fertilizer and pesticides resulted in sharp increases of both the area and production of HYV rice in different seasons. However, the Aus HYV expansion and production lagged behind in comparison which may be attributed to the development of only a few Aus HYV (15) greatly outnumbered by Aman (57) and Boro (55) HYVs as shown in Chapter 2 of this book. HYV Aus rice began to lose its importance as farmers slowly started shifting to the cultivation of irrigated Boro rice encouraged mainly by its higher yield. The relative lag in area coverage and production of HYV Aus rice has been mainly due to non-availability of land as the Aus sowing/transplanting period falls during the months of March and April when Boro rice still remains in the field. Although Aus rice grows in an upland situation and requires less irrigation because of monsoon rains during its growing season, yet farmers choose Boro over Aus rice because of the higher output from Boro rice. The agriculture policy like NAP 2018 advocated the taking advantage of the relatively low irrigation requirement of Aus rice to cut down the exploitation of underground water for irrigation and arrest in the aquifer water level which could be deleterious to the environment in the long run. This merits attention of agricultural researchers and production planners and experts.

Rice diversity is declining rapidly since the introduction of HYVs. Still, about 7.7% of rice growing areas of the country were planted to LV rice in 2021 while 77.7% rice areas were cultivated by local varieties in 1970 (Fig 4.3). There was a major decline in the LV Aman growing area from 3.9 million ha in 1970 to only 0.8 million ha in 2021 plunging by 79.5% (Fig. 4.5).

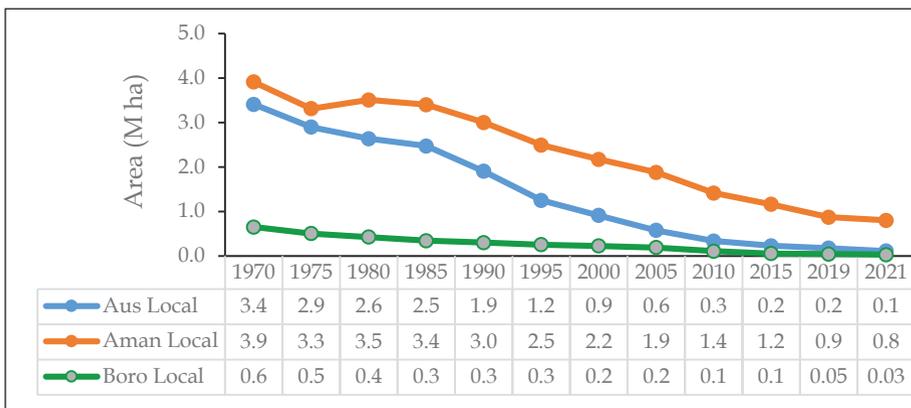


Fig. 4.5. Trend of LV rice growing areas in the Aus, Aman and Boro seasons over the years

Source: BBS 1980, 1985, 1990, 2000, 2005, 2011, 2015, 2019, 2021

During the 52 years period (1970-2021) the LV Aus area has declined by 97% from 3.4 Mha to 0.1 Mha while the LV Boro by 95% from 0.6 Mha to 0.03 Mha. Despite reductions of LV rice growing areas in all three seasons the share of LV Aman area was higher both in 1970 (49%) and in 2021 (86%) than that of local Aus area and local Boro variety area in the respective year (Fig. 4.5).

Over the 1970-2021 period, significant dips in the LV rice growing areas resulted in abrupt decreases in LV rice production by 51.6% (3.10 to 1.50 MMT), 93.3% (2.10 to 0.14 MMT) and 91.4% (0.7 to 0.06 MMT) in the Aman, Aus and Boro seasons, respectively (Fig. 4.6). Despite this decrease, about 4.5% of rice production of the country came from the local varieties in 2021 while 59.4% rice production was derived from local varieties in 1970. The share of LV Aman rice production was higher both in 1970 (31.2%) and in 2021 (4.52%) than that of LV Aus and LV Boro production in the respective year.

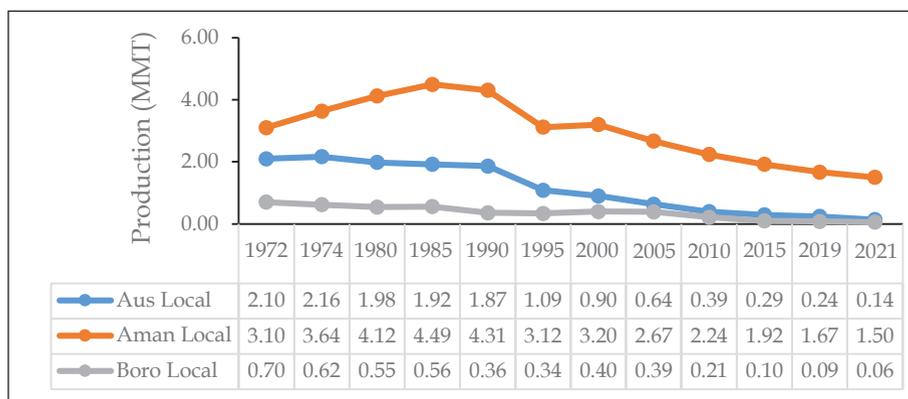


Fig. 4.6. Trend of LV rice production in Aus, Aman and Boro seasons over the years

Source: BBS 1980, 1985, 1990, 2000, 2005, 2011, 2015, 2019, 2021

The effect of technological progress on rice production growth leading to a rice surplus in the country can be gauged from the above data. The total rice crop area increased marginally from 10.3 million ha in 1970 to 11.7 million ha in 2021, but production increased dramatically from 9.93 MMT to 37.6 MMT of un-husked rice. The story of rice production gains in Bangladesh is essentially a story of vertical growth resulting from an almost four-fold yield increase from 0.96 t/ha in 1970 to 3.21 t/ha in 2021 indicating an average annual growth rate of 4.5% over the last 52 years. This remarkable growth in yield was brought about, obviously, due to technological progress as the introduction of HYVs and judicious application of production inputs like irrigation, chemical fertilizers and pesticides. This longed-for growth enabled

Bangladesh to depart from the era of rice deficit by 2000 and move ahead towards achieving rice surplus by 2021 and maintain a favorable food-population balance despite a decline in arable land over the last five decades. There is not much room for complacency, however, climate change as production still remains vulnerable to the vagaries of nature, more so as climate change adversities continue to intensify.

The increase in average yield for Boro HYV rice contributed to the progress in rice production although after the initial gain, yield growth for all HYV rice (Aus, Aman, and Boro) has gradually stagnated. Nonetheless, it is mainly the expansion of Boro HYV rice area that has made a significant contribution towards increased rice production during the period.

Rice production gains in the country resulted in an increase in per capita availability to the populace leading to self-sufficiency in staple food by the early 2000s. A transition from the Green Revolution to “Gene Revolution” starting in the early 2000s paved the way to intensive rice cultivation. This, however, has been under some strains. Soil degradation is continuing undermining the long-term capacity of irrigated and rain-fed agroecosystems. Stretching land and water resources to their limits does not bode well for long-term food production. Failure to confront this problem will leave Bangladesh with low agricultural yields, reduced areas of good agricultural land and high expenditures on modern agricultural inputs to offset losses of land productivity. High nutrient inputs, new crop varieties and technologies may well offset these adverse conditions for the foreseeable future, but the challenge of meeting human need in the 21st century may become increasingly difficult to handle.

Shifting from Green Revolution to genetic engineering since the early 1990s that resulted in the introduction of modern varieties with higher yield potentials than the varieties of Green Revolution period. This provided impetus to impacted rice area expansion encouraging farmers to bring their more lands under rice cultivation reducing the areas for other crops. In effect, rice area increased by 17% in 2021 from the initial phase of the gene revolution period, i.e., 1994-95 driven mainly by a 77.8% increase in the Boro rice area compared with Aus and Aman rice (Table 4.1).

Table 4.1. Rice areas in Aus, Aman and Boro seasons during the “gene revolution” period

Year	Rice area (M ha)				
	Aus	Aman	Boro	Total	% area increase
1994-95	1.7	5.6	2.7	10	-
2004-05	1	5.3	4.1	10.4	4
2014-15	1.1	5.5	4.8	11.4	14
2020-21	1.3	5.6	4.8	11.7	17

Source: BBS 1995, 2000, 2015 and 2021

Similarly, rice production increased massively by 124% in 2021 over that in 1994-95 and Boro rice dominated Aus and Aman with an abrupt increase by 206% (Table 4.2). Application of genetic techniques in rice breeding brought about a 91% yield increase in 2021 compared with that in 1994-95.

Table 4.2. Rice production in Aus, Aman and Boro season during the “gene revolution” period

Year	Rice production (MMT)				% production increase	Average yield (MT/ha)	% yield increase
	Aus	Aman	Boro	Total			
1994-95	1.8	8.5	6.5	16.8	-	1.7	-
2004-05	1.5	9.8	13.8	25.1	49	2.4	44
2014-15	2.3	13.1	19.1	34.5	105	3.0	80
2020-21	3.3	14.4	19.9	37.6	124	3.2	91

Source: BBS 1995, 2000, 2015 and 2021

Boro rice outperformed Aus and Aman in terms of production during 1994-95 through 2020-21. During this period, Boro production increased by 206% compared with 83% for Aus rice and 69% for Aman rice indicating the predominance of Boro rice (Table 4.3). Out of 135 HYVs and hybrids developed so far in Bangladesh, 89 including 11 for Aus, 45 for Aman and 33 for Boro season came during 2001-2021 (Table 4.4) which has contributed the most to achieving rice surplus since 2000 as shown in Fig. 4.1. The decreasing shares of Aus and Aman rice production indicated that more areas could have been brought under Boro rice (Table 4.3).

Table 4.3. Proportions of production increase and contributions of Aus, Aman and Boro rice during the gene revolution period

Year	% production increase in rice			% contribution in production of rice		
	Aus	Aman	Boro	Aus	Aman	Boro
1994-95				10.7	50.6	38.7
2004-05	-17	15	112	6.0	39.0	55.0
2014-15	28	54	194	6.7	38.0	55.3
2020-21	83	69	206	8.8	38.3	52.9

Source: Calculated from Table 4.1 and 4.2

Table 4.4. HYV and hybrid rice varieties developed by different organizations

BIRRI	BINA	BSMRAU
During 1991-2000 (19)		
<p>Aus season (3): BR24 (Rahmot), BR26 (Shrabni), BIRRI dhan27</p> <p>Aman season (9): BR25 (Noyapazam), BIRRI dhan30, BIRRI dhan31, BIRRI dhan32, BIRRI dhan33, BIRRI dhan34, BIRRI dhan37 BIRRI dhan38 and BIRRI dhan39</p> <p>Boro season (4): BIRRI dhan28, BIRRI dhan29, BIRRI dhan35 and BIRRI dhan36</p>	<p style="text-align: center;">BINA</p> <p>Aman season (1): Binadhan-4</p> <p>Boro season (2): Binadhan-5 and Binadhan-6</p>	-
During 2001-2010 (22)		
<p>Aus season (3): BIRRI dhan42, BIRRI dhan43 and BIRRI dhan48</p> <p>Aman season (10): BIRRI dhan40, BIRRI dhan41, BIRRI dhan44, BIRRI dhan46, BIRRI dhan49, BIRRI dhan51, BIRRI dhan52, BIRRI dhan53, BIRRI dhan54 and BIRRI Hybrid dhan4</p> <p>Boro season (6): BIRRI dhan45, BIRRI dhan47, BIRRI dhan50 (Banglamoti), BIRRI Hybrid dhan1, BIRRI Hybrid dhan2 and BIRRI Hybrid dhan3</p>	<p style="text-align: center;">BINA</p> <p>Aman season (1): Binadhan-7</p> <p>Boro season (1): Binadhan-8</p>	Aman season (1): BU dhan 1
During 2011-2021 (67)		
<p>Aus season (6): BIRRI dhan65, BIRRI dhan82, BIRRI dhan83, BIRRI dhan85, BIRRI dhan98 and BIRRI Hybrid dhan7</p> <p>Aman season (21): BIRRI dhan56, BIRRI dhan57, BIRRI dhan62, BIRRI dhan66, BIRRI dhan70, BIRRI dhan71, BIRRI dhan72, BIRRI dhan73, BIRRI dhan75, BIRRI dhan76, BIRRI dhan77, BIRRI dhan78, BIRRI dhan79, BIRRI dhan80, BIRRI dhan87, BIRRI dhan90, BIRRI dhan91, BIRRI dhan93, BIRRI dhan94, BIRRI dhan95, and BIRRI hybrid dhan6</p> <p>Boro season (22): BIRRI dhan55, BIRRI dhan58, BIRRI dhan59, BIRRI dhan60, BIRRI dhan61, BIRRI dhan63, BIRRI dhan64, BIRRI dhan67, BIRRI dhan68, BIRRI dhan69, BIRRI dhan74, BIRRI dhan81, BIRRI dhan84, BIRRI dhan86, BIRRI dhan88, BIRRI dhan89, BIRRI dhan92, BIRRI dhan96, BIRRI dhan97, BIRRI dhan99, BIRRI dhan100, BIRRI hybrid dhan5</p>	<p style="text-align: center;">BINA</p> <p>Aus season (2): Binadhan-19, Binadhan-21</p> <p>Aman season (10): Binadhan-9, Binadhan-11, Binadhan-12, Binadhan-13, Binadhan-15, Binadhan-16, Binadhan-17, Binadhan-20, Binadhan-22, Binadhan-23</p> <p>Boro season (4): Binadhan-10, Binadhan-14, Binadhan-18, Binadhan-24</p>	Aman season (2): BU aromatic hybrid dhan 1, BU dhan 2

During 1991-2021 (108)		
Aus season (12), Aman season (40) and Boro season (32) = Total 84	Aus season (2), Aman season (12) and Boro season (7) = Total 21	Aman season (3) = Total 3
During 1970-2021 (132)		
Aus season (14), Aman season (44) and Boro season (48) = Total 106	Aus season (2), Aman season (13) and Boro season (8) = Total 23	Aman season (3) = Total 3

Source: BRRRI and BINA website, AIS 2021

* Parenthesis indicates number of variety.

Methods for genetic manipulation rapidly improved over the last century from simple selective breeding to inserting genes from one organism into another by more recent methods of directly editing the genome. As conventional breeding alone could not increase crop yield to a level needed to cope with the demand of an increasing population, scientists started to use biotechnology techniques since the early 1990s for a breakthrough in crop yield in the face of diminishing arable land. As a result, the yields of HYVs in Aus, Aman and Boro seasons increased rapidly since 2000 (Fig. 4.7). The yield of Boro rice HYV increased rapidly relative to that of HYV Aus or Aman. HYV Boro yield increased by 62% from 2.61 MT/ha in 1980 to 4.22 MT/ha in 2021.

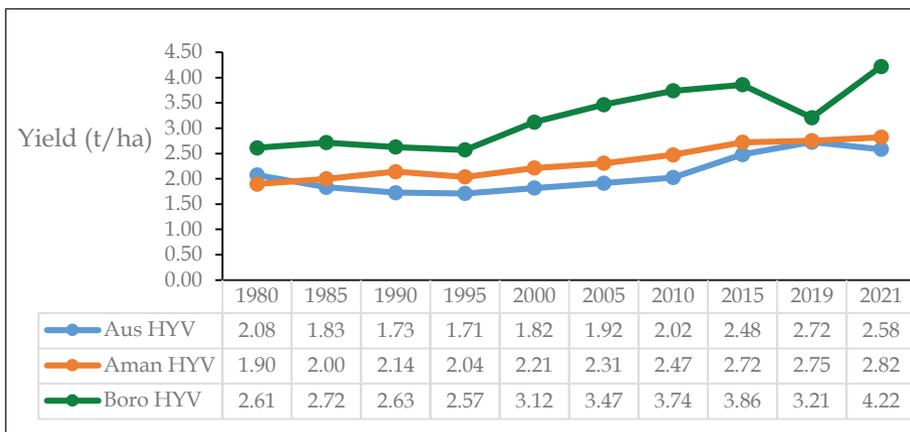


Fig. 4.7. Trend of HYV rice yield during Aus, Aman and Boro seasons over the years

Source: BBS 1980, 1985, 1990, 2000, 2005, 2011, 2015, 2019, 2021

4.1.2 Wheat and Maize

Wheat production gains have not been as dramatic as that of rice. The annual wheat output increased by 12.2 times from 0.09 MMT in 1972 to 1.1 MMT in

2021 with some ups and downs in different years (Fig. 4.8), but this is much less than is required. Considering that the minimum wheat requirement for human consumption is 50 g per capita per day (BIRDEM 2013) the deficit in wheat has risen by 61.5% over 50 years from 1.13 MMT in 1972 to 1.93 MMT in 2021. This deficit can be attributed to the increase in wheat requirement in the country by 148% from 1.22 MMT in 1972 to 3.03 MMT in 2021 with an increase in the population from 66.6 million in 1972 to 166 million in 2021 (<https://www.worldometers.info/world-population/bangladesh-population/>).

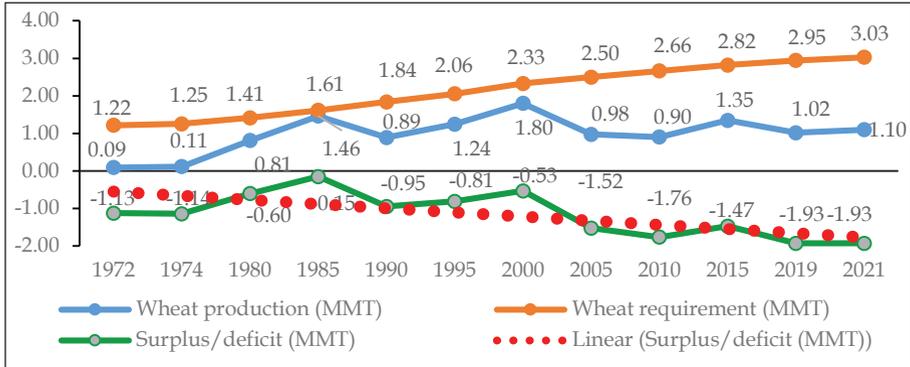


Fig. 4.8. Trend of wheat production over the years

Source: BBS 1980, 1985, 1990, 2000, 2005, 2011, 2015, 2019, 2021

<https://www.worldometers.info/world-population/bangladesh-population/>
BIRDEM 2013

Maize is also an important cereal crop after rice and wheat in Bangladesh being a major ingredient of feeds for the flourishing poultry industry and aquaculture. Also, over the years human consumption of maize as snack

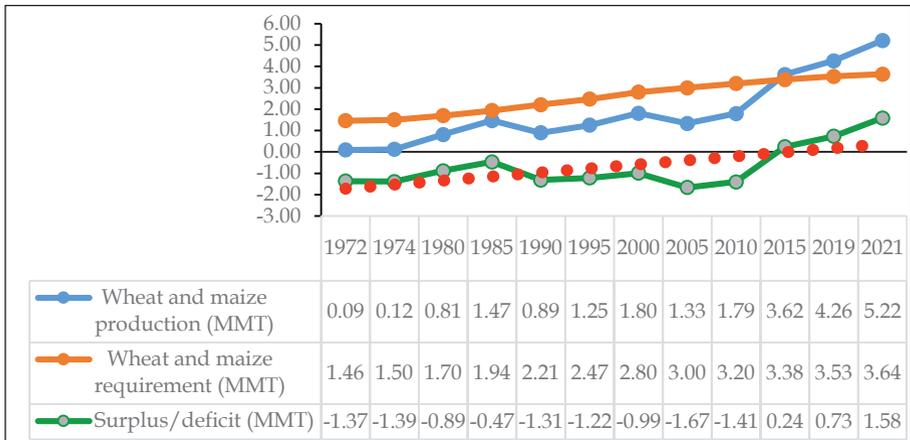


Fig. 4.9. Trend of wheat and maize production over the years

Source: BBS 1980, 1985, 1990, 2000, 2005, 2011, 2015, 2019, 2021

<https://www.worldometers.info/world-population/bangladesh-population/>
BIRDEM 2013

items like popcorn and corn flour has increased. Wheat and maize have together accounted for a significant shift from the combined deficit to sufficiency in 2015 when a surplus of 0.24 MMT (Fig. 4.9) was recorded considering the population and per capita requirement of 60 g per day (BIRDEM 2013). This surplus of wheat and maize has together increased to 1.58 MMT in 2021. Wheat and maize production increased sharply by 58 times from 0.09 MMT in 1972 to 5.22 MMT in 2021 in comparison with the increase of their requirement by 2.5 times from 1.46 MMT to 3.64 MMT during the same period.

The wheat area increased by 2.7 times from 120,000 ha in 1970 to 329,000 ha in 2021 (Fig. 4.10) although fluctuations are recorded. The largest area planted to wheat was 832,000 ha in 2000. A major reason for this expansion in wheat area is the adoption of HYV wheat. The expansion instigated by farmers' access to improved management technologies also helped.

The maize area remains almost stable ranging from 3,300 to 3,200 ha till 2000 and then significantly increased to 480,000 ha in 2021 (Fig. 4.10) leading to an overall increase by 145 times, much higher than that for wheat (2.7 times). This dramatic increase in maize area since 2005 coupled with high yields has contributed to a combined wheat-maize surplus.

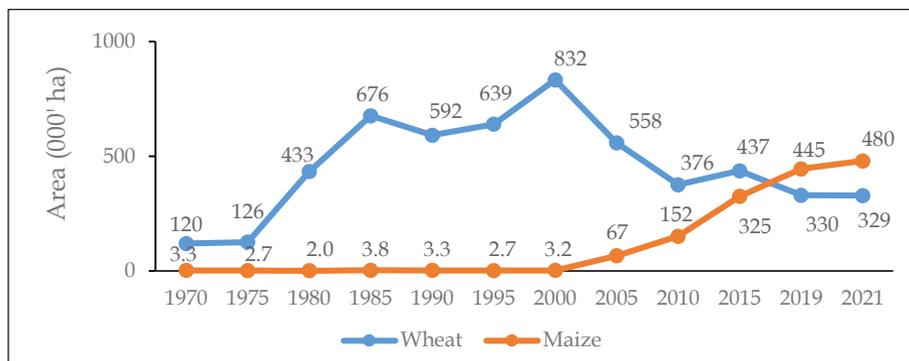


Fig. 4.10. Trend of wheat and maize cultivation area over the years

Source: BBS 1980, 1985, 1990, 2000, 2005, 2011, 2015, 2019, 2021

Wheat area and production started declining after 1985 probably due to some production constraints (Bhuiyan et al. 1993). This decrease in wheat area might have been the result of an aggressive Boro expansion on wheat lands. Introduction of HYVs and research-generated technologies for better management in the mid-1970s, helped wheat cultivation in Bangladesh. Until the mid-1960s wheat cultivation did not attract farmers, rather wheat was known as “poor man’s food” and used to be cultivated mostly by marginal and subsistence farmers. In those days wheat was essentially a non-irrigated

crop and fertilizers was rarely applied which resulted in a very low yield. Introduction of Mexican HYVs of wheat in Bangladesh in 1965, however, changed the wheat production scenario. During early 1970s and particularly after the independence of Bangladesh, prospects of wheat cultivation were brightened with some pilot projects. By the mid-1970s wheat emerged as a second major cereal crop after rice and large-scale production of wheat became possible with the introduction of Sonalika, a short-duration variety. Wheat became increasingly popular as a food grain and its consumption steadily increased making it the second most important cereal crop in the country.

Technological advancement, i.e, the development of HYVs and hybrids and improved production practices brought about a dramatic production of wheat and maize. Of the 39 wheat and 28 maize HYVs, 15 and 22, respectively, have been developed during 2001-2021 (Table 4.5) This eventually contributed to a surplus production of these cereals by 2015 (Fig.4.8).

Table 4.5. Wheat and maize varieties developed after the Green Revolution period

Period	Wheat variety	Maize variety
1991-2000	BARI Gom-17, BARI Gom-18, BARI Gom-19 (Shourov), BARI Gom-20 (Gourob), BARI Gom-21 (Shotabdi) = Total 5	Mohar, BARI Maize-5, BARI Maize-6 = Total 3
2001-2010	BARI Gom-22 (Sufi), BARI Gom-23 (Bijoy), BARI Gom-24 (Prodip), BARI Gom-25, BARI Gom-26 = Total 5	BARI Maize-7, BARI Sweet Corn-1, BARI Hybrid Maize-1, BARI Hybrid Maize-2, BARI Hybrid Maize-3, BARI Hybrid Maize-4, BARI Hybrid Maize-5, BARI Hybrid Maize-6, BARI Hybrid Maize-7, BARI Hybrid Maize-8, BARI Hybrid Maize-9, BARI Hybrid Maize-10, and BARI Hybrid Maize-11 = Total 13
2011-2020	BARI Gom-27, BARI Gom-28, BARI Gom-29, BARI Gom-30, BARI Gom-31, BARI Gom-32, BARI Gom-33, WMRI Gom 1, WMRI Gom 2, WMRI Gom 3 = Total 10	BARI Baby Corn-1, BARI Hybrid Maize-12, BARI Hybrid Maize-13, BARI Hybrid Maize-14, BARI Hybrid Maize-15, BARI Hybrid Maize-16, BARI Hybrid Maize-17, WMRI Hybrid Maize1, WMRI Hybrid Baby Corn 1 = Total 9
1991-2021	Total = 20	Total = 25
1970-2021	Total = 39	Total = 28

Source: BARI and BWMRI website

* Parenthesis indicates amount of variety.

The yield of wheat HYVs increased linearly from 1995 and the overall yield increase was 78.6% from 1.87 MT/ha in 1980 to 3.34 MT/ha in 2021 (Fig. 4.11). Maize had a tremendous yield increase by 2005 (5.33 MT/ha) and the overall increase was 12 times from 0.71 MT/ha in 1980 to 8.58 MT/ha in 2021. The remarkable yield increase of wheat and maize since the early 2000s was mainly due to the development and use of HYVs, particularly of hybrid maize.

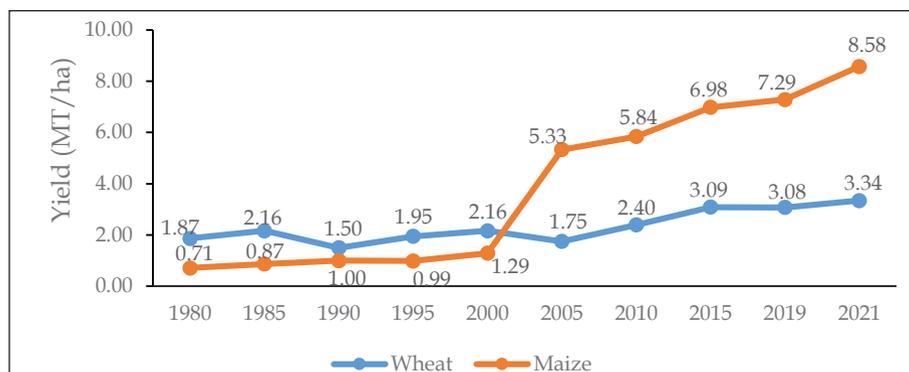


Fig. 4.11. Trend of wheat and maize yield over the years

Source: BBS 1980, 1985, 1990, 2000, 2005, 2011, 2015, 2019, 2021

4.1.3 Vegetables and fruits

Vegetable production

Total vegetable production (potato + different vegetables) increased gradually from 1.4 MMT in 1972 to 2.7 MMT in 1995 and increased abruptly from 4.5 MMT in 2000 to 14.5 MMT in 2021 (Fig. 4.12) achieving per capita

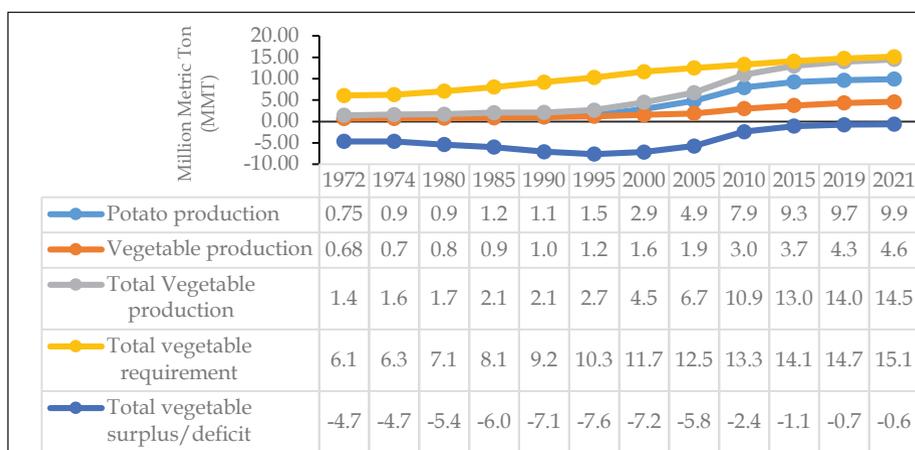


Fig. 4.12. Trend of potato and vegetable production over the years

Source: BBS 1980, 1985, 1990, 2000, 2005, 2011, 2015, 2019, 2021
FAO and WHO (2014)

availability of 239 g/day which is close to the per capita requirement of 250 g as per FAO and WHO (2014). Bangladesh is the 4th largest producer of vegetables in the world. The overall increase of total vegetable production was 10.4 times during 1972-2021 with an annual increase of 18.7%, which correlated with the increasing trend of total vegetable requirement approaching the end of vegetable deficit from 2015.

Due to a significant increase of total vegetable production since 2000 in particular, the vegetable deficit decreased to only 0.6 MMT in 2021 from 4.7 MMT in 1972 and the decrease was remarkable (7.8 times) leading towards vegetable surplus (Table 4.12). Potato and different vegetable crops combinedly contributed to vegetable surplus reducing its deficit to almost zero by 2021.

Production of potato increased from 0.75 MMT in 1972 to 9.9 MMT in 2021 (Fig. 4.12) but had an almost static growth during 1972 through 1995 before a breakthrough occurred with a massive increase from 2.9 MMT in 2000 to 9.9 MMT in 2021. The overall increase was 13.2 times with an average annual growth rate of 24.4% during the last 50 years. Bangladesh ranks the 8th largest producer of potato in the world. This is a combined effect of both area expansion and yield increase. The vegetable production depicts a similar trend to potato showing an increase from 0.68 MMT in 1972 to 4.6 MMT in 2021 but with almost static growth of around 1 MMT during 1972 through 1995. The overall increase in vegetable production was, however, 6.7 times with an average annual growth rate of 11.5% during the last 50 years. This is also a combined effect of both area expansion and yield increase of vegetable crops.

Fruit production

Over the last 50 years the country's fruit production increased by 3.7 times starting from 1.38 MMT in 1972 to 5.1 MMT in 2021 with an average annual growth rate of 5.4 % (Fig. 4.13). Fruit production also fluctuated and became

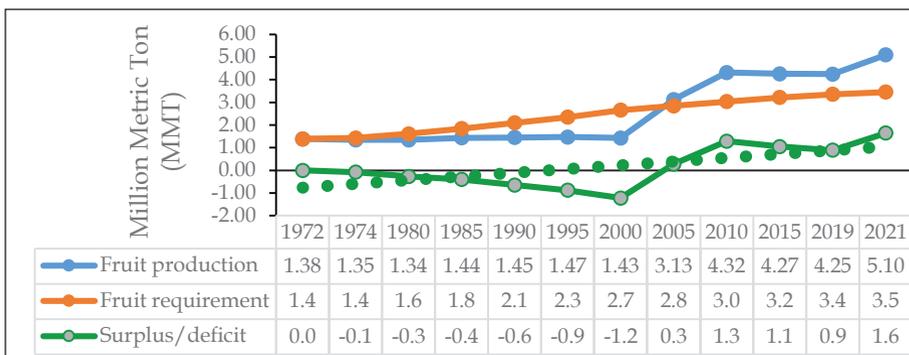


Fig. 4.13. Trend of fruit production over the years

Source: BBS 1980, 1985, 1990, 2000, 2005, 2011, 2015, 2019, 2021
BIRDEM (2013)

almost static around 1.5 MMT during 1972 to 2000 and after there a significant increase occurred from 1.43 MMT in 2000 to 5.1 MMT in 2021. Taking into account of the 57gm per capita per day requirement of fruits (BIRDEM 2013) and population, the increasing trend of fruit production led to its surplus since 2005 (0.3 MMT) and then the surplus increased to 1.6 MMT in 2021. Fruit production increased from 3.13 MMT in 2005 to 5.10 MMT in 2021 in comparison with increase in fruit requirement from 2.8 MMT to 3.5 MMT during the same time, which led to the surplus in fruit since 2005.

