Agricultural Development for Fragile Ecosystems in BANGLADESH

Bangladesh Agricultural Research Council
Farmgate, Dhaka-1215, Bangladesh
www.barc.gov.bd

Published by:

Bangladesh Agricultural Research Council (BARC)
Farmgate, Dhaka-1215, Bangladesh
Phone: +88 02 41025252
Email: ec-barc@gov.bd
Website: www.barc.gov.bd

Published:	February, 2023
Authors:	Dr. S M Bokhtiar Dr. Syed Samsuzzaman Dr. M Jahiruddin Dr. G M Panaullah
Funded by:	Krishi Gobeshona Foundation (KGF) BARC complex, Farmgate, Dhaka-1215
Citation:	Bokhtiar, S. M., Samsuzzaman, S., Jahiruddin, M and Panaullah, G. M. 2023. Agricultural Development for Fragile Ecosystems in Bangladesh. Published by Bangladesh Agricultural Research Council, Dhaka, Bangladesh. p. 369
Cover Design and illustration :	Mohammad Nazmul Islam and S M Bokhtiar
Printed by:	Printcom Bangladesh, 263 Bagichabari, Fakirapool, Motijheel, Dhaka-1000, Phone: +88 01711 940342
Illustration of the Front Cover:	Physical map (not to scale) of Bangladesh highlighting the fragile ecosystems in shaded colors: RED- Barind ecosystem, GREY- Char ecosystem, MEDIUM PURPLE- Coastal ecosystem, BLUE- Haor ecosystem and BROWN- Hill ecosystem

ISBN
978-984-35-3818-5

DEDICATION

Hon'ble Prime Minister Sheikh Hasina

Government of the People's Republic of Bangladesh

"Every inch of uncultivated lands can be used to grow food to avoid an imminent food shortages"

بسم الله الرحمن الرحيم

প্রধানমন্ত্রী

PRIME MINISTER
GOVERNMENT OF PEOPLE'S REPUBLIC OF BANGLADESH

08 January 2023
24 Poush 1429

Message

I am happy to know that Bangladesh Agricultural Research Council (BARC) is going to publish a book titled "*Agricultural Development for Fragile Ecosystems in Bangladesh*."

After the independence, Father of the Nation Bangabandhu Sheikh Mujibur Rahman took bold initiatives for agricultural development realizing its importance in transforming Bangladesh's economy. He initiated the Green Revolution in Bangladesh by introducing modern technologies, mechanization, irrigation and high quality seed in agriculture.

Bangladesh Awami League assuming office in 1996 after 21 years adopted "National Agricultural Policy 1999". Bangladesh became food surplus country from a food deficit one during our 1996- 2001 tenure. Strong political commitment, various institutional and policy supports made an unprecedented success in agriculture and allied sectors.

Bangladesh is now self-sufficient in food grain, fish, meat, egg and milk production. Globally, Bangladesh is ranked second in jute and jackfruit, third in rice and vegetables, seventh in mango and potato and third in inland open water fish catch.

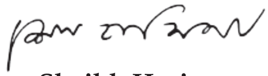
Despite its impressive growth in agricultural sectors, Bangladesh still faces formidable challenges in ensuring food and nutrition security for various reasons, including shrinking of arable land, land degradation and declining soil fertility and climate change.

We have formulated Vision 2041, National Agriculture Policy 2018, National Agricultural Mechanization Policy 2020, Bangladesh Good Agricultural Practices 2020, Sustainable Development Goals, Bangladesh Delta Plan 2100 and other planning documents with a vision to build a safe, sustainable and profitable agriculture.

There is very little scope and possibility of horizontal expansion of agriculture. However, we have some ecologically constrained areas like Haor, Char, Barind, Coastal and Hill Ecosystems where we can expand our agriculture to increase production.

I hope the BARC publication "*Agricultural Development for Fragile Ecosystems in Bangladesh*" will be useful for policy makers, development partners, academicians, research organizations and agri-business community and other stakeholders.

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 very delighted to know that Bangladesh Agricultural Research Council (BARC) is going to publish a book entitled "*Agricultural Development for Fragile Ecosystems in Bangladesh*."

Soon after independence the Father of the Nation, Bangabandhu Sheikh Mujibur Rahman deeply focused on the reconstruction of the agricultural institutes, and started the green revolution by taking all the timely steps for the development of agriculture and farmers. The present government, under the strong and dynamic leadership of his daughter, the Honorable Prime Minister Sheikh Hasina, is adopting an array of agriculture-friendly policies and realistic steps as part of different programs and policies of Bangabandhu. As a result, Bangladesh has already made a bright example in agricultural growth and self-sufficiency in food has been attained. Now, our goal is to ensure safe and nutritious food for all and to achieve Sustainable Development Goals (SDGs) through agricultural modernization, agro-processing and commercialization among others.

Currently, the increasing impact of climate change, cultivable land declining due to rapid urbanization & development activities, increasing salinity in coastal areas and growing population are the major challenges to food security. In these situations, to increase production and productivity; it is very essential to strengthen our agricultural extension in various ecologically constrained areas like Haor, Char, Barind, Coastal and Hill Ecosystems. Despite the challenges in agricultural production in all these adverse areas, there are ample opportunities and potentials to extend our agriculture.

Under these circumstances, important and relevant information were collected and compiled in a book titled *"Agricultural Development for Fragile Ecosystems in Bangladesh."* This book is an informative document on the opportunities and potentials of agriculture, which exist in the ecologically constrained areas of Bangladesh.

I sincerely thank BARC for bringing out this publication & 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 pleased to know that Bangladesh Agricultural Research Council (BARC) is going to publish a book called "*Agricultural Development for Fragile Ecosystems in Bangladesh*." It is an excellent and praiseworthy work and the first publication of its kind providing a brief overview, contextual analysis and strategic investment opportunities for fragile ecosystems of Bangladesh.

After the independence of the country, the Father of Nation Bangabandhu Sheikh Mujibur Rahman started working on the reconstruction of the war-torn country giving highest importance on agriculture. He believed that agriculture was the main driver of development in most rural areas in this country. He introduced modern agriculture in this country with the call of Green Revolution.

Following the path shown by Bangabandhu, Bangladesh has made tremendous contribution in poverty alleviation and economic growth by ensuring nutrition and food security, and creating employment led by our Honorable Prime Minister Sheikh Hasina in a very short period of time. Bangladesh gained independence in 1971 as a food deficit country with a population of 75 million. Today, Bangladesh has 165 million people but we have achieved self-sufficiency in food grains despite more than 2.5 times increase in population which is a noticeable achievement in the 50 years since independent.

Due to proper implementation of various policies of the government at the field level and timely actions in the agricultural sector, subsistence agriculture has transformed into commercial agriculture today and Bangladesh ranks among the top 10 countries in the world in food grain production. Bangladesh is now a global example of a substantial food grain production. A significant transformation is currently underway in Bangladesh to make our agriculture sustainable, safe and profitable. The present transformation being achieved by the agricultural sectors is encountered by challenges, such as population growth, declining crop land per person, land degradation and declining soil fertility, availability of quality water, rapid urbanization, and climate change to ensure food and nutrition security. Addressing the above-mentioned challenges, the government has given special attention in the National Agriculture Policy 2018 to extend our agriculture to the ecologically constrained areas like Haor, Char, Barind, Coastal and Hill regions for future food security.

This book provides agricultural statistics, context and advancement of individual ecosystems, and suggests strategic investment opportunities which will play a unique role specially for policy makers in expanding our agriculture to these ecosystems through which we can achieve SDGs by 2030, Vision 2041 and build a happy, prosperous Bangladesh.

I strongly believe this book will be useful for all those involved in the challenging tasks of agricultural Research and Development (R & D) in Bangladesh. The publication of this book by BARC- apex body of National Agricultural Research System deserves a special appreciation.

Finally, my sincere thanks to all involved for bringing out this valuable publication - a milestone document.

Joi Bangla, Joi Bangabandhu
Long live Bangladesh.

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 functioning since its establishment in 1973 towards developing efficient, effective and sustainable agricultural research system. Apart from working in policy support to the Government, BARC is playing a major role in institutional and individual capacity development of NARS institutes. BARC is inextricably linked to the success of agricultural sectors in Bangladesh today.

Bangladesh agriculture is very intensive and diverse. It is definitely a blessing for such a densely populated country like Bangladesh for ensuring food and nutrition security. Increasing population, decreasing cultivable land, adverse effects of climate change and timely supply of agricultural inputs and ensuring fair prices to produces of farmers are key issues and challenges in food, water and energy security. These are very important for achieving the SDG2 goal if you want to sustain the intensive and diversified agriculture. Even in the midst of so much adversity, Bangladesh has made a significant achievement in one and a half decade. If we consider the base year 2006, we see that the production of rice, wheat, maize, potatoes, pulse, oilseeds and vegetables has increased in 2021 by about 47%, 57%, 981%, 181%, 196%, 273% and 967%, respectively. Such development in agriculture is due to an appropriate institutional mechanism, enabling environment and strong policy supports.

Keeping in view of the visible challenges, and linked with Bangladesh Delta Plan 2100 (BDP2100), Ministry of Agriculture, Government of Bangladesh has formulated many policies giving emphasis on sustainable, safe and profitable agriculture. Due to scarcity of land in Bangladesh, there is a dire need to increase agricultural production and productivity by cultivating the hotspots or ecologically constrained areas like Haor, Char, Barind, Coastal and Hill ecosystems mentioned in the BDP2100.

Every ecosystem has its own inherent problems. Our main goal now is to assess the current problems of each ecosystem and how to solve them through research and inventing new technologies. Especially, varietal improvement together with production technologies of crop, livestock and fisheries for each hotspot is a prime need in view of ever-increasing population and increased immense negative impact of climate change to achieve SDGs.

Taking into account the aforementioned challenges, the important BARC publication entitled "*Agricultural Development for Fragile Ecosystems in Bangladesh*" provides a detailed and possible ways of how to utilize these unfavorable areas through science led technologies to ensure food and nutrition security for the future growing population. It is very essential because food and agriculture are the heart for economic development and maintaining peace and harmony of the country.

I hope this book will open a new horizon in agriculture as no such book has been published before about all these fragile ecosystems with details on agriculture and allied sectors. Therefore, researchers, academicians, policy makers and development partners working in Bangladesh will consider this book as an important document in the development of agricultural sectors in these disadvantaged areas.

Special appreciation goes to the Additional Directors of DAE in 14 agricultural regions of the country, who were gracious in support of providing very precise data on various aspects related to crop production in the fragile ecosystems. This endeavor would not have been completed without support of the Crop Zoning Project, GIS, BARC for providing amazing data on geography and bio-physical characteristics (soil fertility, rainfall, temperature etc) of the ecologically constrained areas. I would like to thank Dr. Jiban Krishna Biswas, Executive Director, KGF for financial support, otherwise this book would not have been possible to publish.

I wish the success of this book.

Joi Bangla, Joi Bangabandhu
Long live Bangladesh.

Dr. Shaikh Mohammad Bokhtiar

Preface

There has been a tremendous development in Bangladesh agriculture in the last decade by the visionary leadership of the Honorable Prime Minister Sheikh Hasina. The country's aspiration is to reach upper middle-income country status by 2030. Food and Agriculture are the cornerstone of civilization and development of a country. Bangladesh is a largest delta in the world as well as a densely populated island. Despite having many disadvantages, policy makers want to take it as an opportunity for development. Bangladesh agriculture faces multiple challenges: an escalating growth of population, smaller rural labour force, soil quality degradation, climate change, food wastage, water scarcity and changing life styles leading to urbanization and more protein intensive diets. Furthermore, increased agricultural productivity would ensure food security for everyone if access to safe, nutritious and sufficient food is secured. In view of the long-term challenges, the Government has formulated National Agricultural Policy 2018, National Extension Policy 2020, Bangladesh Good Agricultural Practices Policy 2020 and National Agricultural Mechanization Policy 2020. All these policies are formulated with a vision of achieving "Sustainable, Safe and Profitable Agriculture'' in line with SDG2 and Bangladesh Delta Plan 2100.

According to the United Nations Population Fund (UNFPA), the population of Bangladesh could reach between 201-245 million in 2051. Based on BARC's study, Rice, wheat, potato and maize are projected to expand 52.1, 1.2, 14.0 and 12.2 million metric ton, respectively in the financial year 2050 from the base line value of 2021. Similarly, pulses, oil crops, spices and fruits are projected to expand substantially. Agriculture for special areas/uncultivated lands of the fragile ecosystems in particular need to be brought under cultivation to meet the food and nutrition security of the growing population by increasing production and productivity of cereals and non-cereals crops, and livestock and fisheries. Bangabandhu Sheikh Mujibur Rahman dreamt of a Sonar Bangla and declared, "Our final goal is socio-economic emancipation of the people and a poverty-free and hunger-free, developed and prosperous nation". To realize this goal, the nation will need to make best use of available natural resources, all of which do not necessarily exist in the most favorable ecosystems. It is in this backdrop that the issue of more fruitful use of the hitherto underutilized fragile ecosystems or marginal lands becomes relevant. In particular, for enhancing productivity and farmers' livelihood, increase in agricultural investments as well as knowledge sharing will be necessary elements of better functioning food and agriculture systems.

Recognizing the importance of agriculture in achieving comprehensive and sustainable livelihood security, the book entitled "Agricultural Development for Fragile Ecosystems in Bangladesh" is written. The book comprises six chapters. A brief description of various fragile ecosystems is given in the chapter 1: Introduction. The other five chapters discuss about the five individual ecosystems like Haor, Char, Barind, Coastal and Hill Ecosystems each of which includes extent and distribution, biophysical characteristics, demographic features, present agricultural systems, cross cutting issues, agricultural advancement and strategic investment opportunities.

All in all, this book is a valuable source of references for researchers, academicians, policy maker and also for developments partners. Moreover, this book will serve as a useful guide in formulating policy for agricultural R & D of ecologically fragile ecosystems and overall development of agricultural sectors. This policy formulation will then meet the future need for food and nutrition security and to address emerging challenges for sustainable development and achieving safe, climate resilient and prosperous Bangladesh.

This book would not have seen the light without its publication by Bangladesh Agricultural Research Council (BARC), and financial assistance from Krishi Gobeshona Foundation (KGF). Special thanks are due to the concerned officials of DLS (Department of Livestock Services), DoF (Department of Fisheries), BADC (Bangladesh Agriculture Development Cooperation) and relevant research organizations for providing data on technologies and production inputs. Finally, deepest gratitude goes to all of those with whom the authors have had the pleasure to work during preparation of this book.

Authors

ABBREVIATIONS

ABBREVIATION

ACIAR	: Australian Centre for International Agricultural Research
AEZ	: Agro-ecological Zones
AI	: Artificial Intelligence
AIS	: Agriculture Information Service
AWD	: Alternate Wetting and Drying
BADC	: Bangladesh Agriculture Development Corporation
BAEC	: Bangladesh Atomic Energy Commission
BARC	: Bangladesh Agricultural Research Council
BARI	: Bangladesh Agricultural Research Institute
BAU	: Bangladesh Agricultural University
BBS	: Bangladesh Bureau of Statistics
BCIC	: Bangladesh Chemical Industries Corporation
BER	: Bangladesh Economic Review
BFDC	: Bangladesh Fisheries Development Corporation
BGS	: British Geological Survey
BHWDB	: Bangladesh Haor and Wetland Development Board
BINA	: Bangladesh Institute of Nuclear Agriculture
BMD	: Bangladesh Meteorological Department
BMDA	: Barind Multipurpose Development Authority
BRRI	: Bangladesh Rice Research Institute
BRTC	: Bangladesh Road Transport Corporation
BSMEC	: Beach Sand Mineral Exploitation Center
BWDB	: Bangladesh Water Development Board
BWMRI	: Bangladesh Wheat and Maize Research Institute
CCC	: Climate Change Cell
CDSP	: Char Development and Settlement Project
CEGIS	: Center for Environmental and Geographic Information Services
CHT	: Chattogram Hill Tracts
CIMMYT	: International Maize and Wheat Improvement Center
CLP	: Char Livelihood Program
CP	: Cropping Pattern
DAE	: Department of Agricultural Extension

ABBREVIATION

DAM	: Department of Agricultural Marketing
DANIDA	: Danish International Development Agency
DFID	: Department for International Development
DLS	: Department of Livestock Services
DoE	: Department of Environment
DoF	: Department of Fisheries
DPHE	: Department of Public Health Engineering
ECA	: Environmentally Critical Area
ESCAPE	: Economic and Social Commission for Asia and the Pacific
FAO	: Food and Agriculture Organization
FD	: Forest Department
FDC	: Fisheries Development Corporation
FGD	: Focus Group Discussion
FIAC	: Farmers Information and Advice Center
FSR	: Farming Systems Research
GAP	: Good Agriculture Practices
GIS	: Geographical Information Systemt
GOB	: Government of Bangladesh
HBT	: High Barind Tract
HDB	: Haor Development Board
HYV	: High Yielding Variety
ICAR	: Indian Council of Agricultural Research
ICZM	: Integrated Coastal Zone Management
IFCS	: Integrated Floating Cage Aqua-Geoponic System
IFPRI	: International Food Policy Research Institute
IFMC	: Integrated Farm Management Component
IRRI	: International Rice Research Institute
ISPAN	: Irrigation Support Project for Asia and Near East
IUCN	: International Union for Conservation of Nature
JCDP	: Jamuna Char Integrated Development Project
KGF	: Krishi Gobeshona Foundation
KII	: Key Informant Interview
LDN-TSP	: Land Degradation Neutrality Target Setting Program
LGED	: Local Government Engineering Department
MT	: Metric Ton
MoA	: Ministry of Agriculture
MoEF	: Ministry of Environment and Forest
MoP	: Ministry of Planning
MoP	: Muriate of Potash

ABBREVIATION

MoWR	: Ministry of Water Resources
NAEP	: National Agricultural Extension Policy
NAP	: National Agriculture Policy
NARS	: National Agricultural Research Systems
NATP	: National Agricultural Technology Program
NGO	: Non-government Organization
OFRD	: On Farm Research Division
SLR	: Sea Level Rice
SRDI	: Soil Resources Development Institute
STW	: Shallow Tube Well
T. Aus	: Transplanted Aus
T. Aman	: Transplanted Aman
TSP	: Triple Super Phosphate
WDB	: Water Development Board
UNCCD	: United Nations Convention to Combat Desertification
UNEP/GPA	: United Nations Environment Program/Global Program of Action
UNFCC	: United Nations Framework Convention on Climate Change
USD	: United States Department

CONTENTS

List of Figures

Page

List of Figures

Page

List of Figures

Page

List of Figures

Page

List of Figures

Page

List of Figures

List of Tables

Page

List of Tables

Page

List of Tables

Page

List of Tables

List of Maps

List of Photos

Chapter 1

Introduction

1.1 Background

An ecosystem is a natural system functioning with biotic and abiotic components like land, soil, water, climate, plants, microbes, animals and humans. To be optimally and sustainably productive, an ecosystem requires stability and resilience maintaining a delicate balance between the land-soil-water-climate milieu and the living plants, animals and humans. Fragility sets in when this delicate balance is disturbed due to internal processes within the ecosystem or external forces and influences or both working simultaneously or in succession. A fragile ecosystem is characterized by a significant loss of stability and resilience as a habitat for plants, animals and humans, the consequence being a deterioration of the ecosystem in terms of its ability to deliver commodities and services and support human lives and livelihoods. Ecosystem fragility may be caused by natural elements such as floods, droughts, salinity intrusion etc. or by human factors like growing population, unplanned industrialization and urbanization and extensive exploitation of natural resources. From the perspective of agriculture in Bangladesh, however, by “fragile ecosystems”, here, is essentially meant ecologically challenged regions where normal agricultural practices do not bring about expected yields. Fragile ecosystems in Bangladesh include low lying wetlands, hills, coastal areas etc. which occupy quite a large area of the country and are home to a sizeable portion of the populace. For example, among the fragile ecosystems of the country, the flood-prone ecosystem accounts for roughly one-third of the land area; the coastal saline ecosystem covers roughly one-fifth of the land area and accommodates as much portion of the population. The adverse agro-ecological conditions and exposure to the vagaries of nature limit the productivity of crops in most of these marginal lands and of livestock and fisheries in some others, and the local people, the vast majority of them are farmers and farm workers, remain socio-economically vulnerable and impoverished.

The agriculture sector in Bangladesh has grown fast, marked by great achievements in all sub-sectors like crops, fisheries and livestock in spite of growing climate change adversities. This has been possible due to research and technology generation and dissemination by agricultural scientists and extension specialists, hard work by the farmers and congenial government policies. The country now produces almost enough grains, vegetables, fruits, fish, milk and meat for domestic consumption and even boasts some surpluses to permit export of assorted food commodities for consumers abroad. Much, however, remains to be done to ensure food, nutrition and livelihood security of a population that grows steadily mandating sustained increases in crop, livestock and fisheries production. Prime Minister Sheikh Hasina, solemnly remembering Bangabandhu Sheikh Mujibur Rahman's cherished dream of a *Sonar Bangla* has declared, "Our final goal is socio-economic emancipation of the people and a poverty-free and hunger-free, developed and prosperous nation". To realize this goal, the nation needs to make the best use of available natural resources, all of which do not necessarily exist in the most favorable ecosystems. It is, in this backdrop, that the issue of more fruitful use of the hitherto underutilized fragile ecosystems or marginal lands becomes relevant. In Bangladesh with a dwindling agricultural land resource base and escalating population pressure, development of the fragile ecosystems to boost the country's agricultural output would be a prudent step forward.

In some countries of the world, fragile ecosystems are now given legislative attention. For example, in the Swedish Natural Resources Act 1987, "areas being particularly sensitive from an ecological point of view" are mentioned as areas that should be given special attention (Nilsson and Grelsson 1995). The Bangladesh Delta Plan 2100 (MoP 2018) outlines policies for the development and utilization of six "hotspots" or fragile ecosystems. Out of this six hotspots, five are fragile to agricultural production. This book summarizes information of these fragile agro-ecosystems with regard to their locations, characteristics, agricultural production problems and potentials and prospects of future development.

1.2 Fragile agro-ecosystems in Bangladesh: Geographic distribution and characteristics

The six "hotspots" or fragile ecosystems of Bangladesh and major risks and vulnerabilities associated with them are:

i. Haor Ecosystem – high precipitation, unpredictable flash floods, low temperature stress, land subsidence and decreased sediment supply, land filling, encroachment, land use change etc.
ii. Char Ecosystem – riverine erosion and accretion, drought, river avulsion, sedimentation off-take, subsidence, tidal fluctuation, sea-level rise, flash floods etc.
iii. Barind Ecosystem – hard soil clay, rising temperature, drought, receded groundwater levels, shrinking wetlands etc.
iv. Coastal Ecosystem –lack of non-brackish water for irrigation, accelerated sea level rise, tidal flooding, salinity intrusion with sea-level rise, cyclones, storm surges etc.
v. Hill Ecosystem – loss of forest and vegetation cover, soil erosion, loss of soil fertility on hill slopes and flash floods in valleys etc.

The geographic distribution of fragile/adverse agro-ecosystems is shown in Fig. 1.1. The three broad physiographic units of Bangladesh such as a) Tertiary hills, b) Pleistocene terraces and c) Recent floodplains are originated in three distinct geological ages. These broad geological-physiographic units have been sub-divided into 20 different geomorphology-soil units where the six fragile agro-ecosystems exist. The geographic location and geo-morphological conditions have made Bangladesh most vulnerable to climate change.

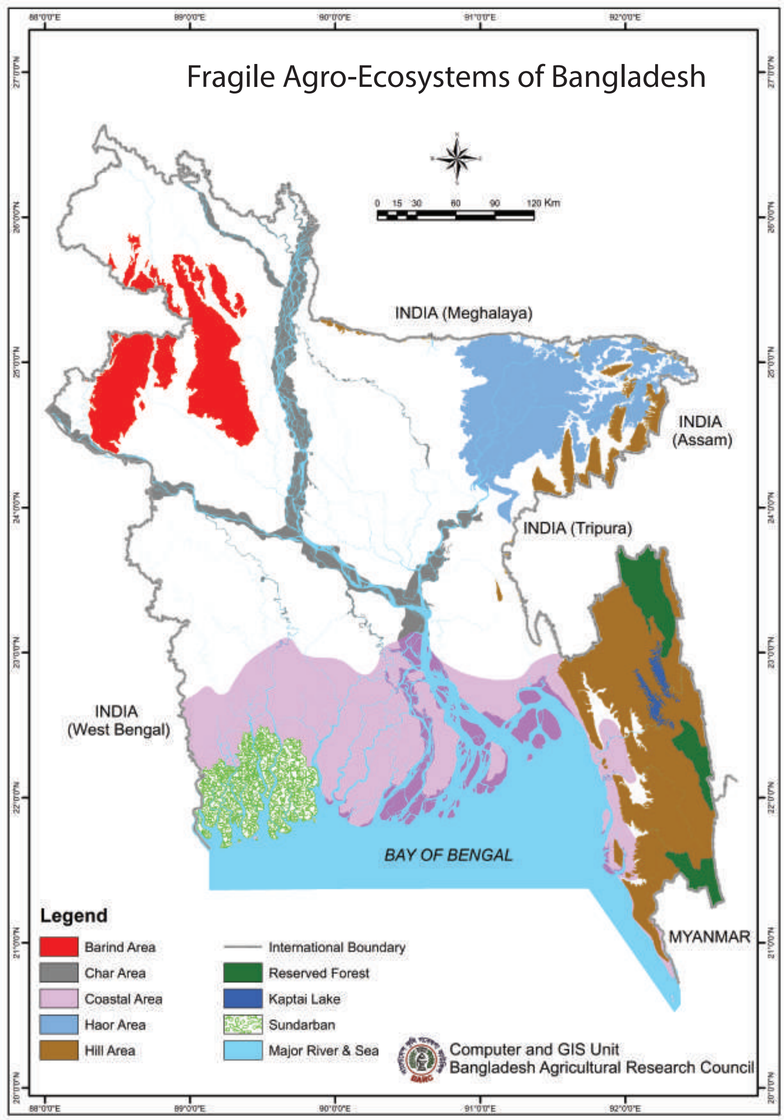


Fig. 1.1. Map of Bangladesh showing the geographic distribution of fragile agro-ecosystems (source: BARC 2020)

Haor Ecosystems

> The haor basin is spread over Sunamganj, Habiganj, Moulvibazar, Sylhet, Kishoreganj, Netrakona and Brahmanbaria districts in southeastern Bangladesh

A haor is a bowl or saucer shaped shallow depression, also known as a back swamp, makes up a wetland ecosystem in the northeastern part of Bangladesh. Haors receive surface runoff water from rivers and canals to become vast stretches of turbulent water during the monsoon season. The haor basin spreads over Sunamganj, Habiganj, Moulvibazar and Sylhet districts, as well as Kishoreganj, Netrakona and Brahmanbaria districts outside the core haor area (Banglapedia 2021). The hill ranges of India – Meghalaya on the north, Tripura and Mizoram on the south, and Assam and Manipur on the east bound the haor basin. The basin extends north to the foot of the Garo and Khasia Hills, and east along the upper Surma Valley to the Indian border. The Tippera surface is connected directly to the south of the haor basin, and is partly low and deltaic and partly higher ground with a piedmont fringe to the east (Akonda 1989). The haors are of tectonic origin and possibly connected with the Madhupur Tract. Floodplains of the Meghna and its tributaries cover the haor basin in its original form, which consisted of a rich mosaic of permanent and seasonal lakes and ponds with abundant aquatic vegetation. But, in recent years, the basin became shallower leading to the formation of reeds and sedges through gradual sedimentation. Nonetheless, this has resulted in providing enough food and shelter for fish and other aquatic fauna. The migratory birds are also attracted which adds to the fertility of the water bodies with their excreta. Thus, the enhanced water fertility promotes a rich growth of phytoplankton and macrophytes, and partly contributes to the process of eutrophication.

The haor area is divided into three zones (Alam and Hossain 2012) as follows:

- The piedmont zone: It is the most elevated zone around the foothills of the Himalayas, where rapid siltation of coarser materials takes place along the levees by flash floods. The back swamp lies across the downslope of levees, acting as a reservoir by storing water and substantially reducing the flooding depth downstream.
- The floodplain zone: Floodplains with gentle slopes are located in the middle of the basin. Sediments, moderately finer and considerably lower in volume, are received by this zone. Flooding depth downstream is reduced as back swamps along this section fill and drain several times during each monsoon season.
- The deeply flooded zone: It is the deepest part of the wetlands known as beel. The beels become deeply flooded and turn into a single water reservoir, especially in the Surma-Kushiyara-Meghna basin during monsoon.

The minor hilly streams like Manu, Khowai, Jadhukata, Piyain, Mogra and

Mahadao in association with the Surma and Kushiyara rivers form the complex drainage network of the haors. The rivers provide rainwater and sediment load to the plains including haors. The haors turn into a vast waterbody resembling an inland sea and remain flooded for about 7 to 8 months during the rainy season within which the villages appear as islands.

Char Ecosystems

The char lands are the byproducts of the hydro-morphological dynamics of the rivers. More specifically, the char lands are the land masses formed through accretion of sedimentation of huge amounts of sand, silt and clay over time carried by three of the mightiest rivers of the world, the Padma, the Meghna, the Brahmaputra-Jamuna and their numerous tributaries (Satter and Islam 2010). The char lands of Bangladesh can be divided into the following sub-areas: the Brahmaputra-Jamuna, the Padma, the upper Meghna and the lower Meghna. The Brahmaputra river originating from Tibet passes through northeastern India and spreads into several districts of Rangpur and Dhaka divisions of Bangladeh. 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 merges with the Padma river and 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 Noakhali district possesses the greatest number of such coastal chars followed by Patuakhali and Bhola districts.

> Char lands are land masses formed through accretion of huge amounts of sediment consisting of sand, silt and clay carried by the Padma, the Meghna, the Bramaputra and the Jamuna along with their numerous tributaries over time

The flood water flow speed is not uniform resulting in an uneven deposition of soil particles on the riverbed. Being heavier in weight, the sand deposits earliest followed by silt and finally the clay particles. Thus, chars in the northern regions are mostly composed of sand, those in the middle central regions are mostly silty and those downward are composed of clay particles (Karim 2015). However, chars are formed through the continual process of erosion and deposition in the major rivers and coastal areas, and, therefore, most char lands are unstable and prone to annual flooding. Even chars older than 100 years may be eroded due to natural geo-hydrological activities and changes in the courses of rivers (Karim 2014). Char lands are sometimes grouped as temporary chars and established or permanent chars. Temporary chars may be defined as the chars that have sparse plantation, minimum crops and cropping and go under flood water every year which is deep enough to damage any crop. These may be demolished within a couple of years to decades. People live there making temporary houses. On the contrary, established chars may be defined as those which have age-old trees, maximum crops and cropping, and minimum vulnerability to floods. These are not demolished even within several decades, and dwellers live on permanent or semi-permanent houses. However, it is not guaranteed that established chars will last like permanent main land.

Barind Ecosystems

The Barind ecosystems covers most parts of the greater Dinajpur and Rangpur areas in the Rangpur division, Sirajganj Rajshahi, Bogura, Joypurhat, Naogaon and Chapainawab-ganj districts of the Rajshahi division.

The largest Pleistocene physiographic unit of the Bengal Basin, has been recognized as a unit of old alluvium, which differs from the surrounding floodplains. The Barind ecosystems covers the most parts of the greater Dinajpur and Rangpur under Rangpur division, and Pabna, Rajshahi, Bogura, Joypurhat and Naogaon districts of Rajshahi division. It is also popularly known as *Varendra Bhumi* in Bangla. The Karatoya river bounds this physiographic unit on the east, the Mahananda river on the west and the northern bank of the Ganges on the south. A lower fault scarp marks the eastern edge of the Barind ecosystems, and the Little Jamuna, Atrai and Lower Punarbhaba rivers occupy fault troughs. The western part of this unit has been tilted up; parts of the western edge are more than 15m higher than the rest of the areas and the adjoining Mahananda floodplain. The southern part of the main eastern block of the Barind area is tilted down towards the southwest and passes under the lower Atrai basin sediments in the south. Barind is a comparatively high, undulating region, with reddish and yellowish clay soils. The Barind ecosystems is widely believed to have been evolved from tectonic uplift and/or exists as an erosional geomorphic feature.

Coastal Ecosystems

The Ganges-Brahmaputra-Meghna (GBM) river system and the Bay of Bengal dominate the coastal areas of Bangladesh geomorphologically and hydrologically. The coastal areas consist of 19 southern districts, viz. Jashore, Narail, Gopalganj, Shariatpur, Chandpur, Satkhira, Khulna, Bagerhat, Pirojpur, Jhalakati, Barguna, Barishal, Patuakhali, Bhola, Laxmipur, Noakhali, Feni, Chattogram and Cox's Bazar (Abu et al. 2003). This area is divided into three parts, (a) the eastern area, (b) the central area, (c) the western area

> The coastal area of Bangladesh consists of 19 coastal districts viz. Jashore, Narail, Gopalganj, Shariatpur, Chandpur, Satkhira, Khulna, Bagerhat, Pirojpur, Jhalakati, Barguna, Barishal, Patuakhali, Bhola, Lakshmipur, Noakhali, Feni, Chattogram , and Cox's Bazar

depending on geographic features. The western area known as the Ganges Tidal Floodplain, comprises the semi-active delta and is crisscrossed by numerous channels and creeks. The central area, the Meghna estuary, is the most active area with ongoing accretion and erosion processes. The eastern area is covered by a hilly area that is more stable. The coastline is composed of the interface of various ecological and economic systems, including mangroves (world largest mangrove forest, called Sundarbans), tidal flats, estuaries, sea grass, islands, accreted land, beaches, a peninsula, rural settlements, urban and industrial areas, and ports. Based on the coastal area policy (MoWR 2005), the Government of Bangladesh (GoB) classified 19 southern districts out of the 64 districts of Bangladesh as the coastal area covering 147 upazilas (sub-districts) of the country. Out of these 19 districts, 12 districts meet the sea or the lower estuary directly which are the most vulnerable areas in the climate change setting. The coastal area is divided into the (i) exposed and (ii) interior coastal areas. The upazilas that face the coast or river estuary are treated as the exposed coastal area comprising 48 upazilas in 12 districts. The other 99 upazilas located farther north of the exposed coast make the interior coastal area. The exposed coastal area is most vulnerable to natural disasters like cyclones, tidal surges, strong salinity etc.

Hill Ecosystems

The hilly regions of the north-eastern and south-eastern part of Bangladesh originated during the elevation of the Himalayas in the Tertiary period. They are similar to Lusai of Assam and Arakan hills of Myanmar. These hills are situated in greater Sylhet, Chattogram and the Chattogram Hill Tracts (CHT).

> Extensive hill areas, known as the Chattogram Hill Tracts (CHT) comprising Rangamati, Khagrachari and Bandarban districts exist in the southeastern part of the country.

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. The hills of Sitakunda and Chandranath are two of them. In the south, there are some small hills which ranges between Cox's Bazar and Teknaf. There are many hills in the three hilly districts of CHT. These hills are extended from north to south. The height of these hills is not more than 600 m (200 ft). Extensive hill areas in Bangladesh lie in CHT- the south-eastern part of the country bordering Myanmar on the southeast, the Indian state of Tripura on the north, Mizoram on the east and Chattogram district on the west. CHT was divided into three individual districts during the early 1980s as part of the countrywide administrative reforms. CHT comprises three hilly districts of Bangladesh: Rangamati, Khagrachhari and Bandarban. The mountainous rugged terrain with deep forests, lakes and falls gives it a different character from the rest of Bangladesh. CHT falls under the Tertiary hill physiography unit covering the Northern and Eastern Hill unit and the High Hill or Mountain Ranges sub-unit. This sub-unit covers most of CHT, some small parts of southern Habiganj and the south and eastern borders of Moulvibazar. All the mountain ranges of CHT are almost hogback ridges. They are steep and most of the ranges have scarps in the west with cliffs and waterfalls. There is a huge network of trellis and dendritic drainage consisting of some major rivers draining into the Bay of Bengal.

1.3 Agricultural development in fragile ecosystems

In order that the fragile ecosystems can contribute to the national goal of improved livelihoods of the people, it is important that the risks and vulnerabilities, on one hand, and the prospects of development, on the otherhand, are adequately understood and analyzed. The Bangladesh Delta Plan 2100 (MoP 2018) seeks to balance economic development in line with the country’s goal to graduate to the upper middle-income status. It also seeks to eliminate extreme poverty by 2031 with the longer-term challenge of managing water, ecology, the environment and land resources, and minimize as much as possible the risks from natural disasters and climate change (Chowhan and Sultana 2017). The plan recognizes the risks posed by climate change to the country's farmers (and other ecosystem dependent communities) and these risks can only be addressed at the ecosystem level. It also recognizes that ecosystem-based adaptation provides a significant means to help people survive in the face of the risks and vulnerabilities.

Agricultural practices, agro-economic activities and farmers’ livelihood in the fragile ecosystems are quite different from those in favorable ecosystems of the country. Evidences indicate that the resources and agricultural production potentials in the fragile ecosystems have remained largely untapped and underutilized. These ecosystems should be amenable to suitable, location-specific technological interventions, and there exist great opportunities for productive agriculture. A dynamic agricultural technology innovation system that can address the needs of different strata of farmers in these fragile ecosystems can go a long way in boosting agricultural production and contributing to national food security and poverty reduction.

1.4 Methodology for assessment of fragile ecosystems

The main purpose of this book is to develop strategic directions of agricultural development for the fragile ecosystems. The specific objectives are to:

a) Assess the existing agricultural systems of those five fragile ecosystems individually.
b) Identify needs for improvement in the agricultural systems.
c) Understand the constraints, risks and vulnerabilities and identify the challenges to agronomic and socioeconomic development.
d) Suggest the strategic investment opportunities for agricultural development in these fragile ecosystems.

Both quantitative and qualitative approaches were used to realize the objectives with a variety of primary and secondary data sources following participatory methods. The quantitative method included collection of primary data and review of documents while the qualitative method included focused group discussions (FGD) and observations to characterize the fragile ecosystems in Bangladesh.

Currently, government has adopted various policies, strategies and action plans aimed at increasing nutrition security and employment opportunities. Accordingly, prevailing challenges in agriculture with special reference to hot-spot areas as specified in the Bangladesh Development Plan 2100, are needed critically to be reviewed for setting priority research by stakeholders at all spheres having in-depth knowledge on their locality. Under this backdrop, regional workshop with a special reference to 'Hot Spots' were organized wherein stakeholders shared their ideas in respect of existing difficulties and potential remedies through priority research. At the beginning, a physical meeting was organized by BARC with Executive Chairman in the chair wherein Director (research) of NARS institutes and all member directors of BARC were attendees. Later on, outlines of power point presentation and manuscript preparation along with a required number of table formats are initially drafted and revised after suggestions from relevant experts. Scientists, university teachers, extension personnel, and other stakeholders of the locality were identified and invited in the workshops after being nominated by their respective authority. For each of the subsector viz. crop, fisheries and livestock, five areas were focused.

Participants are grouped according to their areas of expertise. In each group, representatives from extension services are included to understand local challenges and make recommendations for research priorities. Later, online meetings were held where manuscript preparation outlines and table formats were presented. Suggestions from the participants in the online meetings were incorporated to update the outlines and table formats. Simultaneously, with a lead officer and co-lead officer from groups, manuscripts and presentations were prepared. Afterwards workshops were held wherein principal authors led presentation following open discussions to fetch more information as per opinions from the participants to be included in this book. The groups were advised to consult related policy documents and challenges of the target areas while recommending burning research and development issues on the basis of merit for short-, medium- and long-terms. Local scientists working under National Research System Institutes (NARSIs), extension agencies (DAE, DLS, DoF) and other stakeholders were invited to attend the workshops. Altogether eight regional workshops were organized targeting five fragile ecosystems identified as hotspots in Bangladesh Delta Plan 2100 as follows:

a) The Haor and Flash Flood Areas: Sylhet and Mymensingh region
b) Char ecosystem (The River Systems and Estuaries): Rangpur and Dhaka region
c) Barind and Drought Prone Areas: Rajshahi region
d) Coastal Zones: Khulna and Barishal region
e) The Chittagong Hill Tracts: Chattogram region.

The materials related with the ecologically fragile ecosystems and relevant areas were collected from different journals, reports and review papers of national and international status. Very relevant unpublished materials were collected from Department of Agricultural Extension (DAE), Department of Fisheries (DoF), Department of Forest (FD), Department of Livestock (DLS) etc. Additional information was chosen from group discussion of relevant person at field level of extension services, researchers of NARS Institutes as well as reviewing related policies. However, primary and secondary data were collected from different organizations and from websites on 'Agricultural sub-sectors' covering i) crops, ii) livestock, iii) fisheries and iv) forestry whereas the cross-cutting issues were: i) inputs, ii) marketing, iii) natural resources, and iv) socio-economics.

In the process, key stakeholders included in the FGDs were:

i. National Agricultural Research Systems (NARS) institutes
ii. Department of Agricultural Extension (DAE)
iii. Department of Livestock Services (DLS)
iv. Department of Fisheries (DoF)
v. Department of Forest (FD)
vi. Bangladesh Agricultural Development Corporation (BADC)
vii. Department of Marketing (DAM)
viii. Water Development Board (WDB)
ix. Haor Development Board (HDB)
x. CHT Development Board
xi. Barind Multipurpose Development Authority (BMDA)
xii. Universities
xiii. NGO's, entrepreneurs, local lead farmers, seed dealers, business community etc.
xiv. International development partners (FAO, WorldFish, CIMMYT, etc.)

References

Akonda AW (1989) Bangladesh, A directory of Asian wetlands (PDF), IUCN, ISBN 2-88032-984-1, Retrieved from https://portals.iucn.org/library/node/5933, accessed on February 27, 2021

Abu M, Kamal U and Rob K (2003) Delineation of the coastal zone Dhaka, PDO-ICZMP, Bangladesh, Coast Zone Management 22(1): 466 , Retrieved from http://warpo.portal.gov.bd/sites/default/files/files/warpo.portal.gov.bd/page/aa04373f_0ca3_49a5_b77e_5108186638dc/wp005.PDF, accessed on February 20, 2021.

Alam MS and Hossain MS (2012) "Wetland", In: Islam S and Jamal AA (eds.). Banglapedia: National Encyclopedia of Bangladesh (2nd ed), Asiatic Society of Bangladesh. Retrieved from https://en.banglapedia.org/index.php/Wetland, accessed on June 25, 2021

Banglapedia (2021) “Haor” Retrieved from http://en.banglapedia.org/index.php?title=Haor&oldid=2693, accessed on 28 July 2021

BARC (Bangladesh Agricultural Research Council) (2020) Computer and GIS Unit, BARC, Farmgate, Dhaka.

Chowhan T and Sultana F (2017) Impacts and mitigation of climate change on different sectors of Bangladesh, In: Proc International Conf Disaster Risk Mitigation, Dhaka, Bangladesh, September 23 - 24, 2017. www.bip.org.bd/SharingFiles/journal_book/20140128164211.pdf

Karim MA (2014) A report on validation and upscaling of mungbean-rice pattern in char lands of Kurigram. KGF-World Bank Project Report, Krishi Gobeshona Foundation (KGF), BARC Campus,Framgate, Dhaka.

Karim MA (2015) Chorer Prokriti-Jibon O Krishi (in Bengali), Prokritibarta, 2(3): 34-37. Retrieved from https://barciknews.com/archives/16882 accessed on 23 June 2021.

MoP (Ministry of Planning) (2018) Bangladesh Delta Plan 2100, Govt of the People’s Republic of Bangladesh.

MoWR (Ministry of Water Resources) (2005) Coastal Zone Policy 2005, Govt of the People’s Republic of Bangladesh.

Nilsson C and Grelsson G. (1995). The fragility of ecosystems: A review, The Journal of Applied Ecology 32(4): 677-692, doi: 10.2307/2404808

Sattar SA and Islam MN (2010) Char lands of Bangladesh: their extent, man-agement and future research needs. Paper presented at workshop on Soil Fertility, Fertilizer Management and Future Strategy held at Bangladesh Agricultural Research Council, Farmgate, Dhaka, 18-19 January, 2010

Chapter 2

Haor Ecosystem

2.1 Extent and distribution

"Haor" is the local term for the vast low-lying land depressions forming deep basins which remain filled with water (Fig. 2.1) to various fluctuating depths during different seasons of the year. Haors are found in the north-eastern part of Bangladesh. The haors are seasonally inundated and the region is interspersed with upland areas of 1-10 ha known as haati. Mainly haors, from tectonic subsidence of the geologic Dauki Fault, represent the wetland ecosystem in Bangladesh. They usually dry up in the winter, but within the haors there are several deeper depressions, locally known as beel, which remain filled with water throughout the year. The haor basin comprises about 6300 beels of which 3500 are permanent and 2800 are seasonal (Sharma 2010). These unique land and water formations occur in extensive areas of the districts of Sunamganj, Habiganj, Moulvibazar and Sylhet districts of the Sylhet division, Brahmanbaria of the Chattogram division, Kishoreganj of the Dhaka division, and Netrakona of Mymensingh division (Fig. 2.2). The haor basin is bordered on three sides by the mountain ranges of India, with Meghalaya to the north, Tripura and Mizoram to the south, and Manipur and Assam to the east. The basin extends north to the foot of the Garo and Khasia Hills, and east along the upper Surma Valley to the Indian border.

Fig. 2.1. Photo of Tanguar haor in Sunamganj district

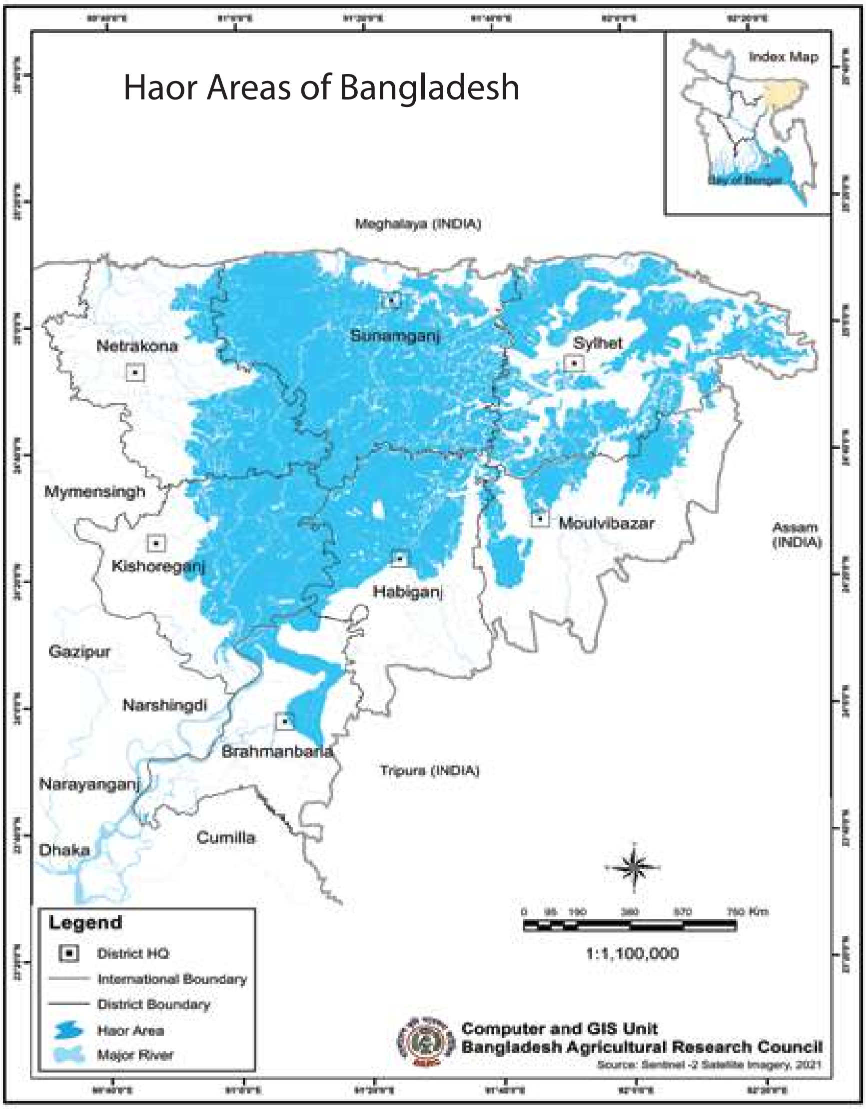


Fig. 2.2. Map of northeastern Bangladesh showing the haor areas
(source: BARC 2022)

Haors exist in 61 out of 74 upazilas of seven districts viz. Sylhet, Moulvibazar, Habiganj and Sunamganj in the northeastern, Netrakona and Kishoreganj in the northcentral and Brahmanbaria in the central-eastern regions of Bangladesh (Table 2.1). It is noteworthy that all upazilas of Sylhet (14) and Sunamganj (12) districts have haors and the majority upazilas (>70%) of the other districts except Brahmanbaria (44%) contain haors. Overall, 12.3 % upazilas of Bangladesh have the haor ecosystem and the problems and prospects that go with it. Names of upazilas containing haors are given by district in Table 2.2.

Table 2.1. Upazila-wise distribution of haor areas in different districts of Bangladesh

District	No. of upazilas	No. of upazilas with haor	% of upazila with haor in a district	% of upazila with haors in Bangladesh
Sunamganj	12	12	100	2.4
Sylhet	14	14	100	2.8
Habiganj	09	07	78	1.4
Moulvibazar	07	06	86	1.2
Netrakona	10	07	70	2.8
Kishoreganj	13	11	85	2.2
Brahmanbaria	09	04	44	0.8
Total	74	61	82	-
Bangladesh	495	61	-	12.3

(Source: BBS 2020 and BARC 2022)

Table 2.2. Names of upazilas containing haors by district

District	Haor based Upazila
Sunamganj	Sunamganj Sadar, Jagannathpur, Dharmapasha, Jamalganj, Chhatak, Derai, Sulla, Tahirpur, Bishambarpur, Dakkhin Sunamganj, Dowarabazar, Madhyanagar.
Sylhet	Jaintiapur, Beanibazar, Fenchuganj, Balagonj, Biswanath, Sylhet Sadar, Sylhet City Corporation, Companiganj, Golapganj, Gowainghat, Kanaighat, Osmaninagar, Zakiganj, Dakkhin Surma.
Habiganj	Ajmiriganj, Habiganj Sadar, Bahubal, Baniachang, Lakhai, Madhabpur, Nabiganj
Moulvibazar	Moulvibazar Sadar, Kulaura, Rajnagar, Sreemangal, Barlekha, Juri
Netrakona	Atpara, Barhatta, Khaliajuri, Mohanganj, Madan, Kendua, Komlakanda
Kishoreganj	Mithamain, Karimganj, Austragram, Itna, Nikli, Bazitpur, Kuliarchar, Tarail, Bhairab, Katiadi, Kiskoreganj Sadar
Brahmanbaria	Bhramanbaria Sadar, Nasirnagar, Bijoynagar, Sarail

Source: BARC 2022

The largest haors or wetlands exist in the districts of Sunamganj, Sylhet, Moulvibazar, Habiganj, Netrakona and Kishoreganj (Fig. 2.3). The district of Sunamganj houses Tanguar Haor, the deepest inland pocket of topographic depression in the country. The other major haors in Sunamganj are Sangair, Joalbhanga, Kalnar, Khai, Dekar, Nandair, Naluar, Chaptir, Kalikota, Bharmohona, Halir, Pagnar Angurali, Karchar, Sonir, Matian, Gurmer, Kanamaiya, Pashua and Rui. Sylhet district also has some large haors such as, Hailkar, Jilkar, Patharchauli, Jainkar, Chauldhani, Balai, Muria, Erali and Damrir. In Moulvibazar district, the major haors are Hakaluki, Kawadighi, Karaiya and Hail while in Habiganj, the major haors are Guingajuri, Makar, Sonadubi and Amadir. The Ghoradoba, Singer, Dingapota, Murali and Karmohuri haors are in Netrakona and the Humaipur, Bara Digha, Dhakir, Gopedighi, Badla, Sonabandha and Dhanpur haors are in Kishoreganj. Brahmanbaria has lesser haors in terms of area, which are Medir, Pattan and Akashishapla.

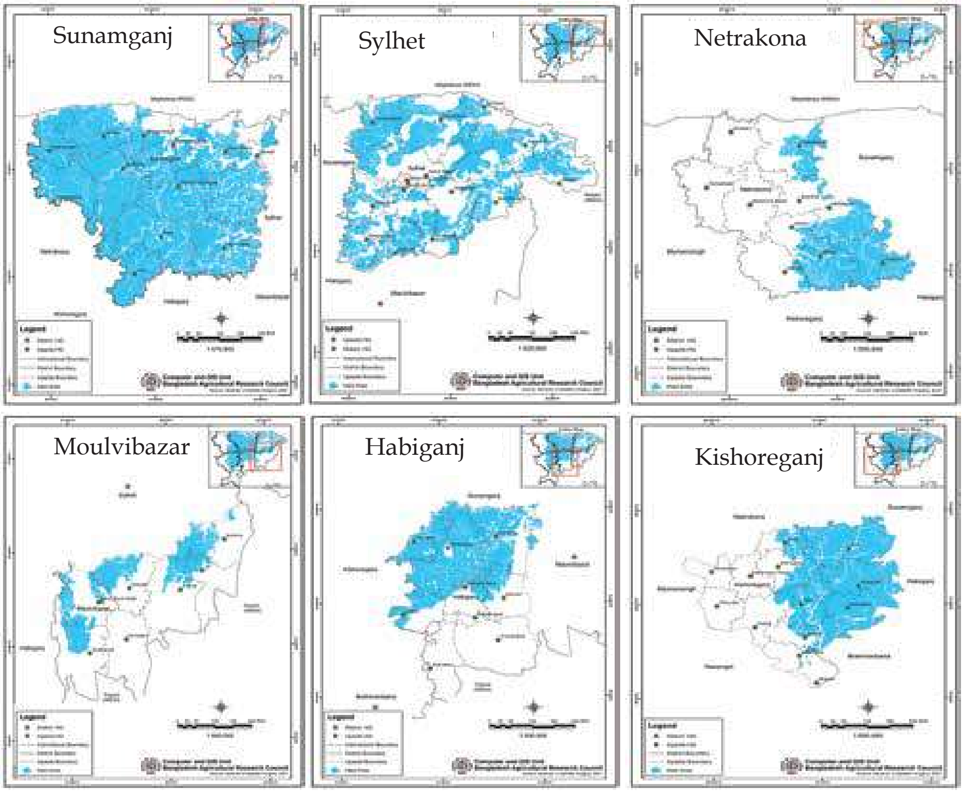


Fig. 2.3. Six northeastern districts of Bangladesh with the largest haors
(Source: BARC 2022)

The haors of Sunamganj, Sylhet, Habiganj, Moulvibazar, Netrakona, Kishoreganj and Brahmanbaria districts occupy nearly 873,524 ha which is about 52.9% of the total area of these districts (1,651,992 ha) and 6% of the total area of Bangladesh, i.e., 14,486,269 ha (Fig. 2.4).

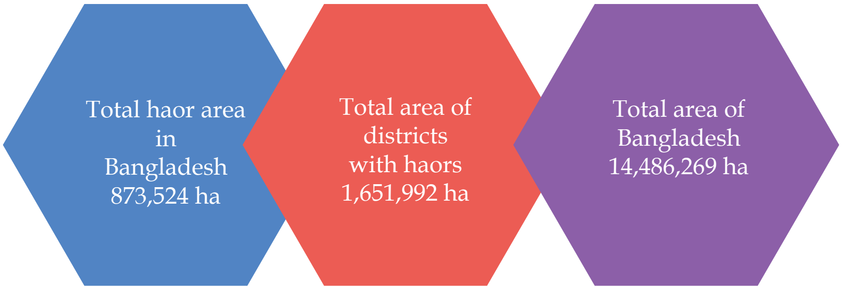


Fig. 2.4. Areas of haors relative to those of haor districts and Bangladesh (Source: BBS 2020 and BARC 2022)

Among the seven northeastern districts, haors are the most prevalent in Sunamganj where they occupy 290,982 ha out of the total area of 366,558 ha of the district (Fig. 2.5). Next to Sunamganj, Sylhet, Habiganj and Kishoreganj have 171,098, 113,689 and 98,478 ha, respectively. Haors in the other three districts, i.e., Netrakona, Moulvibazar and Brahmanbaria, are less extensive. In Sunamganj, haors occupy the largest portion, 79.4%, of the total area of the district. These figures are 55.4%, 50.2% and 50% for Habiganj, Kishoreganj and Sylhet, respectively. The lowest portion of total land occupied by haors, 24.8%, is in Moulvibazar (Fig. 2.4 and 2.5). The problems, risks and vulnerabilities related to agricultural production in haor areas arise from the intrinsic properties of these wetland ecosystems wherever they occur irrespective of their dimensions.

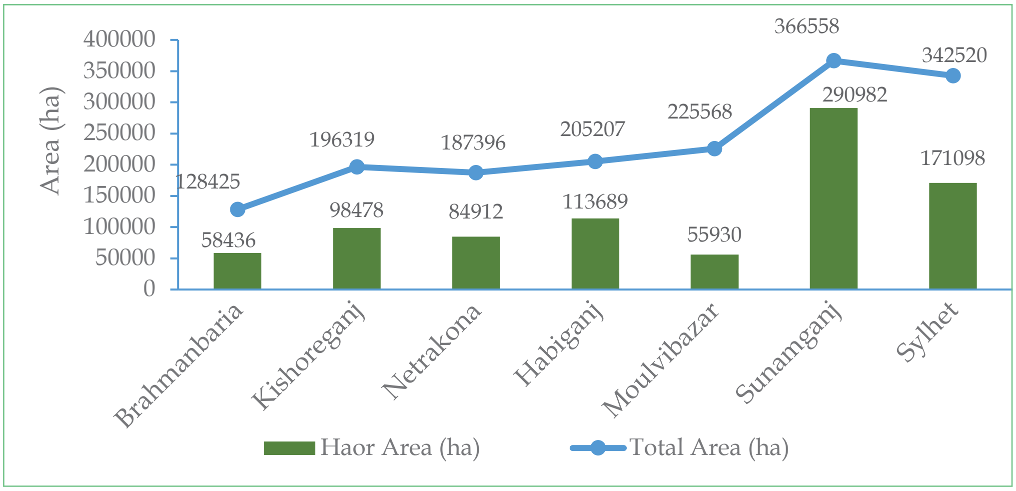


Fig. 2.5. Areas under haors in seven north-eastern districts of Bangladesh and total areas of the districts in 2022 (Source: BARC 2022)

Over time, there have been significant changes in the extent and distribution of haors in northeastern Bangladesh. Earlier reports indicated that the seven "haor districts" covered an area of about 1.99 million ha and had a population of about 19.37 million (Islam et al. 2012, Mustafa et al. 2019, Muzaffar 2004). In these districts, there were 373 haors that occupied nearly 859,000 ha, or about 43% of the total area of the haor districts (Ahmed 2013, Alam et al. 2010). In 15 years, between 2007 and 2022, the area under haors increased by 28% (Table 2.3) from 680,000 ha in 2007 to 873,524 ha in 2022 indicating an annual growth rate of 2.03%. These changes, however, did not occur uniformly across the regions. For example, in Sylhet, the increase, the highest, was 242% followed by 184% in Habiganj and 95% in Brahmanbaria. However, despite an overall increase, decreases ranging from 34 to 39% occurred in the districts of Kishoreganj, Netrakona and Moulvibazar. The increase in haor areas could be the outcomes of repeated flash flood waters overtopping the submersible embankments, inundating vast areas, thereby giving rise to new wetland areas.

Table 2.3. Changes in haor area

District	Haor area (ha) in 2007	Haor area (ha) in 2022	Increase/ decrease (%)
Brahmanbaria	30000	58436	95
Kishoreganj	150000	98478	-34
Netrakona	140000	84912	-39
Habiganj	40000	113689	184
Moulvibazar	90000	55930	-38
Sunamganj	180000	290982	62
Sylhet	50000	171098	242
Total	680000	873524	28

Source: DAE 2007 and BARC 2022

2.2 Biophysical characteristics

2.2.1 Land and soil

The soils of haor region are mainly clay loams on the ridges and clays in the basins or depressions. The Sylhet Basin is a vast depressed area mainly comprising high river levees surrounding extensive basins (haors), the centers of which remain wet in the dry season. Even though the basin is located some 300 km away from the coast, the lowest parts of the basin are less than five meters from mean sea level. The relief is locally irregular due to erratic nature of sedimentation during flash floods. Clay soil predominates in this area. Most of the lands experience deep to very deep flooding in the wet season, when the area often resembles an inland sea with substantial waves generated by monsoon winds. The haors remain wet for most or all of the dry season .

> Peat soils near the ground or at just a few meters below the ground are found in Sunamganj, Netrakona, Kishoreganj and Habiganj districts.

The seasonal wetlands are essentially parts of river floodplains, and the soils are influenced by active river processes. The haors have thick deposits of clay mixed organic soils. This is because during the flow of rivers, the heavier particles, sand and silt, are deposited first and finer particles like clay carried with the overflow accumulate in the depressions away from the rivers. The haors also accumulate suspended organic solids, and have deposition of the remains of aquatic plants. In certain areas, where the organic matter percentage is high, peat soils occur. These are unconsolidated deposits of semi-carbonized plants, containing about 60% carbon, and about 30% oxygen. Sunamganj, Netrakona, Kishoreganj and Habiganj districts have peat soils near the ground, or at just a few meters below the ground. Peat soils are also found at the fringes of some other lowlands, under a layer of silty or sandy top soil.

Soil fertility

Soil pH, organic matter and nutrients

Soil pH values during 2006-2021 are shown in Table 2.4. The pH of soils in all land types such as high land (HL), medium high land (MHL), medium low land (MLL), low land (LL) and very low land (VLL) varies within the low range of 3.4-3.60 (extremely acidic) to the mid-range of 5.8-6.9 (slightly acidic to neutral). In general, HL and MHL soils tend to be more acidic than LL, MLL and VLL soils. Uddin et al. (2019) reported that pH value was higher to near neutrality and ranged from 6.7 to 7.0 with a mean of 6.9 in the wetlands of southeastern part of the Sylhet basin. Wetland soil might be acidic or basic depending on location and other environmental factors. A low pH may be attributed to surface run-off from rains and organic acid production during the decomposition of organic matter within the wetland. The pH of many alluvial wetlands could be near neutral due to flooding by river water with a high calcium (Ca) content (Vimala et al. 2001). Soil acidity decreases the availability of plant nutrients, such as phosphorus (P) and molybdenum (Mo), and increases the availability of some elements to toxic levels, particularly aluminum (Al) and manganese (Mn). Essential plant nutrients can also be leached out below the root zone.

Table 2.4. Ranges and classes of soil pH in haor region during 2006-2021

	HL	MHL	MLL	LL	VLL
Max	5.80	6.4	6.6	6.5	6.9
Class	Slightly acidic	Slightly acidic	Neutral	Slightly acidic	Neutral
Min	3.60	3.55	3.6	3.5	3.4
Class	Extremely acidic	Extremely acidic	Extremely acidic	Extremely acidic	Extremely acidic

Source: BARC 2022

A comparison of maximum and minimum pH values of soils in haor areas between the two periods 1999-2002 (Table 2.5) and 2006-2021 (Table 2.4) indicates that there were no significant changes in soil pH. The exception was that soils of MLL and VLL tended to lose some acidity during 2006-2021 which may be attributed to frequent submergence of these lands by flood water with high Ca content.