Potato, vegetable, and fruit growing areas

The area under potato increased sharply by 5.5 times from 85,000 ha in 1970 to 469,000 ha in 2021, the annual growth rate being 9% over the last 52 years. The potato growing area reached to the highest of 471,000 ha in 2015 (Fig. 4.14). In 2021, the vegetable growing area in the country was 454,000 ha, cultivated mostly during winter. The increase in the vegetable growing area was dramatic particularly during 1980 through 2021. Overall, the vegetable growing area increased from 123,000 ha in 1970 to 454,000 ha in 2021, 3.7 times increase over the last 52 years. The fruit growing area steadily increased by 2.9 times from 139,000 ha in 1970 to 403,000 ha in 2021 with an average annual growth rate of 3.7% during the last 52 years.

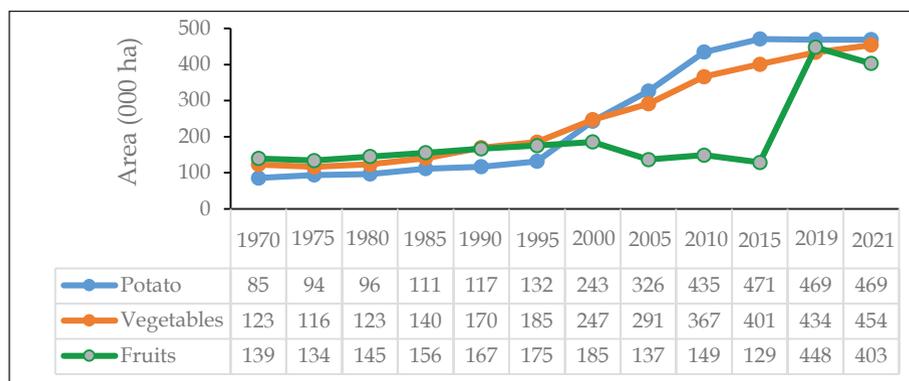


Fig. 4.14. Trend of cultivated area under potato, vegetable and fruits over the years

Source: BBS 1980, 1985, 1990, 2000, 2005, 2011, 2015, 2019, 2021

There is a large gap between average national yield of potato in Bangladesh and that in other potato growing countries of the world like the Netherlands, UK, France, USA and Germany. For instance, potato yield in UK is about 48 MT/ha (http://www.hortex.org/Hortex%20News%20Letter_AprilJune%20issue_Final_collect%20from%20press_29-12-11.pdf), which is about 2.5 times higher than that in Bangladesh. On the other hand, potato productivity in Bangladesh is quite similar as that in some developing countries. In the last

2-3 decades, production of potato in Bangladesh increased with the cultivation of HYVs. However, potato farmers of Bangladesh are rather deprived of the full benefits of such increase as they are stuck with surplus stocks and inadequate export opportunities. Bangladesh is the 7th largest producer of potato in the world, but each year a sizeable portion of the farmers' produce is wasted due to lack of sufficient storage facilities. Bangladesh exports potato to Malaysia, Sri Lanka, Benin, Vietnam, Canada, Bahrain, Qatar, Myanmar, Nepal, Oman, Kuwait, Brunei, Saudi Arabia, United Arab Emirates, and Singapore.

A total of 109 potato HYVs have been developed during 1950-2021 and most of these varieties (96) were developed after the Green Revolution period i.e., during 1991-2021 (Table 4.6). About two-thirds of the potato HYVs (65) were developed in the 2010s, which together with other vegetables HYVs helped the country increase vegetable production and thereby reduce its deficit drastically since 2015. A list of potato varieties developed during 1991-2021 are given in Table 4.6.

Table 4.6. Potato varieties developed during 1991-2021

Period	Potato variety
1991-2000	BARI= Total 16 varieties BARI Alu-4, BARI Alu-5 (Patrones), BARI Alu-6 (Multa), BARI Alu-7 (Diamont), BARI Alu-8 (Cardinal), BARI Alu-9, BARI Alu-10, BARI Alu-11, BARI Alu-12, BARI Alu-13 (Granula), BARI Alu-14, BARI Alu-15, BARI Alu-16, BARI Alu-17 (Raja), BARI TPS-1, BARI TPS-2
2001-2010	BARI = Total 15 varieties BARI Alu-18, BARI Alu-19, BARI Alu-20, BARI Alu-21, BARI Alu-22, BARI Alu-23, BARI Alu-24, BARI Alu-25, BARI Alu-26, BARI Alu-27, BARI Alu-28, BARI Alu-29, BARI Alu-30, BARI Alu-31, BARI Alu-32
2011-2020	BARI= Total 59 varieties BARI Alu-33, BARI Alu-34, BARI Alu-35, BARI Alu-36, BARI Alu-37, BARI Alu-38, BARI Alu-39, BARI Alu-40, BARI Alu-41, BARI Alu-42, BARI Alu-43, BARI Alu-44, BARI Alu-45, BARI Alu-47, BARI Alu-48, BARI Alu-49, BARI Alu-50, BARI Alu-51, BARI Alu-52, BARI Alu-53, BARI Alu-54, BARI Alu-55, BARI Alu-56, BARI Alu-57, BARI Alu-58, BARI Alu-59, BARI Alu-60, BARI Alu-61, BARI Alu-62, BARI Alu-63, BARI Alu-64, BARI Alu-65, BARI Alu-66, BARI Alu-67, BARI Alu-68, BARI Alu-69, BARI Alu-70, BARI Alu-71, BARI Alu-72, BARI Alu-73, BARI Alu-74, BARI Alu-75, BARI Alu-76, BARI Alu-77, BARI Alu-78, BARI Alu-79, BARI Alu-80, BARI Alu-81, BARI Alu-82, BARI Alu-83, BARI Alu-84, BARI Alu-85, BARI Alu-86, BARI Alu-87, BARI Alu-88, BARI Alu-89, BARI Alu-90, BARI Alu-91, BAU= Total 6 varieties BAU Golalu-2, BAU Golalu-3, BAU Golalu-4, BAU Golalu-5, BAU Golalu-6, BAU Golalu-7
1991-2021	Total - 96
1950-2021	Total - 109

Source: Websites of BARI, BAU, BSMRAU, SAU and AIS 2022

As discussed earlier in Chapter 2, more than 60 different types of vegetables of indigenous and exotic origin are grown in Bangladesh. Introduction of modern technologies and HYV vegetables resulted in a huge spike in vegetable production in Bangladesh, even though the land for vegetable cultivation hardly increased. The increase in vegetable production means greater per capita availability, and domestic vegetable availability is nearly fulfilling domestic demand, which explains the small international trade deficit for horticultural products. The USAID-funded Asian Vegetable Research and Development Center (AVRDC) project aiming at introducing new vegetable varieties and technologies received Government policy support which contributed to the success of the project since 2000.

The remarkable improvement in vegetable production could be attributed to technological advancement through development of HYV, hybrids and improved management technologies. A total of 167 vegetable varieties were developed during 1950-2021 and most of them (155) were developed during 1991-2021 (Table 4.7) amidst the assistance of the giant AVRDC project since 2000. Out of the total 155 technologies during 1991-2021, almost half of them (77) were developed during 2011-2021 which together with potato HYVs led to the massive increase in the collective production of potato and vegetables in the late 2010s and thereby helped to reduce their deficit greatly since 2015. A list of different vegetable HYVs and hybrids developed during 1991-2021 is shown in Table 4.7.

Table 4.7. Vegetable varieties developed after the Green Revolution period in Bangladesh

Period	Vegetable variety
1991-2000	<p>BARI= Total 29 varieties</p> <p>Leafy vegetables - 3: BARI Datashak-1 (Laboni), BARI Lalshak-1, BARI Chinacopi-1, Lady's finger - 1: BARI Dherosh-1, Country bean - 3: BARI JharSheem -1, BARI JharSheem -2, BARI Sheem -1, Gourd - 1: BARI Lau-1, Radish - 3: BARI Mula-2 (Pinky), BARI Mula-3 (Druti), BARI Mula-4, Cabbage - 1: BARI Badhacopy-2 (Agradut), Cauliflower - 1: BARI Phulkopi-1, Tomato - 11: BARI Tomato-3, BARI Tomato-4, BARI Tomato-5, BARI Tomato-6, BARI Tomato-7, BARI Tomato-8, BARI Tomato-9, BARI Tomato-10, BARI Tomato-11, BARI Tomato-12, BARI Tomato-13 (Shrabonti), Brinjal - 5: BARI Begun-2 (Tarapuri), BARI Begun-3 (Shuktara), BARI Begun-4 (Kazla), BARI Begun-5 (Nayantara), Padma (F1 Hybrid)</p> <p>BSMRAU= Total 8 varieties</p> <p>Country bean - 2: IPSA seem 1, IPSA seem 2, Cabbage - 2: IPSA badhacopy 1, IPSA patacopy 1, Radish - 1: BU mula 1, Others - 3: IPSA motorshuti 1, IPSA motorshuti 2, IPSA motorshuti 3</p>

2001-2010	<p style="text-align: center;">BARI= Total 34 varieties</p> <p>Leafy vegetable - 4: BARI Datashak-2, BARI Sabuj Danta Shak-1, BARI Puishak-2, BARI Leafy Amaranth-1, Country bean - 4: BARI JharSheem -2, BARI Sheem-3(Summer), BARI Sheem-4, BARI Sheem-5 (dwarf), Palwal - 2: BARI Potol-1, BARI Potol-2, Gourd - 7: BARI Misti Kumra-1, BARI Misti Kumra-2, BARI Chalkumra-1, BARI Korola-1, BARI Lau-2, BARI Lau-3, BARI Lau-4, Radish - 1: BARI Mula-4, Cauliflower - 1: BARI Phulkopi-2, Tomato - 6: BARI Tomato-14, BARI Tomato-15, BARI Hybrid Tomato-3, BARI Hybrid Tomato-4, BARI Hybrid Tomato-5, BARI Hybrid Tomato-6, Brinjal - 5: BARI Begun-6, BARI Begun-7, BARI Begun-8, BARI Begun-9, BARI Begun-10, Aroid - 2: BARI Panikachu-2, BARI Panikachu-3, Others - 2: BARI Borboti-1, BARI Jhinga-1</p> <p style="text-align: center;">BSMRAU= Total 7 varieties</p> <p>Country bean - 1: BU seem 3, Cabbage - 1: BU Chinese cabbage 1, Radish - 3: BU hybrid mula 1, BU mula 2, BU mula 3, Others - 2: BU borboti 1, BU chichinga 1</p>
2011-2020	<p style="text-align: center;">BARI= Total 60 varieties</p> <p>Tomato - 11: BARI Tomato-16, BARI Tomato-17, BARI Tomato-18, BARI Tomato-19, BARI Tomato-20, BARI Tomato-21, BARI Hybrid Tomato-7, BARI Hybrid Tomato-8 (Summer), BARI Hybrid Tomato-9, BARI Hybrid Tomato-10, BARI Hybrid Tomato-11, Country bean - 8: BARI Sheem 6, BARI Sheem-7, BARI Sheem-8, BARI Sheem-9, BARI Sheem-10, BARI Jharsheem 3 (Khaishya), BARI Jack Sheem 1, BARI Kamranga Sheem-1, Gourd - 11: BARI Hybrid Misti Kumra-1, BARI Hybrid Misti Kumra-2, BARI Hybrid Misti Kumra-3, BARI Sita Lau 1, BARI Korola-2, BARI Korola-3, BARI Korola-4, BARI Hybrid Korola-1, BARI Hybrid Korola-2, BARI Hybrid Korola-3, BARI Lau-5, Brinjal - 10: BARI Begun-11, BARI Begun-12, BARI Hybrid Begun-3, BARI Hybrid Begun-4, BARI Hybrid Begun-5, BARI Hybrid Begun-6, BARI Bt Begun 1, BARI Bt Begun 2, BARI Bt Begun 3, BARI Bt Begun 4, Lady's finger - 1: BARI Dherosh-2, Palwal - 1: BARI Hybrid Potol-1, Leafy vegetables - 2: BARI Palongshak-1, BARI PalongShak-2, Cauliflower - 1: BARI Phulkopi-3, Aroid - 7: BARI Mukhikachu-2, BARI Panikachu-4, BARI Panikachu-5, BARI Panikachu-6, BARI Olkachu-1, BARI Olkachu-2, BARI Shahebikachu-1, Others - 8: BARI Chichinga-1, BARI Jhinga-2, BARI Dhundul-1, BARI Dhundul-2, BARI Sajina-1, BARI Brokoli-1, BARI Borboti-2, BARI Squash-1</p> <p style="text-align: center;">BAU= Total 3 varieties</p> <p>Carrot - 3: BAU Carrot-3, BAU Carrot-4, BAU Carrot-5</p> <p style="text-align: center;">BSMRAU= Total 12 varieties</p> <p>Carrot - 1: BU carrot 1, Cauliflower - 1: BU fulcopy 1, Gourd - 3: BU hybrid lau 1, BU lau 1, BU lau 2, Country bean - 6: BU baromasi seem 1, BU seem 1, BU seem 2, BU seem 3, BU seem 4, BU seem 5, Tomato - 1: BU cherry tomato 1</p> <p style="text-align: center;">SAU= Total 2 varieties</p> <p>Country bean - 2: Sikribi Sheem-1, Sikribi Sheem-2</p>
1991-2021	Total - 155
1950-2021	Total - 167

Source: Websites of BARI, BAU, BSMRAU and SAU; AIS 2022

After a pitfall in 1990, the yield of potato and vegetable HYVs increased linearly until 2021 (Fig. 4.15). Potato yield increased by 124% from 9.4 MT/ha in 1980 to 21.1 MT/ha in 2021 while vegetable yield increased by 60.3% from 6.3 t/ha to 10.1 MT/ha during the same period. This significant yield increase of potato and vegetables since 1995 was mainly due to development of HYVs through genetic engineering in addition to conventional breeding.

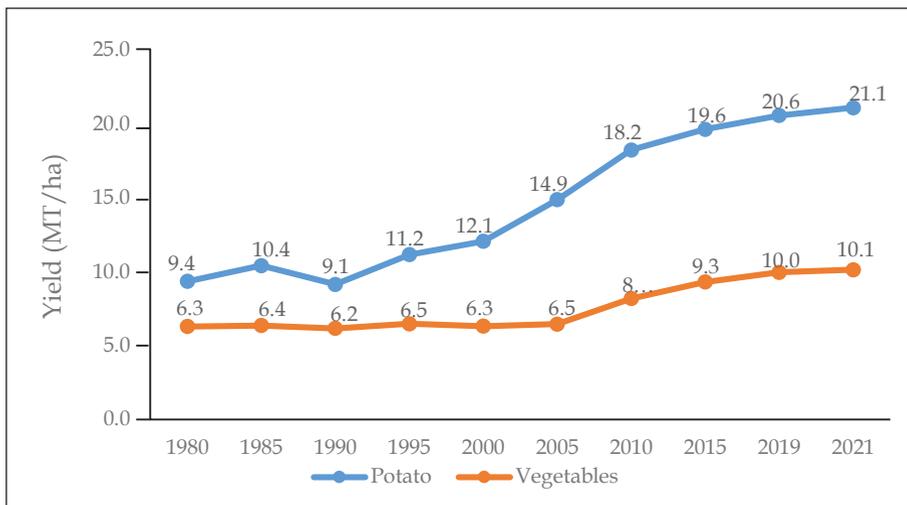


Fig. 4.15. Trend of potato and vegetable yields over the years
 Source: BBS 1980, 1985, 1990, 2000, 2005, 2011, 2015, 2019, 2021

A total of 197 fruit HYVs were developed during 1970-2021 and almost 100% of them (195) were developed after the Green Revolution period, i.e., during 1991-2021 (Table 4.8). Most of these varieties (171) were developed during 2001-2021, which eventually helped increase production significantly and contribute towards surplus since 2005.

Table 4.8. Fruit varieties developed after the Green Revolution era

Period	Fruit variety
1991-2000	BARI= Total 23 varieties Papaya - 1: Shahi Papaya, Lemon - 5: BARI Lebu-1, BARI Lebu-2, BARI Lebu-3, BARI Batabilebu-1, BARI Batabilebu-2, Litchi - 3: BARI Lichu-1, BARI Lichu-2, BARI Lichu-3, Guava - 1: BARI Payera-2, Banana - 2: BARI Kola -1 (Banana), BARI Kola -2 (Banana), Coconut - 2: BARI Narikel-1, BARI Narikel-2 Orange - 1: BARI Komola-1, Mango - 3: BARI Aam-1, BARI Aam-2, BARI Aam-3, Jamrul -1: BARI Jamrul-1, Safeda - 1: BARI Safeda-1, Others - 3: BARI Wax Jambu-1, BARI Anspal-1 (Longan), BARI Toikar-1,
	BSMRAU= Total 1 variety Guava - 1: IPSA Payera1

2001-2010	<p style="text-align: center;">BARI= Total 29 varieties</p> <p>Lemon - 2: BARI Batabilebu-3, BARI Batabilebu-4, Guava - 1: BARI Payera-3, Banana - 2, BARI Kola -3, BARI Kola -4, Malta - 1: BARI Malta-1, Jujube - 3: BARI Kul-1, BARI Kul-2, BARI Kul-3, Mango - 5: BARI Aam-4 (Hybrid), BARI Aam-5, BARI Aam-6, BARI Aam-7, BARI Aam-8, Litchi - 1: BARI Lichu-4, Safeda - 2: BARI Safeda-2, BARI Safeda-3, Kamranga - 2: BARI Kamranga-1, BARI Kamranga-2, Strawberry - 1: BARI Strawberry-1, Jackfruit - 1: BARI Kanthal-1, Others - 8: BARI Anspal-2 (Longan), BARI Tentul-1, BARI Nashpati-1, BARI Passion Phal-1, BARI Lotkan-1, BARI Rambutan-1, BARI Amra-1, BARI Satkora-1</p> <p style="text-align: center;">BAU= Total 62 varieties</p> <p>Mango - 17: BAU Aam-1, BAU Aam-2, BAU Aam-3, BAU Aam-4, BAU Aam-5, BAU Aam-6, BAU Aam-7, BAU Aam-8, BAU Aam-9, BAU Aam-10, BAU Aam-11, BAU Aam-12, BAU Aam-13, BAU Aam-14, BAU Aam-15, BAU Aam-16, BAU Aam-17, Guava - 9: BAU Payera-1, BAU Payera-2, BAU Payera-3, BAU Payera-4, BAU Payera-5, BAU Payera-6, BAU Payera-7, BAU Payera-8, BAU Payera-9, Jujube - 3 BAU Kul-1, BAU Kul-2, BAU Kul-3, Lemon - 3: BAU Kagojilebu-1, BAU Lebu-2, BAU Lebu-3, Jamrul - 3: BAU Jamrul-1, BAU Jamrul-2, BAU Jamrul-3, Litchi - 2: BAU Lichu-1, BAU Lichu-2, Jambura - 2: BAU Jambura-1, BAU Jambura-2, Safeda - 3 BAU Safeda-1, BAU Safeda-2, BAU Safeda-3, Dragon Fruit - 3: BAU Dragon Fruit-1, BAU Dragon Fruit-2, BAU Dragon Fruit-3, Kamranga - 3 BAU Kamranga-1, BAU Kamranga-2, BAU Kamranga-3, Malta - 1: BAU Malta-1, Jackfruit - 1: BAU Kanthal-1, Strawberry - 1, BAU Strawberry-1, Others - 11: BAU Amloki-1, , BAU Kajubadam-1, BAU Dumur-1, BAU Longon-1, BAU Longon-2, BAU Tentul-1, BAU Tentul-2, BAU Kodbel-1, BAU Rambutan-1, BAU Lotkon-1, BAU Amra-1</p> <p style="text-align: center;">BSMRAU= Total 2 varieties</p> <p>Guava - 1: BU kul 1 (Apelkul), Water Melon - 1: BU melon 1</p>
2011-2020	<p style="text-align: center;">BARI= Total 45 varieties</p> <p>Mango - 9: BARI Aam-9, BARI Aam-10, BARI Aam-11, BARI Aam-12, BARI Aam-13, BARI Aam-14, BARI Aam-15, BARI Aam-16, BARI Aam-17, Jackfruit - 2: BARI Kanthal-2, BARI Kanthal-3, Litchi - 1: BARI Lichu-5, Orange - 2: BARI Kamola-2, BARI Kamola-3, Dragon Fruit - 1: BARI Dragon Fruit-1, Banana - 1: BARI Kola -5, Guava - 1: BARI Payera-4, Lemon - 8: BARI Batabilebu-5, BARI Batabilebu-6, BARI Lebu-4, BARI Lebu-5, BARI Mistilebu-1, BARI Mistilebu-2, BARI Kagjilebu-1, BARI Jaralebu-1, Malta - 1: BARI Malta-2, Jujube - 2: BARI Kul-4, BARI Kul-5, Strawberry - 2: BARI Strawberry-2, BARI Strawberry-3, Jamrul - 2: BARI Jamrul-2, BARI Jamrul-3, Water Melon - 2: BARI Tormuj-1, BARI Tormuj-2, Others - 11: BARI Bilatigab-1, BARI Amloki-1, BARI Wax Jambu-2, BARI Ber-4, BARI Ber-5, BARI Jalpai-1, BARI Kodbel-1, BARI Bel-1, BARI Wax Jambu-3, BARI Avocado-1, BARI Amra-2</p> <p style="text-align: center;">BAU= Total 22 varieties</p> <p>Mango - 8: BAU Aam-18, BAU Aam-19, BAU Aam-20, BAU Aam-21, BAU Aam-22, BAU Aam-23, BAU Aam-24, BAU Aam-25, Guava - 1: BAU Payera-10, Lemon - 1: BAU Lebu-4, Jambura - 3: BAU Jambura-3, BAU Jambura-4, BAU Jambura-5, Safeda - 1: BAU Safeda-4, Malta - 1: BAU Malta-2, Dragon Fruit - 1: BAU</p>

	<p>Dragon Fruit-3, Banana - 2: BAU Kola-1, BAU Kola-2, Litchi - 2: BAU Lichu-3, BAU Lichu-4, Others - 2: BAU Bilatigab-1, BAU Bilatigab-2</p> <p>PSTU= Total 9 varieties</p> <p>Lemon - 1: PSTU Batabilebu-1, Kamranga - 2: PSTU Kamranga-1, PSTU Kamranga-2, Others - 6: PSTU Tentul-1, PSTU Boichi-1, PSTU Bilatigab-1, PSTU Bilatigab-2, PSTU Deua-1, PSTU Deua-2</p> <p>BSMRAU= Total 2 varieties</p> <p>Papaya - 2: BU papaya 1, BU papaya 2</p>
1991-2021	Total - 195
1971-2020	Total - 197

Source: Websites of BARI, BSMRAU and PSTU; AIS 2022

According to the FAO, Bangladesh has the highest rate of increase in fruit production among the world's fruit producing countries. The Year-round Fruit Production for Nutrition Improvement Project was designed for the period of July 2015 to June 2020. Under the supervision of the Ministry of Agriculture, this project was implemented by DAE. This project emphasized homestead areas for fruit production. The challenge now is to grow more food with better nutritional quality on a continually shrinking agricultural land area. Developing and adopting newer techniques are necessary to boost fruit productivity in an eco-friendly way.

4.1.4 Pulses, oilseeds and spices

Pulse production went through ups and downs during 1972-2021 (Fig. 4.16), but there was an overall increase by 95.5% from 0.22 MMT to 0.43 MMT. Despite a decrease in the pulse growing area, this increased production was due to adoption of HYVs and improved management technologies. Nevertheless, pulse deficit continued even during the Gene Revolution period since early 1990s and increased by 160% from 1.0 MMT in 1972 to 2.6 MMT in 2021 despite an increase in pulse production (Fig. 4.13) considering

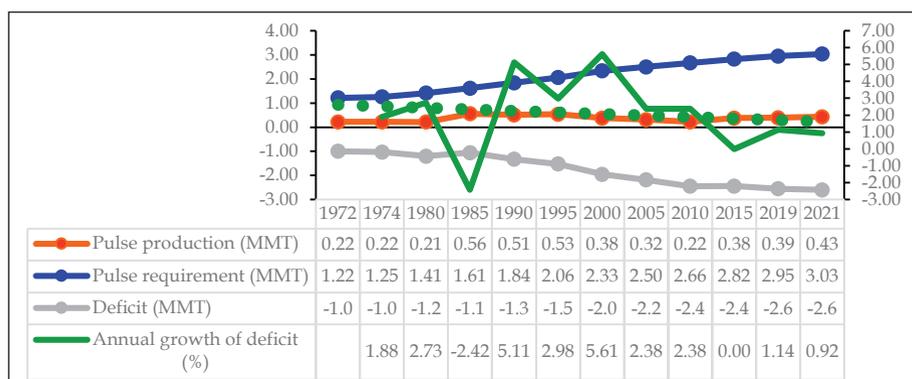


Fig. 4.16. Trend of pulse production over the years

Source: BBS 1980, 1985, 1990, 2000, 2005, 2011, 2015, 2019, 2021
BIRDEM 2013

the recommended intake requirement of 50 g per capita per day (BIRDEM 2013). Pulse production increased at a slower pace (0.22 to 0.43 MMT) than the pulse requirement (1.22 to 3.03 MMT) during 1972-2021. However, the annual pulse deficit declined from 1.88% in 1974 to 0.92% in 2021 indicating that the country is moving towards self-sufficiency in pulse in the years to come.

There has been manifold (14.9 times) increase in the production of oilseeds from 0.20 MMT in 1972 to 0.99 MMT in 2021 (Fig. 4.17) with a serious setback in 2005 (0.27 MMT). This increase in production of oilseed crops was attributed to the combined effect of area expansion and yield increase implying a significant adoption of high yielding varieties and improved management practices. However, oilseed deficit continued even during the Gene Revolution period since the early 1990s and increased by 125% from 2.0 MMT in 1972 to 4.5 MMT in 2021 (Fig. 4.14) considering the recommended intake requirement of 30 g edible oil per capita per day (BIRDEM 2013) with a 33% average extraction of oilseeds for edible oil. The trend of oilseed production increased at a lower level (0.20 to 0.99 MMT) than that of the requirement (2.19 to 5.45 MMT) during 1972-2021. The oilseed deficit increased from 0.74% in 1974 to 1.35% in 2021 which is a great concern, and the country remains burdened with oil imports to date.

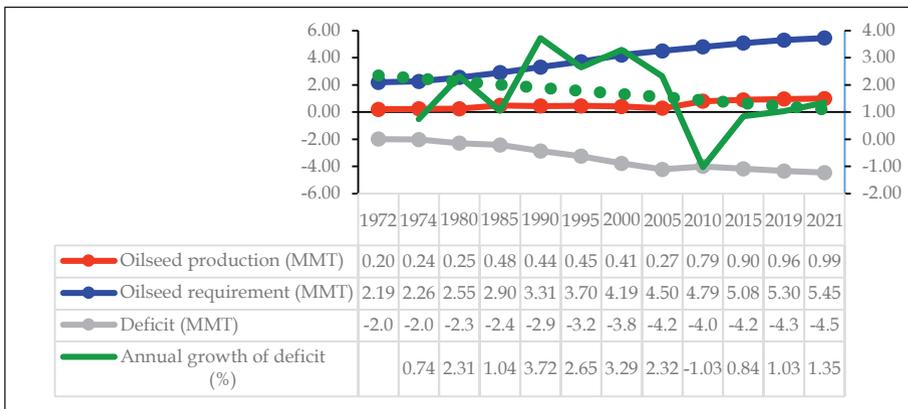


Fig. 4.17. Trend of oilseed production over the years

Source: BBS 1980, 1985, 1990, 2000, 2005, 2011, 2015, 2019, 2021
BIRDEM 2013

The production of spices increased by 11.3 times from 0.32 MMT in 1972 to 0.36 MMT in 2021 reaching a break-even level between production and requirement in 2005 (Fig. 4.18). Expansion of cultivated area coupled with HYVs and other technological interventions helped increase spices production. Spices deficit continued till early 2000s from 0.2 MMT in 1972 to 0.5 MMT in 2000 while there was a surplus of 0.3 MMT in 2010 to 2.4 MMT in 2021 considering 20 g per capita per day requirement (BIRDEM 2013) of

spices. The trend of spices production increased at a higher level from 2005 (1.0 MMT) to 2021 (3.60 MMT) than that of the requirement (1.0 to 1.21 MMT) during the same period although their trend was reversed during 1972-2000 resulting in spices surplus after 2005.

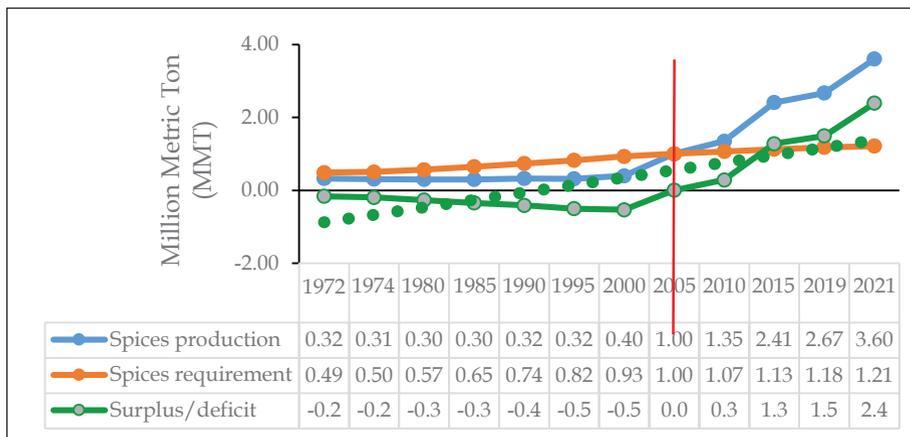


Fig. 4.18. Trend of spices production over the years
 Source: BBS 1980, 1985, 1990, 2000, 2005, 2011, 2015, 2019, 2021, BIRDEM 2013

The pulse cultivation area remained almost stable between 1970 and 1980 from 308,000 ha to 371,000 ha but it increased remarkably to 784,000 ha in 1984-85 followed by a steady decline to 372,000 ha in 2021 (Fig. 4.19). Despite this erratic trend, pulse cultivation area increased by 55% from the smallest area of 240,000 ha in 2010 to 372,000 ha in 2021. Oilseed cultivated area had a similar trend of initial increase from 344,000 ha in 1970 to the peak of 598,000

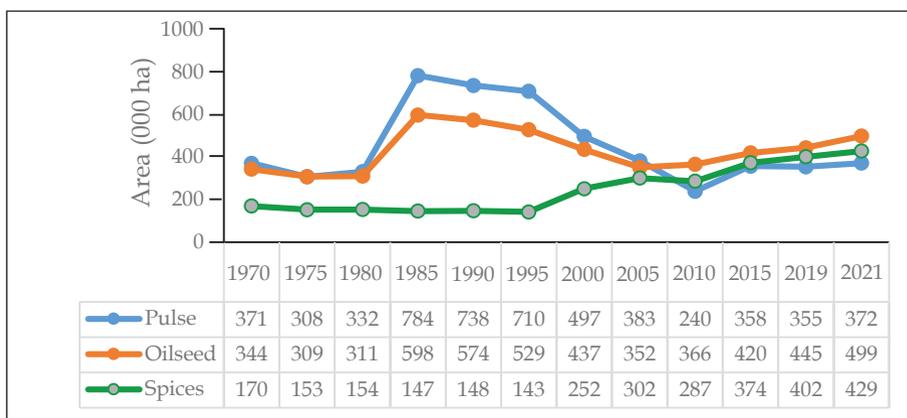


Fig. 4.19. Trend of area cultivated under pulse, oilseeds and spices crops over the years
 Source: BBS 1980, 1985, 1990, 2000, 2005, 2011, 2015, 2019, 2021

ha in 1985 followed by a steady decrease to the lowest area of 366,000 ha in 2010 and a further increase to 499,000 ha in 2021. However, the resultant effect was the overall increase in area of oilseed crops during 1972-2021 (50 years) by 155,000 ha (45%) unlike the decrease in pulse growing area. Similar erratic trend is also reported in case of spice crop area having an initial steady decrease from 170,000 ha in 1970 to 143,000 ha in 1995 followed by a dramatic linear increase to 429,000 ha in 2021. Overall, the area of spice crops increased by 259,000 (152.3%) with an average annual growth rate of 2.9% over the last 52 years.

Due to competition from rice and socio-economic factors, biotic and abiotic stresses, the production of pulse crops was lower in several years than that in the other years. The area under pulse crops declined while the area under rice production increased, which led to huge imports of pulses by the Government. In line with policy directives for crop diversification and nutritional improvement, great efforts for increasing pulse production have been taken. A seed production project for producing climate resilient and pest resistant varieties for sustainable food production has been initiated. The short-duration varieties developed recently helped farmers grow pulses crops in a relay cropping system on lands which otherwise would have

Table 4.9. Pulse and oilseed crop varieties developed after the Green Revolution era

Period	Pulse crop variety	Oilseed crop variety
1991-2000	<p>BARI= Total 20 varieties Lentil - 4: Utfola (lentil), BARI Masur-2, BARI Masur-3, BARI Masur-4, Chickpea - 7: BARI Chola-2, BARI Chola-3, BARI Chola-4, BARI Chola-5, BARI Chola-6, BARI Chola-7, BARI Chola-8, Lathyras - 2: BARI Khesari-1, BARI Khesari-2, Mungbean - 3: BARI mung-3, BARI mung-4, BARI mung-5, Black gram - 2: BARI mash-2, BARI mash-3, Others - 2: BARI Felon-1, BARI Felon-2</p> <p>BINA = Total 8 varieties Mungbean - 5: Binamoog-1, Binamoog-2, Binamoog-3, Binamoog-4, Binamoog-5 (summer variety), Black gram - 1: Binamash-1, Chickpea - 2: Chick pea - 1 Binasola-2</p> <p>BSMRAU= Total 1 variety MUngbean - 1: BU mug 1</p>	<p>BARI= Total 10 varieties Soybean - 3: Shohag (Soyabean), BARI Soyabean-4, Kironi (Sunflower), Mustard - 5: BARI sarisha-6 (Dhali), BARI sarisha-7, BARI sarisha-8, BARI sarisha-9, BARI sarisha-10, Groundnut - 2: BARI Chinabadam-5, BARI Chinabadam-6, BINA= Total 7 varieties Mustard - 4 Sofol, Agrani, Binasarisha-3, Binasarisha-4, Groundnut - 3: Binachinabadam-1, Binachinabadam-2, Binachinabadam-3</p>

2001-2010	<p>BARI= Total 3 varieties Lentil - 2: BARI Masur-5, BARI Masur-6, Mungbean - 1: BARI mung-6, BINA = Total 13 varieties Mungbean - 4: Binamoog-6 (summer variety), Binamoog-7, Binamoog-8, Binamoog-8 (summer variety), Chickpea - 4: Binasola-3, Binasola-4, Binasola-5, Binasola-6, Lathyras - 1: Binakheshari-1, Lentil - 4: Binamasur-1, Binamasur-2, Binamasur-3, Binamasur-4, BSMRAU= Total 4 varieties Mungbean - 3: BU mug 2, BU mug 3, BU mug 3, Chick pea - 1: BU chola 1</p>	<p>BARI = Total 15 varieties Mustard - 6: BARI sarisha-11, BARI sarisha-12, BARI sarisha-13, BARI sarisha-14, BARI sarisha-15, BARI sarisha-16, Groundnut - 3: BARI Chinabadam-7, BARI Chinabadam-8, BARI Chinabadam-9, Sesame - 3: BARI Til-2, BARI Til-3, BARI Til-4, Soybean - 2: BARI Soyabean-5, BARI Soyabean-6, Sunflower - 1: BARI surjumukhi-2 BINA= Total 4 varieties Groundnut - 1: Binachinabadam-4, Sesame - 1: Binatil-1, Mustard - 2: Binasarisha-5, Binasarisha-6</p>
2011-2020	<p>BARI= Total 15 varieties Lentil - 3: BARI Masur-7, BARI Masur-8, BARI Masur-9, Field pea - 3: BARI Motor-1, BARI Motor-2, BARI Motor-3, Mungbean - 2: BARI mung-7, BARI mung-8, Black gram -1: BARI Mash-4, Chickpea - 3: BARI Chola-9, BARI Chola-10, BARI Chola-11, Lathuras - 3: BARI Khesari-3, BARI Khesari-5, BARI Khesari-6, BINA = Total 13 varieties Chickpea - 4: Binasola-7, Binasola-8, Binasola-9, Binasola-10, Lentil - 6: Binamasur-5, Binamasur-6, Binamasur-7, Binamasur-8, Binamasur-9, Binamasur-10, Field pea - 3: Binamotor-8, Binamotor-9, Binamotor-10, BSMRAU= Total 2 varieties Mungbean - 2: BU mug 5, BU mug 6</p>	<p>BARI= Total 6 varieties Mustard - 2: BARI sarisha-17, BARI sarisha-18, Groundnut - 1: BARI Chinabadam-10, Sunflower - 1: BARI surjumukhi-3, Soybean - 1: BARI Soyabean-7, Others - 1: BARI Tishi-2 BINA= Total 16 varieties Groundnut-5: Binachinabadam-5, Binachinabadam-6, Binachinabadam-7, Binachinabadam-8, Binachinabadam-9, Mustard - 4: Binasarisha-7, Binasarisha-8, Binasarisha-9, Binasarisha-10, Sesame - 3 Binatil-2, Binatil-3, Binatil-4, Soybean - 4: Binasoyabean-1, Binasoyabean-2, Binasoyabean-3, Binasoyabean-4, BSMRAU= Total 2 varieties Soybean - 2: BU soybean 1, BU soybean 2</p>
1991-2021	Total - 79	Total - 60
1971-2021	Total - 84	Total - 77

Source: Websites of BARI, BINA and BSMRAU

remained fallow after rainfed-irrigated T. Aman rice harvest. There is a need to strengthen the national campaign for enhanced pulse production through various programs including stimulating value chain actors and community seed bank for quality seed supply. The farmers should be trained on modern HYVs and production technologies.

Table 4.9 provides information on the development of pulse and oilseed varieties (84 and 77, respectively) during 1971-2021. Most varieties were developed during 1991-2021. About the one-third of these varieties (30 pulse and 24 oilseed) were developed during 2011-2021 which positively influenced the production of pulse and oilseeds and helped stabilize or reduce the deficits.

In Bangladesh, a shortage of edible oils has been prevailing since independence. Despite production increases, the domestic production of edible oil can only meet about 20% of the country's annual demand and the remaining 80% has to be imported at a high cost of more than BDT 20 billion payable in hard earned foreign exchange. Soybean oil ranks first among the imports followed by palm oil, mustard seed and sunflower oil. Out of the seven oilseed crops are grown in the country, mustard (*Campestris and Juncea*) alone occupies about 70% of the oilseed land followed by sesame (*Sesamum indicum*), groundnut (*Arachis hypogaea*), linseed (*Linum usitatissimum*), soybean, sunflower and niger. Groundnut and soybean are not currently used for oil extraction. The total quantity of groundnut is used up as a human food item and in the bakery industries and soybean is used as an ingredient of poultry feed or fish meal. The Ministry of Agriculture, Government of Bangladesh and DAE, giving high priority to pulses and oilseeds, took up a plan entitled "Pulses and Oil crops Research and Development Vision: 2030" (BARC 2009) to increase the production of these two essential food commodities. Oilseed research should be directed towards development of cost-effective crusher machines for extraction of edible oil from groundnut and soybean, and high yielding short-duration varieties with tolerance of biotic and abiotic stresses to fit to the major cropping patterns prevailing in the country. Research on seed viability and preservation techniques especially for groundnut, soybean and sunflower should also be emphasized.

An 11-fold increase in spice production in the last 52 years made it possible to cut down the country's imports of the everyday cooking ingredients and become self-sufficient since 2005 with even surplus by 2010. Research and development work by the Spices Research Centre (SRC) of BARI played the key role in this success story. SRC continues research to develop spice HYVs and extension drives to disseminate new seeds and production technologies. The spice stock, however, sometimes falls short of the people's demands as the consumption per capita is higher than the recommended amounts and imports become necessary.

Since the start of spices research in Bangladesh 56 HYVs were developed during 1981-2021 and almost all varieties (55) were developed during 1991-2021 (Table 4.10). The development of most of the spice HYVs happened

during 2001-2021 (45 varieties), which contributed to an increase of their production and helped achieve a zero balance between production and requirement in 2005 and surplus thereafter.

Table 4.10. Spice varieties developed after the Green Revolution period

Period	Spices Crop Variety
1991-2000	<p>BARI= Total 10 varieties</p> <p>Onion - 3: BARI Pia-z-1, BARI Pia-z-2, BARI Pia-z-3, Turmeric - 3: BARI Halud-1 (Dimla), BARI Halud-2 (Sindury), BARI Halud-3, Coriander - 1: BARI Dhonia-1, Betel Leaf - 2: BARI Betel Leaf-1, BARI Betel Leaf-2, Others - 1 BARI Methi-1</p>
2001-2010	<p>BARI= Total 9 varieties</p> <p>Chilli - 2: BARI Mistimorich-1, BARI Morich-1, Onion - 2: BARI Pia-z-4, BARI Pia-z-5, Garlic - 2: BARI Rasun-1, BARI Rasun-2, Ginger - 1: BARI Ada-1, Others - 2: BARI Methi-2, BARI Kalozira-1</p> <p>BAU= Total 2 varieties</p> <p>Garlic - 2: BAU Rasun-1, BAU Rasun-2</p>
2011-2020	<p>BARI= Total 29 varieties</p> <p>Onion - 2: BARI Bunching Onion-1, BARI Pia-z-5, Garlic - 2: BARI Rasun-6, BARI Rasun-4, Coriander - 2: BARI Dhonia-2, BARI Bilati Dhonia-1, Ginger - 2: BARI Ada-2, BARI Ada-3, Chilli - 6: BARI Morich-2, BARI Morich-3, BARI Morich-4, BARI Mistimorich-2, BARI Ornamental Morich-1, BARI Ornamental Morich-2, Turmeric - 2: BARI Halud-4, BARI Halud-5, Pudina - 2: BARI Pudina-1, BARI Pudina-2, Betel Leaf - 1: BARI Betel Leaf-3, Mouri - 2: BARI Mouri-1, BARI Mouri-2, Others - 8: BARI Methi-3, BARI Shaluk-1, BARI Firingi-1, BARI Tejpatha-1, BARI Daruchini-1, BARI Alubokhara-1, BARI Chive-1, BARI Akangi-1</p> <p>BAU= Total 3 varieties</p> <p>Garlic - 3: BAU Rasun-3, BAU Rasun-4, BAU-BAURES Rasun-5</p> <p>BSMRAU= Total 2 varieties</p> <p>Chilli - 1: BU capsicum 1, Others - 1: BU kalijira 1</p>
1991-2021	Total - 55
1981-2021	Total - 56

Source: Websites of BARI and BSMRAU, AIS 2022

The yields of pulse, oilseed and spice HYVs remained almost stagnant from 1980 to 2000 but increased steadily thereafter (Fig. 4.20). Pulse yield increased by 81% from 0.64 MT/ha in 1980 to 1.16 MT/ha in 2021, oilseed yield increased by 150.1% from 0.79 MT/ha to 1.98 MT/ha and spices yield increased by 335% from 1.93 MT/ha to 8.39 MT/ha during the same period. After deceleration in yield from 1995 to 2000, spices yield registered a significant linear increase from 3.31 MT/ha in 2005 to 8.39 MT/ha in 2021.

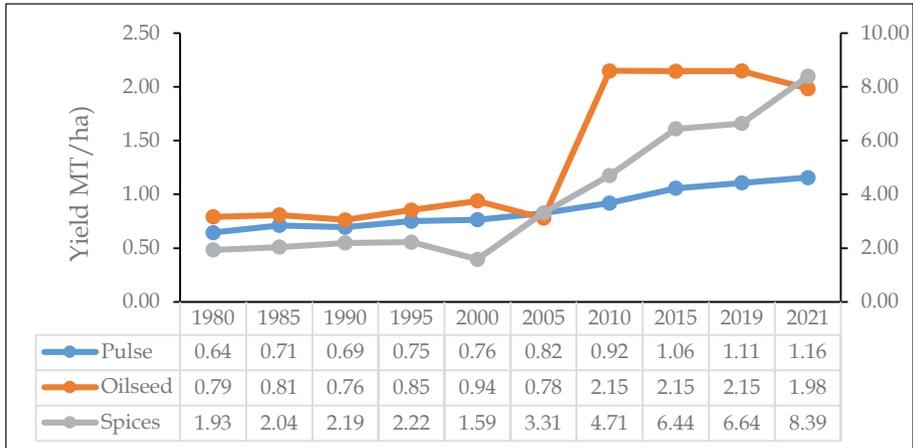


Fig. 4.20. Trend of pulse, oilseeds and spices yield over the years

Source: BBS 1980, 1985, 1990, 2000, 2005, 2011, 2015, 2019, 2021

4.1.5 Tea

Tea is a long-established plantation crop of enormous economic importance to Bangladesh meeting the entire domestic demand of this cheapest health beverage. Now it is one of the largest agro-based industries in the country. Tea production abruptly increased from 23.7 M kg in 1972 to 96.5 M kg in 2021, 4.1-fold increase with average annual growth of 6.1 % over the last 50 years (Fig. 4.21). Bangladesh produced 96.5 M kg of tea in 2021, the highest in 166 years, in favourable weather conditions and supportive measures. A major portion of this production is consumed domestically, and the rest is exported. However, the surplus declined drastically from 16.2 M kg in 2001 to only 0.7 M kg in 2021 and export also declined from 12.9 M kg to 0.7 M kg during the same period indicating a sharp increase in domestic consumption of tea.

Continuous expansion and replantation by tea growers in the last several years as well as favourable weather and pest control measures helped the country set the new record of tea production in 2021. In 2021, a total of 167 tea gardens across the country produced 96.6 M kg tea. Before the latest spell of increased production, annual output actually declined compared to local demand, prompting the country to turn to imports in 2010. The total annual tea production in the country is yet to reach the level of resuming the export volume of 2001.

The Government took a roadmap in 2016 for the development of the tea sector, setting a target to produce 140 million kg by 2025. Some steps like expanding the tea production area and replantation were taken as per the

roadmap. Garden owners infused fresh investments and took up expansion projects in view of the good returns so far.

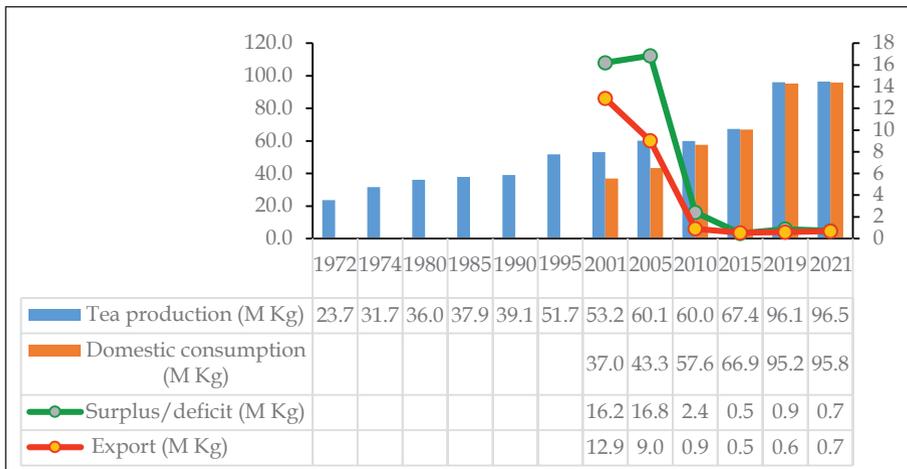


Fig. 4.21. Trend of tea production and surplus over the years
 Source: BTB website, BBS 1980, 1985, 1990, 2000, 2005, 2011, 2015, 2019, 2021

Tea growing area increased significantly by 27% from 43,300 ha in 1970 to 55,000 ha in 2021 with an average annual growth of 0.52% over the last 52 years (Fig. 4.22). The tea growing area peaked to 60,400 ha in 2015.

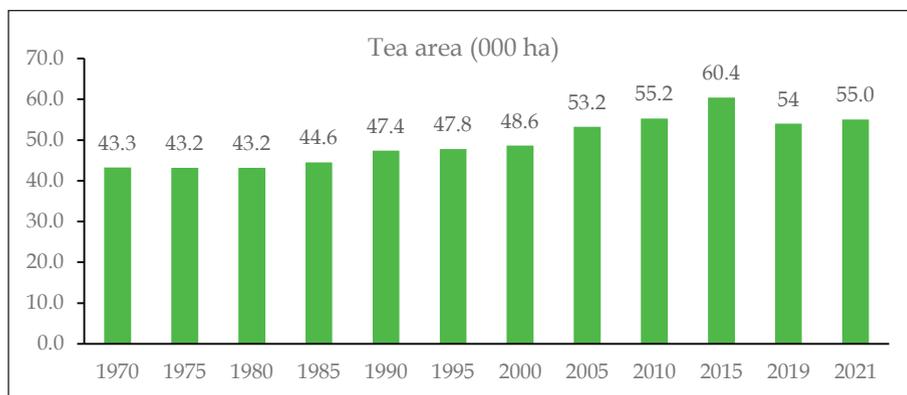


Fig. 4.22. Trend of land area cultivated for tea over the years
 Source: BBS 1980, 1985, 1990, 2000, 2005, 2011, 2015, 2019, 2021

Tea earned the highest foreign exchange equivalent to about 977 million BDT by exporting 8.4 M kg of tea in 2008 (BTB website) but the export earnings declined to only 181 million BDT in 2021 (Fig. 4.23) commensurate with the decline of surplus as shown in Fig. 4.17. In this industry, about 0.15 million

people are employed which is 3.3% of the country's total industrial employment, besides its significant share in total export receipts of an average of 6% (Sana 1989; BBS 2007). About 90% of the garden workers are women, helping women empowerment in terms of contributions to the national economy.

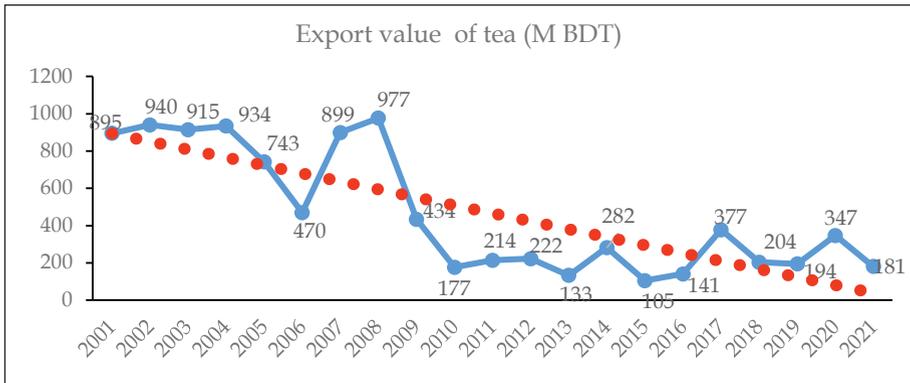


Fig. 4.23. Trend of tea export over the years

Source: BTB website

4.2 Livestock and poultry

There was a shift in the composition of agriculture focusing on non-crop sectors over the past decade or so. While the share of the crop sub-sector declined from 79% in 1991 to 73.2% in 1996, the share of livestock, fisheries and forestry increased from 7.2%, 7.2% and 6.6% to 9.7%, 9.6% and 7.5%, respectively (Chowdhury 2002). Hence, the approach during the Fifth Five Year Plan 1997-2002 was to develop an integrated agriculture including crops, livestock, fisheries and forestry through more efficient utilization of available land and water resources for sustainable agricultural growth.

4.2.1 Meat, milk and egg

Milk, meat, and eggs are three important products of livestock, the production of which showed an increasing trend (Figs. 4.24, 4.25 and 4.26). While the production of eggs and meat registered an impressive growth, the growth of milk production was relatively low. During the last 52 years, meat production increased from 0.3 MMT in 1970 to 8.4 MMT in 2021 with an overall increase by 28 times and an average annual growth of 51.9% (Fig. 4.24). However, meat production underwent an insignificant increase from 1970 to 2010 (0.3 to 1.3 MMT) but with a massive jump to 2021 (8.4 MMT) by 10.5% annual growth respectively in 10 years since 2011. Per capita availability of meat increased from 12.8 g/day in 1970 to 123 g/day in 2021, that, too, in the face of the population increase from 64.2 million in 1970 and

166 million in 2021. A healthy and normal person needs to eat at least 120 g of meat per day (FAO and WHO 2014) and hence the per capita availability of meat has met the requirement. Considering this requirement of population, the country became self-sufficient in meat with a modest surplus (0.2 MMT) generated in 2017 and then this surplus level continued to increase to 1.1 MMT in 2021 with an overall increase of 450% in 5 years.

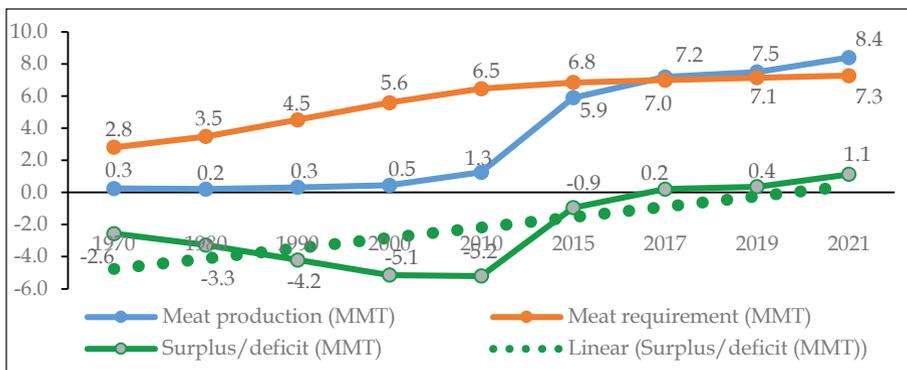


Fig. 4.24. Trend of meat production over the years

Source: <https://knoema.com/atlas/Bangladesh>, BBS 2011, BBS 2021, FAO and WHO (2014)

Milk production increased from 1.1 MMT in 1970 to 11.9 MMT in 2021 with an overall increase of 10.8 times and an average annual growth of 18.9% (Fig. 4.25). However, milk production had an insignificant increase between 1970 and 2010 (1.1 to 2.4 MMT) but thereafter, in 10 years since 2011 increased markedly to 11.9 MMT in 2021. Per capita availability of milk increased from 46.9 ml/day in 1970 to 196.4 ml/day in 2021 while the population increased from 64.2 million in 1970 and 166 million in 2021. Considering 130 g per capita

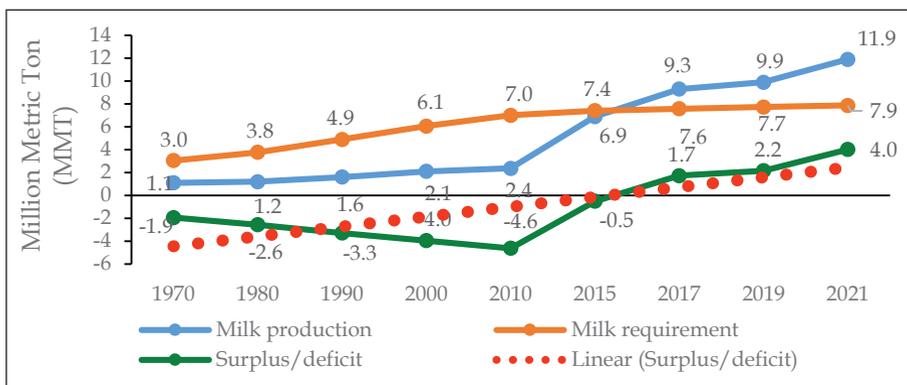


Fig. 4.25. Trend of milk production over the years

Source: <https://knoema.com/atlas/Bangladesh>, BBS 2011, BBS 2021, BIRDEM (2013)

per day requirement (BIRDEM 2013), the country became self-sufficient in milk with a surplus (1.7 MMT) generated in 2017 and then this surplus level continued to increase to 4.0 MMT in 2021 with an overall increase of 135% in 5 years. Considering this per capita requirement, the total milk requirement of the country increased from 3.0 MMT in 1970 to 7.9 MMT in 2021 due to population increase and the trend of milk requirement continued at a higher level than that of the milk production since 2017.

Egg production also increased from 1.2 billion in 1970 to 20.6 billion in 2021, although it remained static around 1.2 billion each in 1970 and 1980, and the overall increase was 17.2 times with an average annual growth of 31.1% over 52 years (Fig. 4.26). Per capita availability of egg dramatically increased from 19 eggs/year in 1970 to 124 eggs/year in 2021, and the latter surpassed the requirement (104 eggs/year) for human consumption as per the standard of FAO and WHO (FAO and WHO 2014). Considering this requirement of the population, the country became self-sufficient in eggs since 2019 when there was a surplus of 0.1 billion eggs and thereafter the surplus continued to increase to 3.3 billion in 2021.

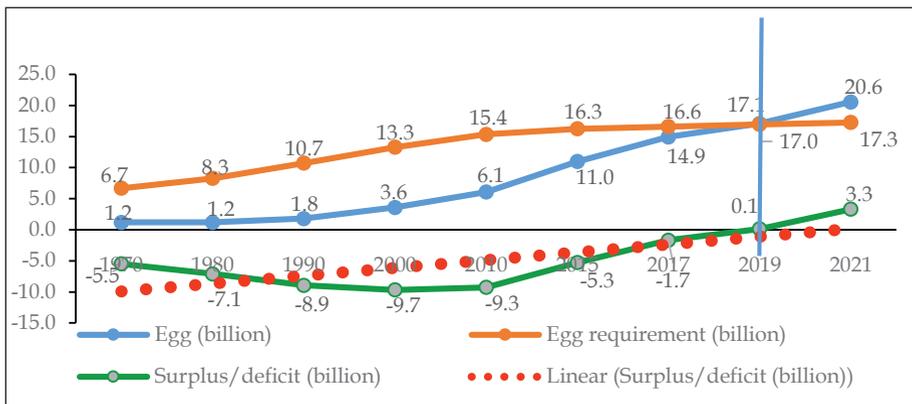


Fig. 4.26. Trend of egg production over the years

Source: <https://knoema.com/atlas/Bangladesh>, BBS 2011, BBS 2021, FAO and WHO (2014)

Livestock and poultry populations

Livestock viz., cattle, buffalo, goat and sheep, and poultry viz., chicken and duck are the important domestic animals in Bangladesh, which provide milk, meat and egg as food for human consumption. The populations of these animals and birds are important indicators of the supply of nutritious foods for the people of Bangladesh.

Cattle, buffalo and poultry

The populations of cattle and buffalo remained almost static starting from 26.5 million in 1970 to 26.1 million in 2021 (Fig. 4.27) experiencing a massive decline to 22 million in 1980 before the population started increasing again to become stable by 2021. This trend in livestock population growth is not encouraging; however, meat and milk production got a boost from technological advancement comprising cross breeding and improved management practices in respect of feeds and fodders, disease control etc. The growth in livestock population mainly occurred in the poultry sector as expected as its overall increase was 4.6 times for 52 years counting from 80 million in 1970 to 366 million in 2021. This was largely due to a combined effect of the Government's emphasis as well as initiatives of NGOs like BRAC, Proshika, RDRS, CARE-Bangladesh etc., and private companies to promote commercial poultry rearing involving mainly women.

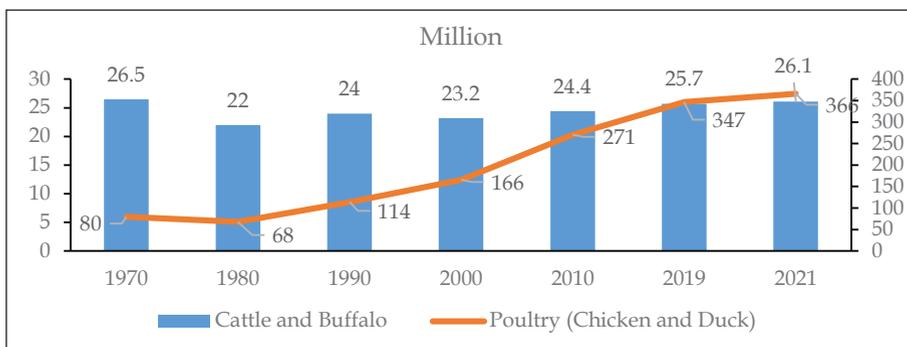


Fig. 4.27. Cattle, buffalo and poultry populations during 1970-2021

Source: <https://knoema.com/atlas/Bangladesh>, BBS 2011, BBS 2021

Policy interventions starting from the 1990s helped livestock growth. The Bangladesh Government supports the livestock industry through three organizations: (a) the Ministry of Fisheries and Livestock responsible for the overall direction and development of the livestock industry, (b) the Department of Livestock Services (DLS) responsible for providing extension services to farmers and (c) the Bangladesh Livestock Research Institute (BLRI) responsible for conducting research on genetics, feed and other management technologies. The private sector also provides significant support for livestock sector development. The poultry sector, due to significant policy and technological interventions in the 1990s and 2010s, provided improved breed, feed, housing, equipment, technology and management services which increased poultry meat and egg production. BLRI developed a new poultry hybrid called 'Sonali', high yielding in terms of both meat and egg, which is now very popular. Leading NGOs such as BRAC, Proshika, Aftab

Bohumukhi Farms Limited (ABFL) and Grameen Bank are also significant players. BRAC, RDRS and Proshika contributed significantly to the development of the poultry industry in Bangladesh involving women.

The dairy sector also showed significant improvements due to policy interventions. Milk production increased due to increased use of cross bred cows. Use of deep-frozen semen for artificial insemination (AI) significantly improved the cattle breeding program. Small scale dairy farming also increased due to the introduction of modern milk processing and packaging techniques. Successful examples of dairy industry are MILK VITA, BRAC-ARONG and PRAN. However, MILK VITA dominates the dairy industry run by the Bangladesh Milk Producers Cooperative Union Limited. The operation involves milk collection from cooperative members, processing in manufacturing plants and then transporting milk to Dhaka. All products ranging from pasteurized liquid milk, butter, powder milk and ghee, etc., are marketed in Dhaka. There is scope for improvement of cattle genetics by setting up a breeding program suited to the bovine characteristics, available feed and climatic conditions. Although there are a number of success stories, the current growth in the livestock sector is inadequate to meet the growing demand. The livestock farms are concentrated in only a few pockets, mainly in Gazipur and Kishoreganj districts or Baghabari in Sirajganj district (<http://www.lrrd.org/lrrd26/10/rahm26173.html>).