Table 2.5. Range and classes of soil pH in haor region during 1999-2002

	MHL	MLL	LL	VLL
Max	4.4	6.4	6.3	4.9
Class	Very strongly acidic	Slightly acidic	Slightly acidic	Strongly acidic
Min	4.3	4.0	4.0	4.1
Class	Very strongly acidic	Very strongly acidic	Very strongly acidic	Very strongly acidic

Source: BARC 2022

Fig. 2.6 reveals that the average soil organic matter (SOM) content, 2.03-3.45%, in the haor region across all land types, HL, MHL, MLL, LL and VLL, is above the critical level of 2% which is good for crops. There has been a slight increase in SOM during the 1985-1998, 1999-2002 and 2006-2021 periods (Fig. 2.6). Over the years, SOM in LL and VLL remained the highest, 2.66 to 3.45%, compared with 2.03-2.56% in HL, MHL and MLL. Alluvium and organic debris deposition in the perennially wet LL and VLL continues throughout the year which slowly increases and maintains the SOM level in soil.

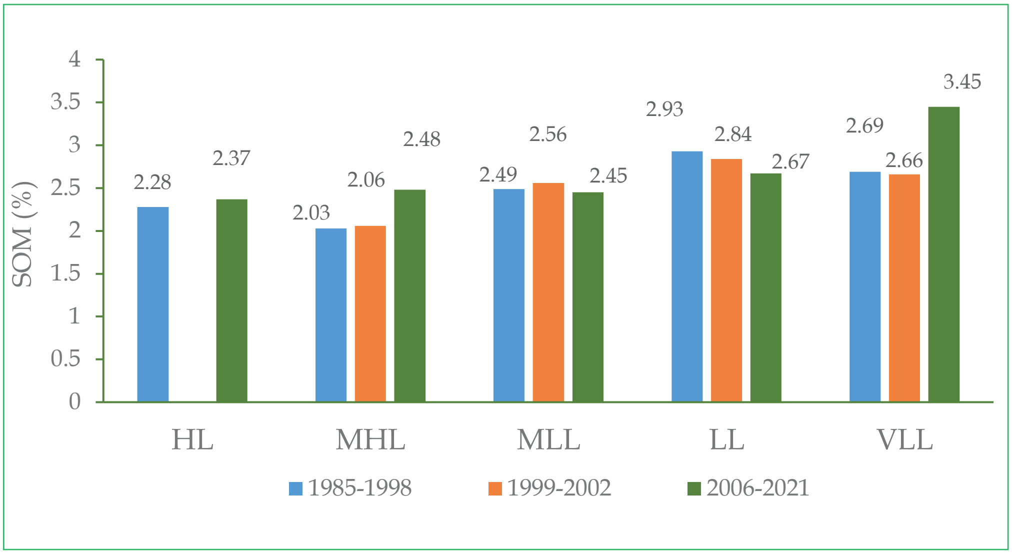


Fig. 2.6. Soil organic matter content in haor region (values in %)
(Source: BARC 2022)

The average available phosphorus (P) level of soils in the haor region across HL, MHL, MLL, LL and VLL ranged from 1.64 to 6.03 ppm during 1999-2002 and 2006-2021 (Fig. 2.7), which is much below the optimum level of 12-15 ppm for crops. However, soils of HL and MHL contain a higher level of P, 5.01 to 6.03 ppm, than those of MLL, LL and VLL ranging from 1.64 to 5.46 ppm. Soils across MHL, MLL, LL and VLL types showed an increasing trend of P level ranging from 5.5 to 6.3, 3.54 to 5.46, 2.74 to 4.32 and 1.64 to 4.9 ppm, respectively. The reason for this increase over time is probably due to increased application of P fertilizer as crop production intensified in haor areas. The higher content of P in soils of HL and MHL may be due to the presence of P-containing minerals in the soil material compared to those on MLL, LL and VLL (Harris 2002).

The average potassium (K) level of soils (exchangeable K) ranging from 0.13 to 0.36 meq/100 g during 1999-2002 and 2006-2021 (Fig. 2.7) in the haor region across HL, MHL, MLL, LL and VLL were below the healthy level of 0.5 meq/100 g for crop production. The soils of MLL, LL and VLL possessed higher level of K regardless of time ranging from 0.19 to 0.36 meq/100 g compared with the 0.13-0.15 meq/100 g level in HL and MHL. The K level in soils across land types did not change significantly in the last 30 years except on VLL where the K level decreased substantially to 0.21 from 0.36 meq/100 g.

The average available sulfate-sulfur (S) level, ranging from 16.8-68.2 ppm during 1999-2002 and 2006-2021 (Fig. 2.8), of soils in the haor region across all

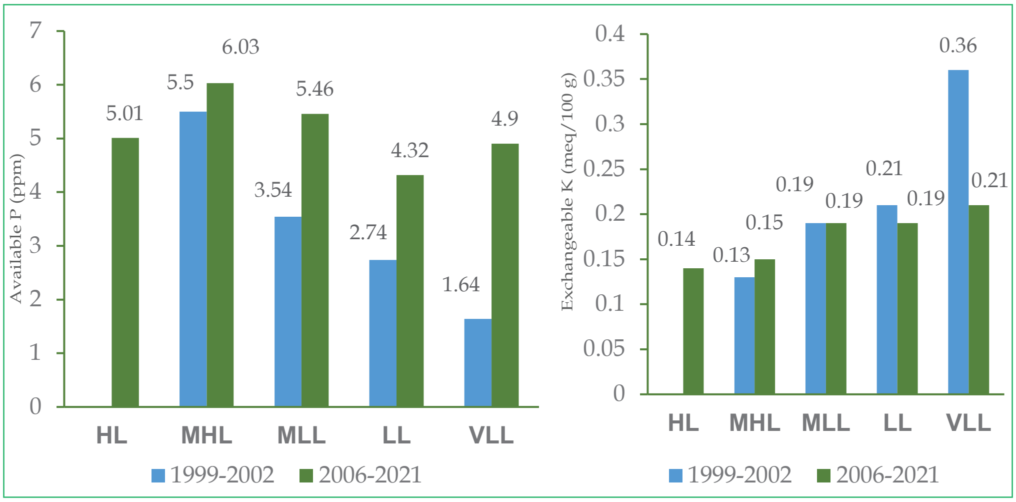


Fig. 2.7. Available P (ppm) content (left) and exchangeable K (meq/100 g) content (right) in soils of the haor region (Source: BARC 2022)

the land types, HL, MHL, MLL, LL and VLL, are much above the critical level (12 ppm) and the optimum level (26 ppm) except in HL (below optimum level). Soils of LL and VLL contain very high levels of S ranging from 40.8 to 68.2 ppm compared with those of HL, MHL and MLL ranging from 16.8 to 39.95 ppm. Soils of MHL, MLL and VLL showed a decreasing trend in S level ranging from 39.25 to 23.87, 39.95 to 34.89, and 68.2 to 54.56 ppm, respectively. The reason for this decrease over time is probably due to frequent flood induced prolonged submergence of haor soils. Due to prolonged submergence, anaerobic soil bacteria convert the sulfate-S to hydrogen sulfide which kills plant roots.

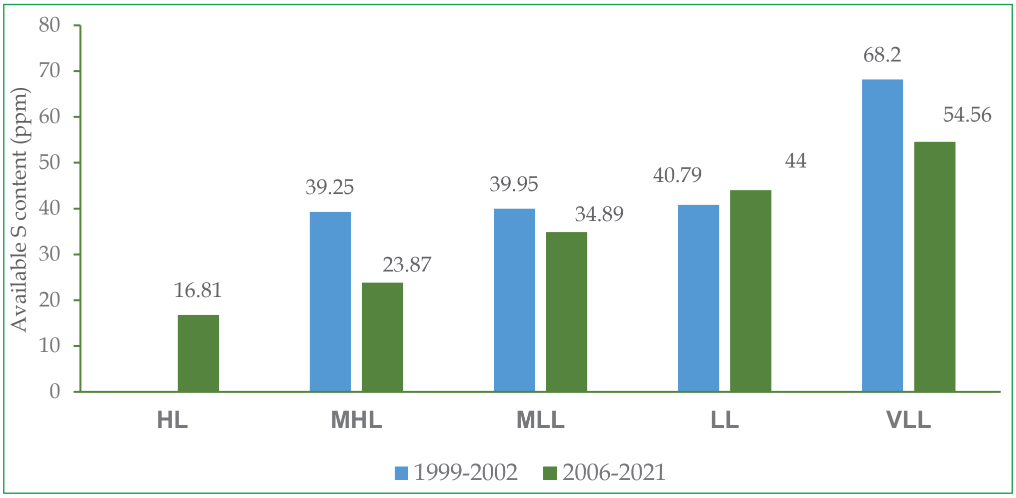


Fig. 2.8. Available S content (ppm) in soils of haor region (Source: BARC 2022)

The available zinc (Zn) level of soils in the haor region, 1.26-2.77 ppm during 1999-2002 and 2006-2021, across HL, MHL, MLL, LL and VLL (Fig. 2.9) is below the optimum level of 4 ppm. Soils of LL and VLL have a higher level of Zn ranging from 2.24 to 2.77 ppm, which is above the critical level of 2 ppm, than those on HL, MHL and MLL (1.26-2.2 ppm). Comparison of these two periods indicates that soils across MLL and LL (data not available for other land types) showed a decreasing trend of Zn level ranging from 2.2 to 1.8 and 2.77 to 2.24 ppm, respectively.

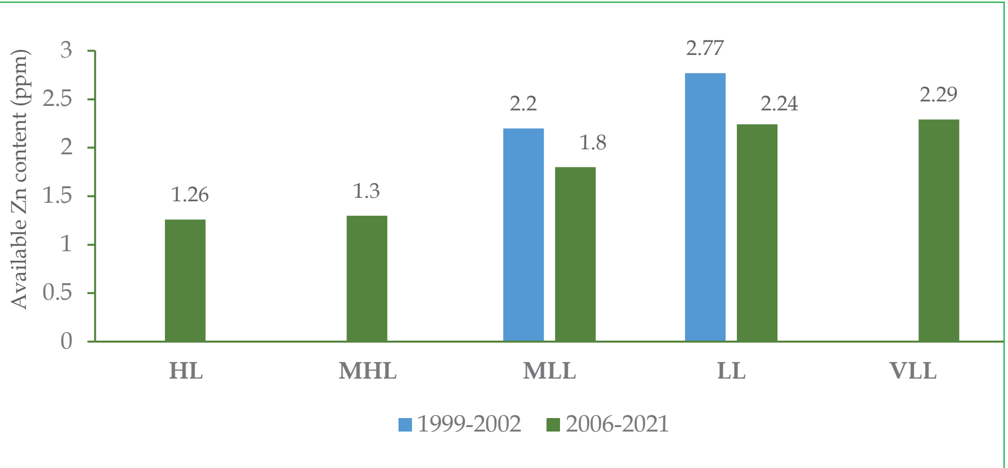


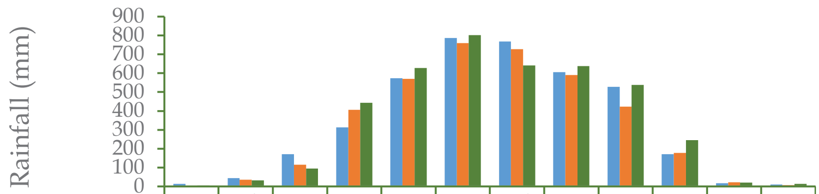
Fig. 2.9. Available Zn content (ppm) in soils of haor region (Source: BARC 2022)

2.2.2 Climate

A subtropical monsoonal climate prevails in the haor region. It has more sharply defined seasons than the tropical climate. Climate variability in the haor basin from available data during 1991-2020 has been extensively studied. There is a huge variation in rainfall in the different catchments of the river systems of the upstream area in India. Rainfall patterns on the adjacent Indian side largely affects flooding in the haor areas of Bangladesh. Annual average rainfall in the haor districts is huge and highly variable across the region. Among the locations of the haor districts, the highest rainfall generally occurs in Sunamganj closest to Cherrapunji in Assam of India, which receives the highest yearly rainfall in the world. The global climate change, occurring as a result of anthropogenic as well as natural events, inducing an alteration in the frequency of some climatic extreme events (IPCC 2007) is impacting the environment and agriculture of Bangladesh including the haor areas.

Rainfall

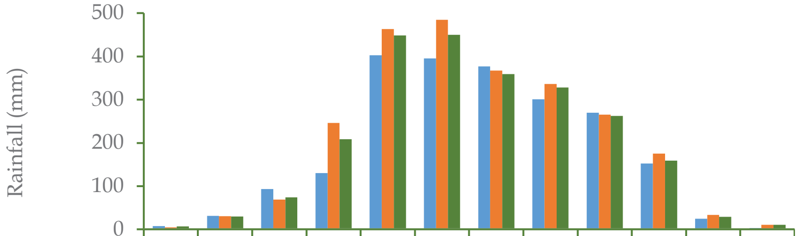
The Sylhet meteorological station provides climate data for two haor districts, Sylhet and Sunamganj, and part of Netrakona including haors. An increasing trend in rainfall was observed with an average monthly rainfall during April (443 mm), May (627 mm), June (802 mm), August (637 mm), September (538 mm) and October (245 mm) during 2011-2020 (Fig. 2.10). This increasing trend was confirmed when the above rainfall data were compared with the average monthly rainfall for the same months averaged over the period from 1991 to 2000 (313 mm, 574 mm, 787 mm, 606 mm, 527 mm and 171 mm, respectively). The trend indicates that the rainfall has been increasing in Sylhet and Sunamganj in these months. In particular, the increasing trend in the months of April, May and June has been critical for the safe harvest of Boro rice, and planting of Kharif-I vegetables and other crops. The extreme flashy character of the rivers and high rainfall in April, May and June cause frequent flash floods in these haor districts. However, average monthly rainfall has decreased severely in January, February and March during 2011-2020 (6 mm, 32 mm and 96 mm, respectively) compared with the average rainfall from 1991 to 2000 (13 mm, 44 mm and 171 mm, respectively). This decrease in rainfall has resulted in severe drought in these months leading to the delayed planting of Boro rice (winter rice) and other winter crops, and in the partial damage of these crops if planted in these months.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg Rainfall duing 1991-2000	13	44	171	313	574	787	767	606	527	171	18	10
Avg Rainfall during 2001-2010	2	35	115	407	570	760	728	590	422	179	23	7
Avg Rainfall during 2011-2020	6	32	96	443	627	802	642	637	538	245	21	13

Fig. 2.10. Long-term trend of monthly rainfall for Sylhet, Sunamganj and part of Netrakona including haor areas (Source: BARC 2022)

Data collected by the Sreemangal meteorological station indicates an increasing trend in rainfall (Fig. 2.11) in two haor districts, Moulvibazar and Habiganj and part of Kishoreganj including haors. There was an intense rains during April (208 mm), May (449 mm), June (450 mm) and August (328 mm) during 2011-2020 when compared with the monthly rainfalls in the same months averaged over the period from 1991-2000 (130, 403, 450 and 301 mm, respectively). This trend indicates that the rainfall has been increasing for these two districts in these months. In particular, the increasing trend in the months of April, May and June has been critical for the safe harvest of Boro rice, and planting of Kharif-I vegetables and other crops. The high rainfall in April and May causes frequent flash floods in these haor districts. The monthly rainfall has, however, poorly distributed in November, December and January during all the three 10-year periods ranging from 3-33 mm. This poor distribution in rainfall in these dry months brings about drought that delays planting of Boro rice and other winter crops with resultant yield losses.



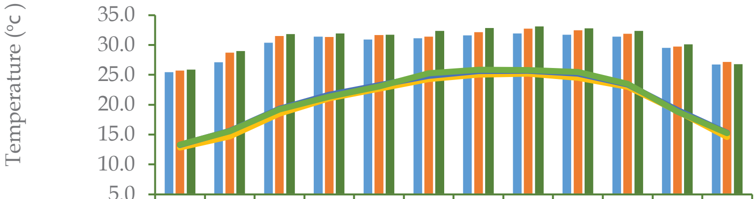
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg Rainfall during 1991- 2000	8	31	93	130	403	395	377	301	270	152	24	3
Avg Rainfall during 2001-2010	5	30	69	246	464	485	368	336	265	175	33	11
Avg Rainfall during 2011-2020	7	30	74	208	449	450	359	328	262	159	29	11

Fig. 2.11. Long-term monthly rainfall for Moulvibazar, Habiganj and part of Kishoreganj including haor areas (Source: BARC 2022)

Temperature

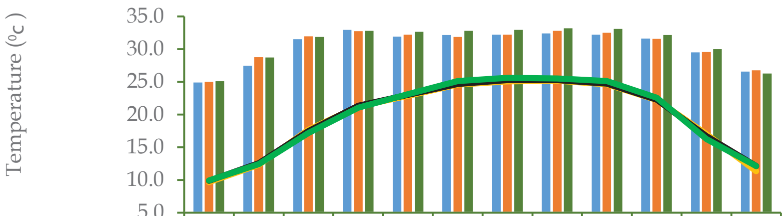
The average monthly maximum temperature has increasded in all the months during 2011-2020 ranging from 25.9 °C in January to 33.1 °C in August compared to that averaged over the period from 1991-2000 ranging from 25.4 °C in January to 31.9 °C in August. Thus, the maximum temperature has increased by the range of 0.50 to 1.20 °C during the last 30 years in Sylhet, Sunamganj and part of Netrokona including haors (Fig. 2.12). The monthly minimum temperatures averaged over 10 years (2011-2020) ranged from 12.8 °C in January to 25.8 °C in August (Fig. 2.12). The minimum temperature has also increased by 0.50 to 0.60 °C in all the months of the year except in November averaged over the last 10 years (2011-2020) compared to that averaged over the 30-years from 1991-2000. Similar increasing trends of temperature were observed in the other haor districts too (Fig. 2.13). Such temperature increases are an unmistakable pointer to the adverse impact of climate change on agriculture in the haor areas and on the lives and livelihoods of the millions of haor inhabitants.

Rising temperatures are projected to increase the severity and frequency of tornadoes and storms in the haor region. Almost every year, Bangladesh, particularly the haor, coastal and char areas face natural calamities like floods, cyclones, storms, and tidal surges. Warmer climate will increase the flooding risks (Hirabayashi and Yukiko 2013). Globally, the haors/wetlands are at risk



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg MaxT during 1991- 2000	25.4	27.1	30.4	31.4	30.9	31.1	31.6	31.9	31.7	31.4	29.5	26.7
Avg MaxT during 2001- 2010	25.7	28.7	31.5	31.3	31.7	31.4	32.1	32.7	32.4	31.9	29.8	27.1
Avg MaxT during 2011- 2020	25.9	29.0	31.8	31.9	31.7	32.4	32.9	33.1	32.8	32.4	30.1	26.8
Avg MinT during 1991-2000	12.8	14.7	18.5	21.1	22.7	24.3	25.1	25.2	24.5	23.0	18.9	14.6
Avg MinT during 2001-2010	13.2	15.6	19.3	21.7	23.3	24.8	25.6	25.7	25.2	23.4	19.1	15.3
Avg MinT during 2011-2020	13.3	15.6	19.2	21.4	23.0	25.2	25.8	25.8	25.5	23.5	18.8	15.2

Fig. 2.12. Long-term trend of monthly maximum and minimum temperatures in Sylhet, Sunamganj and part of Netrokona including haor areas (Source: BARC 2022)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg MaxT during 1991- 2000	24.9	27.4	31.5	32.9	32.0	32.2	32.2	32.4	32.2	31.6	29.5	26.6
Avg MaxT during 2001-2010	25.0	28.8	32.0	32.8	32.2	31.9	32.2	32.8	32.5	31.6	29.6	26.8
Avg MaxT during 2011- 2020	25.1	28.7	31.9	32.8	32.7	32.8	33.0	33.2	33.1	32.2	30.0	26.3
Avg MinT during 1991- 2000	9.7	12.3	17.7	21.3	22.9	24.6	25.1	25.2	24.6	22.2	17.0	11.4
Avg MinT during 2001-2010	9.9	12.6	17.5	21.4	23.0	24.7	25.3	25.3	24.7	22.3	16.7	12.1
Avg MinT during 2011- 2020	9.9	12.4	17.2	21.0	23.1	25.1	25.6	25.5	25.1	22.6	16.2	12.1

Fig. 2.13. Long-term trend of monthly maximum and minimum temperatures in Moulvibazar, Habiganj and part of Kishoreganj including haors (Source: BARC 2022)

of declining rapidly both in terms of quantity and quality. The Ramsar Convention on Wetlands, in a 2018 report titled "Global Wetland Outlook: State of the World's Wetlands and their Services to People", claimed that globally, the wetlands are disappearing three times faster than forests, with 35% of the world's wetlands lost since 1970. This trend is, without any doubt, alarming. Bangladesh is well known as a riverine country with vast areas of low-lying land including haors. These wetlands can help stabilize emissions of greenhouse gas (GHG) and cope with climate change impacts in a number of ways. Moreover, the wetlands also have economic importance, providing livelihood opportunities to millions of people living in the areas. But, alarmingly, the wetlands of Bangladesh are at risk of disappearing as the ecology of our wetlands is under constant threat. The Bangladesh Delta Plan 2100 identified only means of livelihood for most of the people living there and an important contributor to food security. In the context of climate change and increased risk of disaster, conservation of the wetlands is no less important for Bangladesh than achieving the goals of the Paris Agreement and the 2030 Agenda for Sustainable Development.

2.2.3 Water regime

The haor region lies in the Meghna basin which is a part of the Ganges-Brahmaputra-Meghna (GBM) basins. Flow from about 66,640 km^2 of the Meghna basin is drained ultimately into the Bay of Bengal through the Kalni-Kushiyara and Surma-Baulai river systems. Of this area 35%, or 23,137 km^2, lies in Bangladesh. The estimated outflow of water from this region into the Bay amounts on average is 162,619 million m^3/year. Fifty seven percentage of this flow is generated at the upstream outside of Bangladesh while 43% is generated within the country (BHWDB 2012).

The wetland ecosystem ranges from perennial aquatic lowlands to seasonally dry uplands. The haors expand and shrink in an annual cycle, as there are major variations in rainfall from summer to spring. Rainfall is the minimum during winter and spring and by March, water from the lowlands and lakes is drained down to the lowest levels everywhere. In April, the thunderstorms start and the lowlands start to get filled at places again. Rainfall for consecutive days in this period swells the water bodies upstream. Transboundary flow from India is 70%, 60%, 37% and 80% of total flow in pre-monsoon, monsoon, post-monsoon and dry seasons, respectively. This inflow (mainly pre-monsoon flow) from India into Bangladesh is the main cause of flash floods in the haor areas. As the average ground level in the haor areas is very low, the flash floods fill the lowlands (Fig. 2.14) and inundates crop fields of vast areas, inflicting huge damage to the nation almost every year.

Building low-elevation submersible embankments along the riverbanks with drainage outlets is the commonly applied method in the haor areas. Sudden runoff water from rainfall can be drained out through these outlets, but the drainage outlets fail during an onrush of floodwater at the advent of summer.

As a result, Boro rice, the main standing crop at the stage of maturity becomes submerged to depths of 3-6 m of flash flood water within a few days.

Fig. 2.14. Flash flood in a haor area

Flash floods

Flash floods overtop the submersible embankments of the haor areas, and inundate crop fields in vast areas inflicting huge damage to the nation almost every year.

Flash floods generally occur in haor areas first in April and then in June depending on water rushing in from India. Unseasonal flash floods from hilly areas may also hit the haors 2-3 times a year, first in March, second in mid-April and the third, massive one, in May/June. The flood waters may remain stagnant due to poor drainage. Water coming in from the Mona, Jhuri and Kushiara rivers and water from canals of hill slopes may cause flash floods submerging lands for several days. Vigorous growth of *kalmi* and water hyacinth in the rivers and canals in plain land hinders drainage. A severe flash flood started in March coupled with heavy rainfall for a period of 3-4 days, which continued up to November in 2017. In Moulvibazar, flash floods occurred in May 2011, April 2012, March 2013, April-May in 2015, in early April 2016 and March 2017.

Damage of agriculture/vegetable crops is caused mainly by high rainfall/flash floods. Due to flash floods, siltation with sand changes soil texture and structure. Erosion of hills also causes deposition of sands in the rivers and canals reducing water area and aggravating drainage problems. Due to inundation, crop planting is delayed and cropping intensity is affected. At least 10-30 % crop loss occurs every year due to flash floods. Homestead vegetables and Boro rice were fully damaged while 60% Aus rice (summer rice) and 45% T. Aman rice (monsoon rice) were damaged due to floods in 2017. Disease and pest attacks were also severe. Low temperature and dense fog in the winter season (mid- December to mid-January) damage standing vegetable crops due to chilling injury, increase in disease infestation and pest attack. Prolonged floods also affect poultry and livestock causing animal health problems and death due to scarcity of feed and increased incidence of diseases. Goats are very sensitive to water borne diseases. Chicken mortality increases in damp weather. Due to flooded and wet conditions, poultry birds are kept in a polluted home environment which increases disease incidences. During flooding, there is no dry place for scavenging birds, which causes shortage of natural feed and reduces body weight due to malnutrition.

During floods ponds are flooded and consequently fingerlings/fish are washed away. In some cases, pond dykes are broken due to surface runoff induced by heavy rainfall and fish are also lost through these broken dykes. Mortality especially of SIS (Small Indigenous Species) as well as big fish due to toxins produced in floodwater from decomposition of rice plants or other organic debris may become quite a big problem. Effluents carried by the flash flood water may fill the wetlands and damage fish habitats.

In addition to climate change effects, human activities aggravate the flash flood and water stagnation situations. Among the human actions, changing of river flow by narrowing down the width of the rivers by illegal occupation, erecting of bamboo fences in the rivers for harvesting open water fish, unplanned and unscientific extraction of sand from the river beds, obstructing drainage passages by unplanned construction of rural roads, culverts with inadequate span etc. are responsible for the increasing frequency and intensity of the flash floods. Unless urgent actions are taken, climate change and human interventions will undermine efforts to ensure food security and livelihood improvement in the haor region. Thus, immediate actions with innovative approaches to climate change adaptation and community resilience are of utmost importance for the haor region.

2.2.4 Biodiversity

Flora

The natural vegetation in the haor areas comprises mainly such flora as they can survive in continued or intermittent submergence (Fig. 2.15). Submerged plants found in the haors are *panikola, ghechu*, etc. Examples of floating plants are water hyacinth, *kuripana* and rooted floating plants are *shapla, panifol, makhna*. Grasses such as, *binna, khag, nolkhagra* and swamp forest plants like *hijol, koroch, barun* etc. are found in the haor areas. There are also hill forests, social forests, fresh water swamp forests, reed lands, *murta* and cane bush, bamboo groves and homestead vegetation etc. Each type is an aggregated assemblage of particular plant species, and is a characteristic vegetation of a particular set of environmental conditions (hydro-period, flow regime, water quality and soil). In addition, 1308 ha of land and 145 km of strip area are being planted each year in the haor region, amounting to about 1% of the land. Such strip plantation includes trees like bamboo, cane, *murta, shegun*, agar, etc.

Fauna

The most significant wetlands in the haor region are Hakaluki Haor, Tanguar Haor, Hail Haor, Matian Haor, Pasuar Beel Haor, Dekar Haor, Baro Haor, Gurmar Haor, Sonamorol Haor, Baram Haor, Kalnar Haor, Kauadighi Haor, and Pagnar Haor. These wetlands have a rich wildlife community including 257 bird species, 40 reptile species, 29 mammal species 9 amphibian species (BHWDB 2012). Haors such as, Tanguar Haor, Pasuar Beel, Gurmer Haor, Hakaluki Haor, Hail Haor, Khaliajuri, Bara Haor, Kawadighi Haor, and Balai Haor are famous worldwide as a habitat for migratory birds.

Fig. 2.15. Natural vegetation in a haor

In the past, the haors, *baors* and *beels* were full of fish and other aquatic organisms, but increasing human population greatly disturbed biodiversity, lands have been drained for rice cultivation. Embankments have been built to check inundation of crops by early floods. This resulted in loss of birds, fish and other aquatic wildlife. The major threats to the wetland birds are agricultural development, wetland reclamation, and clearing of vegetation, planting of alien species, water bird hunting and poaching. Some rare birds and aquatic species have become almost extinct. The Bangladesh government has given due importance to haors and wetlands in its National Water Policy 1999 (as stated in article 4.9) and is committed to reviving the environmental balance that was lost. During Flood Action Plan (FAP 6), two ornithology surveys were conducted in February-March 1992 and April-May of 1992 for the northeastern haor areas. It was found that, only two sites, the Tanguar Haor and the Hakaluki Haor, supported more than 20,000 waterfowls. The Department of Environment (DoE) declared the Hakaluki Haor as Environmentally Critical Area (ECA) in 2000, to protect its biodiversity.

2.2.5 Mineral Resourses

Various types of mineral and energy resources are found in the haor area. The mineral resources discovered here are natural gas, crude oil, limestone, white clay, glass sand, peat, coal and gravel and sand as construction materials. A projection has been made based on the daily gas production and total remaining reserve of the different wells in haor districts. Up to 2010, the cumulative gas production from gas wells in the haor districts was 8,095 billion cubic feet (BCF) and the remaining reserve is 8,717 BCF (BHWDB 2012).

2.3 Demographic features

2.3.1 Population

According to the population census of 2011 (BBS 2011), the haor areas were home to a total of 14.52 million people (Table 2.6) constituting 81.3% of the total population of the seven haor districts (17.87 million). Out of the total population in haor areas, 50.5% were female. One hundred percent of the of populations of Sunamganj and Sylhet districts and more than 80% of the populations of Habiganj, Moulvibazar and Kishoreganj districts were haor inhabitants. Overall, the haor people represent 10.1% of the total population of Bangladesh indicating that one-tenth of the national population is threatened by risks and vulnerabilities associated with haor/wetland conditions. Thus, the haor region in terms of both area (as stated earlier) and population merits serious consideration of researchers, development workers, planners and policy makers for developing and implementing risk mitigation measures.

Table 2.6. Populations in the seven northeastern districts and haor areas

District	Total population (million)			Population in haor upazilas (million)				
	Total	Male	Female	Total	Male	Female	% of total district population	% of national population
Sunamganj	2.47	1.24	1.23	2.47	1.24	1.23	100	1.7
Sylhet	3.43	1.73	1.70	3.43	1.73	1.70	100	2.4
Habiganj	2.09	1.03	1.06	1.79	0.88	0.91	85.6	1.2
Moulvibazar	1.91	0.94	0.97	1.66	0.82	0.84	86.9	1.2
Netrakona	2.22	1.11	1.11	1.32	0.66	0.66	59.5	0.9
Kishoreganj	2.91	1.43	1.48	2.48	1.22	1.26	85.1	1.7
Brahmanbaria	2.84	1.37	1.47	1.19	0.57	0.62	41.6	0.8
Total	17.87	8.85	9.02	14.53	7.20	7.33	81.3	10.1

Source: BBS 2011

2.3.2 Socioeconomic situation

Challenges arising from unique topographic and hydrologic features of the haor ecosystem are the day to day realities for the haor people. Flashflood is a major disaster in the haor areas threatening the lives and livelihoods of the inhabitants. Besides, siltation and sedimentation of major rivers, river bank erosion, impeded navigability, degradation of the ecosystem etc. adversely affect the haor people. Human interventions and failings like indiscriminate exploitation of natural vegetation and fisheries resources, lack of proper sanitation, scarcity of drinking water, fragile and inadequate road network, illiteracy, poverty, inadequate health facilities and inadequate operation and maintenance of the existing infrastructure etc. are critical socioeconomic issues in haor areas (CEGIS 2012). Land inundation for six to seven months from June to November of the year almost confines haor people to their small homes, limits their mobility, and practically eliminates the possibility of finding jobs.

The haor is a region generally considered to have lagged behind the overall progress of national development in Bangladesh in terms of various key indicators of social and economic development. For example, the overall poverty head count rates (HCR) for the division of Sylhet which range from 0.319 – 0.337 are only slightly higher than the HCR of 0.319 for Dhaka division, and are markedly lower than the rates reported for the western divisions of Khulna, Rajshahi and Barishal. There are pronounced variations in the prevalence of poverty and extreme poverty within the haor region (Gillingham 2016). Most of the upazilas in the districts of Sunamganj and Habiganj reported markedly higher HCRs of 0.45 – 0.55 than upazilas in other districts of the haor region. The region also experiences widespread problems of food insecurity due to a combination of factors which includes: crop losses due to early or flash floods and erosion; poor access to markets, especially during the flood season; and isolation from traders and services. In terms of social indicators the Haor region is characterized by notably low rates of literacy (51% of the total population compared with the national rate of 57.9%). A high incidence of water borne diseases, and very poor indicators of maternal and child nutrition and health add to the haor people's woes. Overall, the Haor region remains a part of Bangladesh where natural shocks, seasonal food insecurity and patterns of socio-economic and political exploitation create conditions of extreme and widespread vulnerability for a significant proportion of the population for long periods of the year. The region is also considered to be highly vulnerable to climate change impacts due to its unique physical setting and hydrology. Women and girls in the haor region are particularly vulnerable due to access to healthcare and education facilities. Households are also disproportionately vulnerable to adverse climate change because they tend to live at margins of *haati* which are most likely to be affected by erosion, have limited assets or food stocks to fall back on in the event of harvest losses due to flash floods and have few alternative livelihood opportunities to engage in during the flood season.

A vast majority of people are either landless or have only some homestead land. About 39.2% of the *haor* farmers practice a crop-livestock-fish farming system. The differences in the productivity of crop farming and poultry rearing between *haor* areas and the main land were found to be statistically significant. Remarkable differences between *haor* areas and the main land in terms of quantity and price of inputs and outputs are noticed. A favorable farming environment and proper utilization of agricultural resources are the major strengths, but a weak marketing system and lack of access to agricultural credit are the major bottlenecks for agricultural development in the *haor* areas of Bangladesh (Uddin et al. 2019). People in haors face burdens in transport costs, they have to communicate through water travels for 7 to 8 months usually in haors. Time consuming transportation, restricted access to social services, detachment from social networks (IUCN 2011) are some of the other general problems the haor people face.

2.4 Agricultural systems

2.4.1 Land use patterns

Table 2.7. Land use pattern in haor areas in 2022

Land Use	Area (ha)	% of total area
Floodplain agricultural land	780,328	89.4
Perennial *beels* and *baors*	32,203	3.7
Herb dominated area	22,764	2.6
Ponds	271	0.03
Fresh water aquaculture	3,059	0.4
Swamp reed land	12,910	1.5
Others	21,559	2.5
Total	873093	-

Source: BARC 2022

The seven haor districts comprise a region of 16,51,992 ha with a net agricultural land of about 780,328 ha (Fig. 2.16). Agricultural lands in the haor areas account for 47% of the total haor district areas and constitute 8.9% of the total agricultural land area in Bangladesh (BBS 2020). The floodplain agricultural lands dominate the other land use types due to its major share in area, of 89.4% across the seven haor districts. Perennial beels/baors and herb dominated areas account for only 3.7% and 2.6%, respectively (Table 2.7).

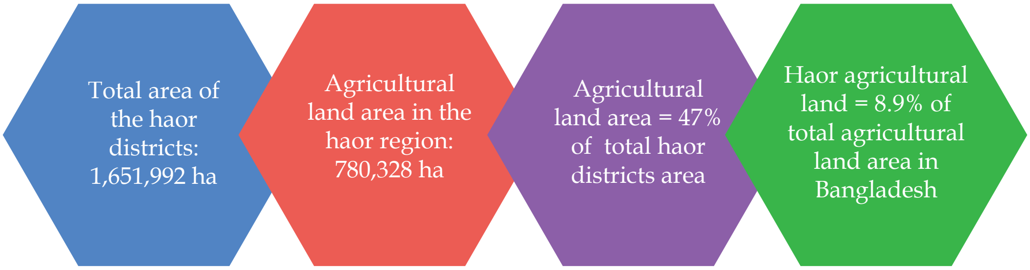


Fig. 2.16. Agricultural land area in the haor region (Source: BARC 2022)

Among the seven districts, the largest area of agricultural land (257,507 ha) is available in the haor areas of Sunamganj, accounting for 70% of the total area of the district (Fig. 2.17). Considering the importance of productivity gains in haor areas, Kishoreganj haor areas follows Sunamganj in terms of proportion of agricultural land (61%) and next to this, Habiganj, Sylhet and Netrakona have substantial areas of agricultural land in their haor areas ranging from 41-53% of the total areas. However, in Moulvibazar, agricultural lands account for only 17% (39,205 ha) of the total area of the district. The crop cover is the maximum in the haor areas during the dry season, when the water bodies shrink. In the wet season, the crop cover decreases when the water bodies swell up.

The wetlands are unique and dynamic ecosystems, which have immense productive and ecological value e.g., storage of rainfall-runoff, groundwater recharge etc. These wetlands provide habitats for fish, wildlife, aquatic plants and animals, resort to migratory birds, support biodiversity, plant based socioeconomic activities, fishing and recreation. Haor area can be altered by forces other than anthropogenic. Natural events such as weather, flooding, climate fluctuations, and ecosystem dynamics may also initiate modifications of the land cover of haor areas. Human/natural modifications of land cover in haor areas have largely resulted in deforestation, biodiversity loss, global warming and increased incidences of natural disasters (Mas et al. 2004). Changes in both human-induced and natural land cover can influence the terrestrial ecosystem (Houghton 1994), biodiversity (Sala et al 2000) and landscape ecology (Reid and Landsberg 2000). In addition, it reflects impacts of human interventions on the environment at temporal and spatial scales. Therefore, accurate and up-to-date land use/cover information is essential for environmental planning (Muttitanon and Tripathi 2005) and to achieve sustainable development. Land cover changes modify the reflectance of the land surface, determining the fraction of the sun's energy absorbed by the

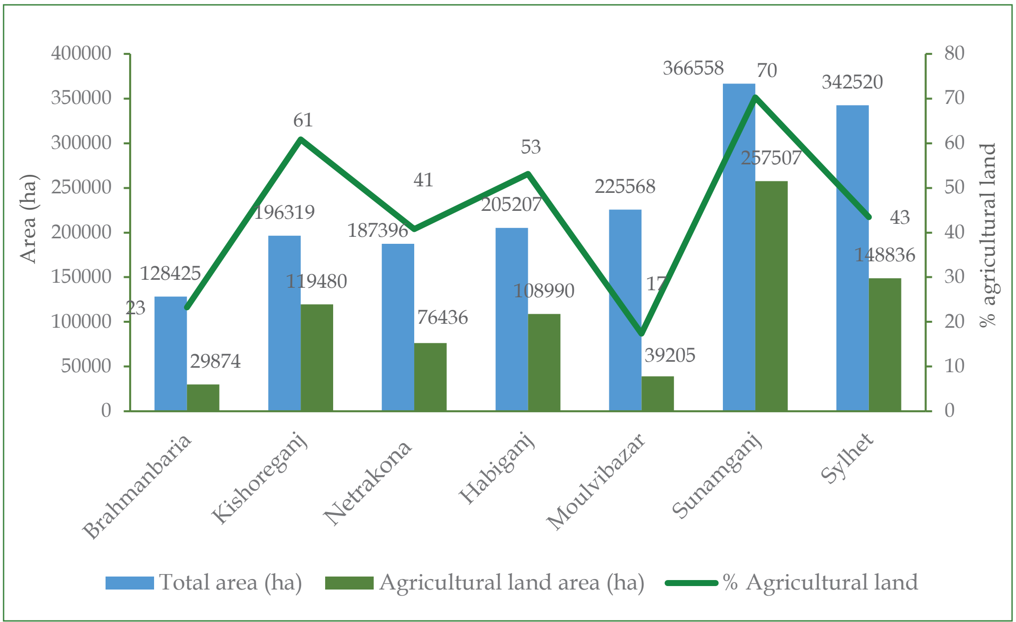


Fig. 2.17. Total area (ha), agricultural land area (ha) and % agricultural land in haor region by district in 2022 (Source: BARC 2022)

surface and thus affecting heat and moisture fluxes. These processes also alter vegetation transpiration and surface hydrology and determine the partitioning of surface heat into latent and sensible heat fluxes. Land cover changes also contribute to increasing the risk of flash floods in the haor region. The early flash floods of April 2017 in the northeast have been the worst of its kind in the history of floods in the country. Landless and marginal farmers in particular are affected by such natural calamities.

Usually only one field crop, Boro rice, is grown annually in the haor area, cultivated during the winter season. In the seven haor districts the largest agricultural land area (586,012 ha) is under single cropping (Table 2.8) followed by double cropped area (567,800 ha) out of the net cropped area (1,323,805 ha). Overall in Bangladesh, double cropping has the largest coverage (4,127,126 ha) out of the net cropped area of 8,106,478 ha (Table 2.8). The predominance of single cropping in the haor districts is primarily due to the occurrence of wetlands/floodplains that prevent growing of crops during the rainy season.

Cropping intensity in Sunamganj is the lowest (137%) due to a large single cropped area (Table 2.8). On the contrary, the double cropped area is the highest (with lowest triple cropped area) in Kishoreganj that led to the highest cropping intensity (187%) among the haor districts. Overall the cropping intensity in seven haor districts is 169%, which is lower than the national average cropping intensity of 197% (Table 2.8).

Table 2.8. Land use by number of crops grown per year in haor districts in 2020

District	Area under cropping (ha)				Cropping intensity(%)
	Single cropped	Double cropped	Triple cropped	Net cropped	
Brahmanbaria	45865	75495	10360	131720	173
Kishoreganj	107412	47928	56358	211698	176
Netrakona	56949	130674	29560	217183	187
Habiganj	103113	53989	32120	189222	162
Moulvibazar	43555	66939	17887	128381	180
Sunamganj	174495	64636	14725	253856	137
Sylhet	54623	128139	8983	191745	176
Haor districts	586012	567800	169993	1323805	169
Bangladesh	2111741	4127126	1867611	8106478	197

Source: BBS 2020

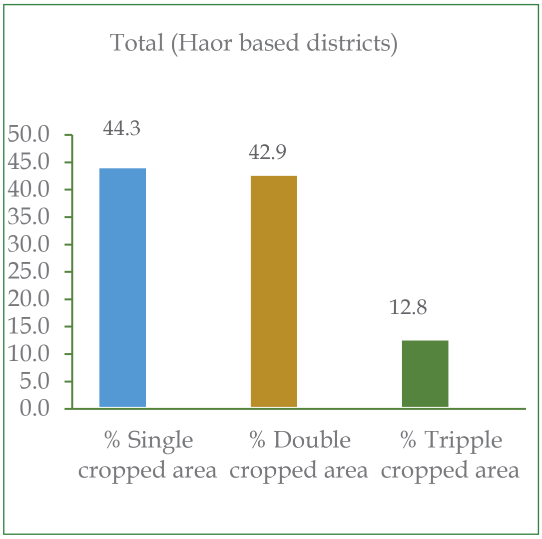


Fig. 2.18. Status of land use for cropping in haor districts (Source: DAE 2022)

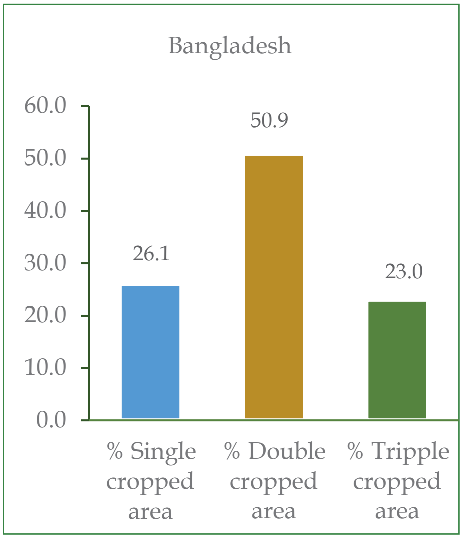


Fig. 2.19. Status of land use for cropping in Bangladesh (Source: BBS 2020)

In the Bangladesh context, the haor region has the highest proportion of single cropped area (44.3%) compared with the national average of 26.1% (Figs. 2.18 and 2.19). Besides, there are 42.9% double cropped area and 12.8% triple cropped area in the haor districts. This poor land utilization may be due to the excess water in the floodplains that does not permit cultivation of two or three crops a year in this region.

Among the haor districts, the proportion of single cropped area is the highest (69%) in Sunamganj (Fig. 2.20) followed by Habiganj (54%) and Kishoreganj (51%). Sylhet has the highest proportion of double cropped area (67%) followed by Netrakona (60%), Brahmanbaria (57%) and Moulvibazar (52%).

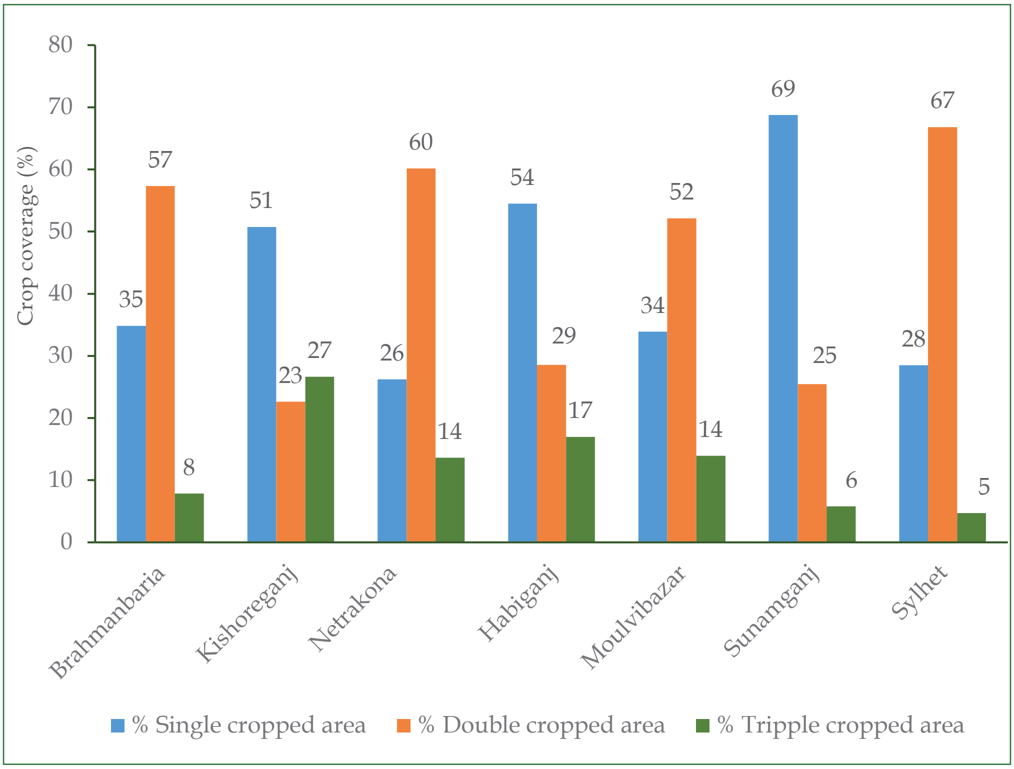


Fig. 2.20. Status of cropping in haor districts in 2020

> Vast opportunities still exist in all the haor districts, where the remaining fallow land (123,482 ha) i.e., 14% of the haor area (873,524 ha) can be brought under cultivation of at least a single crop during the winter season.

The single cropped area has increased from 24% in 2007 to 44% in 2021 averaged over all the haor districts (Fig. 2.21). This increase may be attributed to bringing wetlands under single cropping by 2021, which remained otherwise uncultivated round the year during 2007. Among the seven haor districts, the highest increase in single cropping has occurred in Kishoreganj (14% in 2007 vs 51% in 2021) followed by Habiganj (27% in 2007 vs 54% in 2021) and Brahmanbaria (18% vs 35%). There has been no change at all in Sylhet (28% during both 2007 and 2021). It is interesting to note that, almost half (42%) of the fallow area in the region vanished in 7 years from 2013 to 2020, the total fallow land area of 212,145 ha in 2013 having declined to 123,482 ha in 2020 (Table 2.9). This means that 88,663 ha of fallow land were brought under cultivation during 2013 through 2020, which eventually resulted in an increase in the single cropped area in the haor region. The deceasing trend was noticed in all the haor districts ranging from 12-56% between 2013 and 2020 except in Netrakona which experienced an increase in fallow land area by 52% from 13,360 ha. The largest decrease in fallow land (56%) happened in Sylhet followed by that in Sunamganj (53%) while the smallest was in Brahmanbaria (only 12%). It also implies that there is enough scope of increasing the rice area and thus increasing rice cropping intensity in the haor region. These areas usually remain under-utilized with quite low cropping intensity (Jabber and Alam 1993). It has become imperative to exploit the crop production potentiality of the large haor areas.

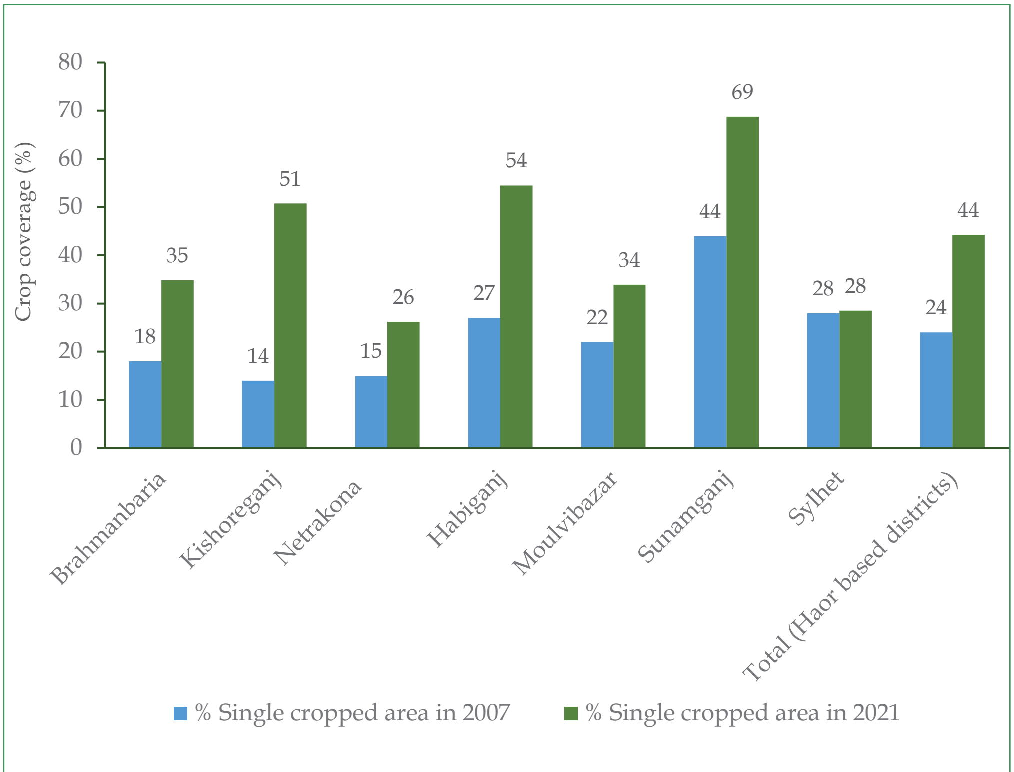


Fig. 2.21. Changes in single cropping situation in the haor districts
(Source: DAE 2007, DAE 2022)

Table 2.9. Decrease in fallow land in the haor districts

District	Fallow land area (ha)		% decrease/ increase
	2013	2020	
Brahmanbaria	13360	11741	-12
Kishoreganj	23481	12551	-47
Netrokona	13360	20243	+52
Habiganj	26316	14170	-46
Moulvibazar	32794	18219	-44
Sunamganj	59109	27530	-53
Sylhet	43725	19028	-56
Total (haor districts)	212145	123482	-42

Source: BBS 2015, 2020

2.4.2 Crops and cropping patterns

In the past traditional deep water rice (DWR) (broadcast Aman rice, grown during the entire Kharif period) used to be the major crop in the haor and other deep flooded low land areas of Bangladesh. Local DWR varieties such as, Baisbish, Gabura, Gutak, Lalkani etc. used to be grown. With the development of modern varieties (MV) of Aus and Boro rice and improved production practices, however, the traditional DWR began to give way to Aus and Boro MVs, and at present DWR acreage is negligible in the haor areas. Today, rainfed upland Aus rice grows on the higher patches of the landscape while transplanted Aman (T. Aman) grows on the fringes of the marshes, subject to inundation during floods in haor areas. The beds of the low-lying areas and the marshes in the the haor region receive organic deposits and are very rich in fertility. Boro rice is cultivated in the winter in the knee-height water of marshlands. Draining the low-lying marshes and reclaiming lands for crop cultivation has brought in opportunities of cultivating Boro rice in larger areas. Irrigation is provided to Boro rice by both groundwater lifting and surface water pumping from the adjacent channels. The problem is if transplanting starts late, the Boro rice may face flash floods at the start of summer. Farmers prefer modern varieties to local varieties of rice.

Rice-based agriculture is dominant in the haor region. Other crops like potato, groundnut, sweet potato, mustard and pulses are grown in the Rabi season to a small extent. In Sunamganj and Kishoreganj, more than 80% of the total cropped area was under the Boro-Fallow-Fallow cropping pattern in 2007 (Table 2.10). The other haor districts were also dominated by the Boro-Fallow-Fallow cropping pattern in 2007 ranging from 60-78% of the total cropped areas. In 2022, Boro-Fallow-Fallow is still the dominant cropping pattern in the haor areas. Boro-Fallow-T.aman is the second most prevalent croppingpattern indicating an improvement of the cropping intensity over a

15-year period from 2007 (Table 2.10). Boro-Fallow-Fallow is a cropping pattern where crops are grown only in the Rabi season (Nov-April) and land remains uncultivated during the Aus (April-July) and T. Aman (July-Nov) seasons. In the haor region some T. Aus and T. Aman rice are grown on relatively elevated lands by the side of a haor. The Boro-Fallow-Fallow is the dominant cropping pattern with the highest coverage (39.64%) in 36 upazilas out of 38 upazilas in the Sylhet region (including haor areas) followed by the second dominant pattern Boro-Fallow-T. Aman occupying 15.74% of net cropped area (Muttaleb et al. 2017). The rice-based cropping pattern is dominant because in the lowland ecosystem recession of flood water is usually delayed which does not permit timely establishment of non-rice upland crops.

Table 2.10. Changes in major cropping patterns in the haor areas

District	Major cropping pattern	
	2007	2022
Brahmanbaria	Boro-Fallow-Fallow (72) Fallow-B.Aman-Fallow (6) Boro-Fallow-T. Aman (5)	Boro-Fallow-Fallow Boro-Fallow-T. Aman Boro-B. Aman-Fallow
Kishoreganj	Boro-Fallow-Fallow (82) Wheat-Fallow-Fallow (3) Groundnut-Fallow-Fallow (2)	Boro-Fallow-Fallow Boro-Fallow-T. Aman Boro-Jute-Fallow
Netrokona	Boro-Fallow-Fallow (78) Mustard-Fallow-Fallow (6) Boro-Fallow-T. Aman (9)	Boro-Fallow-Fallow Mustard/Boro-Fallow-T. Aman Fallow-Jute-T. Aman
Habiganj	Boro-Fallow-Fallow (68) B.Aman-Fallow-Fallow (12) Boro-B. Aman-Fallow (8)	Boro-Fallow-Fallow Boro-Fallow-T. Aman Vegetable-Fallow-T. Aman
Moulvibazar	Boro-Fallow-Fallow (64) Fallow-B. Aman-Fallow (18) Fallow-Aus-T. Aman (7)	Boro-Fallow-Fallow Boro-Fallow-T. Aman Vegetable-Fallow-T. Aman
Sunamganj	Boro-Fallow-Fallow (86) Fallow-B. Aman-Fallow (2) Wheat-Fallow-Fallow (2)	Boro-Fallow-Fallow Boro-Fallow-T. Aman Vegetable-Fallow-T. Aman
Sylhet	Boro-Fallow-Fallow (60) Fallow-B. Aman-Fallow (21) Fallow-Fallow-T. Aman (4)	Boro-Fallow-Fallow Boro-Fallow-T. Aman Vegetable-Fallow-T. Aman

Figures in the parentheses indicate percent of the total area of the patterns
(Source: DAE 2007, DAE 2022)

In the haor areas, homesteads serve as potential sites for growing assorted vegetables during Rabi and Kharif-1 seasons. The major vegetable cropping patterns in the homesteads of the haor areas is shown in Table 2.11. The Vegetable-Vegetable-Fallow cropping pattern cover 5,395 ha in the Sylhet region while the Vegetable-Vegetable-Vegetable pattern is practiced in 5,890 ha (BRRI 2017).

Table 2.11. Vegetable cropping patterns in the homestead areas of haor region

Spot	Cropping patterns with vegetables homesteads in the haor region		
Open/sunny land	Kharif-I (April to June)	Kharif-II (July to October)	Rabi (November to March)
Bed 1	Kangkong (LP-1)	-	Spinach (Shathi)
Bed 2	Indian spinach (Madhuri)	-	Red amaranth (Altapati)
Bed 3	Red amaranth (Lalita)	-	Carrot (New Kuroda)
Bed 4	Green amaranth (Panna)	-	Kangkong (LP-1)
Roof/fence/trellis	Sweet gourd (Baromashi)/snake gourd/ridge gourd/long bean	-	Country bean (Goal Gatha)/ bottle gourd (BARI Lau/Khet Lau)

Source: DAE 2022

In the haor region, there are lands which are comparatively high and locally known as *kanda* comprising 10-40% of the haor area, varying from haor to haor. Usually, recession of flood water from raised *kanda* lands is faster and the lands become ready for agricultural activity 30 to 45 days ahead of the low lands. Again, inundation of raised *kanda* lands by flash flood water is delayed and the standing crops can avert damage. Unfortunately, most *kanda* lands are kept fallow throughout the year. The only difficulty of cultivation in *kanda* is lack of irrigation facilities (CCC 2009, Islam 2010). There is a good opportunity of intensifying cultivation on *kanda* lands of haor areas by ensuring timely irrigation.

The total area under Boro rice in the haor areas of the seven northeastern districts is about 475,188 ha (Fig. 2.22) which stands at 54% of the total area of the haor districts (873,524 ha) and 9.9% of the total Boro area of Bangladesh (4,764,372 ha). It is noteworthy that 100% haor area i.e., 98,478 ha of Kishoreganj is devoted to Boro cultivation followed by 78% haor area of Brahmanbaria, 63% of Netrakona, 57% of Sunamganj and 52% of Moulvibazar and the smallest area under Boro is in the haor areas of Sylhet (Fig. 2.23). As mentioned above, Boro rice still remains vulnerable to elements of nature like flash floods and low temperature. Added to this is a socioeconomic risk, i.e., scarcity of labor during harvest. Farmers in the haor areas generally employ a large number of migrant labor to expedite rice harvesting with a view to escaping unexpected crop loss due to flash floods. The availability of harvester machines would be a big respite for the haor farmers.

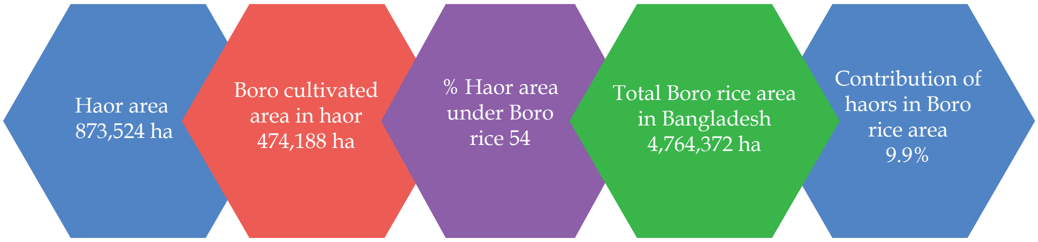


Fig. 2.22. Boro rice area in the haor region relative to the total Boro rice area in Bangladesh (Source: BARC 2022, BBS 2020, DAE 2022)

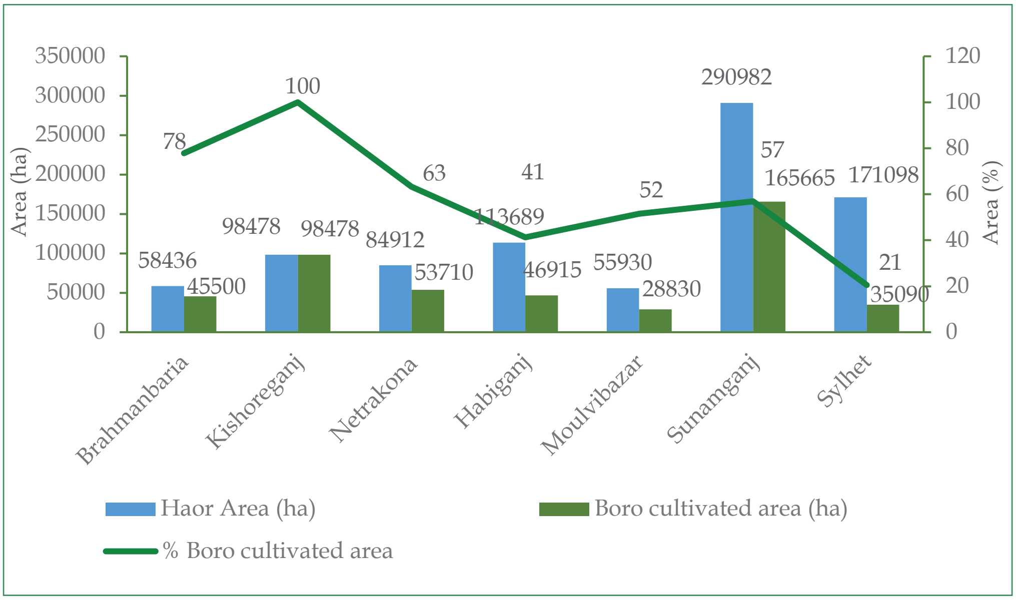


Fig. 2.23. Status of Boro rice cultivation in the haor region in 2020

2.4.3 Livestock and poultry

Livestock is an important part of Bangladesh's agricultural economy, contributing to food and nutrition security for the populace, generating incomes for the rural households, supplying manure to enhance soil fertility, etc. Cattle, buffaloes, goats, sheep, chickens, and ducks are the most popular livestock (Alam et al. 2010, Aziz et al. 2021) in the haor region. In 2019, the total livestock and poultry head counts in the haor areas were 37.33 million accounting for 9.3% of the total counts of livestock and poultry (402.5 million) in Bangladesh (Fig. 2.24). Ducks in the haor areas accounted for more than a quarter of the country's total duck population.

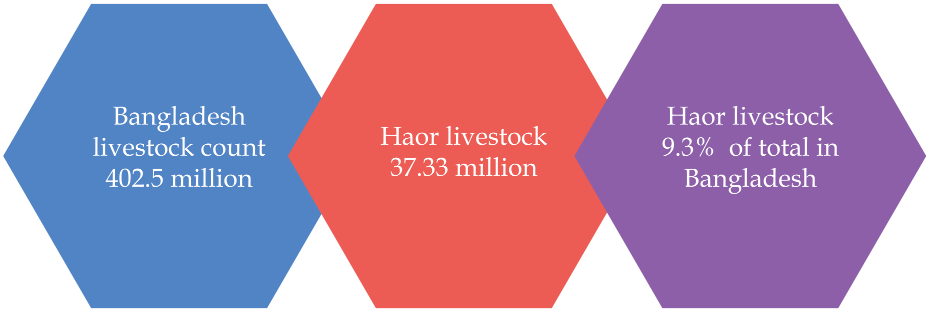


Fig. 2.24. Livestock heads in the haor region and in Bangladesh overall
(BBS 2020)

In the haor areas, between 2010 and 2019, the populations of cattle, buffalo and goat declined from 5.01 to 3.74 million, 0.3-0.127 million and 1.28-0.973 million which amounted to 25%, 58% and 24% decreases, respectively (Table 2.12). However, the sheep population increased by 67% from 0.19 million in 2010 to 0.318 million in 2019. The cattle population decreased in all the haor districts between 2010 and 2019 except in Sylhet where an increase from 0.86 to 1.04 million occurred. The goat population also decreased in the haor districts except in Habiganj, Moulvibazar and Sylhet where goat head counts increased by 30%, 12% and 43%.