Domestic water buffaloes are a valuable animal genetic resource of Bangladesh. They are found throughout the country but are concentrated in particular agro-ecological zones. These zones are mainly the sugar cane belt located in the western and central parts of the country, in the sandy islands of the Brahmaputra and Jamuna rivers, in the marshy lands of the eastern part and in the coastal areas of the country. They are still preferred as draught animals for the muddy fields and for pulling carts. Single animal ploughing with water buffaloes is practiced only in the Sylhet district. They are not usually vaccinated but dewormed against ascaris. The semi-intensive management system is practiced all over the country except the lower part of coastal area where water buffaloes are reared in extensive system, especially, in *bathans*, a fallow land covered with green grasses. Buffalo raising in *bathans* is also practiced in the central part of the country throughout the year but in the western part it remains only for the dry season. Hundreds of water buffaloes belonging to different farmers in a particular locality are allowed to graze in a *bathan*. The animals in a *bathan* are not housed and are managed by paid cowboys under the supervision of a *karbari*. The animals are often infected with contagious diseases and in most cases are treated by non-registered local practitioners.

Commercial chicken production has developed at a faster rate compared to other poultry species. On the other hand, the production system of native

chicken did not change very much. Most of the native chicken is still raised under low-input system and their productivity remains low. Semi-scavenging chicken production is developed in collaboration with the DLS and NGOs and considered to be a viable income-generating system for the distressed and poor women and unemployed youth in the rural areas. The exotic pure breeds and their crosses are used in the system supporting with supplementary feeding, rearing techniques and health care. Commercial farming system is developed in the private sector and mainly based on imported germplasm. Commercial hatcheries are developed mostly based on parent stocks and produced and marketed commercial broiler and layer day-old hybrid chicks to a range of small to large farmers. The local hatcheries produce day-old layer and broiler chicks which meet the market demand.

Ducks are mainly raised by the rural people under a traditional management system. Rural and smallholder duck production systems are most popular in the country. The duck-cum-fish production system has been extensively demonstrated in different regions of the country. Ducks are mainly reared with chicken in scavenging system allowing their access to ponds, confined water areas, canals, beels (big water reservoir) and rivers. Duck eggs are mainly hatched, and day-old ducklings are brooded by broody chicken, but growing ducklings are managed by farmers, especially, by women and children. The smallholder duck production is a unique system that is developed based on natural feed resources available in low lying water bodies of the country. The small and landless farmers are engaged in scavenging duck production in the typical Sylhet basin of the country. The average range of duck numbers kept by different farmers was found as 50-600 per farm and average annual egg production per duck was recorded as 204. However, the productivity of eggs was found to be low in the dry period. To support the smallholder duck production, the Government established hatcheries with intensive duck management system to distribute ducklings to farmers. Duck-cum-fish production system was introduced by the Bangladesh Fisheries Research Institute and has already been scaled up in certain parts of the country. BLRI also demonstrated the integrated systems, and some NGOs took initiatives to disseminate the technology at the field level.

Goat and sheep

The populations of goat and sheep enormously increased with linear growth from 9.2 million in 1977 to 30.3 million in 2021 and the overall increase was 3.3 times over the 45 years showing an average annual growth of 5.1% (Fig. 4.28). This growth is very encouraging.

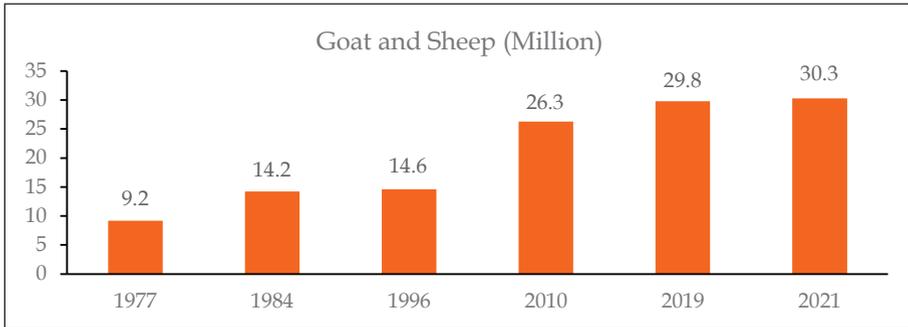


Fig. 4.28. Trend of goat and sheep over the years

Source: <https://knoema.com/atlas/Bangladesh>, BBS 2011, BBS 2021

Goats are used for meat and milk. The native goat breed, the Black Bengal, has some reputed features: early sexual maturity, high proliferation, adaptability to hot and humid environments, and superior quality skin and meat (Chowdhury et al. 2002). The Black Bengal goat is reared by rural people under a semi-intensive or extensive production system. However, some commercial goat farms have been established as the Government moved with a strong national policy to alleviate poverty of the landless and marginal farmers through goat rearing. The Black Bengal goat is evenly distributed throughout the country but are relatively concentrated in the north-western areas of the country belonging to the High Ganges River Floodplain agro-ecological zone (AEZ 11). The Jamunapari, another bigger size goat breed is popularly known as Ram Chhagal. They are found in a limited scale in urban and peri-urban areas in the form of pure or Jamunapari × Black Bengal cross with varying degrees of inheritance. They are reared both in intensive and semi-intensive management systems. However, the population size of Jamunapari is not large (about 6-7 %) in the country.

Sheep is mostly of indigenous type and is called Bangla sheep. They are small in size with an average adult weight of 25.0 kg for ram and 17.0 kg for ewe. The Bangla sheep are sparsely distributed throughout the country, but a higher concentration of sheep is found in the coastal region of Noakhali and Cox's Bazar, and in many char lands. However, the river basins of the greater Rajshahi and Tangail districts have also higher concentrations of sheep, where farmers maintain larger commercial (meat) flocks. Garole, another indigenous sheep of the country is found in Sundarban area in the southern part of the country and is also reared in char lands. They are reputed for multiple births (Sharma et al. 1999). Sheep are reared in an extensive system without any input support. Most of the sheep under extensive system belong to large farmers. However, farmers also keep a few sheep with their cattle herd. Observations on husbandry practices and biological adaptability of

sheep suggest that less problems are associated with sheep management, nutrition and health than that with goats (Faylon 1990).

The significant improvement in the livestock and poultry sector could be attributed to the technological advancement through development of improved breeds and management technologies. Out of the total 76 technologies, 34 (about 50%), were developed during 2011-2021 followed by 28 technologies during 2001-2010 that led to a significant increase in meat, milk and egg production in the late 2010s (BLRI and CVASU website). The major livestock and poultry technologies developed by BLRI and Chattogram Veterinary and Animal Sciences University (CVASU) are given below:

Major livestock and poultry technologies

A. During 1991-2000

BLRI breeds

1. Exact level of crossbred foreign bulls in dairy production

BLRI management technologies

2. Urea-molasses-straw (UMS) feed
3. Preservation of fresh and wet straw during rainy season
4. Urea-molasses block preservation technique
5. Production and use of LG as cow-feed
6. Conservation of green grass in a native way
7. Use of *chitagur* as cow feed
8. Cultivation and use of ipilipil as cattle feed
9. Production and use of maize and cowpea as mixed forage
10. Preservation and use of banana plantations as cattle feed
11. Preservation and use of sugarcane bi-products as cow feed
12. Grass production for saline flood prone and Madhupur areas
13. Production and use of green grass in hilly areas
14. Production and use of duckweed from farm waste

B. During 2001-2010

BLRI breeds

1. Development of cow breeds through artificial insemination

BLRI management technologies

2. Leaf pruning of jackfruit tree as goat feed
3. Goat selection strategies for setting up Black Bengal goat farms
4. Goat kid rearing
5. Production and marketing of Ashtagram cheese
6. Use of embryo transfer technique in native cows
7. Production and use of Baska-a high yielding native grass in dairy cattle

8. Preservation and use of maize straw
9. Cattle worm disease control model
10. Cost-effective hemolysis for compression fixation test
11. Salmonella vaccine
12. Antigen is the diagnostic antigen of chicken salmonellosis
13. ELISA-based FMD diagnosis method
14. Integrated treatment of PPR disease
15. PPR vaccine
16. Antigen is the diagnostic antigen of chicken mycoplasma
17. Collection of blood samples with the help of filter paper for HI testing
18. ELISA method for diagnosing PPR rinderpest
19. HI antigen test for diagnosis of chicken Ranikhet disease
20. Poultry safety management in commercial farms
21. Use of coconut, mustard oil cake and ipil-ipil leaf in the poultry feed
22. Non-electric chick-brooder
23. Advanced techniques in domestic (organic) chicken production
24. Goat pox vaccine
25. EISA method for determination of goat pox disease
26. C-EISA method of diagnosing antibodies against PPR virus
27. Mina-mixed as a source of mineral for livestock
28. Corn straw pellet feed

C. During 2011-2020

BLRI breed/variety

1. BLRI Layer Strain-1 (Shuvra)
2. BLRI Layer Strain-2 (Swarna)
3. MCTC (Multi Colour Table Chicken) - high yielding meat type chicken
4. BLRI Napier-4 (high yielding grass variety)

BLRI management technologies

5. Heat tolerant PPR vaccine
6. Powder based milk replacement for calves
7. BLRI DNA extraction kit
8. Production of milk replacement from Soti powder
9. BLRI FMD Master Seed (O, A, Asia-1)
10. BLRI model for controlling PPR disease of goat and sheep
11. BLRI Feed Master Mobile App
12. Embryo production in the laboratory
13. Selection and rearing of buffalo bull for breeding
14. Internal parasite or worm control model in buffalo farms
15. Bio-security management in buffalo farm
16. Buffalo estrus synchronization technology
17. Raw grass conservation technology in bucket method (dole silage)
18. Innovation of AH Antigen to test HI for Avian Influenza disease (H5NI)

19. Scientific techniques for the production of improved breeds of indigenous chicken
20. FMD control model
21. TMR technology as grain-derived animal feed
22. Cultivation method and use of Moringa as cattle feed
23. Buffalo fattening technology for safe meet production
24. Meat production on a commercial basis from native sheep (Bangla Lamb)
25. Sheep rearing technique in hilly areas
26. Community bio-security model of commercial poultry farms
27. Biometric ranking tool for fodder
28. Mobile and web-based data recording and storage application development
29. Technology of animal feed production from vegetable waste CVASU management technologies
30. Adaption of appropriate technique for the treatment of urolithiasis of small ruminants in Bangladesh
31. Development of chickens suitable for meat and egg production under semi-scavenging system
32. Development of cattle biscuit in Bangladesh
33. Development of whole genome sequence database of Black Bengal Goat
34. Establishment of non-invasive DNA sexing facility for exotic and pet bird species

4.3 Fisheries

The fisheries sector in Bangladesh underwent rapid changes over the past several decades. After being self-sufficient in fish production for the first time since 2015, Bangladesh started to get global recognition as one of the biggest fish producers. Fish has emerged as one of the most critical contributors to the export earnings of Bangladesh, and its contribution is the highest in agricultural export.

4.3.1 Total fish production

Total fish production increased dramatically over the last 5 decades from only about 0.15 MMT in 1971 to 4.50 MMT in 2021 (Fig. 4.29). Production in 2021 was almost 30 times higher than that in 1971. The average annual growth of fish production was 58% from 1971 to date and the highest during 1970s (32.7%) compared to that in the other decades.

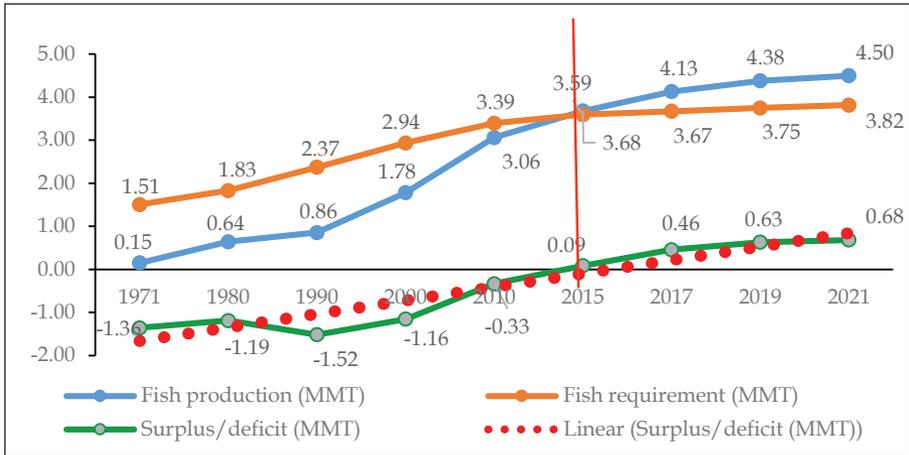


Fig. 4.29. Trend of fish production over the years

Source: <https://data.worldbank.org/indicator/ER.FSH.PROD.MT?locations=BD>
BBS 2011, 2015, BBS 2021

Bangladesh has achieved self-sufficiency in fish; whereas the per capita consumption of fish was 7 kg/year in 1990 it is now about 30 kg/year (FRSS, 2017). According to total fish production (4.50 MMT) in 2021 (Fig. 4.29) and population in the same year (166 million), the per capita availability of fish stood at 27.11 kg/year meaning 74.3 g/day in excess of the 63 g fish per capita per day requirement (FAO and WHO 2014). The country today is self-sufficient in fish with a surplus of 0.09 MMT in 2015 and the surplus continued to increase to 0.68 MMT in 2021 due to higher level of fish production than its requirement during this period.

4.3.2 Fish production by category

Fisheries fall broadly into three categories (a) inland capture (floodplain fishery), (b) inland culture (primarily pond fishery and coastal aquaculture), and (c) marine. Inland capture fish production increased steadily from 0.44 MMT in 1980 to 1.25 MMT in 2020 except a decline to 0.42 MMT in 1990 and the overall increase was 2.8 times with an average growth of 4.5% over 41 years (Fig. 4.30). The highest growth of fish production was reported in case of inland culture fisheries, which increased linearly from 0.1 MMT in 1980 to 2.6 MMT in 2020 showing an overall increase by 26 times and an average annual growth of 61% during the same period. Marine fisheries production steadily increased from 0.12 MMT in 1980 to 0.67 MMT in 2020 indicating an overall increase by 5.6 times with an average annual growth of 11.2%. Inland capture fisheries contributed 67% of the country's total fish production in 1980, but this share went down to only 27.7% in 2021. Inland culture fisheries

contributed only 15.2% of the total fish production in 1980 and the share enormously went up to 57.5% in 2021. However, the marine fisheries' share of total fish production remained almost stable around 18.2% in 1980 and 14.8% in 2020. A small improvement in the average yield of inland open water capture fisheries could significantly increase national fish production and consumption. Open water capture fisheries consist of rivers, estuaries, flooded lands, beels, haors and the Kaptai Lake.

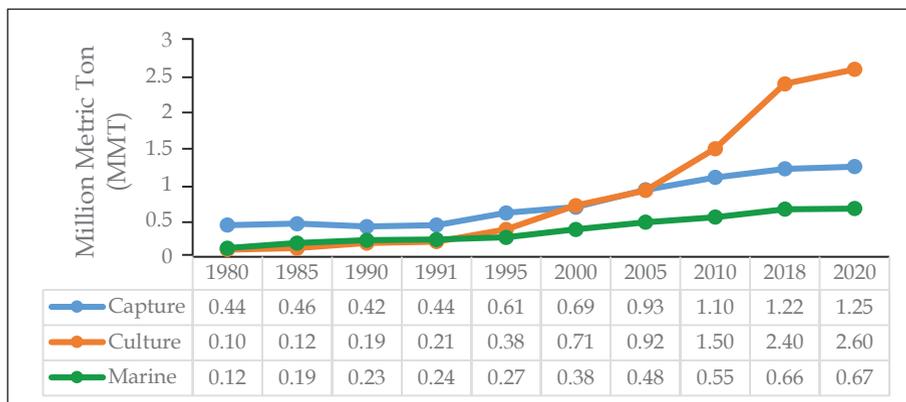


Fig. 4.30. Trend of fish production by categories over the years

Source: BBS 1985, 1990, 1995, 2000, 2005, 2011 and 2021

Improved breeds and management technologies developed by the fisheries scientists of the country have been instrumental in the remarkable fish production growth. Most of the technologies (47 out of 68) were developed during 2009-2021 that led to the massive increase in fish production in the late 2010s (BFRI and CVASU website). The major fisheries technologies developed by BFRI and CVASU are given below:

Major fisheries technologies

A. During 1986-2008

BFRI

1. Controlled breeding technique of *Tor putitor* (mahaseer), *Labeogonius* (gonia), *Labeobata* (bata), *Cirrhinusarhiza* (reba) *Puntius sarana* and *Anabas testudeneus* (koi) has been developed.
2. Techniques for culture and breeding of *Ompokpabda*, *Mystuscavasius* and *B- gonionotus* have been perfected.
3. Genetically improved strain of *B. gonionotus* has been development through several generation of selection.
4. Monosex male tilapia of GIFT strain has been produced successfully using hormone-treated feed and given to farmers for large-scale adoption.
5. Genetic clones in *Labeorohita* (rohu) has been developed.

6. Optimized technique to produce 4-5 fingerlings of carps and the know-how to different hatchery operators has been developed.
7. Techniques for breeding and culture of *Clariasbatrachus* (magur) and *Heteropneustesfossilis* (shing) have been evolved.
8. Stocking density of *Macrobrachiumrosenbergii* (prawn) has been standardized in out-door and in-door nursery system.
9. Cost effective feeds from indigenous raw materials for carp broodstock management has been made.
10. A package of technology on rice-cum-fish farming in irrigated and floodprone ecosystem has been evolved.
11. Fingerlings of *Pangassiuspangasius*, *Mystusaor* and *Rita* are collected from the river system, domesticated in the pond system, and broods were developed. Artificial breeding and culture technology of native *Pangassiuspangasius*, *Mystusaor* and ayer fish were developed. Techniques for controlled breeding and fingerling production of exotic pangas (*P. sutchi*) were evolved.
12. Polyculture of carps in pen in borrow pit canals in different irrigation project areas yielded 1-2 MT/ha/crop of 6 months with low-cost supplemental feeding.
13. Technology for prawn seed production in backyard hatchery was developed.
14. Techniques for large-scale production of post-larvae under different hatchery operation systems (circulatory and open) have been developed.
15. Proper stocking density and species combination of *P. monodon* with certain brackish water finfish have been standardized.
16. Range of desirable soil and water quality for effective management of shrimp-finch farming have been established.
17. Stocking density of 6000/ha of mud crab, *Scylla serrata*, have been found as optimum density for controlled culture.
18. Dry fish produced by solar dryer reduce bacterial load significantly compared to those produced by traditional methods. Time required to produce dry fish by solar dryer is less compared to traditional methods.
19. Quality fishmeal produced through improved methods yielded better nutritive value compared to traditional commercial fishmeal available in Bangladesh.
20. Crop rotation between finfish and shrimp reduces the incidence of disease epidemic in shrimp farm. Successive semi-intensive shrimp crops/year in the same pond increases the risk of disease occurrence.
21. Polyculture of non-carnivore fish and shrimp appears to be promising and environment friendly. Sea bass raised with live tilapia in mixed culture attained 6.5kg in average within 3 and half years.

B. During 2009-2021

BFRI

Fish breeding and seed production

1. Breeding and hatchery management of carps
2. Collection and preservation of pituitary gland for induced breeding
3. Improved carp seed production and nursery management
4. Breeding and seed production of GIFT tilapia
5. Breeding and seed production of silver barb
6. Breeding and seed production of pabda
7. Breeding and seed production of gulsha
8. Induced breeding and seed production of pangasius
9. Golda seed production in backyard hatchery
10. Seed production and culture of magur
11. Seed production and culture of shingi
12. Induced breeding and culture management techniques of Tengra fish
13. Breeding and farming of Koi
14. Seed production and fattening of mud crab
15. Stock improvement of Rui

Fish culture

1. Carp polyculture in perennial ponds
2. Culture of GIFT in seasonal ponds
3. Culture of silver barb in seasonal ponds
4. Culture of improved hybrid catfish
5. Culture of pangasius in ponds
6. Fish culture in pen
7. Carp polyculture along with prawn in ponds
8. Improved shrimp culture in ghers
9. Technology for crab fattening
10. Crop rotation-based shrimp and fish culture in coastal areas
11. Seabass culture using tilapia
12. Low-cost fish and shrimp feed production and its application
13. Farming of Super Tilapia
14. Low-cost feed preparation and improved feed management

Integrated farming

1. Integrated chicken-fish farming
2. Integrated duck-fish farming
3. Integrated rice-fish farming

Management

1. Diagnosis of common diseases, treatment and healthy management
2. Conservation and development of hilsa resources
3. Floodplain fisheries resources development and management

Biotechnological

1. Seed production of endangered fish species through in vitro fertilization
2. Production of carps, catfishes and GIFT through selective breeding
3. Production of monosex tilapia
4. Development of hybrid variety of magur and punti
5. Freshwater pearl production

CVASU

1. Establishment of fish oil as a substitute of vegetable oil
2. Improvement of the Culture Practice of the Soft-Shell Mud Crab (*Scylla serrata*) in Bangladesh.
3. Development of Culture System of Green Mussel (*Perna viridis*) in Coastal Areas of Bangladesh
4. Establishment of a Low-cost Improved Fish Dryer
5. Innovation of low cost "Auto Feeder" for effective feed management in fish farm
6. Development of Rooftop Aquaculture Model for Urban Household
7. Use of fish oil for preventing coccidiosis of poultry.

Scientists have been successful in discovering the genome sequence of the hilsa fish, which will provide a holistic understanding of the organism's biology and can be used to increase its production and ensure its conservation. Hilsa production substantially increased due to implementation of a unique coordinated management program including *jatka* conservation and development of hilsa fish sanctuaries and preservation of natural breeding grounds, etc. Hilsa, the country's national fish, has been declared as a Geographical Indicator (GI) for Bangladesh (DoF 2017). About 12% of the country's total fish production comes from hilsa, and as a single species, it makes the highest contribution to the country's total fish production (Toufique 2015). About 65% of Bangladesh's total catch of hilsa currently originates from the marine environment. Hilsa production increased over the last thirty years in Bangladesh. Total hilsa catch rose from 255,000 MT in 2003–04 to 394,000 MT in 2015–16. In 2016–17, hilsa production reached its peak with a production of 496,000 metric tons. The growth rate of hilsa production is 25.7% (DoF 2017). Total shrimp and prawn production, including capture, increased from 160,000 MT in 2002–03 to 246,000 MT in 2016–17. Frozen shrimp and prawn is the most important export commodity of Bangladesh which accounts for a big chunk of the country's foreign currency earning (Vohra 2001).

The formal foundation for fish culture in ponds and lakes in Bangladesh was laid during 1960s, and the development of carp farming in ponds and beels happened during the time between late 1960s and early 1970s. A considerable advancement was made in some areas, eg. success in induced breeding of indigenous carp with pituitary gland extracts. Over the last few decades,

however, fish habitats in Bangladesh were degraded drastically by the development of flood control measures which resulted in a decline in natural fish production. As a result, GOs, NGOs and private entrepreneurs have come forward to develop improved fish farming techniques especially in ponds and floodplains (FAO 2005). There are two types of aquaculture practices in Bangladesh - freshwater and coastal aquaculture. Freshwater aquaculture comprises mainly pond farming of carps - (indigenous and exotic), Mekong pangasid catfish, tilapia, Mekong climbing perch and a number of other domesticated fish though in lesser scale. Coastal aquaculture consists mainly of shrimp and prawn farming in *ghers* (coastal pond or enclosures). Inland pond culture represents the mainstay of aquaculture in Bangladesh, accounting more than 80% total recorded aquaculture production and presently dominated by carps (indigenous and exotic), Mekong pangas and tilapia. Many hatcheries and nurseries have already been established by the private sector in recent years to breed and sell hatchlings, fries, and fingerlings from the carp family.

The major growth in artisanal marine fishery has been made possible by the use of trawlers, motorized fishing boats, and more efficient fishing equipment. The development and promotion of these boats have been a contribution of the Bangladesh Fisheries Development Corporation (BFDC), but since 1983-84 the number of fishing craft did not increase and the number of trawlers in operation actually declined. In the last few years, overall fish production increased. This growth was boosted by the introduction of aquaculture technology in shrimp farms and pond fishery. Now a days, pen and cage cultures are becoming popular and are the most widely practiced culture systems in Bangladesh. Coastal aquaculture, shrimp, prawn and finfish farming are expanding. The marine fisheries resources play a crucial role in the economy of the country, contributing about 16% of the total fisheries production. The entire fish group in marine fisheries showed a significant change in production where Sea catfish, Jewfish, Indian salmon, shark, and other marine fish showed a gradual decrease over the last two decades. The highest output from marine fish catch was Bombay duck (*Harpodon neherius*) in comparison with other Pomfret (*Pampus argenteus*), Indian Salmon (*Eleutheronematetra dactylum*), Jewfish, catfish, etc.

Inland aquaculture of indigenous and exotic carp species, as well as tilapia, pangas, koi, mola, expanded massively. These indigenous and alien carp species, as well as tilapia, pangas and koi, are becoming scarce in open water bodies, but they are the most widely cultured species (Murshed-e-Jahan et al. 2014). Fish farming in Bangladesh traditionally has been a low-intensity semi-subsistence activity, but rapid commercialization, gradual intensification and specialization took place over the last decade, leading to an unprecedented expansion in production of farmed fish (Belton and Azad 2012). Horizontal expansion of aquaculture has been taking place in the riverine floodplains. Over the last few years, many crop farmers converted

their land to fishponds, mainly in Mymensingh and parts of Rajshahi owing to a diminishing benefit-cost ratio in paddy farming.

Drought coupled with siltation and lowering water level are reducing overwintering habitat for indigenous fish species resulting into less recruitment into grazing field to grow inland fisheries. Reduced water flow in major rivers has resulted in a severe depletion of riverine fisheries. Due to decrease in groundwater and surface water, extreme pressure was exerted on floodplains to convert them to crop field, brick kiln and other infrastructures, resulting in an alarming decline in fish diversity and production. More and more intense and long droughts have been observed since 1970s in almost all areas especially in northern Bangladesh. Water with poor quality and less availability for aquaculture and reduced production of fish is very common. Loss of both wild and farmed fish stocks has been going on for a long time. There are conflicts among different water users and irrigation to crop fields.

Alteration of species and ecosystem caused by exotic invasive animals and plants influence the functioning and overall health of the affected ecosystems (Ameen 1999). The invasive species rapidly spread over the wetlands as biological explosives during the rainy seasons. Most of the introduced species were meant only for captive cultivation in closed pond systems but nobody succeeded in maintaining the fish in captivity. During monsoon and/or flood the escapees easily find their ways to the rivers and floodplains throughout the country. This is one of the major threats to the biodiversity of many indigenous fishes. Several introduced species are highly carnivorous and predatory and eat almost everything including the small indigenous species of fish - which grow to a maximum length of 5- 25 cm (Felts et al. 1996). At present, significant carp species such as *Catla catla*, *Labeo rohita*, *Cirrhinus mrigala* and *Labeo calbasu* along with exotic carp, such as silver carp (*Hypophthalmichthys molitrix*), grass carp (*Ctenopharyngodon idella*), and common carp (*Cyprinus carpio*) are the most widely cultured fishes available in the market. Now a days, new interest is growing in live fishes like koi (*Anabas testudineus*), singh (*Heteropneustes fossilis*), magur (*Clarias batrachus*), pabda (*Ompok pabda*), gulsha (*Mystus cavasius*), etc.

The Government of Bangladesh and several NGOs have invoked regulatory and development interventions for sustainable management of the natural fisheries. Among the measures are:

- a) the implementation of Fish Protection and Conservation Act 1950 and related rules including new fisheries management policy (licensing the fishing rights directly to the true fishers),
- b) community based fisheries management (CBFM), establishment of fish sanctuary in the strategic points of the rivers and floodplains,
- c) fish stock enhancement through releasing fish seed in seasonal floodplains and
- d) fish habitat improvement through excavation of link canals (between rivers and floodplains) and beels.

The Fish Act 1950 provides regulations for:

- (i) restriction on capture size of some fish for a specific period,
- (ii) restriction on catch of any species for specific time or season,
- (iii) closure of fishing in any water body for any stipulated time period,
- (iv) restriction of fishing by dewatering or any other destructive method,
- (v) restriction on the use of any kind of gear and mesh size of net and
- (vi) restriction on placing fixed engine in a water course, which may restrict fish migration.

The Fish Act 1950 element - 'closure of fishing in specific area for specific period' which may be termed as 'fish sanctuary' is easier to apply than other regulations of the Fish Act. The "sanctuary" concept was tested and found to be a powerful tool for the protection and conservation of fish stock in Bangladesh. Keeping this in view, the Bangladesh Government has established fish sanctuaries under different development projects following several management approaches since 1960 and more intensively in the last decade. NGOs like BRAC, CARITAS, CNRS, PROSHIKA and WorldFish Centre (CBFM project) are involved in fish stock development by establishing traditional sanctuaries in beels and rivers of Bangladesh. In addition, a number of silted up beels, baors, dead rivers and link canals have been re-excavated by the Government under the Food for Work programs over the years.

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Chapter 5

Moving towards Sustainable Food Surplus

Appropriate planning and timely support by the Government coupled with dedicated work by agricultural research institutions and extension agencies have contributed to the attainment of food surplus in Bangladesh by the year 2000. Today, the country is surplus in rice, fruits, fish, meat, and milk during 2010s considering people's requirements. However, this food surplus needs to be sustainable in the long run for fulfilling the needs of current and future generations. Bangladesh must maintain food surplus as the current population of 166 million (BBS 2022) is projected to swell to 204 million by 2050 and 176 million in 2100 (<https://www.populationpyramid.net/bangladesh/2050/>). Government policies and plans since 2010 have created an enabling environment for the farmers in the agriculture, livestock and fisheries sectors to accelerate production resulting in food surplus. This chapter describes the country's i) long-term visions, policies, and plans, ii) strategic investments and iii) initiatives for the fourth industrial revolution in favor of sustainable food surplus utilizing every inch of arable land.

5.1 Long-term visions, policies, and plans

The instruments to help the country maintain sustainable food production in the long run are incorporated in various documents: Vision 2041: Perspective Plan of Bangladesh (2021-2041), Bangladesh Delta Plan 2100, various agricultural policies for the future, the five-year plans and Agricultural Research Vision 2030 and beyond.

5.1.1 Vision 2041

The Government adopted Vision 2041 and the associated Perspective Plan 2021-2041 (PP2021-41) setting up the road map for the promotion of Bangladesh to an Upper Middle-Income Country (UMIC) eliminating extreme poverty by FY2031, and to a High-Income Country (HIC) status by FY2041. Vision 2041 or PP2021-41 formulated in March 2020 (BPC 2020) emphasized agricultural development outlining six strategic approaches for:

- a) bringing fragile agroecosystems under productive sustainable agricultural practices,
- b) intensification of crop cultivation in productive agricultural land maintaining sustainability of soil health,

- c) sustainably intensifying agricultural production systems without bringing new land under cultivation,
- d) increasing resilience of crop and livestock production systems in the face of climate change,
- e) diversification in agricultural output and livelihoods involving more plant HYVs, animal breeds, off-farm activities and employment, and
- f) coping with uncertainty in developing responses due to uncertainty about the scale and eventual nature of adaptation needed to address climate change.

In addition, strengthening local adaptive capacity by providing public goods and services, such as better climate information, development of heat-tolerant, salinity-tolerant crop varieties and climate smart production technologies, efficient irrigation practices and early forecasting/warning systems has been emphasized. Integrated farming systems will be followed adopting good agriculture practices (GAP) like conservation agriculture (CA), integrated plant nutrition system (IPNS) and integrated pest management (IPM). These aspects of sustainable food production from the agricultural sectors are envisioned in the Bangladesh Delta Plan (BDP 2100). The Government has already adopted BDP 2100 in 2018 and its implementation is underway. Vision 2041 strongly advocates proper implementation of BDP 2100. Commercializing of agricultural production would be given high priority during the next two decades.