Table 2.12. Changes in livestock population (in million heads) in the haor region

District	Cattle		Buffalo		Goat		Sheep	
	2010	2019	2010	2019	2010	2019	2010	2019
Brahmanbaria	0.48	0.14	0.01	0.006	0.11	0.006	0.02	0.031
Kishoreganj	0.67	0.58	0.03	0.005	0.30	0.132	0.03	0.015
Netrakona	0.60	0.36	0.01	0.001	0.23	0.129	0.01	0.013
Habiganj	0.52	0.38	0.01	0.004	0.14	0.182	0.03	0.004
Moulvibazar	0.53	0.50	0.15	0.030	0.13	0.146	0.01	0.026
Sunamganj	1.35	0.74	0.03	0.021	0.21	0.150	0.04	0.142
Sylhet	0.86	1.04	0.06	0.060	0.16	0.228	0.05	0.088
Total (haor area)	5.01	3.74	0.3	0.127	1.28	0.973	0.19	0.318
Bangladesh Total	22.9	24.2	1.26	1.48	21.56	26.27	2.78	3.54
% of Bangladesh total	21.9	15.5	23.8	8.6	5.9	3.7	6.8	9.0

Source: BBS 2012, 2020

The livestock numbers have decreased alarmingly. One of the reasons for this is the continual shrinking of pastures. On the other hand, the usefulness of cattle in farm operations has diminished, farmers now can hire machines for tillage and post-harvest operations. With human population growth, homesteads are becoming smaller inhibiting livestock rearing, and also, farmers are often forced to sell livestock during crisis of cash.

Livestock farming is recognized as an informal financial institution based on mutual benefit or interest. To the poor haor households, this arrangement reduces financial burdens and provides opportunities (e.g., accessibility to informal sources, increase in social capital, extra income from milk and dry cowdung) during difficult times. In this institutional arrangement, the farmer takes care of another person's livestock (cows, goats and poultry) in his/her homestead. Although the farmer is solely responsible for all associated costs, at the end of the contract, either annually or seasonally, the offspring or added value have to be shared by both parties. Such share contracts vary with different livestock species although a standard format exists for each species. In shared undertakings such as livestock rearing where working capital is required, first the extremely poor and then the moderately poor relatives and neighbors are given priority by the non-poor households to earn some money.

Table 2.13. Changes in poultry population (million heads) in the haor region

District	Poultry		Duck	
	2010	2019	2010	2019
Brahmanbaria	2.11	2.214	0.78	0.635
Kishoreganj	3.83	3.932	1.63	1.897
Netrakona	2.32	1.869	2.81	2.290
Habiganj	0.98	3.655	1.17	0.542
Moulvibazar	1.81	2.380	0.44	0.800
Sunamganj	1.17	3.669	1.97	2.730
Sylhet	3.94	4.252	0.95	1.309
Total (haor area)	16.16	21.970	9.75	10.203
Bangladesh total	212.47	289.28	39.84	57.75
% Bangladesh total	7.6	7.6	24.5	17.7

Source: BBS 2012, 2020

The poultry population has, by and large, increased in all the districts except Netrakona which showed a 19% decrease from 2.32 million in 2010 to 1.869 million in 2019 (Table 2.13). The duck population increased in Kishoreganj, Moulvibazar, Sunamganj and Sylhet while it has decreased in Brahmanbaria, Netrakona and Habiganj. In the haor area, poultry farming is limited to females who may also be involved in duck and livestock rearing. Children from poor households are employed in herding cattle but such labor inputs reduce average literacy rates. The homestead is a livestock production unit (Alam and Masum 2005) contributing income and nutrition to haor households. Share based livestock rearing is a social institution providing an additional extra income source for the poor; those with high social capital can more readily avail themselves of such opportunities.

2.4.4 Fisheries and aquaculture

The haor region of Bangladesh is blessed with great opportunities for fisheries and aquaculture. There are vast floodplains along with some perennial water bodies in the deeper portions of the haor basin which provide spawning, nursing and feeding grounds for a wide variety of finfish. This includes 143 indigenous and 12 exotic species along with several species of freshwater prawns during pre-monsoon, monsoon, post-monsoon and dry periods. Tanguar haor is home to roughly 141 fish species, including several rare introduced species, accounting for more than half of the country's freshwater fish species, according to different reports (Liong et al. 2000, Miah 2013). Large fish like major carp, large catfish, *chital*, Gangetic stingray, *gazar*, and *shol* and small fish such as, *air, gang magur, baim, tara baim, gutum, gulsha, tengra, titna, garia, beti, kakia* are some of the notable species of fish.

Table 2.14. Fish catch areas in the haor region in 2020

Area (ha)				
Bangladesh floodplain open water area	Haor area	Annual fish catch area	% haor area	% Bangladesh floodplain open water area
2,651,567	873,524	251,717	28.8	9.5

Source: BBS 2020

The haor region's total annual fish catch area in 2020 was about 251,717 ha, 28.8% of the total haor area (873,524 ha) and constitutes 9.5% of the total floodplain areas of Bangladesh (2,651,567 ha) (Table 2.14). Inland open water capture fisheries in haor areas is, therefore, important to the country’s overall economy.

The open-water fishery is a self-sustaining system although human interventions have significantly deteriorated its health and productivity in recent years. A small improvement in the average yield of inland open water capture fisheries in haor areas could significantly affect national fish production and consumption. Siltation and lowering water level are reducing the wintering habitat for indigenous fish species. Moreover, the floodplains came under pressure for conversion to crop fields, brick kilns and other infrastructures, resulting in an alarming decline in fish diversity and production.

Among the haor districts Sunamganj accounts for the highest annual fish catch area (64.9%) comprising 63,956 ha of its total haor area of 98,478 ha followed by Netrakona (47.4%) and Moulvibazar (43.3%) and Brahmanbaria (13.8%) (Fig. 2.25).

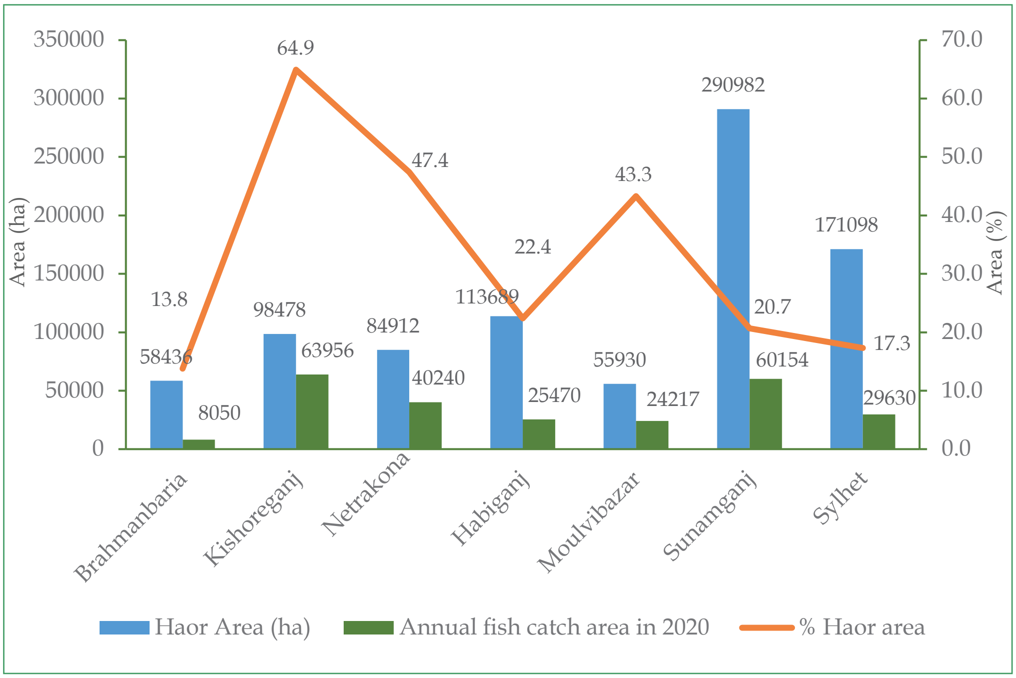


Fig. 2.25. Status of recent annual fish catch in the haor region by district in 2020
(Source: BBS 2020)

Open water fish catch area in haor region is reported to have increased by 10% from 228,823 ha in 2013 to 251,717 ha in 2020 (Table 2.15). On the contrary, total floodplain water area of Bangladesh has decreased by 1.63% during the same period. This indicates the important role the haor region plays in open water fish production in Bangladesh.

This growth in the open water fish catch area has been made possible by the use of motorized fishing boats, and more efficient fishing equipment. The development and promotion of these boats have been a contribution of the

Table 2.15. Changes in fish catch areas in the haor region

Fish catch domain	Fish catch area (ha)		
	Annual fish catch area in 2013	Annual fish catch area in 2020	% increase/ decrease
Haor districts	228823	251717	10
Bangladesh floodplain water area	2695529	2651567	-1.63

Source: BBS 2015, 2020

Bangladesh Fisheries Development Corporation (BFDC). Open water fisheries are major aquatic common property resources in Bangladesh. Compared to its total cultivable area, Bangladesh has a fairly large inland open water area for which, however, there is a general absence of reliable resource status information. There is no evidence that the comparison of the real status of resources and the exploitation rate has been made within the socio-economic context of the country, which is very important for policy makers to be able to assess the current practices.

2.4.5 Forestry

A forest is a space spanning more than 0.5 ha with trees higher than 5 meters and a canopy cover of more than 10% or trees able to reach these thresholds *in situ*. The haor basin is the only region in Bangladesh where remnant patches of freshwater swamps and reed lands still exist (Bennett et al. 1995). In the past extensive forests of *hijal* in the haor area used to be an important source of firewood, but these forests are now almost completely destroyed. In recent times, various herbs and aquatic plants are being collected for use as fuel. On top of that, aquatic plants are also being collected for use as fertilizers (Alam and Sazzad 2012). Only a few patches remain of the swamp forests that once dominated the area, featuring flood tolerant trees like *hijal (Barringtonia acutangula)* and *koroch (Pongamia pinnata)*. The *hijal* or *hual*, *korij* or *koroch*, *bhui dumur (Ficus heterophylla), nol (Arundo donax), khagra (Pharagmites karka), ban golap (Rosa involucratia)* and *barun (Crataeva nurvala)* are the main plant species found in the swamp forests of the haor region. All of them are flood-tolerant species and can survive in the submerged condition for extended periods of time. However, among these, *hijal, tamal* and *koroj* trees are of the greatest value to the people and the environment (Bennett et al. 1995). Other plant species available in the wetlands include *madar (Erythrina variegata), gab (Diospyros peregrina), makna (Euryale ferox), singara (Trapa bispinosa), jaldumur* (a kind of *Ficus*), *chitki* (*Phyllanthus reticulatus*), *thankuni* (*Centella asiatica*), *kalmi* (*Ipomoea aquatica*), *helencha* (*Enhydra flactuans*), *hogla* (*Typha elephantina*), duckweed, water hyacinth, lotus and water lily.

Only 4.37% (72,128 ha) of the total areas of the seven haor districts (1,651,992 ha) is covered by forest (Table 2.16) in comparison with the overall 17.78% forest area in Bangladesh. A country or any geographic area should have at least 25% forest cover to maintain a proper ecological balance, and thus, the haor area falls far behind it's threshold. Among the haor districts Moulvibazar has the highest forest cover (12.81%) with 28,900 ha of forest followed by Habiganj (7.17%) with 14,721 ha while the lowest forest cover, only 0.43% is in Netrakona (799 ha). Brahmanbaria and Kishoreganj have virtually no forest cover.

Table 2.16. Forests in the seven haor districts in 2020

District	Total area (ha)	Forest area (ha)	Forest cover (%)
Brahmanbaria	128425`	-	-
Kishoreganj	196319	-	-
Netrakona	187396	799	0.43
Habiganj	205207	14721	7.17
Moulvibazar	225568	28900	12.81
Sunamganj	366558	7292	1.99
Sylhet	342520	20416	5.96
Haor districts	1651992	72128	4.37
Bangladesh	14486269	2575196	17.78

Source: BBS 2020

Forest covers in the haor districts shrank from 77,922 ha in 2010 to 72,128 ha in 2020 amounting to a 7.44% decline with an average annual decrease of 0.67% over the decade (Table 2.17). All the haor districts experienced a decline in forest cover during this period except Netrakona that showed a 8.1% increase.

Table 2.17. Changes in forest cover over time in the haor region

District	Forest area (ha)		% increase/ decrease
	2010	2020	
Brahmanbaria	0	0	0.0
Kishoreganj	0	0	0.0
Netrakona	739	799	8.1
Habiganj	14955	14721	-1.6
Moulvibazar	31054	28900	-6.9
Sunamganj	7131	7292	2.3
Sylhet	24043	20416	-15.1
Haor districts	77922	72128	-7.44
Bangladesh	2598664	2575196	-0.90

Source: BBS 2012, 2020

To halt deforestation and expand the forest cover in the haor region, the Government decided to increase the extent of the Protected Area Network from 5% of total forest area to 10% (Forestry Sector Master Plan 1993-2012). The 1989 moratorium on tree felling to conserve the health of forests is still operational. The total forest land includes classified and unclassified state lands, homestead forests and tea and rubber gardens. But the forests are shrinking rapidly due to encroachments resulting from serious population pressure (Hossain and Hossain 2014). So, at the beginning of the management of these forests, the main objective was to replace these heterogeneous natural forests with the plantations of commercially valuable species (Hossain 1998).

2.5 Cross-cutting issues

2.5.1 Agricultural mechanization

For Boro rice, haor farmers prepare their land during mid-October, transplant seedlings during mid-December and harvest in mid-May. The power tiller is the machine exclusively used for tillage and land preparation. *Beels* are the main source of irrigation water in the haor areas and rivers are the second most important source. The other small scale irrigation sources are *khal* (canal), pond, and *dubas* (small depressions). Low lift pumps (LLP) and shallow tube wells (STW) are mostly used to pump water to irrigate the crop fields. Most of the farmers use 150-250 feet long plastic hoses for irrigation water delivery. In the low lands, water remains in the fields most of the time, so farmers do not use machines, rather they use traditional equipment like *dhones* and swing baskets. Their irrigation requirement is almost fulfilled by rainwater. The relatively high lands are irrigated by machines mostly during mid-December to mid-March, relatively rarely during mid-November to mid-March or mid-February.

About 80% (745,748 ha) of the Boro area in the haor region (931,451 ha) has been brought under irrigation by 2020 (Table 2.18) while in Bangladesh, overall, almost all Boro areas (97%) are now irrigated. Among the seven haor districts, Kishoregonj has the largest (96%) Boro irrigation acreage followed by Brahmanbaria (94%) and Netrakona (93%) while Moulvibazar has the lowest (63%) acreage. However, scarcity of water due to drying up of the canals at the end of the monsoon season hampers irrigation. In some years prolonged drought spells occur. On the other hand, the beels are leased out to fishery entrepreneurs who do not permit farmers to pump out water for irrigation. Also, sometimes water from the haors does not flow over to the *beels* and *dubas* and surface water for irrigation becomes limiting.

The total number of agricultural laborers now engaged in farming has morethan doubled from that in the 1950s, yet labor shortage during the

Table 2.18. Status of irrigation for cultivation of Boro rice in the haor region

District	Boro area in 2020 (ha)	Irrigated Boro area in 2020 (ha)	% Boro irrigated area	Irrigated Boro area in 2014 (ha)	Increase /decrease in irrigated Boro area (%)
Brahmanbaria	112275	106073	94	96357	10.1
Kishoreganj	165114	158704	96	161134	-1.5
Netrakona	182891	170445	93	162348	5.0
Habiganj	119661	83806	70	85425	-1.9
Moulvibazar	53029	33198	63	34008	-2.4
Sunamganj	215991	139271	64	132794	4.9
Sylhet	82490	54251	66	64373	-15.7
Haor districts	931451	745748	80	736439	-1.25
Bangladesh	4762130	4638866	97	4621862	0.4

Source: BBS 2015, 2020

sowing/planting and harvesting seasons has become a nagging problem in the haor areas. The situation for the farmers has become further complicated due to a sharp increase in labor wages. This has necessitated the use of machinery for Boro field operations from transplanting to harvesting. Farmers find using machinery like rice transplanters, reapers and combine harvesters cost effective and, thus, the use of such machinery is slowly expanding in the haor areas. There has been a substantial increase (55%) in the number of combine harvesters in the haor region from 348 in 2019 to 540 in 2020, the use of these machines being on the rise in every haor district (Table 2.19). The number of reapers also increased by 8%, although not substantial, from 784 in 2019 to 849 in 2020 in the haor districts.

Table 2.19. Status of combine harvester and reaper in the haor region

District	Combine harvester (no.)		% increase in combine harvester	Reaper (no.)		% increase in reaper
	2019	2020		2019	2020	
Brahmanbaria	22	39	77	17	20	18
Kishoreganj	48	88	83	86	99	15
Netrakona	49	102	108	24	25	4
Habiganj	35	57	63	162	195	20
Moulvibazar	39	44	13	121	124	2
Sunamganj	98	142	45	203	213	5
Sylhet	57	68	19	171	173	1
Total	348	540	55	784	849	8

Source: DAE 2020

These machines have turned out to be useful for the haor farmers in reducing production costs of Boro rice and especially, by dint of their ability to harvest Boro rice from a large area within a short period of time. These machines are well accepted by the farmers as a means of averting Boro rice damage from flash floods. Notably, the Government has allocated subsidy funds for the purchase of combine harvesters and reapers before commencing harvesting of Boro rice in haor areas. The Department of Agriculture Extension (DAE) took the necessary initiatives for distributing newly purchased harvesters and reapers and repairing the old machines. However, the average capacity of a combine harvester is in the range of 30-35 ha (Islam 2018), and, thus, a huge number of this machine is required to harvest the Boro rice acreage across the haor region. The number of available combine harvesters in the haor districts is still too inadequate to cover the total Boro rice area. There are some rice reapers, too, but they can only harvest rice and collection of harvested paddy from the fields and threshing, again, require the services of threshing machines as well as laborers. Thus, although harvesters and reapers were duly mobilized by the suppliers, albeit in numbers falling far short of those required. Farmers still need to hire migrant laborers for harvesting Boro paddy in the haor areas almost every year. The situation can be improved through a quick extension of farm mechanization across the haor districts.

2.5.2 Agricultural marketing

In the haor region, about one in five inhabited *mouzas* (small unit of an upazila) has a *haat* (market) in addition to a weekly market day(s). Travel to and from the market is easier in the monsoon season when boats can navigate almost door to market, whereas in the dry season long walks across dried haor ridges are often necessary. The volumes of farmers' produce are very small and far from the market and the farmers are not organized and prepared for marketing of their produce and they are even not aware of the market demands and prices. The *paikers* (brokers) make rounds of villages purchasing farmers' produce and sell them through the arots (a common selling shed) to the retailers by giving a certain commission to the *arotdar (arot* owner). The producers, *paikers, arotdars*, retailers and consumers are the main actors in the supply and market chain. In this chain, the intermediaries consume a large share of the profit and the primary producer (farmer) is left with only a marginal profit. The farmers are not satisfied with the *paikers* as at this stage of the market chain it is an almost total buyer's (*paiker's*) monopoly because the farmers are neither organized nor skilled enough for bargaining with the *paikers*.

Demands for poultry, cattle and sheep are very high. Sheep is profitable and easy to rear compared with goat as they eat any grass, even rice straw during floods and are less susceptible to diseases. It is also reported that local improved breed of poultry Fayomi has a great potential in the market. During winter, seeds of hybrid and HYV Boro rice, onion, red amaranth, *kangkong*, coriander etc, have high demands while in summer season red amaranth, pumpkin, ridge gourd, snake gourd, long bean, Indian spinach etc, have high demands among the farmers.

With the increasing use of computer, mobile phone, motorized two wheelers and with rapid expansion of electricity in rural areas, skilled mechanics could do brisk business. Women can take care of computer and mobile phone mechanics business. Value chains and relationship among farmers, *paikers,* retailers and *arotdars* need to be developed using digital facilities including mobile phone apps.

2.6 Advances in haor agriculture

2.6.1 Crops

Adaptation of crops to a fragile ecosystem like the haor wetlands in the face of climate change adversities requires resilient varieties, suitable cropping patterns, appropriate irrigation techniques, sustainable land management etc. Agricultural researchers and extension experts of Bangladesh are trying to develop packages of production technologies and ensure their quick dissemination to cope with the adversities and vulnerabilities associated with a fragile ecosystem. The NARS researchers are developing climate smart, stress tolerant (salinity, submergence, drought, extreme temperature tolerant) varieties and improved production practices for sustainable crop agriculture. Some stress tolerant rice and wheat varieties have already reached famers' 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 rices 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. The 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.

The soil resources of the country are under pressure for increased food production. Increasing cropping intensity and mineralization of soil organic matter exhaust the capacity of soil to support crops. The Soil Resource Development Institute (SRDI) is working to improve soil health. The institute has prepared the Upazila Land and Soil Resources Utilization Guide for 459 upazilas throughout the country including the haor upazilas. This will contribute to sustainable crop production and at the same time maintain soil health through rational and integrated nutrient management. The Ministry of Agriculture (MoA) is encouraging farmers to apply organic fertilizers like compost, farmyard manure, green manure and bio-fertilizers etc. in addition to chemical fertilizers to safeguard soil health. Good agronomic practices like intercropping with leguminous crops, reduced tillage, alternate cropping, soil mulching, etc. have been developed and are being familiarized with the farmers to improve soil and land productivity.

In the haor areas, Boro-Fallow-Fallow is the main cropping pattern where crops are grown only in the Rabi season (Nov-April) and the land remains uncultivated during the Aus (April-July) and T. Aman (July-Nov) season. In some areas, there are small acreages of Aus and T. Aman rice on relatively high land. The most popular Boro rice varieties are BRRI dhan29, BRRI dhan28, BR19, BR14, Gochi, Rata etc. BRRI dhan28 and BRRI dhan29 are grown in 80% of the haor rice lands. These two HYV rice varieties require 140 and 160 days to mature and harvesting is done usually in mid-April and mid-May, respectively. But, early flash floods occur almost every year partially or even completely damaging the Boro rice crop just before harvest. To escape this flash flood, it is essential to plant crops early and harvest by March or latest by early April. This requires developing varieties that are tolerant to cold both at the seedling and reproductive stages. To protect Boro rice from cold stress in the haor areas, cold tolerant short-duration HYVs are necessary. A KGF-IRRI-BRRI project is ongoing to develop such HYVs, some prospective breeding materials have been identified very recently which may be developed as varieties.

Aroids or *latiraj kachu* (BARI Pani Kachu-1) and quick growing kangkong or *gima kalmi* (BARI Gimakolmi-1,2,3) are the examples of varieties that can survive under submergence for several days during flash floods. The BARI developed country bean is suitable for homestead vegetable gardening. Tomato, potato, cabbage, cauliflower, carrot cannot grow due to late recession of flood water in low land/haor/flash flood area, but these crops can be adapted using zero tillage cultivation method. 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 of BARI has developed a year-round homestead gardening model following raised bed systems through on farm testing in its Farming Systems Research Site, Golapganj, Sylhet (called BARI Golapganj, Sylhet model). In a KGF sponsored recent research project (2017-2021) on integrated farming systems for the haor areas of Sunamganj implemented by the Sylhet Agricultural University, 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 increase family incomes 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 grown for year round cultivation in the homesteads.

Growing vegetables on floating beds (Fig. 2.26) 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, karalla, 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 has been 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).

Fig. 2.26. Growing vegetables on floating beds in a perennially flooded area in Gopalganj

2.6.2 Livestock and poultry

Fayoumi chicken has been found to outperform local chickens in the haor areas in terms of weight gain, egg production and mortality rate. The Jinding duck performs better than local and Khaki Campbell in terms of body weight, growth rate, egg quality and mortality rate. Sheep, especially *garole* sheep grow and reproduce very well in haor areas and they are a very good source of protein for the rural people because of their excellent body weight gain and prolific nature. The cattle fattening program offers hope for the haor people as a good source of income. These simple livestock technologies can substantially help the haor inhabitants with food and nutrition security, incomes and poverty alleviation.

2.6.3 Fisheries

In haor areas, different culture methods are used for fish production, such as, monoculture practice using one species or polyculture practice using more than one species in seasonal or homestead ponds. However, polyculture systems are more beneficial because surface, column and bottom feeder fishes are cultured together and, in this system, feeds are properly utilized. In recent years, the cage culture practice has been tested in haor areas. Cage culture is suitable for open water bodies. Growth promoter probiotics are used to increase fish production. The NGO, Practical Action, has been working on a proven model for co-production of fish and vegetable crops with the potential to protect them 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 (Haque et al. 2015).

Kata fish culture – one side of homestead pond is cut to link to cropland to receive *mola* and other small fish species once in every 15 days. During floods tree branches are dumped into the flooded pond. Rice bran is provided as feed and then fishes are grown even in floods. Piles of bush are tacked to lure wild fishes to flock to the ponds during floods. In addition, some feeds may be applied to attract fishes. This technique was tested in Sylhet and proven to be useful. Protein-rich fishes like *shing, koi, mola, tilapia* etc can be reared starting in April, which would provide two harvests. The fish are not lost during floods as they prefer to stay under the mud in the pond.

2.6.4 Impacts of technologies

Agricultural revolution has taken place in Bangladesh over the past decades through development and adoption of modern varieties and breeds, mechanization, irrigation and other management technologies. Bangladesh agriculture has been greatly influenced by research and technology development and dissemination. The major public agricultural extension organizations in Bangladesh are i) Department of Agricultural Extension (DAE), ii) Department of Livestock Services (DLS), iii) Department of Fisheries (DoF), and iv) Forest Department (FD). Apart from private sectors, the main public organizations involved in selling HYV seeds, fertilizers, irrigation inputs etc is Bangladesh Agricultural Development Corporation (BADC). All these organizations are contributing substantially in increasing area/household coverage and production of crops, livestock, fisheries and forestry through information, technology transfer, input distribution, market chain development etc.

Crops

Due to improved, stress tolerant varieties and production technologies, HYV Boro rice area expanded dramatically in the haor districts. The HYV Boro coverage in the haor region (84.1%) has exceeded the overall HYV coverage in Bangladesh (80.7%) (Table 2.20).

It is worth mentioning that in 2020 HYV Boro area in the haor region represented 20.4% of the total HYV Boro acreage and contributed 19.8% (3,066,433 metric ton) to the total Boro rice production (15,457,679 metric ton) in the country.

Table 2.20. HYV Boro rice area (ha) and production in metric tons (MT) by district in the haor region in 2020

District	HYV Boro area	% total Boro area	HYV boro production	% of total Boro production
Brahmanbaria	111624	99.4	507293	99.4
Kishoreganj	138172	83.7	579767	83.2
Netrakona	160496	87.8	694755	85.6
Habiganj	77253	64.6	249917	60.7
Maoulvibazar	50956	96.1	178889	95.6
Sunamganj	176274	81.6	642889	80.4
Sylhet	68154	82.6	212923	85.3
Haor districts	782929	84.1	3066433	83.6
Bangladesh	3843000	80.7	15457679	78.7

Source: BBS 2020

The HYV Boro area area has increased slightly from 742,237 ha in 2013 to 782,929 ha in 2020 (Table 2.21) with 5.5% increase per year over 8 years in the haor districts while during the same period HYV boro area in Bangladesh decreased by 6.3% (BBS 2015, 2020). HYV Boro production has significantly increased by 14.3% from 2.68 million tons in 2013 to 3.07 million tons in 2020 in the haor region while the national HYV boro production decreased by 2.8% during the same time. The increase in HYV Boro production in the haor region in the context of decrease at the national level may be attributed to adoption of improved technologies by the farmers of the haor areas.

Table 2.21. Changes in HYV Boro area and production in metric ton (MT) during 2013-2020

District /country	HYV Boro area (ha)		% increase /decrease	HYV Boro production (MT)		% increase /decrease
	2013	2020		2013	2020	
Haor districts	742,237	782,929	5.5	2,681,661	3,066,433	14.3
Bangladesh	4,101,276	3,843,000	-6.3	15,898,467	15,457,679	-2.8

Source: BBS 2015, 2020

The highest increase in HYV Boro area occurred in Sylhet by 21.4% from 56,153 ha in 2013 to 68,154 ha in 2020 (Fig. 2.27) followed by Moulvibazar (14.5%) from 44,491 ha in 2013 to 50,956 ha in 2020. Kishoreganj, Netrakona and Habiganj districts encountered a slight decrease in HYV Boro area in the same period ranging from 1.1 to 3.2%. This decrease in HYV Boro area may be due to frequent flash floods in these haor districts.

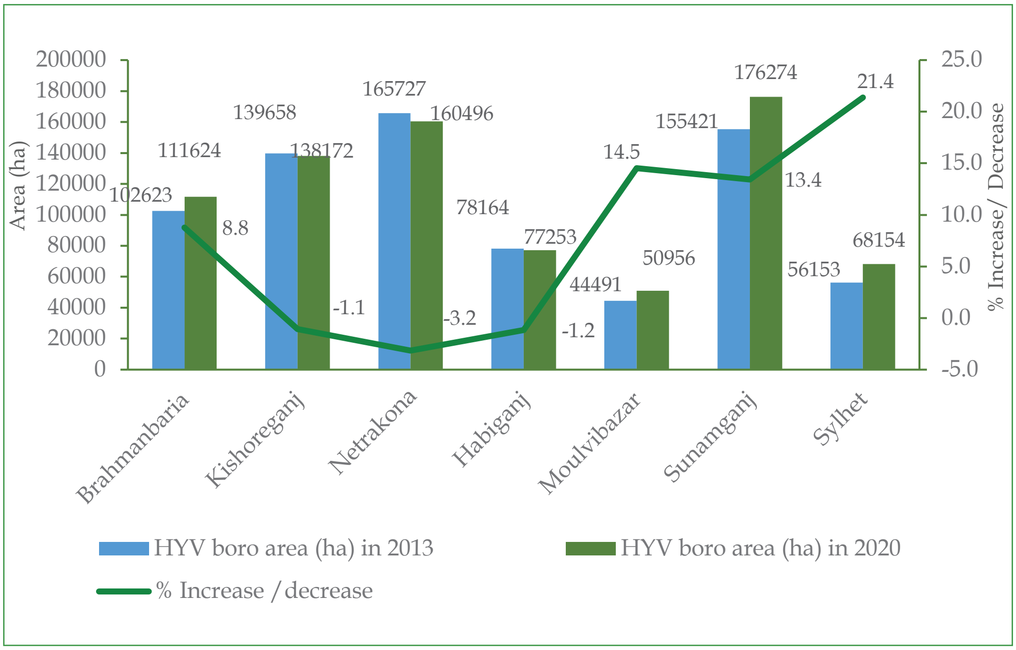


Fig. 2.27. Changes in HYV Boro area by district (Source: BBS 2015, 2020)

The highest increase in HYV Boro production occurred in Brahmanbaria by 32.3% from 383,464 MT in 2013 to 507,229 MT in 2020 (Fig. 2.28) while the lowest was reported in Kishoreganj (3.5%) from 560,110 MT in 2013 to 579,767 MT in 2020. Despite decrease in area, Kishoreganj, Netrakona and Habiganj districts experienced an increase in HYV Boro production in the same period ranging from 3.5 to 11.8% which could be due to the massive adoption of improved technologies.

Hybrid Boro area increased abruptly from 86,823 ha in 2013 to 134,789 ha in 2020 (Table 2.22) with 55% increase over 8 years in haor districts while hybrid boro area in Bangladesh has increased by 39% during the same time. Hybrid Boro production also significantly increased by 54% from 373,914 MT in 2013 to 577,055 MT in 2020 while the national hybrid boro production has increased by 37% during the same period. The increase in hybrid boro production in haor region may be attributed to adoption of improved technologies by the farmers of the haor areas.

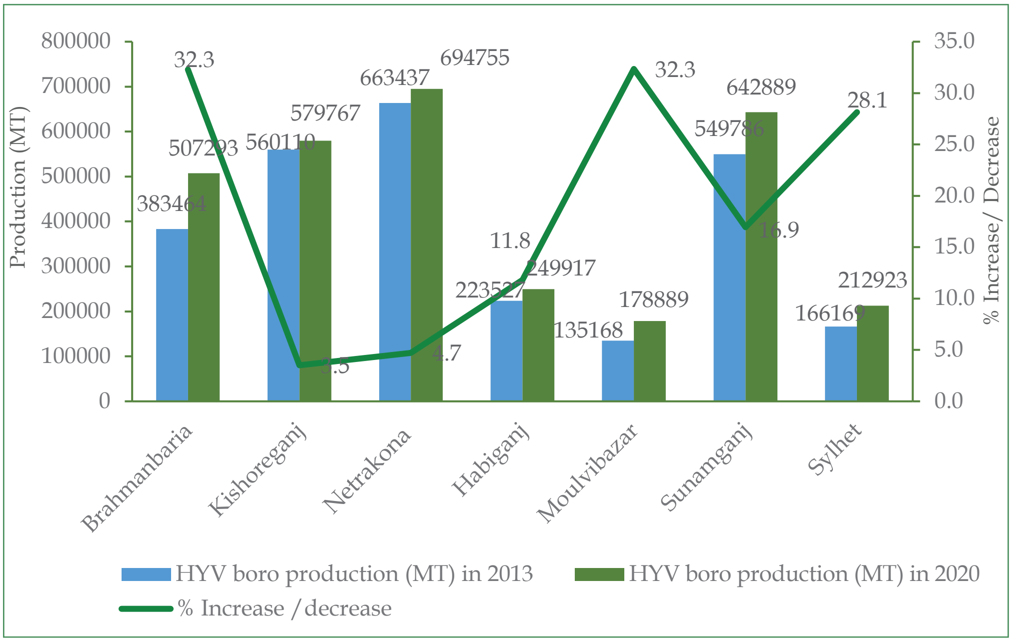


Fig. 2.28. Changes in HYV Boro production by district (Source: BBS 2015, 2020)

Table 2.22. Changes in hybrid Boro area and production during 2013-2020

District /country	Hybrid Boro area (ha)		% increase /decrease	Hybrid Boro production (MT)		% increase
	2013	2020		2013	2020	
Haor districts	86823	134789	55	373914	577055	54
Bangladesh	635963	885976	39	3008893	4127145	37

Source: BBS 2015, 2020

The highest increase in hybrid Boro area occurred in Sylhet by 187% from 1963 ha in 2013 to 5,632 ha in 2020 (Fig. 2.29) followed by that in Netrakona (158%) from 8,558 ha in 2013 to 22,074 ha in 2020. On the other hand, Brahmanbaria and Moulvibazar encountered a significant decrease in hybrid Boro area in the same period with 87% and 14%, respectively. This decrease in HYV Boro area might be due to the threat of frequent flash floods in these haor districts.

In terms of production of hybrid Boro production, Netrokona registered the highest growth with a 169% increase from 43,344 MT in 2013 to 116,442 MT in 2020 (Fig. 2.30) followed by Sylhet (146%) from 8,884 MT in 2013 to 21,891 MT in 2020. Brahmanbaria and Moulvibazar, however, had significant decreases in hybrid Boro production in the same period, by 86% and 14%, respectively. This decrease in hybrid Boro production may be due to the decrease of hybrid Boro area.

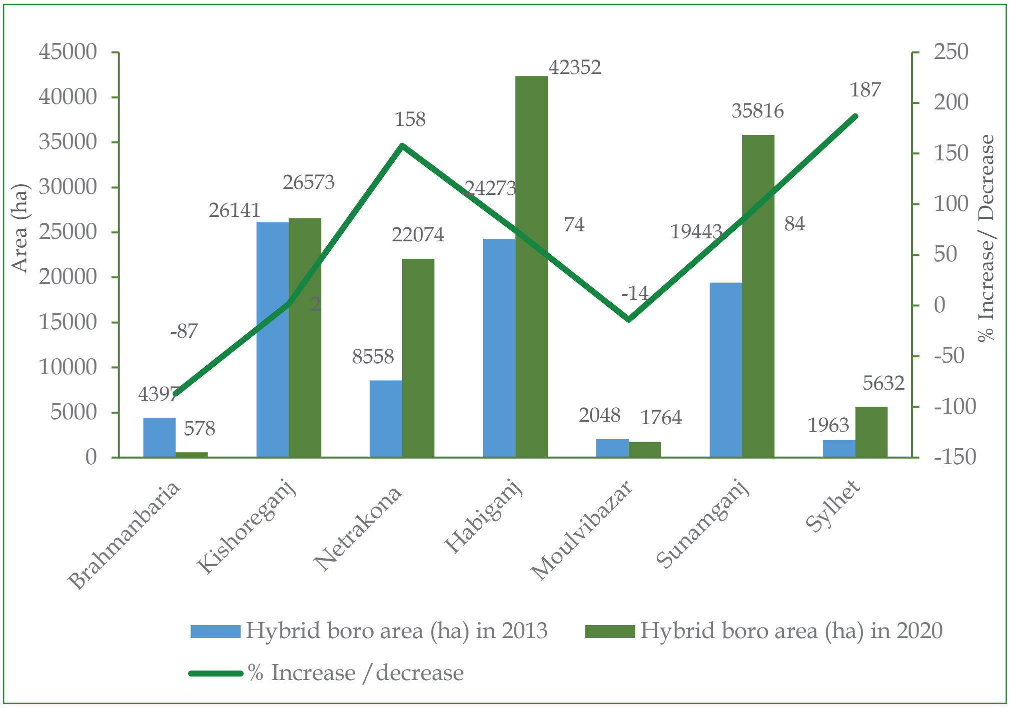


Fig. 2.29. Changes in hybrid Boro area by district (Source: BBS 2015, 2020)

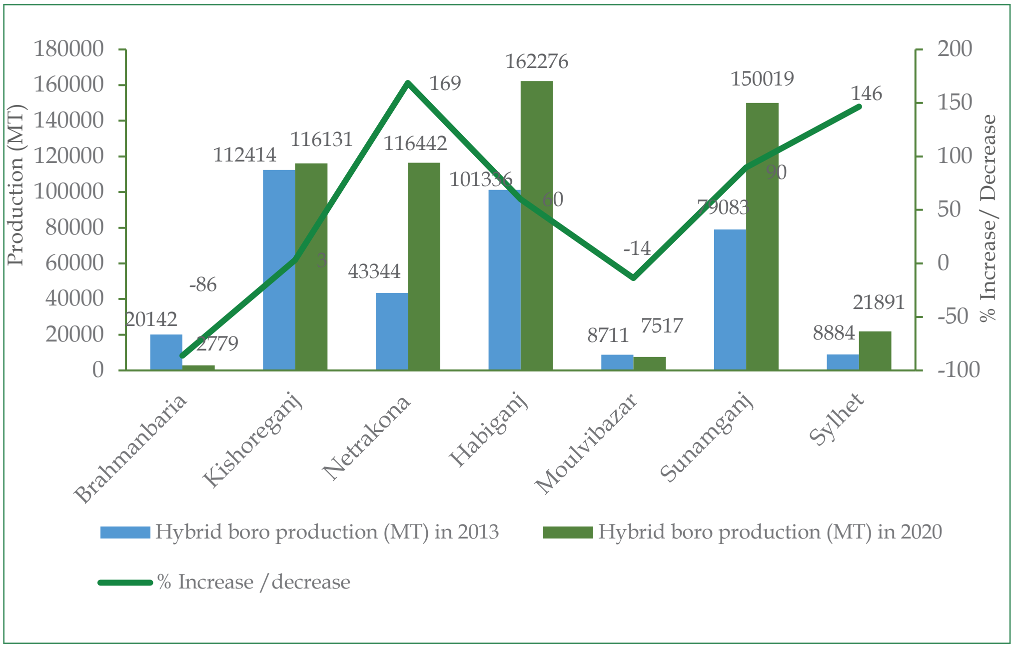


Fig. 2.30. Changes in hybrid Boro production by district (Source: BBS 2015, 2020)

During 2007, 78% of the rice area was covered by different Boro HYVs (Fig. 2.31). The highest area was covered by BRRI dhan29 (39%) followed by BRRI dhan28 (20%) while the lowest area was covered by BR14 (8%). These two HYVs, although popular and performed better, had a severe risk of 100% damage due to early flash floods before harvest in the recent years.

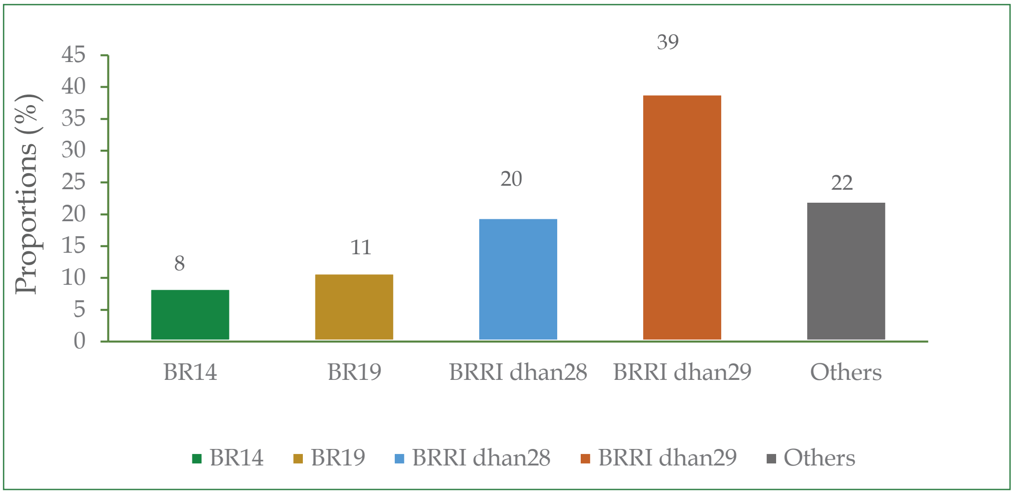


Fig. 2.31. Proportions (%) of area coverage with different HYVs of Boro rice in the haor districts in 2007 (Source: DAE 2007)

Table 2.23 reveals that Brahmanbaria had the highest proportion of area with different HYV Boro rice varieties (85%) while Sylhet had the lowest (67%) of their total Boro area in 2007. The lower coverage of BRRI dhan29 in Sylhet (22%) and Moulvibazar (27%) compared to that in other districts may be due to the risk of early flash flood. The farmers of these districts prefer to grow BRRI dhan28 rice has shorter growth period (140 days) than compared to BRRI dhan29 (160 days) despite lower yield of BRRI dhan28.

Table 2.23. Proportion of area coverage by different HYVs of Boro rice in the haor region in 2007

District	% Area covered by HYV of Boro rice in haor areas				
	BR14	BR19	BRRI dhan28	BRRI dhan29	Others
Brahmanbaria	6	12	27	40	15
Kishoreganj	14	4	12	49	21
Netrakona	14	6	20	40	20
Habiganj	3	7	14	52	24
Moulvibazar	6	19	28	27	20
Sunamganj	5	15	15	43	22
Sylhet	11	13	21	22	33

Source: DAE 2007

Five major Kharif vegetables viz. pumpkin, Indian spinach, ridge gourd, long bean and snake gourd covered a substantial area of 3,456 ha in 2019 which was 6.9% of the total area under these vegetables (49,906 ha) in Bangladesh (Table 2.24). Among the five vegetables in haor districts, the largest area was covered by ridge gourd (878 ha) and the lowest was with snake gourd (567 ha), which were 8.6% and 7.1%, respectively, of their total areas in Bangladesh. The lowest proportion of the national area coverage was reported with pumpkin (5.2%). This indicates a very small contribution of the haor region to the country's vegetable production which is primarily due to the threat of early flash flood during Kharif-I. Pumpkin, ridge gourd and long beans grew well in Sylhet with areas of 139 ha, 194 ha and 155 ha, respectively. Indian spinach covered the largest area in Netrakona (192 ha) while snake gourd had the largest area in Moulvibazar (104 ha).

Table 2.24. Area coverage of major Kharif vegetables grown in the haor region in 2019

District	Pumpkin (ha)	Indian spinach (ha)	Ridge gourd (ha)	Long bean (ha)	Snake gourd (ha)	Total (ha)
Brahmanbaria	97	192	107	84	83	563
Kishoreganj	96	113	155	62	93	519
Netrakona	124	91	99	56	90	460
Habiganj	111	92	132	90	69	494
Moulvibazar	93	64	133	142	104	536
Sunamganj	58	65	58	32	53	266
Sylhet	139	55	194	155	75	618
Haor districts	718	672	878	621	567	3456
Bangladesh	13726	11029	10156	6988	8007	49906
% Bangladesh	5.2	6.1	8.6	8.9	7.1	6.9

Source: BBS 2020

The area of the five Kharif vegetables has increased enormously from 4023 ha in 2013 to 7,419 ha in 2019 with a 85.9% increase over 8 years in the haor districts. The total area of these vegetables in Bangladesh also increased abruptly by 86.2% during the same period (BBS 2015, 2020). The highest increase in area of five vegetables occurred in Sylhet by 89.2 % from 693 ha in 2013 to 1,311 ha in 2019 followed by that in Habiganj (87.7%) from 563 ha in 2013 to 1057 ha in 2019 (Fig. 2.32). This overwhelming increase in the area of the five Kharif vegetables during the 8-year period despite the threat of flash floods in this season was due to the expansion of vegetable cultivation in the homestead areas coupled with improved technologies tackling erratic rainfall.

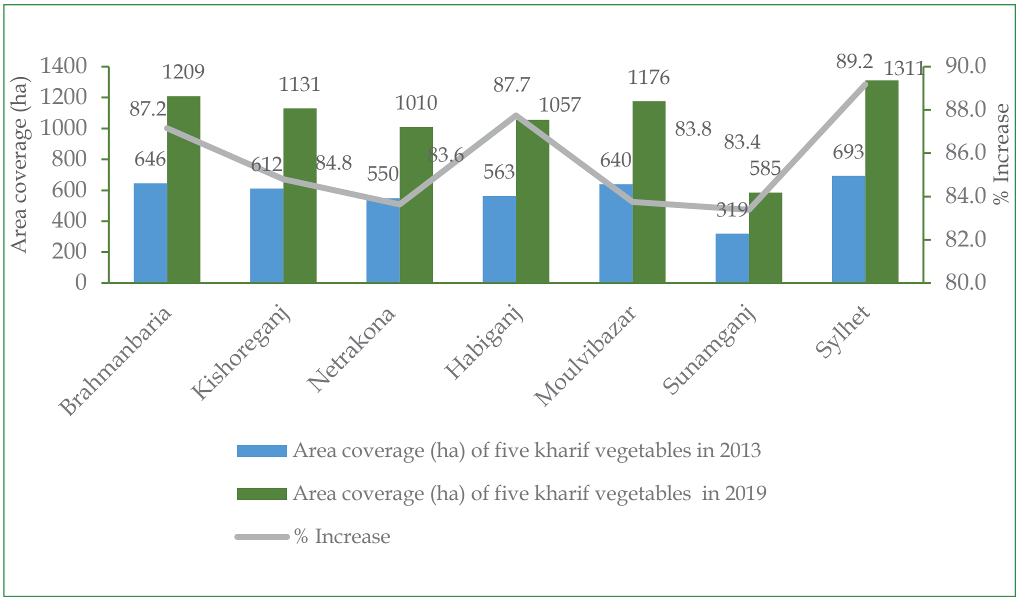


Fig. 2.32. Changes in area coverage of five Kharif vegetables by district during 2013-2019 (Source: BBS 2015 and BBS 2020)

The total production of these five Kharif vegetables was 18,309 MT in 2019 (Table 2.25) accounting for 5.3% of the national production of these vegetable (348,464 MT). Among the five vegetables in haor districts, the highest production was reported for Indian spinach (4,510 MT) and the lowest for snake gourd (2,319 MT) representing 5.1% and 5.4% of the total production of these vegetables, respectively, in Bangladesh.

Table 2.25. Production of major Kharif vegetables grown in the haor region in 2019

District	Pumpkin (MT)	Indian spinach (MT)	Ridge gourd (MT)	Long bean (MT)	Snake gourd (MT)	Total (MT)
Brahmanbaria	538	1796	745	771	289	4139
Kishoreganj	782	685	891	199	391	2948
Netrakona	545	344	360	124	360	1733
Habiganj	820	488	788	151	160	2407
Moulvibazar	775	426	675	835	514	3225
Sunamganj	320	596	194	171	420	1701
Sylhet	645	175	522	629	185	2156
Haor districts	4425	4510	4175	2880	2319	18309
Bangladesh	136269	88272	52575	28410	42938	348464
% Bangladesh	3.2	5.1	7.9	10.1	5.4	5.3

Source: BBS 2020

Livestock and poultry

The overall livestock population density (cattle, buffalo and goat) declined in the haor areas from 7.4 to 4.3, 0.4-0.1 and 1.9-1.1 per ha accounting for 42%, 75% and 42% decreases, respectively during 2010 to 2019 (Table 2.26). However, the density of sheep population increased by 33% from 0.3/ha in 2010 to 0.4/ha in 2019. This overall decrease in the density of livestock except that of sheep was primarily due to the loss of grazing grounds to recurrent flash floods in recent years. Sheep could withstand to some extent the harsh environment and feed on assorted grasses that other livestock species despised.

Table 2.26. Changes in ruminant population density in the haor region

District	Ruminant population/ha							
	Cattle		Buffalo		Goat		Sheep	
	2010	2019	2010	2019	2010	2019	2010	2019
Brahmanbaria	16.0	2.4	0.3	0.1	3.7	0.1	0.7	0.5
Kishoreganj	4.5	5.9	0.2	0.05	2.0	1.3	0.2	0.2
Netrakona	4.3	4.2	0.1	0.02	1.6	1.5	0.1	0.1
Habiganj	13.0	3.4	0.3	0.04	3.5	1.6	0.8	0.03
Moulvibazar	5.9	8.9	1.7	0.5	1.4	2.6	0.1	0.5
Sunamganj	7.5	2.5	0.2	0.1	1.2	0.5	0.2	0.5
Sylhet	17.2	6.1	1.2	0.3	3.2	1.3	1.0	0.5
Total (haor)	7.4	4.3	0.4	0.1	1.9	1.1	0.3	0.4
Total (country)	1.8	1.7	0.1	0.1	1.7	1.8	0.2	0.2

Source: BBS 2012, 2020

Despite decreases in two districts, the overall poultry density in the haor region slightly increased by 6% from 23.8 to 25.2/ha when the country had a 22% increase during the 2010-2019 period (Table 2.27). Unlike poultry, the density of the duck population increased in Kishoreganj, Netrakona and Moulvibazar but decreased in Brahmanbaria, Habiganj, Sunamganj and Sylhet (Table 2.27).

Table 2.27. Changes in poultry and duck populations density in the haor region

District	Poultry/ha		Duck/ha	
	2010	2019	2010	2019
Brahmanbaria	70.3	37.9	26.0	10.9
Kishoreganj	25.5	39.9	10.9	19.3
Netrakona	16.6	22.0	20.1	27.0
Habiganj	24.5	32.1	29.3	4.8
Moulvibazar	20.1	42.6	4.9	14.3
Sunamganj	6.5	12.6	10.9	9.4
Sylhet	78.8	24.9	19.0	7.7
Haor area total	23.8	25.2	14.3	11.7
Bangladesh total	16.3	20.0	3.1	4.0

(Source: BBS 2012, 2020)

Fisheries

There was a significant annual fish production (111,779 MT) in the haors accounting for 43% of the total annual fish production in the haor districts (2,58,033 MT) during 2020 (Table 2.28). It is worth mentioning here that the annual fish production in haors amounts to 14% of the total annual fish production (779,801 MT) in Bangladesh and the total annual fish production in the seven haor districts contributes 33% to the total annual fish production in Bangladesh.

Table 2.28. Annual fish production in the haor region in 2020

District	Haors (MT)	Haor districts (MT)	% haor district production
Brahmanbaria	4419	20631	21
Kishoreganj	21383	42671	50
Netrakona	23414	36700	64
Habiganj	8959	28102	32
Moulvibazar	11041	23881	46
Sunamganj	29177	65294	45
Sylhet	13386	40754	33
Total (haor)	111779	258033	43
% Bangladesh	14	33	

Source: BBS 2020

Annual fish production in haor areas increased by 52% from 73,448 MT in 2013 to 1,11,779 MT in 2020, which greatly surpassed the increase of national annual fish production (only 9%) during the same time (BBS 2015, 2020). This dramatic increase in annual fish production during the last 8 years despite serious natural calamities like flooding was due to increased access of fishermen to modern equipment for fish catching in the open water bodies of the haor areas.

2.7 Strategic investment opportunities for Haor Ecosystem

Heavy rainfall as well as onrush of water from the upstream Meghalaya hills in India has led to the inundation of a vast areas of croplands of haors areas in Bangladesh. Rising water overflow has broken embankments in many places and inundated vast areas of croplands and homesteads. Flash flood generally occurs in April and/or June. Water coming from Mona, Jhuri, and Kushiara rivers and water from canals of hill slopes causes flash flood and lands go under water for a period until flood recedes. Flash flood, when coupled with heavy rainfall, causes severe and prolong flood. Prolong drought is also evident in haor areas, source of irrigation is principally surface water, so many areas remain fallow.

For the haor development, the Government of Bangladesh 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 the 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
- Bangladesh Delta Plan 2100
- Vision 2041: Perspective Plan of Bangladesh (2021-2041)
- 8^{th} Five Years Plan (2020-2025)

The Bangladesh Haor and Wetland Development Board (BHWDB) has developed a master plan to alleviate the residents of the haor regions from poverty. The master plan framework was developed in 2012 and it is to be implemented 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. Nevertheless, a significant portion (12%) of the total funding (BDT 2,804,305) is dedicated to Power and Energy.

Therefore, climate resilience and agricultural development strategies should be undertaken for haor areas based on the above plans/policies and projects of the Government.

Strategy A: Technology up-scaling addressing flash floods and droughts

Climate change induced incidences of floods, droughts, high temperature, flash floods, etc. are predicted to be more frequent and intense in the haor areas. For example, flood damages crop due to submergence, livestock due to lack of feeds and fisheries due to overflow of ponds and water bodies. Similarly, drought damages crop due to high heat load, livestock due to poor growth of grasses and fisheries due to lowering of water level. Therefore, the following strategies could be adopted to address these problems.

Sub-strategy A.1: 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.

Sub-strategy A.2: 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 seedling 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
- Large scale plantation of *hijol (Barringtonia acutangula), korock (Pongamia pinnata)* and other common trees like *mandair, mera* and *barun* should be ensured to maintain eco-system balance and halt deforestation

Sub-strategy A.3: Varietal replacement of Boro rice to reduce crop damage due to flash flood and drought

Boro rice is the main crop in the haor areas, which is severely affected by flash floods and drought. BRRI dhan28 and 29 should be replaced by BRRI dhan88 (yielding 7 MT/ha and matures 4 days earlier than BRRI dhan28), BRRI dhan89 (yielding 8 MT/ha and matures 5 days earlier than BRRI dhan29), BRRI dhan92 (yielding up to 9.3 MT/ha and matures 3-4 days earlier than BRRI dhan29 and also adapts to drought situation). BRRI dhan79 (a submergence tolerant variety) can be cultivated in haor areas, which survives up to 21 days of submergence. A long duration drought spell occurs in haor areas during Rabi season. To adapt to this drought, BRRI dhan71 (a drought tolerant variety of 115 days growth duration yielding 4 MT/ha with prolong drought and 5 MT/ha without drought) can be promoted in the severe drought prone areas of the haor districts, particularly in the upper basin of the haors.

Sub-strategy A.4 Up-scaling of innovative technologies

The NARS institutes and local farmers have developed a good number of innovative technologies to adapt to flash flood/flood condition for successful crop production. These technologies should be promoted, where feasible. Some of these technologies are outlined here:

- Sac gardening technology: This technology can be promoted in haor areas: Plastic sacks are filled with soil and compost (cow dung mixed with fertilizers). Seedlings are then raised in these plastic sacs. These seedlings are either planted in main land after flood or even seedlings in the sack are allowed to grow throughout their lifecycle if flood is prolonged. The major cultivable crops are country bean, sweet gourd, bottle gourd, wax gourd, cucumber, ribbed gourd and Indian spinach etc. Short-cycle, indigenous, leafy vegetables such as amaranth, kangkong (water spinach) and Indian spinach can also be grown, particularly in the sides of the sack.
- Vegetable cultivation on raised bed covered by polythene shed: On-Farm Research Division, BARI has developed a year-round homestead gardening

model following raised bed systems through on-farm testing in its Farming Systems Research Site, Golapganj, Sylhet (called BARI Golapganj, Sylhet model). Raised beds are developed by soils at 20-25 cm height from the ground. Two raised beds are developed in a cluster keeping 30 cm drain between 2 beds. Each cluster of beds is covered with polythene shed making a shape of a boat providing bamboo pillars of 2-meter size at the middle and 1.5 meter at the ridges of each shed. A 75 cm wide drain is developed between two polythene sheds so that rain water can be drained out quickly and intercultural operations can be done easily. This technology can be widely promoted in the haor areas.

- Tower Garden: Suspending horticulture activities above the ground can result in high production of vegetables when the challenges of flooding, water logging, and land and water constraints are encountered. A vertical tower is a cylindrical structure made from bamboo, live wood, soil, coconut coir, brick chips, compost and cow manure for growing vegetables. The vertical tower allows for yearlong vegetables production in the homestead, where vegetables can grow on top of or within other structures, such as the roof of a house, nets or trees. At the base of the tower, a pile of soil and bricks is created to raise the tower 0.15 meters (m) above ground level. The base can also be covered with a polythene sheet to prevent waterlogging from damaging the soil. The main frame of the tower is built by firmly burying the ends of kocha or jiga tree limbs in the ground in a circle. On the top of the tower, vegetables such as bottle gourd, sweet gourd, ridge gourd, bitter gourd, ash gourd, dhondol, tomato, brinjal and beans can be grown. Plants that are short rooted can be grown on the side of the tower. These include chili, Indian spinach, kholkhol, beet and sweet potato. The strategy should also aim at promoting this technology extensively in haor areas.
- *Sorjan system:* 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. Bangladesh Agriculture Research Institute (BARI) has developed this technology through a series of testing in its Farming Systems Research (FSR) site, Lebukhali, Patuakhali. Vegetable gardening in sorjan system is applicable to lands that go under water for most time of the year. Thus, efforts should be given to promote sorjan technology in the haor areas.
- *Floating agriculture*: 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. This system can be integrated with fish culture, where a raft is made with bamboo and is kept suspended above the water by plastic containers as floats. Earthen or plastic pots with soil placed on the frame are used to grow vegetables. A net cage is installed beneath the floating structure to culture fish. It is a useful adaptive option in low-lying areas, which go under water for most time of the year, to grow vegetables and quick growing fish, like tilapia. Thus, this floating agriculture technology should be disseminated widely in the haor areas.

Strategy B: Technological advancement for addressing flood/flash flood and drought

- Development of vegetable and fruit varieties and production practices for year-round production escaping flash floods and other hazards
- Hybrid variety development for high-value vegetables such as palwal, carrot, cabbage, cauliflower, leafy vegetables, lady's finger and fruits such as mango, litchi, jackfruit, guava, jujube, pineapple, banana etc. which can adapt to the wetland environment and avert damage from flash floods
- There is a lack of suitable short-duration varieties of rice to avert damage from flash floods. So, much efforts need to be given for developing short-duration rice varieties that are tolerant to cold both at the seedling stage to avert damage from flash floods.

Strategy C: Strengthening agricultural mechanization

Since the proportion of medium and large farmers is very small, the agricultural labor market can generate employment for only a small number of the vast landless and marginal landowning households in the haor areas. When the modern rice varieties were introduced the demand for hired laborer increased substantially, but over time labor use in rice cultivation has declined with the spread of mechanization in land preparation, irrigation, and post-harvest processing. The availability of wage workers for harvesting Boro rice is usually scarce in the haor areas and farmers mostly rely on migrant laborers for harvesting. Although harvesting by combine harvesters is cost-effective, it involves additional costs of collecting and carrying the straw from fields. The quality of the hay becomes unsuitable for feeding cattle if it rains during 2-3 days when these are kept in the fields for drying. However, there is a good opportunity of saving Boro rice from damage due to flash floods by increasing the availability of combine harvester and reaper machines. Therefore, it is essential to intensify and strengthen farm mechanization in the face of acute labor shortage. The agricultural machinery manufacturing sector should be supported to improve its capacity to manufacture competitively priced and high-quality machines and spare parts by providing incentives, they should be encouraged to produce farmer-friendly machinery.

Strategy D: Addressing dwindling natural resources

Rice dominates the agricultural production system in terms of area and production volume in the haor region. Research and development (R&D) efforts in rice production have given handsome returns. However, investment in R&D for other crops, livestock and fisheries has been limited, crop diversification and resource utilization have not taken place as expected. This deserves attention particularly for non-cereal crops and other sub-sectors of agriculture.

Strategy E: 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 the Government of Bangladesh will increase soil fertility in 2000 km^2 of 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 10,000 farmers per year with balance fertilizer use following online and offline fertilizer recommendation system or fertilizer recommendation Guide, use of organic manure, farm compost, vermicompost, biochar etc. Moreover, alternate wetting and drying (AWD) technology will be implemented for Boro rice in 200 km^2. This investment plan of LDN as committed by the Government of Bangladesh through UNCCD should be widely implemented in the haor areas in support of increasing soil fertility so as to address soil degradation.

Strategy F: Improvement of livestock and poultry

The main challenges in livestock rearing in haor areas are scarcity of grazing fields, insufficient livestock care services, lack of feeds & fodder and lack of modern technologies. Furthermore, lack of quality supplies, insufficient facilities and physical infrastructure, and insufficient scientific and technical innovation have all hindered livestock production in haor areas. Expanding economic opportunities and increasing incomes through livestock production is a potentially promising strategy to enhance livelihood development and poverty reduction in the haor areas. 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.
- Cattle fattening program opens up a new hope for local people in haor areas, gaining a noticeable financial support.
- Sheep rearing especially garole sheep, which can withstand drought and eat on any grasses available, should be promoted for incomes and protein supplements for the rural people in haor areas.
- Locally improved breed (Sonali/Faomi) may be reared which are disease resistant.
- Development of important traditional and recombinant vaccines and biologics against major diseases of ruminants and poultry using molecular biotechnological approach.
- Development and application of the methodology to link the haor climate data with animal disease surveillance system could be another good strategy.
- Ipil ipil and dhaincha plant with creeper vegetables can be grown in the homestead area. 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.
- In haor areas, leaves of floating grasses eg, pana (a natural quick growing grass) can be fed to goat. The other good alternative is to grow German grass, which can survive in flood water and also withstand partial shading.

Strategy G: Improvement of aquaculture

Loss of fish biodiversity is evident in the haor areas which is directly linked to the loss of habitats. There are not enough fish pass structures for roads, protecting fisheries resources from the adverse effects of flood control embankments and road etc. The major causes of biodiversity loss or the major problems of the fisheries sub-sector have been identified as:

- Degradation of habitats due to siltation
- Habitat alteration and fragmentation
- Over and indiscriminate fishing
- Over exploitation of swamp forests
- Water pollution
- Increasing use of fertilizers and pesticides for crop production

So, the following strategies should be adopted in order to address the above stated problems.

Short-term

- Investigation on disease causing factors in aquaculture system
- Prevention of bacterial disease through vaccination and immunostimulants
- Surveillance of aquatic animal disease in Surma Kusiyara river basin
- Screening of bacterial disease in aquafarms and hatcheries
- Netting around the ponds will help protect fishes from over flow due to flood. Netting around the homestead mini pond before releasing fingerlings can be an alternative option to protect loss of fingerlings/ fishes from overflow during flooding

Medium-term

- Assessment of agrochemicals used in haor areas on the fatality of fisheries
- Exploring novel fish feed ingredients from the haor based aquatic plant and animal sources for strengthening fish feed industry
- Measurement of siltation in haor, beel and river each year to help researchers and policy makers take proper management plan
- Bank of the ponds can be raised above flood level for fish culture. Raising dykes higher than the flood level will protect the pond from inundation and dyke cropping with horticulture crops will protect the dykes from erosion. In addition, growing horticulture crops at dyke will provide extra profit and nutrition to the households.

Long-term

- Re- excavation of beels, canals and rivers in haor areas to revive fish breeding ground and mother fishery
- Establishment of fish pass or fish friendly structure to reconnect river

water with haor and floodplain water for successful fish migration
- Identification of breeding season of indigenous fish species
- Impact assessment of climate change on fish breeding season and fecundity
- Integrated floating cage aqua-geoponic system (IFCAS): Cage culture fish farming is one of the best options for farmers without land of their own to grow fish using open water or rivers, canals or ponds. 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 Barisal. Conceptually, cages utilize existing water resources to raise fish, but enclose them in a cage or basket which allows water to pass freely between the fish and the pond. The plant growing media in aquaponics can be soil, coconut fiber, gravel etc. In the IFCAS, dried pond mud collected from the same pond is used as a holding medium for plants.
- Development of breeding protocol of some freshwater important SIS (Pabda, Gulsha, Tengra, Balachata, Angush, Kakila, Rani, Meni, Piali, Gutum, Baim, Bata, Tatkini, Bacha, Barashi, etc.)

Strategy H: Strengthening agricultural information and marketing through digitalization

The most vital constraint in the haor areas is high prices of inputs (fertilizer, seed, labor etc.). Transportation of produce (e.g. rice grain) after harvesting is also a major problem since in most areas the roads are non-metal katcha roads. There is a good agribusiness environment with plenty of local resources in haor areas. Higher local and regional demand for good quality agricultural energy inputs (i.e., fertilizers, pesticides, feed, etc.) has created opportunities for fertilizer and pesticide industries, feed mills, etc. and business. Value chains and relationships among farmers, paikers, arotdars and retailers need to be developed using modern digital facilities such as, mobile phone apps. The government has established a countrywide network of one-stop information and service delivery access points known as Union Digital Centers (UDCs) which need to be expanded to the haor areas to deliver agricultural extension and marketing, education, health and social services. In these digital centers, an effective early warning system should be in place so that the farmers can prepare for unexpected weather and adjust their cropping/fish culture accordingly. With increasing use of computer, mobile phone, motorized two wheelers and with rapid expansion of electricity in haor areas, skilled mechanics in these areas can do brisk business. Women can be involved in taking care of computer and mobile phone business.

References

Alam MS, Quayum M and Islam M (2010) Crop production in the haor areas of Bangladesh: insights from farm level survey, The Agriculturists, 8(2):88-97.

Alam MS and Masum KM (2005) Status of homestead biodiversity in the offshore island of Bangladesh, Research Journal of Agriculture and Biological Science, 1: 246-253

Alam MS and Sazzad HM (2012) 'Haor'. In: Islam S, Jamal A (eds.). Banglapedia: National Encyclopedia of Bangladesh (Second ed.), Asiatic Society of Bangladesh.

Ahmed A (2013) Bangladesh: Environmental and Climate Change Assessment, International Fund for Agricultural Development: Rome, Italy.

Alauddin SM and Rahman KF (2013) Vulnerability to Climate Change and Adaptation Practice in Bangladesh, Journal of SUB, 4(2): 25-42.

Asian Disaster Preparedness Centre and Bangladesh Centre for Advance Studies (2008) Draft Disaster Management Information Link Report, Ministry of Food and Disaster Management, Government of Peoples Republic of Bangladesh, Dhaka, Bangladesh

Aziz MSB, Hasan, Mondol NA, Alam MMR and Haque MM (2021) Decline in fish species diversity due to climatic and anthropogenic factors in Hakaluki haor, an ecologically critical wetland in northeast Bangladesh, Heliyon 7 (1): 1-13, https://doi.org/10.1016/j.heliyon.2020.e05861

BARC (Bangladesh Agricultural Research Council) (2022) Computer and GIS Unit, BARC, Farmgate, Dhaka

BBS (Bangladesh Bureau of Statistics) (2011) Bangladesh Population and Housing Census 2011, National Report. Statistics and Information Division, Ministry of Planning, Government of the People's Republic of Bangladesh

BBS (Bangladesh Bureau of Statistics) (2012) Year Book of Agricultural Statistics 2012, Ministry of Planning, Government of the People's Republic of Bangladesh.

BBS (Bangladesh Bureau of Statistics) (2015) Year Book of Agricultural Statistics 2015, Ministry of Planning, Government of the People's Republic of Bangladesh.

BBS (Bangladesh Bureau of Statistics) (2020) Year Book of Agricultural Statistics 2020, Ministry of Planning, Government of the People's Republic of Bangladesh

Bennett S, Scott D, Karim A, Sobhan I, Khan A and Rashid SMA (1995) Chapter 3: Interpretive Description of the Region's Wetlands, Wetland Specialist Study, Northeast Regional Water Management Plan, Bangladesh Flood Action Plan 6, Bangladesh Water Development Board. Archived from the original on 2008-08-07. Retrieved on 2007-12-04.

BHWDB (Bangladesh Haor and Wetland Development Board) (2012) Master Plan of Haor Area, Ministry of Water Resources, Government of the People's Republic of Bangladesh.

BRRI (Bangladesh Rice Research Institute) (2017) Croping Systems and Land Use in Sylet Region. Bangladesh Rice Journal, 21(2): 273-288 (special issue).

CCC (Climate Change Cell) (2009) Adaptive Crop Agriculture Including Innovative Farming Practices in Haor Basin. Climate Change Cell, DoE, MoEF; Component 4b, CDMP, MoFDM, Dhaka. ISBN:984-300-003 312-5.

CEGIS (Center for Environmental and Geographic Information Services) (2012) Master Plan of Haor Area, Vol. 1, Summary Report. Ministry of Water Resource, Government of the People's Republic of Bangladesh, pp. 72.

DAE (Department of Agricultural Extension) (2007) Unpublished data, Field Crops Wing, DAE, Khamarbari, Farmgate, Dhaka-1215.

DAE (Department of Agricultural Extension) (2020) Unpublished data, Field Crops Wing, DAE, Khamarbari, Farmgate, Dhaka-1215.

DAE (Department of Agricultural Extension) (2022) Unpublished data, Field Crops Wing, DAE, Khamarbari, Farmgate, Dhaka-1215.

Gillingham S (2016) CARE Bangladesh Program Strategy: Haor Region 2015 –2020, https://www.carebangladesh.org/publication/Publication_5340141.pdf.

Haque MM, Alam R, Alam MM, Basak MB, Sumi KR, Belton B, Murshed-E- Jahan K (2015) Integrated floating cage aquageoponics system (IFCAS): An innovation in fish and vegetable production for shaded ponds in Bangladesh, Aquaculture Report, 2 2015): 1-9

Harris WG (2002) Phosphate Minerals. In JB Dixon and DG Schulze (eds) SSSA Book Series, https://doi.org/10.2136/sssabookser7.c21

Hirabayashi and Yukiko (2013) Global flood risk under climate change. Nature Climate Change, 3:816.

Hossain MK (1998) The potential role of plantations on the rehabilitation of native forest biodiversity in degraded hilly areas of Bangladesh, Proceedings 20th Bangladesh Science Conference Part 2, pp. 99-104.

Hossain MK and Hossain MA (2014) Biodiversity of Chunati Wildlife Sanctuary: Flora, Arannayk Foundation and Bangladesh Forest Department, Dhaka, Bangladesh. 175p.

Houghton RA (1994) A worldwide extent of land-use change. Bio-Science, 44: 305–313.

IPCC (2007) Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Annex I., Parry, ML, Canziani OF, Palutikof JP, van der Linden PJ and Hanson CE (eds.), Cambridge University Press, Cambridge, UK.

Islam MA (2010) Adaptive Crop Agriculture Including Innovative Practices in Haor Basin. Centre for Natural Resource Studies (CNRS), Bangladesh, Proceedings of the South Asia Regional Consultations on Strengthening Climate Resilience through a Climate Smart Disaster Risk Management Approach, Faridabad, Delhi NCR, India, 14 – 16 June, 2010.

Islam MM, Bhuiyan MNK and Harun MY (2012) Development of Value Chain: An Effective Way of Profitable Duck Farming in Haor Areas of Bangladesh. INFPD Good Practices of Family Poultry Production Note No 04.

Islam AKMS (2018) Rice Mechanization in Bangladesh, Publication number 260, Bangladesh Rice Research Institute, Gazipur, Bangladesh.

IUCN Bangladesh Country Office (2011) DRR: A Case Study of Tanguar *Haor*. International Union for Conservation of Nature, Dhaka, Bangladesh, pp.x+89. 2011.

Jabber MA and Alam MS (1993) Adoption of modern rice varieties in Bangladesh, The Bangladesh Journal of Agricultural Economics, 16(2):77-95.

Liong SY, Lim WH, Kojiri T and Hori T (2000) Advance flood forecasting for flood stricken Bangladesh with a fuzzy reasoning method, Hydrological Processes, 14(3):431-448.

KGF (Krishi Gobeshona Foundation) (2021) Unpublished data. Krishi Gobeshona Foundation, AIC Building (3rd Floor), BARC Campus, Farmgate, Dhaka-1215.

Mas JF, Velazquez A, Gallegos JRD, Saucedo RM, Alcantare C, Bocco G, Castro R, Fernandez T and Vega AP (2004) Assessing land use/cover changes: a nationwide multi-date spatial database for Mexico, International Journal of Applied Earth Observation and Geoinformation, 5: 249-261.

Miah MR (2013) Enhancing food security through acclimatized species domestication in the haor region, ABC Journal of Advanced Research, 2(1): 49-65.

MoA (Ministry of Agriculture) (2007) Hand Book of Agricultural Statistics. Ministry of Agriculture, Agro-Economic Research Unit, Government of the People's Republic of Bangladesh, Dhaka, December, 2007.

Mustafa MG, Sarker GC, Anwar SN, Ahsanuzzaman M, Rahman S, Azher S and Morshed RM (2019) Analysis of pond fisheries in climate change scenario in the Haor region of Bangladesh, Advances in Research, 2019: 1-14.

Muttaleb MA, Shahidullah SM, Nasim M and Saha A (2017) Cropping systems and land use in Sylhet region. Bangladesh Rice Journal, 21(2): 273-288.

Muttitanon W and Tiıpathi NK (2005) Land use/land cover changes in the coastal zone of Ban Don Bay, Thailand using Landsat 5 TM data. International Journal of Remote Sensing, 26(11): 2311-2323.

Muzaffar S (2004) Diurnal time-activity budgets in wintering Ferruginous Pochard Aythya nyroca in Tanguar Haor, Bangladesh, Forktail, 20(2): 25-27.

Reid N and Landsberg J (2000) Tree decline in agricultural landscapes: what we stand to lose, In Hobbs RJ and Yates CJ (eds.) Temperate Eucalypt Woodlands in Australia: Biology, Conservation, Management and Restoration, Surrey Beatty, Chipping Norton, pp. 127-166.

Sala OE, Chapin FS, Armesto JJ, Berlow E, Bloomfield J and Dirzo R (20000 Biodiversity: Global biodiversity scenarios for the year 2100, Science, 287: 1770–1774.

Sharma PK (2010) Scenario of haor vulnerabilities and other obstacles for sustainable livelihood development in Nikliupazila, Journal of Bangladesh Agricultural University, 8(2): 283-290.

Uddin MT, Hossain N and Dhar AR (2019) Business prospects and challenges in *Haor* areas of Bangladesh. Journal of Bangladesh Agricultural University, 17(1):65–72.

UNCCD Bangladesh (2018) National Report on Land Degradation Neutrality Target Setting Program (LDN-TSP) of Bangladesh 2018, United Nations Convention to Combat Desertification (UNCCD).

UNFCCC (United Nations Framework Convention on Climate Change) (2006) Technologies for Adaptation to Climate Change.

Vimala DN, Donald AG, Reddy KR and Oscar GO (2001) Soil Development in phosphate-mined created wetlands of Florida, USA, Wetlands, 21(2): 232-239.

Chapter 3 Char Ecosystem

3.1 Extent and distribution

Bangladesh is a riverine country in South Asia situated in a delta plain of the Ganges (Padma), Brhmaputra (Jamuna), Meghna and Tista rivers, and their tributaries. During monsoon season (June to October), about 844,000 million cubic water flows through these rivers (Rakib et al. 2017). “Char” is a Bengali word which denotes small landmasses (Fig. 3.1) formed along the lower streams of rivers. Chars are essentially riverine islands formed through the accretion of alluvium carried by the rivers. Rogers et al. (2013) defined charlands as the temporary sandbars developed in the Bengal Delta, which are >100m across with a duration of around 10 years.

The low rate of river discharge causes river-bed siltation and piles up enormous volume of sediments in specific point or alomg with the river channel and forms char land. It may again start to erode during flooding hazards or due to overflow of river water. Char lands are thus newly developed lands in diffient river beds.

Fig. 3.1. A char formed in the downstream area of the Jamuna river

The northwest region of Bangladesh is the entry point of the Brahmaputra (the Jamuna in Bangladesh) and the Ganges (the Padma in Bangladesh) and a lesser river, the Tista originating from the Himalayas. The Meghna, one of the three major rivers that form the Ganges Delta, is created by the confluence of two rivers, the Surma and the Kushiyara, both of which originate in the hilly regions of eastern India. The Jamuna, the Padma and the Meghna meander hundreds of kilometers through different regions and districts of Bangladesh in their southward drift towards the Bay of Bengal. Every year these three great rivers carry about 1000-2500 million tons of sediment, mainly from the Himalayan Mountains (UNEP/GPA 2006, Wasson 2003). Approximately one third of the annual sediment load is deposited in the river floodplains contributing to the development of chars in downstream areas and the rest is transported to the Bay of Bengal (Goodbred Jr and Kuehl 1999). The old Brahmaputra and Tista also contribute to the formation of some chars (Kabir 2006). In addition, the Bay of Bengal along its northern coastline has created significant char areas in several districts of the Barishal and Chattogram divisions. The charlands of Bangladesh can be divided into five sub-areas such as, the Brahmaputra-Jamuna, the Ganges-Padma, the upper Meghna and the lower Meghna chars.

> Every year major rivers of Bangladesh, the Brahmaputra-Jamuna, the Ganges-Padma and the Meghna carry about 1000-2500 million tons of sediment, mainly from the Himalayan Mountains. Approximately one third of the annual sediment load is deposited in the river floodplains. Accretion of these sediments forms small land masses locally known as chars.

In the char ecosystem there are two main livelihood zones – the char zone and the river basin zone or adjacent char zone. The char zone comprises riverine islands and the adjacent char zone refers to adjacent villages which are located on the banks of the rivers and the coast. Chars are found in 14 of the 30 Agro-Ecological Zones (AEZ) of Bangladesh (Fig. 3.2): (1) Active Brahmaputra-Jamuna Floodplain, (2) Old Brahmaputra Floodplain, (3) Young Brahmaputra-Jamuna Floodplain, (4) Active Tista Floodplain/Tista Meander Floodplain, (5) Active Ganges Floodplain, (6) Ganges Tidal Floodplain, (7) High Ganges River Floodplain, (8) Low Ganges River Floodplain, (9) Lower Meghna River Floodplain, (10) Middle Meghna River Floodplain, (11) Young Meghna Estuarine Floodplain, (12) Old Meghna Estuarine Floodplain (13) Young Brahmaputra and Jamuna Floodplain and (14) Chattogram Coastal Plain.

These chars and adjacent chars occur in 170 out of 495 upazilas in 41 out of 64 districts Bangladesh (Table 3.1). These 41 char-containing districts belong to 7 divisions viz. Barishal, Chattogram, Dhaka, Khulna, Mymensingh, Rajshahi and Rangpur of the country. Overall, about one-third upazilas (34.3%) of Bangladesh are strewn with chars representing a fragile ecosystem.

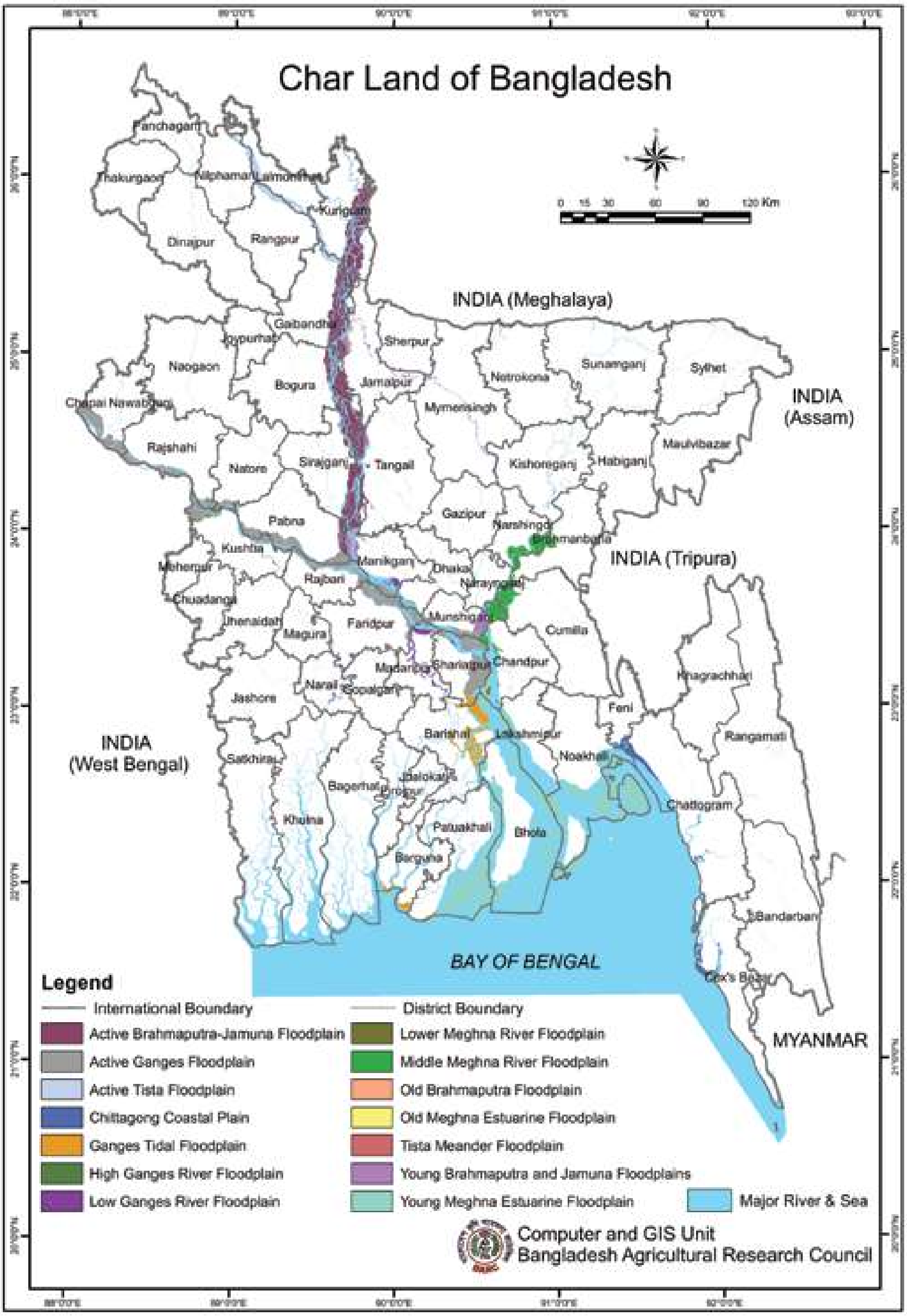


Fig. 3.2. Map of Bangladesh showing char areas along with agro-ecological zones
(Source: BARC 2022)

Table 3.1. Distribution of chars in upazilas, districts and divisions in 2022

Division	District (no.)	Districts with chars (no.)	Total upazila (no.)	Upazila with chars (no.)	% of districts with chars	% of upazilas with chars	% of upazilas (all Bangladesh) with chars
Barishal	6	4	42	21	66.7	50.0	4.2
Chattogram	11	8	105	35	72.7	33.3	7.1
Dhaka	13	11	90	44	84.6	48.9	8.9
Khulna	10	4	59	12	40.0	20.3	2.4
Mymensingh	4	3	45	15	75.0	33.3	3.0
Rajshahi	8	6	67	20	75.0	29.9	4.0
Rangpur	8	5	58	23	62.5	39.7	4.6
Total	60	41	466	170	68.3	36.5	34.3
Bangladesh	64	41	495	170	64.1	34.3	34.3

Source: BBS 2020 and BARC 2022

The char areas of Barishal, Chattogram, Dhaka, Khulna, Mymensingh, Rajshahi and Rangpur divisions occupy nearly 9,16,894 ha which is about 18.7% of the total area (48,97,014 ha) of the divisions with chars and 6.3% of the total area of Bangladesh (1,44,86,269 ha) (Fig. 3.3). The Dhaka division has the largest area of chars, 1,95,544 ha, Chattogram, Barishal and Rajshahi following in that order with about 1,94,782, 1,86,426 and 1,59,054 ha, respectively which are significantly larger than those in the other 3 divisions, Rangpur, Mymensingh and Khulna (Fig. 3.4).

Fig. 3.3. Areas of charland in Bangladesh in 2022
(Source: BBS 2020 and BARC 2022)

According to an ISPAN (Irrigation Support Project for Asia and Near East) report, areas of chars formed by all the rivers of Bangladesh increased during 1989 to 1993, except in the upper Meghna (ISPAN 1995) basin. The net increase in char area during this period amounted to 36,000 ha which was equivalent to about 25% of the total char area during 1984. ISPAN also reported (Newsletter,

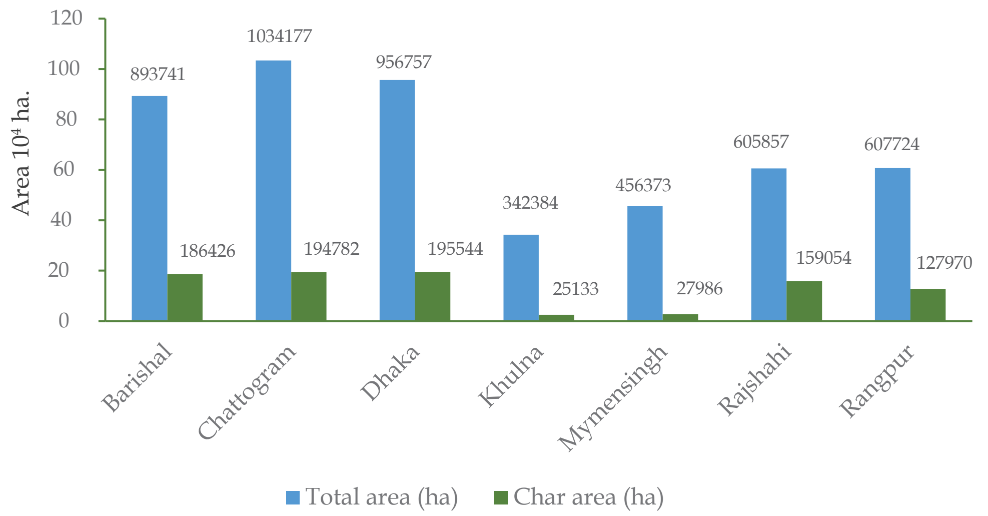


Fig. 3.4. Char areas in seven divisions of Bangladesh (Source: BBS 2020 and BARC 2022)

March, 2006) that riverine chars in Bangladesh in 2004 occupied around 1,723 km^2 which was equivalent to the area of the district of Natore. Besides, there are lots of chars on minor rivers of the country. The areas of charlands as mentioned in the reports of Satter and Islam (2010) and the Daily Prothom Alo (published on 24 July 2015) were in line with that reported by the Department of Agricultural Extension (DAE): 834,348 ha. The total char area has increased by 8.7% from 843,726 ha in 2015 to 916,894 ha in 2022 (BARC 2022) indicating an annual growth rate of 1.24 % (Table 3.2).

Table 3.2. Changes in char area between 2015 and 2022

Division	Char area (ha)			Increase/ decrease in char area over 2015** (%)	Increase/ decrease in char area over 2015*** (%)
	2015*	2022**	2022***		
Barishal	177122	186426	158215	5.3	-11
Chattogram	163379	194782	181870	19.2	11
Dhaka	181234	195544	190872	7.9	5
Khulna	24082	25133	21513	4.4	-11
Mymensingh	25734	27986	83813	8.8	226
Rajshahi	141192	159054	179595	12.7	27
Rangpur	130982	127970	114889	-2.3	-12
Total	843726	916894	930767	8.7	10

Source: *FD 2015, **BARC 2022, ***DAE 2022

The highest increase of char area during 7 years between 2015 and 2022 occurred in Chattogram (19.2%) followed by Rajshahi (12.7%) and Mymensingh (8.8%). Despite an overall increase throughout Bangladesh, there was a decrease in char areas in the Rangpur division (2.3%). The increase in char areas is attributed to natural river flow and sedimentation processes.

The Meghna River has created the largest char area (341,000 ha). The chars formed by the Padma, the Brahmaputra-Jamuna and the Tista systems occupy 254,000, 219,000 and 43,000 ha, respectively. The coastal chars have a total area of 23,000 ha (Fig. 3.5).

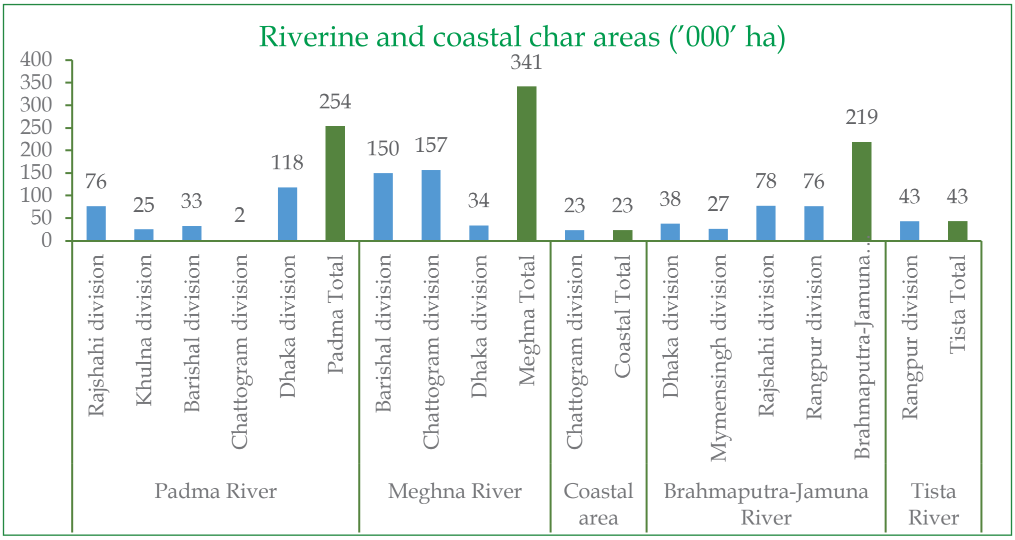


Fig. 3.5. Areas of chars formed by rivers systems and the Bay of Bengal in different divisions of Bangladesh in 2022 (Source: BARC 2022)

Table 3.3 shows the areas of chars in different upazilas existing in the Brahmaputra-Jamuna, Tiasta, Padma and Meghna river basins. In the Brahmaputra-Jamuna basin, the largest char area (49,649 ha) is in the Sirajganj district followed by Kurigram (46,077 ha). Lalmonirhat has the largest char area (12,383 ha) in the Tista basin followed closely by Kurigram (12,114 ha).

The Ganges River enters northwestern Bangladesh and merges with the Jamuna at the Manikganj-Rajbari-Pabna point and then flows south taking the name "Padma". The Padma has created a great number of chars with a total area of 253,538 ha in the districts of Shariatpur, Pabna, Faridpur, Barishal, Kushtia, Rajbari, Rajshahi and Chattogram. The Meghna River on its way to the Bay of Bengal merges with the Padma river and in its path has formed a significant number of chars in 12 districts covering 3 divisions with a total area of 3,41,821 ha (Table 3.3). Coastal chars exist in the Chattogram, Cox's Bazar, Feni and Noakhali districts in southeastern Bangladesh, their total area (23,394 ha) being much smaller than that of the riverine chars.

Table 3.3. Char areas in different upazilas in the major river basins of Bangladesh

Division	District	Upazila	Char area (ha)
Brahmaputra-Jamuna Basin			
Dhaka	Kishoreganj	Hossainpur, Pakundia	1131
	Manikganj	Doulatpur, Shibalaya	10344
	Munshiganj	Gazaria, Munshiganj Sadar	7677
	Narayanganj	Sonargaon	611
	Rajbari	Goalandaghat	289
	Tangail	Bhuapur, Delduar, Gopalpur, Kalihati, Nagarpur, Tangail Sadar	18093
Mymensingh	Jamalpur	Bakshiganj, Dewanganj, Islampur, Jamalpur Sadar, Madarganj, Melandaha, Sarishabari	21699
	Mymensingh	Gaffargaon, Gouripur, Ishwarganj, Mymensingh Sadar, Nandail, Trishal	4252
	Sherpur	Nakla, Sherpur Sadar	523
Rajshahi	Bogura	Dhunot, Sariakandi, Sonatola	20958
	Pabna	Bera	7036
	Sirajganj	Belkuchi, Chouhali, Kazipur, Shahjadpur, Sirajganj Sadar	49649
Rangpur	Gaibandha	Fulchari, Gaibandha Sadar, Saghata, Sundarganj	30422
	Kurigram	Char Rajibpur, Chilmari, Kurigram Sadar, Nageshwari, Roumari, Ulipur	46077
Total	14	49	218760
Tista Basin			
Rangpur	Kurigram	Chilmari, Kurigram Sadar, Nageshwari, Fulbari, Rajarhat, Ulipur, Bhurungamari	12144
	Lalmonirhat	Aditmari, Hatibandha, Kaliganj, Lalmonirhat Sadar, Patgram	12383
	Nilphamari	Dimla, Jaldhaka	5055
	Rangpur	Gangachara, Kaunia, Pirgachha	8226
	Gaibandha	Sundarganj	5144
Total	5	18	42953

Padma Basin			
Rajshahi	Chapainawabganj	Chapai Nawabganj Sadar, Shibganj	24224
	Natore	Lalpur	5492
	Pabna	Bera, Ishwardi, Pabna Sadar, Sujanagar	29099
	Rajshahi	Bagha, Charghat, Godagari, Paba, Rajshahi City Corporation	16808
Khulna	Jhenaidah	Shailkupa	200
	Kushtia	Bheramara, Doulatpur, Khoksa, Kumarkhali, Kushtia Sadar, Mirpur	22521
	Magura	Magura Sadar, Mohammadpur, Sherpur	925
	Narail	Kalia, Lohagora	1366
Barishal	Barguna	Barguna Sadar, Patharghata, Taltali	5771
	Barishal	Babuganj, Barishal Sadar, Hizla, Mehendiganj, Muladi	24760
	Bhola	Bhola Sadar	316
	Patuakhali	Kalapara	1949
Chattogram	Chandpur	Chandpur Sadar, Matlab Uttar	2308
Dhaka	Dhaka	Dohar, Nawabganj	2089
	Faridpur	Alfadanga, Bhanga, Boalmari, Char Bhadrasan, Faridpur Sadar, Modhukhali, Sadarpur	27531
	Madaripur	Kalkini, Madaripur Sadar, Rajoir, Shibchar	12007
	Manikganj	Dalatpur, Harirampur, Manikganj Sadar, Shibalay	8652
	Munshiganj	Sreenagar, Tongibari, Louhajang, Munshiganj Sadar	7693
	Rajbari	Kalukhali, Pangsha, Rajbari Sadar, Goalandaghat, Baliakandi	16908
	Shariatpur	Bhedarganj, Damudya, Gosairhat, Naria, Zanjira	42920
Total	20	69	253538
Meghna Basin			
Barishal	Barishal	Bakerganj, Barishal Sadar, Hizla, Mehendiganj	10200
	Bhola	Bhola Sadar, Burhanuddin, Char Fasson, Doulatkhan, Lalmohon, Manpura, Tazumuddin	70749
	Patuakhali	Bauphal, Dashmina, Galachipa, Kalapara, Rangabali	68967

Chattogram	Brahmanbaria	Ashuganj, Bancharampur, Nabinagar	7936
	Chandpur	Chandpur Sadar, Haimchar, Matlab Dhakshin, Matlab Uttar	11574
	Chattogram	Sandwip	41645
	Laxmipur	Kamalnagar, Laxmipur Sadar, Ramgati, Roypur	9207
	Noakhali	Companiganj, Hatiya, Subornachar	76546
	Cumilla	Daudkandi, Homna, Meghna, Titas	10562
Dhaka	Munshiganj	Gozaria, Louhajang, Munshiganj, tongibari	11329
	Naraynganj	Araihazar, Sonargaon, Narsingdi Sadar, Roypura	21343
	Shariatpur	Bhedarganj, Gosairhat	1763
Total	12	45	341821
Coastal Chars			
Chattogram	Chattogram	Anowara, Banshkhali, Boalkhali, Chattogram City Corporation, Mirsarai, Patiya, Raozan, Sitakunda	9180
	Cox's Bazar	Chakoria, Cox's Bazar Sadar, Idgaon, Kutubdia, Moheshkhali, Pekua, Teknaf	9081
	Feni	Sonagazi	3799
	Noakhali	Companiganj	1333
Total	4	17	23394

Source: BARC 2022

3.2 Biophysical characteristics

3.2.1 Land and soil

The char landscape

Chars 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 changes due to erosion and accretion in the large river systems also change the landscape of the erosion, nor'westers, hailstorms, excessive rains etc. Chars are also vulnerable to recurrent natural calamities like floods (Fig. 3.6) during monsoon season. Chars in the Tista, the Brahmaputra and the Jamuna floodplains are affected by floods from mid-June to September (Karim et al. 2017). On the other hand, chars of the rivers Padma and Meghna experience floods from mid-July to September, except the chars of coastal region. The coastal chars are not usually affected by floods, although these chars are sometimes affected by tropical cyclones mostly during October to December and April to May, when the intrusion of seawater is very common. The coastal chars are affected by salinity during hot dry period (March-June).

Fig. 3.6. A flooded char

Chars in the Tista, Brahmaputra-Jamuna and Meghna floodplains are very different in terms of formation process and physiographic characteristics from those in the lower Meghna estuary. Within the braided belt of the Jamuna, chars have different sizes varying in length between 0.35 and 3.5 km (Banglapedia 2022). Char formations in the meandering Padma are different with a higher incidence of attached chars, which are connected with the mainland, creating new opportunities for settlement and agricultural activities.

There are few stable chars in the Jamuna, Ganges and Padma rivers, while, as mentioned above, all chars in the upper Meghna river are very stable. Chars in the lower Meghna river are relatively new and little can be said about their stability. The instability of the chars in the Jamuna is inherent in the dynamic characteristics of this braided river. The earthquake of 1950 in Assam and adjacent areas might also have contributed to the instability of the Jamuna chars (Banglapedia 2021). Due to this earthquake, huge amounts of sediments might have been dumped into the river, which travelled downstream during subsequent decades. As the total supply of sediments exceeded the transport capacity of the river, sediments were gradually deposited in the riverbeds. To compensate for its reduced water-carrying cross section, the river eroded substantial parts of its riverbanks. This resulted in a continuous process of char formation and river widening in the Jamuna whereby relatively fine bank material was eroded and coarser material got accreted. Analysis of recent satellite images show that the rate of widening of the Jamuna has been decreasing since the early 1990s. On the other hand, the Padma has been showing an increasing trend of widening in the last decades. The increase in sediment supply might have been due to deforestation and intensive cultivation upstream. This could result in the formation of more chars in the Padma river (Banglapedia 2021).

The Jamuna chars, particularly in the Kazipur-Sirajganj area, are largely island chars between river channels. Some of the island chars are old and long-established. In the last 50 years, the Kazipur upazila lost over one third of its land area due to continuous westward migration of the Jamuna River. Floods damage crops, seeds, animal feed and houses in many chars, especially in the Tista-Brahmaputra-Jamuna basins, e.g., in Aditmari (Lalmonirhat), Nageshwari (Kurigram), Dewanganj (Jamalpur) and Daulatpur (Manikganj) upazilas.

Land and soil type

The land type and soil characteristics of the chars vary with the river system (Brahmaputra-Jamuna/Ganges-Padma/Meghna) that had formed them. On the basis of the FAO-UNDP (1988) land classification for Bangladesh, high land is rare in the chars. Most chars have medium high land (MHL), low land (LL) and very low land (VLL). The chars of the Brahmaputra-Jamuna-Tista-Padma rivers systems are generally less elevated with usually MHL, MLL, LL and VLL than those of the Meghna River or the costal chars with usually MHL (Karim et al. 2017). The soils are mostly coarse textured, sandy loam, loamy sand and loamy with some silty loam and silty clay soils.

Soil fertility

Soil pH and organic matter

The soils are mostly neutral and mildly to moderately alkaline (average pH 7.30 to 7.80) in chars of the Brahmaputra, Padma and Meghna river systems and coastal areas, while those in the Tista and Jamuna chars are near neutral with average pH values of 6.75 to 6.90 (Karim et al. 2017).

Table 3.4 shows the trends in pH values of char soils over two decades from 1999 to 2021. The minimum soil pH values across land types, i.e., MHL, MLL, LL and VLL ranged from 4.1 to 4.6 (strongly to extremely acidic) during 2003-2021 and from 3.5 to 7.9 (extremely acidic to moderately alkaline) in 1999-2002. The corresponding maximum soil pH values were 8.5-8.8 and 8.3-8.9, respectively. The development of soil acidity in charlands may be due to runoff loss of bases on the one hand and organic acid production during the anaerobic decomposition of organic matter in a wetland environment while alkalinity (high pH) originated from calcareous material in the alluvial sediments deposited during flooding (Vimala et al. 2001). A comparison of maximum and minimum pH values of soils in char areas between these two periods (1999-2002 and 2003-2021) indicates that there were no significant changes in soil pH except that some VLL soils tended to become acidic. An increase in soil acidity may decrease the availability of essential plant nutrients like phosphorus and molybdenum and, increase the concentrations of aluminum and manganese which could be toxic to crop plants.

> The chars are often unstable at least for the first few years. The land type and soil characteristics of the chars vary with the river system that had formed them. The chars have mostly medium high or low lands. The soils are usually coarse-textured, neutral to moderately alkaline, have very low organic matter indicating poor fertility.

Table 3.4. Range and class of soil pH in charlands during 1999-2021

pH (2003-2021)				
	MHL	MLL	LL	VLL
Min	4.1	4.3	4.2	4.6
Class	Extremely acidic	Extremely acidic	Extremely acidic	Strongly acidic
Max	8.5	8.8	8.7	8.6
Class	Strongly alkaline	Strongly alkaline	Strongly alkaline	Strongly alkaline
pH (1999-2002)				
Min	3.5	4.2	4.5	7.9
Class	Extremely acidic	Extremely acidic	Strongly acidic	Moderately alkaline
Max	8.7	8.6	8.9	8.3
Class	Strongly alkaline	Strongly alkaline	Strongly alkaline	Moderately alkaline

Source: BARC, 2022

The soil organic matter (SOM) content in the chars is low, mostly below 2.0% many soil samples having as low SOM as <1.0%, irrespective of the river system where the chars were developed (Karim et al. 2017). The chars of the Padma and Meghna river systems have generally higher SOM than those of the Tista-Brahmaputra-Jamuna systems.

The trends in SOM accumulation in charlands over three decades from 1989 to 2021 (Fig. 3.7) have been interesting. It has increased by 0.3-0.8% across the land types in 1999-2002 from the levels in 1989-1998, but decreased slightly in the 2003-2021 period. However, SOM in the various land types, being mostly <2% has always remained inadequate for soil productivity. The fluctuations in the SOM content in charlands could be attributed to that in the sediment loads of the rivers and shifting patterns of yearly deposition of sediments carrying coarse organic materials and humus. Himalayan sediments with sand, silt and clay sized particles and organic matter carried by the rivers are deposited differentially along the flood zones, the coarser particles, i.e., sand and coarse silt are deposited first and fine silt, clay and humus are carried further downstream. The charlands upstream receive sand and little organic matter and, thus, most of the riverine chars contain sandy to sandy loam soils and a low SOM.

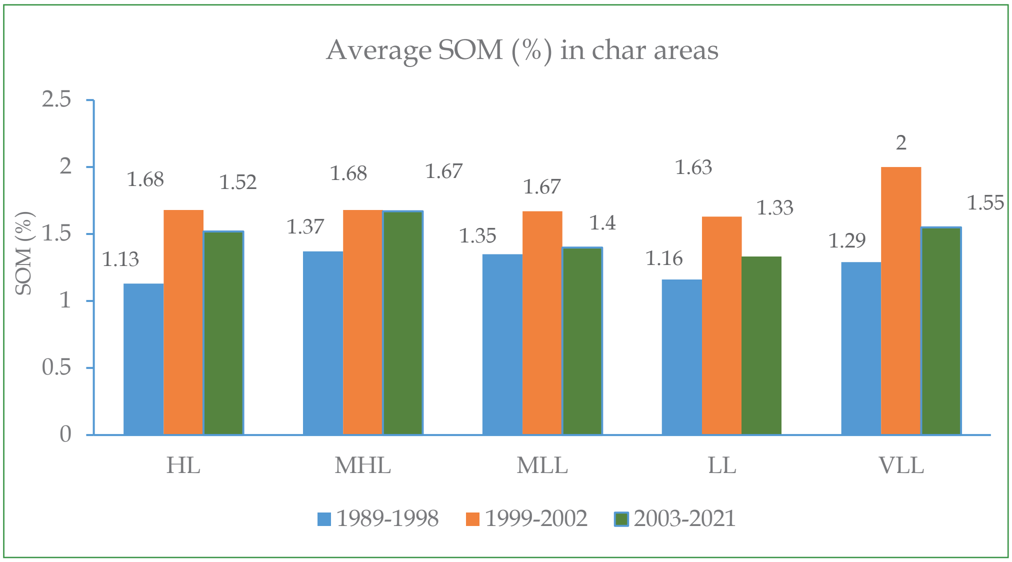


Fig. 3.7. Organic matter content in soils of different char areas (Source: BARC 2022)

Plant nutrients

Most soils have a very low total nitrogen (N) content, 0.04-0.15%, which is inadequate for crops. Soils of the costal chars have particularly low available phosphorus (P), only 1.89 to 5.75 ppm. Soils in the riverine chars have a higher available P content which is barely sufficient for crop plants. Thus, mild to severe P deficiency may be a problem in crop production in the char areas. The available potassium (K), i.e., exchangeable K content, in soils of the Tista, Brahmaputra and Jamuna river systems is generally low, indicating K deficiency. However, in the Padma and Meghna chars soil K is adequate (0.21-1.50 meq/100g). The available sulfur (S) in the char soils is quite high, in a range of 10-40 ppm (Karim et al. 2017). The available zinc (Zn) content in the char soils is generally low, <1.0 ppm, indicating Zn deficiency in most char soils. The available boron (B) content of the soils is well below the toxic level for crop plants; the B level is generally higher in the coastal char soils than that in the riverine char soils (Karim et al. 2017).

Fig. 3.8 and 3.9 illustrate changes in available P and exchangeable K contents, respectively, in char soils over a period of two decades, 1999-2021. Irrespective of land types, during 1999-2002 and 2003-2021. The available P levels in char soils ranged from 3.5-9.43 ppm (Fig. 3.8) which were much below the optimum level of >15 ppm for crop production. The char soils, are, thus, generally moderately to severely P deficient. The changes in available P level in the char soils over the two decades did not follow any consistent pattern with respect to land type or time.

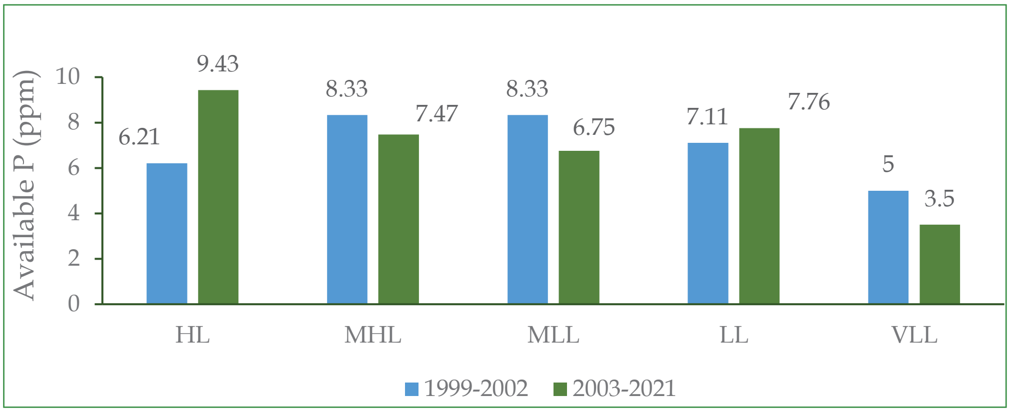


Fig. 3.8. Available P in soils of different land types in char areas of Bangladesh during 1999-2002 and 2003-2021 (Source: BARC 2022)

The exchangeable (available) K level of soils in the char areas across land types, ranging from 0.19 to 0.40 meq/100 g (Fig. 3.9), is generally lower than the optimum level of 0.5 meq/100 g needed for good crop productivity. The soils could well be categorized as mildly to moderately K deficient. Over time, there has been generally a decline in the exchangeable K in the char soils which was obviously due to K depletion from soils for increasing cropping intensity without adequate K fertilizer application.

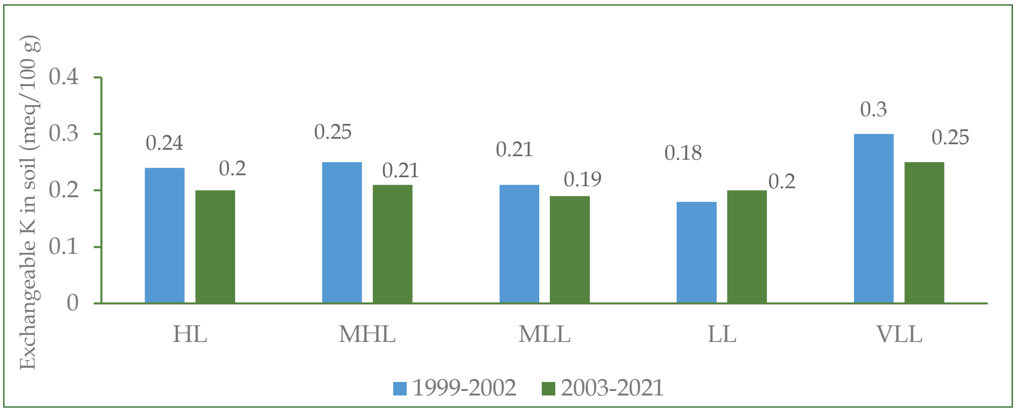


Fig. 3.9. Exchangeable K in soils of different land types in char areas of Bangladesh during 1999-2002 and 2003-2021 (Source: BARC 2022)

the last two decades (1999-2021) at such high levels as 17.16-68.85 ppm (Fig. 3.10). However, irrespective of land types, there has noticeably been a decline in the soil S level over time. While in the 1999-2002 period the available S level was 34.8-68.8 ppm, it decreased by almost 50% to 17.2-34.7 ppm which is clearly a consequence of expansion of crop cultivation in the charlands with no or inadequate S fertilization.

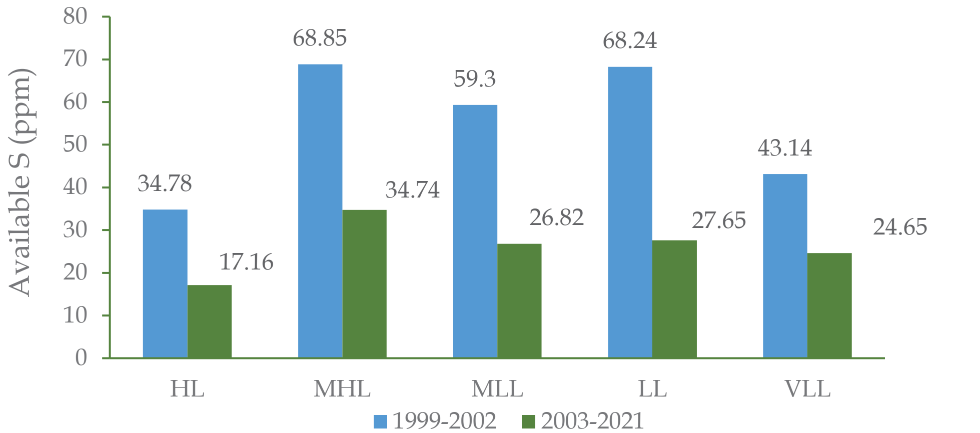


Fig. 3.10. Available S in char soils of Bangladesh during 1999-2002 and 2003-2021 (Source: BARC 2022)

The available Zn content in the char soils, ranging from 0.57 to 0.96 ppm (Fig. 3.11), during the last two decades has remained much below both the critical level (2.0 ppm) and optimum level (4.0 ppm) during 1999-2002 and 2003-2021. However, an increase from 0.57-0.88 ppm in 1999-2002 to 0.71-0.96 ppm in 2003-2021 has occurred across the land types.

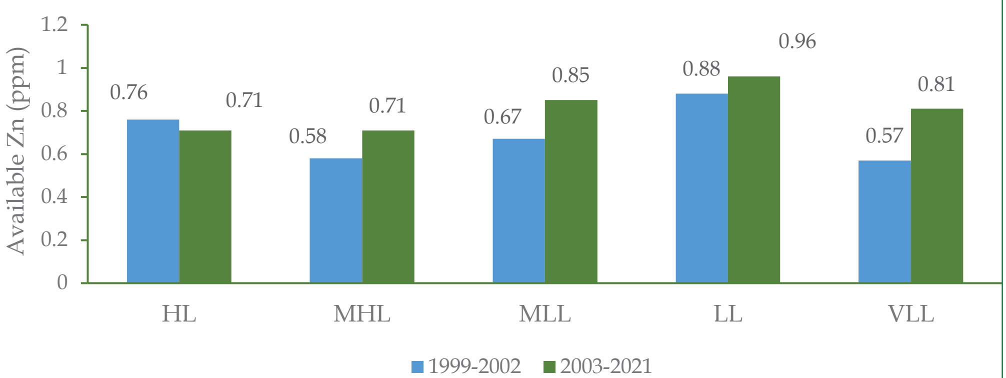
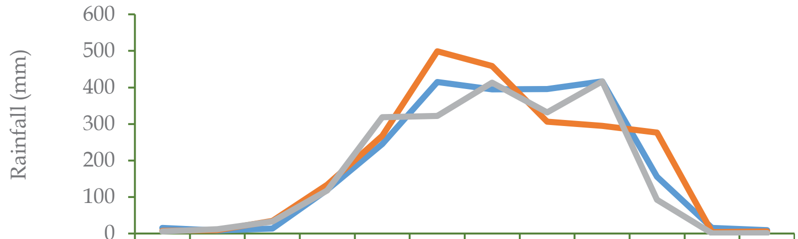


Fig. 3.11. Available Zn in char soils of Bangladesh during 1999-2002 and 2003-2021 (Source: BARC 2022)

3.2.2 Climate

Rainfall

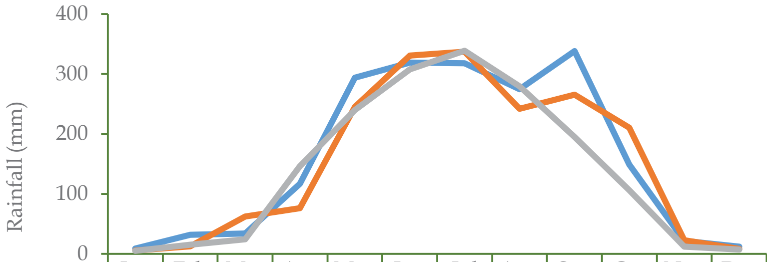
Precipitation in the Brahmaputra-Tista char areas of Rangpur division during the last three decades (1991-2020) remains concentrated during April-October of a year peaking in the months of May-September (Fig. 3.12). During 2011-2020, the highest amounts of rainfall occurred in May (318 mm), July (413 mm) and September (417 mm). Over the last 20 years the amount of total rainfall has increased sharply during May (first part of Kharif-I), but has dropped drastically in October and almost to zero in the months of November-December and January-February (Fig. 3.12). These shifts in the rainfall pattern are potentially unfavourable for crop agriculture in the char areas affecting the whole gamut of the yearly crop calendar. In particular, increased rainfall in May affects planting of Kharif-I vegetables and jute due to submergence by floods at the vegetative stage. On the other hand, the dry spells in October-February cause water stress at the productive stage of Boro rice and hampers the establishment and growth of non-rice Rabi (winter) crops.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg Rainfall during 1991-2000	15	8	14	119	244	415	395	395	417	155	15	9
Avg Rainfall during 2001-2010	7	9	35	133	267	499	459	306	295	276	4	5
Avg Rainfall during 2011-2020	5	12	33	118	318	322	413	332	417	92	0	1

Fig. 3.12. Long-term trend of monthly rainfall in the Brahmaputra-Tista River char areas of Rangpur division (Source: BARC 2022)

The Jamuna chars exist mostly in the Tangail and Manikganj districts of Dhaka division where, like in the chars of the Brahmaputra-Tista up north, most rainfall occurs during April-October (Fig. 3.13). But the amounts of rainfall are lower in the Jamuna chars than that in the Brahmaputra-Tista chars. During 2011-2020, July recorded the highest rainfall (339 mm) followed by June (308 mm) and August (279 mm). The months of November, December, January and February during 2011-2020 received very little rainfall. In these char areas, there has been particularly a steep increase in rainfall in April but rainfall decreased over time in the lean months of October-December and January-February. These consequences affect the harvest and post-harvest processing of Boro rice and causes water stress during maturing of T. Aman rice.

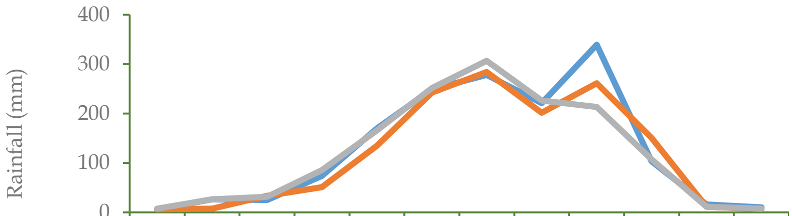


	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg Rainfall during 1991-2000	9	32	34	117	294	319	318	275	338	149	22	12
Avg Rainfall during 2001-2010	6	13	62	77	245	331	337	242	265	210	23	8
Avg Rainfall during 2011-2020	5	15	25	146	240	308	339	279	195	106	12	8

Fig. 3.13. Long-term trend of monthly rainfall in the Jamuna River char areas (Tangail, Manikganj) of Dhaka division (Source: BARC 2022)

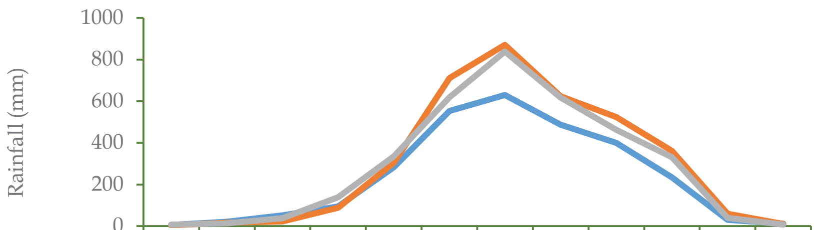
Rainfall patterns (Fig. 3.14) in the Padma chars at Ishawrdi, Pabna of Rajshahi division are similar as those in the Brahmaputra-Jamuna chars. Precipitation was mostly concentrated in the months of April-October and there is almost zero rainfall in the Rabi season. Over the last 20 years, like in the Brahmaputra-Jamuna chars, the wet Kharif months became wetter and Rabi months drier aggravating risks for vegetables and Boro rice crops.

Rainfall in the Meghna char areas of the southern costal districts of Chattogram division differs in terms of amounts and trends from that in the char areas up north although the period of highest precipitation is similar, i.e., April-October (Fig. 3.15). Within the April-October period, rainfall in the Meghna chars is more evenly distributed than it is in the Brahmaputra-Tista-Jamuna-Padma chars. Also, the total yearly rainfall is higher in the southern Meghna chars than that in the northern riverine chars. During 2011-2020, the total rainfall in chars of Hatiya, Noakhali amounted to 838 mm in July, 618 mm in August and 330 mm in October. Unlike the northern chars, there is little rainfall in the Rabi season (Fig. 3.15). In the last 30 years, an increasing trend in rainfall amounts has been observed during April, May, June, July, August and October, unlike in the northern chars, in November, too when compare the periods, 1991-2000 and 2011-2020. Rainfall, however, declined in the months of December, February and March. In this char region, high rainfall in the entire Kharif-I period could be an advantage for growing Aus rice (summer rice). On the other hand a good amount of rainfall in the months of September and October would be beneficial for T. Aman rice. Some amount of rainfall in November would facilitate planting of Rabi crops. Also, with abundant rainfall in September and October there would be enough residual moisture in the soil which would be beneficial for Rabi crops.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg Rainfall during 1991-2000	6	26	25	74	170	249	279	222	340	104	16	10
Avg Rainfall during 2001-2010	7	7	34	51	135	243	284	202	262	151	12	7
Avg Rainfall during 2011-2020	7	26	32	86	166	252	307	226	214	108	11	8

Fig. 3.14. Long-term trend of monthly rainfall in the Padma River char areas (Ishawrdi, Pabna) of Rajshahi division (Source: BARC 2022)

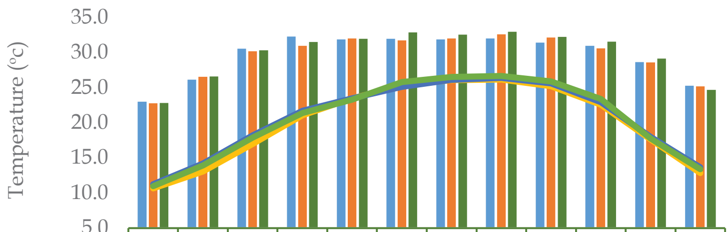


	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg Rainfall during 1991-2000	5	21	52	94	283	553	630	488	399	233	30	12
Avg Rainfall during 2001-2010	5	17	23	89	305	711	871	624	524	361	59	11
Avg Rainfall during 2011-2020	6	13	38	139	335	619	838	618	463	330	40	6

Fig. 3.15. Long-term trend of monthly rainfall in the Meghna River char areas (Hatiya, Noakhali) of Chattogram division (Source: BARC 2022)

Temperature

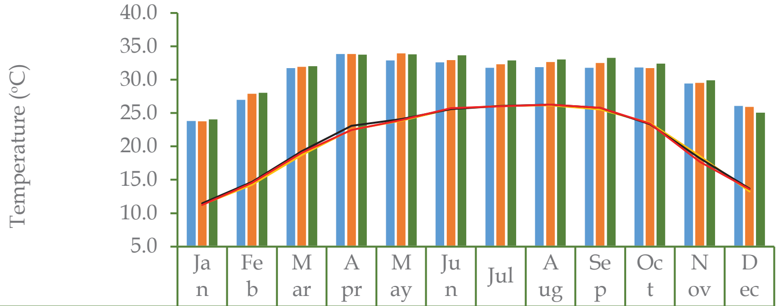
As in other parts of Bangladesh, the ambient minimum and maximum temperatures (T_{min} and T_{max}) in char areas throughout the year have a common pattern. The lowest temperature in January which rises steadily, reaches the peak in June-August and then falls continuously during the rest of the year (Fig. 3.16), the difference between January and August temperatures hardly exceeding 12 °C. Nowhere in the char areas across Bangladesh does the T_{min} and T_{max} difference at any given time of the year exceed 15 °C. However, temperatures vary considerably across the char areas. In the last 30 years T_{max} did not exceed 35 °C and T_{min} did not fall below 10 °C anywhere in the char areas. During 2011-2020, in the Brahmaputra-Tista char areas of Rangpur division the monthly T_{max} ranged from 22.8 °C in January to 33 °C in August and T_{min} from 11 °C in January to 26 °C in August (Fig. 3.16). In the last 30 years (1991-2020), T_{max} has increased by 0.5-1 °C in 8 months of the year (Fig. 3.16) while it has decreased in January, March, April and December. The T_{min} has also increased by 0.10-0.9 °C in all months of the year except in May (Fig. 3.16) indicating an adverse impact of global warming.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg MaxT during 1991-2000	23.0	26.1	30.5	32.3	31.9	32.0	31.9	32.0	31.4	31.0	28.6	25.3
Avg MaxT during 2001-2010	22.8	26.5	30.2	30.9	32.0	31.7	32.0	32.6	32.1	30.6	28.6	25.2
Avg MaxT during 2011-2020	22.8	26.6	30.3	31.5	32.0	32.9	32.5	33.0	32.2	31.5	29.1	24.7
Avg MinT during 1991-2000	10.7	13.1	17.0	21.1	23.5	25.3	26.1	26.1	25.2	22.6	17.6	12.8
Avg MinT during 2001-2010	11.3	14.2	18.2	21.7	23.5	25.1	26.1	26.4	25.6	22.9	18.0	13.7
Avg MinT during 2011-2020	11.0	13.9	17.9	21.4	23.3	25.8	26.5	26.6	25.9	23.4	17.7	13.4

Fig. 3.16. Long-term trend of monthly maximum and minimum temperatures in the Brahmaputra-Tista char areas of Rangpur division
(Source: BARC 2022)

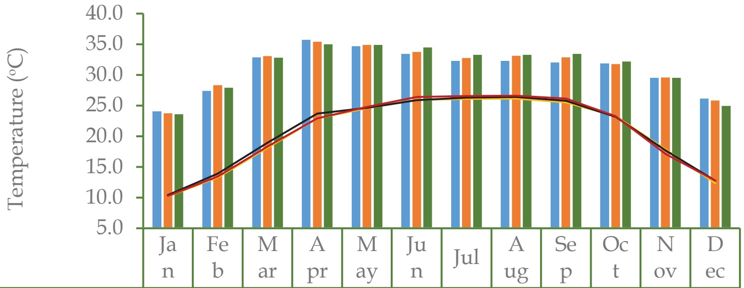
The pattern of temperature fluctuation through the year in other char areas of the country is similar (Fig. 3.17-3.19) as that observed in the Brahmaputra-Tista chars discussed above. Also, like Brahmaputra-Tista chars, an increasing trend of temperature over the last 30 years in certain periods of the year has been observed in the Brahmaputra-Jamuna, Padma and Meghna chars. However,



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg MaxT during 1991-2000	23.8	27.0	31.7	33.8	32.9	32.6	31.8	31.9	31.8	31.8	29.5	26.1
Avg MaxT during 2001-2010	23.7	27.9	31.9	33.9	33.9	33.0	32.3	32.7	32.5	31.8	29.5	25.9
Avg MaxT during 2011-2020	24.1	28.1	32.0	33.8	33.8	33.6	32.9	33.0	33.3	32.4	29.9	25.1
Avg MinT during 1991-2000	11.3	14.2	18.7	22.5	23.9	25.6	26.0	26.2	25.6	23.5	18.6	13.2
Avg MinT during 2001-2010	11.5	14.7	19.3	23.1	24.1	25.6	26.1	26.3	25.8	23.3	18.2	13.7
Avg MinT during 2011-2020	11.2	14.5	19.1	22.5	24.0	25.7	26.0	26.2	25.8	23.4	17.7	13.6

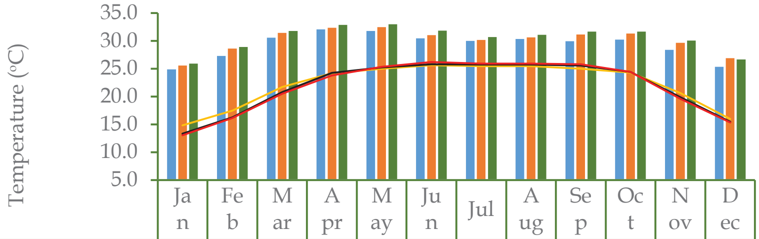
Fig. 3.17. Long-term trend of monthly maximum and minimum temperature in the Jamuna River char areas (Tangail and Manikganj) of Dhaka division (Source: BARC 2022)

the chars vary considerably from region to region in terms of the actual temperatures in different months of the year. For example, the Padma chars of Rajshahi division are generally cooler in the Rabi season but warmer in the Kharif period of the year than any of the other chars. In the Padma chars (Ishawrdi, Pabna), during 2011-2020, T_{min} ranged from 10.3 °C (January) to 26.6 °C (August) and T_{max} from 23.6 °C (January) to 35 °C (August) (Fig. 3.18). In the last 30 years T_{max} has increased in the Padma chars by 0.2 to 1.4 °C in all months of the year except January, March, April, November and December. The T_{min} has also increased by 0.1 to 0.7 °C in all months of the year except April, October and November. On the other hand, in the Meghna chars of the coastal region (Hatiya, Noakhali), the Rabi season is warmer and the Kharif period is cooler compared to Padma char areas (Fig 3.19). The T_{min} ranged from 13.1 °C (January) to 26.2 °C (July) and T_{max} from 25.9 °C (January) to 33 °C (May) during 2011-2020. In the last 30 years, T_{min} increased by 0.1 to 0.8 °C during May-October. While T_{max} has increased by 0.7 to 1.8 °C in all months of the year, the greatest increase being in the month of November (1.8 °C) during reproductive stage of T. Aman rice. This indicates relatively high night temperature which could reduce net photosynthesis and, thus, affect yield adversely. In the Rabi to Kharif-I period (November to April), on the other hand, T_{min} generally decreased in the last 30 years by 0.4 to 1.7 °C which could be rather beneficial for the winter vegetables, legumes, oilseeds etc. and Aus rice.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg MaxT during 1991-2000	24.1	27.4	32.8	35.7	34.7	33.4	32.3	32.3	32.0	31.9	29.5	26.1
Avg MaxT during 2001-2010	23.7	28.3	33.1	35.4	34.9	33.8	32.8	33.1	32.8	31.8	29.6	25.8
Avg MaxT during 2011-2020	23.6	27.9	32.8	35.0	34.9	34.5	33.2	33.3	33.4	32.2	29.5	24.9
Avg MinT during 1991-2000	10.2	13.3	18.1	22.9	24.6	25.9	26.1	26.1	25.5	23.3	17.9	12.3
Avg MinT during 2001-2010	10.4	13.9	19.0	23.7	24.6	25.9	26.3	26.4	25.8	23.2	17.7	12.8
Avg MinT during 2011-2020	10.3	13.5	18.3	22.9	24.8	26.4	26.5	26.6	26.2	23.3	17.1	12.7

Fig. 3.18. Long-term trend of monthly maximum and minimum temperatures in the Padma char areas (Ishawrdi, Pabna) of Rajshahi division
(Source: BARC 2022)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg MaxT during 1991-2000	24.9	27.3	30.6	32.0	31.8	30.5	30.0	30.3	30.0	30.2	28.3	25.3
Avg MaxT during 2001-2010	25.5	28.6	31.4	32.3	32.5	31.0	30.2	30.6	31.1	31.3	29.7	26.9
Avg MaxT during 2011-2020	25.9	28.9	31.8	32.9	33.0	31.8	30.7	31.1	31.6	31.6	30.1	26.6
Avg MinT during 1991-2000	14.8	17.4	21.7	24.2	25.0	25.6	25.4	25.5	25.0	24.3	20.6	15.9
Avg MinT during 2001-2010	13.3	16.3	20.8	24.2	25.2	25.8	25.7	25.7	25.6	24.4	19.9	15.4
Avg MinT during 2011-2020	13.1	16.1	20.5	23.8	25.3	26.2	25.9	25.9	25.8	24.4	19.6	15.3

Fig. 3.19. Long-term trend of monthly maximum and minimum temperatures in the Meghna char areas (Hatiya, Noakhali) of Chattogram division
(Source: BARC 2022)

3.2.3 Biodiversity

The flora can be broadly divided into two categories: natural vegetation and human influenced vegetation. Natural vegetation includes wooden areas, grassland and other natural habitats. Human influenced vegetation includes homestead gardens, plantation, cropland and other planned or cultivated habitat. Many of the chars have extensive areas of grasslands. These are used as grazing lands for cattle. Catkin grass, which grows quite extensively on chars during the early period of vegetation, is used as thatching material. The natural vegetation in chars prevents soil erosion from wind and channel cutting. The charland vegetation exhibits zonation into pioneer, closed herbaceous, middle mixed and bushy zones (http://open_jicareport.jica.go.jp/pdf/11702909_37.pdf).