Vision 2041: Agriculture sector priorities

a) Creating opportunities for sustainable agriculture and green growth

One of the 17 goals of the UN Sustainable Development Goals (SDGs) for 2030 is to implement sustainable food production systems and resilient practices needed to double agricultural productivity and incomes of small-scale food producers while maintaining the genetic diversity of crops, livestock, and fisheries. Sustainable agriculture will be built on current agricultural achievement adopting a sophisticated approach that can maintain high yields and farm profits at the same time conserving natural resources.

b) Crop zoning, land use planning and promotion of precision agriculture

Considering the increasing demand for food production, emphasis has been given on soil and water conservation, land development, drainage and flood control and reclamation programs. Production programs will have to be organized based on crop zoning and adoption of precision agriculture practices. Land levelling with laser equipment, conservation agriculture comprising minimum tillage practices, buried pipe irrigation, drip

and sprinkler irrigation, hydroponic culture of vegetables, bed planting, floating agriculture, organic farming, use of urea super granule (USG), IPNS and IPM are some of the examples of precision agriculture.

c) Agricultural inputs

The current seed policy encourages private sector involvement in research and development of hybrid and HYV seeds. Seed production through biotechnology will be expanded. Facilities and infrastructure support for hybrid seed production, marketing and development have been underpinned.

d) Promoting agricultural diversification

Agricultural diversification will be promoted through non-cereal based high-value cropping patterns with value-added products, including the expansion of horticultural, pulse and oilseed crops. Policy support will be provided to small and marginal farmers in selling their surplus products at remunerative prices by linking them with domestic and international markets.

e) Use of water resources and water economy

Irrigation efficiency will be ascertained, and modern water management technology will be promoted to enhance irrigation efficacy and water productivity through building water reservoirs/rainwater harvesting in rainfed/coastal/hilly areas and development of small-scale water resources systems.

f) Introduction and popularization of good agricultural practices (GAP)

Protocol development for GAP suitable for Bangladesh agro-ecological and socio-economic conditions will be a priority as required under the Agricultural Policy that calls for development and implementation of such protocols, i.e., codes, standards, and regulations for the fulfilment of trade and food safety and quality requirements. Research and extension will put efforts jointly to promote the process of meeting the four pillars of GAP: economic viability, environmental sustainability, social acceptability, and food safety and quality.

g) Farm mechanization

The Government will continue to play a pro-active role in popularizing the use of selected demand-led agricultural tools and machinery and facilitating the use of renewable energy including solar power in agricultural production.

h) Post-harvest management

Technologies are already increasingly becoming available for the development and growth of agro-processing industries in the country. There will be supporting policies and a regulatory environment to facilitate higher levels of private sector investments with incentives to use technological innovations in post-harvest management.

i) Value chain development

Value chain development identifying constraints to the marketing supply channel is a new tool for rationalizing prices of agricultural produce between farm gate and consumer. A viable private sector-led value chain will be pursued by strengthening institutional capacity through minimization of financial and regulatory constraints to address the complex production and marketing milieu. Durable packaging materials like plastic crates, corrugated fiberboard packaging and minimally processed product development technologies will be popularized through training and demonstrations.

j) Smooth flow of agricultural credit

Microfinance institutions have always been at the forefront in providing agriculture credit. This will be strengthened and made amenable to market needs.

k) Agricultural research

Generation of demand-led technologies (varieties and management practices) and information and also scaling-up the newly developed technologies will be emphasized and adequately funded to address the problem areas (hill, char, coastal, haor and Barind areas) that especially prone to the vagaries of weather and prone to the home of poor and vulnerable people. Research will gear towards the development of measures to ensure sustainable natural resource management e.g., rainwater and river water harvesting for agricultural production, disease and pest management, integrated nutrient management for qualitatively and quantitatively high yields of crops, post-harvest technologies for high-value agricultural commodities, mechanization, etc.

5.1.2 Bangladesh Delta Plan 2100

BDP 2100 has been formulated as an adaptive, holistic and long-term integrated plan to steer the opportunities and vulnerabilities created by the interface of water, climate change, natural disasters, environment, ecological balance, agriculture, land use and inland water management for national development (BPC 2018). Sustainable use of water resources and prevention of water-related natural disasters provides the backbone to the Delta Plan.

The strategies in BDP 2100 are meant to address specific challenges of hot spots like:

- a) water shortage in the drought prone Barind ecosystem,
- b) river erosion problems of the river and estuary region in the char ecosystem,
- c) coastal inundation and salinity problems of the coastal ecosystem,
- d) flash-flooding and wetland management issues of the haor ecosystem,
- e) water shortage problem of the hill ecosystem and
- f) water shortage, sanitation, and drainage problems of the urban region

BDP 2100 will help the country achieve sustainable agricultural production through the following specific measures:

a) Sustainable land use and spatial planning

Planning, managing and developing strategies for land resources are integral parts of BDP 2100. Land use strategy encompasses natural areas for agriculture, forests and watercourses as well as areas for urban and industrial needs. The utilization of land includes both for agricultural and non-agricultural purposes for which making spatial planning an integral part of land use management will be important. The strategies include:

- develop effective policy guidelines and rules for the balu mahal and sediment management,
- preserve/ conserve agricultural land from floods or erosion to sustain food grain production,
- prevention of salinity intrusion and desertification,
- management of newly accreted land in the Meghna Estuary,
- sustainable coastal land management for enhancing agriculture and non-agriculture land.
- development of a digital land resource management system,
- reviewing and updating/enactment of laws/regulations relating to alluvion and diluvion to improve efficiency of land administration of accreting and reclaimed land,
- formulation of necessary laws and acts to form land zoning,
- increase climate change adaptation capacity for land management,
- formulation of a Spatial Planning and Land Resource Management Act,
- enhance afforestation and plantation in the coastal zone for stabilizing land,
- restoration and protection of soil health, erosion, and land loss,
- integrated management of coastal water infrastructures to protect land.

b) Agriculture, food security, nutrition, and livelihoods

Agriculture is likely to bear the main brunt of output losses due to climate change adversities and natural disasters. By 2100, climate change could impose costs on the Bangladesh economy that could be significantly higher

than the estimated global average loss. Mitigation strategies include:

- increasing resilience of agricultural production systems,
- diversification in agricultural output and livelihoods,
- lower emissions (GHGs) from agricultural land,
- encourage establishing commercial farms,
- introduction of aquaponics farming system to culture fish and plants together,
- using nanotechnology in agriculture for processing, distribution, and packaging,
- introduce precision agriculture model,
- encouraging solar power in irrigation,
- improvement of farm practices and technologies for mediating negative impacts of climate change,
- preservation of ecosystems for plant, wild animals, fishes, birds, etc. and encourage fruit tree plantation,
- improvement of wetland management in haor areas for development of fisheries,
- maintaining biodiversity to ensure long term fish availability,
- sustainable marine fisheries resources management, and
- production of climate resilient livestock

c) Advancing blue economy

With the settlement of maritime border disputes with neighboring countries, Myanmar and India, in 2014, the Government of Bangladesh (GoB) began to explore the opportunities of tapping the huge marine resources lying in Bangladesh's Exclusive Economic Zone (EEZ) in the Bay of Bengal and developing a lucrative blue economy which is now a new 'development space' for Bangladesh. The key sectors of this prospective blue economy may be shipping, coastal shipping, seaports, ship building and recycling, marine fisheries, sea salt, coastal tourism, ocean energy, land reclamation, maritime surveillance etc. A total of 16 different approaches have been proposed of which regional partnerships in developing the blue economy are ranked high in the agenda. Major strategies to exploit the blue economy opportunities include:

- quick completion of multidimensional surveys of marine resources,
- expansion of maritime shipping by increasing the number of sea-going vessels and modernization and capacity building of the sea ports,
- intensifying both shallow and deep sea fishing,
- introduction of eco-tourism and private sector initiatives in sea cruise and
- keeping the coasts and seaports pollution free.

d) Renewable energy

Bangladesh has an enormous potential in renewable energy development

including solar power, hydropower, energy from winds and biomass for cost effective and environment friendly irrigation. Plans for developing renewable energy are to:

- develop long-term renewable energy policy as well as strategies and formulate a master plan for at least 50 years to harness the potential of renewable energy resources in the country involving public and private sector investments,
- promote research on the development of technology in the field of renewable energy in universities and research institutions as well as build capacity for its application,
- enhance green growth through research and development of renewable technologies including clean development mechanism (CDM),
- devise innovative financing packages for grant funding and low interest financing to address affordability for both grid and off-grid renewable energy projects and
- target for at least 30% energy production from renewable sources by 2041 in the context of being a prosperous country.

5.1.3 Agricultural policies

The policy documents related to food production can be classified into three sub-categories- agriculture, livestock, and fisheries.

Agriculture sector

The following matrix gives an overview of major goals and thrusts of various policies in agriculture sector implemented by the Ministry of Agriculture (Table 5.1).

Table 5.1. Matrix of agriculture sector related major policies

Name of the policy	Major policy thrusts
1. National Agriculture Policy (NAP) 2018	Increase availability of food and right to food; Modernize agricultural research, education, extension, input management and develop skilled manpower for sustainable technology innovation. Increase farmer's capability through institutional infrastructure development and efficient technology services; Adopt and implement food production plans to meet the needs of nutritious, safe and demand driven foods; Develop agricultural research for promoting exports of products through coordination with local and international partner organizations; Ensure marketing facilities of agricultural commodities; Increase productivity through proper management of natural resources; Introduce cost saving farming systems through agricultural mechanization; Create agricultural commercialization through export oriented agricultural development; Ensure proper use of water resources through inter-ministerial/interagency coordination.

2. National Agricultural Extension Policy 2020	Climate resilient, environment friendly, safe, sustainable, nutrition rich and profitable crop production for all categories of farmers and entrepreneurs by providing demand-based technology and information service.
3. Good Agriculture Practices 2020	Ensure sustainable production of safe and nutrition enriched crops; Ensure climate resilient crop production, and health safety and security for the welfare of agricultural employees; Health safety of consumers; Increase production and export of quality high value crops;
4. Draft National Seed Policy 2018	To breed, develop and maintain improved crop varieties with special emphasis on those suitable for high-input and high-output agriculture; To multiply and distribute, on a timely basis, to all farmers sufficient quantities of quality seed of improved high yielding varieties that are resistant or tolerant to disease and insect pests; To promote, through education, training and financial supports, balanced development of public and private sector seed enterprises; To simplify the importation, for research and commercial purposes, of high-quality seeds and planting materials.
5. Fertilizer dealer recruitment and fertilizer distribution based coordinated policy 2009	Introduction of retail seller of fertilizer dealers; Provide ID card to fertilizer retail sellers; Abolition of sales representatives of dealers; Recruitment of dealers at union level; Dealership limited to the residents of the district.
6. National Integrated Pest Management Policy 2002	Enable farmers to grow healthy crops in an increased manner and thereby increase their income on a sustainable basis while improving the environment and community health.
7. Integrated Minor Irrigation Policy 2017	Ensure food security and poverty alleviation by increasing crop production with lower irrigation cost, increased skills and modern irrigation systems.
8. National Organic Agriculture Policy 2016	Conduct agriculture program maintaining soil fertility through integration of soil physical, chemical and organic qualities; Identification of zone, location and crops suitable for organic agriculture; Development and extension of crop based organic agricultural production systems; Make organically produced seeds easily available; Involvement of indigenous and traditional knowledge and practices related to organic agriculture in crop production.
9. National Agricultural Mechanization policy 2020	Encourage the introduction of farmer-friendly agricultural machinery according to the socio-economic status of the farmers, small size of the farm and fragmented land and soil type of the farmers. Accelerating agricultural mechanization for the profitable, commercial and sustainable agricultural production system.
10. National Jute Policy 2018	Ensure fair price of produced jute; Extend multifaceted jute products and jute stick bi-products to the national and international markets; Attract national and international investors by creating encouragement and incentives, and by creating opportunities for infrastructure development by the government; Strengthening research for development of jute sector.

Livestock sector

The following matrix gives an overview of major thrusts and objectives of various policies on livestock sector implemented by the Ministry of Fisheries and Livestock (Table 5.2).

Table 5.2. Matrix of livestock sector related major policies.

Name of the policy	Major policy thrusts
1. National Livestock Development Policy 2007	<p>Promote sustainable improvements in productivity of milk, meat and egg production including processing and value addition;</p> <p>Promote sustained improvements in income, nutrition, and employment for the landless, small and marginal farmers; and</p> <p>Facilitate increased private sector participation and investments in livestock production, livestock services, market development and export of livestock products and by-products.</p>
2. National Poultry Development Policy 2008	<p>Increase production of safe and quality egg and meat to meet the national demand of animal protein;</p> <p>Make self-sufficiency in poultry feed production;</p> <p>Develop improved poultry breed suitable for the weather of the country;</p> <p>Develop entrepreneurs involving unemployed youth, landless and marginal farmers;</p> <p>Create international market for poultry commodities and increase export opportunities for earning foreign currency;</p> <p>Establish environment friendly poultry farm by ensuring bio-security;</p> <p>Extension and modernization of poultry health services;</p> <p>Strengthening research programs in the poultry sector at the government and private sector levels;</p>
3. National Livestock Extension Policy 2013 (Final Draft)	<p>Fortify research-extension-farmers linkages, mobilize, build and develop farmer groups and producer organizations for better access to technologies;</p> <p>Promote sustainable improvements in safe milk, meat and eggs production to satisfy national demands;</p> <p>Processing and value addition for optimal income and employment generation;</p> <p>Facilitate increased private sector participation and investments in livestock production, market development and export of livestock products and by products;</p> <p>Strengthen health services, veterinary public health, diagnostic facilities, diseases surveillances and reporting.</p>

Fisheries sector

The following matrix gives an overview of major thrusts and objectives of various policies on fisheries sector implemented by the Ministry of Fisheries and Livestock (Table 5.3).

Table 5.3. Matrix of fisheries sector related major policies.

Name of the policy	Major policy thrusts
1. National Fishery Policy, 1998	Enhancement of the fisheries production; Poverty alleviation through creating self-employment and improvement of socioeconomic conditions of the fishers; Fulfil the demand for animal protein; Achieve economic growth through earning foreign currency by exporting fish and fisheries products; Maintain ecological balance, conserve biodiversity, ensure public health provide recreational facilities.
2. National Shrimp Policy 2014	Increase shrimp production applying environment friendly appropriate technologies in the areas that comply with economic, social, environment, geo-natural status and climate change; Introduce sustainable preservation, management and catching strategy for shrimp resources produced naturally in the sea and internal water bodies; Emphasize environment friendly integrated shrimp culture through crop diversification and crop rotation; Enhance foreign currency earning through export following scientific management in production, catching, processing, transport etc; Take necessary steps for alternative employment or income of the shrimp fingerling catchers to effectively stop catching of fingerlings from natural sources; Production of healthy, strong and disease-free fingerling through Specific Pathogen Free (SPF) brood stock; Develop and apply effective strategies to mitigate climate change risks.
3. Cage Culture Policy 2019	Increase fish production through extension of cage culture in the river and other water bodies in a planned and environment friendly manner; Provide legal approval to the cage culture farmers; Create self-employment of the poor people through cage culture.

5.1.4 Five-year plans

Under visionary and prudent leadership of the Father of the Nation Bangabandhu Sheikh Mujibur Rahman, the First Five Year Plan (1973-78) was

formulated to guide the transformation of the country into ‘Sonar Bangla’, free of poverty, hunger, and corruption along with rapid income growth and shared prosperity. Between FY1973 and FY2020 Bangladesh implemented 8 successive Five-Year Plans (FYP) and an interim Two-Year Plan (1979–80). From FY2003 to FY2010, there was a deviation from FYP to a process of shorter-term Poverty Reduction Strategy Paper (PRSP). In 2009 the GoB decided to switch back to the FYP mechanism. The 8thFYP (2021-2025), mainly targeted the achievement of an 8.51% economic growth and reduction of poverty to 15.6% and of extreme poverty to 7.4% (BPC 2020). 8thFYP is the first in the series of four medium-term development plans aimed at implementing PP2041. The lessons from the 6th and 7th FYPs as instruments for implementing the PP2021 including adjustments for the COVID-19 pandemic will be particularly useful in the implementation of 8thFYP as it starts its journey in the backdrop of a massive and unprecedented global crisis.

Strategies for agricultural sectors in 8thFYP

8thFYP envisages ensuring food security and nutrition through:

- a) increasing agricultural production and minimizing yield gaps,
- b) stabilizing price of agricultural products,
- c) improving farmers’ profitability and securities,
- d) diversification of products towards climate-resilient production,
- e) strengthening agricultural supply chains,
- f) increasing commercialization through uses of information and communication technology (ICT),
- g) easing credit facilities for small farmers,
- h) escalating human resources development (HRD) for undertaking frontier research and delivery services and
- i) ensuring efficient utilization of natural resources.

The Plan, therefore, focuses on consolidating and expanding the productivity gains through designing policies, strategies and actions to accelerate the diversification and commercialization process by increasing local and export market opportunities for the farmers and other stakeholders.

Agriculture sector

The major objectives of 8thFYP in respect of the agriculture sector are to:

- increase availability of food, right to food and purchasing power by increasing productivity and production of crops
- increase farmers' capability and income through institutional infrastructure development and efficient technology services
- adopt and implement food production plans to meet the needs of nutritious, safe and demand-driven foods
- restore and develop the agricultural supply chain aftermath of

COVID-19 crisis; minimize the impact of COVID-19 for smooth agriculture growth and ensure food security after the crisis

- develop agricultural research for promoting export of products through coordination with local and international partner organizations
- modernize agricultural research, education, extension, input management and develop skilled manpower for sustainable technology innovation
- provide assistance to the farmers in increasing agricultural production and ensuring marketing facilities of agricultural commodities and obtaining fair prices
- introduce precision agriculture and synchronize farming, reduce the use of physical labor and introduce cost saving farming system through farm mechanization
- encourage more use of surface water for irrigation and reduction of pressure on ground water
- installations of solar panels for small scale irrigation in rural areas will be a priority.
- promote gradual shifting of high water- consuming crops to low water consuming high value crops
- introduce nanotechnology and encourage research and adoption of modern agricultural practices for development of drought, submergence, and saline prone agriculture
- proper use of genetically modified technology in agriculture, and promote adoption of modern agricultural practices in dry land, wetland, hills and coastal areas including use of climate-smart/resilient technologies (e.g. IPM, INM, AWD, etc.)
- create new sectors of agricultural commercialization and employment generation through value addition, improving supply chain, and export-oriented agricultural development
- ensure proper use of water resources through active participation in the formulation of strategies and their proper implementation through inter-ministerial/inter-agency coordination
- enhance farmers' income and livelihood through Holistic Farming System Approach (HFSA) with special emphasis on productivity enhancement of homestead areas
- maintain plant genetic resources, genetic diversity of seeds of food crops and medicinal plants and conserve local and land races for protection from extinction
- emphasize soil and water conservation, land development, drainage and flood control, and reclamation programs - land use planning will be promoted and production programs will be managed based on crop zoning

Livestock sector

The main objectives of 8thFYP for the livestock sector is to meet the increasing demand of animal protein by sustainably enhancing production, productivity and value addition of milk, meat and egg. The specific objectives are to:

- promote sustainable production of milk, meat, and egg including processing products
- ensure a nutritional-sensitive production system and consumption to tackle malnutrition among poor and vulnerable population groups, including the children and women
- generate need-based technology and improve livelihood of livestock farmers through adaptive research and to transfer developed technologies to users through training of extension workers, planners, livestock farmers and other stakeholders,
- develop climate resilient and low-cost crossbreeds, feeds and fodders production and
- facilitate entrepreneurship and increased participation of the private sector in the production, marketing and export of livestock products and by-products on a commercial basis.

Policy support will be provided to accelerate the development of private and community-based veterinary services, including compliant private veterinary diagnostic centers, clinics and hospitals. An autonomous quality control agency would be established to ensure quality of veterinary drugs, vaccines, feeds, feed ingredients and breeding tools and materials. A massive program on disease prevention and control of cattle and poultry diseases, awareness building and mass program for de-worming of animals against parasitic diseases will be designed. Measures will be taken to extend veterinary services up to union level with adequate service provider and infrastructural facilities.

Breed development through crossbreeding local variety with suitable exotic variety should be of utmost priority. For backyard farming, where investment potential is limited, local breeds that have relatively higher productivity and are hardy in nature will be promoted. Besides, artificial insemination (AI) programs will be strengthened in promoting quality breeds of livestock.

To meet the huge target of milk, meat, and egg production by 2025, many small growers will be given access to finance. Short- to medium-term collateral-free loan facilities at subsidized interest rates, amongst others, will be introduced for poultry and livestock farmers. Besides, policy options for vaccine coverage for poultry birds and ensuring quality feed supplies will be taken care of.

Research capacities of BLRI and other universities/institutes undertaking the relevant research activities will be enhanced to ensure safe production of

animal products and by-products, animal protein supplement, feed additives, premixes, probiotics, and mineral and vitamin supplements as inputs for poultry and livestock development. Initiatives will be taken to encourage and support private agencies and NGOs to undertake livestock research.

Fisheries sector

The major objective of the fisheries sector in the 8thFYP is to support sustainable growth in fish and shrimp production with other aquatic resources for domestic consumption and exports by managing open water fisheries resources, exploring blue economy through community participation. The strategic objectives for the sub sector are to:

- enhance fisheries resources and production
- alleviate poverty through creating self-employment and improvement of socio-economic conditions of the fishers
- achieve economic growth and earn foreign currency by exporting fish and fisheries products
- manage resources for ensuring optimum productivity, sustainability of production and conservation of fisheries resources
- establish and maintain fish and wetland sanctuaries which include ban on fishing in certain eco-sensitive areas
- harness the potential of blue economy, stock assessment of marine fisheries and promote sustainable exploitation of marine fishes, especially tuna and tuna like other pelagic fishing
- promote value chain in fish and fisheries products and
- ensure safe and quality fish supplies in the domestic and international market.

The following priority strategies have been identified for aquaculture development:

Culture fisheries

- Aquaculture intensification and species diversification will be promoted, avoiding water pollution
- Farm mechanization and vertical expansion of aquaculture will be the major priority for sustaining and diversifying of aquaculture production
- Fish health management strategy and aquaculture policy will be adopted and implemented for sustaining development of the fisheries sector
- Operation of hatcheries, nurseries and supply of spawn and fry, in which the private sector is the key player, will be constantly monitored by GO-NGO collaboration and public-private partnerships
- Production, import and marketing of fish and shrimp feed, feed ingredients, minerals and vitamin premix, and other inputs will be monitored constantly

- Cage culture in the flood plains, with private ownership will be encouraged which can certainly contribute to productivity
- Aquaculture and conservation will be restructured to reinforce the strengths of each other, sustainable and community-based flood plain aquaculture will be combined with maintaining sanctuaries and restocking of indigenous species
- Natural breeding, spawning, nursery, and grow-out areas will be conserved to complete the whole lifecycle and natural reproduction process to ensure pure brood and fingerlings and
- Development of tractability system to identify the sources of contaminants/banned antibiotics and other chemicals used for fish farming and fish processing times so as to take lawful and corrective measures to improve/ratify them.

Open water fisheries

- Inland unused water resources will be conserved and developed for fish production. Pollution control of river and lakes will be a major focus for government agencies
- Prevent further deterioration of water logging, blockade of water-flows and shrinkage of waterbodies because of unplanned infrastructures like embankments, roads, urban housing projects and industrialization
- Fish and wetland sanctuaries will be established with complete ban on fishing in certain eco-sensitive areas like the Sundarbans, parts of Kaptai Lake, and several sections of the river Halda, selected beels and haor areas and certain sections of the Bay of Bengal
- For sustainable Hilsa fish production, community-based Management Approach and other precautionary measures will be applied to avoid overfishing. Management of Hilsa sanctuary will be strengthened. Measures will also be taken to improve Hilsa marketing system and its value chain and
- The fishermen will be organized in sustainable community-based organizations and such organizations will be given management responsibility of khas 'jalmohal' on long term basis so that they conserve rather than just exploit resources.

Marine fisheries

- Restrict and control poaching of resources and illegal entry of foreign trawlers
- Introduce Vessel Tracking and Monitoring System (VTMS)
- Identify conservation needs and methods that can be effectively administered and regularly monitored
- Institutional capacity building of the concerned agencies, strengthening of monitoring, control and surveillance system (MCS) in the Bay of Bengal
- Digital Marine Fisheries Resource Mapping for the marine waters using

digital cartography of the marine fisheries resources is an essential tool for efficient and sustainable harvesting of the marine resources

- Collaborative effort for distant water fishing (beyond 200m of EEZ and ABNJ) to explore and exploit tuna and large pelagic fishes and
- Establish MPAs (marine protected areas) as breeding grounds.

5.1.5 Agricultural research vision 2030

BARC in 2000 prepared a Vision Document 2020 for agricultural research that significantly contributed to the development of appropriate technologies by NARS institutes, agricultural universities and private organizations and its adoption by farmers. Thereafter in 2012 BARC, with financial support from the National Agricultural Technology Project (Phase-1) financed by the World Bank, prepared the Vision Document 2030 in 2012 for agricultural research in Bangladesh (BARC 2012). This Vision Document points out the overall research needs of the country based on key challenges in developing and scaling up the agriculture of the country.

Vision 1: Food security through increased production, availability, access and utilization of Food crops

Enhancing food security will be achieved through increasing crop production, agricultural diversification, creation of employment in farm and non-farm activities as well as supply chain development for income enhancement.

Vision 2: Ensure intake of safe nutritious food through diversified food

Crop production, pre and post-harvest processing, storage, availability and access of non-cereal crops in diet are some of the areas required to meet the nutritional requirements. These aspects will be considered in preparing the research agenda.

Vision 3: Improve crop production

Exploration and use of genomes that could contribute to yield increase and to cope with adverse environmental condition will be given emphasis in varietal development program.

Vision 4: Enhancing genetic resources

A national action plan will be developed to collect, evaluate, characterize, conserve and utilize plant, insect, animal, fish, and microorganism genetic resources of indigenous and exotic origins. To address future needs, attention will be given on sustainable use of available genetic resources through characterization, genetic enhancement and pre-breeding, functional genomics, proteomics, phenomics, gene mining, molecular breeding through tools like

marker-aided selection and gene stacking and customized genetic engineering.

Vision 5: Breeding options for crop improvement

New genotypes will be created with higher yield potentials in a greater range of environment mainly through recruiting genes from within gene pool of interbreeding plants and also through bio-technology assisted hybridization and tissue regeneration. Heterosis breeding and radiation breeding will also be employed to develop hybrid and varieties.

Vision 6: Unfavorable agro-ecosystems

A large area of agricultural land still remains unutilized/under-utilized specially in the unfavorable agro-ecosystems like coastal, hill, hoar, char, Barind, peat, etc. Special attention will be given to develop crop varieties and management practices. Development of salt tolerant varieties, water shed management, water conservation and utilization, development of farming system, hill slope management, agro-forestry will receive priority attention.

Vision 7: Efficient management of natural resources

Potential of conservation agriculture, zero tillage, precision agriculture and micro-irrigation will be properly addressed for different agro-ecoregions. Efficient farming systems, composite farming, integrated crop management, integrated nutrient management, integrated pest management, water saving efficiency technology, water management, storage and processing will be given due importance.

Vision 8: Mechanization in agricultural production and processing

Labor intensive agricultural activities such as sowing of seeds and seedlings, fertilizer application, drying, design of water saving technologies and water management, cool chain management, storing and processing, livestock housing and management, and small-scale feed meal design are equally demanding areas of mechanization.

Vision 9: Post-harvest management and value addition

Post-production technology with emphasis on on-farm handling and storage system for different commodities, covering sanitary and phytosanitary measures, packaging, transport, marketing, value addition, both for domestic and export markets are considered important. Utilization of crop residue and by-products for food and feed will be strengthened. These activities require multi-disciplinary and multi-stakeholders research for agri-commodities, especially post-harvest engineering, horticulture, plant protection, etc.

Vision 10: Climate change and bio-risk management

To address climate change it is necessary to increase the adaptive capacity by a) changing varieties/species to fit appropriately to the changing temperature and hydrological condition, b) changing timing of irrigation and adjusting nutrient management, c) developing water conserving technologies along with its judicious use and promoting agro-biodiversity for increased resilience of agricultural system, d) addressing research on altering timing or location of cropping activities and diversification of agriculture, e) improving soil carbon retention by promoting biodiversity as a tool for climate mitigation and adaptation, promote Conservation Agriculture (residue retention, minimum tillage and legumes in crop rotation), f) developing technologies for rainfed agriculture, g) developing integrated nutrient management practices to lower nitrous oxide (N₂O) emission and optimizing nitrogen uptake efficiently by controlling the application rates, methods and timing, h) increasing the efficiency of livestock production, improving animal diets, increasing feed efficiency, aerating manures before composting and recycling agriculture and forest residues.

Vision 11: Agricultural diversification

Greater will be given on commercialization and diversification of farming systems through horticulture, animal husbandry, milk, poultry and fish and other non-food crops such as fiber, mushroom, spices, condiments, medicinal and aromatic plants. Thus, research focus is required for efficient and competitive production of such commodities through development of improved genotypes and management practices for different agro-ecoregions and consumer-preference.

Vision 12: Management of energy and agricultural wastes

Research will be targeted to develop biofuels without compromising food security and by effectively utilizing huge agri-wastes, wastes from crude oil after refinement and solar energy. A strategy to explore new biological sources of ethanol, specially from non-food stocks, explore management practices and opportunities to grow bio-fuel stocks in low productive areas and process high quality animal feeds from crop residues and wastes from food processing industries need to be explored and adapted.

Vision 13: Enhanced productivity of livestock and poultry products through improvement in the genetic capacity and breeding process combined with bio-technology

There is ample scope to increase productivity of livestock products to satisfy the huge production target set for the year 2030. The tools, such as characteri-

zation, genetic enhancement, functional genomics, phenomics, proteomics, etc., gene mining, molecular breeding through tools like marker aided selection and gene stacking, etc., will help develop appropriate technology.

Vision 14: Enhance productivity through improving efficiency of feed and feeding system

Research and development focus will be on increasing the prospect of using agro-industrial by-products and low-quality roughages as complete feed using modern frontier science tools. Research and development strategies will be taken enough to meet the challenges faced by small, marginal, and landless farmers for different species of livestock and poultry in meeting the feed requirements.

Vision 15: Animal health protection, prevention, and production of vaccines for increased production

Research and development will aim to develop diagnostic and immunoprophylactics for various diseases using bio-tech and nano-tech tools, recombinant DNA vaccines. Immediate transmission of recurring and newly emerging diseases due to transboundary and other management faults is having a driving demand for more preventive products, such as vaccines, rapid detection diagnostics, etc. that help avert diseases and infestations. These will be made possible by advances in genetic engineering and by preventing chemical, biological products that carry organisms before infestations.

Vision 16: Reclaim degraded fisheries, enhance production from natural resources and conservation of fish biodiversity

Physical, chemical, and biological degradation of fisheries resources made the achievements for increased production from the resource more challenging. Degradation and shrinkage of fisheries habitats, water and soil quality and pollution, siltation and biological depression are major causes of resources degradation. Research will be conducted with the incorporation of advance sciences to address these issues to make pace with vision target.

Vision 17: Enhance fish production from culture-based fisheries

Improvement of existing culture technologies, protein rich quality feed, inbred free quality fish seed of cultures species, improvement of culture and health management of fish and shrimp, affordable cost of fertilizers chemicals, medicines, and inputs, AEZ based water budgeting in aquaculture, pond designing, polyculture and farming system research and

integrated fish farming would be given due priorities to ensure increased output.

Vision 18: Sustainable harvest and management of marine fisheries resources

Post-harvest loss, lack of data base, absent of mariculture practices, pollution, adaptation technologies for breeding and culture of fish due to sea level and temperature rise will be the major areas of research.