Human/natural modifications of land cover in char areas have largely resulted in deforestation, biodiversity loss, global warming and increase in the frequency of disastrous floods. Land cover changes modify the reflectance of the land surface, determining the fraction of the sun's energy absorbed by the surface and thus affecting heat and moisture fluxes. Accurate and up-to-date land use/cover information is essential for environmental planning, to understand the impact on terrestrial ecosystems (Muttitanon and Tripathi 2005) and to achieve sustainable development.

Charlands support faunal habitats and also play an important role for fish breeding ground during the rainy season (http://open_jicareport.jica.gojp/pdf/11702909_37.pdf). The areas have very few or no trees but bushes and the ground soil act sometime as a habitat for some amphibians, reptiles, birds and mammals.

3.3 Demographic features

3.3.1 Population, social structures and facilities

Information on population specifically of the char areas is not available from the population census of 2011, the latest census of this kind in Bangladesh. However, earlier studies regarding the social and economic lives of char dwellers in the early 1990s indicated that some 4.3 million people lived in 3300 mouzas (several mouzas constitute a village) in the main riverine charlands (ISPAN 1995). This population could have increased to about 4.9 million by the year 2000 (Thompson 2000). Additionally, there were probably about 1.5 million people living in coastal chars and there were an unknown number living in or dependent on chars along other rivers (Thompson 2000). The island chars of the Jamuna and Meghna had relatively high population in the 1980s that increased faster than the overall population growth rate (Thompson 2000). Today an estimated 6.5 million people (around 5% of the

Bangladeshi population) live in the char areas which make up 5% of the total land area of the country (Alam et al. 2018).

The char dwellers' age and family structure vary from place to place. In a study of chars in the Tista, Brahmaputra, Brahmaputa-Jamuna, Ganges-Padma, Jamuna and Meghna basins, Karim et al. (2017) found the char dwellers to be on the average 42-46 years old with an age range of 24 to 80 years. The study also found that the family size varied, the number of family members ranging from 3 to 14. The minimum average number of family members of 5 (range 3-8) was found in the Brahmaputra char in the Nageshwari upazila (Kurigram) (the range 3-8), while the maximum average number of family members of 9 (range 4-14) was found in the Jamuna char of Bhuapur upazila (Tangail). A large portion of the char dwellers are almost illiterate, they can barely write their signatures, and only a few have completed higher education (Sarker et al. 2022). School enrolment and attendance levels are on an average lower in the char lands than in the country as a whole due to a smaller number of schools, poverty and problems of mobility in both monsoon and dry seasons.

Social structures are important for the char dwellers. They live in *samaj*, which may be kin based. They have *matbars* (*samaj* leaders) and landlords who manage the settlements. Lineage or *gushti* tends to determine the groups of households that associate with one another and where possible move together when erosion occurs or if floods force them to seek temporary shelter. Char lands have a bad reputation of being law and order hotspots where conflicts and violence are endemic.

Infrastructure is poor, travel from place to place is time consuming. Schools are few and far between. Health care facilities are inadequate. Some flood shelters have been built by NGOs especially in the Brahmaputra-Jamuna river chars. For potable water the char people rely on the rivers and hand tube wells (HTW) which, again, become unusable during floods. Char dwellers face some of the major problems in their live are: a) helplessness in the face of natural hazards, b) inadequate government and NGO services, c) poor access to income enhancing opportunities, e) greater vulnerability of women and children.

3.3.2 Socio-economic conditions

Livelihood

Chars are home to some of the poorest and most vulnerable people in Bangladesh. The production and livelihood patterns of char people are quite different from those living in the interior areas of the country. The life of the char people is closely related to dynamics of the river system and char formation as well as the land erosion and flood hazards. Each year large portions of the chars are flooded. People in many chars have to leave their homesteads due to floods, which entail a host of problems with regard to transportation, shelter, security and rehabilitation. The socio-economic conditions of people living in chars vary widely among river basins and sometimes even among the upper, middle and lower reaches of the same river. In a study of chars of different river systems, Karim et al. (2017) found that among the char dwellers cultivated land per family ranged from 0.05 to 8.0 ha in different chars. In general, farmers of the riverine chars (Tista, Brahmaputra, Jamuna, Padma, Meghna chars) possess relatively small cultivable land, 0.05-5.0 ha/family while farmers of the lower Meghna/coastal chars (Lalmohan, Bhola and Subornachar, Noakhali) possess larger areas of cultivable land, 1.5-8.0 ha/family. In a study of chars in the Brahmaputra-Jamuna and Ganges-Padma chars. Sarker et al. (2022) found the majority char dwellers (54%) to be landless peasants. In addition to cultivated land, grasses are an important resource in newly accreted chars in the Jamuna and Padma. Most grass is used as fodder on-site or cut for sale. There are also substantial amounts of grazing lands for cattle in *bathan* (open char land used for raising cows for milk).

Char dwellers are almost exclusively small farmers, but may be engaged in assorted off farm occupations. Almost all char dwellers are involved in more than one livelihood option. They are generally involved in crop cultivation, livestock and poultry rearing, fishing, working as day laborers, cloth business, soil lifting, shop keeping, working as boatmen and vehicle driving.

Char dwellers are almost exclusively small farmers, but may be engaged in assorted off farm occupations. They use their ingenuity and experience to adopt livelihood strategies that are well adapted to the strongly seasonal and uncertain environment. Almost all char dwellers are involved in more than one livelihood option. This is because nature does not give them scope to settle down with one definite livelihood strategy. Here off farm opportunity is rare. Alam et al. (2018), in a study on livelihood in the Jamuna char areas found ten types of livelihood option for the char dwellers such as, crop cultivation, livestock and poultry rearing, fishing, work as day laborers, cloth business, soil lifting, shop keeping, work as boatmen and vehicle driving. Most char dwellers have agriculture as their main livelihood. As a subsidiary livelihood option livestock rearing is the first choice. Livelihoods in char areas are highly vulnerable to both natural hazards and anthropogenic stressors (Alam et al. 2018, Sarker et al. 2022).

3.4 Agricultural systems

3.4.1 Land use patterns

The largest part, some 50%, of the charlands with a total area of 916,894 ha is devoted to crop agriculture (Table 3.5 and Fig. 3.20). A total of 170 upazilas of 7 divisions have chars covering about 4.89 million ha (Fig. 3.21). Out of this the net agricultural land area is 0.45 million ha, i.e, about 9.3% of the total area of upazilas containing chars. The agricultural land area in chars comprises 5.2% of the total agricultural land area in Bangladesh which is 8,800,810 ha (BBS 2020).

Table 3.5. Land use in char areas of Bangladesh during 2022

Land use	Area (ha)
Agricultural Land	455635
Fresh and brackish water aquaculture	1479
Herb dominated Area	25827
Forest, orchard and other plantation	57916
Mud flats or Intertidal Area	117621
Rural settlement	70480
Sand	168214
Others	19719
Total char land	916894
% Agricultural land	49.7

Source: BARC 2022

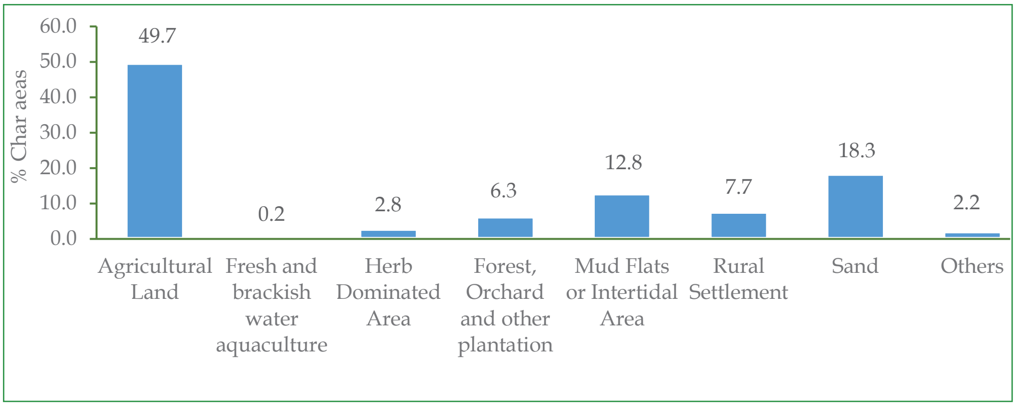


Fig. 3.20. Proportions of land under various usage in the char areas

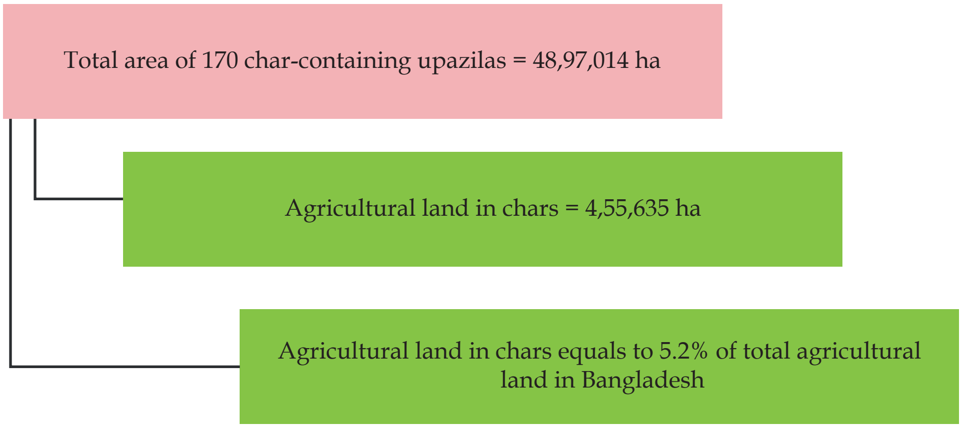


Fig. 3.21. Agricultural land area in chars relative to the total agricultural land in Bangladesh

Among the 7 divisions, Dhaka has the largest agricultural land area (133,898 ha) in the chars which amounts to 71% of the total char land area of the division (Fig. 3.22) indicating a relatively high agricultural production gain from the chars. Substantial land areas exceeding 50,000 ha, potentially productive agriculturally, also exist in each of the other divisions except Khulna and Mymensingh with <16,000 ha each (Fig. 3. 22).

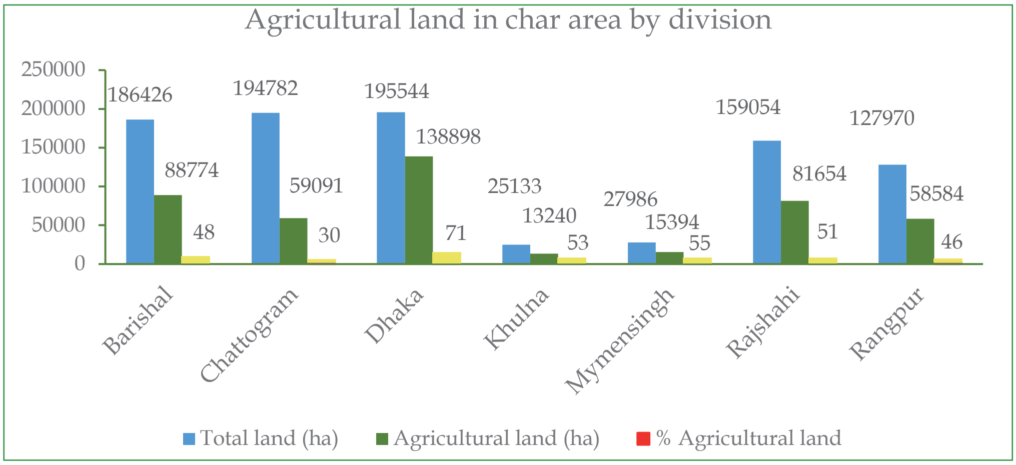


Fig. 3.22. Total land areas and agricultural land areas in chars of different divisions of Bangladesh (Source: BARC 2022)

Agricultural land in char areas in the 7 divisions has decreased by 11.6% from 515,554 ha in 2015 (FD 2015) to 4,55,635 ha in 2022 (BARC 2022) at an annual decrease rate of 1.66 % (Table 3.6). The greatest decrease of agricultural land in

Table 3.6. Changes in agricultural land in chars of different divisions

Division	Agri. land in 2015 (ha)	Agri. land in 2022 (ha)	% inecrease (+)/ decrease (-)
Barishal	125666	88774	-29.4
Chattogram	90640	59091	-34.8
Dhaka	132280	138898	5.0
Khulna	12970	13240	2.1
Mymensingh	13693	15394	12.4
Rajshahi	85571	81654	-4.6
Rangpur	54733	58584	7.0
Total	515554	455635	-11.6
Total char land (ha)	843726	916894	8.7
% Agricultural land	61.1	49.7	-18.7

Source: FD 2015, BARC 2022

char areas during 7 years was noticed in Chattogram (34.8%) followed by Barishal (29.4%). However, despite an overall decrease, there was an increase in agricultural land in char areas of Mymensingh, Rangpur, Dhaka and Khulna divisions ranging from 2.1-12.4%. The decrease in agricultural land in char areas could be attributed to repeated submergence of chars by flood water. This leads to restricted growth of agricultural vegetation coupled with deposition of sand carried by flood water which rendered land agriculturally unproductive. In the upper reaches of the Jamuna, newly accreted soils consist mainly of coarse sand and are less suitable for agricultural use. In the lower Meghna region, saline waters intrude only during the dry season, with limited impacts on the char environment. Even where soil and water conditions are favorable, cultivation and settlement development are constrained by the instability of chars and flood hazards.

Cultivation practices in the char areas depend mainly on the land type, soil characteristics and flooding patterns. Areas under single, double and triple cropping in different char areas and in Bangladesh overall are shown in Table 3.7. In the char areas, about 54% (366,566 ha) of the agricultural land is under double cropping. The single cropped area (186,210 ha) is about half of that under double cropping, 27.3% of the net cropped area (681,013 ha). Area coverages under double and single cropping in Bangladesh overall are slightly less than those in the char areas, 50.9% and 26.1%, respectively. However the

Table 3.7. Number of crops grown per year and cropping intensity in char areas and in overall Bangladesh in 2022

Division	Net cropped area (ha)	Single cropped		Double cropped		Triple cropped		Cropping intensity (%)
		Area (ha)	% of net cropped area	Area (ha)	% of net cropped area	Area (ha)	% of net cropped area	
Rangpur	89760	21824	24.3	51296	57.1	16640	18.5	194
Rajshahi	129037	31706	24.6	59644	46.2	37687	29.2	205
Dhaka	135068	37955	28.1	76847	56.9	20266	15.0	187
Mymensingh	67093	9199	13.7	40164	59.9	17730	26.4	213
Chattogram	138950	40267	29.0	78884	56.8	19799	14.2	185
Barishal	105959	42379	40.0	51217	48.3	12363	11.7	172
Khulna	15146	2880	19.0	8514	56.2	3752	24.8	206
Total	681013	186210	27.3	366566	53.8	128237	18.8	191
Bangladesh	8106478	2111741	26.1	4127126	50.9	1867611	23.0	197

Source: DAE 2022, BBS 2020

triple cropping situation is different. In the char areas, triple cropping is practiced in 18.8% of the net cropped area, the national figure for which is 23.0% (Table 3.7).

Among the seven divisions, Chattogram has the highest double cropped area followed by Dhaka and Rajshahi. However, Mymensingh has the highest cropping intensity (213%) due to a large proportion double cropped area (59.9%) in the net cropped area. Overall, the cropping intensity in the seven divisions with char lands is 191%, which is very close to the national average cropping intensity of 197% (Table 3.7). Improvement of the flooding situation and introduction of different short-duration crop varieties including rice have helped increase the acreage under double cropping in the charlands. Triple cropping in the char areas is very low due to submergence of the lower catena during the rainy season.

Over the years the single cropped area has decreased by 54% from 4,04,543 ha in 2015 to 1,86,210 ha in 2022 in all the divisions (Table 3.8). This decline in the single cropping acreage has been due to the continual conversion of single cropping lands into multiple cropping lands. The highest decline in single cropping occurred in Khulna (77%) followed by Dhaka (65%) and Rajshahi (59%). Simultaneously with the reduction in single cropped area, the multiple cropping acreage increased sharply by 905% from 49,242 ha in 2015 to 4,94,803 ha in 2022 in the char areas of all the 7 divisions (Table 3.8). The most abrupt

Table 3.8. Changes in single cropped and multiple cropped areas in the char regions between 2015 and 2022

Division	Single cropped area (ha) in 2015	Single cropped area (ha) in 2022	% decrease in single cropped area	Multiple cropped area (ha) in 2015	Multiple cropped area (ha) in 2022	% increase in multiple cropped area
Barishal	82515	42379	49	11980	63580	431
Chattogram	60017	40267	33	5117	98683	1829
Dhaka	109121	37955	65	22860	97113	325
Khulna	12335	2880	77	570	12266	2052
Mymensingh	12444	9199	26	1127	57894	5038
Rajshahi	77650	31706	59	3334	97331	2820
Rangpur	50462	21824	57	4254	67936	1497
Total	404543	186210	54	49242	494803	905

Source: FD 2015 and DAE 2022

increase (5038%) in multipple cropping acreage was noticed in Mymensingh followed by Rajshahi (2820%) and Khulna (2052%). The multiple cropped area as per satellite imagery in 2022 stands at 494,803 ha which exceeded the single cropped area in 2015 (404,543 ha) (Table 3.8) indicating an expansion of multiple cropping into fallow lands which had not been utilized earlier.

It is interesting to note that, the net cropped area in the chars increased by 50% during 7 years from 4,53,785 ha in 2015 to 6,81,013 ha in 2022 (Table 3.9) which means that 2,27,228 ha fallow lands in the char areas were brought under cultivation during 2015-2022. A sharp increase (394%) in the net cropped area occurred in Mymensingh followed by Chattogram (113%) and Rangpur (64%), but in Dhaka the increase was minimal, only 2% (Table 3.9). Vast opportunities of increasing the cropping acreage through bringing 168,214 ha sandy lands and 117,621 ha mud flats or intertidal areas under cultivation of at least one single crop during the winter season using appropriate technologies like pit cropping in sandy lands, zero tillage in mud flats etc. still exist. This opportunity is particularly there in the Dhaka, Barishal and Khulna divisions.

Table 3.9. Changes in net cropped area in char regions during 2015-2022

Division	Net cropped area (ha) in 2015	Net cropped area (ha) in 2022	% increase in net cropped area
Barishal	94495	105959	12
Chattogram	65133	138950	113
Dhaka	131981	135068	2
Khulna	12905	15146	17
Mymensingh	13570	67093	394
Rajshahi	80983	129037	59
Rangpur	54717	89760	64
Total	453785	681013	50

Source: FD 2015, DAE 2022

Despite an increase in the net cropped acreage in the char areas of the seven divisions, there are still 104,730 ha of cultivable fallow lands (DAE 2022). Dhaka contains the largest area of fallow lands (33,303 ha), which is followed by Rangpur (18,372 ha), Chattogram (19,265 ha) and Barishal (16,068 ha) which can be brought under cultivation with improved crop varieties and appropriate management practices.

Fallow lands in char areas

Rangpur	18,372 ha
Rajshahi	9,127 ha
Dhaka	33,303 ha
Mymensingh	6,642 ha
Chattogram	19,265 ha
Barishal	16,068 ha
Khulna	1,953 ha
Total	1,04,730 ha

With appropriate technologies these fallow lands may become productive resources

3.4.2 Crops and cropping patterns

Climatic conditions, soil type, access to irrigation facilities and other agricultural inputs, transport and marketing facilities etc. determine the crops and cropping patterns in char areas (Sarker et al. 2022). In the char areas currently there are 46 major cropping patterns, about the one-third (16) of them is dominated by rice (Table 3.10). Vegetables are an important component of 13 cropping patterns, maize is grown in 5 cropping patterns. Other than rice, vegetables and maize, pulses, wheat and oilseeds are also grown in a few cropping patterns indicating crop diversity to a good extent. However, this diversity of crops is confined mainly to the Rabi season while T. Aman rice remains the single most dominant crop in the Kharif-II season. This narrow cropping base during the Kharif season is primarily due to the late recession of flood water mainly from the lower catena limiting the scope of introducing any crop other than wetland transplanted rice that tolerates waterlogging. Usually, flood water enters the upper catena later than the lower catena and the lands become ready for sowing/planting earlier than that in the low-lying lower catena. But, unfortunately, most of the upper catena lands are kept fallow during Kharif season (Table 3.10). The only difficulty for crop agriculture in the upper catena is inadequate irrigation facilities. Developing irrigation facilities can go a long way in boosting land productivity in the upper catena of the char areas.

Table 3.10. Major crops and cropping patterns in char areas in 2022

Serial No.	Rabi season	Kharif-I season	Kharif-II season
1	Boro	Jute	Vegetable
2	Mustard	Jute	Fallow
3	Wheat	Jute	Fallow
4	Boro	Fallow	T. Aman
5	Boro	Jute	T. Aman
6	Boro	Vegetable	Vegetable
7	Groundnut	Fallow	Fallow
8	Maize	Jute	Fallow
9	Maize	Fallow	Fallow
10	Vegetable	Vegetable	Vegetable
11	Maize	Aus	T. Aman
12	Pulses	Jute	Fallow
13	Chili	Jute	Fallow
14	Chili	Fallow	T. Aman
15	Wheat	Aus	Fallow
16	Mustard-Boro	B. Aman	B. Aman
17	Onion	Jute	T. Aman
18	Pulses	Aus	Fallow
19	Sweet gourd	Fallow	Fallow

20	Chili	Aus	T. Aman
21	Maize	Jute	T. Aman
22	Pulses	Fallow	Fallow
23	Wheat/maize	Pulses	T. Aman
24	Kalojira (black cumin)	Jute	Fallow
25	Cheena	Dhaincha	T. Aman
26	Sweet gourd	Onion	Fallow
27	Banana	Banana	Banana
28	Mustard	Sesame	Mashkalai
29	Tomato	Sesame	Fallow
30	Boro	B. Aman	Fallow
31	Mustard	Vegetable	Fallow
32	Lentil	Fallow	Mashkalai
33	Wheat	Maize	Fallow
34	Vegetable + tomato	Fallow	Fallow
35	Tomato	Vegetable	T. Aman
36	Garden (mango + guava)	Garden (mango + guava)	Garden (mango + guava)
37	Boro	Aus	Black gram
38	Tomato	Aus	Maize
39	Pulses	Aus	T. Aman
40	Winter vegetables	Fallow	T. Aman
41	Watermelon /bangi/khira	Fallow	Fallow
42	Potato	Fallow	Fallow
43	Bottle gourd	Bottle Gourd	Fallow
44	Winter vegetables	Summer vegetables	Fallow
45	Groundnut/mustard	Summer vegetables	T. Aman
46	Wheat	B. Aman	B. Aman

*Boro, Aus, T. Aman and B. Aman are the rice crops

Source: DAE 2022

Despite the low water holding capacity of soils and poor soil fertility in the Brahmaputra, Jamuna and Padma chars, the farmers grow Boro rice that needs huge irrigation water which substantially increases production costs. Scarcity of water also threatens non-rice crop production. The poor and marginal farmers can hardly afford to buy water pumps. This results in fallowing of lands, and, thus, reduced agricultural productivity of the charlands.

The cropping scenarios in different char regions of the country are described below which may help understand the problems and prospects of crop production in the char areas and design research and development strategies to enhance production and improve farmers' conditions.

Cropping patterns

Brahmaputra-Tista chars

In general, very poor crop diversity exists in the Kharif season where T. Aman rice predominates in Kharif-II and jute in Kharif-I season (Table 3.11) . On the lower catena, most of the lands remain fallow during Kharif-II although farmers in Nageshawri, Kurigram chars grow a pulse crop like black gram and those of Aditmari, Lalmonirhat grow vegetables. However, there is a significant diversity of crops in the Rabi season across the chars of these rivers. Despite flooding in the Kharif season, farmers in Dewanganj and Aditmari grow some crops but farmers in Nageshawri chars do not grow any crop indicating that there are possibilities of improvement of cropping in the Kharif season.

Table 3.11. Cropping patterns in the Brahmaputra-Tista chars

Site (upazila, district)	Cropping pattern at lower catena (near the river)			Cropping pattern at upper catena (away from the river)		
	Rabi	Kharif-I	Kharif-Ii	Rabi	Kharif -I	Kharif-II
Dewanganj, Jamalpur	Maize Maize Chili/onion Chili/maize/ sweet potato	Jute Jute Jute Fallow	T. Aman Fallow Fallow Fallow	Wheat/mustard Mustard-Boro Boro Maize Maize	Jute - Pulses Jute Jute	T. Aman T. Aman T. Aman T. Aman T. Aman
Nageshwari, Kurigram	Wheat/cheena Wheat Mustard Groundnut	- - - -	Black gram Black gram Black gram Black gram	Boro Wheat Black gram	- Jute Jute	T. Aman T. Aman T. Aman
Aditmari, Lalmonirhat	Tobacco Wheat Potato Groundnut Onion Vegetable	Maize Jute Groundnut Jute Jute Jute	T. Aman Vegetable Vegetable Vegetable Vegetable Vegetable	Groundnut Onion Wheat Groundnut Onion	- - Jute Jute Jute	T. Aman T. Aman T. Aman T. Aman T. Aman

*Boro, Aus, T. Aman and B. Aman are the rice crops

Source: KGF 2015

Jamuna chars

Farmers in the chars of Daulatpur under Manikganj districts keep most of their lands fallow both at the lower and upper catenas of the Jamuna chars during Kharif-II while char farmers of Bhuapur under Tangail district are able to grow T. Aman rice at the upper catena and at least some pulse crops at the lower catena as shown in the Table 3.12. However, crop diversity is low throughout the year, wheat and/or mustard are the predominant crops in Rabi, B. Aman rice/jute, sesame are in Kharif-I season. In this region, flood waters enter in during mid-June to September, but despite this farmers in Bhuapur chars grow T. Aman rice or pulses in Kharif-II while chars in Daulatpur remain fallow. There might have an opportunity to improve the cropping pattern through crop adjustments with early or late varieties according to the flooding time.

Table 3.12. Cropping patterns in Jamuna chars

Site (upazila, district)	Cropping pattern at lower catena (near the river)			Cropping pattern at upper catena (away from the river)		
	Rabi	Kharif-I	Kharif-II	Rabi	Kharif-I1	Kharif-II
Daultapur, Manikganj	Fallow Fallow Gram/mustard/wheat/khesari	B.Aman+til B. Aman/groundnut/sesame -	Fallow Fallow -	Mustard-Boro Boro Mustard-Boro	- Fallow B.aman	Fallow Fallow Fallow
Bhuapur, Tangail	Fallow Wheat Fallow Chili/groundnut Groundnut	Sesame Sesame Aus B. Aman/Aus Aus	Black gram Fallow Black gram/Khesari/chili Fallow T. Aman	Wheat Wheat Maize Groundnut	Jute Jute Aus Sesame	T. Aman B. Aman T. Aman T. Aman

*Boro, Aus, T. Aman and B. Aman are the rice crops

Source: KGF 2015

Padma chars

Table 3.13. Cropping patterns in Padma chars

Site (upazila, district)	Cropping pattern at lower catena (near the river)			Cropping pattern at upper catena (away from the river)		
	Rabi	Kharif-I	Kharif-II	Rabi	Kharif-I	Kharif-II
Ishwardi, Pabna	Wheat/lentil Wheat/lentil Wheat/lentil	Aus rice Aus rice Sesame/mungbean	Vegetables - Vegetable	Lentil Pea Chick pea Mustard Onion Garlic Groundnut Sesame Boro Vegetable	Aus Aus Aus Aus Aus Aus Aus Aus Aus Aus	T. Aman T. Aman T. Aman T. Aman T. Aman T. Aman T. Aman T. Aman T. Aman T. Aman
Goalanda, Rajbari	Onion/coriander Khesari-Boro Wheat Mustard-Boro	Jute B. Aus - Sesame	Fallow Fallow Fallow Fallow	Vegetables Wheat/mustard lentil Khesari/coriander	Jute Aus B. Aman	Fallow Fallow Fallow

*Aus, T. Aman, B. Aus and B. Aman are the rice crops

Source: KGF 2015

On land relatively far from the river in Ishwardi chars only Aus and T. Aman rice are grown in Kharif-I and Kharif-II seasons, respectively (Table 3.13). Vegetables are grown in the later part of Kharif-II in place of T. Aman rice in the relatively low-lying land nearer the river mainly due to flood during July through September. On the other hand, in Goalanda under Rajbari district most of the char lands remain fallow during Kharif-II. Crop diversity is low at the lower catena. Boro rice is totally missing in Ishwardi due to high production costs and low market price. Way and means to expand Boro rice cultivation should be explored in order to enhance food security.

Meghna chars

Most char farmers in Bhedarganj, Shariatpur keep their lands fallow in Kharif-II at lower catena, but grow T. Aman rice on most of the lands away from the river Meghna (Table 3.14). Kharif-I is mainly devoted to jute crop near the river and a pulse crop like mungbean on the upper catena. Rice is mostly missing on both land types. As flood occurs during mid-July to September farmers find it difficult to grow crops on most of their lands during Kharif-II. However, Boro rice can be grown in the Rabi season which can be harvested before the floods come in. Late and short-duration crops including rice can be planted as soon as the flood water recedes in September.

Table 3.14. Cropping patterns in Meghna chars

Site (upazila, district)	Cropping pattern at lower catena (near the river)			Cropping pattern at upper catena (away from the river)		
	Rabi	Kharif-I	Kharif-II	Rabi	Kharif-I	Kharif-II
Bhedarganj, Shariatpur	Chili/ coriander	Jute	Fallow	Boro-mustard	Fallow	Fallow
				Chili/mustard	Jute	Fallow
	Khesari	Jute	Fallow	Wheat	Mung	T. Aman
	Mustard	Vegetable	Fallow	Mustard	Mung	T. Aman
	Mustard	Jute	Fallow	Chili	Jute	T. Aman
	Kalizira/ coriander	Jute	T. Aman	Wheat	Aus	T. Aman
				Coriander	Jute	T. Aman
	Wheat/lentil	Jute	T. Aman			

*Aus and T. Aman are the rice crops

Source: KGF 2015

Coastal chars

Farmers in the coastal chars keep most of their lands fallow in Kharif-I and grow T. Aman rice widely in Kharif-II (Table 3.15). However, farmers in chars of Lalmohan under Bhola district grow diverse crops including Boro rice during the Rabi season while farmers in Subarnachar under Noakhali district do not grow Boro rice although a variety of crops including pulses and oilseeds are grown in the Rabi season. Severe soil salinity in January-May affects Rabi crops. Growing of salt tolerant crops and varieties and effective soil management practice need due attention.

Table 3.15. Cropping patterns in coastal chars

Site (upazila, district)	Cropping pattern at lower catena (near the river)		
	Rabi	Kharif-I	Kharif-II
Lalmohan, Bhola	Boro	Fallow	T. Aman
	Potato	Fallow	T. Aman
	Mungbean	Aus	T. Aman
	Chili	Fallow	T. Aman
	Chili	Fallow	T. Aman
Subarnachar, Noakhali	Khesari	Aus	T. Aman
	Watermelon	Fallow	T. Aman
	Soybean	Fallow	T. Aman
	Khesari	Fallow	T. Aman
	Mung/ cowpea	Fallow	T. Aman

*Aus and T. Aman are the rice crops

Source: KGF 2015

Crop yields

It is obvious that yield of every crop is rather low compared with the national average (Karim et al. 2017). For example, the average yield of Boro rice in Bangladesh is about 4 t/ha which is attained nowhere in the char areas. However, the yield of spices in Goalanda and Vedorganj chars was appreciable (Karim et al. 2017). Irrigation facilities in the char areas are inadequate. Mostly Boro rice is grown with irrigation; wheat and vegetables are also irrigated to some extent. In Subornachar, watermelon and chili have emerged as important cash crops. Farmers irrigated these two crops there.

Farmers of Brahmaputra and Tista chars generally use local varieties except for Boro rice, wheat, maize, jute, potato and some vegetables. The crop grown in Rabi season receives irrigation from shallow tube wells (STW) and some low lift pumps (LLP) but these facilities are minimal compared with the demands and also the cost of irrigation is high. In the Jamuna chars, too, local varieties are used except for Boro rice and wheat for which BRRI dhan28/29 and BARI Gom-26 are grown with irrigation. Crop yields in general are poor. Local varieties of crops especially for T. Aman rice, mustard and jute could be replaced by suitable HYVs. New crops like potato etc. could be introduced with early varieties so that they can be harvested before flooding. Farmers in chars of Ishwardi (Padma chars) grow BARI HYVs of wheat, pulse, mustard, vegetables etc. but their yields are not as expected primarily due to limited irrigation facilities. Improvement in irrigation facilities can increase crop yields substantially. Crops like Boro rice, potato etc. could be introduced with early varieties. In the Meghna chars, farmers mostly grow local varieties of Aus and Aman rice, jute, chili, coriander, but for Boro rice they use HYVs developed by BRRI (BRRI dhan29) and for wheat and mustard HYVs developed by BARI (BARI Gom-26, BARI Sarisha-11). However, here only Boro rice receives irrigation with the help of LLP, but there is a good scope of growing other HYV crops also if supported with alternative irrigation devices like shallow tube wells. Because of poor access to irrigation and use of local varieties crop yields in general are low. Development of irrigation facilities will pave the way for growing HYV of high value crops like pulses, vegetables, potato etc. through adjustments of times of planting taking into account flooding patterns. In the costal char areas (Subornachar, Noakhali and Lalmohan, Bhola), farmers grow HYV rice like BR11, BR23, BRRI dhan28, 47, 40, 41, 42, Binadhan-8 and 10, HYV mungbean (BARI Mug-5, 6 and Binamug-6, 8) and a mix of early or late varieties and crops like soybean (Shohag). But they get poor yields primarily due to inadequate irrigation facilities. Introduction of salt-tolerant HYVs and development of irrigation facilities may boost production in these coastal chars.

3.4.3 Constraints of crop production

Crop agriculture in char areas are seriously affected by both natural and human factors which limit both the extent and productivity of cropping. Char farmers are to continuously struggle against recurrent natural calamities. Among the natural calamities, floods are responsible for the most damages (49.34%), followed by river erosion (33.12%), excessive rain (5.08%), drought (4.21%), cold wave (3.21%), hailstorm (2.89%), and nor'wester (2.15%). About 93.26% of the farmers opine that natural disasters occur more frequently now than in the past and 52.94% of them think that crop production is being affected more by the increasing frequency of natural calamities than before (Sarker et al. 2022).

In a study on crop production in char areas of Bangladesh, Karim et al. (2017) identified eight major root constraints and their consequences on crop production in char areas through focused group discussion (FGD) and key informant interview (KII). In addition to natural calamities, farmers suffer greatly due to inadequate technology transfer and logistics assistance services by researchers, extension officials, bankers etc. In the chars of northern and central regions of the country the soils are sandy requiring frequent irrigation for crops, but irrigation facilities are inadequate. Farmers use mostly N, P and K fertilizes and are not much aware of the need to apply some other nutrients such as, Mg, S, Zn and B. Plant protection measures are also poor due to a lack of availability of pesticides in the charlands. There is no good storage facility in the chars to store agricultural products and the farmers are compelled to sell their produce immediately after harvest at lower than expected prices due to lack of an organized marketing system which reduces their incomes and affects their lives and livelihoods. Furthermore, most of the farmers do not have enough money to buy agricultural inputs timely and there is no institutional credit facilities for the char farmers.

3.5 Livestock and Poultry

3.5.1 Livestock rearing

Bangladesh livestock 402.5 million

Livestock in char areas 58.8 million

14.6% livestock in chars

Apart from crop agriculture, cattle rearing is an important livelihood option for char dwellers, and over time livestock has become a key asset for them. Cattle, buffalo, goat, sheep, chicken and duck are the most popular livestock in the char areas. In 2019, livestock and poultry heads totaled 58.8 million which accounts for 14.6% of the total counts of livestock and poultry (402.5 million) in Bangladesh (DLS 2019) implying a significant contribution to livestock in the country. Among the seven divisions, the char areas of Dhaka divisions has the highest livestock population (12.1 million) followed by Rangpur division (11.2 million) and Barishal division (10.8 million). Among the livestock, cattle population is the highest (6.55 million) followed by goat (4.04 million) (Table 3.16). The total poultry population in chars stands at (37.07 million and the duck population is 9.32 million. It is, however, noteworthy that chars have the greatest share (38.7%) of the sheep population of Bangladesh. Some 27.1% of the cattle population of Bangladesh and the same proportion of buffalo inhabit in the char areas. Cattle, goat and sheep populations (2.26, 0.96 and 0.43 million, respectively) are the highest in Rangpur division while buffalo, poultry and duck populations are the highest in Barishal (0.20 million), Dhaka (8.60 million) and Barishal (2.86 million), respectively.

Cattle and goats are the main livestock species in the riverine chars (KGF 2015). Buffaloes are rare in the riverine chars but being more tolerant of salinity, they are preferred in the new coastal chars. The breeds are mostly local although cross-breeds are also there in the Padma chars of Ishawrdi, Pabna and Goalanda, Rajbari. However, livestock ownership per farm family varies widely across the char locations.

Table 3.16. Livestock status in char areas by division in 2019

Division	Livestock population (million)						
	Cattle	Buffalo	Goat	Sheep	Poultry	Duck	Total
Barishal	0.68	0.20	0.31	0.05	6.67	2.86	10.8
Chattogram	1.04	0.12	0.33	0.42	5.12	1.26	8.3
Dhaka	1.10	0.01	0.57	0.16	8.60	1.68	12.1
Khulna	0.33	0.01	0.59	0.05	2.86	0.49	4.3
Mymensingh	0.34	0.01	0.15	0.11	2.99	0.41	4.0
Rajshahi	0.80	0.03	1.12	0.15	5.19	0.77	8.1
Rangpur	2.26	0.03	0.96	0.43	5.64	1.85	11.2
Total in char areas (a)	6.55	0.40	4.04	1.37	37.07	9.32	58.8
Bangladesh Total (b)	24.2	1.48	26.27	3.54	289.28	57.75	402.5
(a/b)*100	27.1	27.1	15.4	38.7	12.8	16.1	14.6

Source: DLS 2019

Cattle are more abundant in Subarnachar of Noakhali (coastal), Lalmohan of Bhola (coastal), Dewanganj of Jamalpur (Brahmaputra chars) and Bhuapur of Tangail (Jamuna chars) than at other char locations. Goats are poor in number per family in Aditmari, Dawlatpur, Goalanda and Lalmohan compared with other char locations. However, sheep being easier to rear by free grazing in a group are almost non-existent in Dewanganj, Aditmari, Bhuapur, Goalnanda, Lalmohon and Bhedarganj but they are found in the other char areas. Buffalos are relatively abundant in Subornachar and Ishwardi but they are not fund in other char areas although they can adapt to the harsh char environment. Non-ruminant livestock like poultry and duck are abundant almost in all the chars although they reportedly suffer from diseases.

A notable feature of the riverine chars is the abundance of grasses known as *khaisa grass*. These grasses are used as grazing/cut and carry fodder, as fuel and home construction material (thatching and fencing). These grass patches on the chars are mainly controlled by the land owners (or claimants) of land. These may also be controlled by outsiders and/or groups of char dwellers. Open access is very rare. In some areas char dwellers act as caretakers of grasslands on behalf of powerful people, and grass is harvested for sale through traders as fodder or housing material.

Large ruminants especially buffalo are very common in the coastal chars, while ducks are abundant in the Hatia upazila of Noakhali and in Bhola district. Bhola and Barishal are reputed for dairy products like yogurt, sweets and ghee (clarified butter) with contributions from the char livestock.

3.5.2 Problems of livestock and poultry rearing

Compared to other parts of the country cattle grazing facilities are better in the chars because of the existence of fallow lands. The char farmers are aware and attentive about milking cow rearing, cattle fattening and poultry rearing but they are not knowledgeable enough about goat and duck rearing and their management.

Poor small farmers do not own or have easy access to livestock feed. They usually have to collect livestock feed by cutting the grass from distant grazing lands or buy it from the local haat (market). During floods all the grazing grounds are inundated and the prices of the livestock feeds rise sharply.

Farmers are not sufficiently aware about artificial insemination (AI), preventive treatment, combinations of natural and readymade feeds and maintenance of good hygienic conditions for the animals and birds. Technical advice, vaccination, vet care and AI services are very poor due to remoteness of the chars. Input supplies (ready feeds, medicines) are scarce in char areas. Thus, overall productivity of livestock and poultry is low primarily due to use of local breeds.

Marketing opportunities are very poor, livestock farmers are compelled to sell dairy produce at the local char *haats* at minimal prices because of the perishability of the produce. The prices of the livestock products are comparatively low in the char *haats*, generally milk is sold in the main land at Tk. 70/liter whereas its price in a char *haat* is only Tk. 40/liter.

Like in other parts of the country, poultry is an important subsidiary livelihood option in the char areas. Poultry farms are almost non-existent in the char areas (Alam et al. 2018). Char dwellers rear chickens and ducks at their homesteads. Poultry feed is one of the weak links in the poultry rearing enterprise. During seasonal floods the poultry shelters are often inundated and, additionally, the collection of poultry feed becomes difficult and expensive, char dwellers have to buy poultry feed from markets or dealers outside the char at high prices. On the other hand, poultry birds are vulnerable to diseases and morbidity, vaccination services are totally lacking or inadequate. Consequently, char dwellers are forced to sell off chickens and ducks at nominal prices during periods of natural hazards like floods. Moreover, poultry and poultry products fetch low profits from the local char *haats* in the absence of an organized marketing system.

3.6 Fisheries and Aquaculture

3.6.1 Water bodies and fishing practices

Perennial availability of water in the rivers provides year round opportunities for fishing for the char communities. However, the adoption of fishing as the principal or subsidiary livelihood depends on the environmental conditions and profitability which vary from char to char. In general, about 15-20% of the char dwellers depend on fishing as the main livelihood and they fall under the extreme poor category. Most of these people depend on fishing in deep sea and open water bodies (mainly rivers and canals) during the whole year (Fig. 3.23). There are also ponds/ditches in some chars but these are not well managed and do not yield good fish harvests. Many char people adopt fishing as a subsidiary livelihood.

Fig. 3.23. Fishing in open water of a char area

Different fish species, very popular among the Bangladeshi people, are captured from a range of closed and open water bodies in the char areas (KGF 2015). These include rui, katla, pangas, boal, baim, shrimp, tengra etc. which occupy a very special place in the Bangladeshi food bowl. Very few farmers in Dewanganj, Lalmohan, Bhedarganj and Subornachar culture fish in ponds. Farmers in most of the chars do not have ponds rather they catch fish from the open water bodies. In general, the high value species *rui* and *katla* are common in the rivers for open fishing while the traditional but highly nutritious fish species *tengra, boirali, bacha, baila* are also available in the rivers. However, quick growing poly culture of species like silver carp, *pangas*, tilapia, *sorputi* etc., are generally grown in ponds. In all chars mostly local breeds of fish are reared.

The total fish culture area in the chars of Bangladesh, according to up to date estimates including ponds, *beels, baors,* lakes, fresh water bodies, brackish water bodies etc. is 2,777 ha (Fig. 3.24), which is only 0.30% of the total char area (916,894 ha) and constitutes only 0.33% of the total fish culture area of Bangladesh (836,796 ha). Inland closed water culture fisheries in char areas thus, contribute insignificantly to the country's overall economy. Moreover, inland closed water fish culture area in chars s reported to have decreased by

29% from 3,928 ha in 2015 to 2,777 ha in 2022 (Fig. 3.24). On the contrary, total closed water fish culture area of Bangladesh increased by 5.1% from 7,95,841 ha in 2015 to 8,36,796 ha in 2020 (BBS 2017, 2020). The Chattogram division suffered the greatest decline (59%) in char fishing area where it fell from 1,275 ha in 2015 to only 519 ha in 2022. In Rajshahi, however, this decline was very little, only 1% (Fig. 3.24). This decrease in fish culture area in the char regions may be attributed to accelerated conversion of closed water bodies to crop fields and infrastructures.

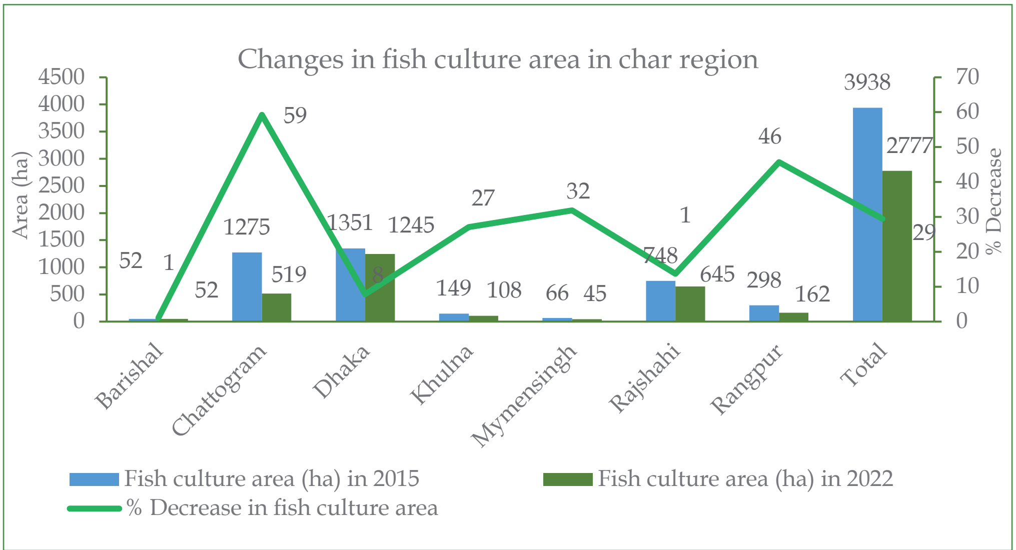


Fig. 3.24. Changes in fish culture area in char region by division
(Source: FD 2015, BARC 2022)

Despite the small area available for fishing and the poor growth of inland closed water fish culture in char areas, the total annual fish catch production from the major rivers viz, Meghna, Padma, Jamuna and Brahmaputra within the char boundaries is substantial. In 2020, the catch amounted to about 223,892 MT (BBS 2020) comprising 17.9% of the total open water fish production in Bangladesh (1,248,401 MT). Open water capture fisheries in char areas is, therefore, important to the country's overall economy. The open water fish catch from parts of the major rivers around the char areas is reported to have increased significantly by 76% from 127,308 MT in 2015-16 to 2,23,892 MT in 2020 (Fig. 3.25). The annual fish catch increase was reported to be the greatest (1213%) from the Brahmaputra and the smallest (64%) from the Meghna. These increases correlate well with the status of total open water fish production of Bangladesh, which increased by 19.1% from 1,048,242 MT to 1,248,401 MT during the same period (BBS 2017, 2020).

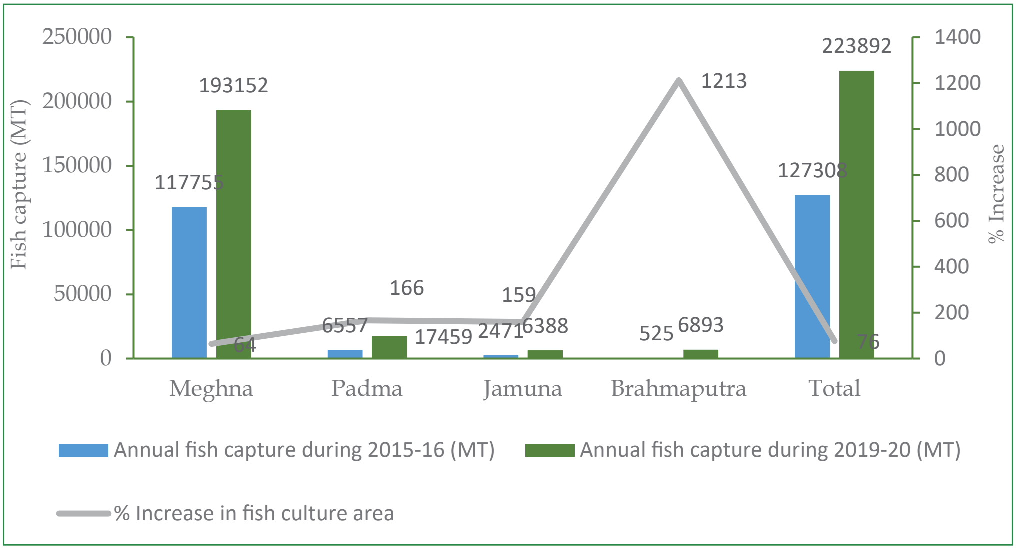


Fig. 3.25. Annual fish catches from parts of the major rivers around the char areas (values on left axis represent annual fish capture in MT and those on the right axis represent increase in %) (Source: BBS 2017, 2020)

This growth in the open water fish catch has been made possible by the use of motorized fishing boats and modern, relatively efficient fishing equipment. The development and promotion of these boats have been a contribution of the Bangladesh Fisheries Development Corporation (BFDC).

3.6.2 Problems of fisheries and aquaculture

As has been mentioned earlier, fishing is an important livelihood option in the char areas. Whereas cropping and livestock rearing are highly vulnerable to natural calamities that frequently strike the chars and almost come to a halt at such times, fishing can still go on. However, fisheries, too, has its downsides.

The most vulnerable time for the fishermen is the dry season when the water levels in the water bodies subside. Farmers are reluctant to practice pond fish culture because open water bodies like rivers are available. The ponds dry up during the dry season. Moreover, densely planted trees on pond embankments intensely shade the pond water which adversely affects fish growth and yield. In addition, the growth of culture fish area becomes restricted due to heavy deposition of sands that are carried by river water during floods; this sand has a poor water holding capacity and consequently many closed water bodies dry up during winter. On the other hand, most of the ponds get over-flooded during the rainy season making fish culture difficult. Traditional fishermen suffer most due to the unavailability of open water fish in the nearby areas, restriction of open water fishing during November to April, but they are reluctant to accept alternative professions. A good number of poor farmers, who have small pieces of land, are also engaged in seasonal fishing (non-traditional fishers) are also affected. In coastal chars, pond water is also used for crop irrigation purpose during the dry season because there is no other alternative irrigation facility due to salinity, this hampers fish culture. Fish producers in the char areas do not practice modern fish culture methods like the use of artificial feed for fish and chemicals to maintain good water quality.

Most of the traditional fishermen are very poor, they do not own boats fishing nets and other fishing tools. They are compelled to borrow money at high interest rates from the *mohajans* (interest-collecting money lenders) to pay for rents for the use for the boat, nets, ropes etc., which eats into their profits from fishing. Moreover, there are no fish storage facilities, and, since fish is highly perishable, fishermen are compelled to quickly sell off fish at low prices with a meager profit margin.

3.7 Forestry

Only 6.31% (57,899 ha) of the total char areas (916,894 ha) in seven divisions is covered by forest, orchard and other plantations as of 2022 in comparison with the 17.78% forest cover in Bangladesh overall (Table 3.17). A country or any geographic area should have at least a 25% forest cover to maintain a healthy ecological balance which is yet to be achieved in Bangladesh, much less in the char areas. In the char ecosystem, the largest forest area (30,633 ha) is reported in Barishal followed by that in Chattogram (22,337 ha) while the lowest is in Rangpur, only 13 ha, in 2022 (Table 3.17).

The forest cover in char areas shrank by 4.2% from 60,426 ha in 2015 to 57,899 ha in 2022, indicating an annual decline by 0.6% during the last 7 years (Table 3.17). A decline by 1.6-8.3% in forest cover occurred in every division (over the

Table 3.17. Changes in forest area in char region

Division	Forest, orchard and other plantation (ha)		% increase/ decrease
	2015	2022	
Barishal	31121	30633	-1.6
Chattogram	24366	22337	-8.3
Dhaka	170	166	-2.8
Khulna	65	62	-5.1
Mymensingh	123	121	-1.6
Rajshahi	4570	4568	0.0
Rangpur	12	13	+6.9
Total	60426	57899	-4.2

Source: BARC 2022

last 7 years except in Rajshahi where there was no change and in Rangpur where there was an increase by 6.9% which in actual terms meant only 1.0 ha. Forests are disappearing rapidly in the char areas due to natural problems like frequent erosion and submergence of char lands and to anthropogenic pressures like forest clearing for settlements (Hossain and Hossain 2014).

3.8 Cross-cutting issues

3.8.1 Agricultural inputs

There are three general categories of input suppliers in the char areas: private company, government and NGOs. Private companies dominate the markets (Table 3.18). Agricultural inputs are mostly concentrated in the district centers or at best in upazila centers, the union or village level channel is very weak. Farmers purchase seeds, fertilizers, insecticides, livestock feeds, fish feeds and fingerlings from dealers from the local markets while some farmers collect seeds from BADC dealers. Farmers also preserve some seeds especially rice at home. Livestock feeds are scarce in situ, some farmers are able to meet the feed demands with rice straw of their own.

Table 3.18. Collection of major agricultural inputs by char dwellers

Type	Item	Source
Input	Seed, fertilizer Insecticide Livestock feed Fish feed and fingerling Livestock and fish medicine	Own, market, BADC dealer, BCIC dealer Dealer Shop, private farm Shop, village vet, DLS office
Commodity	Rice, wheat, potato, milk, egg, hen, fish, cow, goat	Farm gate (paikar, faria), local market

They generally buy livestock and fish medicines from village vets but this opportunity does not exist in many chars, so farmers buy these from markets. Although seeds are available in the local markets, prices are relatively high, hybrid rice and maize seeds, compared with those at the mainland outlets BCIC (Bangladesh Chemical Industries Corporation) fertilizer dealers are also accessible in some char areas. Farmers purchase only urea, TSP and MoP, but the prices of TSP and MoP are relatively high. Other fertilizers such as gypsum, zinc sulfate etc. are either not readily available in the local market or farmers are not aware of the benefits of these fertilizers. It is important that a strong input marketing channel be established with private companies and registered dealers of the government so that char farmers have easy access to quality inputs at reasonable prices.

3.8.2 Agricultural product marketing

Farmers generally sell their products like rice, wheat, milk, egg, hen, cow, goat, fish etc. to the local markets mainly through assorted intermediaries. In the char areas markets are few and far between, char dwellers have to navigate quite a distance, 1-8 km, often by boat (Fig. 3.26) during the rainy season, to reach a market which, again, is not set up every day but only 2-3 days a week.

Fig. 3.26 The country boat, the common transport in the char areas

These markets are in effect the only outlets for the char dwellers where they can sell their produce and buy essential commodities. About one in five inhabited mouzas has a *haat* in addition to market days that may be weekly or more frequently. Such markets are concentrated on unprotected mainland where they form a link between the island chars and the mainland. The markets on unprotected mainland tend to be more important for char people, while some secondary markets have been developed in the island chars which ease transport problems of char people when bulky commodities need to be moved. Travel to and from the markets is easier in the monsoon when boats can navigate almost door to market, whereas in the dry season long walks across exposed sandbanks are often necessary.

There are different types of actors along the marketing chain in the char areas like in other parts of the country. They are the *faria, bepari, paiker, arotdar* etc. The *farias* operate as product buyers in the village level markets and *paikers /beparis* in big markets at the union, upazila and district levels (KGF 2015). Farmers get good prices when retailers directly buy from them at farm gate. Both *goala* and egg buyers have some contract producers, who take advance money against their produce with prices fixed. Brokers deal with local and outside *beparis* and sell farmers' produce and get some commission.

Each *bepari* employ some *farias* who help the *bepari* purchase a commodity, say, watermelons, from the farmers and in this transaction the *faria* receives commission per piece of watermelon determined on the basis of the demand and supply situation of watermelon in the locality. Sometimes, *beparis* visit farmers' fields and purchase stuff directly from the farmers. The markets in distant places usually start very early in the morning, and if the produce does not enter the market early on the price decline. Traders sometime fail to reach the market timely due to transport problems (Fig.3.27).

Fig. 3.27. Transportation of agricultural produce by horse cart at Goalanda, Rajbari

Small farmers sell their produce either at the farm gate or in village/union level markets. The volume of produce is very small and they have to transport their produce to far away markets. Farmers, having little knowledge of market prices, demand specifications and seasonality and being not at all organized for marketing of their produce, have to remain satisfied with low sale prices and small profit margins.

3.9 Advances in char agriculture

3.9.1 Crops and cropping patterns

Natural calamities like floods and land erosion and the overall harsh environment notwithstanding, the charlands, with proper planning and development and use of suitable technologies, have a good potential of contributing appreciably to agricultural production in Bangladesh. For instance, CIMMYT and DAE identified charlands as potential areas for growing wheat and maize hybrids with limited irrigation and reaping very good harvests in the char areas of the Brahmaputra (CIMMYT 2012). NARS researchers have developed a great number of varieties of cereals, legumes, vegetables, oilseeds etc. tolerant of such stresses as salinity, submergence, drought and temperature extremes and associated production technologies.

For example, the Bangladesh Rice Research Institute (BRRI) has released rice HYVs for a range of stress conditions such as, BRRI dhan51 and BRRI dhan52 (submergence tolerant), BRRI dhan42 and BRRI dhan43 (drought tolerant), salt tolerant BRRI dhan56 and BRRI dhan57 (cold tolerant) etc. The Bangladesh Agricultural Research Institute (BARI) has developed heat tolerant wheat and tomato varieties. Some of these crop varieties and production technologies like optimum time of planting, improved fertilizer, water and pest management are suitable for the harsh char environment (Fig 3.28).

Fig. 3.28. Growing crops in a char area

The fertility and productivity of the charlands are very low compared with soils of other areas of the country (Rahman et al. 2021). Proper soil management is essential for good crop production. Chars, especially in northern Bangladesh, have sandy soils with a low water holding capacity and poor fertility. The char soils may become more productive with organic amendments which can improve soil physical conditions and enhance fertility. Soil physicochemical properties are positively improved by the application of organic amendments (Rahman et al. 2020). The application of various organic materials to char soils in three different districts of Bangladesh improved soil fertility and substantially increased the yields of pumpkin and sweet potato; biochar treated plots gave the best results (Afrad et al. 2022).

In the past, the rice farmers of char areas used to grow only local varieties, BR11 and Swarna (an Indian variety) in the T. Aman season which were highly vulnerable to total or partial damage due to early floods. Development of short-duration HYV rice varieties like BRRI dhan56, BAU dhan1, BINA dhan7 enabled farmers grow T. Aman rice with a minimal risk of crop damage on the one hand and go for a second crop in the Rabi season on the other. After the early harvest of short-duration T. Aman rice, assorted Rabi crops like lentil or chickpea can be comfortably cultivated and a third crop like summer mungbean or jute can be grown in Kharif-I (pre-monsoon moist/dry period in March through June). For the coastal saline areas, BRRI and the Bangladesh Institute of Nuclear Agriculture (BINA) have recently developed some short-duration, salt tolerant and submergence tolerant HYVs. These are BRRI dhan40, BRRI dhan41, BRRI dhan53, BRRI dhan54 (salt tolerant), BR23, BRRI dhan53, BRRI dhan54, BRRI dhan56, BRRI dhan57 and BINA dhan7 (short-duration), BRRI dhan51 and BRRI dhan52, BINA dhan11 (submergence tolerant). These recent developments have transformed char lands, which were once covered with wild vetiver grass, into agriculturally productive fields vibrant with the greenery of multifarious crops. Technologies generated by agricultural scientists and their dissemination by extension experts have been instrumental in boosting agricultural production in the char lands and improving farmers' incomes and livelihood.

Most of the char lands are suitable for cultivation during the Rabi season, as the river water recedes during this time. Among the vegetable crops, sweet pumpkin grows very well in well drained silty soils of char areas. Some NGOs found that char farmers were benefited in terms of income and nutrition by cultivating a variety of vegetables, sweet pumpkin in particular. In addition, (i) vegetables like country bean, bottle gourd and okra, (ii) pulses like *khesari* (grass pea), *felon* (cowpea), soybean, ground nut, (iii) spices and condiments like *methi* (fenugreek), chili and turmeric and (iv) sweet potato are grown in the char areas. Recently soybean and ground nut have been introduced as oilseeds in the coastal chars. HYVs are slowly replacing traditional local varieties contributing substantially to land productivity in the char areas.

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. These varieties are superior to traditional local varieties in terms of fruit size, shape, color of the shell, 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. In addition, BARI has developed HYVs and improved management practices for a range of crops which have been tested in on-farm trials across the char areas of the country with very good results. Some of these are listed below:

A. High Yielding Variety

a) Mustard: BARI Sarisha-11 performed well in the Padma River chars. Alternately, BARI Sarisha-14 and BARI Sarisha-9 may be grown if the land is to be freed before mid-February.

b) Maize: BARI Hybrid maize-7 showed better performance than other varieties in the Padma chars.

c) Pea: BARI Matorshuti-2 performed very well in char areas of Jamalpur district;. BARI Matorshuti-3 can be harvested (green pod) about 15-20 days earlier.

d) Groundnut: Farmers chose BARI Cheenabadam-8 because of its short field duration and higher selling price which resulted in extensive cultivation of this peanut variety in the char areas of the Jamalpur region.

e) Sessame: BARI Til-4 was found to be superior to local varieties of sesame char areas of Kushtia and Tangail.

f) Wheat: The wheat HYVs, BARI Gom-25 and BARI Gom-26, performed very well in the Padma and Jamuna char areas.

B. Improve management practices

a) Maize: Intercropping: BARI 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 were found economically profitable in char areas.

b) Groundnut: Cultivation of BARI Cheenabadam-8 along with 47-38-25-15-0.5 kg ha-1 N-P-K-S-B fertilizer doses (soil test based) was found to be agro-economically viable in large scale production in the char areas of Bhuapur, Tangail.

c) Mustard: Recommended fertilizer doses (84-18-33-10-0.5-1 kg/ha NPKSZnB) brought about economically profitable yield of mustard in Golapnagar char of Kushtia district.

d) Potato: Potato cultivation in a single eye double row zig zag system with a 30 cm x 10 cm spacing was found to be agro-economically sound for the char ecosystem. Potato cultivation in a half cut tuber system with a 45 cm × 15 cm spacing performed well in char areas of the Kushtia district.

The Char Development and Settlement Project IV (CDSP 2014) 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.

Mahmud et al. (2020) conducted an experiment 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*). Theimproved three-crop CP gave a rice equivalent yield (REY) of 12.95 MT/ha which was much higher than that produced by the existing two-crop CP (4.20 MT/ha). The total field duration and turnaround time were 323 and 42 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 improved CP pattern (Tk 141,600/ha/yr) compared with that from the farmers' existing CP cropping pattern (Tk 38,350/ha/yr).

Practicing agroforestry (Fig. 3.29) and intercropping with various vegetables and tubers (malta+chili, litchi+sweet gourd, moringa+maize, mahogany+okra, mango+potato guava+garlic etc.) was found to be agro-economically remunerative in the Tista chars of Rangpur and Nilphamari (KGF 2020).

Fig. 3.29. Litchi + taro in an agroforestry system on *char* land

As a consequence of the development of stress tolerant and climate smart HYVs of cereals, pulses, oilsedds etc. and improved crop-soil-water-pest management practices, crop diversity and cropping intensity in char areas have sharply increased over the years. The land area under multiple cropping increased drastically (Fig. 3.30) by 905% from 49,242 ha in 2015 to 494,803 ha in 2022 in the char areas of the seven divisions of Bangladesh as revealed by sattelite imagery in 2022. The greatest increase (5038%) occurred in Mymensingh followed by Rajshahi (2820%) and Khulna (2052%).

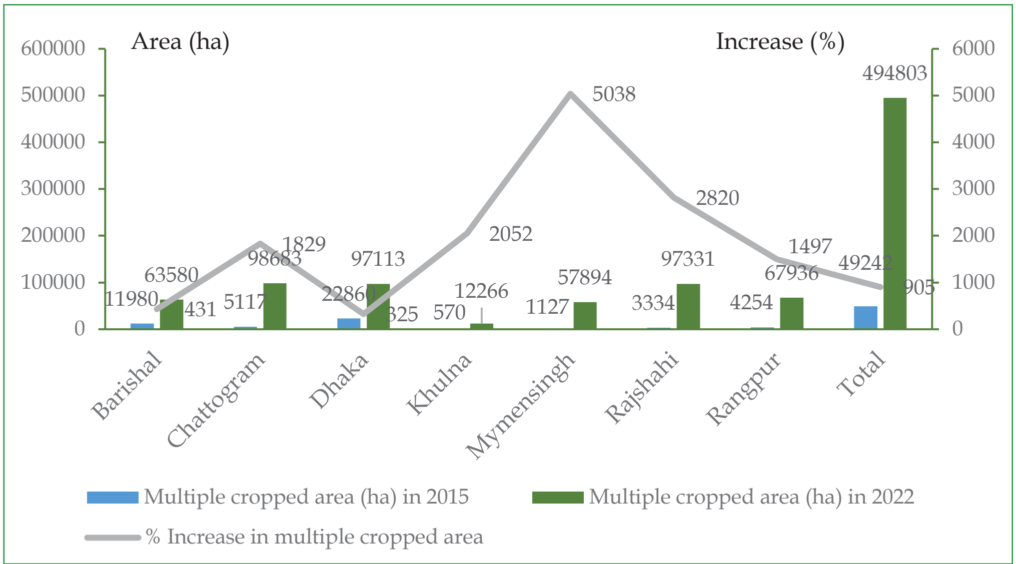


Fig. 3.30. Changes in multiple cropped area in charlands of different divisions during 2015-2022 (Source: FD 2015, BARC 2022)

3.9.2 Livestock and Poultry

The Fayoumi chicken performs relatively well in the char areas in terms of weight gain, egg production and livability than the Sonali and local chicken breeds. To some extent, the Jinding duck performs better than local and Khaki Campbell breeds in terms of body weight, growth rate, egg quality and livability. Sheep especially garole sheep with their excellent body weight gain and prolific nature, contribute greatly to fulfilment of the protein demands of the char people. Cow fattening has become very popular with local people in char areas fetching handsome profits. Although several unpredictable environmental conditions, mainly floods, remain a limiting factor, the aforementioned livestock technologies offer good opportunities for char dwellers to improve their nutrition and at the same time generate incomes to alleviate poverty.

The development of 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%) in livestock experiments (KGF 2017).

Heat stress, drought and flooding are the main environmental stresses affecting sheep and cattle in char areas. Also, climate change could further complicate things for cattle and sheep producers in the future. The Bangladesh Agricultural University (BAU) has selected a new breed of sheep, which is very popular among the char people (The Independent 2021). These animals are hardy and can graze easily in char areas. Raising this breed of sheep does not cost much. This new breed of sheep opens up a window of hope for the impoverished char dwellers.

3.9.3 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 are used to increase fish production in cage culture. Practical Action (NGO) 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.

In another innovative fish technology, kata fish culture, one side of a homestead pond is cut to link to cropland to receive *mola* and other SI species– once every 15 days. During floods tree branches are dumped into the flooded pond. Rice bran is provided as feed and fish species are grown even during floods. Through bush piling wild fish can be encouraged to enter the ponds and grow during flood. Protein-rich fish species like *shing, koi, mola, tilapia* etc. can be reared. These fishes are not lost during floods as they prefer to stay under the mud of the pond bed.

3.10 Strategic investment opportunities for Char Ecosystem

Char ecosystem is mainly constrained by river erosion, flood, drought, forest degradation, low soil fertility, inundation of pasture lands, loss of fish habitats etc. Three development projects for char areas were initiated by the Government of Bangladesh in the last decades. One of these projects is Char Development and Settlement Project (CDSP), Phase -IV which was implemented by the GoB 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 Jamuna Char Integrated Development Project (JCDP) and Char Livelihood Program (CLP) of DFID (Department of Foreign and International Development of UK) were initiated in 2003. Char Livelihood Program 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 Government'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 saline coastal area), and adapting to climate change.

Agricultural development strategies should, therefore, be undertaken for char areas based on the following plans/policies of the Government in place:

- Bangladesh Delta Plan 2100
- Vision 2041: Perspective Plan of Bangladesh (2021-2041)
- National Agricultural Policy (2018)
- 8th Five Years Plan (2020-2025)
- Bangladesh Forestry Master Plan 2017-2036
- Agricultural Research Vision 2030 and beyond

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 should take into account of the following strategies:

Strategy A: Integrated and diversified agricultural production

Long-term approaches are required for the char areas to maximize food production from minimum land holdings through improved agricultural practices of integrating and diversifying agricultural production (crops, vegetables, livestock, fisheries, etc.). This should also include homestead production (fruits, vegetables, livestock, fisheries etc) and at the same time improving and maintaining productivity of soil resources. This needs to be supplemented by technology, credit, marketing, and extension support. Further, it is important to build up the capacity of char farmers to add value to their produce.

Strategy B: Technology up-scaling for enhancing crop production round the year

Poor crop performances due to lack of quality seeds, use of local varieties, inappropriate crop management practices and techniques are evident. In coastal chars, the soils are fine textured where the clay becomes hard during the dry season and it is difficult for farmers to grow vegetables and other Rabi crops. So, the strategies should aim at the followings:

- 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 in the 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 lands 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.

- Alternate cropping patterns: Four/ five crop base cropping pattern intervention, being tested promising, should be promoted widely in char areas to increase cropping intensity and to avert risk due to unpredictable flood and drought. The promising cropping patterns are as follows:

  i) Potato – Potato – Maize or Mungbean – T. Aman rice
  ii) Potato - Wheat or Maize or Mungbean - T. Aman rice
  iii) Potato -Mungben - T. Aus rice - T. Aman rice
  iv) Mustard – Red amaranth – Mungbean -T. Aus rice - T. Aman rice
  v) Potato – Red amaranth - Mungbean - T. Aus rice - T. Aman rice
  vi) Garden pea – Boro rice - T. Aus rice -T. Aman rice
  vii) Garden pea – Red amaranth - Mungbean - T. Aus rice - T. Aman rice
  viii) Potato - Wheat - T. Aus rice - T. Aman rice

- Improved management practices: Potato cultivation under half cut tuber system (45 cm × 15 cm) was more profitable compared to other treatments in char land eco-system and hence should be promoted widely. Potato cultivation under single eye double row zig zag system with10 cm/30 cm x 10 cm spacing was more profitable compared to other planting systems in char land eco-system and hence, it needs to be widely disseminated. Soil test-based fertilizer dose gave the highest yield in Kustia, Pabna and Tangail char areas and may be recommended for large scale production in the char areas. Char lands can provide high-value crops that can be harvested before the first flood peak occurs. Due to residual ground water after the rainy season, it is possible to grow early vegetables in these areas; these vegetables have the potential of fetching 30% more profits.

Strategy C: Varietal replacement of Boro rice to reduce damage of harvest due to flood and drought

Quite often early flood occurs in char areas, which damages Boro rice as the harvest in April is seriously affected. Severe drought also occurs in winter season when Boro rice is affected due to drought coupled with limited irrigation facilities. This Boro rice is the main staple crop cultivated by char farmers in lower catena (mostly affected by flood) and upper catena (mostly affected by drought) of the chars. BRRI dhan28 and 29 should be replaced by BRRI dhan88 (yielding 7 MT/ha and matures 4 days earlier than BRRI dhan 28), BRRI dhan89 (yielding 8 MT/ha and matures 5 days earlier than BRRI dhan 29), BRRI dhan92 (yielding up to 9.3 MT/ha and matures 3-4 days earlier than BRRI dhan29 and also adapts to drought situation). BRRI dhan79 (a submergence tolerant variety) can be cultivated in char areas, which survives up to 21 days of submergence. There is a significant yield loss of rice, if drought occurs up to 28 days during reproductive stage. This long duration drought spell occurs in char areas as in haor areas during Rabi season. To adapt to this drought, BRRI dhan71 (a drought tolerant variety of 115 days growth duration yielding 4 MT/ha with prolonged drought and 5 MT/ha without drought) can be promoted in the severe drought prone areas of the char districts, particularly in the upper catena of the chars.

Strategy D: Strengthening breeding for development of climate resilient crop varieties

- Promoting cultivation of flood and drought resistant high yielding varieties (HYV) of crops/vegetables having importance in terms of biodiversity in char areas. Selection of short duration, drought tolerant modern varieties of different crops along with improved management practices and different intercropping systems would be the potential strategies.
- Giving special attention to cultivation of hybrid maize, potato, mustard, sugarcane, sesame, groundnut, sweet gourd.

Strategy E: Enhancing crop protection through prevention and control of insects and pests

Insect surveillance should be done for identifying harmful insect pests of major crops cultivated in char areas and measuring crop loss by these insect pests. Bio-rational based insect pests management should be developed. Bio-pesticides should be readily available and affordable to the farmers. New bio-control agents such as parasitoid, predator, beneficial microbes, etc. should be identified. Farmers should be trained in the use of bio-control agents. Varietal screening program against insect pests should be taken. Technologies for insect and pest management developed by NARS institutes should be disseminated among the farmers.

Strategy F: Development of irrigation facilities for year-round crop production

Due to poor communication facilities and a lack of institutional support, the expansion of irrigation facilities is very limited. Electricity is limited on island chars and has mainly reached the mainland fringe of the char lands, a few chars have electricity. Natural hazards specially drought in Rabi season and scarcity of irrigation facility are the major hindrance to crop production in char areas. Regular inundation of most parts of char areas occurs due to flood during monsoon and frequent upstream flash floods leaving the homesteads, drinking water and sanitation infrastructures particularly hand tube wells damaged. Irrigation water infrastructure may be established for crop production round the year that includes individual shallow tube wells (STW), rainwater harvest and filtration units for surface waters with small scale pipe network for distribution to different crop fields.

Five profoundly powerful techniques for irrigation are sprinkler irrigation, drip irrigation, surface irrigation, basin irrigation, and furrow irrigation. Among them, the drip irrigation system is the most proficient and suitable water system framework. Instead of wetting an entire field surface, water is applied only to the plant root zone. Water is applied when plants need it most and in rates required for appropriate plant development. The irrigation expansion project of the Government in Rangpur District including char areas aims to ensure the best use of surface water and also 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 water-logging 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, which still remains fallow in char areas would be brought under cultivation of at least single crop during the winter season, particularly in Dhaka (33,330 ha), Chattogram (19,265 ha) and Rangpur (18,372 ha).

Strategy G: Stabilizing settlement of char dwellers and agricultural production by reducing river erosion

The river erosion and char land slide make the char areas vulnerable. The settlement relocation is a common problem to the people of char lands due to frequent river erosion. However, the people have learnt how to survive with river erosion and massive floods in the char lands. Cropping systems are also unstable. Based on the success of Land Degradation Neutrality Target Setting Program (LDN-TSP) during December 2016 through February 2018 with the support of United Nations Convention to Combat Desertification (UNCCD), Bangladesh has put further commitment to achieve LDN leverage plan to reduce river bank erosion in char areas (UNCCD 2018). According to the target

6 of LDN, the Government of Bangladesh will reduce river bank erosion in char areas at 100 ha/year covering 100 km^2 areas by 2030. The target will address river morphology, rush of flood water and unsustainable land management. Measures will be taken to establish green belt through afforestation along river banks and accreted char lands. River/channel dredging program will also be undertaken. This investment plan of LDN as committed by the Government of Bangladesh through UNCCD needs to be widely implemented in the char areas in support of stabilizing settlement of char dwellers and agricultural production by reducing riverbank erosion.

Strategy H: Development and settlement of accreted land through afforestation and agro-forestry

Char lands should be stabilized first by tree planting which facilitates sustained agriculture in the long run. The char people will be protected against natural calamities by establishing a green belt on char lands and river banks. Fodder production should be intensified outside forest areas and stall feeding needs to be promoted. Research on development of appropriate farming systems and extension work should be strengthened and administratively linked to agricultural research and extension. Special emphasis needs to be given for promotion of multipurpose trees and fruit trees on farms which will be linked to rural manufacturing centers and agro-industries. Research should be focused on multipurpose trees, bamboo, firewood and fodder species.

As the main thrust for improvement is the full involvement of the villagers in tree growing on char lands, all tree growing should be free from state control. Efforts should be given to establish a Tree Farming Fund for reforestation which will be used to channel the financial assistance to tree farmers through the agricultural and rural banking systems. The credit period shall be extended to cover at least one rotation of the tree crop concerned. Once established, the growing tree stocks can be insured and the Tree Farming Fund shall accept it as collateral. The Government should support establishment of independent tree growers' cooperatives and associations with support from appropriate government institutions in order to provide reliable information and marketing options. The Forest Department should assist tree farmers with technical advice and high-quality planting materials.

Strategy I: Strengthening agricultural mechanization

Particularly in char areas, migration of agriculture laborers is significant during both planting and harvesting times due to their high demands in the main land. Farm mechanization is necessary to compensate for the labor shortage. But mechanization of irrigation, pesticide sprays and threshing are almost non-existent. 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 to improve its capacity to manufacture competitively priced and high-quality machines and spare parts. They should be encouraged to produce char farmer-friendly machinery. Renewable energy use in farm machinery/equipment and irrigation should be piloted in char land areas through solar systems and bio-gas production using cow dung and waste materials.

Strategy J: Improvement of livestock and poultry

In peak floods, shifting cattle to high land such as an embankment is a problem for char households, while lack of fodder and shortage of funds farmers are to sell this important asset. Natural feed for livestock is scarce during the rainy season. There are outbreaks of various livestock and poultry diseases in the wet season. Veterinary doctors are rarely available in the char areas. Cattle and goats are the main livestock species in the riverine chars, buffaloes are rare in the riverine chars but being more tolerant of saline grazing are preferred in the new coastal chars. 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 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.

Strategy K: Improvement of fisheries

Farmers do not systematically practice pond cleaning, soil and water treatment, using right species, size and number of fingerlings, maintain fingerling ratio, partial harvesting of fish etc. Late rain impacts on brood fish maturation, immature eggs and sperms lower growth rate, susceptible to disease. Low water level in rivers, canal etc. increases fishing pressure, which causes an indiscriminate catching of brood to juvenile. High temperature causes mortality of spawn, fry and fingerlings. All these ultimately cause loss of aquatic biodiversity. Perennial availability of water in the rivers provides a year-round opportunity for fishing which can be a good additional income source for the char people. 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. Domestication and induced breeding of endangered species needs to be enhanced. 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/Ruhu 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.

Decision makers will need to evaluate trade-offs across sectors (e.g., hydropower versus fisheries), beneficiaries (upstream versus downstream), and generations, since hydropower dams and climate change induce long-term, largely irreversible alterations to water systems.

Strategy L: Digitalization of agriculture

Farmers of char lands should be equipped and linked with digital platforms serving the agricultural sector. As per the National Agricultural Policy (2018), Farmer Information and Advice Centers (FIAC) housed in Union Parishad premises have been spreading across the country through DAE. This facility should be extended to all chars of Bangladesh quickly. Advanced digital agricultural engineering approaches like mechanized planting and harvesting, precision agriculture, renewable energy, advanced tools like GPS, GIS, robotics, artificial intelligence etc. should be adopted in agriculture, fisheries and livestock.

Strategy M: Strengthening early warning system

An effective early warning system should be in place so that the farmers can

- adjust their cropping/fish culture according to information on likely weather patterns in the particular area. The Bangladesh Meteorological Department (BMD) working in collaboration with DAE through the Ministry of Agriculture (MoA) has developed an agro-meteorology model using satellite information to provide early warnings about unexpected weather events that can affect agriculture.
- Based on weather information alternative options (e.g., hanging vegetable gardening, floating agriculture, Sorjan bed agriculture, raised poultry/livestock housing, pond fish culture by netting, integrated cage fish culture and vegetable cultivation etc.) may be adopted. This strategy will help minimize damages to crops/livestock/fisheries from floods, tidal surges, salinity etc. and avoid or tolerate prolonged flood or salinity etc.

References

Afrad MASI, Rahman GKMM, Alam MS, Ali MZ and Barau AA (2022) Organic amendments influence the yield of vegetables and soil properties at charlands in Bangladesh. Asian Journal of advanced Agricultural Research, 18(1): 9-21

Alam MR, Malak MA and ohammad Abdul Quader MA (2018) Livelihood vulnerability of charland people in Brahmaputra-Jamuna river system, Jagannath University Journal of Life and Earth Sciences, 4(1): 54-64.

BARC (Bangladesh Agricultural Research Council) (2022) Computer and GIS Unit, BARC, Farmgate, Dhaka.

Banglapedia (2022) 'Char', Retrieved from https://en.banglapedia.org/index .php/Char, accessed on 23/5/2022.

BBS (Bangladesh Bureau of Statistics) (2017) Year Book of Agricultural Statistics 2017, Ministry of Planning, Government of the People's Republic of Bangladesh.

BBS (Bangladesh Bureau of Statistics) (2020) Year Book of Agricultural Statistics 2020, Ministry of Planning, Government of the People's Republic of Bangladesh.

CIMMYT (International Maize and Wheat Improvement Center) (2012) Farmers in the charlands of Bangladesh benefit from new wheat and maize interventions, CGAIR: Reasearch Program on Wheat. <http://wheat.org /wheat-articles-andrelated-stories/item/farmers-in-the-charlands-of-bangladesh-benefit-from-new-wheat-and-maizeinterventions>

DAE (Department of Agricultural Extension) (2022) Unpublished data, Field Services Wing, Khamarbari, Farmgate, Dhaka-1215

DLS (Department of Livestock Services) (2019) Unpublished data regarding union-wise statistics on livestock and poultry in Bangladesh, Ministry of Fisheries and Livestock, Government of the People's Republic of Bangladesh.

FAO-UNDP (1988) Land Resources Appraisal of Bangladesh for Agricultural Development: Agro-ecological Regions of Bangladesh, Technical Repor No. 2, FAO (Rome), pp. 1-40.

FD (Forest Department) (2015) Land cover atlas of Bangladesh 2015, Forest Department, Ministry of Environment, Forests and Climate Change, Government of the People's Republic of Bangladesh.

Goodbred Jr SL, and Kuehl SA (1999) Holocene and modern sediment budgets for the Ganges-Brahmaputra River System: evidence forhigh stand dispersal to flood-plain, shelf, and deep-sea depo centers. Geology, 27:559-562.

Hossain MK and Hossain MA (2014) Biodiversity of Chunati Wildlife Sanctuary: Flora, Arannayk Foundation and Bangladesh Forest Department. Dhaka, Bangladesh, p. 175.

ISPAN (1995) Char land Socio-Economic Summary Report Bangladesh Flood Action Plan 16, Dhaka, Flood Plan Coordination Organization, IUCN.

Kabir RD (2006) The state of char education in Bangladesh: focus on selected chars of Gaibandha district. Asian Affairs, 28(3):5-24.

Karim MA, Quayyum MA, Samsuzzaman S, Higuchi H and Nawata E (2017) Challenges and opportunities in crop production in different types of char lands in Bangladesh: diversity in crops and cropping patens. Tropical Agriculture and Development, 61(2): 77-93.

KGF (Krishi Gobeshona Foundation) (2015) Study on char land agriculture in Bangladesh. Krishi Gobeshona Foundation, BARC Campus, Farmgate, Dhaka-1215

KGF (Krishi Gobeshona Foundation) (2020) Annual Report for 2018-19, p. 72, Krishi Gobeshona Foundation, BARC Campus, Farmgate, Dhaka-1215.

Mahmud AA, Alam MJ, Islam MA, Molla MSH and Ali MA (2020) Millet-Jute-T. Aman cropping pattern for increasing system productivity in the active Brahmaputra-Jamuna Floodplain chars. The Agriculturists, 18(1):129-136

Muttitanon W, Tiıpathi NK (2005) Land use/land cover changes in the coastal zone of Ban Don Bay, Thailand using Landsat 5 TM data, International Journal of Remote Sensing, 26 (11), pp. 2311-2323.

Rahman GKMM, Rahman MM, Alam MS, Kamal MZ, Mashuk HA, Datta R and Meena RS (2020) Biochar and organic amendments for sustainable soil carbon and soil health. In Carbon and nitrogen cycling in soil. Springer, Singapore, 2020, p. 45–85.

Rahman MA, Jahiruddin M, Kader MA, Islam MR, Solaiman ZM (2021) Sugarcane bagasse biochar increases soil carbon sequestration and yields of maize and roundnut in charland ecosystem. Archives of Agronomy and Soil Science, 2021: 1–14

Rakib MA, Islam S, Nikolaus I, Bodrud-Doza M and Bhuiya MAH (2017) Flood vulnerability, local perception and gender role judegement using multivariate analysis: a problem based "participatory action to future skill management" to cope with flood impacts, Weather Climate Extremes, 18: 29-43

Rogers KG, Syvitski JPM, Overeem I, Higgins S, and Gilligan JM (2013) Farming practices and anthropogenic delta dynamics. Deltas: Landforms, Ecosystems and Human Activities. Proceedings, HP1, IAHS-IA PSO-IAPEI, Assembly, Gothenberg, Sweeden, July 2013. IAHS publ. Wallingford), pp. 133-142.

Sarker UK, Kaysar MS, Uddin MR, Hossain MA, Hassan S and Hassan MM (2022) Exploring Farmers' Insight on Cropping Pattern for Sustainable Crop Production in Char Area of Bangladesh, Sustainability, 14, 1475. https://doi.org/10.3390/su14031745.

Sattar SA and Islam MN (2010) Char lands of Bangladesh: Their extent, management and future research needs. Papers presented in a workshop on Soil fertility, fertilizer management and future strategy held at BARC, 18-19 January, 2010.

Thompson PM (2000) Bangladesh charlands a review of assets and change, DFID.

UNCCD Bangladesh (2018) National Report on Land Degradation Neutrality Target Setting Program (LDN-TSP) of Bangladesh 2018, United Nations Convention to Combat Desertification (UNCCD). https://www.unccd.int/sites/default/files/ldn_targets/2019-

UNEP/GPA (United Nations Environment Program/Global Program of Action) (2006) The State of Marine Environment: Trends and Processes, The Hague, pp. 1-28.

Vimala DN, Donald AG, Reddy KR and Oscar GO (2001) Soil Devel opment in phosphate-mined created wetlands of Florida, USA, Wetlands, 2001-21(2): 232-239.

Wasson RJ (2003) A sediment budget for the Ganga-Brahmaputra catchment, Current Science, 84:1041-1047.

Chapter 4

Barind Ecosystem

4.1 Extent and distribution

The Barind Tract, historically known as the *Barendra Bhumi*, is the largest Pleistocene physiographic unit of the Bengal Basin covering an area of about 7,770 sq km (Banglapedia 2021) in northwestern Bangladesh. Geographically, this unit lies between latitudes 24°20´N and 25°35´N and longitudes 88°20´E and 89°30´E. It 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 (Fig. 4.1). Physiographically the Barind Tract was formed due to upliftment, subsidence, erosion and depositional activities in the area in response to neotectonics as well as fluvial processes (Rashid et al. 2018). It lies northwest of the confluence of the upper Padma and Jamuna rivers and is bordered by the floodplains of the Mahananda river to the west and the Karatoya river to the east-tributaries of the upper Padma and of the Jamuna, respectively. Barind is a comparatively high, undulating region, with reddish and yellowish clay soils. It is cut by ravines and is divided into separate sections by the Atrai river and one of its tributaries (Britannica 2009). To the east and southeast of the Barind Tract is the lower Atrai Basin (*Bhar* Basin), a vast area of lowland marshes that floods completely during rainy season.

The Barind Tract is clearly differentiated from other parts of the country by its terraced lands, sparse vegetation, absence of major river channels and low rainfall with a long dry period during October-May. It is regarded as the most drought prone area of the country because of limited groundwater reserves and recharge and poor water holding capacity of surface soil in the post-rainy season.

The Barind Tract spreads over 3 of the 30 agro-ecological zones (AEZ) of Bangladesh, i.e. AEZ-25 (Level Barind Tract), AEZ-26 (High Barind Tract) and AEZ-27 (North Eastern Barind Tract). AEZ 25-Barind exists in Dinajpur and Gaibandha districts of the Rangpur division and Joypurhat, Bogura, Naogaon, Sirajganj and Natore districts of the Rajshahi division. AEZ 26-Barind (western part of Barind Tract) is in Rajshahi, Chapainawabgonj and Naogaon districts of the Rajshahi division. The AEZ 27-Barind region occupies several discontinuous areas on the northeastern margins of the Barind Tract pervading Dinajpur, Rangpur and Gaibandha districts of the Rangpur division and Joypurhat and Bogura districts of the Rajshahi division. Out of

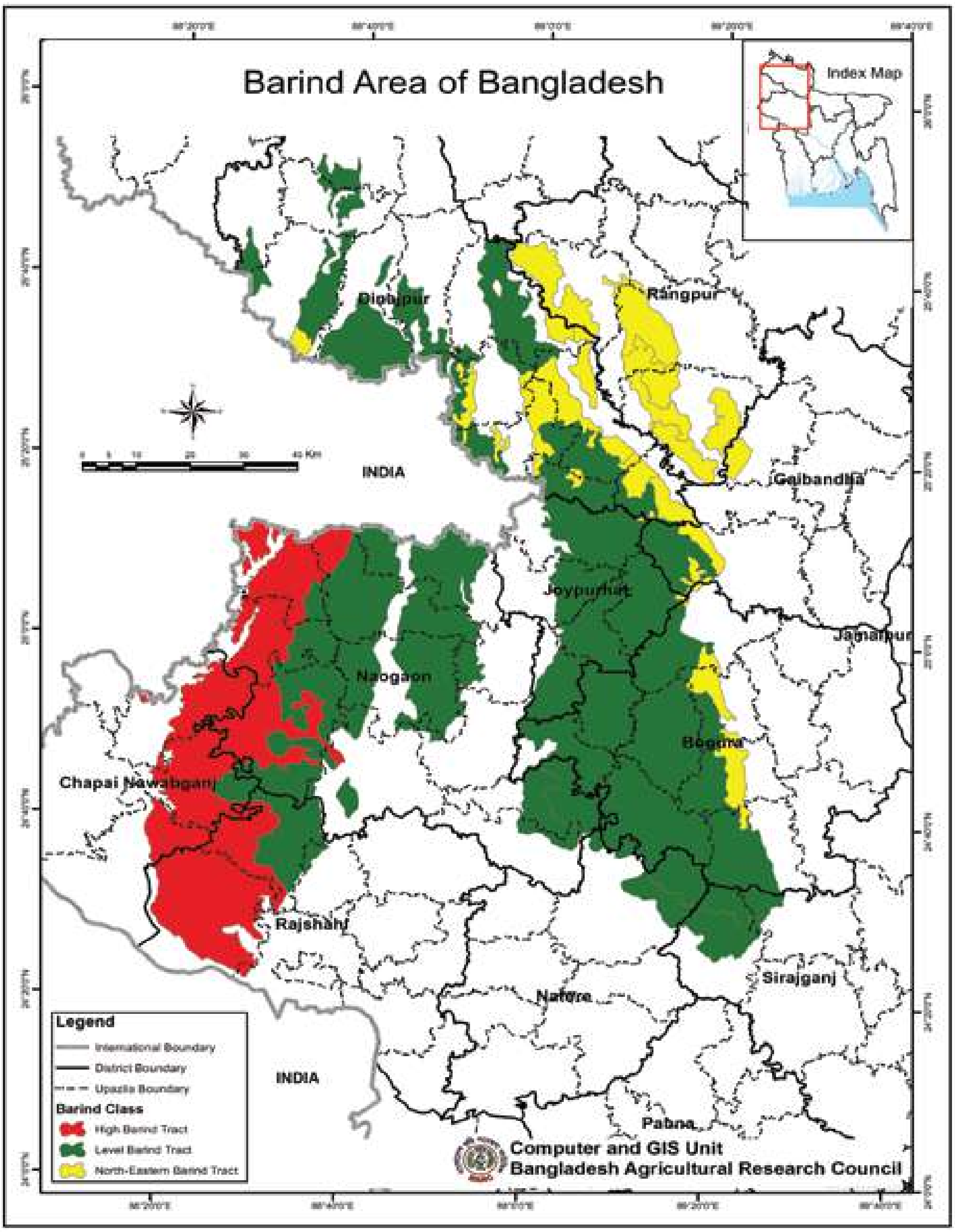


Fig. 4.1. Map of northwestern Bangladesh showing the Barind Tract
(source: BARC 2022)

the 100 upazilas of the northwestern districts, 56 are in the Barind Tract. These 56 upazilas comprise 11.3% of the total of 495 upazilas of Bangladesh (Table 4.1). Names of the upazilas of the north-western districts and upazilas situated in the Barind Tract are listed in Table 4.2.

Table 4.1. Barind Tract covering upazilas of the northwestern districts

District	Upazila (no.)	Barind Tract upazila (no.)	Proportion of total (%)
Bogura	12	8	67
Chapainawabganj	5	3	60
Joypurhat	5	5	100
Noagaon	11	11	100
Natore	6	1	17
Rajshahi	13	4	31
Sirajganj	9	2	22
Dinajpur	13	12	92
Gaibandha	7	3	43
Nilphamari	6	1	17
Rangpur	8	5	63
Thakurgaon	5	1	20
Total	100	56	56
Bangladesh	495	56	11.3

Source: BBS 2020, BARC 2022

Table 4.2. Upazilas of northwestern districts under the domain of Barind Tract

District	Upazila which belongs to the Barind Tract
Bogura	Adamdighi, Bogura Sadar, Dhupchanchia, Kahalo, Nandigram, Shajahanpur, Sherpur, and Shibganj
Chapainawabganj	Chapainawabganj Sadar, Gomastapur and Nachole
Joypurhat	Akkelpur, Joypurhat Sadar, Kalai, Khetlal and Panchbibi
Naogaon	Atrai, Badalgachhi, Dhamoirhat, Mahadebpur, Manda, Naogaon Sadar, Niamatpur, Patnitala, Porsha, Raninagar and Sapahar
Natore	Singra
Rajshahi	Godagari, Mohanpur, Paba and Tanore
Sirajganj	Royganj and Tarash
Dinajpur	Biral, Birampur, Birganj, Bochaganj, Chirirbandar, Dinajpur Sadar, Fulbari, Ghoraghat, Hakimpur, Kaharole, Nawabganj and Parbatipur
Gaibandha	Gobindaganj, Palashbari and Sadullapur
Nilphamari	Saidpur
Rangpur	Badarganj, Mitha Pukur, Pirganj, Rangpur Sadar and Taraganj
Thakurgaon	Pirganj

Source: BARC 2022

All upazilas of Joypurhat (5) and Noagaon (11) districts, and also most upazilas (12 out of 13) of Dinajpur district are parts of the Barind Tract. The Barind Tract occupies 755,155 ha which is 27.2% of the total area (2,776,330 ha) of the 12 northwestern districts and 5.21% of the total area of

The Barind Tract, known historically as the *Barendra Bhumi,* is the largest Pleistocene physiographic unit of the Bengal Basin. It covers 755,155 ha in 56 upazilas of 12 northwestern districts of Bangladesh occupying 5.21% of the total area of Bangladesh (14,486,269 ha).

Bangladesh (14,486,269 ha) (BBS 2020, BARC 2022). Among the northwestern districts, Noagaon contains the largest Barind Tract area of 202,589 ha out of the total district area of 343,560 ha (Fig. 4.2). Next to Naogaon, Bogura, Dinajpur, Joypurhat and Rajshahi districts account for 135,417, 132,175, 70,107 and 66,679 ha, respectively, of the Barind Tract. In comparison, the other seven districts possess quite small areas of the Barind Tract.

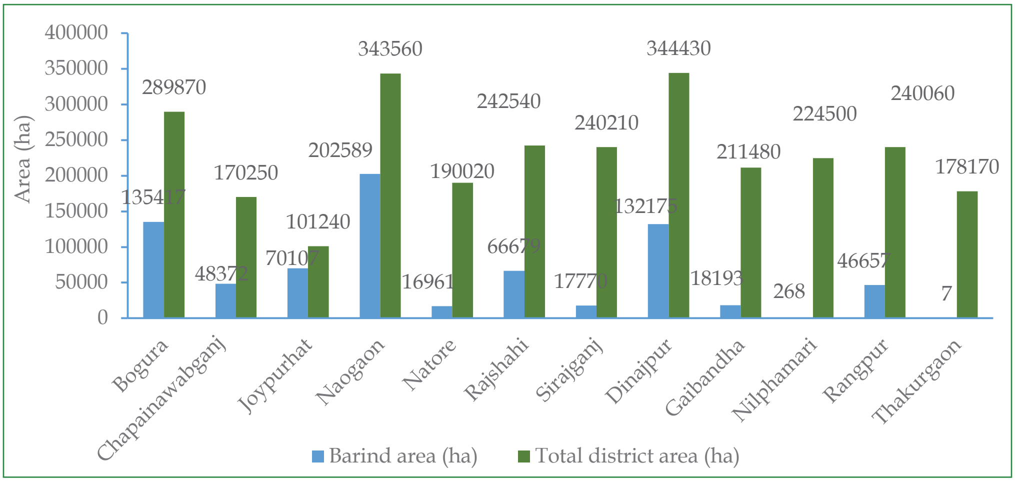


Fig. 4.2. Barind Tract areas in different northwestern districts in 2022

(Source: BARC 2022)

In terms of proportions of total district areas in the Barind ecosystem, Joypurhat district has the highest proportion (69.2%) followed by Naogaon (59%), Bogura (46.7%) and Dinajpur (38.4%), ans a very small proportion is in Thakurgaon (0.004%) (Fig.4.3). Earlier communications indicate that the Barind Tract covering 8,720 km^2 in northwestern Bangladesh is spread over parts of the greater districts of Rajshahi, Dinajpur, Rangpur and Bogura of Bangladesh with an area of 773,000 ha of which 532,000 ha is cultivable (Riches 2008).

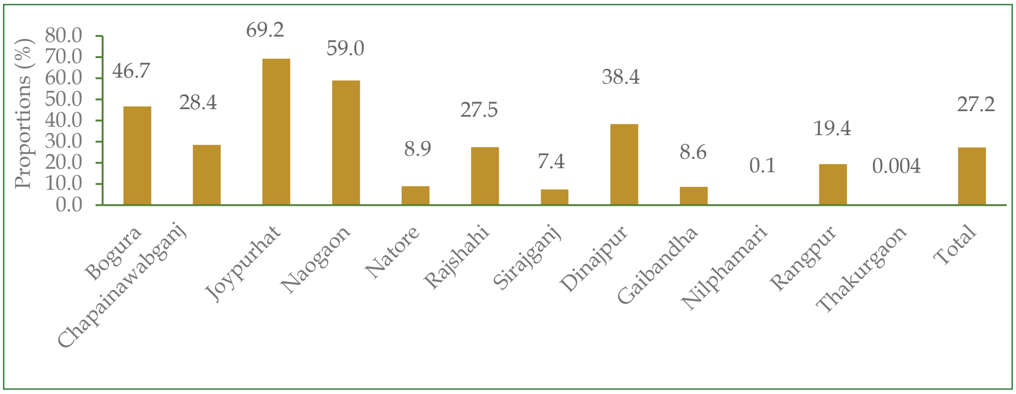


Fig. 4.3. Proportions (%) of district areas occupied by the Barind Tract

4.2 Biophysical characteristics

4.2.1 Land and soil

Barind Tract is a relatively elevated, about 11-48 m above mean sea level (AMSL) triangular wedge of landmass (Rashid et al. 2018). It is one of the many Pleistocene terraces present in northwestern Bangladesh. Different parts of the Barind Tract and its surrounding areas have distinguishing characteristics of their own. 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. In this part of the Barind Tract drainage density is high compared with that in the eastern part (Rashid et al. 2018). The sub-drainages or tributaries of main channels flow roughly in E-W and W-E directions from a saddle like area and join the roughly N-S flowing main channel. The south-central part represents a number of depressions with anastomosing drainage patterns.

Surface water of the northern Ganges (the Padma) floodplain flows to the northern rivers and channels. The Tangon and Punarbhaba rivers show multi-channel anastomosing systems in the Tangon and Punarbhaba valleys and these valleys do not continue up to the Mahananda river. Laterally migrated drainage is present in the floodplain areas but is absent in the Barind Tract (Rashid et al. 2018). About 47% of the Barind region is classified as highland, about 41% as medium highland and the remaining 12% as lowland (Faisal et al. 2005).

Barind Tract was developed during the Pleistocene age, the geological epoch which lasted from about 2.5 million to 11,700 years ago, and probably land formation in the Barind region ended around 10,000 years ago (Zakaria 2009). The 10-15 m thick surface layer of clay (Brammer 1996), and lack of alluvial characteristics in the deposits suggests that the area had developed under marine conditions. These marine sediments have since been uplifted, block faulted and eroded, resulting in the present day terraced surface topography.

Barind tract is densely forested but with a long subsequent history of rainy season, transplanted, puddled rice cultivation. This has resulted in severely degraded soil properties important for non-rice crops. Water use efficiency is a crucial consideration for the region due to the limited water holding capacity of soils, recent depletion of groundwater reserves, limited surface water catchment and increasing effects of climate change. The clay mineralogy of the Barind Tract parent material and soils is dominated by illite and kaolinite, with a trace of montmorillonite (Brammer 1996). Soils were developed through ferrolysis, a process that occurs in alternate cycles of reduction and oxidation in an alternate wetting and drying cycle in the topsoil. Ferrous ion is formed upon wetting, but it returns to the ferric form and hydrogen ions are released upon re-oxidation after water recession of flood water. The hydrogen ions attack clay minerals, reducing the clay content in the soil surface, releasing aluminum and acidifying the surface soil. This removes cations and reduces the cation exchange capacity (CEC) of the soil. Montmorillonite and part of the illite are destroyed during this process. Thus, kaolinite becomes dominant, with illite contributing about 20% and vermiculite 5-20% of total clay minerals. Weatherable minerals range from 4 to 9% in the eastern part from 8 to 14% in the western part of the Barind Tract (Brammer 1996).

Soil texture ranges from silt loam to silty clay loam in the top soil (usually 0-20 cm), mainly silty clay loam or clay in the subsoil and the substratum is usually clayey (Brammer 1996). The substratum can be either partially weathered or un-weathered clay and usually occurs at a depth of around 1 m. In the subsoil, the structure is moderately to strongly coarse and finely angular to sub-angular blocky. The peds are locally coated with fine clay, silt and humus. The structural stability is weak and, as a result, the soils become soft and sticky in the rainy season and hard in the dry season.

Soil color ranges from grey to mixed grey and brown, and locally pale brown to red brown (Brammer 1996). Soil porosity varies from layer to layer and the topsoil has 0.5-2 pores cm^{-2} compared to more than 2 pores cm^{-2} in the subsoil. Pores are usually fine or very fine making barind soils poorly drained. The soil is highly compact hampering crop root penetration and soil moisture storage. Bulk density ranges from 1.4-1.7 g cm^{-3} compared to 1.2-1.3 g cm^{-3} in floodplain soils. The initial rate of permeability is within 2.5 cm per hour but after four hours of wetness this decreases in the grey terrace soils whereas it increases in the red brown soils. Permeability rate is higher below the plough pan (at 10-15 cm soil depth), which indicates that the plough pan reduces the infiltration rate. The high compactness of soil hampers root penetration of crops as well as water infiltration and soil moisture storage (Ali 2000).

4.2.2 Soil fertility

pH and soil organic matter (SOM)

Soil pH values observed in three periods, 1985-1999, 1999-2002 and 2003-2021 are presented in Table 4.3. The minimum soil pH values averaged over the 2003-2021 period ranged from 4.0 to 5.2 (extremely acidic to strongly acidic) and tended to be higher at the lower land elevations (Table 4.3). The maximum observed soil pH veried from 6.5 to 7.9, and unlike in case of the lower pH range, the soils appeared to be more alkaline (higher pH) on higher land than on lower land. Soil acidity may have arisen from the release of hydrogen ions upon oxidation of the soils (upland condition at higher elevations). The hydrogen ions attack clay minerals releasing aluminum which, upon hydrolysis acidifies the surface soil (Brammer 1996). Over time (1985-2021) there is no significant changes in soil pH (Table 4.3).

Table 4.3. Soil pH in the Barind Tract during 1985-1999, 1999-2002 and 2003-2021

pH (1985-1999)				
	HL	MHL	MLL	LL
Min	3.9	3.9	4.3	4.6
Class	Extremely acidic	Extremely acidic	Extremely acidic	Strongly acidic
Max	7.4	8.0	6.9	6.1
Class	Moderately alkaline	Strongly alkaline	Neutral	Moderately acidic
pH (1999-2002)				
	HL	MHL	MLL	LL
Min	4.0	4.4	4.7	Data not available
Class	Extremely acidic	Extremely acidic	Strongly acidic	Data not available
Max	8.1	7.7	7.5	Data not available
Class	Moderately alkaline	Moderately alkaline	Moderately alkaline	Data not available
pH (2003-2021)				
	HL	MHL	MLL	LL
Min	4.1	4.0	4.4	5.2
Class	Extremely acidic	Extremely acidic	Extremely acidic	Strongly acidic
Max	7.9	7.7	6.5	6.6
Class	Moderately alkaline	Moderately alkaline	Moderately acidic	Moderately acidic

Source: BARC 2022

The SOM level (averaged over three periods, 1989-1998, 1999-2002 and 2003-2021) across HL, MHL, MLL and LL, ranged from 1.37% to 1.80% in the Barind Tract (Fig. 4.4). In general, soils on MLL and LL have higher organic matter content than those on HL and MHL. However, SOM in the Barind Tract historically remains below the critical level of 2% needed for good crop production although soils on MLL and LL have relatively high SOM content (around 2% or slightly higher). A comparison of the three periods indicates that SOM increased over time on all land types over time. The reason for this increase might be due to decaying vegetation from crop residues such as Boro rice, maize, potato etc. that are extensively grown in the Barind areas. This implies an improvement in fertility of the Barind Tract soils which Brammer (1996) had in the past found to be infertile to moderately fertile due to a low soil OM content (<1 %), low cation exchange capacity (CEC) of 10-15 meq/100 g soil) and low available nutrient contents.

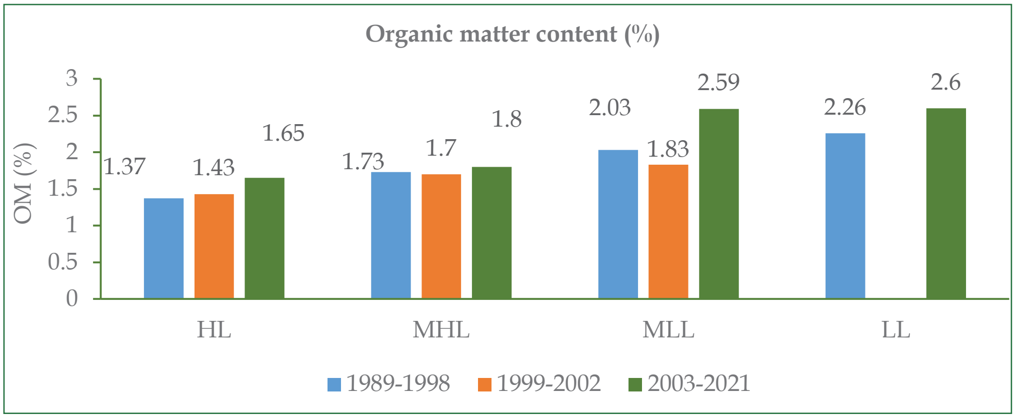


Fig. 4.4. Organic matter content of soils in Barind area (Source: BARC 2022)

Nutrient content

During 1999-2002 and 2003-2021, the available phosphorus (P) levels in soils of the Barind Tract across the land types (HL, MHL, MLL and LL) ranged from 5.1 to 8.5 ppm and 6.1 to 12.1 ppm, respectively which were much below the optimum level of 25 ppm for crops. Available P content of soils across HL, MHL and MLL appeared to increase with time between 1999 and 2021 (Fig. 4.5). The reason could be increasing application of P fertilizer for increasing cropping intensity in the Barind areas.

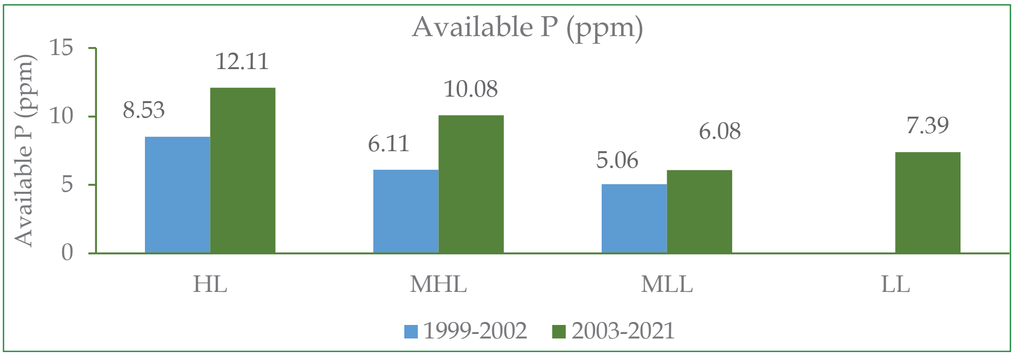


Fig. 4.5. Available P content soils of the Barind Tract (Source: BARC 2022)

The available potassium (K) levels in soils of the Barind Tract, during the periods, 1999-2002 and 2003-2021, measured as exchangeable K, ranged from 0.13 to 0.20 meq/100g and 0.17 to 0.34 meq/100g, respectively (Fig. 4.6). The K level of soil is generally higher on higher land than that on lower land. Soils had an exchangeable K level ranging from 0.20 to 0.34 meq/100g compared with 0.13-0.16 meq/100 g in soils on HL and MHL, respectively. The available K level in soil has increased with time irrespective of land type. However, at no time the exchangeable K level was sufficient (0.5 meq/100g or higher) for crops.

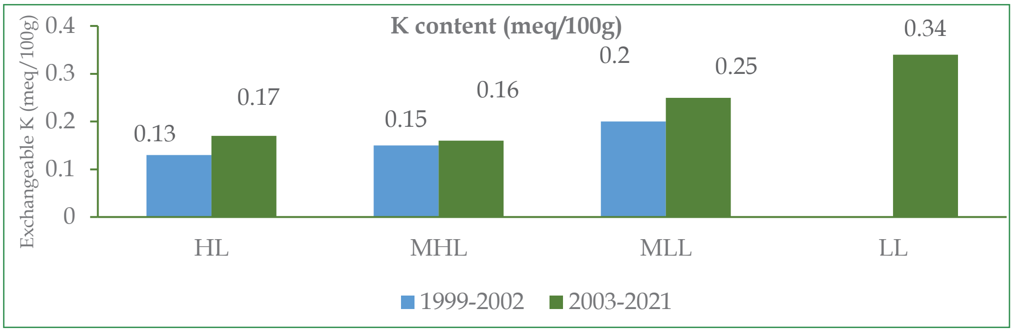


Fig. 4.6. Exchangeable K content in soils of the Barind Tract (Source: BARC 2022)

Available sulfur (S) content in soils of the Barind Tract across land types (HL, MHL, MLL and LL) has remained above the critical limit (12 ppm) during the last two decades (1999-2021), but the values have been much below the optimum level of 26 ppm (Fig. 4.7). During 1999-2001, the available S content in soils was 15.07-17.45 ppm which declined slightly to 14.06-14.88 ppm during 2003-2021. The available S in soils did not differ significantly with land type. The decrease in the available S content of soils is attributed mainly to an increased cultivation of HYV of crops applying high-analysis S-free fertilizers over the years. The HYVs which absorbed large amounts of S from soils which were not adequately replenished with S addition. Also, prolonged submergence of soil for rice cultivation with the application of higher rates of NPK fertilizers but no S (Islam 1990).

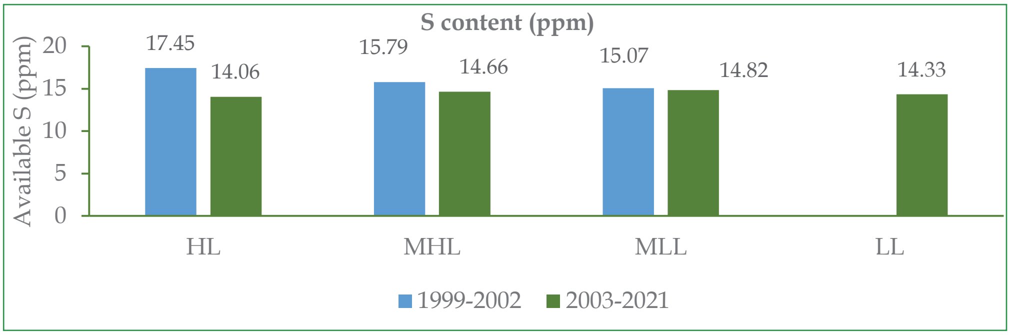


Fig. 4.7. Available S content in soils of the Barind Tract (Source: BARC 2022)

The available zinc (Zn) content in soils of the Barind Tract ranged from 0.97 to 1.39 ppm during 1999-2021 (Fig. 4.8) which was below the critical level of 2.0 ppm indicating Zn deficiency for crops. Soils on MLL contained a higher Zn level than those on any of the other land types. Two factors, high pH that reduces Zn availability in soils and continuous flooding of the soil for wetland rice cultivation that creates an anaerobic condition are responsible for Zn deficiency in soils. Appropriate soil and crop management including the application of adequate amount of Zn fertilizer is required for optimum crop growth and yield on Zn deficient soils.

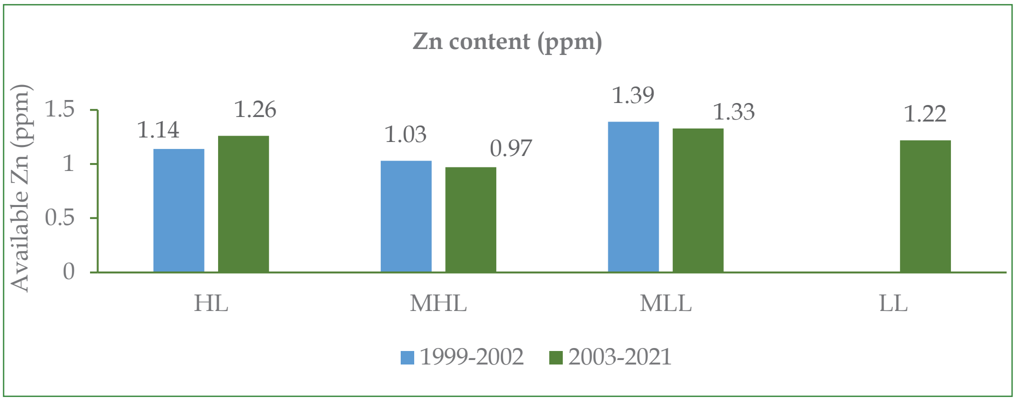


Fig. 4.8. Available Zn content in soils of the Barind Tract (Source: BARC 2022)

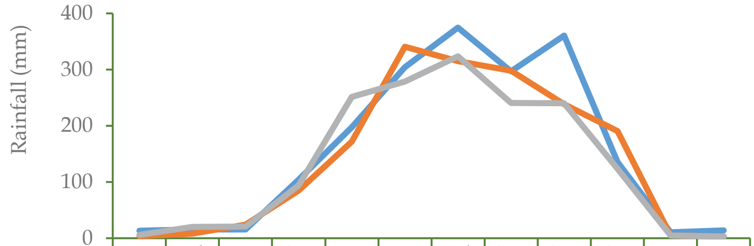
In general, soil fertility problems in soils of the Barind Tract are low SOM, P, K, calcium (Ca), magnesium (Mg), S, Zn, boron (B) and molybdenum (Mo) (BARC 2005). Both physical and chemical properties of the Barind soils were considered less than ideal for crop production or for woody vegetation (Hussain et al. 1991). Nutrient depletion and deterioration of physical properties will likely continue as long as the present cultivation systems with little regard for recycling of crop residue recycling and addition of organic amendments.

4.2.3 Climate

Rainfall

Unlike the relatively low-lying central and southern parts of Bangladesh, the Barind Tract is not expected to be affected by excess water problems due to its elevation above flood levels. Total rainfall in the Barind areas is predicted to increase to a lesser extent or even decrease in the future. The drought-prone areas of Bangladesh like the Barind tract, are indeed warmer and drier than 50 years ago. The Barind Tract is the most drought-prone area of the country and it is not prone to large scale flooding. This could be seen as a major advantage compared with low-lying areas of the country. The Bogura Meteorological

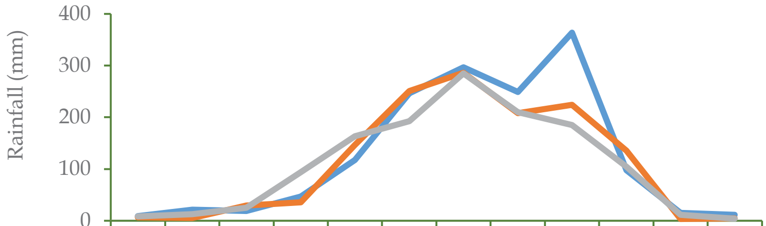
Station recorded monthly precipitations in the Bogura-Joypurhat-Naogaon-Sirajganj region. From the data, three periods (1991-2000, 2001-2010 and 2011-2020) of monthly averages of rainfall were derived (Fig. 4.9). The months receiving the highest precipitation were, obviously, the Kharif months of May to September irrespective of the periods. The average rainfall in May, June, July, August and September amounted to 198, 305, 375, 297 and 360 mm in 1991-2000 and 251, 279, 324, 240 and 240 mm, respectively, during 2011-2020. The total average rainfall in the Kharif period of a year during 1991-2000 was 1535 and it was 1365 mm during 2001-2010 while during the 2011-2020 period it was 1036 mm (derived from data in Fig. 4.9). Apparently, precipitation tended to decrease slightly over time. This could be interpreted as an decreasing trend of rainfall in this part of the Barind Tract. In particular, decrease in rainfall in the months of July and August has been critical for the safe planting of Kharif-II crops including T. Aman rice. The monthly average rainfall over the last 10 years (2011-2020) in May, June, July and September in these Barind districts was still lower than the normal monthly average rainfall in other parts of the country.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg Rainfall during 1991-2000	14	16	16	104	198	305	375	297	360	135	11	14
Avg Rainfall during 2001-2010	4	8	24	85	172	341	315	298	239	191	5	3
Avg Rainfall during 2011-2020	6	20	21	94	251	279	324	240	240	124	5	4

Fig.4.9 Monthly rainfall in the Bogura-Joypurhat-Naogaon-Sirajganj region (Bogura Meteorological Station) during 1991-2020 and 2011-2020
(Source: BARC 2022)

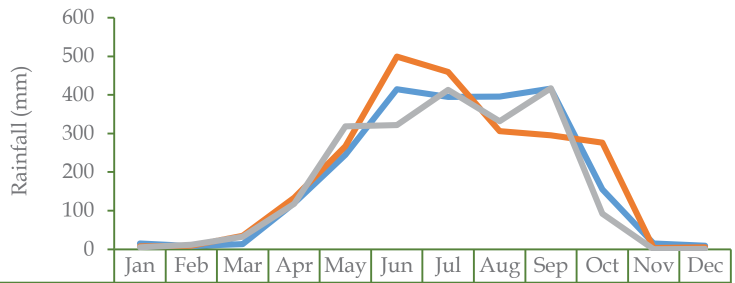
In the Rajshahi-Chapainawabganj-Natore region, rainfall in the months of May, June, July, August and September during 1991-2000 amounted to 117, 247, 297, 249 and 364 mm, respectively as recorded by the Rajshahi Meteorological Station (Fig. 4.10). Average amounts of rainfall in the same months during 2011-2020 were 164, 192, 285, 210 and 185 mm, respectively. A comparison of average rainfall during 1991-2000 with that in 2011-2020 indicates a decreasing trend in rainfall in the Kharif season. Moreover, rainfall decreased generally consistently in the Rabi season with almost zero rainfall in the months of November-January during 2011-2020. This indicates increasing dryness and probable drought spells in the peak dry months of the year which could adversely affect T. Aman rice and Rabi crops.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg Rainfall during 1991-2000	9	21	19	47	117	247	297	249	364	98	15	12
Avg Rainfall during 2001-2010	6	6	29	36	147	251	286	208	224	136	3	5
Avg Rainfall during 2011-2020	9	13	25	94	164	192	285	210	185	104	12	4

Fig.4.10. Monthly rainfall in the Rajshahi-Chapainawabganj-Natore region (Rajshahi Meteorological Station) during 1991-2020
(Source: BARC 2022)

The Rangpur Meteorological Station recorded relatively high rainfall in May (318 mm), June (322 mm), July (413 mm), August (332 mm) and September (417 mm) during 2011-2020 in the Rangpur-Gaibandha-Nilphamari-Dinajpur-Thakurgaon region of Rangpur division (Fig. 4.11) compared with other areas of the Barind Tract. In the same months during the 1999-2000 period the average rainfall amounted to 244, 415, 395, 395 and 417 mm and during the 2001-2010 period to 267, 499, 459, 306 and 295 mm, respectively, indicating substantial increase in rainfall during May and June. In particular, an increased rainfall in the Kharif-I season has been harmful for Boro rice harvest and Kharif-I planting. However, monthly rainfall average over the last 10 years (2011-2020) in these Barind districts was still lower than the normal monthly average rainfall in other parts of the country. In addition, the peak rainy months of June and August received lower average monthly rainfall (322 and 332 mm respectively) during the last 10 years from 2011 to 2020 compared with the same months' averages from 1991 to 2000 (415 and 395 mm, respectively). Moreover, monthly rainfall has decreased severely during November through January in the period of 2011-2020 compared with that in the period of 1991 to 2000. This resulted in drought spells in these months leading to delayed planting of Boro rice and other Rabi crops, and in partial damage to these crops if planted at the start of the winter. Furthermore, the decreasing trend of average monthly rainfall during June, July and August in the last 10 years compared with the monthly rainfall in the same months during 1991-2000 indicates that the rainy season in these Barind districts is getting drier which is not desirable.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg Rainfall during 1991-2000	15	8	14	119	244	415	395	395	417	155	15	9
Avg Rainfall during 2001-2010	7	9	35	133	267	499	459	306	295	276	4	5
Avg Rainfall during 2011-2020	5	12	33	118	318	322	413	332	417	92	0	1

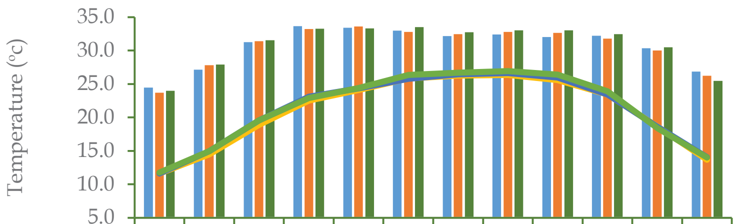
Fig. 4.11. Monthly rainfall in the Rangpur-Gaibandha- Nilphamari- Dinajpur-Thakurgaon region (Rangpur Meteorological Station) during 1991-2020 and 2011-2020 (Source: BARC 2022)

Drought, even in the rainy season, is more common in the Barind Tract than elsewhere in Bangladesh (Shahid and Behrawan 2008). Probability analysis of rainfall data showed about 30-40 % chance of a dry spell exceeding 5 days in the first three months of the rainy season (June, July and August) (Selvaraju et al. 2006). The chance of a dry spell exceeding 10 days during the same period was only 10%. The chances of extended dry spells increase from September. The dry spell length would exceed 5-10 days almost every year from October to December and 20 days in about 20% of years during October, when T. Aman rice reached its reproductive stage. In November, the dry spell length would exceed 25 days in 80 % of the years, indicating the threat to T. Aman rice of terminal drought for a long duration and that of sub-optimal soil moisture during sowing time of rainfed Rabi crops. These forecasts indicated that short-duration T. Aman rice with a reasonable yield potential would be a safer option for the Barind Tract. Cultivation of short-duration T. Aman rice varieties would also permit timely seeding of rainfed or partially irrigated Rabi crops like chickpea, lentil, wheat, barley, mustard, linseed, potato and maize.