Vision 19: Foster fish genetic resources

Research on development of breeding and culture technologies for the threatened fish species, overcoming of genetic and breeding depression of cultures species, cataloguing and developing genetic chart for important fish and shellfish species, cryo preservation and biotechnology research for fish disease control will be the priority areas.

Vision 20: Breeding and culture of fish and aquaculture diversification

Breeding and marketing of several indigenous and exotic ornamental species for aquarium can be a good venture for economic activities and employment. The non-conventional species can be used as local food, and as export item and source of raw materials for production of gelatins, ornaments, cosmetics, decoration materials, and valuable ingredients for medicines and food items, such as soup, nodules, etc. Among the worthiest, mentionable non-conventional species are species of clams and snails, kuchia, edible oyster, pearl oyster (marine), sea grass and weeds, rock lobster, soft shell turtle (fresh water) and marine turtle, green crabs and marine fin fishes, snake heads, etc.

5.2 Strategic investment

Article 15 of the Constitution of the People's Republic of Bangladesh that was formulated under the visionary leadership of the Father of the Nation, Bangabandhu Sheikh Mujibur Rahman, states that it is a fundamental responsibility of the State to secure for its citizens through planned economic growth, the provision of basic necessities of life including food, clothing, shelter, education and medical care. Article 18 (1) states that raising the level of nutrition and improvement of public health are among the primary duties of the State. These have laid the foundation for the formulation of multisectoral national policies and strategies for sustainable development and economic growth. A Perspective Plan: 2021-2041 (PP2041) has been developed to achieve the SDGs Agenda 2030, and to graduate to an upper middle-income country by 2031 and become a prosperous high-income country by 2041. The Eighth Five Year Plan (8th FYP) for the period July 2020

to June 2025, initiated the implementation of PP2041, having as one of its objectives the achievement of the SDG targets, including the elimination of extreme poverty by 2031. A long-term comprehensive Bangladesh Delta Plan (BDP) 2100 has also been formulated that focuses on economic growth, environmental conservation, and enhanced climate resilience. The National Food and Nutrition Security Policy (NFNSP) (2020), and its Plan of Action (2021-2030) recognize the need for transformation of food systems. In line with the vision for a Digital Bangladesh and in readiness for the 4th Industrial Revolution (4IR), the Government of Bangladesh is also working to mainstream ICTs, e-commerce and the Internet of Things (IoT) across all sectors.

5.2.1 Strategic investment for increasing food production

One of the Government's key goals is to achieve self-sufficiency in food while also assuring nutritious and safe food, improving productivity, building marketing systems and establishing profitable agricultural systems. With the highest consideration for the development of agriculture and the welfare of the farmers, the Government is continuing its all-out efforts for the overall development of the agriculture sector in the light of Vision 2041, 8thFYP, SDGs, BDP 2100 and other policy and planning documents. To increase crop production, improved and adaptable varieties are being developed and expedited, small and marginal farmers are being provided incentives for natural disasters, free and subsidized high yielding varieties and development assistance is being provided in agricultural inputs including fertilizers. Along with this, mechanization of agriculture, innovation of new cropping systems, development of irrigation system, implementation of IPM system, production of transgenic crops, etc., have been undertaken. Measures have been taken for targeted agricultural expansion, quality control of agricultural products, adequate crop protection measures, development of marketing system, and ensuring fair prices for all agricultural products. Along with the expansion of improved varieties of local fruits, the cultivation of exotic fruits suitable for cultivation in the country, such as teen, dragon, avocado, Arabic date, rambutan, persimmon, etc., has also increased. Initiatives have been taken to expand coffee and cashew nut cultivation in hilly areas. Initiatives have been taken to increase crop cultivation and production using fallow lands. Farmers have been given training to enhance crop density to increase productivity by cultivating seasonal fallow fields, planting vegetable and orchards in other fallow lands, including homesteads, and diversifying crops. According to the Hon'ble Prime Minister's directives, 32 vegetable and nutrition gardens are being established in each union of the country with the goal of cultivating every inch of land and ensuring family nutrition security. To mark the commemoration of the birth centenary of the Father of the Nation, steps have been taken to create 100 additional Family Nutrition Gardens in each union of the country. All the homeless people who have been given houses by the Hon'ble Prime Minister through the Ashrayan

Project will be included in the Family Nutrition Gardens program. In response to the COVID-19 pandemic, extreme floods and natural disasters, GoB has adopted short-, medium-, and long-term action plans to maintain food security for the people of the country by continuing the expansion in agricultural productivity. Increased agricultural subsidies, incentives, and support cards for other agricultural inputs such as fertilizers and seeds, lower irrigation prices, agricultural commodity transportation at reduced rates and special agricultural loan facilities with low interest and easy terms have been provided for rehabilitation assistance. Implementation of various programs are underway to increase food production by expanding the coverage of agricultural land and by creating the opportunities of multiple cropping with expansion of irrigation by using groundwater in various regions of the country, and reduction of waterlogging and planned drainage of water, drought, and salinity in different fragile ecosystems. Programs have been launched to popularize the use of organic and balanced fertilizers to maintain soil fertility and productivity.

(https://mof.portal.gov.bd/sites/default/files/files/mof.portal.gov.bd/page/f2d8fabbb_29c1_423a_9d37_cdb500260002/16_BER_22_En_Chap07.pdf)

5.2.2 Strategic investment for fragile ecosystems

a) Haor ecosystem

For haor development, GoB has formulated some national policies and plans as follows:

- National Fisheries Policy 1998 is directly related to haors under the water sector for the development of fish culture
- National Policy for Safe Water Supply and Sanitation 1998 with the objective of making water and sanitation services accessible to all including the haor inhabitants
- National Water Policy 1999 with policy directives for particular issues related to the haor areas
- National Agriculture Policy 2018 with necessary directives for the haor region
- National Rural Development Policy 2001 with several statements related to the haor regions
- National Jute Policy 2002 with plans for the development of jute production in the haor areas.
- National Industrial Policy 2005 with policy directives for the development of the industrial sector in the haor region
- National Land Transport Policy 2004 with some major statements related to haors
- National Jalmahal Management Policy 2009 emphasizing increased production and biodiversity conservation of fish resources in the country including haor region

- Bangladesh Climate Change Strategy and Action Plan 2009, which especially mentions development of navigational facilities in the haor areas
- A 20-year master plan (2012-2032) for the overall development of the haor areas
- BDP 2100

The Bangladesh Haor and Wetland Development Board (BHWDB) has developed a master plan to alleviate poverty of the haor dwellers. The master plan framework was developed in 2012 with the mandate to implement until 2032 while incorporating changes as necessary along the way. The project is divided into 3 categories: Short-term (1-5 years), Medium-term (6-10 years) and Long-term (11-20 years). Currently, there are 154 development projects in the haor region with the top three areas of development being Transportation, Fisheries and Agriculture. A significant portion (12%) of the total funding (BDT 2,804,305) is dedicated to power and energy development.

Addressing soil degradation

Soil degradation is undermining the long-term capacity of the wetland haor agro-ecosystem. Failure to address this problem will erode crop productivity. Although nutrient inputs, new crop varieties and technologies may work well in the foreseeable future, the challenge of meeting human needs will keep growing. Excessive use of chemical fertilizers and pesticides may soon result in productivity losses. Land Degradation Neutrality Target Setting Program (LDN-TSP) was implemented in Bangladesh from December 2016 to February 2018 with the support provided by the United Nations Convention to Combat Desertification (UNCCD) (UNCCD 2018). Bangladesh has further committed to achieve LDN leverage plan and implement transformative LDN projects to achieve LDN by 2030. According to Target 1 of LDN soil fertility will be enhanced in 2000 km² of the cropland area by 2030. This target will address unsustainable land management which includes inappropriate agronomic practices, imbalanced fertilizer usage, pesticides, inappropriate irrigation mechanism, unavailability of quality and availability of fertilizers, organic/farm manures, etc. Measures will be taken to ensure the use of balanced fertilizers by 10,000 farmers per year online and offline fertilizer recommendation systems or fertilizer recommendation guides, use of organic manure, farm compost, vermicompost, biochar, etc. Moreover, alternate wetting and drying (AWD) technology will be implemented for Boro rice in 200 km².

Advances in haor agriculture

Crops

Some stress tolerant rice and wheat varieties have already reached farmers'

fields with the prospect of up to 20% yield increase under varied environmental pressures. For example, the Bangladesh Rice Research Institute (BRRI) has developed and released submergence tolerant HYV rice such as, BRRI dhan51 and BRRI dhan52, drought tolerant BRRI dhan42 and BRRI dhan43, and cold tolerant BRRI dhan56 and BRRI dhan57. The Bangladesh Agricultural Research Institute (BARI) has developed heat tolerant wheat and tomato varieties. BRRI scientists have adapted the “Alternate Wetting and Drying (AWD)” irrigation technique to local conditions for irrigation of rice to increase water use efficiency and conserve water resources.

BARI Lau-4 and BARI Shim-7 varieties have been tested and found adaptive particularly to the changing climate of the Sylhet region. The On-Farm Research Division (OFRD) of BARI has developed a year-round homestead gardening model following raised bed systems through on-farm testing units at the Farming Systems Research Site, Golapganj, Sylhet (called BARI Golapganj, Sylhet model). In a KGF (Krishi Gobeshona Foundation) sponsored research project (2017-2021) on integrated farming systems for the haor areas of Sunamganj implemented by the Sylhet Agricultural University (SAU), vegetable production in homesteads has been highly successful (KGF 2021). Introduction of early winter vegetables (cabbage, cauliflower and tomato) has enabled the poor farmers to produce for domestic consumption as well as increasing family income through sale of vegetables. Other seasonal vegetables like cabbage, cauliflower, tomato, eggplant, chili, bottle gourd, country bean, pumpkin, squash, red amaranth, spinach, bitter gourd, ash gourd, ridge gourd, sponge gourd, snake gourd, Indian spinach, etc., have been successfully tried for year-round cultivation in the homesteads.

Growing vegetables on floating beds is a popular practice in Gopalganj, Madaripur, Barishal, Pirojpur and Jhalokhathi districts where land remains submerged most of the time in a year. Cultivated vegetables in floating bed include okra (lady’s finger), cucumber, bitter gourd, pumpkin, water gourd, turmeric, ginger, arum, tomato, and potato (Alauddin and Rahman 2013; UNFCCC 2006). During periods of flooding and water logging, field crops often perish but crops on floating garden called *baira* can survive. DAE is promoting this floating gardening technology particularly for haor areas with support of the National Agricultural Technology Program (NATP) and Integrated Farm Management Component (IFMC) project supported jointly by the Government of Bangladesh (GoB) and the Danish International Development Agency (DANIDA).

b) Char ecosystem

Three development projects for char areas were initiated by GoB in the last decades. One of these projects is the Char Development and Settlement Project (CDSP), Phase I - IV which was implemented by Govt. organizations

and 5 local NGOs in the Meghna River chars. The objective of this project was poverty reduction through improvement in economic situation and living conditions of the people in the char areas. The other projects namely the Jamuna Char Integrated Development Project (JCDP) and the Char Livelihood Program (CLP) of DFID (Department of Foreign and International Development of UK) were initiated in 2003. The CLP supported char dwellers particularly through raising community grounds above the flood level together with livestock asset building and year-round vegetable gardening.

The char land projects fit very well with the GoB's secondary poverty reduction strategy (National Strategy for Accelerated Poverty Reduction 2009). In this strategy water management, agriculture, forest, rural roads, land policy and disaster management are the focal areas for pro-poor growth. Supporting strategies include actions to reach extreme poor groups, support for better water and sanitation, especially where groundwater conditions are unfavorable (such as the coastal saline zone) and adapting to climate change.

To move ahead with agricultural development for the char ecosystem in line with the existing policies of Bangladesh, assertive actions by planners, policy makers, researchers, educationists, and other stakeholders have taken into account of the following strategies:

Development of irrigation facilities for year-round crop production

The irrigation expansion project of the Government in Rangpur District including char areas aims to ensure the best use of surface water and conserve rainwater. The project has started in October 2019 and will end in December 2024. This project would make the land fit for agriculture through solution of waterlogging problem and using renewable energy for irrigation. It will also help produce low water consuming crops through digging of wells in a bid to aid the creation of additional forest resources and planting fruit, forest, and medicinal saplings. With these irrigation facilities, a large area, 104,730 ha, hitherto remaining fallow in char areas would be brought under cultivation of at least a single crop during the winter season, particularly in Dhaka (33,330 ha), Chattogram (19,265 ha) and Rangpur (18,372 ha).

Stabilizing settlement of char dwellers and agricultural production

Char areas are vulnerable to river erosion and landslides making settlement relocation a common problem for the char inhabitants. However, people living in the char areas have learnt to cope with river erosion and massive floods. Cropping systems are also unstable. Based on the success of LDN-TSP during December 2016 through February 2018 with the support of United Nations Convention to Combat Desertification (UNCCD), Bangladesh has

committed further to achieve the LDN leverage plan to reduce riverbank erosion in char areas. According to Target 6 of LDN, the Government of Bangladesh will reduce riverbank erosion in char areas at the rate of 100 ha/year covering 100 km² by 2030 (UNCCD 2018). The target will address river morphology, rush of flood water and unsustainable land management. Measures will be taken to establish green belts through afforestation along riverbanks and accreted char lands. River/channel dredging program will also be undertaken.

Advances in *char* agriculture

Crops

For the coastal saline areas, BRRI and the Bangladesh Institute of Nuclear Agriculture (BINA) have recently developed some salt tolerant HYVs such as BRRI dhan47, BRRI dhan55, BRRI dhan61, BRRI dhan67, Binadhan-8 and Binadhan-10; short duration HYVs viz., BRRI dhan33, BRRI dhan39, BRRI dhan49, BRRI dhan56, BRRI dhan57 and Binadhan-7, and submergence tolerant HYVs e.g., BRRI dhan51, BRRI dhan52 Binadhan-11 and Binadhan-12. These recent developments have transformed char lands, especially the coastal char areas which were once covered with wild vetiver grass into agriculturally productive fields vibrant with the greenery of multifarious crops. BARI has developed a good number of HYVs of various crops which have been tested and found to perform well in the char areas. For example, five HYVs of sweet pumpkin have been released by BARI so far of which three are hybrids and two are free pollinated varieties which are superior to traditional local varieties in terms of fruit size & shape, colour & sweetness of the shell, number of fruits per plant, etc. Among them BARI Hybrid Sweet Pumpkin-1 is cultivated extensively in remote chars of Rangpur, Bogura and Gaibandha districts.

The Char Development and Settlement Project IV (CDSP 2019) has brought about following improvements for coastal chars:

- Cucumber, bitter gourd, snake gourd and okra are the most potential vegetables which can be grown in coastal chars in the sorjan method.
- HYVs were introduced and farmers of the coastal chars began growing varieties like Alavi, Elin, Green Line (hybrid) for cucumber, Tia (Hybrid), Papiya for bitter gourd, BARI dherosh-1, Hi-soft (hybrid) for okra.

Cropping patterns (CP) in char areas vary from region to region depending on natural and socioeconomic factors. Many improved cropping patterns have been developed, tested and recommended by crop scientists for various char regions of the country. For example, Mahmud et al. (2020) experimented with cropping patterns in char lands (Saghata, Gaibandha) of the Jamuna River to increase land productivity. They tested a triple crop CP in comparison with the local farmers' double crop practice of double cropping.

The triple crop improved CP, millet (BARI Kaon-2)-jute (O-9897)-T. Aman (*Gainja*) was compared with the existing cropping pattern, millet (local)-fallow-T. Aman (*Gainja*). The improved 3-crop CP gave a rice equivalent yield, REY of 12.95 t/ha which was much higher than that produced by the existing 2-crop CP (4.20 t/ha). The total field duration and turnaround time were 323 and 242 days, respectively with the improved CP compared with the 215 and 150 days, respectively for the existing pattern. This indicated that through the introduction of an improved CP 108 days more could be made productive. The gross margin was also three times higher from the 3-crop CP pattern (Tk 141,600/ha/yr) compared with that from the farmers' existing 2-crop CP pattern (Tk 38,350/ha/yr).

Practicing agroforestry and intercropping with various vegetables and tubers (malta+chili, litchi+sweet gourd, moringa+maize, mahogany+okra, mango+potato guava+garlic etc.) have been found agro-economically remunerative in the Tista chars of Rangpur and Nilphamari (KGF, 2020).

Livestock and poultry

A new breed of sheep developed by BAU has become very popular among the char people; this sheep breed can withstand to some extent the harsh environment and feed on grasses that cattle or other livestock do not like. This new sheep breed offers a good opportunity of livestock rearing for the char people should be widely promoted. Breed development of cattle with artificial insemination facilities at the char union level should be enhanced.

Improved animal health service and milk marketing channels for the char areas of Rangpur and Jamalpur (disease incidence rate reduced by 37%, milk production increased 0.8 L/day/cow, producer price of milk increased 37%) have been developed through livestock experiments, funded by WB (KGF 2017).

Fisheries

In recent years, cage culture, an improved fisheries technology, has been tested in char areas. Cage culture is suitable for open water bodies. Growth promoter probiotics (Rapid Grow, Biozyme, Miracure, Safe Gut etc.) are used to increase fish production in cage culture. The NGO, Practical Action, has been working on a proven model for co-production of fish and vegetable crops, which protect fish from floods. This model is also called an integrated floating cage aqua-geoponic system (IFCAS), an innovation in fish and vegetable production for shaded ponds in Bangladesh.

c) Barind ecosystem

Following some national policies e.g., National Agriculture Policy (NAP) 2018, Minor Irrigation Policy 2017, Good Agriculture Practice (GAP) 2020, etc.,

the Government has re-excavated some derelict *kharis* (canals) in the Barind areas to increase its water conserving capacity. To retain the storm water, cross dams are constructed in the re-excavated *kharis*. The re-excavated *kharis* are used to conserve storm water mainly for supplementary irrigation. There are about 2,000 km re-excavated *kharis* with 749 cross dams in the Barind Tract region (BMDA 2018). A rubber dam has also been constructed at the Barnoi River of Puthia upazila under Rajshahi district; water at the upstream of the rubber dam is used for the recharge of groundwater. There are also about 3,098 re-excavated ponds in the Barind Tracts (BMDA 2018). These ponds are usually re-excavated with the aim to facilitate fish culture and supplementary irrigation. There are many *beels* (large water bodies) in the Barind Tract, which are generally located at the lower elevations, where runoff water coming from the surrounding catchment areas accumulate. The beels are re-excavated to conserve more water and greater groundwater recharge. About 240 numbers of Dug Well (DW) have been constructed with a view to irrigate low water consuming crops like cauliflower, cabbage, potato, chilis, etc. Rainwater receiving structure with solar panel has been constructed over the dug well, and an overhead water tank has also been set on an elevated tower. Rainwater is received by the solar panel cum rainwater receiving structure during rainfall and stored in the DW. The conserved water is then lifted to the overhead tank by solar energy driven pumps and used for irrigation.

Enhancement of surface water irrigation

To reduce pressure on groundwater, GoB took an initiative for implementing a big project called “North Rajshahi Irrigation Project” for enhancing surface water irrigation. Initially, the Government conducted a feasibility study of this project during 1987-1988 with the assistance from the Government of Japan through JICA. Based on this feasibility study, this project worth about BDT 4,490 million was proposed in 1994 and later the project was transformed into a mega project with a cost of BDT 16,250 million in 2013 (Prothom Alo 2022). In September 2022, this mega project was marked by the Government as a priority project to augment surface water irrigation in the Barind areas. The proposed project will provide irrigation facilities to 74,800 ha of land. Within this facility, fallow lands (57,731 ha) identified in the Barind areas can be brought under cultivation of at least a single crop during the winter season. This opportunity especially exists in Bogura. It can increase cropping intensity. Through this project, water will be pumped from the Mohananda and Padma rivers for irrigation through canals. This project also includes a component of fish production in the irrigation canals. It is expected that this project will increase rice production by 211,000 MT and other crops by 17,000 MT. Moreover, farmers will receive irrigation water at a very low cost of BDT 100-600/100 decimal land instead of BDT 3,300-6,000/100 decimal in case of groundwater irrigation.

Advances in Barind agriculture

Crops and cropping patterns

- New HYVs of crops and production technologies have been recently developed by agricultural scientists which are resilient to climate change and tolerant of abiotic stresses such as drought which have the potential to ensure sustainable agricultural production in harsh environments. For example, BRRI has released drought tolerant rice varieties such as BRRI dhan56, BRRI dhan57, BRRI dhan66 and BRRI dhan71, cold tolerant varieties viz., BRRI dhan36, BRRI dhan55 and BRRI dhan69
- Drought-tolerant and high-yielding wheat varieties, especially BARI Gom-26, have started gaining popularity among farmers of the Barind Tract. The Bangladesh Wheat and Maize Research Institute (BWMRI) has developed high-yielding wheat varieties such as BARI Gom-30, BARI Gom-32 and BARI Gom-33 which are giving good yield in the Barind Tract over the last few years. A new drought tolerant lentil variety with the potential to produce high yield in drought condition has been released in 2016. Binamasur-10 is also suitable for relay cropping in areas which left fallow after rice cultivation because this variety matures within 110 days, almost a week earlier than the existing varieties. Binamasur-10, with its drought tolerant trait, is expected to be quickly adopted throughout the northwestern drought-prone districts of Bangladesh
- BRRI dhan 48, a drought tolerant Aus rice variety developed by BRRI, has been gaining popularity among farmers in the Barind region. The Barind Station of the On-Farm Research Division (OFRD) of BARI has included this variety in its 4-crop based cropping pattern (Aus-T. Aman-lentil-mungbean) for the Barind Tract
- BARI has released two hybrid maize varieties, BARI Hybrid Bhutta-12 and BARI Hybrid Bhutta-13 which showed good prospects of expanding among the maize growers in the drought-prone Barind areas. An additional 280,000 MT of white maize could be harvested from 35,000 ha of land in the Rabi season through single time irrigation and
- OFRD, BARI has identified several potential cropping systems for the Barind Tract. For T. Aman-Boro cropping it is recommended that Boro rice be limited to valleys and elevated areas be used for high-value and relatively water efficient crops like potato, mustard, maize, onion, garlic, and mung bean following harvest of short-duration T. Aman rice. In fact several commercial enterprises have begun to follow these recommendations. For example, over the previous decade the 'Aman Group' leased in farmers' lands at Amnura and Nachole, and elsewhere in the Barind region for potato seed cultivation.

Fisheries

BMDA usually re-excavate derelict kharis (canals) to increase their water conserving capacity. To retain the storm water, cross dams are constructed in the re-excavated kharis at different positions maintaining a certain gradient. The re-excavated kharis are used to conserve runoff storm water mainly for supplementary irrigation and fish culture. About 2000 km re-excavated kharis with 749 cross dams are in the Barind tract (BMDA 2018). About 1248 ponds have been re-excavated; 3098 ponds are there in the whole Barind Tract (<https://link.springer.com/article/10.1007/s13201-021-01530-1-ref-CR13>). The extra water in the re-excavated ponds is also helpful for groundwater recharge.

d) Coastal ecosystem

Attempts to implement area-specific strategies for the coastal ecosystem were taken through several earlier initiatives:

- Off-Shore Islands Development Board (1977-82),
- Bangladesh National Conservation Strategy (1987),
- UN/ESCAP-GoB Coastal Environment Management Plan for Bangladesh (1987),
- Coastal Area Resources Development Plan (1988),
- Formation and Activities of the Special Parliamentary Committee on Coastal Area Development (1988-90),
- National Capacity building on Integrated Coastal Zone Management (ICZM) initiative (1997) and
- The Coastal Zone Policy (2005).

In 1999 the Government expressed its commitment through a policy note titled 'Integrated CZ Management: Concept and Issues' to Prepare for a Plan for the Operational and Effective Introduction of ICZM in Bangladesh.

Scientists of different agricultural research organizations (BARI, BRRI and BINA) and also local farmers have developed a good number of innovative technologies to combat soil and water salinity for successful crop production.

Sorjan system: Farmers are practicing sorjan system of cultivation in saline tidal flooded areas. Shallow depth sorjans are suitable for the year-round cultivation of vegetables and monsoon rice, where the sorjans with higher depths also allow rice-fish or rice-duck farming along with the year-round vegetables cultivation on raised beds. This sorjan system is very popular among the farmers in the coastal district of Patuakhali. BARI has developed this technology through a series of testing at its Farming Systems Research (FSR) site, viz., Lebukhali, Patuakhali. Vegetable gardening in sorjan system is applicable in lands that remain under water for the most time of a year.

Floating agriculture: In Barishal, Gopalganj, Madaripur and Pirojpur, the farmers have been practicing floating agriculture for decades. Over the last two decades, this indigenous, wetland-based agro-system has turned into something of a "climate celebrity". Floating beds are traditionally made with compactly intertwined water hyacinths and other plant materials during monsoon. Once the bed surface gets rotten, farmers plant different crop seedlings and grow vegetables on these buoyant platforms.

Management of polders and sluice gates in coastal areas

To address salinity problem in coastal areas, the GoB has constructed polders or embankments surrounding low-lying areas. A regional workshop in Khulna organized in August 2022 indicated that there are about 139 polders in the coastal zone of Bangladesh that was constructed in the 1960s and 1970s to protect farmlands from saline water intrusion and tidal floods. Almost half (1.2 million ha) of the 2.8 million ha of coastal lands are protected by polders. Sluice gates are equipped with a system of preventing or controlling water flow rates in rivers and canals to protect the hinterland from saline water intrusion. Sea dykes/embankments (1,000 km) have been constructed at locations facing the Bay of Bengal and along the banks of major rivers or channels. The dikes do not cover the entire seacoast, though they provide the first line of defense against storm surges and possible sea level rise. It is apprehended that by 2030 the sea level will rise by 30 cm. The maintenance cost of sea dikes is very high and presently the embankments are in a terrible state of disrepair.

According to Target 5 of LDN, the Government of Bangladesh will protect non-saline land areas from salinity intrusion in 1200 km² in coastal zone area by 2030 (UNCCD 2018). This target will address the major constraints viz, uncontrolled use of salt water for salt bed/shrimp production, weak polder management, extension of salt bed/shrimp production in cropland area, conflicts of interest, and climate change impacts. Measures will be taken to restrict salt and shrimp land areas; introduce high yielding salt-tolerant crops; increase surface (fresh) water reserve in channels and ponds and establish community-based polder management.

Introduction and expansion of renewable energy

The strategy is designed to ensure generation and distribution of energy in selected islands and chars by utilizing solar energy, winds and tides in remote coastal areas. The Local Government Engineering Department (LGED) has developed a model of green energy generation for the St. Martin's Island. The Power Development Board (PDB) is also implementing a pilot project. The possibility of electricity generation using tidal fluctuations at suitable locations in the CZ can be tested.

Advances in coastal agriculture

Crops

The Commonwealth Scientific and Industrial Research Organization (CSIRO) of Australia has been leading a research project, “Cropping systems intensification in the salt-affected coastal zones of Bangladesh and West Bengal, India” since 2015 (Yadav and Jagadish 2021) partnering with Murdoch University of Australia, BARI, BRRI, Institute of Water Modelling (IWM), and Khulna University of Bangladesh and the Central Soil Salinity Research Institute (CSSRI), Bidhan Chandra Krishi Viswavidyalaya (BCKV) and Tagore Society for Rural Development (TSRD) of West Bengal, India. The project is funded jointly by the Australian Centre for International Agricultural Research (ACIAR) and KGF of Bangladesh. The project aims to sustainably increase the cropping intensity and productivity in the coastal zones of the Ganges delta, particularly in the dry (Rabi) season, through integrated soil, water, and crop management. In Bangladesh, the project has covered three selected polders, including Amtali, Barguna district and Dacope, Khulna district and Gosaba Island in West Bengal, India. Research findings of the project include:

1. Surface water, groundwater and salinity interaction models for the polders can assist in simulating scenarios such as saline groundwater pumping for drainage and climate change impacts.
2. Adaptive research along with crop modeling can be a fast-track assessment and simulation of crop response to management change and environmental drivers in the coastal zone.
3. Several new high-yielding and short-duration varieties of Aman rice such as BRRI dhan87, BRRI dhan77, and BRRI dhan76 for Bangladesh are suitable, profitable, and preferred by the farmers. These varieties yield 0.5-1.0 t/ha higher compared to the existing rice, and they mature 15-20 days earlier which allows early sowing of Rabi crops and bring about more than 50% higher net benefit.
4. Growing Aus rice (BRRI dhan48) in the Kharif-I season is feasible (the average yield is more than 4.0 t/ha) and profitable in Bangladesh. Farmers can grow Aus rice in the coastal area to intensify their cropping system, an option that is becoming popular for them. Boro rice varieties (BRRI dhan67, BINA dhan10) have been introduced at the project sites in Bangladesh and are found to be highly suitable agronomically (average yield is >6 t/ha) and economically profitable (net benefit above 40,000 Tk/ha) and well adopted by the farmers.
5. In Bangladesh, several old and new crops such as foxtail millet, English spinach, barley, garlic, sunflower, maize, mustard, pumpkin, among others

are suitable and profitable for cultivation. Optimum sowing times, establishment methods (zero tillage, dibbling, transplanting, use of machinery), management practices (use of mulch, fertilizer rate and application, spacing, intercropping) and conjunctive use of fresh water and saline water for irrigation for some of the suitable crops have been developed.

6. Zero tillage (ZT) potato cultivation is a breakthrough technology of the project, which has been taken up by the farmers in Gosaba rapidly. ZT potato is also successful at Dacope, Khulna.

7. Several suitable and profitable cropping patterns have emerged based on this research over the last five years for the study areas. Some of the highly profitable cropping patterns for Bangladesh sites are Aman rice-sunflower/-maize-Aus rice, Aman rice-Boro rice, Aman rice-Aus rice, Aman rice-spinach/ mustard/garlic/ZT potato- Aus rice, among others.

Fisheries

BFRI has been conducting applied and adaptive research on freshwater, brackish water, and coastal aquaculture; riverine and marine fisheries for quite a number of years now. Achievements of brackish water fisheries research are significant and consequently shrimp (including *bagda*, *Microbrachium rogenbergii*) culture has been spread in several coastal areas. Rotational shrimp and rice-fish culture system have been demonstrated by the scientists and extension experts (Saiful 2013). Crop diversification in coastal aquaculture, integrated crab-fish fattening and early brooding of shrimp in a 'Green House' system to develop sustainable and environment-friendly shrimp fields are some of the novel systems that are found to be tenable in the coastal environment. Like inland capture fisheries, coastal and marine fisheries are becoming increasingly commercially focused. Research and development initiatives have brought about a notable progress in technology innovations to support the coastal and marine sector. The important achievements include:

- Culture and brood development of sea bass (*Lates calcarifer*), mullets (*mugil sp.*)
- Development of low-cost health friendly sun dryer for fish drying
- Development of improved devices e.g., behundi net (set-bag net)

Further research is focused on pollution, stock assessment, breeding and culture of selected finfish, improvement of post-harvest processing and product development and socioeconomic survey of fishers.

e) Hill ecosystem

Promoting Village Community Forest (VCF) in the hilly areas

Since 1900, Village Community Forests (VCF) have been regarded as excellent

examples of traditional forest management by the indigenous communities in the Chattogram Hill Tracts (CHT). The presence of good understory vegetation consisting of many herbs and other plants is the primary indicator of good site conditions prevailing in the VCF areas. This understory vegetation is helpful in soil and water conservation. In some areas, communities are totally dependent on VCF to sustain water flows into perennial streams that meet their year-round water requirements. Besides VCF management, indigenous techniques of jhum cultivation such as terracing, minimum tillage, controlled burning of debris, mulching and gully control by vegetative cover appear to have a time-tested and proven positive impact on soil and water conservation.

Effective management of sloping land

According to Target 4 of LDN, the Government of Bangladesh will reduce soil erosion in 600 km² of hilly area by 2030 (UNCCD 2018). The target will address unsustainable land management on sloping land (growing tuber/root crops on sloping land), deforestation and infrastructure development, cultural practices (shifting cultivation) etc. Measures will be taken to establish agroforestry/horticulture, no tillage on slope, introduce hedgerow across the slope by leguminous shrubs/trees.