Temperature

A review of the average monthly maximum temperature (Tmax) for the three periods viz. 1991-2000, 2001-2010 and 2011-2020 collected at the Bogura

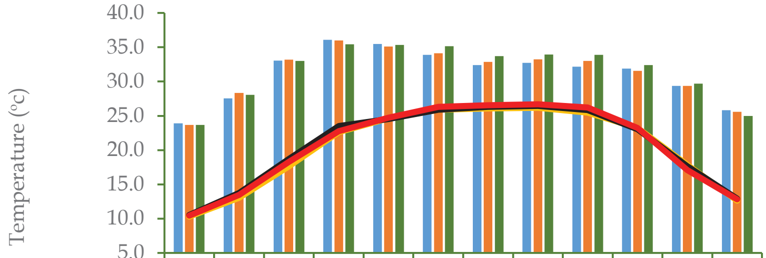
Meteorological Station for the Bogura-Joypurhat-Sirajganj region indicated an increase in Tmax with time in most months of a year except January, April, May and December (Fig. 4.12). The magnitude of T_{max} increase was 0.2-1°C. Likewise, the minimum monthly temperatures (T_{min}) during the same 30-year period also increased (Fig.4.12). In 2011-2020, T_{min} ranged from 11.8 °C in January (the lowest) to 26.9 °C in August (the highest) while lower T_{min} values, 11.6 °C in January to 26.4 °C in August were recorded during 1991-2000 Thus, T_{min} increased by 0.2-0.5 °C.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg MaxT during 1991-2000	24.5	27.2	31.3	33.6	33.4	33.0	32.2	32.4	32.0	32.2	30.3	26.9
Avg MaxT during 2001-2010	23.7	27.8	31.4	33.2	33.6	32.8	32.5	32.8	32.7	31.8	30.0	26.2
Avg MaxT during 2011-2020	24.0	27.9	31.5	33.3	33.3	33.5	32.7	33.1	33.0	32.5	30.5	25.5
Avg MinT during 1991-2000	11.6	14.5	18.9	22.5	24.1	25.8	26.2	26.4	25.6	23.4	18.6	13.7
Avg MinT during 2001-2010	11.6	15.0	19.6	23.1	24.3	25.8	26.5	26.6	26.0	23.4	18.6	14.0
Avg MinT during 2011-2020	11.8	15.0	19.6	22.9	24.4	26.4	26.7	26.9	26.4	23.9	18.4	14.0

Fig. 4.12. Monthly maximum and minimum temperatures in the Bogura-Joypurhat-Sirajganj region (Bogura Meteorological Station) during 1991-2020 (Source: BARC 2022)

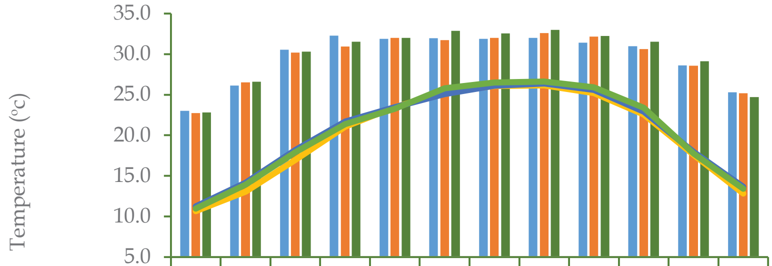
In the Rajshahi-Chapainawabganj-Naogaon-Natore region, according to average monthly temperature data recorded by the Rajshahi Meteorological Station, the monthly T_{max} ranged from 28 °C in February to 35.2 °C in June. In the 1991-2000 period, T_{max} ranged from 27.5 °C in February to 33.9 °C in June. There was generally an increase in T_{max} by 0.5-1.3 °C, the increase being most marked by 0.5 to 1.7 °C in the months of June-October. The recorded average T_{min} for the 2011-2020 and 1991-2000 periods amounted to 10.4 °C in January to 26.7 °C in August and 10.3 °C in January to 26.2 °C in August, respectively (Fig. 4.13). The data indicated an increasing trend of T_{min} over time in the Rajshahi-Chapainawabganj-Naogaon-Natore part of the Barind Tract, the magnitude of increase being 0.1 to 0.5 °C. The increase was greater in the Kharif months than that in the Rabi months (Fig. 4.13).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg MaxT during 1991-2000	23.9	27.5	33.1	36.1	35.5	33.9	32.4	32.7	32.2	31.9	29.4	25.8
Avg MaxT during 2001-2010	23.7	28.4	33.2	36.0	35.1	34.1	32.9	33.3	33.0	31.5	29.4	25.6
Avg MaxT during 2011-2020	23.7	28.0	33.0	35.5	35.3	35.2	33.7	33.9	33.9	32.4	29.7	25.0
Avg MinT during 1991-2000	10.3	13.0	17.6	22.6	24.6	25.9	26.1	26.2	25.5	23.2	17.8	12.6
Avg MinT during 2001-2010	10.5	13.7	18.7	23.5	24.6	25.9	26.3	26.5	25.8	23.1	17.6	12.9
Avg MinT during 2011-2020	10.4	13.5	18.3	22.8	24.7	26.3	26.5	26.7	26.2	23.2	17.1	12.8

Fig. 4.13. Monthly maximum and minimum temperatures in the Rajshahi-Chapainawabganj-Naogaon- Natore region (Rajshahi Meteorological Station) during 1991-2020 (Source: BARC 2022)

The average T_{max} in the Rangpur-Gaibandha-Nilphamari-Dinajpur-Thakurgaon during the 1991-2000 period as recorded by the Rangpur Meteorological Station ranged from 23 °C in January to 32 °C in August (Fig. 4.14). During the past 10-year period, too, January was the coolest (22.8 °C) and August the warmest (33 °C) month. In Barind areas of Rangpur division, T_{max} has increased in all the months of the year except in January, March, April and December as is revealed by a comparison of the average T_{max} values of the 1991-2000 and 2011-2020 periods (Fig. 4.14). The T_{max} rise with time in this part of the Barind Tract ranged from 0.1 °C to 1 °C in 8 months of the year. In this part of the Barind Tract, T_{min} in the 1991-2000 period ranged from 10.7 °C in January to 26.1 °C in August, and in the last 10 years from 11 °C in January to 26.6 °C in August (Fig. 4.14). Over time, like T_{max}, the monthly T_{min} had also increased to various extents in different months of the year except in May. For example, in the last 10 years (2011-2020), the average T_{min} in February was 11 °C and that in August was 26.6 °C increasing from 10.7 °C and 26.1 °C, respectively, in the 1991-2000 period (Fig. 4.14).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg MaxT during 1991-2000	23.0	26.1	30.5	32.3	31.9	32.0	31.9	32.0	31.4	31.0	28.6	25.3
Avg MaxT during 2001-2010	22.8	26.5	30.2	30.9	32.0	31.7	32.0	32.6	32.1	30.6	28.6	25.2
Avg MaxT during 2011-2020	22.8	26.6	30.3	31.5	32.0	32.9	32.5	33.0	32.2	31.5	29.1	24.7
Avg MinT during 1991-2000	10.7	13.1	17.0	21.1	23.5	25.3	26.1	26.1	25.2	22.6	17.6	12.8
Avg MinT during 2001-2010	11.3	14.2	18.2	21.7	23.5	25.1	26.1	26.4	25.6	22.9	18.0	13.7
Avg MinT during 2011-2020	11.0	13.9	17.9	21.4	23.3	25.8	26.5	26.6	25.9	23.4	17.7	13.4

Fig. 4.14. Monthly maximum and minimum temperatures in the Rangpur-Gaibandha-Nilphamari-Dinajpur-Thakurgaon region (Rangpur Meteorological Station) during 1991-2020 (Source: BARC 2022)

4.3 Biodiversity

Vegetation of the Barind Tract is semi-deciduous, upper canopy contains the deciduous species and other area is dominated by evergreen species (Faisal et al. 2005). Hamid and Hunt (1987) quoted a report from Simson in 1859 regarding the Barind region that stated, "Here were large tracts of tree jungle, with palms, bamboos and all the common Bengal trees: at the foot of these trees shrubby, thorny jungle afforded the best cover for all game." The local people called the area *Kantal* ban (thorny jungle) as it was difficult to penetrate. Hamid and Hunt (1987) also cited the British statistician Hunter who wrote about the existence of mixed forests in the High Barind Tract (HBT) apparently dominated by *shal* trees (*Shorea robusta*) but with many other trees, shrubs, herbs and grasses. Among the thorny species probably common in the region since ancient times, *fanimonosha (Opuntia dillenii)* is still to be found in HBT and is used for fencing. These past reports suggest that the Barind region supported a large biomass, with rapid turnover of organic matter in the relatively warm and moist climate. It is also believed that up to 500 plant species were used for medicinal purposes in HBT area; most of them have been lost with forest clearing and change of ecosystems.

The natural vegetation, however, was gradually lost. Nelson (1923) described how successive increases in human habitation in and around the HBT increased the need to bring more land area under cultivation by clearing forests. The peasant farmers cultivated the land with the requirement of paying high revenue to the landlord, who in turn was required to pay revenue to the British rulers (Misra 2009). Therefore, there was increased pressure to clear more land for rice cultivation, to meet revenue requirements. Zuberi (2009) reviewed British records indicating that from 1795 the forest was slowly cleared for cultivation and within 1818-1856 almost half of the Barind region was brought under cultivation. Statistical reports of the land survey from 1849 indicated that forests covered about 55 % of the Barind region. But by 1874, about 70 % land of the region had been changed into cultivable land. The level areas were cleared first, and then the undulating HBT. At the end of 19th century, only a few forest areas were left. Zuberi (2009) quoted a 1928 British report indicating that within 1920-1928 most of the forest had been cleared and sloping land was terraced and leveled for rice cultivation, but there was still some mixed shal forest present. Most of the cleared land was used for rice cultivation and a portion of it for indigo cultivation in the 19th century. In this process the entire HBT became almost bare with the appearance of a drought-prone desertified area during the dry season. Drinking water was scarce and it became difficult to move around in the summer due to the hot weather and lack of shade. Recent reports show that forest covered only about 33% of the Barind Tract in 1989, which decreased to 25% in 2000 and further to 19% in 2009 (Ullah et al. 2014). The deforestation rate has been much higher than the afforestation rate during the last 20 years due to climate change and human interventions Rapid depletion of vegetation coverage in recent years might create adverse condition in Barind Tract and its surrounding areas. Three factors contributed to the decline of natural vegetation in the Barind Tract:

a) the incidence of solar radiation per unit area of soil surface in HBT is the highest in the country (Datta et al. 2014); this increases soil temperatures, exacerbating soil drying and exposing seedlings to water and temperature stress especially in November to June when there is little or no precipitation,
b) there is evidence that deforestation decreases rainfall (Los et al. 2006) and
c) the ongoing demand for fuel results in pruning or felling of recently planted trees.

The forest during the 19th century provided shelter for a wide range of mammals, reptiles and birds. Game animals included tigers, leopards, spotted-deer, mousedeer, hog-deer, rabbits, wild hog, wild buffalo and nilgai (blue bull; *Boselaphus tragocamelus*). Other mammals included elephants, monkeys, porcupines (or *sajaru; Histrix indica*), pangolins (or bon rui; *Manis crassicaudata*), civets (*Viverricula indica*) and many species of bats

(Khalequzzaman 2009). Birds included ducks, geese, water fowl, partridge, quail, kingfishers, various pigeons and vultures, among a large range of other big and small birds (Khalequzzaman 2009). Reptiles included snakes, crocodiles and tortoises. Tigers were reported to survive in the Barind region into the late 1890s. But increasing human population drained these lands for cultivation of rice and other crops. This has led to imbalance of the nature by loss of fish, birds, and wildlife.

4.4 Demographic features

4.4.1 Population, social structures and facilities

The current information of demography is meagre, information of population of the Barind region is not available from the population census of 2011, the latest census of this kind in Bangladesh. However, an earlier study (Ali et al. 2018) indicates that there were around 3 million people living in the High Barind Tract. There were around 700,000 households in this region, which meant that a household comprised on an average 4-5 persons. The majority of people, 82%, lived in rural areas and the rest in urban areas. About 60-67% of the people were aged over 18 years. A total of 20-50 households lived predominantly in village clusters, and some in small roadside towns. People in the villages lived mostly in *katcha* (soil made) houses.

4.4.2 Socioeconomic conditions

Socioeconomic conditions of people in the Barind Tract are influenced by incidence and severity of droughts. Historically, droughts have been largely confined to the post-monsoon season but increasingly, due to the effect of climate change, the wet season, too, is being affected by intermittent drought spells. However, the Barind Tract remains free from floods which seriously affect vast areas in the floodplain regions of the country. Farmers are experienced in coping with the risk of drought and are thus to some extent prepared to face increasing risk.

In their survey of 1985, Hamid and Hunt (1987) categorized land tenure in the Barind region as follows:

a) Landless – no formal land ownership rights but just occupation of a homestead
b) Small farmer – owns up to 1 ha
c) Middle farmer – owns 1-3 ha
d) Large farmer – owns >3 ha.

Share cropping is a common feature of the Barind region, with various forms of sharecropping arrangements. The harvest is shared in either proportions agreed to beforehand or on the basis of a fixed amount going to the landlord, irrespective of seasonal yield. In addition to grain, there is also a sharing of the straw, which results in its almost complete removal from the field for animal feed, fuel or building material. In this system there is little incentive for either the landlord or the tenant to consider the longer-term sustainability of the production system. The large landholders are usually absentee landlords, who live in regional towns or cities relying on the regular income derived from the usually reliable rainy season rice crop but have limited contact with the production system (Hamid and Hunt 1987). The landless work mainly as agricultural laborers, as sharecroppers or in other laboring jobs such as in public works or menial work in towns and cities. They usually live on a day-to-day subsistence basis. There is an increasing trend for larger farmers to also become involved in agricultural business enterprises, such as retail of agricultural inputs (seeds, fertilizers, agro-chemicals, etc.). This system aggravates social inequity and is not conducive to long-term sustainability of the land resource.

Severe drought in rainfed areas has a drastic effect on the livelihoods of all categories of farmers but more so on resource poor farmers. It is assumed that for covering the loss due to severe drought in one year, at least three years are required for farmers to restore their livelihood status. However, when continuous drought or near drought occurs for 2-3 consecutive years many poor farmers cannot cope with the situation. They are thus forced to change their occupation, migrate to urban areas to seek employment or face complete destitution. This situation also makes people more prone to illness and disease, which further exacerbates their financial situation. The most vulnerable households are those that lack resources and therefore have limited access to services and systems that sustain livelihoods (TANGO 2002). Families or households can respond to risk in different ways. The most commonly employed coping strategies are: limiting food portions at mealtime, relying on cheaper or less preferred foods, purchasing food on credit, borrowing from relatives/friends/neighbors, seeking off-farm employment and reducing adult consumption to provide for children (TANGO 2004). When farmers lose much of their crop(s) to drought or some other calamity they first sell their livestock or trees. In a dire situation, they may also sell off their household assets, such as furniture and utensils, to cover food cost. However, many small and marginal farmers lose their land in extreme situations and thus become landless. There is now an increasing trend for small, marginal and landless farmers to cope by migrating to larger towns or cities to sell their labor or engage in rickshaw pulling, small business or transporting grocery goods, etc. Many landless, marginal and small farmers are tempted to avail small loans from different NGOs or money lenders. They are often caught in a debt trap as interest rates imposed by money lenders and some NGOs are high.

4.5 Agricultural systems

4.5.1 Land use pattern

The 12 Barind districts have a total area of about 2.78 million ha. The net agriculture land in the Barind region totals about 0.60 million ha (Fig. 4.15). Agricultural lands in the barind areas account for 21.5% of the total barind based district areas and 6.77% of Bangladesh agricultural land area. The total agricultural land of Bangladesh is 8,800,810 ha (BBS 2020).

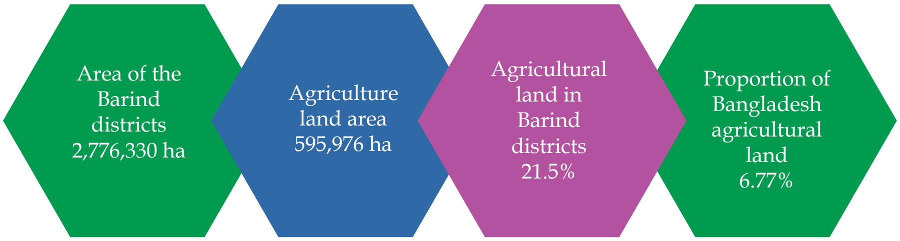


Fig. 4.15. Agricutltural land area in the Barind region (Source: BARC 2022)

Agriculture, occupying 78.92% of the Barind Tract spread over 12 districts, dominates the land use scenario there (Table 4.4 and Fig. 4.16). Ponds, rivers and canals occupy 0.40% area each. Fresh water aquaculture and perennial beels occupy 0.11% and 0.08% of the Barind land, respectively.

Among the 12 districts, the highest acreage under agriculture (167,283 ha) is in the Barind areas of Naogaon occupying 83% of the total land area of the district (Fig. 4.17). Considering the importance of productivity gains in barind areas, Dinajpur barind areas follows Naogaon in terms of its agriculture land (104,980 ha). Next to this, Bogura, Rajshahi, Joypurhat and Chapainawabganj have substantial amount of agriculture land in their barind areas ranging from 71-85%. However, Thakurgaon district is constrained by the presence of only 2 ha agriculture lands in its total Barind areas (7 ha).

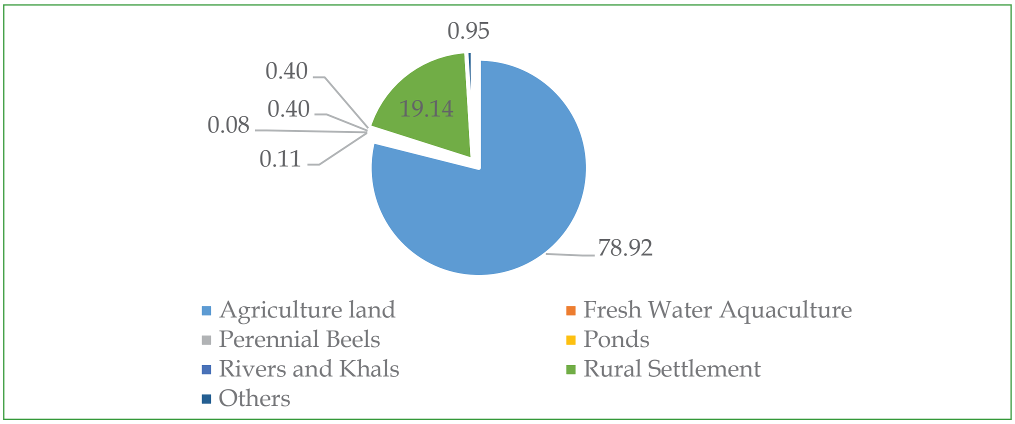


Fig. 4.16. Proportion (%) of land use pattern in Barind areas (Source: BARC 2022)

Table 4.4. Land use pattern in Barind areas in 2022

Land use	Area (ha)
Agriculture land	595976
Fresh Water Aquaculture	846
Perennial Beels	570
Ponds	3006
Rivers and Khals	3013
Rural Settlement	144544
Others	7240
Total	755195

Source: BARC 2022

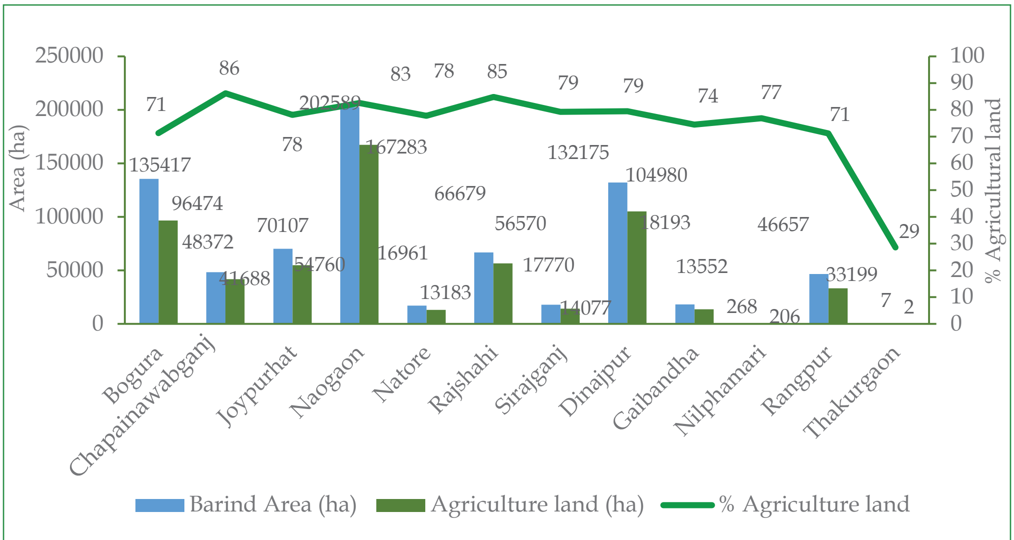


Fig. 4.17. Agricultural land in the Barind Tract by district (Source: BARC 2022)

Recently a number of farmers are converting their crop lands into mango orchards and continuing cultivation of field crops in the young mango orchards. Like in the other parts of the country, rice is the major crop in the Barind region and is the backbone of the rural economy. Diversified land use pattern may be an option for the farmers as a coping strategy against risks.

In the last 7 years (2015-2022) there has been no significant decrease in agricultural land area. There has been only a 0.26% decrease from 597,512 ha in 2015 (FD 2015) to 595,975 ha in 2021-2022 (Table 4.5). The greatest decrease of agricultural land in the Barind region during the 7 years was noticed in Naogaon (0.36%) followed by Sirajganj (0.35%). The decrease in agricultural land in the Barind areas could be attributed to the conversion of agricultural lands into infrastructure e.g, rural settlements, roads etc.

Table 4.5. Changes in agricultural land area of the Barind Tract during 2015-2022

District	Agriculture land (ha)		% decrease
	2015	2022	
Bogura	96673	96474	0.21
Chapainawabganj	41798	41688	0.26
Joypurhat	54837	54760	0.14
Naogaon	167880	167283	0.36
Natore	13195	13183	0.09
Rajshahi	56618	56570	0.08
Sirajganj	14126	14077	0.35
Dinajpur	105303	104980	0.31
Gaibandha	13573	13552	0.16
Nilphamari	206	206	0.00
Rangpur	33299	33199	0.30
Thakurgaon	2	2	0.00
Barind area	597512	595974	0.26

Source: FD 2015, BARC 2022

4.5.2 Crops and cropping patterns

The Barind area has a triple crop coverage of 49% which is more than double of the national average for triple cropping (23%) (Fig. 4.18 and 4.19). Double cropping and single cropping account for 39% and 12%, respectively, of the agricultural land in the Barind Tract. This efficient land utilization in the Barind region has been made possible by technological advancement in drought tolerance of crops and production practices suitable for drought affected areas.

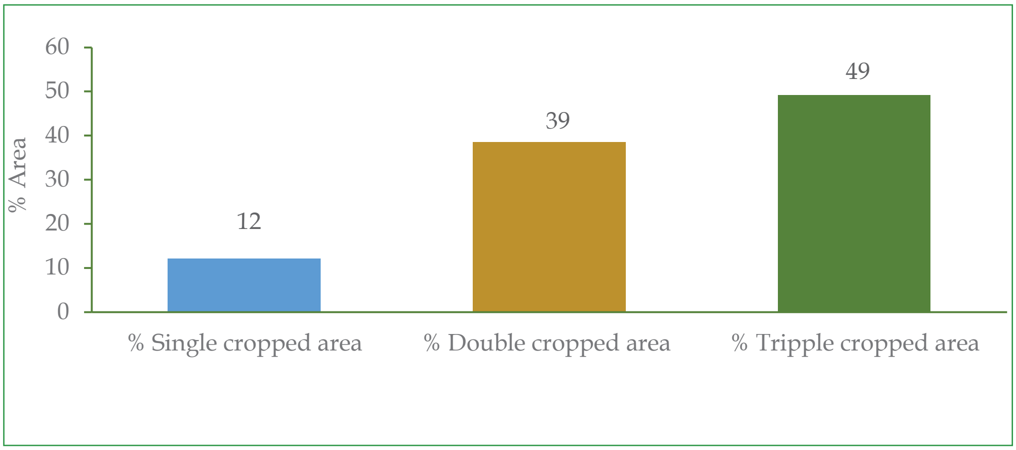


Fig. 4.18. Cropping situation in the Barind area in 2022 (Source: DAE 2022)

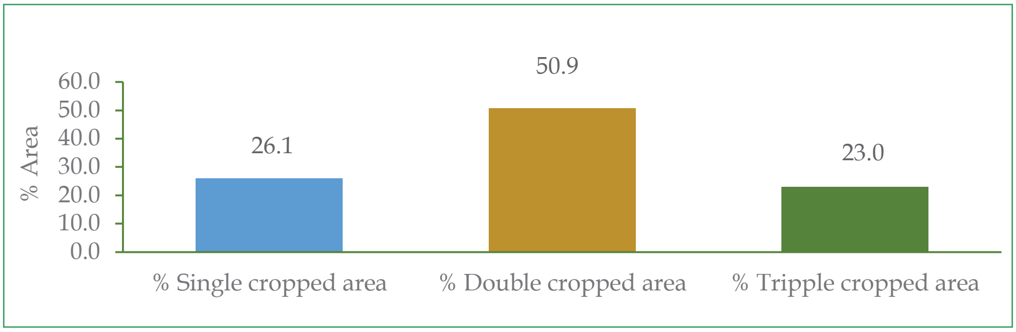


Fig. 4.19. Cropping situation in Bangladesh in 2020 (Source BBS 2020)

In the 12 Barind districts, triple cropped area is 361,137 ha, double cropped area is 287,614 ha and single cropped area is 90,820 ha (Table 4.6). Notwithstanding the dominance of triple cropped areas in the Barind Tract districts, Naogaon, Dinajpur and Nilphamari possess the highest double cropped areas. The triple cropped area has increased by 14.3% during 2010-2022 compared with 13.8% at the national level (Table 4.6). This increase occurred due to a conversion of single and double cropped areas into triple croped areas. A reduction in the single cropped area by 16.8% and double cropped area by 9.1% during 2010-2022 could have eventually led to the increase in the triple cropped area. The highest increase in triple cropping

Table 4.6. Changes in cropping status in the Barind areas during 2010-2022

District	Single cropped area (ha)		% inc/dec (+)/(-)	Double cropped area (ha)		% inc/dec (+)/(-)	Triple cropped area (ha)		% inc/dec (+)/(-)
	2010	2022		2010	2022		2010	2022	
Bogura	3843	4470	16.3	29655	23710	-20.0	47600	53050	11.4
Chapainawabganj	24750	26262	6.1	54460	47625	-12.6	50541	54470	7.8
Joypurhat	1630	4119	152.7	23153	21205	-8.4	55369	53984	-2.5
Naogaon	52863	45558	-13.8	137211	129455	-5.7	81019	88377	9.1
Rajshahi	14081	4474	-68.2	30970	23600	-23.8	18232	35632	95.4
Sirajganj	1500	1500	0.0	4500	4500	0.0	18957	24957	31.7
Dinajpur	2380	316	-86.7	14709	16214	10.2	10965	11524	5.1
Gaibandha	2996	1971	-34.2	5471	5155	-5.8	10766	10366	-3.7
Nilphamari	0	0	0.0	7320	9650	31.8	3540	4382	23.8
Rangpur	5100	2150	-57.8	8950	6500	-27.4	18995	24395	28.4
Barind	109143	90820	-16.8	316399	287614	-9.1	315984	361137	14.3
Bangladesh	2439000	2110000	-13.5	3840000	4125000	7.4	1641000	1867000	13.8

Source: DAE 2022, BBS 2012, 2020

occurred in Rajshahi (95.4%) followed by Sirajganj (31.7%) and Rangpur (28.4%) while there was a decrease in Gaibandha (3.7%) and Joypurhat (2.5%) (Table 4.6).

The increased availability of irrigation water due to the installation of deep tube wells and use of pumps, channels and pipes to distribute water more efficiently, has permitted cultivation of Rabi crops such as wheat, tomato, potato, rapeseed mustard, etc. in the dry winter season. These crops require much less water per unit of yield than does rice. Improvements in rainfed cropping techniques have also increased the scope for cultivation of winter crops. For example, in the case of chickpea, improved cultivars such as BARI chola 5 are better able to produce than traditional ones under receding soil moisture conditions. This has increased farmers' interest in further diversifying their farm enterprises, to include livestock rearing, aquaculture, vegetable cultivation, orchards, etc.

Expansion of irrigation facilities has also increased yield stability of the T. Aman rice crop. Since 1985, the Barind Multipurpose Development Authority (BMDA) has developed a network by installing deep tube wells bringing barind agricultural lands under irrigation. The cultivation of Boro and T. Aus rice has largely contributed to increasing the triple cropped area and turning this flood free area into a national food granary. However, the flowering stage of T. aman rice is particularly susceptible to drought stress, resulting in a 11-34% yield loss for local varieties and a 43-50% yield loss for modern varieties (Selvaraju et al. 2006, BRRI 2016). The Barind tract regularly experiences breaks in the monsoon rains during this flowering period, in August and September, and most farmers report yield losses of T. Aman attributable to drought stress (Islam et al. 2011). In previous years, farmers relied on any existing ponds or any other nearby water bodies to try to save the T. Aman crop at least partially. However, in recent years, many of the traditional ponds have dried up due to declining rainfall, siltation and over-use. These facts need to be seriously considered for sustained productivity of the Barind lands.

The net cropped area has remained almost static during 2010-2022 although a slight decrease by 0.26% has occurred in the Barind districts (Table 4.7) which may be attributed to increasing current fallow land and utilizing some lands for development of infrastructure. Among the Barind based districts, the greatest decrease in net cropped area has occurred in Gaibandha (9.05%) followed by Naogaon (2.84%) while this decrease was negated by a significant increase in Nilphamari (29.21%) and Sirajganj (24.04%). Despite a slight decrease in net cropped area, cropping intensity of 10 barind districts overall is higher (237%) in 2022 in comparison with the national average cropping intensity (197%) in 2020 (Table. 4.7). Among the barind districts, Sirajganj has the highest cropping intensity (276%) followed by Rangpur (267%) and

Joypurhat (263%). Higher proportion of triple and double cropped areas than the single cropped areas has led to the larger cropping intensity in barind areas than the national average cropping intensity.

Table 4.7. Changes in net cropped area in the Barind Tract during 2010-2022 and cropping intensity during 2022

District	Net cropped area (ha)		% inc(+) /dec (-)	Cropping intensity (%) in 2022
	2010	2022		
Bogura	81098	81230	0.16	260
Chapainawabganj	129751	128357	-1.07	222
Joypurhat	80152	79308	-1.05	263
Naogaon	271093	263390	-2.84	216
Rajshahi	63283	63706	0.67	249
Sirajganj	24957	30957	24.04	276
Dinajpur	28054	28054	0.00	240
Gaibandha	19233	17492	-9.05	248
Nilphamari	10860	14032	29.21	231
Rangpur	33045	33045	0.00	267
Total	741526	739571	-0.26	237
Bangladesh	7838000	8106478	3.43	197

Source: BBS 2012, DAE 2022

Among the Barind districts, the proportion of triple cropped area is the highest (100%) in Sirajganj (Fig. 4.20) followed by Rangpur (74%), Joypurhat (68%) and Bogura (65%), while Nilphamari has the highest proportion of double cropped area (69%) followed by Dinajpur (58%) and Naogaon (49%).

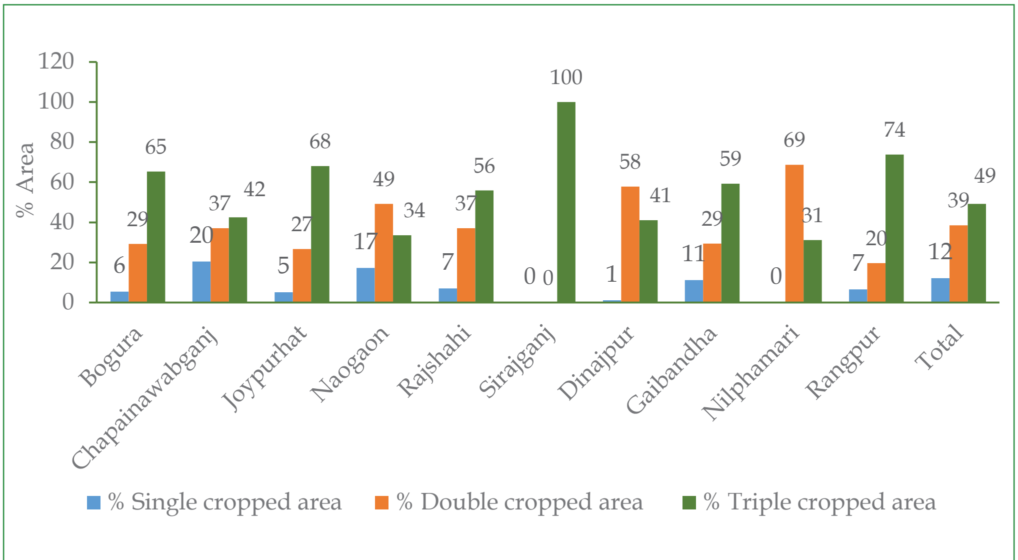


Fig. 4.20. Single, double and triple cropping proportions in Barind districts

It is interesting to note that, more than one fourth (27.6%) of the fallow land in the Barind region has decreased in 12 years (2010-2022) compared to the national average of 7.7% decrease in fallow land (Table 4.8). In effect, the 79, 721 ha of fallow lands in 2010 decreased to 57,731 ha in 2022. This means that 21,990 ha fallow lands were brought under cultivation during 2010 through 2020, which eventually resulted in increasing the triple cropped area in the Barind Tract (Table 4.8). The deceasing trend is noticed in all the Barind districts ranging from 9.1-100% between 2010 and 2022 (no fallow land was reported in Sirajganj and Dinajpur during 2010 and 2022). The greatest decrease in fallow land (100%) occurred in Nilphamari, Rangpur and Joypurhat followed by Rajshahi (86.5%) and Bogura (29.2%) while the lowest was in Gaibandha (only 9.1%). There are still opportunities of converting the remaining fallow land (57,731 ha) i.e, 10% of the agriculture land area of the Barind Tract to cultivated lands by growing at least single crop during the rainy season. This opportunity exists particularly in Bogura (37,250 ha) and Gaibandha (17,492 ha).

Table 4.8. Decrease in fallow land in the Barind region during 2010-2022

District	Fallow land area (ha)		% decrease
	2010	2022	
Bogura	52630	37250	29.2
Chapainawabganj	3228	2864	11.3
Joypurhat	50	0	100
Naogaon	0	0	0.0
Rajshahi	928	125	86.5
Sirajganj	0	0	0.0
Dinajpur	0	0	0.0
Gaibandha	19233	17492	9.1
Nilphamari	3172	0	100
Rangpur	480	0	100
Barind area	79721	57731	27.6
Bangladesh	467000	431000	7.7

Source: DAE 2022, BBS 2012 and 2020

Basically, rice-based agriculture is dominant in the Barind areas. Non-rice crops potato, groundnut, sweet potato, mustard, maize, pulses and vegetables are grown in the Rabi season. The extent of crop diversification over time is obvious from the information given in Table 4.9 which shows that the earlier winter fallow has been superseded by not only Boro rice but also by crops like wheat, mustard, potato, maize, vegetables and lentil in the cropping patterns. Currently there are 9 major cropping patterns all of them are rice-based. T. Aman rice is a major component of 8 cropping patterns while Boro rice is grown in 7 of the 9 major cropping patterns. Next to rice, mustard is introduced in 4 cropping patterns followed by potato in 3 cropping patterns.

Other than rice, mustard and potato there is 1 cropping pattern with lentil and 1 cropping pattern with maize. This indicates that cropping in Barind areas is highly diversified with different crops. However, this diversity of crops is high in the Rabi season while it is narrowed to mostly T. Aman rice in the Kharif-II season. This narrow cropping base during the Kharif season is primarily due to a rainfed situation which forces farmers to grow T. Aman rice as their major staple crop. There were no significant changes in major cropping patterns during 2010 through 2022 although 10 major cropping patterns were practiced during 2010 instead of 9 during 2022. However, area coverage of the Boro-T.Aus-T.Aman rice cropping pattern has increased from 16% to 25% of

Table 4.9. Changes in major cropping patterns in the Barind areas

District	Major cropping patterns	
	2021-22	2010-2011
Bogura	Boro-Fallow- T. Aman (30) Potato-Boro-T. Aman (26) Mustard-Boro-T. Aman (15)	Boro-Fallow-T. Aman (33) Potato-Boro-T. Aman (23) Mustard-Boro-T. Aman (13)
Chapainawabgonj	Fallow- Fallow-T. Aman (44) Boro- Fallow- T. Aman (24) Mustard+Boro -T. Aus - Fallow(9)	Fallow- Fallow-T. Aman (53) Boro- Fallow- T. Aman (7) Mustard+Boro-T. Aus-Fallow (24)
Joypurhat	Potato- Boro- T. Aman (71) Boro- Fallow -T. Aman (33) Mustard- Boro- T. Aman (20)	Potato- Boro- T. Aman (70) Boro – Fallow -T. Aman (34) Mustard- Boro- T. Aman (22)
Naogaon	Boro-Fallow-T. Aman (30) Boro-T. Aus -T. Aman (25) Mustard+Boro-Fallow-T. Aman (17)	Boro-Fallow-T. Aman (53) Boro-T. Aus-T. Aman (16) Boro- T. Aus– Fallow (15)
Rajshahi	Boro-Fallow-T. Aman (22) Potato-T. Aus-T. Aman (20) Mustard-Boro-T. Aman (17) Boro-T. Aus-T. Aman (12) Lentil-Fallow-T. Aman (4)	Boro-Fallow-T. Aman (54) Mustard-Fallow-T. Aman (9) Wheat-Fallow-T. Aman (5) Lentil-Fallow-T. Aman (5) Boro-T. Aus-T. Aman (4)
Sirajganj	Mustard-Boro-Fallow-T. Aman (60) Boro—T. Aus--T. Aman (15) Potato-Boro-Fallow-T. Aman (15)	Mustard-Boro-Fallow-T. Aman (64) Boro-Fallow-T. Aman (10) Boro-- Fallow- Fallow (6)
Dinajpur	Boro-Fallow- T. Aman (77) Maize-Fallow- T. Aman (13)	Boro- Fallow-T. Aman (80) Maize-Fallow-T. Aman (4)
Gaibandha	Boro-Follow-T. Aman (56) Mustard+Boro-Follow-T. Aman (28) Potato+Boro- Follow-T. Aman (12)	Boro-Follow-T. Aman (56) Mustard+Boro-Fallow-T. Aman (28) Potato+Boro- Fallow-T. Aman (13)
Rangpur	Boro- Fallow- T. Aman (39) Potato- Boro- T. Aman (15) Mustard-Boro-T. Aman (10)	Boro- Fallow- T. Aman (46) Potato- Boro- T. Aman (10) Mustard-Boro-T. Aman (7)

* T. Aus, Boro and T. Aman are the rice crops.
Figures in parentheses indicate % of the area covered

Source: DAE 2022

the total cropped area during 2010 through 2022 in Naogaon district. Similarly, the maize-fallow-T. Aman rice area has increased from 4% to 13% of the total cropped area in Dinajpur during the same period. Moreover, Boro rice is included in the mustard-fallow-T. Aman rice in Rajshahi between 2010 and 2022.

4.5.3 Livestock and poultry

Cattle, buffalo, goat, sheep, chicken, and duck are the most popular livestock in the Barind areas. In 2022, livestock and poultry heads numbered 46.16 million which accounted for 11.47% of the total livestock and poultry (402.5 million) in Bangladesh (Fig. 4.21).

Fig. 4.21. Livestock in the Barind areas as a proportion of that in Bangladesh (Source: DLS 2019)

In 2022, livestock population is the highest in Naogaon district of the Barind Tract (17.01 million) followed by Dinajpur (9.62 million) and Bogura (5.64 million) (Table 4.10). Among livestock, cattle population is the highest (4.33 million) followed by goat (4.22 million) in the Barind areas. It is noteworthy that the highest share of sheep (23.86%) of the Bangladesh population exists in the Barind region followed by cattle (17.9%) and goat (16.05%). There is a good opportunity of promoting sheep, goat and cattle as they grow well in drought-prone areas like the Barind Tract. Cattle, buffalo, sheep, poultry and duck populations (1.45, 0.018, 0.41, 12.1 and 2.1 million respectively) are the highest in the Barind district of Naogaon while goat population is the highest in Joypurhat district (0.99 million). The poultry population is 30.79 million, ducks number 5.92 million (Table 4.10). Also, the livestock and poultry population density (61.13/ha) in the Barind region is above the national average (45.74 /ha) in Bangladesh (Table 4.10). The highest population density of livestock in the Barind region is recorded in case of cattle (5.74/ha) followed by goat (5.58/ha). Then poultry population density (40.77/ha) is high compared with that of duck (7.84/ha). However, the buffalo population density in the Barind Tract is low (0.08/ha) compared with the national average (0.17/ha).

Table 4.10. Status of livestock and poultry in the Barind areas by district in 2019

District	Cattle	Buffalo	Goat	Sheep	Poultry	Duck	Total
	Head counts in million						
Bogura	0.68	0.006	0.32	0.10	3.86	0.68	5.64
Chapainawabganj	0.08	0.010	0.26	0.01	0.43	0.12	0.92
Joypurhat	0.16	0.002	0.99	0.05	1.85	0.34	3.38
Naogaon	1.45	0.018	0.95	0.41	12.10	2.10	17.01
Natore	0.03	0.000	0.14	0.01	0.52	0.08	0.78
Rajshahi	0.09	0.008	0.34	0.03	1.27	0.36	2.10
Sirajganj	0.08	0.003	0.07	0.02	0.75	0.31	1.23
Dinajpur	1.14	0.006	0.67	0.12	6.37	1.30	9.62
Gaibandha	0.13	0.004	0.09	0.02	0.74	0.18	1.17
Nilphamari	0.02	0.000	0.01	0.00	0.06	0.01	0.10
Rangpur	0.44	0.002	0.37	0.07	2.79	0.43	4.11
Thakurgaon	0.02	0.000	0.01	0.00	0.07	0.01	0.11
Barind Area Total	4.33	0.059	4.22	0.84	30.79	5.92	46.16
Bangladesh Total	24.2	1.48	26.27	3.54	289.28	57.75	402.5
% Bangladesh	17.90	3.99	16.05	23.86	10.64	10.25	11.47
Livestock/ha (Barind area)	5.74	0.08	5.58	1.12	40.77	7.84	61.13
Livestock/ha (Bangladesh)	2.75	0.17	2.99	0.40	32.87	6.56	45.74

Source: DLS 2019

For the Barind farming communities, livestock rearing is a very important risk management strategy against droughts. The dung is also a good source of cooking fuel and manure. Cash obtained from sale of milk and the animals helps rural families cover expenses throughout the year. This is particularly important during drought periods when income from cropping is minimal. However, cattle health is generally poor due to scarcity of green and nutritious forage and feed. Currently, to increase crop output, fallow land has been converted into cultivable land, free grazing land has shrunk. On the other hand, rice straw is preserved and served as a major feed for cattle and buffalo. Green fodder such as palatable weeds from rice fields and leguminous tree leaves are provided when available. In the rainy season, when most land goes under T. Aman rice, grazing area is further restricted to small areas of fallow lands and field bunds. However, there is a good scope of cultivating quick growing fodder crops like para grass (*Brachiaria mutica*) or napier grass (*Pennisetum purpureum*), tropical pasture legumes and other suitable species which are tolerant to drought. Some of these species are quite adapted to growing under trees, on pond banks and along road sides. Many of the tropical fodder grasses are perennial and can be grown for many years with regular cutting. In addition, such fodder has good market value.

4.5.4 Fisheries and aquaculture

The fisheries area in the Barind tract is reported to increase by 5.4 % from 6,942 ha in 2010 to 7,292 ha in 2020 (Table 4.11). The highest increase (44.6%) has been in fresh water aquaculture followed by perennial *beels* (12.9%) and ponds

(4.3%). However, areas of small rivers and *khals* have decreased by 3.1% which is primarily due to low rainfall leading to drying of these reservoirs.

Farmers of the Barind areas are not quite convinced about fisheries as erratic and irregular rainfall as well as temperature change affect the brood, maturity and gonad development of fishes in the breeding season.

Table 4.11. Status of fisheries in the Barind Tract

District	Fresh water aquaculture	Perennial *beels*	Ponds	Rivers and *khals*	Total
	Area (ha)				
Bogura	159	44	265	557	1025
Chapainawabganj	29	84	564	229	906
Dinajpur	190	92	187	620	1089
Gaibandha	12	0	105	38	155
Joypurhat	30	0	199	193	422
Naogaon	124	67	992	860	2043
Rajshahi	45	260	586	225	1116
Rangpur	165	23	13	173	374
Sirajganj	79	0	59	24	162
Total (2022)	833	570	2970	2919	7292
Total (2015)	576	505	2848	3013	6942
% Increase (+)/ decrease (-)	44.6	12.9	4.3	-3.1	5.04

Source: FD 2015, BARC 2022

4.5.5 Forestry

During the period of British rule, the landscape of the Barind Tract was dramatically changed with almost all of the natural forest area indiscriminately destroyed for the purpose of cultivation without considering its environmental effects (Hamid and Hunt 1987). The whole ecosystem was changed, including creation of terraces on sloping land, primarily to grow T. Aman rice during the monsoon season to increase revenue collection. This caused the Barind environment to have two distinct phases, i.e. greenish and moist during the monsoon period of June-October but harshly dry and resembling a desert landscape during November-May. The region became hot with lack of shading from trees, moisture holding capacity of soils decreased, rain water runoff exceeded infiltration which caused erosion of surface soil and the nutrients therein.

Since the independence of Bangladesh, the Bangladesh Agricultural Development Corporation (BADC) and over the last 25 years the BMDA embarked on planting trees along roadsides and elevated areas not suitable for rice cultivation. An obvious advantage has been the provision of shade for humans and animals, especially during the pre-monsoon season when temperatures can reach as high as 40-45°C. Other advantages include prevention of erosion, provision of building material and firewood, soil organic matter enhancement through leaf fall, fodder availability from palatable species and habitat for birds that prey on crop insect pests. Initially, fast growing introduced tree species, particularly *sisu (Dalbergia sissoo)*, was favored. However, over time, sisu became prone to the dieback, root and gummosis diseases. More recently tree species like palmyra palm (*Borassus flabellifer*), date palm (*Sylvestris sp*), *babla (Acacia nilotica), neem (Azadirachta indica), ghora neem (Melia azedarach),* river red gum (*Eucalyptus camaldulensis*), leucaenea (*Leucanea leucocephala*), etc. have been favored. These trees are also suitable for growing along crop field boundaries, on pond or stream banks and in homestead areas. To mitigate the scarcity of forest resources and deforestation, the government decided to raise the forest area to 20% of the national area, and to expand the extent of Protected Area Network from 5% of total forest area to 10% (Forestry Sector Master Plan 1993-2012). The 1989 moratorium on tree felling to conserve the health of forest is still operative.

4.6 Cross-cutting issues

4.6.1 Irrigation

About 60.3% (777,457 ha) of the total cropped area in the Barind Tract was brought under irrigation by the year 2022 compared with 49.1% of Bangladesh overall (Table 4.12). Over the last 7 years the irrigation area in the Barind Tract increased by 12.1% from 693,575 ha in 2015 to 777,457 ha in 2022. In terms of irrigation coverage, Sirajganj and Gaibandha with 100% topped the list of the 12 Barind districts followed by Bogura (81.7%) and Chapainawabganj (67%)

Table 4.12. Status of irrigation in the Barind Tract

District	Irrigated area (ha) in 2015	Irrigated area (ha) in 2022	% increase
Bogura	105250 (83.4)	108000 (81.7)	2.6
Chapainawabganj	112000 (61.2)	130000 (67.0)	16.1
Joypurhat	79670 (41.2)	80659 (41.9)	1.2
Naogaon	232560 (51.6)	245390 (54.1)	5.5
Rajshahi	55938 (49.5)	62280 (48.5)	11.3
Sirajgonj	35,300 (60.1)	70,800 (100)	101
Dinajpur	26815 (53.0)	28050 (48.7)	4.6
Gaibandha	17492 (93.6)	19233 (100)	10.0
Rangpur	28550 (68.2)	33045 (71.8)	15.7
Total	693575 (56.1)	777457 (60.3)	12.1
Bangladesh	7407000 (48.6)	7879000 (49.1)	6.4

Figures within parentheses indicate % irrigated area
Source: DAE 2022, BBS 2015, 2020

while the lowest was 41.9% in Joypurhat. All the Barind districts experienced an increase in irrigation coverage in 2015 through 2022, the greatest increase (101%) being in Sirajganj followed by Chapainwabganj (16.1%) and Rangpur (15.7%). However, irrigation water is not abundant throughout the year, being restricted in September onwards until the monsoon.

Overexploitation has caused the ground water level to recede to such an extent that full replenishment in the monsoon recharge season would not occur. The groundwater-based irrigation system in the Barind Tract has reached a critical phase as the phreatic water level has dropped below shallow wells in many places. A groundwater zoning map shows that a record high of 60% irrigated croplands in Naogaon and 10% in Rajshahi and Chapainawabganj districts have become critical for shallow tube well operation (BADC 2005). Before the 1980s, the only form of supplementary irrigation available in the Barind Tract was with low lift pumps and manual irrigation from ponds and other water bodies with buckets. A marked change in irrigation came in 1986 with the formation of the 'Barind Integrated Area Development Project" by the Government. It later became an autonomous organization under the Ministry of Agriculture with the new name 'Barind Multipurpose Development Authority' (BMDA). BMDA is fully government funded and has been installing deep tube wells (DTW) in different areas where there is a potential aquifer. However, the command areas of most DTWs are less than originally planned probably due to limited water extraction as a result of receding aquifers in the dry months, undulating topography and farmers' management.

4.6.2 Agricultural marketing

Northwest Bangladesh, and particularly the Barind areas, mostly depend on agriculture as almost no industry is located here. However, initiation of irrigation expansion, road development, electrification, afforestation since 1986 through BMDA has facilitated a large change in agricultural production and economic development across the Barind Tract. The construction of the Jamuna river bridge in 1998 directly linked northwestern Bangladesh with eastern Bangladesh, particularly with Dhaka, thus opening up markets. Due to improvement of road communication and increased production, the marketing sector has considerably developed. High-value crops like early tomato, fruits (mango, jujube, papaya) and vegetables are packaged and directly transported to Dhaka by trucks. Surplus rice is also being transported to Dhaka and other parts of the country mainly by road. Agricultural products from remote villages can now reach large and distant markets, initially via feeder roads. Commercial organizations and businessmen from adjacent areas and cities have come forward to lease comparatively cheap land in the Barind Tract to produce high-value crops like tomato, potato, maize and mung bean, as well as HYV/hybrid boro and T. Aman rice. These business ventures have brought in modern technology along with capital. Some are even sinking DTWs at their own cost to produce different crops around the year, but without much concern about the sustainability of water extraction. Anecdotal information suggests that they are achieving good yields and desirable profits, and the land owners are also satisfied as they are receiving higher income compared with traditional T. Aman farming. This process is transforming subsistence agriculture to commercial agriculture, albeit slowly. It also hastens the dissemination of modern agriculture technology among the local farmers.

4.7 Advances in Barind Agriculture

4.7.1 Crops and cropping patterns

Varietal development

New HYVs of crops and production technologies have been recently developed by agricultural scientists which are resilient to climate change and tolerant of abiotic stress 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 dhan42 and BRRI dhan43 and cold and drought tolerant varieties like BRRI dhan56 and BRRI dhan57. BARI has developed heat tolerant wheat and tomato varieties.

- Drought-tolerant and high-yielding wheat varieties, especially BARI Gom-26, have started gaining popularity among the farmers of the Barind Tract. Many farmers are now becoming interested in wheat farming as they are facing problems in cultivation of Boro rice in the water stress conditions of the Barind Tract. The Bangladesh Wheat and Maize Research Institute (BWMRI) has developed high-yielding varieties like BARI Gom-30, BARI Gom-32 and BARI Gom-33 which gave good yield in the Barind Tract for the last few years. BMDA adopted special measures to promote these varieties among the growers to mitigate water-stress conditions. A new drought tolerant lentil variety with the potential to achieve high yields in difficult drought conditions was released in 2016. Binamasur-10 is also suitable for relay cropping in areas left fallow after rice cultivation because it matures within 110 days, almost a week earlier than existing varieties. Binamasur-10, with its drought tolerant trait, is expected to be quickly adopted throughout the northwestern drought-prone districts of the Barind Tact;
- BRRI dhan48, a drought tolerant Aus rice variety developed by BRRI, has been gaining popularity among farmers in the region. The Barind Station of the On-Farm Research Division (OFRD) of BARI has included this variety in its four crop-based cropping pattern (Aus-T. Aman-lentil-mung-bean) for the Barind Tract;
- BARI released two hybrid maize varieties, BARI Hybrid Bhutta-12 and BARI Hybrid Bhutta-13 which showed good prospects of expanding among 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 only a single irrigation every year.

Soil-water management

- Soil resources of the Barind Tract in particular are under pressure for increased and sustainable food production. Increasing cropping intensity and mineralization of soil organic matter exhaust the capacity of soils to support crops.
- The Soil Resource Development Institution (SRDI) has prepared an Upazila Land and Soil Resources Utilization Guide for 459 upazillas throughout the country including the Barind upazilas that may help, with appropriate soil fertilization and management, increase and sustain increased crop production in the face of climate change and other environmental stresses. The MoA is encouraging farmers to use organic fertilizers like compost, farmyard manure etc. to safeguard soil health as per policies viz. NAP 2018, NAEP 2020 and GAP 2020. The farmers are advised to use green manure and bio-fertilizers in addition to chemical fertilizers to sustain soil health.
- The agricultural scientists of Bangladesh have also modified and adapted the "alternate wetting and drying (AWD)" irrigation technique to save irrigation water. These technologies and innovations have substantially increased crop production in the Barind region.

Cropping patterns

Crop production and livelihoods of farmers in the Barind areas are critically influenced by the incidence and severity of drought spells. This stress is by and large confined to the post-rainy season but, of late, has started occurring in the monsoon period, too, due to erratic and insufficient rainfall induced by climate change. Farmers' coping strategies against such elements of nature should comprise:

i) Use of supplementary irrigation from ponds, kharis and nearby tube wells to cultivate watermelon, khira (*Cucumis anguina*), aroids, sweet gourd, mustard, potato (local), onion, garlic, cabbage, cauliflower, tomato, brinjal etc.;
ii) Cultivation of T. Aman rice in rotation with chickpea, linseed, barley and black gram under rainfed conditions;
iii) Cultivation of drought tolerant crops like man kochu, moulavi kochu (aroids under different *Colocasia spp.*), drumstick and sponge gourd;
iv) Planting of drought tolerant and income generating trees like Palmyra palm, date palm and neem;
v) Mango and ber gardening in homesteads and nearby crop fields which are more drought prone;
vi) Excavation of existing ponds and kharis, and digging of small ponds at

the corner of rice fields for supplementary irrigation, for rain water harvesting, vegetable cultivation and seasonal fish culture;

vii) Cultivation of low water requiring but high-value crops like potato, onion seed, maize, mustard, black gram, mung bean, tomato, and other vegetables, along with mango, litchi and guava gardening.

Boro rice requires at least 25-30 times irrigation with 6-10 cm standing water in the field (depending on growth stages of the crop) whereas upland crops require only 2-8 times irrigation and no standing water is needed. With cropping system diversification including low water requiring crops, farmers can increase the productivity of their lands and improve the profitability of their cropping systems and at the same time minimize depletion of the aquifer so vital for crop agriculture especially in the ecologically challenged Barind Tract.

OFRD, BARI has identified several potential cropping systems for the Barind Tract. For T. Aman-Boro rice cropping they recommend 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.

4.7.2 Livestock and poultry

Information of livestock and poultry improvement is meagre especially for the Barind Tract. There are, however, evidences of very good prospects of sheep rearing, especially garole sheep rearing for meeting the protein demands of rural people in the Barind areas because of their excellent body weight gain and prolific nature. Heat stress and drought are the main factors affecting livestock rearing in the Barind areas. Climate change could present further challenges to cattle and sheep producers in the future, impacting production by hurting fertility or growth. The Bangladesh Agricultural University (BAU), Mymensingh has selected a a new breed of sheep which has gained popularity among farmers. These animals can graze easily in the Barind areas. These animals are drought-tolerant, healthy and large and can be raised with minimal costs. Cattle fattening can be a god income generating endeavor for the local farming community.

Fayoumi chickens perform better in terms of weight gain, egg production and livability than Sonali and local chicken. To some extent, Jinding duck performs better than local and Khaki Campbell in terms of body weight, growth rate, egg quality and livability.

4.7.3 Fisheries

Carp fattening with a species combination of 40% surface feeder, 30% column feeder and 30% bottom feeder was found best in terms of environmental tolerance, growth, production and economic performance in ponds of the Barind areas. Inclusion of an appropriate number of surface feeding carp especially *H. molitrix* favored the growth of column and bottom feeding carps. Use of a higher stocking weight (100 g) can be a suitable option for carp polyculture in ponds in drought-prone Barind areas. Considering the water quality, growth and yield of fish and economic viability of carp polyculture in pond under, stocking of *C. carpio* as bottom dwelling species is recommended as a suitable option for carp polyculture in ponds of the Barind areas.

For better pond management in the Barind region, application of lime and ash was found to be useful. Hardy fish like tilapia performed better than other species under traditional management by poor and extreme poor farmers. Based on the production, economics and pond management, larger size tilapia with lower stocking density was found suitable for fish farming in the drought prone Barind area.

Derelict kharis (canals) are generally re-excavated by BMDA to increase their water conserving capacity. To retain the rain 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 there in the Barind tract (BMDA 2018). About 1248 ponds have been re-excavated, 3098 ponds are there in the whole Barind Tract (BMDA 2018). These ponds are usually re-excavated with the aim of fish culture and supplementary irrigation. The extra water in the re-excavated ponds may be used for groundwater recharge.

4.7.4 Impact of technologies

Agriculture in the Barind Tract has been greatly influenced by technological innovations and market forces. The major public agricultural extension organizations involved in agricultural development in the Barind region are i) Department of Agricultural Extension (DAE), ii) Department of Livestock Services (DLS), iii) Department of Fisheries (DoF) and iv) Forest Department (FD). Apart from the private sector enterprises, the main public organization involved in selling HYV seeds, fertilizers, irrigation inputs etc is BADC. All these organizations are contributing greatly to increasing area/household coverage and production of crops, livestock, fisheries and forestry through technology dissemination and transfer, input distribution, market chain development etc.

Crops

Rice covered 981,788 ha in 2021-22 which was 8.6% of the total rice area in Bangladesh (Fig. 4.22). Next to rice, potato is cultivated in 100,364 ha followed by mustard (73,814 ha) and the lowest area cultivated by lentil (7,680 ha) accounting for 21.7%, 23.9% and 5.4% of the areas in Bangladesh, respectively. The rice area in the Barind Tract, however, has experienced a slight decline (Fig. 4.23) from 1,048,915 ha in 2010 to 981,788 ha in 2022 with a 6% decrease over the last 12 years. However, areas under other crops increased substantially. For example lentil registered an increase 1686% from 430 ha in 2010 to 7,680 ha in 2022, maize by 40% from 16,600 ha in 2010 to 23,213 ha in 2022, mustard by 20% and vegetables by 14%.

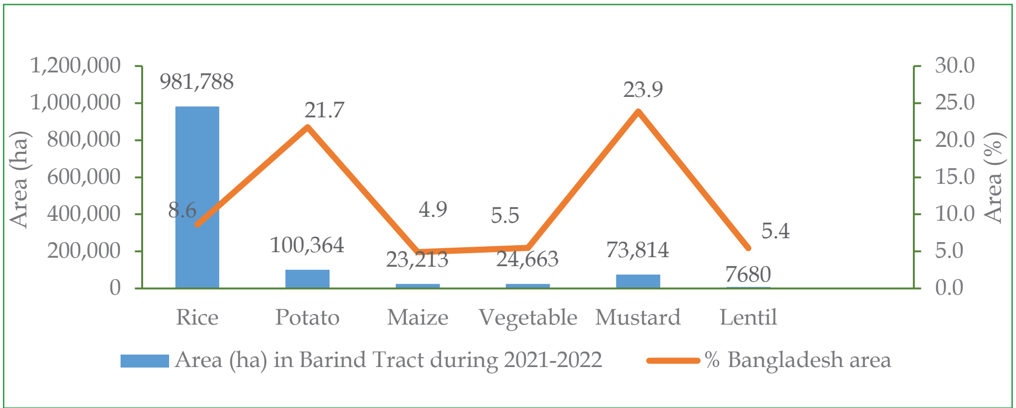


Fig. 4.22. Areas under major crops: Barind Tract and Bangladesh overall during 2021-2022 (Source: DAE 2022)

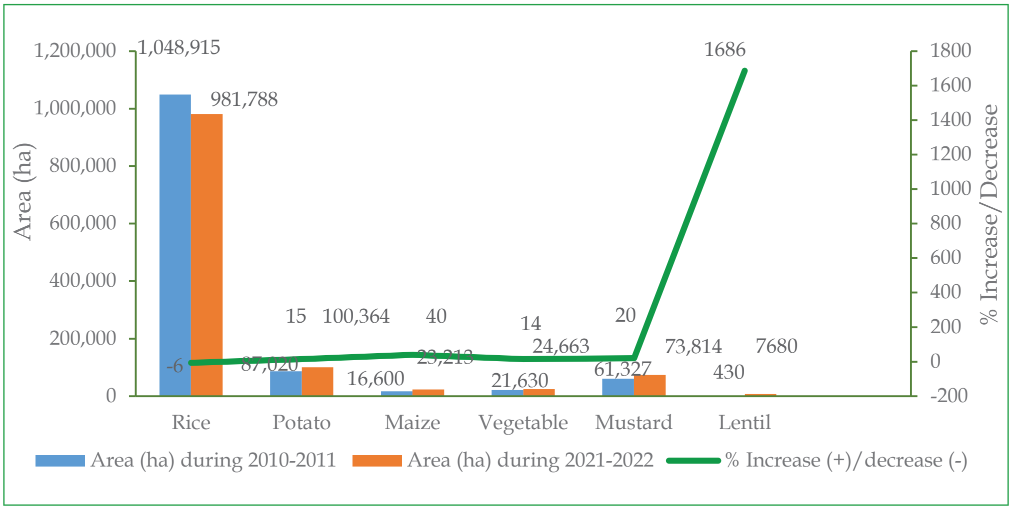


Fig. 4.23. Changes in area of major crops in Barind Tract during 2010-2022 (Source: DAE 2022)

District-wise (Table 4.13), the decline in rice area has been: Sirajganj (7%), Rajshahi (6%) and Joypurhat (3%). Lentil in Rajshahi registered the biggest jump in area coverage by 1686% to 7,680 ha in 2022 from only 430 ha in 2010. The potato acreage has increased by 433% in Sirajganj followed by Rajshahi (114%) and Dinajpur (63%). The highest increase in area of mustard occurred in Dinajpur (879%) followed by Rajshahi (94%), but there was a slight decrease in area, by 7%, in Sirajganj. There was a huge expansion of the maize acreage in Rajshai, by 353% followed by 254% in Dinajpur. The highest increase in vegetable area occurred in Chapainawabganj (21%). The increase in area of non-rice crops in the Barind Tract may be attributed to adoption of improved cropping patterns with diverse crops of low water requirement leading to reduced pressure on underground water.