Advances in hill agriculture

Crops and cropping patterns

The Hill Agriculture Research Station (HARS) of BARI, Ramgarh, Khagrachari developed MATH (Modern Agricultural Technology in Hill) model. Although the design and purpose of the model is excellent, it could not be expanded due to various reasons. After that HARS developed another model called the Multi-Strata Fruit Orchard which is promoted widely in CHT. Cultivation of cashew nut and coffee in the hills has a very good prospect in terms of export earnings. Considering this, a mega project was initiated by the Ministry of Agriculture. Now the cashew nut and coffee research, development and extension project are being jointly implemented by BARI and DAE in the hilly areas of Bangladesh. Production of value-added products by processing fruits like mango, banana, jackfruit, pineapple, papaya, watermelon, olive, etc. is another high-potential enterprise in CHT.

BARI malta 1 is a high yielding-*malta* (sweet orange) variety developed by HARS. The demand for this fruit variety is on the increase for commercial cultivation in CHT. Successful production of malta with quality fruits warrants good management practices including the availability of soil moisture during flowering and fruiting stages and ensuring sufficient fruit retention reducing fruit and flower drops. However, in the hilly areas, farmers of the hilly areas do not get adequate water for irrigation during the

water-deficit dry months (October to April). Drip irrigation technology has been developed for not only saving production costs but also for reducing water loss in crop fields.

Fisheries

The Department of Fisheries (DoF) implemented a project in the mid-1990s "Fish Culture Development and Extension in Hills, which created 11.5 ha of nursery ponds and 92 ha of other water bodies by modification of creek flows and construction of small dams, which were brought under fish culture. Training of farmers on aquaculture was given special attention from this project. DoF also implemented a project entitled "Improvement and extension of fish culture by developing creeks in the Chittagong Hill Tracts" during 2000 to 2010. Under this project DoF developed 287 creeks and established 3 mini hatcheries in CHT. In the 3rd phase of the project, 903 creeks will be renovated and one hatchery will be established.

5.3 Fourth industrial revolution (4IR)

Bangladesh is driven by far-reaching digitalization in public and private sectors. The government has established a countrywide vast network of one-stop information and service delivery access points known as Union Digital Centers (UDC). A total of 5,838 UDCs is currently operational in the country providing services to 422 million people. There are just a few technologies e.g., robotics, big data analytics, artificial intelligence, the Internet of Things, etc., that will enable anyone and anywhere to access personalized resources for education, technologies, nutrition and customized extension and marketing services. The 4IR is an advanced digital technology, which focuses on opportunities that the farms and factories should implement to move forward fast.

In South Asia, Bangladesh is gradually emerging as one of the fastest growing economic powers with notable progresses in many fields. It is expected that Bangladesh will leave the Least Developed Country (LDC) category by 2024 provided the country can sustain this development rate. Innovations of 4IR can be a vital force in the 21st century that can help Bangladesh achieve its goals. Advances in computing power, connectivity, artificial intelligence, robotics, etc., and other more capable technologies hold a tremendous promise for the farmer-dominated Bangladesh agriculture. The 'Digital Bangladesh' program is working for transforming the country's rural economy and creating jobs in the rural areas for skilled people.

An online platform for farmers should be created that will integrate agricultural markets online allowing the farmers and traders alike to view all agriculture product marketing-related information and services, commodity arrivals and prices and buy and sell trade offers. This will help farmers bid for the best prices across markets. Similarly, comprehensive crop insurance could be introduced covering all farmers.

Power tiller/tractor services, digitalized land registration, mobile phones etc., are possibilities that can contribute to improved farm management by the farmers. The Government needs to further encourage agent banking and rapidly expand the mobile phone payment technology. In rural areas, insufficient connectivity along with a lack of basic computer knowledge and literacy hinders development. To truly reap the benefits of 4IR, substantial investments are needed in physical infrastructure, power, next generation broadband, transportation and education, particularly in rural areas and among the poorest population groups.

Through 4IR, a smart farming culture is specified, which allows an agricultural site to enhance productivity in a competitive way. Agricultural robotics technology in 4IR has beneficial outcomes for promoting advanced agricultural systems by reducing labor costs and improving quality (Duckett 2018). The farmers will get free access to internet, web and online sites, and get all the updated field information using mobile phones. These devices are connected to IoT (Internet of Things) devices and cloud computing. Farmers should be provided with access to IoT-based smart farming system tools for information on real time statuses of light, temperature, humidity and soil moisture in their fields using connected sensors.

There are intermediate stakeholders between customers of farm produce and farmers causing a gap in the latter's farm business. In this respect 4IR can minimize this gap by creating a knowledge bridge between the farmers and make the production services available to the field workers. Demand based agricultural production and crops distribution information can be fetched and analyzed in computers by applying 4IR technology. To keep prices stable and normal in markets customized production through optimizing the supply and demand chain is necessary (Imam et al. 2014).

It is predicted that 4IR may destroy job opportunities in many sectors including agriculture, but in effect thousand numerous other job opportunities will be opened up for skilled persons in diverse sectors like smart phones, biometric sensors, GPS systems, Wi-Fi and social media.

5.3.1 Artificial Intelligence (AI) in agriculture

The National Strategy for Artificial Intelligence (AI) was developed by the ICT Division of the Government of Bangladesh in 2020 which emphasized accelerating AI for the digitalization of the nation including its agricultural sectors while the digitization process started a decade earlier.

(Source:https://www.academia.edu/44450021/National_Strategy_-for_Artificial_Intelligence_Bamngladesh)

AI is likely to enhance the flexibility of autonomous tractors, irrigation systems, and even drones well equipped with devices such as sensors, radars and GPS systems. AI technology will enhance crop production and improve

real time monitoring, harvesting, processing and marketing. To determine various important parameters like weed detection, yield detection and crop quality and many other techniques, various hi-tech computer-based systems have been designed (Liakos et al. 2018), Bangladesh agriculture may be benefited by these modern technologies and techniques.

AI will contribute to the agricultural sector in various ways as follows:

- a) Manual weeding will be replaced by the laser weeding technology, where a mobile focused infra-red light disrupts the cells of the weeds, this beam will be controlled by computers (Griepentrog et al. 2006).
- b) Manual irrigation will be replaced by automatic irrigation scheduling techniques. Through wireless technology, automatic plant irrigators will be planted in the field for drip irrigation. The smart irrigation technology has a bright prospect of increasing production, without involvement of large manpower, by detecting the level of water, temperature of the soil, nutrient content and weather forecasting. The rain drop sensor and soil moisture sensor of the GSM module will inform the farmer or irrigation pump operator about the moisture content of soil through SMS on their cell phone. The farmer/pump operator can then give commands using SMS to put the water supply on or off.

Bangladesh has started to use digital agriculture technology platforms. This platform generates base data for AI, IoT for crop field conditions, behavior analysis of cow, fish feeding, etc., crop stage mapping using satellite image processing, hydroponics and vertical agriculture for moving towards building plant factories and data for prediction mapping. The country has much potential to solve some problems by AI like dynamic soil topology map, diseases forecast team system for a single crop, harvesting prediction automation, image-based disease recognition, etc. Asian countries such as, India, Japan, China, South Korea, Malaysia, Singapore, etc., are already using AI technology in agriculture.

5.3.2 Robotics in agriculture

The National Strategy for Robotics was developed by the ICT division of the Government of Bangladesh in 2020. This strategy emphasizes the needs to keep complementing labor with technology to reach the economic targets of the country set for 2021, 2030 and 2041. Robotics will be one of the technologies. If robotics is used in agriculture, agricultural productivity will be increased and Bangladesh will step into high precision manufacturing, food processing and also farming.

(https://bcc.portal.gov.bd/sites/default/files/files/bcc.portal.gov.bd/page/588ddd53_acia_4214_ae01_b1f398687f2f/2020-09-21-16-29-38a296c7a172e5e673860983d18da7e2.pdf)

The work of 10 persons can be performed more accurately and efficiently by one robot. Use of robotics in agriculture is becoming increasingly popular. Improving food quality, production security and finally reducing end product cost can be achieved by robotics in agriculture. Post-harvest work including cleaning and packaging of agricultural products can be performed quickly and with high precision by specially built robots. The cows can milk themselves by using robotic milking machines. GPS (global positioning system)-based automated power tillers, tractors, weeders, planters/seeder, harvesters, threshers, etc., can be used which can be more efficient than conventional tools using less fuel and at the same time conserving soil quality. Advanced agricultural operations such as pruning, weeding, spraying and monitoring can be done by robots. Harvesting robots can be used to enhance efficiency and quality. Vegetable-picking robots can be used for harvesting vegetables without physical damage to vegetables thus maintaining quality. Similarly, fruit picking robotic arms farmers can pick up fruits quickly and efficiently without damaging any fruit, so quality is maintained. With the given human commands and programs embedded, a robot can follow it up and farmers will not be required to work physically to perform any kind of actions. Programming can be set by instructions which accepts and makes rapid action based on real time information.

5.3.3 Blockchain technology in agriculture

The National Blockchain Strategy was developed by the ICT division of the Government of Bangladesh in 2020 emphasizing advancing technical capacity, increasing efficiency in e-governance and fostering innovations in agricultural sectors.

(https://bcc.portal.gov.bd/sites/default/files/files/bcc.portal.gov.bd/page/bdb0a706_e674_4a40_a8a8_7cfccf7e9d9b/2020-10-19-15-03-391a6d9d1eb062836b440256cee34935.pdf)

A ledger consisting of consecutive blocks chained together following a strict set of rules is a blockchain technology. The ledger is then distributed in a P2P (peer-to-peer) network which is then stored by all nodes within the network. This technology will be useful for the following agricultural domain:

- a) **Procurement:** The agriculture sector in Bangladesh lacks proper tracking of agricultural products for ensuring payment after product delivery. The whole process of coordination currently depends on the third parties. There are agents of both the seller and the buyer for delivery and payment of food, ultimately these agents add additional cost to the system. Buyers and sellers can directly interact with each other which will speed up the process and reduce time and cost for the farmers, if block chain technology can be leveraged. A block chain system will ensure that farmers receive a large share of the sale proceeds (Chowdhury et al. 2019).

- b) **Agricultural insurance:** Agricultural insurance systems are mainly the collection of non-formal private mutual and community-based crop and livestock initiatives in Bangladesh. Still some low-cost agricultural insurance schemes are used for ensuring social protection to various natural disasters affected people. The adoption rate of insurance is very low as the benefits are not well communicated. Farmers can get the benefit instantly in adverse weather through automatic data feed and local hype data of a blockchain based insurance system without the need for any claim assessment (SDG 2019).
- c) **Livestock tokens for cattle financing:** Blockchain technologies are designed to decentralize the control of data across a network of participants, unlike traditional centralized systems. This means transactions carried out by any parties in the blockchain are immutable even from the creator of the transactions, or the network itself. Network participants can issue digital tokens which can be safely traded on the block chain, by delegating trust to the network's algorithm or protocol. A blockchain network called Sentinel Chain that is developed by InfoCorp is designed to facilitate cross-border financing of tokenized livestock asset in addressing financial inclusion. The livestock tokens can then be used for traceability and provenance while unlocking liquidity from alternative channels such as the crypto world using Sentinel Chain tokens (SENC). Moreover, a simple mobile app, iFarmer, can be used by farmers and farm facilitators to collect farmer profiles, update farm information and so on. This information pertains to the health, legitimacy, ownership of the livestock and whether the livestock has been collateralized for other loans, among other things.
- d) **Record-keeping and access to financial services:** Farmers can use their digitalized ledger for better record-keeping and proof of income. This makes it easy for farmers to access supply chain finance, loans and other financial services.

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Chapter 6

Way Forward and Future Strategies

In the coming days of the 21st century, researchers, extension workers and government planners would have to face the challenges of producing more food for the increasing population from the decreasing arable land. This would not be an easy task since the population is increasing, natural resources (soil, water) are degrading and farmers would need to cope with harsher environments resulting from climate change. Strategies, plans and actions are required to achieve goals and objectives that include increasing production of nutrient-dense food, protecting soil, water and wildlife and the climate change and enhancing equity and justice in food. The size and volume of agriculture as well as management is going through continual forward-looking changes since independence of the country and will continue to change in the coming days of the 21st century and beyond. These changes would occur for two reasons, a) fulfil the needs of the increasing population and b) face the emerging challenges and issues.

6.1 Challenges of Agriculture Sector in the 21st Century

Agriculture (crops, livestock and fisheries) is at the nexus of the five greatest challenges that the country would face in varying degrees during the 21st century. Therefore, these challenges need to be addressed by developing and implementing efficient strategies in agriculture. These five key challenges are given below:

- i) Feeding an increasing population,
- ii) Meeting demands for diverse, safe and nutritious foods,
- iii) Impact of climate change on food production,
- iv) Sustainable use of ecologically constrained or fragile ecosystems, and
- v) Capacity gaps in human resources required for agricultural research and development.

The future scenario of Bangladesh agriculture and food production will be shaped by how well today's planners, policy makers, researchers, educationists, extension workers and agencies respond to the needs and challenges of the future. The above five challenges are described in detail below:

6.1.1 Feeding an increasing population

There is a dire need for sustainable agricultural production for feeding the increasing population of 184 million in 2030, 197 million in 2040, 204 million in 2050 and 176 million in 2100 (Fig. 6.1). Bangladesh requires 496 g rice, 50 g wheat, 50 g pulse, 90 g oilseeds, 20 g spices, 250 g vegetables (including

potato), 100 g fruits, 63 g fish, 250 ml milk, 120 g meat and 30 g egg per capita per day (FAO and WHO 2014, BIRDEM 2013). Going by these estimates, the country needs to produce a total of 102 MT (million ton) food in 2030, 109 MT in 2040, 113 MT in 2050 and 98 MT in 2100 (Fig. 6.1) from agricultural sectors to feed the population in a given year as mentioned above. Bangladesh produced a total of 89.4 MT food in 2021 (37.6 MT rice, 1.1 MT wheat, 0.43 MT pulse, 0.99 MT oilseeds, 3.60 MT spices, 14.5 MT vegetables including potato, 5.1 MT fruits, 4.5 MT fish, 11.9 MT milk, 8.4 MT meat and 1.23 MT eggs). Taking into account of 65 kg wastage of food by a Bangladeshi per year (UNEP 2021), a total of 79 MT food became available from agricultural sectors for human consumption in 2021. If this 79 MT total food availability is considered business as usual from 2021, the country needs to increase its total production from agricultural sectors by 23 MMT in 2030, 30 MT in 2040, 34 MT in 2050 and 19 MT in 2100. This means that the total food production needs to be increased by 29% in 2030, 43% in 2050 and 24% in 2100 if not otherwise constrained by severe impact of climate change.

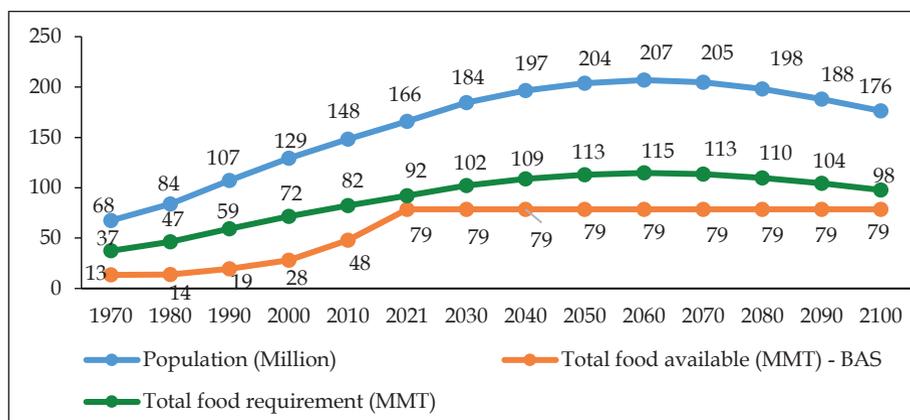


Fig. 6.1. Population versus food production requirement of Bangladesh up to 2100

Source: FAO and WHO (2014), BIRDEM (2013), UNEP (2021)

<https://www.populationpyramid.net/bangladesh/2100/>

6.1.2 Meeting the demands for diverse, safe and nutritious foods

The diversity of agricultural production is becoming narrower with time to a few crops like rice, potato, maize, some vegetables and fruits. Even though the existing wheat varieties in Bangladesh are high-yielding, the area and production are not increasing sufficiently to match the growth of the human population. Moreover, the wheat crop in many areas is replaced by various other Rabi crops such as potato, Boro rice, maize and different short-duration

vegetables. Despite many improved varieties, a narrow genetic base is identified as the main constraint for the desired genetic gains in pulses. Despite recent production increases, the domestic production of edible oil can only meet about 20% of the country's annual demand and the remaining 80% is imported at a staggering cost of more than BDT 20 billion in hard cash amounting to about USD 200 million USD. Constraints to oilseeds production in Bangladesh are related to climatic variability, competition with other crops, production and post-harvest management and market access.

Securing safe and nutritious foods is a major challenge to achieving goals set by National Agricultural Policy (NAP) 2018, Sustainable Development Goals (SDGs), Vision 2041 and Delta Plan 2100. Although Bangladesh has achieved significant increases in food production from agricultural sectors, the country still lags behind in fulfilling the demands for safe and nutritious food. Indiscriminate use of antibiotics as growth promoters are increasing concerns for antibiotic resistance in both livestock and humans (Rafiq et al. 2022) and residual antibiotics have been found in meat, which also poses a threat to consumer's health (Beyene, 2016). Heavy metals are growing concerns as they are major contaminants in poultry meat, feed and other poultry products ((Korish and Attia 2020). Bioaccumulation of heavy metals in meat or other sources of food does not bode well for human health as these toxic substances eventually find their way into the human body tissue (Zeitoun & Mehana, 2014).

In recent years, the food safety issue has attracted good attention of the people of Bangladesh, particularly in the light of widespread adulteration of food items and sale of unsafe food. Apart from being a major public health issue, this has had serious economic consequences for Bangladesh as consumer confidence has dwindled leading to a decline in the demands for several products. For instance, a recent testing of some samples of pasteurized and raw milk, found the presence of antibiotics and heavy metals, which caused the demand for locally produced milk to plummet and the import of powdered milk to spiral. This has affected the dairy industry adversely, particularly the local dairy farmers (The Daily Star 2019). Food safety is also important in determining trade relations between countries, particularly with developed countries. Bangladesh has faced restrictions on its exports to EU and the US on several occasions due to non-compliance. The costs of these restrictions have been heavy, both in monetary terms as well as in terms of loss of credibility, leading to uncertainty of sustained access to export markets.

Due to the limited role of the public extension workers, farmers frequently depend on private extension agents and are often misled by the latter's advice, which is largely driven by the urge to maximize profits. A classic example is the inappropriate and excessive use of pesticides in food production. In fact, pesticide use has more than doubled in the past two

decades from 1997 to 2017 (BBS 2000 2017). The so-called “dirty dozen” pesticides which are banned globally for their hazardous impact on health including cancer, DNA damage and birth defects, are still being used in Bangladesh. The use of banned protein concentrate, meat and bone meal (MBM) and tannery wastes in poultry and animal feed is a case in point. With unsafe food, people are exposed to a range of contaminants including microbial pathogens, zoonotic diseases, parasites, adulterants, naturally occurring toxins, antibiotic drug residues, pesticide residues, and presence of heavy metals (Jaffee et al. 2019). These contaminants result in low absorption of nutrients leading to many food-borne diseases. The ultimate outcome is malnutrition.

6.1.3 Impact of climate change on food production

Climate change is one of the major reasons for the decline in agricultural production. Bangladesh is the country most vulnerable to climate change which causes river erosion, floods, flash floods and salt water intrusion. Changes in temperature and rainfall patterns caused by climate change take a heavy toll on agriculture. Temperature and rainfall changes have already affected crop production in many parts of Bangladesh. A 4°C increase in temperature is projected to take place due to climate change. This may severely impact food production in this country and may result in a 28% reduction of rice and a 68% reduction of wheat output (<https://www.thefinancialexpress.com.bd/views/impact-of-climate-change-on-agricultural-1518619832>). The intensity of salinity intrusion into farmlands in coastal areas is growing due to a rise in the sea level. According to the Bangladesh National Adaptation Program of Action, the sea level along the Bangladesh coast is rising at a rate of about 3 millimeters per year. High salinity, waterlogging and drought render some agricultural land uncultivable. Due to increasing ingress of salts from the sea with a congruent reduction in the availability of sweet water for irrigation and an increase in soil salinity, rice and wheat production in the country are estimated to fall by 8% and 32%, respectively by the year 2050. In the southern parts and coastal areas of Bangladesh groundwater aquifers are also being increasingly contaminated by salt ingress.

Climate change induced incidences of floods, droughts, high temperature, flash floods, saline water intrusion etc. are predicted to be more frequent and intense with time. For example, floods damage crops due to submergence, livestock due to lack of feeds and fisheries due to overflow of ponds and water bodies. Similarly, drought damages crops due to a high heat load, livestock due to poor growth of grasses and fisheries due to lowering water level leading to less recruitment in inland fisheries.

6.1.4 Sustainable use of ecologically constrained or fragile ecosystems

Haor ecosystem

Heavy rainfall as well as onrush of water from the upstream Meghalaya hills in India recurrently inundates cropland of the haor areas in Bangladesh. An onrush of excess water often breaks embankments in many places and inundates vast cropland and homestead areas. Water coming from the Mona, Jhuri and Kushiara rivers and water from canals of hill slopes causes flash floods and croplands go under water for varying periods. Flash floods, when coupled with heavy rainfall, cause severe and prolonged flooding. On the other extreme, prolonged droughts also occur in haor areas. The main source of irrigation is surface water but the waterbodies dry up during droughts forcing the farmers to keep their lands fallow. Floods, droughts, high temperature, flash floods, etc. are predicted to be more frequent and intense in the haor areas, expected to severely damage crops, livestock and fisheries. The main challenges in livestock rearing in haor areas are scarcity of grazing fields, insufficient livestock care services, lack of feeds and fodder. There are not enough fish pass structures in flood control embankments and road to benefit fisheries.

On the socioeconomic front, too, agricultural production in haor areas is constrained by several factors. A major problem is the scarcity of agricultural laborers for harvesting Boro rice. Farmers need to give attention to high prices of inputs (fertilizer, seed, labor, etc.) and inadequate transportation facilities for their produce.

Char ecosystem

The char ecosystem is mainly constrained by river erosion, flood, drought, forest degradation, low soil fertility, inundation of pasture lands, loss of fish habitats etc. Quite often early flood occurs in char areas, which damages the almost mature Boro rice. Severe drought also occurs in the winter season when limited irrigation facilities affect Boro rice. Cropping systems are also unstable. Migration of agricultural laborers is significant during both planting and harvesting times due to high demands in the mainland. In peak flood periods, shifting cattle to high land such as an embankment is a problem for char dwellers, while lack of fodder and shortage of funds compel the farmers to sell out this important asset at nominal prices. There are outbreaks of various livestock and poultry diseases in the wet season. Veterinary doctors are not readily available in the char areas. Late rain impacts brood fish maturation, immature eggs and sperms lower growth rate, fish disease infestation. Low water level in rivers, canal, etc., increases fishing pressure, which causes an indiscriminate catching of broods and juvenile fish. High temperature causes mortality of spawn, fry and fingerlings.

Barind ecosystem

The major problems of agriculture in the Barind ecosystem are drought, ground water decline, degradation of forests, low soil fertility, reduction of pasture lands, loss of fish habitats etc. The groundwater level (GWL) is receding continually indicating overuse of groundwater for irrigation on the one hand and inadequate recharge due to low rainfall on the other. A thick top clay layer (Barind clay of Pleistocene age) is one of the major obstacles against good tillage for crop establishment and growth and also for groundwater recharge. Depletion of underground water severely affects crops not only in the dry season but also in some years in the Kharif season so that transplanting of T. Aman rice is delayed which results in reduced yield of crops. The Barind households encounter problems with livestock feed shortages both in the dry and wet seasons. Most ponds are seasonal due to drought that limits fish production throughout the year. Use of chemical pesticides destroys aquatic biodiversity and leads to aquatic pollution.

Coastal ecosystem

Soil salinity in drier months (February to May) affects crop growth, which reduces yield and in severe cases causes total crop losses in the coastal areas. Presence of saline ground water table within one meter for the surface throughout the year affects crop production. Variability and uncertain rainfall, cyclone, storms, etc., delays sowing/transplanting and flooding damages Aus and Aman rice crops. Late harvest of T. Aman rice with short winter season restricts Rabi crop cultivation. Sea level rise due to climate change results in flooding and salinity intrusion, and thus reduces grazing grounds and fodder production for livestock. Flooding, waterlogging, erosion and siltation also result in the scarcity of free grazing area. Increase of salinity coupled with inadequate water management affects freshwater aquaculture. Drought and tidal waves, rain and flood affect fish culture round the year. Upstream water flow and siltation reduce reservoirs for fish culture.

Hill ecosystem

Long dry spells leading to severe crisis of water coupled with very poor irrigation system limit crop production in the hilly areas. Inadequate HYVs of crops for the jhum system hinder cultivation of hilly areas. Traditionally, the local communities practice jhum farming which basically involves cultivation of food crops in forest land through clearing and burning of undergrowth in the dry season, usually leaving a certain fallow period of 3-15 years between successive crops on the same piece of land. However, increasing population pressure has resulted in the shortening of the fallow period to as little as 1-2 years with a sharp decline in jhum productivity. The most serious problem resulting from pineapple gardening and growing of some root crops such as

ginger and turmeric is the direct exposure of the soil surface to heavy downpour and surface runoff gradually reducing the harvests of crops. The main challenges in livestock rearing are lack of quality veterinary facilities and physical infrastructure and insufficient scientific and technical innovations. Storage facilities including cold storages are few and very poor marketing facilities exist in the hilly areas. Farmers have poor access to agricultural inputs, technologies, extension services, marketing, etc., due to remoteness.

6.1.5 Capacity gap in human resources required for agricultural research and development

Despite growing attention to the agricultural sector and the role of agricultural research, Bangladesh like many low- and middle-income countries continues to struggle with serious and deepening capacity and funding constraints in agricultural research. There was a significant vacancy of agricultural researchers during 2022 (842 out of 2,564 sanctioned posts; 33%) in 13 NARS institutes and BARC – the apex organization of NARS (BARC 2022a). All NARS institutes and BARC have vacancies; SRDI has the highest percentage vacancy, 50.4% (207 out of 411 posts) followed by BARI (131 out of 685 posts) and BFRI – fisheries (100 out of 225 posts). The total number of researchers in NARS institutes and BARC remained almost static between 2020 (1,797) and 2022 (1,722), although the number increased significantly from 1,419 in 2009 to 1,722 in 2022. This indicates a serious capacity gap of NARS institutes due to shortage of researchers that slows down achievement of the desired technological advancement for increased agricultural production to feed the increasing population in future.

There is also a skill gap in NARS institutes due to a relatively low proportion of researchers having advanced degrees. In 2022, 41% of 1722 researchers in the 13 NARS institutes and BARC held PhD degrees, which was lower than the corresponding share in ICAR (Indian Council for Agricultural Research), India (77.5% in 2018) (<http://www.asti.cgiar.org/>). The situation is particularly precarious in different disciplines of animal science and fisheries with only a few working scientists with advanced degrees primarily due to a poor share of technical assistance in the agricultural ADP. The present quality of education particularly at the master's and doctoral levels are not high enough to achieve SDGs and other forthcoming global requirements in the 21st century.

6.2 Strategic Investment Opportunities to Address Emerging Challenges

Major areas of way forward and strategies to meet the future needs of the country by tackling the emerging challenges/issues and by using corresponding policy support are outlined below.

6.2.1 Gene editing for intensification of food production

Although the country has attained surplus in rice, fruit, fish, milk, meat and egg and is expecting to be self-sufficient in vegetables shortly, the challenge now is to grow more food to feed an increasing population in the 21st century with a shrinking agricultural land area. The Government has projected demand and supply of essential food crops for the period of 2030 to 2050 (Table 6.1) (BARC 2022b).

Table 6.1. Projection of future supply and demand of essential food crops: 2030-2050

Crops	Demand				Supply			Surplus (+)/Deficit (-)				
	2021	2030	2040	2050	2021	2030	2040	2050	2021	2030	2040	2050
Cereals (Million MT):												
Rice:	35.2	39.1	41.3	42.6	35.7	41.0	45.9	52.1	0.5	1.9	4.6	9.5
Wheat	4.1	4.6	5.0	5.2	1.0	1.2	1.2	1.2	-3.1	-3.4	-3.8	-4.0
Maize	5.7	5.8	7.4	8.7	4.2	6.2	9.0	12.2	-1.5	0.4	1.6	3.5
Pulses (Lakh MT) :												
Lentil	6.4	7.1	7.5	7.8	1.8	2.3	3.0	3.8	-4.6	-4.8	-4.5	-4.0
Mungbean	2.6	2.8	3.0	3.1	0.4	0.8	1.2	1.9	-2.2	-2.0	-1.8	-1.2
Blackgram	1.3	1.3	1.5	1.6	0.4	0.3	0.3	0.3	-0.9	-1.0	-1.2	-1.3
Lathyrus	2.6	2.8	3.0	3.1	1.3	1.9	2.9	3.9	-1.3	-0.9	-0.1	0.8
Chickpea	1.3	1.4	1.5	1.6	0.1	0.1	0.1	0.02	-1.2	-1.3	-1.4	-1.6
Pea	3.3	3.6	3.8	4.0	0.1	0.2	0.3	0.4	-3.2	-3.4	-3.63	-3.6
Oilseeds (Lakh MT) :												
Mustard	1.5	2.1	2.9	3.9	1.5	1.8	2.0	2.3	-0.0	-0.3	-0.9	-1.6
Groundnut	0.1	0.1	0.1	0.1	0.3	0.5	0.6	0.7	0.2	0.4	0.5	0.6
Spices (Lakh MT) :												
Onion	27.0	34.1	40.1	45.5	18.5	25.4	35.1	48.8	-8.5	-8.7	-5.0	3.3
Garlic	13.7	17.4	20.5	23.3	4.9	6.7	9.6	12.9	-8.8	-10.7	-10.9	-10.4
Chili	3.8	4.8	5.2	6.4	1.4	3.4	5.3	7.5	-2.4	-1.4	-0.1	1.1
Turmeric	6.5	8.2	9.6	10.9	2.4	3.8	5.5	7.3	-4.1	-4.4	-4.1	-3.6
Ginger	2.4	3.1	3.6	4.1	0.9	0.9	1.0	1.1	-1.5	-2.2	-2.6	-3.0
Coriander	0.5	1.0	1.2	1.4	0.2	0.3	0.4	0.5	-0.3	-0.7	-0.8	-0.9
Fruits (Lakh MT) :												
Mango	10.9	12.6	14.4	16.1	12.1	14.0	15.8	17.7	1.2	1.4	1.4	1.6
Pineapple	1.3	1.5	1.7	1.9	2.1	2.2	2.5	2.8	0.8	0.7	0.8	0.9
Watermelon	3.0	3.6	4.4	5.3	3.0	4.0	4.7	5.6	0.0	0.4	0.3	0.3
Lemon	1.0	1.4	1.7	2.1	1.2	1.4	1.8	2.3	0.2	0.0	0.1	0.2
Banana	8.3	10.3	12.2	14.1	8.7	10.7	13.8	17.5	0.4	0.4	1.6	3.4
Guava	2.2	2.8	3.5	4.2	2.4	3.2	4.5	5.8	0.2	0.4	1.0	1.6
Root crop (Lakh MT) :												
Potato	95.6	116.2	122.6	126.6	98.7	117.8	130.4	140.9	3.1	1.6	7.8	14.3
Sweet potato	4.1	3.2	3.4	3.5	3.7	5.4	9.9	15.8	-0.5	2.2	6.5	12.3
Vegetables (Lakh MT) :	41.2	51.5	63.4	65.5	41.7	53.8	70.3	89.0	0.5	2.3	6.9	23.5

Source: BARC 2022b

* 1 Lakh= 0.1 Million

All the crops except fruits and vegetables will fall short of demands in 2030, 2040 and 2050. The demand evaluation was made considering human food

and use as seed, feed of livestock and poultry and industry and wastage, business as usual was considered for the projection of crops other than rice.

Achieving the targeted food production levels to negate the deficits can only be possible with the development and quick uptake of newer technologies to boost agricultural productivity in an eco-friendly way. Diversification and productivity gains mainly require breed development (vertical gains) using gene editing technique of biotechnology. Gene editing techniques need to be exploited to boost and commercialize agricultural production. Transgenic varieties or GMOs with built-in insect resistance have the potential to significantly reduce the use of insecticides, but this needs vigilant supervision to limit the natural selection of insect pests with tolerance to the engineered traits. In addition, issues related to time, cost, efficiency, bioethics, regulation and public acceptance of genetically modified plants are the major concerns. The UN recently stated that it would be harder to achieve SDG 2 by 2030 if the world does not change its strategy regarding crop improvement and development.

There are numerous genomes editing technologies, such as clustered regularly interspaced short palindromic repeats (CRISPR), site directed nuclease and oligonucleotide-directed mutagenesis. These are genome site-directed technologies, capable of up-regulating, down-regulating or silencing a specific gene or genes. Breeding new plant varieties is not a simple, or rapid process, with development times of 12–15 years. One estimate identifies that the application of genome editing technologies could shorten this time requirement to as few as 2–3 years (Friedrichs et al. 2019) that will help to produce new breeds frequently and to boost agricultural production within a short span of time.

Bangladesh agriculture aims at achieving food and nutritional security of the increasing population, but this is becoming increasingly difficult due to mounting threats of climate change and overuse of cultivable lands. In this backdrop, genome editing technologies, especially the CRISPR/Cas9 method, which are evolving very fast since their discovery in 2012, can be of great help. More and more biochemists and molecular biologists should be trained to work with the genome editing technology to keep pace with the fast evolution of these tools and use their expertise not only in sustainable agricultural development, but also in creating biodiversity.

Bangladesh's rice scientists should make use of gene editing techniques to implant different stress and disease-tolerant traits in existing mega varieties and upcoming breeding materials to quickly develop biotic and abiotic stress tolerant HYVs. It is noteworthy that BRRI scientists have attained early success in developing some of the country's first-generation gene-edited breeding lines of rice which are expected to effectively fight diseases like blast and insects like brown plant hopper (BPH) and tolerate a major abiotic stress,

i.e., high soil salinity. Besides, work is underway to infuse high yield potentials in hybrid rice and premium quality fine grained aromatic rice through applications of CRISPR/Cas9 gene-editing tool (<https://www.dhakatribune.com/bangladesh/2021/12/18/rice-sciences-graduation-to-gene-editing-technology>).

Gene editing using CRISPR/Cas9 to facilitate the knockout of genes responsible for the biosynthesis of gibberellins will facilitate the development of semi-dwarf or dwarf crop varieties which may be resistant to lodging from intense winds, typhoons and storms anticipated to increase in severity as a result of climate change (Shao et al. 2020). Semi-dwarf rice and wheat varieties have historically been an important tool in bringing about the Green Revolution (Khush, 1999).

In animals, too, gene editing could be applied to mitigate abiotic stresses imposed by climate change. Researchers focused on replicating the SLICK phenotype originally identified in cattle through gene editing. Variations of this phenotype in cattle contribute to thermo-tolerance (Porto-Neto et al. 2018). Cattle possessing SLICK genes are more thermo-tolerant, as exhibited by lower vaginal temperatures, lower rectal temperatures, lower respiration rates and more sweating, thus leading to increased milk production during summer months (Dikmen et al. 2014). Using gene editing approaches, Acceligen seeks to replicate SLICK genetics, to improve thermo-tolerance of important cattle breeds (Bellini, 2018).

The benefits of gene editing are huge. The Government should create an enabling environment for the scientists to use gene editing techniques so that the country can produce enough food to overcome any food deficit situation in the near or distant future even in the face of climate change adversities.

6.2.2 Technological advancement for year-round crop production

Further investments need to be made in the 21st century to ensure that the country can grow crops, animals, birds and fish round the year, increase yields and reduce post-harvest wastage. For instance, BARI has developed a mango variety (BARI Aam-11) and a vegetable variety (BARI Lau-4), which are grown round the year. Some vegetable and fruit varieties can grow in more than one season like tomato, brinjal, etc., and expand production for more than 6 months through early and late varieties of mango, jackfruit, banana, etc. NARS scientists should emphasize the production of an increasing number of nutrition-enriched crop varieties including fruits and vegetables in the future, so that their production is spread round the year and wastage is minimized avoiding dumping of seasonal production. Crops like pulses, oilseeds, wheat, etc., should also be brought under production in at least two seasons by breeding of appropriate OP (open-pollinated) and

hybrid varieties using gene editing techniques to increase crop diversification by fitting into cropping patterns.

Similarly, scientists should emphasise the development of high-yielding breeds of livestock, poultry and fisheries having traits to grow round the year shortening the lean season of availability. For instance, currently eggs, milk and meat are not uniformly available round the year due to lack of adequate breeds that are resistant to high and low temperatures, moisture conditions and diseases. Cross breeds/hybrids of milking cows should be developed extensively in future for massive increase of milk production round the year. Most ponds of the country are seasonal due to climate induced drought that limits fish production throughout the year. Alternative systems of fish production like cage culture, pen culture etc. in open water bodies should be promoted widely. BFRI has already started work on the conservation of locally endangered fish species. All the above initiatives will not only increase year-round production and also enhance the commercial value of the produce, help achieve surpluses enabling foreign currency earning through export. This strategy is supported by the National Agriculture Policy (NAP) 2018, Good Agriculture Practices (GAP) policy 2020, National Livestock Policy 2007, National Poultry Development Policy 2008, National Fisheries Policy 1998 and Cage Culture Policy 2019.

6.2.3 Development of hybrid varieties of high-value crops

Agricultural scientists of Bangladesh have developed some hybrid varieties of a few crops, e.g., 8 hybrids of rice, 18 hybrids of maize, 27 hybrids of vegetable crops, etc. Massive efforts are needed to expedite development of hybrid varieties for high-value vegetables such as, pointed gourd, carrot, cabbage, cauliflower, leafy vegetables, lady's finger, etc., and fruits such as mango, litchi, jackfruit, guava, jujube, pineapple, banana etc. through biotechnological advancement. Efforts are also needed to expedite development of hybrid varieties for high-value and nutrient-rich pulse and oilseed crops such as lentil, mungbean, blackgram, field pea, soybean, sunflower etc. Pulses and oilseed research should be directed towards development of short-duration hybrids to fit into the niches of profitable cropping patterns. Research on seed viability and preservation techniques especially for groundnut, soybean and sunflower should be emphasized. In addition to varietal development, refinement of the management practices and management of biotic and abiotic stresses of oilseed crops should be addressed.

Private companies having research experience in hybrid variety development of different crops should be encouraged to work with NARS institutions in public and private partnership projects through joint funding by the Government, international development partners and private companies meeting the guidelines of Good Agriculture Practices (GAP) 2020. In this

regard, the best example could be the Krishi Gobeshona Foundation (KGF) which has developed effective mechanisms of public-private and national-international partnerships for agricultural R&D in Bangladesh.

6.2.4 Safe, nutritious and demand driven foods

Ensuring safe food requires production of crop livestock, poultry and fisheries free from residues of chemicals, pollutants, heavy metals, insects and pests, pathogens, physical infection, etc., as per Good Agriculture Practices (GAP) 2020. It is not only required for domestic consumption but also to abide by the strict regulations of foreign countries while exporting agricultural products.

Production of safer and nutritious foods

The price ratio of nutritious foods to staple foods has been increasing and is higher in Bangladesh than in other south asian countries. Encouraging the production of more nutritious foods can lead to lower prices for these foods. Small-scale production of nutritious foods such as fruits, vegetables, and animal-source protein-rich foods can enhance access and affordability of these foods. Post-harvest fortification and biofortification can improve the nutritional quality of food. At a much larger scale, investments in transport and storage infrastructure such as roads, cold storages and innovative technologies can address the geographical disparities and seasonal differences in access to nutritious foods. Such investments in infrastructure can promote both the availability of nutritious food and food safety in the food system. Programs such as the National Agricultural Technology Program (NATP-2) and the Livestock and Dairy Development Project (LDDP) have been taken to boost the production of nutritious food. It is increasingly important that agriculture must diversify more rapidly if Bangladesh is to meet the changing food demands and improve overall nutrition of the populace. Carefully reorientation of the agricultural development strategies may promote diversification, encourage more nutritious food consumption patterns and improve nutritional outcomes, without sacrificing basic food security. To encourage farmers to produce of non-rice high nutrition crops their net returns need to be further stabilized and solidified through investments in technology, supply chains, markets, and infrastructure.

Development of varieties tolerant to biotic stresses

Bangladeshi scientists have successfully developed pest and disease tolerant varieties of rice, wheat, vegetable etc. using gene-marker technology which plays an important role in reducing less pesticide use. Bangladesh has entered the arena of growing genetically modified food such as pest-resistant Bt

Brinjal and Vitamin A-enriched Golden Rice through the development of genetically modified (GM) crops. Additional efforts are needed to develop many more pest and disease resistant varieties using gene editing techniques along with safe harvesting without physical infection of the product. Scientists should also take care of producing year-round fruit and vegetable varieties using biotechnology and bioinformatics tools.

Nano technology

New technology should be in place for producing more food within the shortest period of time. High doses of fertilizers and chemicals are used by the farmers to increase the yield, which affect the quality of food and the environment. Nano technology provides opportunities to minimize the use of hazardous chemicals, reduce nutrient losses from the added fertilizers and increase yield through pest and nutrient management, nanotechnology became very potential for agriculture. Nano coating with elemental Zn, Mn, Pa, Pt, Au, Ag etc. will not only protect seeds and will also reduce the amount of seeds. Nano membrane coated seeds will sense the availability of water and allow seeds to imbibe only when time is right for germination and even, reduce the use of herbicides and pesticides (Khodakovskaya et al. 2009).

Nanomaterials offer the prospect of desired slow release of nutrients from fertilizers and reduce losses of the applied nutrients through physical, chemical and biochemical pathways from the soil. Nano coatings or surface coatings on fertilizers provide surface protection for larger particles (Brady and Weil 1999). Application of nanomaterials with kaolin, polymeric chitosan etc. controls the release of NPK fertilizers sources (Corradini et al. 2010). Nanoparticle capsulated herbicides help detect the target species and kill them.

The Government should take necessary steps to encourage and promote the use of nano technology. Agricultural research institutions need to develop and nurture human resources with skills in nano technology for smart agriculture of the future. The National Agriculture Policy 2018 emphasized research on nano technologies and their use for agricultural development in future.

6.2.5 Climate resilient agriculture technologies

Climate-smart agriculture (CSA) initiatives are meant to sustainably increase productivity, enhance resilience and reduce or eliminate emission of greenhouse gases (GHGs), and require planning to address tradeoffs and synergies among the three pillars of agriculture, i.e., productivity, adaptation and mitigation. Mainstreaming CSA requires critical stocktaking of ongoing and promising practices for the future and of institutional and financial enablers for CSA adoption. Rice production under irrigated conditions keeping the land continuously submerged is the top contributor to GHG

emission in Bangladesh. In an effort to reduce these emissions farmers should be encouraged to irrigate rice in the alternative wetting and drying (AWD) method, deep place briquetted urea fertilizer instead of broadcasting prilled urea, grow non-rice crops and incorporate straw stubble in the soil as an alternative to burning crop residues which can contribute to soil organic matter build-up. Climate smart agricultural strategies that address saline intrusion (up to 8 km by 2030) resulting from sea level rise and tropical storm swells are especially critical in Bangladesh where many smallholders occupy low-lying, flood prone deltas. CSA interventions can draw on traditional practices like the Sorjan system (tall beds for vegetable and crop production alternating with furrows suitable for submergence tolerant crops and fish production) as well as new practices like vertical gardens. Floating bed cultivation of vegetables in the low-lying southern districts, homestead production and roof top gardening of fruits and vegetables should also be promoted widely.

The lack of accessible and reliable climate information among farmers represents a considerable challenge to the scaling out of CSA practices. Strengthening climate information services and making them easily accessible to farmers would greatly improve their capacity to adapt farming practices. For instance, salt intrusion into irrigation canals prevents their use for commercial or household gardening in the southern region of Bangladesh. Knowing where and when intrusion will occur using simple salinity meters would allow farmers to make crop choices and also plan for appropriate response and mitigation. Microcredit has been insufficient in boosting agricultural sector growth as many CSA activities require more macro-credit (e.g., conservation machinery). However, several low-risk interventions like pond excavation and ghers (rice and aquaculture ponds with tall dikes for vegetable production) are more likely to be eligible for commercial funding. Improvements in agro-meteorological services are essential for increased private sector investment in agriculture. More information on the long-term impacts of such investments on natural landscapes is needed in order to ensure sustainability. New forms of CSA as well as innovative production systems finance need to be explored, including the allocation of domestic funding for priority CSA interventions and strengthening cooperation with development partners to access funds for CSA activities. Creating an enabling environment for private capital will require improved coordination between the ministries involved in planning for climate change impact mitigation in Bangladesh.

6.2.6 Strategies for sustainable use of fragile ecosystems

Haor ecosystem

a) Spatial adjustment of crops in the fallow lands

In the haor basin there is kanda/ridge land (10-40% of the haor area, varies from haor to haor) which is under-utilized, most kanda lands are kept fallow throughout the year. The only difficulty of cultivation on kanda lands is lack of irrigation facilities. There is an ample opportunity of increasing the productivity of these kanda lands by developing irrigation facilities. Further crops, which require less irrigation, can be grown in these fallow lands and thus Rabi crops can be grown, for example, pulses, oil seeds, and vegetables, etc. Vast opportunities still exist in all the haor districts, where the remaining fallow land (123,482 ha) ie, 14% of the total haor areas (873,524 ha) is possible to be brought under cultivation of at least single crop during winter season.

b) Temporal adjustment of crops to address floods and flash floods

- Early transplanting of Boro rice would ensure harvest before flash flood arises.
- Seedling raising under plastic shade to compensate degree-day for reducing growth duration of rice, which will help rice to escape from flash flood. Growth duration of rice can be reduced by around a week using 30-day-old seedlings instead of 45-day-old seedlings. If 30-day-old seedling of BRRI dhan28, BRRI dhan84, BRRI dhan88 and 40-day-old seedling of BRRI dhan58 is transplanted, crop will be matured by 10 April and could escape from the flash flood in April ie, Baishaki Dhall. Growth duration can also be reduced by about one week by using direct seeding in the main field.
- Harvesting of rice by one week earlier can be made possible if double transplanting of rice is followed –the 1st transplanting of seedlings by 15 December in the upper basin and the 2nd transplanting by 25 January in the lower basin. One-fourth seedlings should remain in the 1st transplanted plot and three-fourth seedlings could be double transplanted in the lower basin. Crop diversification with high-value short-duration vegetables like tomato, cauliflower, pulse crops like mungbean, lentil, spices like onion, garlic and tuber crops that could be harvested early to avoid flash floods

c) Livestock improvement

The following strategies should be taken into account for improving livestock

and poultry in haor areas:

- Huge fallow land and water provide the natural resource base for the intensification of livestock production. Land can be used for grass production for forage.
- Sheep rearing especially garole sheep, which can withstand drought and eat on any grasses available, should be promoted
- Locally improved breed (Sonali / Faomi) may be reared which are disease resistant.
- *Ipil ipil* and *dhaincha* plants with creeper vegetables can be grown in the homestead areas. These plants are highly tolerant to prolong submergence/flood and leaves of these plants can be used as feed for goats. Flood tolerant fodder grasses like napier, para, etc., can be grown as fodder/silage for livestock.

d) Fisheries improvement

- Re- excavation of beels, canals and rivers in haor areas to revive fish breeding ground and mother fisheries
- Establishment of fish pass or fish friendly structure to reconnect river water with haor and floodplain water for successful fish migration
- Cage culture can also be established for landless/marginal group of people in the river side/canal/haor. Co-production of fish and vegetable crops is potential to protect them from flood. This model is also called an integrated floating cage aqua-geoponic system (IFCAS) - an innovation in fish and vegetable production for shaded ponds in Bangladesh, which is a proven technology tested in Barishal.

Char ecosystem

a) Up-scaling of technologies for crop production round the year.

- **Modern varieties:** Increasing cropping intensity with HYVs of rice, potato, maize, groundnut, mustard, lentil, onion, carrot, cauliflower, radish, etc. BARI Sarisha-11 and BARI Hybrid Maize-7 need to be promoted for cultivation in char land of Padma River. BARI Chhola-4, BARI Soybean-5, BARI Mung-6 and BARI Mung-5 performed better and would be suitable for cultivation in the char land of Kushtia, Bogra, etc. BARI Til-4, BARI Til-2 and BARI Til-3 could be suggested for cultivation on char lands. BARI Kaon-1 and BARI Kaon-2 perform better in char lands. Farmers chose BARI Cheenabadam-8. BARI Cheenabadam-8 for its higher nut selling price and short field duration may be selected for extensive cultivation in the char land areas. Wheat varieties of BARI Gom-27 and BARI Gom-28 showed higher grain yield (3450-3708 kg/ha) at Padma and Jamuna char land areas and hence, these wheat varieties

need to be piloted for wider adoption among the farmers of char lands.

- **Intercropping:** Now hybrid maize has become popular in the char areas as monoculture during the Rabi season due to its diverse use and high productivity. Intercropping of hybrid maize with legume crops or other compatible crops may maintain soil fertility and increase total productivity per unit area and reduce the risk of total crop failure. Hybrid maize paired row + 8 rows spinach, hybrid maize paired row + 4 rows bush bean, hybrid maize paired row + 8 rows red amaranth, hybrid maize paired row + 2 rows cabbage and hybrid maize paired row + 8 rows coriander are found economically profitable for char land areas. Hence, these intercropping technologies should be promoted in char areas through pilot programs.

b) Improvement of livestock and poultry

A notable feature of substantial areas of accreted char land is the extent of grasses in the riverine chars known as khaisa grass which may be promoted extensively in char areas as grazing/cut and carry fodder. Cultivation of quick growing fodder crops using improved technologies demands high priority. A new breed of sheep developed by BAU has become very popular among the char people; this sheep breed can withstand to some extent the harsh environment and feed on grasses that cattle or other livestock do not like. This new sheep breed offering a good opportunity of livestock rearing for the char people should be widely promoted. Breed development of cattle with artificial insemination facilities at the char union level should be enhanced.

c) Improvement of fisheries

Cage culture is a suitable fishing technology for open water bodies which can be practiced by the local char population. However, for better quality fisheries, there should be collection, characterization and conservation of wild fishes in captivity. The strategy should also aim at increasing genetic diversity of hatchery stocks through collection from wild stock as well as exchange brood among the hatcheries. Live gene pool and fingerling production techniques of threatened indigenous fishes should be developed for conservation as well as for sustainable aquaculture. Development of genetically improved breeds of koi/magur/rui for higher yield is also essential in char areas. Year-round fish culture using cage culture, cole (in deep area on the riverbed) should be widely promoted in char areas.

Barind ecosystem

a) Introduction of low water requiring crops

Crops like lentil, mustard and maize can be promoted in the Barind areas during Rabi season due to their low water requirement, diverse uses and

reasonable yields. Intercropping of maize with legumes, oilseeds or other compatible crops may increase land productivity and at the same time reduce the risk of total crop failure in drought situations. Barind areas can provide high-value crops that can be harvested before the onset of drought. With the residual soil moisture after the rainy season, it is possible to grow short-duration pulse, oilseed and vegetable crops. Growing and selling of early vegetables may boost farmer's income.

b) Watershed management and rainwater harvesting

A prime requirement for improving agricultural productivity in a sustainable manner in the Barind Tracts (BT) is to maximize capture and make optimum use of available water, primarily stored from rainfall to minimize pressure on the ground water. Being largely undulating, the BT is amenable to a watershed approach, aimed at capturing the maximum amount of rainfall for the purpose of growing crops and trees. A first step in this regard could be a comprehensive topographic and groundwater survey of the BT to identify optimum sites to establish water catchments, which could provide supplementary irrigation as needed.

c) Enhancing veterinary services and forage production

To be viable, veterinary services would need to be markedly improved across the BT, with creation of para-vets at community level. Further, targeted fodder production would be needed, with fodder grasses, legumes and trees, utilizing roadsides, pond banks and marginal land. Huge fallow lands provide the natural resources base for livestock intensification. Lands otherwise unsuitable for field crops can be used for forage production.

d) Alternative systems of fish production

Alternative systems of fish production like cage culture, pen culture etc. in open water bodies (eg. rivers and khals) of barind areas should be developed and promoted widely. Increased water capture in ponds, dighis and reservoirs would permit increased fisheries practice thus considerably widening livelihood options.

Coastal ecosystem

a) Establishing rain water harvest reservoirs for surface water irrigation

Efforts are needed to establish rainwater harvest reservoirs and expedite its use for irrigation and thereby minimizing use of underground water. Canals should be excavated/re-excavated to establish sweet water reservoirs conserving rainwater. Vast opportunities still exist in all the coastal areas, where the remaining fallow land (222,952 ha) can be brought under cultiva-

tion of at least a single crop during the winter season using irrigation of fresh water from rainwater harvest reservoirs.

b) Salinity management options for the coastal areas

Salt tolerant varieties: BRRRI has developed different climate resilient rice varieties. BRRRI dhan40 and BRRRI dhan41 are salt tolerant rice varieties which grow during then T. Aman season. It can tolerate salinity of up to 8 ds/m during its reproductive stage. BRRRI dhan47, BRRRI dhan67 and BRRRI dhan99 are salt tolerant rice varieties for the Boro season which can tolerate salinity of up to 14 ds/m during the seedling stage and 6 ds/m during other growth stages. BRRRI dhan55 can tolerate 8-10 ds/m and BRRRI dhan61 can tolerate salinity 12-14 ds/m. BRRRI dhan53 and 54 are also salt tolerant short-duration Aman rice varieties which can be harvested 12-14 days ahead of BRRRI dhan41. It can also tolerate salinity of 8-10 ds/m during its reproductive stage. BINA dhan-8 and BINA dhan-10 can tolerate salinity of 8 -10 ds/m at the mature stage with a 6.0 t/ha yield potential. Salt tolerant varieties of groundnut are BINA chinabadam-1, BINA chinabadam-2. Salt tolerant species like chili, methi, watermelon, cucumber etc. should be cultivated in the coastal saline areas. One potato variety named "Saikat" has been recommended by BARI for cultivation in the saline belt (up to 8 ds/m).

c) Up-scaling of innovative technologies

- Year-round vegetables cultivation on shrimp boundary bed in Khulna region could be promoted to ensure the maximum utilization of land and thereby to produce vegetables round the year in low saline areas. This cultivation technique would also increase soil fertility and prevent soil erosion.
- Vegetables can easily be cultivated by using the edge of the pond at homestead area, especially in Barishal-Patuakhali region where vegetables cannot be cultivated in time due to high tidal floods.
- Tomato/watermelon, if cultivated using black polythene mulch, will reduce soil salinity levels through conserving soil moisture and also reduce weed infestation level and thereby increase the crop yield.

d) Utilizing fallow land for fodder production with freshwater irrigation from rain harvest reservoirs

Huge fallow lands and an abundance of water provide the natural resources base for intensification of livestock production in the coastal areas. Land can be used for forage using freshwater from rain harvest reservoirs. Sheep rearing especially with garole sheep could be strengthened for incomes and protein supplements for the rural people in coastal areas as sheep are usually tolerant of harsh environments like drought, salinity, etc.

e) Improvement of fisheries

Strategies should be taken to increase adoption of salt tolerant fish culture technologies and to develop short cycle culturable fish species. Natural breeding and nursing ground conservation will be the best alternative for improvement of coastal aquaculture. Further emphasis should be given on endangered fish propagation and mass seed production and for development of Fish Live Gene Bank in the coastal areas.

Hill ecosystem

a) Watershed management and rainwater harvesting

There is a need for irrigation-based projects to construct small pucca or cemented ponds for rainwater harvest. Repair and management of the drying creeks and streams is essential for water reservation. Water reservoirs could be constructed for harvesting and capturing monsoon rains. The water thus stored could be used for irrigating crops. Such an approach would increase the scope and lower the risk of Rabi cropping. Using this surface water irrigation opportunity, the remaining fallow land (134,432 ha) in the hilly areas can be brought under cultivation of at least a single crop. Fallow lands especially exist in Bandarban (52,414 ha), Chattogram (42,980 ha) and Rangamati (23,121 ha). This will also help increase cropping intensity.

b) Crop choice and zoning

- Due to the increasingly erratic rainfall and limited surface water resources of the Chattogram Hill Tracts (CHT), special consideration needs to be given to low water requiring crops and crop rotations.
- Considering the water limitations in CHT, Boro rice cultivation should be restricted to the valley zone at the bottom of the hills. Higher terraced land and hill slopes should be reserved for fruits, vegetables, and other non-rice crops.
- Farmers should be encouraged to adopt mixed plantations. Small reservoirs should be built to increase the area under irrigation. Plots of land thus fed with water could support a second winter crop, either vegetables or wheat. In addition, the reservoirs could be used for seasonal aquaculture during the monsoon rains.
- Development and promotion of water stress tolerant and short life span variety of rice and vegetables for jhum cultivation would be a good way for judicious use of water during dry season.
- With the residual soil moisture after the rainy season, it is possible to grow short-duration rice, vegetable crops, etc., using irrigation water from creeks, streams and rain harvest reservoirs.

c) Improving animal feeding

Most animals in CHT are grazed, usually watched over by children. Stall feeding would improve the health conditions of animals and reduce the incidence of parasites both in animals and humans. In addition, it would have an added advantage of sending children to school. It would, however, be feasible to shift from grazing to stall feeding only with assured higher returns, which are in turn dependent on improved veterinary services.

d) Improvement of fisheries

There are numerous small waterways in hilly areas, although most are seasonal and are dried up during winter. It is possible to construct small dams in the valleys, to provide irrigation water. These reservoirs could then be used for aquaculture round the year, perhaps involving fast-growing species such as pangas (*Pangasianodon hypophthalmus*) or tilapia. To raise this production capacity, floating aquaculture technologies may be used, such as cages and pens.

6.2.7 Human resources development (HRD)

Strengthening human resources in agricultural research can be a significant contribution to increasing agricultural production to the levels required to feed the country's growing population. Additional efforts in agricultural research should also be given to address emerging challenges, such as increasing weather variability, adaptation to climate change, water scarcity, and increased price volatility in global markets. To carry out more research for developing HYVs and climate smart technologies using advanced breeding and improved management technologies, recruitment of additional qualified researchers is essential for meeting the requirement of Vision 2041 and beyond. The Government should take initiatives to fill up the current vacancies of agricultural researchers at BARC and NARS institutes (842 out of 2,564 sanctioned posts; 33% vacancy) by providing additional budget in the 8th Five-Year Plan (FYP) and the subsequent FYPs.

It is widely recognized that the knowledge and skills of scientists can be improved through advanced studies like MS and PhD. The Government should take initiatives to increase the share of researchers with the PhD degree as proposed in the HRD plan of BARC 2023-2041 (Table 6.2).

Table 6.2. Plan for the development of scientific manpower to raise the level of 40% PhD degree holders to 70% at the NARS institutes during the period of 2023 - 2041

NARS Institutes	2023-2025 (PhD level 40%)	2026-2030 (PhD level 50%)	2031-2035 (PhD level 60%)	2036-2041 (PhD level 70%)	Total (2023-2041)
BARI	412	619	990	1684	3705
BRRI	23	39	44	51	157
BJRI	9	13	16	20	58
BINA	54	62	55	63	234
BSRI	11	22	12	13	58
BWMRI	8	11	18	17	54
SRDI	40	40	40	50	170
BTRI	8	16	8	8	40
BFRI	30	30	30	30	120
CDB	5	9	14	14	42
BSRTI	7	7	14	14	42
BFRI (fish.)	69	112	135	157	473
BLRI	22	20	15	8	65
BARC	100	120	140	160	520
Total	798	1120	1531	2289	5738

Source: BARC 2022a

6.2.8 Agricultural mechanization

Crop sector mechanization

The labor force of the country has started to shift from the agricultural to the industrial and services sectors, creating an acute agricultural labor shortage during peak planting and harvesting times. Agricultural operations cannot be maintained timely due to labor shortage resulting in yield reduction. Farm mechanization is inevitable to increase crop production. Sowing/planting and harvesting operations especially need immediate mechanization. Wages of agricultural laborers have increased so much that even the use of imported rice transplanters, reapers and combine harvesters have become cost effective in the country, and farmers are using these implements in limited areas. Initiatives should be taken for rapid adoption of combine harvesters and reapers, rice transplanters, weeders, threshers, dryers, etc. The agricultural machinery manufacturing sector should be supported by providing soft loans to improve its capacity to manufacture competitively priced and high-quality machines and spare parts. Introduction of farmer-friendly agricultural machinery according to the socio-economic status of the farmers, size of the farm and soil type is supported by National Agricultural Mechanization Policy 2020.

Fisheries sector mechanization

Rural electrification can create a new opportunity for mechanization of fish farms mainly through fish feed delivery system, water distribution and exchange system, aeration system, water quality monitoring system and support services like electric equipment operation and maintenance, security services with CCTV cameras, etc. Mechanization of a fish farm reduces fish farm labor requirement and feed costs and increases fish farm productivity along with the reduction of water pollution through effective fish farm management and can create another aquaculture revolution. For example, automatic fish feeders can supply fish feeds to the right place at the right time, being controlled automatically by a programmed device in the machine. In addition, water aerator, pellet feed machine etc. are also important for fish farm mechanization. All these potential machinery should be promoted extensively in 21st century to make aquaculture an export oriented commercial farming enterprise.

Livestock sector mechanization

In the future, animal products can be a huge export sector like the readymade garments industry. If meat, eggs and milk can be exported in a large scale, the production of this industry will increase tremendously. Dairy, poultry and cattle farmers should be provided with all modern equipment including milking machines, grass cutting machines, tractors, milk cans, hay cutting machines, milk cream separators and pasteurization plants. The need for mechanization of the livestock sector becomes evident from the decreasing availability of livestock farm workers.

6.3 Conclusion

The government of Bangladesh has already taken up good measures to achieve food security by increasing food production, but many more strategies are required to achieve sustainable food production in the 21st century. The growth rate of food production attained in the past cannot be sustained without technological breakthroughs vitally needed to shift the yield frontier through advanced breeding and improved management technologies. With global warming, more lands are likely to be lost due to advancing flood and river erosion. Water availability for irrigation has also increasingly become scarce. Actions are, therefore, needed on many fronts, including agricultural technology development, improved input (seeds, fertilizers, irrigation, machinery) delivery system, and critically, rural financing, especially those for small and marginal farmers. Renewed crop diversification efforts need to be pursued by clear understanding of the relative profitability of competing crops, physical and location-specific conditions for non-crop enterprises, the supply chain of high-value products and provision for processing, storage, and marketing activities, as well as by

a clear understanding of international trade opportunities. Thus, achievements in the areas of food availability and access need to be consolidated by multi-pronged policy efforts to address remaining issues and emerging challenges in the 21st century. Further, to address increasing population and climate change impacts, the country needs a balanced mix of innovation in agricultural technologies and policy supports that will enable increasing production of safe and nutritious food from the agriculture sector (crops, livestock, and fisheries).

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