Rice production in the Barind region has amounted to 4.28 million MT in 2021-2022, which is 11.7% of the total rice production in Bangladesh (Fig. 4.24). Potato produced 2.39 million MT followed by vegetables 0.44 million MT and lentil 11,652 MT covering 24.9%, 9.5% and 6.6% of the total Bangladesh area respectively. It is noteworthy that despite a decrease in area, rice production has increased by 25% from 3.42 million MT in 2010 to 4.28 million MT in 2022 (Fig. 4.25). Lentil registered a production increase by 2019% from 550 MT in 2010 to 11,652 MT in 2022, maize by 65% from 148,652 MT in 2010 to 244,867 MT in 2022, mustard by 38% and potato by 17% from 2.04 million MT in 2010 to 2.39 million MT in 2022. The increase in production of rice and other crops in the Barind region resulted from varietal improvement, increased irrigation coverage and better soil-water-crop management.

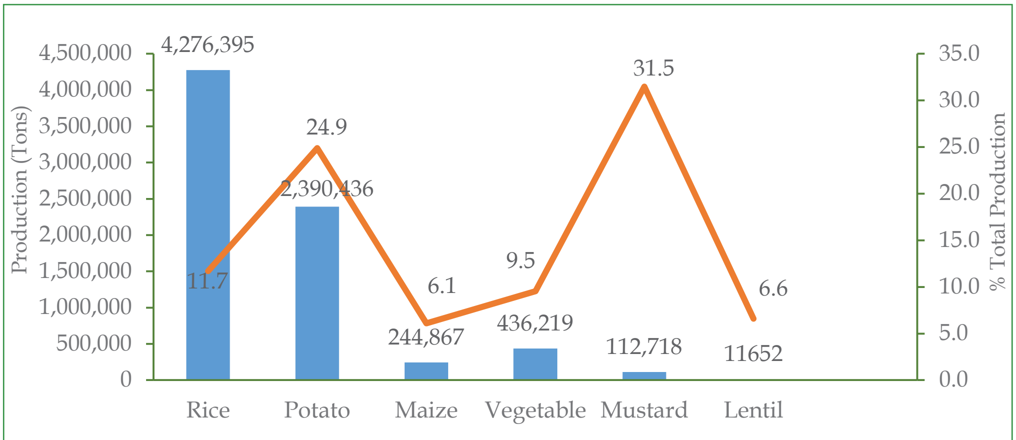


Fig. 4.24. Production of major crops in 2021-22: Bars represent production in tons and line represents % of total production in Bangladesh in 2021-2022 (Source: DAE 2022)

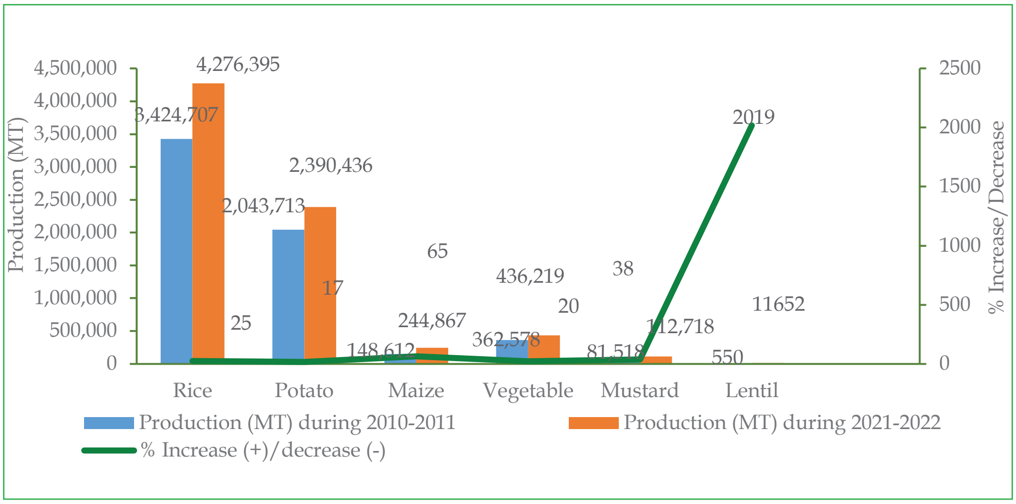


Fig. 4.25. Changes in production of major crops in Barind Tract during 2010-2022 (Source: DAE 2022)

There was an increase in rice production in almost all the Barind districts (Table 4.13) with the largest increase of 49% increase in Sirajganj, from 0.12 million MT in 2010 to 0.18 million MT in 2022 followed by a 35% increase in Rajshahi and 30% in Dinajpur. However, Joypurhat and Naogaon have experienced a decrease in production by 17% and 2%, respectively. Lentil production increased sharply in Rajshahi from only 550 MT in 2010 to 11,652 MT in 2021-22, a phenomenal 2019% increase. Potato had the highest production increase in Sirajganj (525%) followed by Rajshahi (139%) and Dinajpur (135%). The highest increase in production of mustard was recorded in Dinajpur (1034%) followed by Rajshahi (133%) and Chapainawabganj (71%). Maize production increased steeply, by 728%, in Rajshahi followed by 314% Dinajpur. The highest increase in production of vegetables occurred in Chapainawabganj (31%).

An increase in cultivation area and corresponding increase in production of almost all the major crops has been a blessing for the farmers of the Barind districts. This indicates a significant breakthrough in technological advancement positively impacting incomes and livelihood of farmers in the drought hit Barind areas of Bangladesh.

Yields of all the major crops grown in the Barind region increased since 2010 which has eventually contributed to production boosts (Fig. 4.26). Rice registered the highest yield increase (33.4%) from 3.3 MT/ha in 2010 to 4.4 MT/ha in 2022 followed by of lentil (18.6%), maize (17.8%), vegetables (17.7%) and mustard (14.9%). The lowest yield increase was noticed in potato (1.4%).

Table 4.13. Changes in area and production of major crops in Barind Tract by district during 2010-2022

District	Major crops	Area (ha)		% inc/dec (+)/(-)	Production (MT)		% inc/dec (+)/(-)
		2010-2011	2021-2022		2010-2011	2021-2022	
Rajshahi	Rice	99933	93817	-6	315057	423812	35
	Potato	7300	15620	114	182809	437793	139
	Mustard	4830	9374	94	6339	14756	133
	Lentil	430	7680	1686	550	11652	2019
	Maize	400	1810	353	2143	17740	728
Chapai-nawabgonj	Rice	151258	153590	2	473869	527963	11
	Maize	5290	6925	31	37030	72712	96
	Mastard	13180	17610	34	14451	24752	71
	Veg.	13130	15825	21	201078	264320	31
Bogura	Rice	82550	86085	4	734000	765421	4
	Maize	1850	1988	7	15775	16955	7
	Potato	27350	28250	3	611200	621500	2
	Mustard	14450	15800	9	24565	27175	11
Joypurhat	Rice	143120	139152	-3	573266	478271	-17
	Potato	39250	40280	3	952556	928120	-3
	Mustard	11125	12855	16	20424	21210	4
Dinajpur	Rice	48609	51280	5	177781	230700	30
	Potato	750	1224	63	12000	28152	135
	Maize	1120	3970	254	10080	41685	314
	Mustard	120	1175	879	145	1645	1034
Naogaon	Rice	442091	444510	1	1556440	1523039	-2
	Veg.	8500	8838	4	161500	171899	6
Sirajganj	Rice	43024	51161	19	121,105	180,748	49
	Mustard	15,572	14,500	-7	13236	19430	47
	Potato	150	800	433	2250	14064	525
Gaibandha	Rice	11230	11170	-1	44359	46691	5
	Potato	5320	5490	3	113848	122427	8
	Maize	2140	2220	4	22684	25530	13
Rangpur	Rice	27100	28500	5	89430	99750	12
	Potato	6900	8700	26	169050	238380	41
	Maize	5800	6300	9	60900	70245	15
	Mustard	2050	2500	22	2358	3750	59

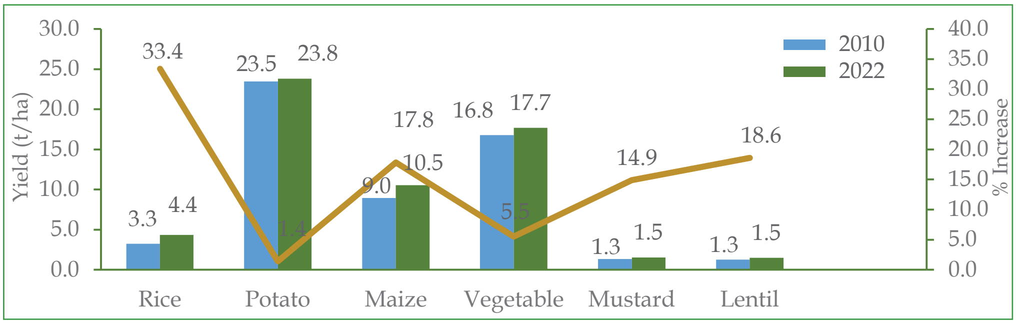


Fig. 4.26. Increase in yield of major crops in the Barind Tract during 2010-2022: the bars represent yield in t/ha and the line represents % increase in yield (Source: DAE 2022)

Considering the increases in cultivation area, yield and production gains, lentil, mustard, maize and vegetables, apart from rice, can be further promoted in the Barind region utilizing fallow areas and introducing these crops in single and double cropped areas where feasible.

4.8 Strategic investment opportunities for Barind Ecosystem

Barind ecosystem is mainly constrained by drought, ground water decline, degradation of forests, low soil fertility, reduction of pasture lands, loss of fish habitats etc, that pose challenges to agricultural production. Many natural and manmade water resources are the potential opportunities in the Barind Tracts. These resources can play an important role to get rid of water stress in these areas through their proper management with application of appropriate technology.

Due to enabling policies of Bangladesh eg. National Agriculture Policy (NAP) 2018, Minor Irrigation Policy 2017, Good Agriculture Practice (GAP) 2020 etc, the Government has re-excavated some derelict Kharies (canals) in Barind areas to increase their water conserving capacity. To retain the storm water, cross dams are constructed in the re-excavated Kharies. The re-excavated Kharies are used to conserve storm water mainly for supplementary irrigation. There are about 2,000 km re-excavated Kharies with 749 cross dams in Barind Tracts (BMDA 2018). A rubber dam has also been constructed at the Barnoi River of Puthia Upazila under Rajshahi district and water at the upstream of the rubber dam is used for the recharge of ground water. There are also about 3,098 re-excavated ponds in the Barind Tracts (BMDA 2018). These ponds are usually re-excavated with the aim of fish culture and supplementary irrigation. There are many Beels (comparatively large water body) in Barind Tracts. Beels are generally located at the lower elevation, where run off water comes from the surroundings catchment area and gets accumulated. The Beels are re-excavated to conserve more water and use for 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 rain water receiving structure during rainfall and stored in the DW. The conserved water is then lifted to the overhead tank by solar energy driven pump and used for irrigation. Thus, further investment opportunity prevails to use the surplus water for minimizing use of groundwater for irrigation in the water stressed Barind Tracts.

Based on the on-going investments to address the multifaceted constraints taking the advantages of enabling policies, the strategies for agricultural development in the Barind areas should focus mainly on the followings:

A) Addressing drought in Joypurhat, Bogura and Dinajpur districts,
B) Minimizing groundwater declines in Rajshahi, Bogura, Chapainawabganj and Naogaon,
C) Balancing conservation of forests with food production;
D) Addressing low soil fertility, organic matter content and acidic soil;
E) Intensification of livestock farming; and
F) Alternative systems of fish production

To enhance on-going development activities in Barind areas, the following strategies should be undertaken in favor of the sustainable agricultural production:

Strategy A: Addressing drought in Joypurhat, Bogura and Dinajpur districts

Erratic rainfall in terms of both volume and spatial and temporal distribution, as a consequence of climate change, is one of the major challenges for agricultural enterprises in the Barind region. Adequate and evenly distributed rainfall is necessary round the cropping practice and at the same time for crucial groundwater recharge. The Barind strategy should aim to balance supply and demand of freshwater, in support of sustainable crop growth.

Sub-strategy A.1 Irrigation expansion

Immediate plans should include deep groundwater development and expansion of irrigation to provide farmers with more water. In the long run, there is a dire need to also increase recycling of wastewater to help meet people's need.

Sub-strategy A.2 Introduction of less water requiring crops

It is important to introduce less water requiring crops and far more efficient irrigation systems, to make freshwater go further. Crops like lentil, mustard and maize have become popular 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 farmers' incomes.

Sub-strategy A.3 Crop improvement and management

To identify the best adapted crop cultivars for the Barind Tract (BT), participatory varietal selection techniques need to be applied. Genetic improvement integrating water use efficiency (WUE) needs to be researched.

Additionally, as climate change progresses, research is needed to identify and develop heat tolerant varieties. Barind eco-friendly crop cultivation techniques should be followed.

Further investment could be done so that the Barind areas can grow crops round the year with profitable technology. For instance, BARI has developed a mango variety (BARI Aam-11) and a vegetable variety (BARI Lau-4), which can be grown round the year. BRRI has developed two drought tolerant rice varities – BRRI dhan56 and 57. Some vegetable and fruit varieties grow more than one season like tomato, brinjal etc. and spread production for more than 6 months through use of early and late varieties of mango, jackfruit, banana etc. Development of short duration, high yielding and heat stress tolerant crop varieties are needed. Early and late maturing fruit varieties should be developed to expand its availability. Important fruit germplasm can be conserved by grafting or top working on existing plant. Much efforts should be paid by the NARS scientists to produce more and more year-round nutrition enriched crop varieties including fruits and vegetable in future. Thus, their production is spread all round the year with escaping from drought.

Sub-strategy A.4 Undertaking preventive measures against pests and diseases

Research should be strengthened for identifying invasive pests and assessing their ecological problems, economic damage and environmental concerns in Barind ecosystem. Research should also be strengthened on the development of genetically modified pest resistant varieties of crops to fit in the existing cropping pattern. Natural control agents should be augmented and conserved by avoiding non-judicious pesticides application.

Sub-strategy A.5 Crop choice and rotation

Due to the water limitation of the Barind Tract areas, it is proposed that Boro rice cultivation be restricted to valley land (locally called *byde*) or plain land at low elevation. Higher terraced land should be reserved for vegetables, pulses, potato, maize, wheat, oilseeds, and other non-rice crops in the Rabi season. However, T. Aman rice could be grown across the land types, as it mainly depends on monsoon rain, but could be provided supplementary irrigation as and when required.

Strategy B: Minimizing use of groundwater for irrigation in Rajshahi, Bogura, Chapainababganj and Naogaon districts

The groundwater level (GWL) is receding continually indicating over-use of groundwater for irrigation on the one hand and inadequate recharge due to low rainfall on the other. Diminishing water flow in the rivers - during dry season, water level in the rivers dips and causes an undesirable movement of groundwater from the aquifer to the river further deteriorating the GWL situation. 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 groundwater recharge. More than 15 m thick top clay prevails in almost all Barind land. The bore log lithology shows that 19.81–30.48 m thick clay layer exists from the ground surface to the aquifer which resists the percolation of water as well as natural recharge of groundwater. 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, the mainstay of the cropping system, is delayed and hampered resulting in reduced yield.

Barind strategy should, therefore, be emphasized on the increasing water capture and use through surface water irrigation, watershed management and rain water harvest, construction of water reservoirs, increasing infiltration and minimizing evaporative loss.

Sub-strategy B.1 Enhancement of surface water irrigation

To reduce pressure on groundwater, the Government of Bangladesh took initiative for implementing one of the biggest projects 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 Japan International Cooperation Agency (JICA). Based on this feasibility study, this project worth about BDT 4,490 million was proposed in1994 and later the project was transformed in to a mega project with a cost BDT 16,250 million in 2013 (Prothom Alo 2022). In September 2022, this mega project has been considered by the Government as a priority project to augment surface water irrigation in Barind areas. The proposed project will provide irrigation facilities to 74,800 ha lands. Within this facility, the fallow land (57,731 ha) identified in the barind areas can be brought under cultivation of at least 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 Mohananda and Padma rivers for irrigation through canals/khals. This project has also included 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, the farmers will receive irrigation water at a very low-cost BDT 100-600 per 100 decimal lands instead of BDT 3,300-6,000 using groundwater. This project should be implemented immediately in the Barind areas integrating with buried pipe line irrigation systems, so that ground water loss is minimized and surface water is judiciously used for irrigation with minimal conveyance loss. Therefore, there is a great investment opportunity for enhancing surface water irrigation in Barind areas through this mega project for sustainable and profitable agricultural production without undermining the level of groundwater.

Sub-strategy B.2 Watershed management and rainwater harvesting

A prime requirement for improving agricultural productivity in a sustainable manner in the 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. The south-western part of the BT is particularly suited to watershed development. Such surveys would allow optimum excavation and re-excavation of ponds, kharis/canals, etc. This would require active participation of local farmers, government agencies, research organizations, development partners and NGOs. Research and demonstration by OFRD, BARI has shown that digging of mini-ponds alongside rice fields is useful in alleviating drought stress during flowering stage of T. Aman rice. Not only can the yield of T. Aman rice be protected from drought, vegetables also can be cultivated on the pond banks and seasonal, fast-growing fish (e.g. rajputi, tilapia) can be cultured. Further, water remaining at the end of the T. Aman season can be used for Rabi cropping, such as fast growing, short-duration vegetables.

Sub-strategy B.3 Construction of water reservoirs

Water reservoirs could be constructed for harvesting and capturing monsoon precipitation. These could be supplemented by pumping of water from nearby Padma and Punorvaba rivers to fill out those reservoirs during monsoon season. Similarly, weirs could be strategically placed on natural seasonal waterways to capture rainfall so that it does not drain out to the floodplain area, as it currently does. The water thus stored could be leased out annually to local farmer groups for fish cultivation and for irrigation. Such an approach would minimize the pressure on ground water, increase the scope and lower the risk of Rabi cropping.

Sub-strategy B.4 Increasing infiltration and minimizing evaporative loss

A particular problem of Barind Tract soils is its high bulk density, which mitigates against infiltration of rainwater into the soil and thus depresses potential water holding capacity. In adequately bunded fields this assists retaining standing water in rice fields, but if water is allowed to flow off the field, this reduces potential for stored soil water.

Due to high clay content and high bulk density, the Barind soils have tendency to crack on drying. This greatly increases the surface area from which evaporation may occur, thus accelerating soil drying. This may be an advantage in allowing deeper percolation of subsequent rainfall but would be detrimental to seedlings reliant on moisture near the soil surface, such as T. Aman seedlings. Once cracks are formed, twice the amount of water is required to close the cracks. Traditionally, advanced farmers manually disturb the surface soil at early stages of T. Aman crops to avoid development of cracks. However, it works well to minimize the effect of drought on T. Aman rice at early stages to increase the efficiency of rain water use.

Sub-strategy B.5 Strengthening irrigation management through buried pipeline

Traditional methods of flood irrigation from a channel allow less flexibility in timing and amount of irrigation application and result in considerable water loss. Boro rice is by far the biggest user of irrigation water as farmers try to maintain 4-10 cm of water in the field, during the hottest period of the year. This not only wastes water but also hampers tillering. Use of PVC and plastic pipes permits implementation of the alternative wetting and drying (AWD) method for increasing WUE in Boro rice. Use of AWD can reduce boro rice irrigation water requirement by as much as 27 % but it needs social motivation and training, as well as the arrangement of necessary pipes and pump. Earlier in Barind areas, earthen (kancha nala) channel was used to carry the irrigation water from the irrigation pump to the crop field. Due to the open surface channel, huge amount of irrigation water is lost which leads to over lift groundwater posing bad impact on the environment. More than 40% of water is lost due to conveyance. To minimize this loss, BMDA has introduced Buried pipe line irrigation distribution system. This buried pipeline irrigation could be promoted widely. This system allows movement of irrigation water from the lower land to the higher land in the undulated terrace topography of barind areas. There is no loss of valuable agricultural land in the pipe lined area as the pipe line is constructed beneath the ground surface. So, the water loss, irrigation cost and land loss have been reduced. Buried pipe line is used for both groundwater and surface water irrigation schemes. Thus, much more investments are necessary for expediting buried pipeline irrigation systems in the Barind Tracts developed by BMDA so that the sustained agricultural production is ensured by minimizing ground water decline.

Strategy C: Balancing conservation of forests with food production

Particularly as the HBT has been denuded of trees over time, it is important to return them to the extent possible in order to improve the ecosystem in various ways. This involves all manner of trees, from orchards to trees providing food, building materials, fuel and fodder. This includes bamboo clumps, which should get preference due to their drought tolerance, low management requirement and multiple uses as construction material, fuel, trellises and cash value. The land which not allocated for cropping or infrastructure should be considered in a multi-strata homestead agroforestry farming approach. A greater tree population will also moderate ground temperature, likely to rise with climate change, and attract precipitation. Farmers need to be trained in establishing and managing tree nurseries to provide saplings of good quality. A tree particularly suited to BT homesteads and marginal land is the highly drought and heat tolerant drumstick (*Moringa* spp.). It is a tree full of nutrition as green leaves can be consumed as vegetables, or leaves may be dried, processed and consumed, to alleviate malnutrition among children and women. The medicinal value (root, bark, leaf, flower and pod) of drumstick should be exploited.

Strategy D: Addressing low soil fertility, organic matter content and acidic soil

Soil degradation is undermining the long-term capacity of the Barind agro-ecosystem to deliver in terms of agricultural production. Although nutrient inputs and new crop technologies may offset declining soil health, the long-term implications need to be addressed especially in the face of increasing peoples' demands for food and other necessities.

Sub-strategy D.1 Conservation agriculture

To improve BT soils, and reduce labor requirement and overall cost of crop cultivation, conservation agriculture (CA) technique need to be promoted. This involves development and dissemination of the relevant seeding machineries, able to cope with the compact soil of the BT. Also particularly important for the BT is to encourage return of crop residues to build up soil organic matter and minimize erosion of topsoil.

Sub-strategy D.2 Crop rotation with soil resovalent crops

Greater emphasis should be given to include pulses in the crop rotation, to enhance both soil organic matter and soil N contents. Chickpea is well adapted to the region, mainly due to its deep rooting capability and the lesser incidence of lodging. There should be greater reliance on legume cultivation to build up soil N reserves, and thus reduce the requirement for chemical N fertilizer, which is currently often over-supplied in relation to other major nutrients (P, K, S). However, successful legume cultivation relies on meeting their particular nutrient requirements, primarily ensuring that they are effectively nodulated, enabled by *Rhizobium* inoculation if required.

Strategy E: Intensification of livestock farming

The Barind households encounter problems with livestock feed shortages both in the dry and wet seasons. Gradual transformation of fallow land to cultivable land, over-grazing, inaccessibility to pasture and the annual deluge are the constraints limiting livestock rearing in the Barind villages. So, suitable strategic directions could be followed for intensification of livestock farming:

Sub-strategy E.1 Enhancing veterinary services and forage production

Farmers' livelihoods could be diversified with intensive livestock farming including beef/cattle fattening, sheep and goat raising, poultry farming and dairying. Ability to sell livestock provides insurance against crop failure, or other crisis. However, 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 road sides, pond banks and marginal land. Increasing incomes through livestock rearing is a promising strategy for livelihood improvement and poverty alleviation. Huge fallow lands provide the natural resources base for livestock intensification. Lands otherwise unsuitable for field crops can be used for forage production.

With increased livestock farming it would become feasible to consider community-based bio-gas installation to address the endemic fuel shortage. The resultant bio-slurry/compost could be applied to homestead gardens or crop fields.

Sub-strategy E.2 Advancement of breeding for year-round livestock production

Scientists should emphasize the development of high yielding breeds of livestock and poultry to grow all-round the year reducing lean season of availability. For instance, current production of egg, milk and meat are not equally available round the year due to lack of adequate breeds that are resistant to the impact of drought, heat, cold and diseases. Drought-tolerant fodder varieties and modern feeding management practices should be developed. Appropriate breeding animals or semen should be used to improve indigenous animals, and bucks and rams should be selected for efficient local goat and sheep breeding. Artificial Insemination (AI) facilities should be increased for buffalo, sheep and goat. Initiative should be taken for selection, conservation and development of local Animal Genetic Resources (AnGRs). A dedicated wing in Bangladesh Livestock Research Institute (BLRI) should be developed to oversee the phenotypic features and measures on morphometric structures for selecting and conserving existing indigenous AnGRs through establishing the national data base for genomic research.

Strategy F: Alternative systems of fish production

The majority ponds are seasonal due to drought that limits fish production throughout the year. Changing climatic conditions, human encroachments, urbanization and modernization have resulted in loss of fish habitats. Use of chemical pesticides destroys aquatic biodiversity and leads to aquatic pollution. Introduction of invasive species like Sucker fish, Red Piranha, Mosquito etc. are destroying the natural habitat for indigenous fish species. So, 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.

Sub-strategy F.1 Conservation of endangered fish species

The Bangladesh Fisheries Research Institute (BFRI) has already advanced in conservation of locally endangered fish species and therefore, priority should be given to domesticate these fish species through research. Conservation of endangered fish species in aquatic ecosystem should be ensured through regeneration and restoration considering the climate change. There should be sustainable conservation and scaling up of small indigenous fish species (SIS) in wild aquatic ecosystems (beels, lakes, rivers and reservoirs) through multiple functions.

Sub-strategy F.2 Enhancing natural fish breeding

Natural brood fish and spawn in the Padma River (Teroduna Channel) should be protected sustainably through implementation of fishing limitations/bans, fish sanctuary establishment and mass awareness. Interconnection between rivers, beels and other inland water sources should be established to increase natural breeding.

References

Ali MY (2000) Influence of phosphorus fertilizer and soil moisture regimes on root system development, growth dynamics and yield of chickpea. PhD thesis, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur, Bangladesh.

Ali MY, Johansen C, Musa AM (2018) Evolution of agriculture in the high Barind Tract of Bangladesh, Arik Prokashona, Dhaka.

BADC (Bangladesh Agricultural Development Corporation) (2005) The Minor Irrigation Survey Report of 2005, Dhaka, Bangladesh.

Banglapedia (2021) 'Barind Tract' Retrieved from https://en.banglapedia.org › index.php › Barind_Tract, accessed on 20/02/2021.

BARC (Bangladesh Agricultural Research Council) (2005) Fertilizer Recommendation Guide - 2005, Bangladesh Agricultural Research Council, Farmgate, New Airport Road, Dhaka, Bangladesh.

BARC (Bangladesh Agricultural Research Council) (2022) Computer and GIS Unit, BARC, Farmgate, Dhaka.

BBS (Bangladesh Bureau of Statistics) (2020) Year Book of Agricultural Statistics 2020. Ministry of Planning, Government of the People's Republic of Bangladesh.

Brammer H (1996) The Geography of the Soils of Bangladesh, University Press Limited, Dhaka, Bangladesh.

BRRI (Bangladesh Rice Research Institute) (2016) Modern Rice Cultivation, 19th edition, BRRI, Gazipur, Bangladesh.

BMDA (Barind Multipurpose Development Authority) (2018) Development Activities, Monthly Report FY 2017- 2018, BMDA, Rajshahi, Bangladesh

Datta D, Chowdhury S, Saha AK, Islam MM and Rahman MM (2014) Tilted and horizontal solar radiation for six zones in Bangladesh, International Journal of Scientific and Technology Research, 3(2): 98-102.

DAE (Department of Agricultural Extension) (2022) Unpublished data, Field Services Wing, Khamarbari, Farmgate, Dhaka-1215.

DLS (Department of Livestock Services) (2019) Unpublished data regarding union-wise statistics on livestock and poultry in Bangladesh, Ministry of Fisheries and Livestock, Government of the People's Republic of Bangladesh

Faisal IM, Parveen S and Kabir MR (2005) Sustainable Development through groundwater management: A case study on the Barind Tract, Water Resources Development, 21: 425-435

Hamid A and Hunt JM (1987) Poverty and Nature: A socio-ecological analysis of the Barind Tract, A report prepared for the Agriculture Sector Team, Ministry of Agriculture and Forestry, Government of the People's Republic of Bangladesh, CIDA (Canadian International Development Agency), Dhaka, Bangladesh.

Hussain MS, Rahman MZ, Ahmed FU, Haque F, Quddus MA, Musa AM, Islam S, Dey MM, Momin MA, Alam MK, Siddique AB, Kar NK, Abedin MZ and Torquebiau E (1991) Agroforestry research planning for the High Barind Tract, Rajshahi, Bangladesh. Report of diagnostic and design survey (edited by E Torquebiau), pp. 18-21, BARI, BARC and ICRAF, Dhaka.

Islam MB, Ali MY, Amin M and Zaman SM (2011) Climatic variations: farming systems and livelihoods in the High Barind Tract and coastal areas of Bangladesh, In: R Lal, Sivakumar MV, Faiz SMA, Rahman AHMM and KRR Islam (eds.), Climate Change and Food Security in South Asia, Part 7, Springer, Dordrecht, The Netherlands, pp. 477-497.

Islam MS (1990) Soil characteristics and their effects on sulfur and zinc deficiency problems in Bangladesh. Paper presented at a workshop on Sulfur and Zinc Management of Soils and Crops and Balanced Fertilization in Bangladesh, on lo-11 April, 1990 at Dhaka, Bangladesh.

Khalequzzaman M (2009) Animal and plant of Barind area. In C Saifuddin, T Islam, A Fazal and S Rahman (eds) *Varendra Anchaler Itihas* (in Bengali - A history of the Barind region), Gatidhara, Banglabazar, Dhaka, Bangladesh, pp. 77-89.

Los SO, Weedon GP, North PRJ, Kaduk J, Taylor CM and Cox PM (2006) An observation-based estimate of the strength of rainfall-vegetation interactions in the Sahel, Geophysical Research Letters, 33(16): L16402.

Misra C (2009) Some economic aspects of ancient Bengal: Epigraphic evidence, Journal of Varendra Research Museum, 9: 17-21.

Nelson WH (1923) Final report on the survey and settlement operations in the district of Rajshahi, The Bengal Secretariat Modern Depot, Calcutta, India.

Prothom Alo (2022) Editorial news. The Daily Prothom Alo. 28 September 2022.

Rashid B, Islam SU and Islam B (2018) Physiography of the Barind Tract and its surrounding areas of Bengal Basin, Bangladesh. American J ournal Earth Science 5(1): 1-9.

Riches CR (2008) The High Barind Tract: a challenging drought-prone agricultural environment, In: Riches CR, Harris D, Johnson DE and Hardy B (eds.) Improving Agricultural Productivity in Rice-Based Systems of the High Barind Tract of Bangladesh.

Selvaraju R, Subbiah AR, Baas S and Juergens I (2006) Livelihood adaptation to climate variability and change in drought-prone areas in Bangladesh: Developing institutions and options, implemented under the project "Improved adaptive capacity to climate change for sustainable livelihoods in the agriculture sector-DP9/1-BGD/01/004/01/99", Asian Disaster Preparedness Centre and Food and Agriculture Organization of the United Nations, Rome, ISBN978-92-5-105602-8.

Shahid S and Behrawan H (2008) Drought risk assessment in the western part of Bangladesh, Natural Hazards 46(3): 391-413.

TANGO (Technical Assistance to NGOs International) (2002) Household Livelihood Security Assessment. A Toolkit for Practitioners, prepared for CARE USA, PLHS Unit, CARE, PLHS Unit, Atlanta, Georgia, USA

TANGO (Technical Assistance to NGOs International) (2004) Northwest Bangladesh Livelihoods Survey Panel Data Analysis -Livelihood Change in Northwest Bangladesh: Pattern and Processes, prepared for the Livelihoods Monitoring Program, CARE Bangladesh.

Ullah MS, Ara M and Khan AA (2014) Change detection of vegetation coverage in Barind Tract, Rajshahi: using Normarized Difference Vegetation Index (NDVI) and Erdas Imagine's DeltaCue, Bangladesh, Journal of Geoinformatics, 1(2014): 1-10

Zakaria AKM (2009) Geographical and geological introduction of Barind area, In: Saifuddin C, Islam T, Fazal A and Rahman SA (eds.), Varenra Anchaler Itihas (in Bengali: A history of Barind region), Gatidhara, Banglabazar, Dhaka, Bangladesh, pp. 33-46.

Zuberi MI (2009) Environment of Barind: past and present. In Saifuddin C, Islam T, Fazal A and Rahman SA (eds) *Varendra Anchaler Itihas* (in Bengali - A history of the Barind Region), Gatidhara, Banglabazar, Dhaka, Bangladesh, pp. 59-76.

Chapter 5 Coastal Ecosystem

5.1 Extent and distribution

The coast, where the land, the atmosphere and the sea meet represents one of the most fragile ecosystems on earth (Fig. 5.1). In the coastal zone, farmers and other agricultural entrepreneurs, to produce and prosper, keep struggling against such natural forces as the waves, currents, tides, winds and water and soil salinity. The coastal zone of Bangladesh is geo-morphologically and hydrologically dominated by the Ganges- Brahmaputra-Meghna (GBM) river system and the Bay of Bengal.

Fig. 5.1. Photo of a coastal area in Patuakhali

The daily water level fluctuations and the corresponding incoming and outgoing water flows are dominating characteristics of the coastal areas. These are the driving forces behind several physical processes, such as, salinity intrusion, drainage congestion/inundation, and land erosion and accretion, which dominate the coastal ecosystem and affect agriculture and human activities in the coastal zone. Tidal fluctuations determine agricultural practices and set the timing of river transportation and riverine commercial activities. Filling and emptying of land areas during each tidal cycle result in tidal flows that bring new influxes of water and nutrients and maintain a variety of special ecosystems, such as mangrove forests. This tidal cycle keeps rivers and channels open for navigation and draining of adjacent land areas and sometimes are used to generate energy.

Out of the 30 agro-ecological zones (AEZ) of Bangladesh, 11 exist in the coastal zone (Fig. 5.2). These 11 AEZs are: Active Ganges Floodplain (AEZ 10), High Ganges River Floodplain (AEZ 11), Low Ganges River Floodplain (AEZ 12), Ganges Tidal Floodplain (AEZ 13), Gopalganj-Khulna Bils (AEZ 14), Lower Meghna River Floodplain (AEZ 17), Young Meghna Estuarine Floodplain (AEZ 18), Old Meghna Estuarine Floodplain (AEZ 19), Chattogram Coastal Plain (AEZ 23), St. Martin's Coastal Island (AEZ 24) and Northern and Eastern Hills (AEZ 29).

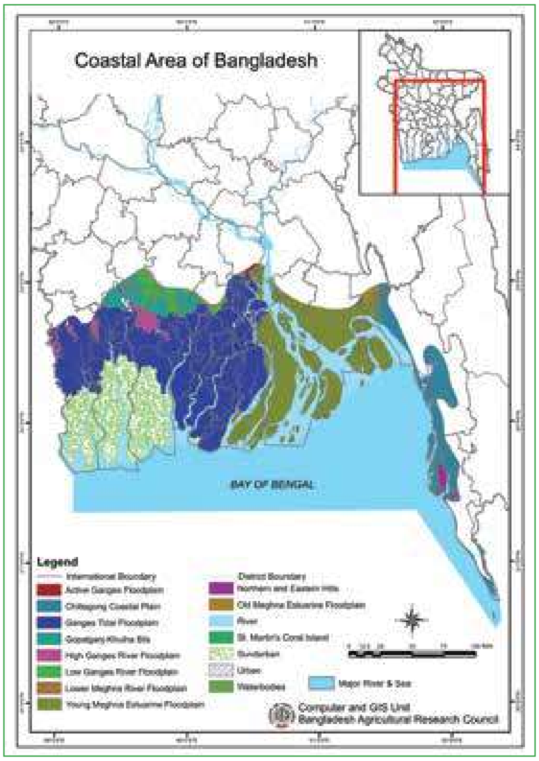


Fig. 5.2. Map of southern Bangladesh showing the coastal areas
(Source: BARC 2022)

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. Out of the 142 upazilas of these 19 districts, 111 fall within the coastal zone. All upazilas of Barishal division (6 districts), Khulna and Bagerhat districts of Khulna division, and Cox's Bazar district of Chattogram division have coastal areas. In total, 78% upazilas of the 19 coastal districts and 22.2% upazilas of Bangladesh overall have the coastal ecosystem (Table 5.1). The names of upazilas containing coastal areas are given in Table 5.2.

Table 5.1. The coastal zone of Bangladesh: divisions, districts and upazilas

Division	District with coastal area	Total upazila (no.)	Upazila with coastal area (no.)	% of upazilas with coastal area	% of upazilas (all Bangladesh) with coastal area
Khulna	Khulna	9	9	100	1.8
	Bagerhat	9	9	100	1.8
	Satkhira	7	6	86	1.2
	Jashore	8	2	25	0.4
	Narail	3	1	33	0.2
Barishal	Barishal	10	10	100	2.0
	Bhola	7	7	100	1.4
	Barguna	6	6	100	1.2
	Jhalakati	4	4	100	0.8
	Patuakhali	8	8	100	1.6
	Pirojpur	7	7	100	1.4
Chattogram	Chattogram	15	14	93	2.8
	Cox's Bazar	9	9	100	1.8
	Feni	6	3	50	0.6
	Lakshmipur	5	4	80	0.8
	Noakhali	9	5	56	1.0
	Chandpur	8	3	38	0.6
Dhaka	Gopalganj	5	3	60	0.6
	Shariatpur	7	1	14	0.2
Total	19	142	111	78	-
Bangladesh	64	495	111	-	22.2

Source: BBS 2020, BARC 2022

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 22.8% of the total area of Bangladesh, i.e., 14,486,269 ha (Fig. 5.3).

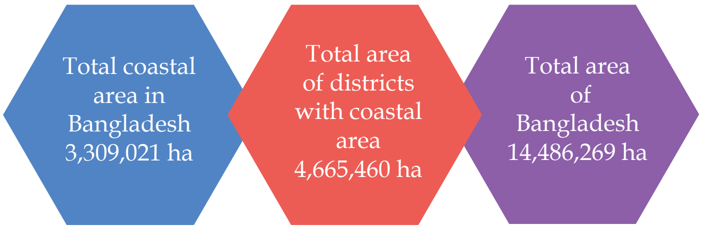


Fig. 5.3. Coastal areas in 19 districts and relative to the total Bangladesh area (Source: BBS 2020, BARC 2022)

Among the 19 coastal districts of Bangladesh, coastal areas are most prevalent in Khulna which has the largest coastal area, 426,609 ha out of the total area of 446,374 ha of the district (Fig. 5.4) followed by Bagerhat, Bhola and Satkhira

Table 5.2. Upazilas having coastal areas in different districts and divisions of Bangladesh

Division	District	Upazila with coastal area
Khulna	Khulna	Dumuria, Koyra, Paikgachha, Phultala, Terokhada, Dacope, Dighalia, Batiaghata and Rupsa
	Bagerhat	Bagerhat Sadar, Chitalmari, Fakirhat, Kachua, Mollahat, Mongla, Morrelganj, Rampal and Sharankhola
	Satkhira	Satkhira Sadar, Debhata, Assasuni, Kaliganj, Shyamnagar and Tala
	Jashore	Abhaynagar and Keshabpur
	Narail	Kalia and Lohagara
Barishal	Barishal	Agailjhara, Bakerganj, Banari Para, Barisha Sadar, Gaurnadi, Wazirpur, Muladi, Babuganj, Mehendiganj and Hizla
	Bhola	Bhola Sadar, Burhanuddin, Char Fasson, Daulatkhan, Lalmohan, Manpura and Tazumuddin
	Barguna	Amtali, Bamna, Barguna Sadar, Betagi, Patharghata and Taltali
	Jhalakati	Jhalakati Sadar, Kanthalia, Nalchity and Rajapur
	Patuakhali	Patuakhali Sadar, Bauphal, Kala Para, Rangabali, Dumki, Dashmina, Galachipa and Mirzaganj
	Pirojpur	Pirojpur Sadar, Kawkhali, Mathbaria, Nesarabad (Swarupkati), Zianagar, Nazirpur and Bhandaria
Chattogram	Chattogram	Anowara, Banshkhali, Boalkhali, Chandanaish, Hathazari, Mirsharai, Patiya, Rangunia, Raozan, Sandwip, Satkania, Sitakunda and Karnaphuli
	Cox's Bazar	Chakaria, Cox's Bazar Sadar, Kutubdia, Maheshkhali, Pekua, Ramu, Teknaf, Ukhia and Idgaon
	Feni	Feni Sadar, Sonagazi and Chhagalnaiya
	Lakshmipur	Lakshmipur Sadar, Kamalnagar, Ramgati and Roypur
	Noakhali	Noakhali Sadar (Sudharam), Companiganj, Kabirhat, Hatiya and Subarnachar
	Chandpur	Chandpur Sadar, Haim char and Kachua
Dhaka	Gopalganj	Gopalganj Sadar, Kotali Para and Tungi Para
	Shariatpur	Gosairhat

Source: BARC 2022

with 394,955, 355,871 and 333,579 ha of coastal land, respectively. Coastal lands in the districts of Jashore, Narail, Feni, Lakshmipur, Chandpur, Gopalganj and Shariatpur are less extensive. However, 100% lands in Barguna, Jhalakathi, Patuakhali and Pirojpur districts are coastal lands. More than 80% lands in Bagerhat, Barishal, Bhola, Khulna, Satkhira and Noakhali are coastal lands. Jashore with 2.26% of its area under the coastal situation is the least affected among the 19 districts (estimated from data presented in Fig. 5.4).

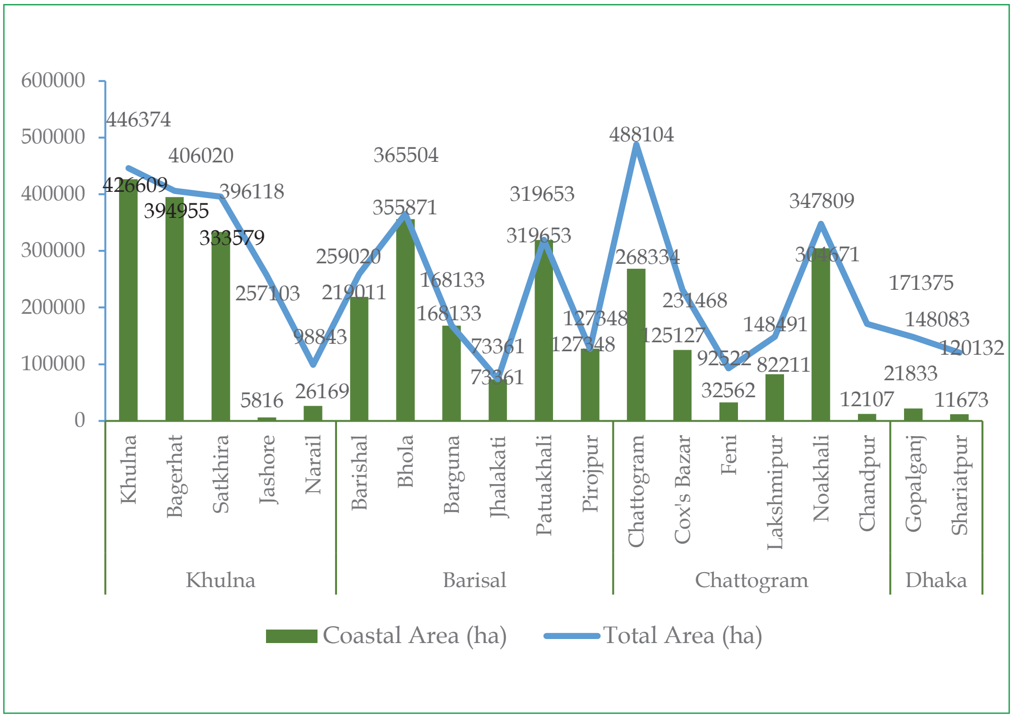


Fig. 5.4. Coastal land areas in different costal districts and divisions of Bangladesh in 2022 (Source: BARC 2022)

Available sources (FD 2015, BARC 2022) indicate that there was no change in the coastal land areas in the 19 districts (as shown in Fig. 5.4) during 2015 through 2022 in Bangladesh. Earlier, Allison (1998) had calculated an annual net increase of 14.8 km^2 between 1792 and 1840 and of 4.4 km^2 between 1840 and 1984 in the Meghna estuary. Although there was a net gain of land, there were also considerable land losses in the Meghna estuary. For instance, about 40% of the Sandwip island in the east was eroded, there were considerable losses in the north of Hatia, north-east of Bhola and the southwest of the former Ramgati island. Beyond the estuary, rates of change were small or undetectable. On the south-western coast, there have been small amounts of erosion locally; Allison (1998) made similar observations. In the south-east, changes are generally small or undetectable on the coast of the Chattogram Coastal Plains, except in the south of Kutubdia island which has lost approximately 10% of its previous area.

The constraints, challenges and opportunities related to agricultural production in the coastal areas arise from the bio-physical properties of the ecosystem irrespective of their spatial dimensions.

5.2 Biophysical characteristics

5.2.1 Land and soil

The coastal and off-shore area of Bangladesh include tidal, estuarine and meander floodplains. The tidal floodplain land occurs mainly in the south of the Ganges floodplain and also on large parts of the Chattogram coastal plains. The Ganges tidal floodplains constitute about 49% of the coastal zone. The tidal lands on the coastal plain including the Chattogram coastal floodplain and the Matamuhuri tidal floodplain occupy less than 6%. Estuarine floodplains occupy about 18% of the total coastal zone located in greater Noakhali, Barishal, Patuakhali and a smaller area of Chattogram (Karim et al. 1982).

Depending on geographic features, the coastal zone of Bangladesh consists of three parts: (a) Eastern zone, (b) Central zone, (c) Western zone (Ahmad 2019). 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 in this zone. The eastern region is covered by hilly area that is more stable. The coastline of Bangladesh is 710 km long comprising interfaces of various ecological and economic systems. This includes mangroves (the greater part, 6,017 km^2, of the Sundarbans, the world's largest mangrove forest), tidal flats, estuaries, sea grass, about 70 islands, accreted land, beaches, a peninsula, rural settlements, urban and industrial areas and ports (Hossain 2001, Iftekhar 2006).

The coastal zone of Bangladesh has a low relief, 1.2-4.5 m above the mean sea level (MSL) (Banglapedia 2021). The entire western coastal zone is a part of the floodplain of the river Ganges (Ganges Tidal Floodplain) containing the Sundarbans. The average land elevation of this zone 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 central coastal zone is a part of the floodplains of the Ganges and Meghna rivers; the most dynamic Meghna estuary is located in this region and it suffers from continuous erosion and accretion. The eastern zone is the most stable part of the coastal zone of Bangladesh; it is covered by hilly region and it contains the world's longest sea beach, the 120 km long Cox's Bazar sea beach.

The Bangladesh coastal zone is characterized by a vast network of rivers (24,000 km in length) covering an area of 9380 km^2, a large number of islands between channels, a submarine canyon (Swatch of no Ground), the funnel shaped part of the northern Bay of Bengal, a huge amount of sediment transportation (annually about 2.4 billion tons) and devastating tropical cyclones (Banglapedia 2021).

The coastal areas are subjected to flooding in the monsoon season and water logging in parts of basin areas in most parts of the dry season (Karim et al. 1982). Tidal flooding through a network of tidal creeks and drainage channels connected to the main river system inundates the soil loading it with soluble salts that make the topsoil and subsoil saline. Following the construction of coastal polders, the daily inflow of tidal water is reduced and consequently the active sedimentation and erosion process almost ceased except in brackish water shrimp cultivation areas. Outside the polders, the sedimentation and inundation process are still active with saline water in brackish water shrimp cultivation area. The northern part of the coastal zone within the polder is flooded mainly with rain water.

Soil type in the coastal zone depends mainly on the characteristics of the geological deposits (deltaic deposits, paludal deposits, coastal deposits) and the geomorphological setting where the soil occurs (Alam et al. 1990). For example, in the deltaic and tidal deltaic environments, the soils are light grey to grey fine sandy silt to clayey silt, light grey to brownish and yellowish grey silt to clayey silt, light to greenish grey silt to clayey silt. In the paludal deposit environment, the soils are usually grey to bluish grey clay, black herbaceous peat and yellowish grey silt, while in the coastal deposit areas the soils are relatively coarse textured, light to whitish grey sand (Alam et al. 1990).

Soil fertility

Soil salinity

Soil and water salinity is the most serious and common problem for agriculture, especially crop agriculture, in the coastal zone. Seawater, with a high concentration of soluble salts, is the source of salinity in soils of the coastal zone. Seawater intrusion through tidal inundation or infiltration renders the soils salinity to various extents. However, unlike in the arid regions of the world, soil and water salinity in the coastal zone of Bangladesh fluctuates with substantial quantitative variation with the seasons of the year. The salinity peak coincides with the peak dry season (March-May) of the year and is the lowest during the wettest monsoon months of the year (July-August). Soluble salts are leached out from the topsoil root zone due to the monsoon rains and returns through capillary rise as the dry season progresses following the cessation of the monsoon rains. The general trend is a gradual increase in salinity starting in October-November of the year reaching a peak in March-May and then a gradual decrease with the start of the per-monsoon rains in Kharif-I reaching the lowest level in July-August after the start of the heavy monsoon rains (Fig. 5.5). Poor drainage and/or poor irrigation water quality (high EC) also contribute to a build-up of salinity in soil. As evapotranspiration progresses soluble salts from soil water are left behind increasing soil salinity. To prevent a salt build-up, the soil needs to be leached with sufficient fresh water (e.g., rainwater).

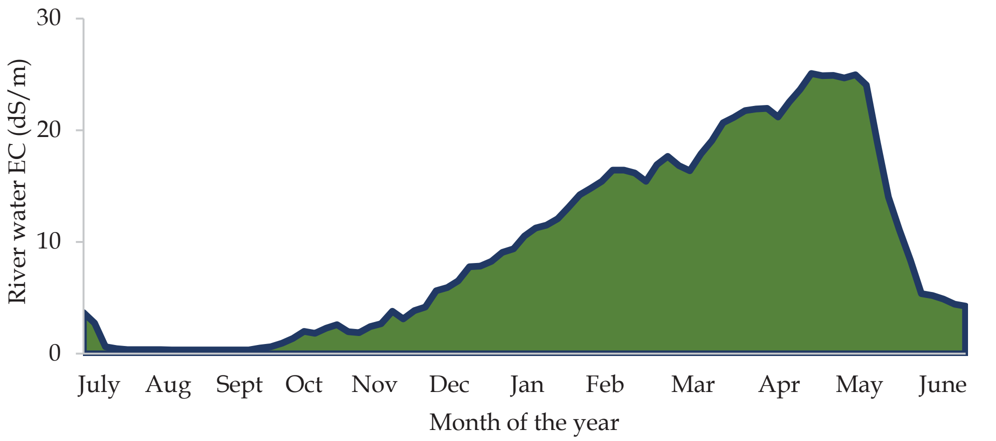


Fig. 5.5. A typical surface water salinity profile in the coastal zone of Bangladesh: Seasonal fluctuation in river water salinity measured as EC (electrical conductivity) at Dacope in the coastal district of Khulna, averaged over 3 years, 2016-2019 (Source: KGF 2020)

Extreme salinity in the dry season has been recorded in soils of the coastal zone of Bangladesh. In the past three decades (1989-2021) soil salinity as high as ECe 7.9-68 dS/m, much higher than the critical level of ECe 4.0 dS/m, has been observed (Table 5.3).

Table 5. 3 Soil salinity (ECe) in the coastal zone during 1989 – 2021

Land type				
	HL	MHL	MLL	LL
Soil ECe (dS/m)				
2005-2021				
Min	0.29	0.10	0.15	0.52
Class	Non-saline	Non-saline	Non-saline	Non-saline
Max	18	68	31	10.50
Class	Strongly saline	Extremely saline	Extremely saline	Strongly saline

1999-2002				
Min	0.21	0.50	0.30	0.25
Class	Non-saline	Non-saline	Non-saline	Non-saline
Max	29	60	24.42	24.84
Class	Extremely saline	Extremely saline	Extremely saline	Extremely saline
1989-1998				
Min	0.90	0.20	0.40	0.83
Class	Non-saline	Non-saline	Non-saline	Non-saline
Max	7.90	40	19.50	21
Class	Strongly saline	Extremely saline	Extremely saline	Extremely saline
HL= high land, MHL= medium high land, MLL= medium low land, LL= low land				

Source: BARC 2022

Soil pH

Soils of the coastal zone of Bangladesh vary in acidity (soil pH) depending on the soil type and presence or absence of acid-forming materials like peaty deposits or bases like calcium carbonates. Thousands of soil samples collected from the coastal districts of Bangladesh coastal zone have been analyzed over the years which indicated a wide range of acidity in the soils from very strongly acid (pH <4.5) to alkaline (pH >7.5) (BARC 2022). In pH measurements of 5268 soil samples during 2005-2021, 155 samples were found to be very strongly acidic (pH 3.5-4.4), 1412 strongly acidic (pH 4.5-5.5), 1329 moderately acidic (pH 5.6-6.5), 1403 near neutral or neutral (pH 6.6-7.4) and 969 slightly to moderately alkaline (pH 7.5-8.1) (Fig. 5.6). The pH measurements, thus, show that most soils of the coastal zone are strongly acidic to near neutral.

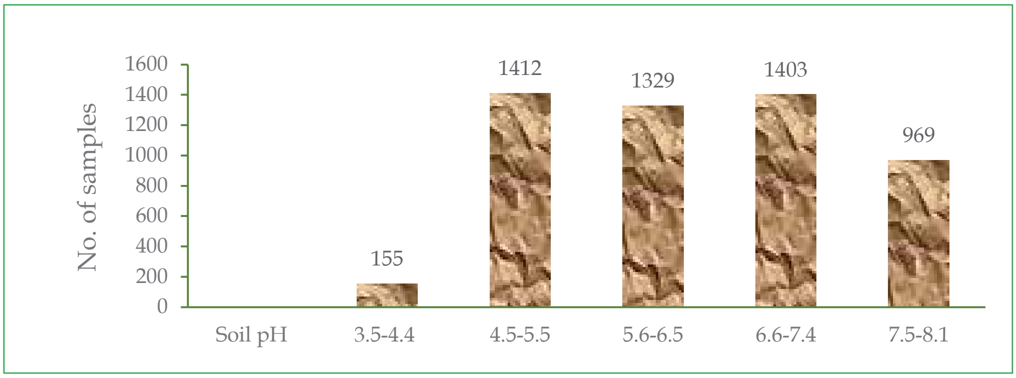


Fig. 5.6. Soil pH in the coastal zone during 2005-2021 (Source: BARC 2022)

Soil pH values according to land type are shown in Table 5.4. The pH of soils on HL, MHL, MLL and LL varies within a range of 3.55-6.10 (extremely to slightly acidic) to the mid-range of 7.9-8.0 (slightly alkaline) during 2005-2021. In general, HL and MHL soils tend to be more acidic than MLL and LL soils. Haque (2006) and Naher et al. (2011) also found soil pH in coastal regions ranging from 6.0 to 8.4. Low soil pH could be accounted for by the accumulation of sulfate containing materials in a high-organic matter anaerobic environment inducing the formation of sulfides and oxidation of the soil resulting in the formation of acids (Islam et al. 2014). Increased acidity has many negative effects on plant growth such as, reduced availability of plant nutrients like phosphorus, calcium, magnesium and molybdenum and toxicities of aluminum, iron and manganese (Brady and Weil 2013).

There were no significant changes in maximum and minimum soil pH values measured during 1989-1998, 1999-2002 and 2005-2021 (Table 5.4). However, soils of LL had some acidity during 2005-2021 which may be attributed to frequent submergence of these lands by seawater with a high pH and high calcium and magnesium concentrations.

Table 5.4. Ranges and classes of soil pH in the coastal zone during 1989-2021

pH range and class	Land type			
	HL	MHL	MLL	LL
2005-2021				
Min	3.9	3.55	4.4	6.1
Class	Extremely acidic	Extremely acidic	Extremely acidic	Slightly acidic
Max	8.0	8.0	8.0	7.9
Class	Slightly alkaline	Slightly alkaline	Slightly alkaline	Slightly alkaline
1999-2002				
Min	3.7	3.5	4.7	4.5
Class	Extremely acidic	Extremely acidic	Strongly acidic	Strongly acidic
Max	7.9	8.0	8.0	7.8
Class	Slightly alkaline	Slightly alkaline	Slightly alkaline	Slightly alkaline
1989-1998				
Min	4.7	3.5	4.3	4.7
Class	Strongly acidic	Extremely acidic	Extremely acidic	Strongly acidic
Max	8.0	8.0	8.0	7.5
Class	Slightly alkaline	Slightly alkaline	Slightly alkaline	Slightly alkaline

Source: BARC 2022

Soil organic matter (SOM)

The SOM content in the coastal areas across MHL, MLL, LL and VLL has been found to vary from 2.16 to 4.64% in measurements made at different times in the past, i.e., in 1985-1998, 1999-2002 and 2005-2021 (Fig. 5.7). The SOM content, over the years has remained above the critical level of 2% which is good for crops, except in soils on HL where the average SOM content has been found to be <2% (1.69-1.95). With time, there has been a slight change in SOM (Fig. 5.7). Throughout 1985-2021 SOM in MLL MLLand LL has remained the highest, 2.55-4.64%, 2.16-2.19% in MHL and 1.69-1.95% in HL. Alluvium and organic debris deposition in the perennially wet MLL and LL continues throughout most of the year which progressively increases and maintains the SOM level in coastal soils.

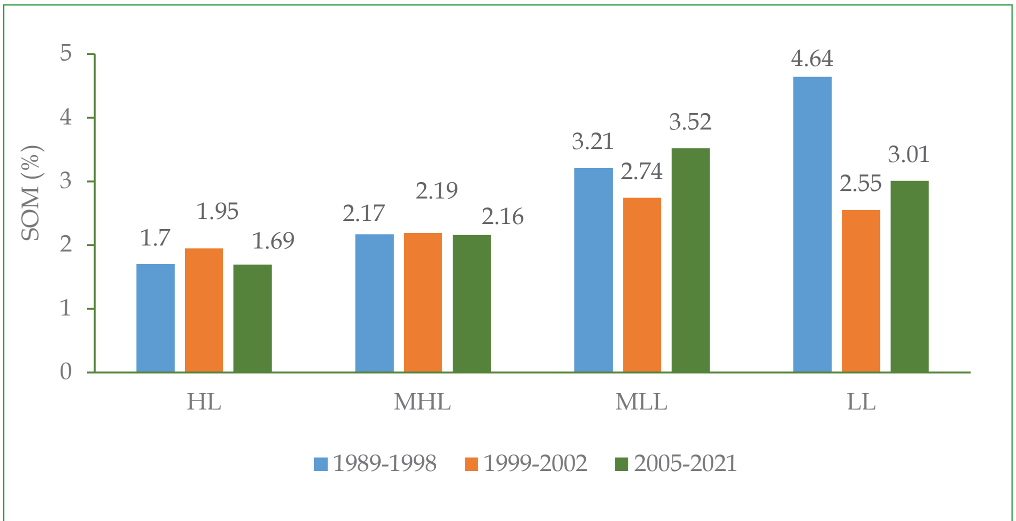


Fig. 5.7. Organic matter content in soils on various land types of coastal zone (figures represent SOM in %) (Source: BARC 2022)

Soil nutrients

The average available phosphorus (P) level of soils in the coastal zone across HL, MHL, MLL and LL ranged from 4.36 to 8.73 ppm during 1999-2002 and 2005-2021 (Fig. 5.8), which were much below the optimum level of 12-15 ppm for crops. Available P in soils on MHL and MLL types appears to have decreased with time (Fig. 5.8). Phosphorus deficiency in the coastal zone soils may aggravate if appropriate P fertilization is not followed for crop agriculture.

The available potassium (K) level of soils (exchangeable K) ranged from 0.16 to 0.33 meq/100 g during 1999-2002 and in measurements during 2005-2021 it has been found to vary from 0.19 to 0.32 meq/100 g (Fig. 5.8). These values are below 0.5 meq/100 g which is the optimum level for good crop production. Soils on MLL and LL generally possess higher levels of available K (0.25-0.33 meq/100 g) than do soils on MHL and LL (0.16-0.29 meq/100 g). The available K in soils has not changed significantly in the last 30 years except on LL where the K level increased substantially from 0.25 to 0.32 meq/100 g. Naher et al. (2011), however, reported higher levels of exchangeable K in some coastal zone soils, e.g., in soils of Assasuni upazila of the coastal district of Satkhira and Kalapara upazila of the coastal district of Patuakhali ranging from 0.45 to 1.45 meq/100 g and from 0.57 to 1.10 meq/100 g, respectively.

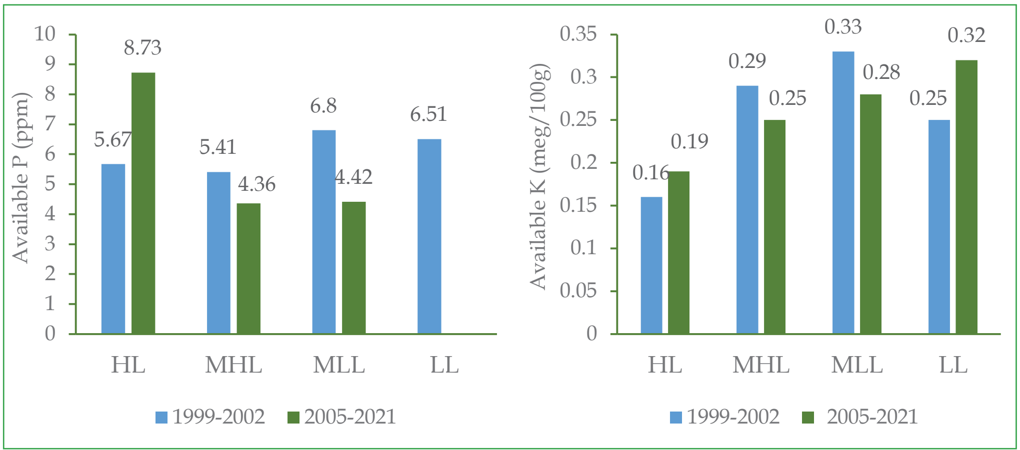


Fig. 5.8. Available P (ppm) content (left) and exchangeable K (meq/100 g) content (right) in soils of coastal zone (source: BARC 2022)

The available sulfur (S) content of soils of the coastal zone were found to be very high to extremely high, ranging from 31.74 to 124.42 ppm in soil analysis during 1999-2002 and 2005-2021(Fig. 5.9). These values are much above the critical level of 12 ppm and optimum level of 26 ppm for crop production. In general, soils on MHL and MLL contain very high levels of S ranging from 86.74 to 124.42 ppm compared with those on HL and LL (31.74-60.42 ppm). Available S in soils of HL, MHL, MLL and LL decreased over time from 41.39 to 31.74, 124.42 to 86.74, 99.6 to 87.47 and 60.42 to 36.89 ppm, respectively (Fig. 5.9). This decrease in the available sulfate-S content over time occurred due to frequent tidal surge induced prolonged submergence of coastal soils with the consequent reduction of sulfate-S to sulfide-S which is unavailable to plants (Islam 1977). Moreover, coastal wetlands contribute to the emission of sulfides like carbonyl sulfide, hydrogen sulfide etc.

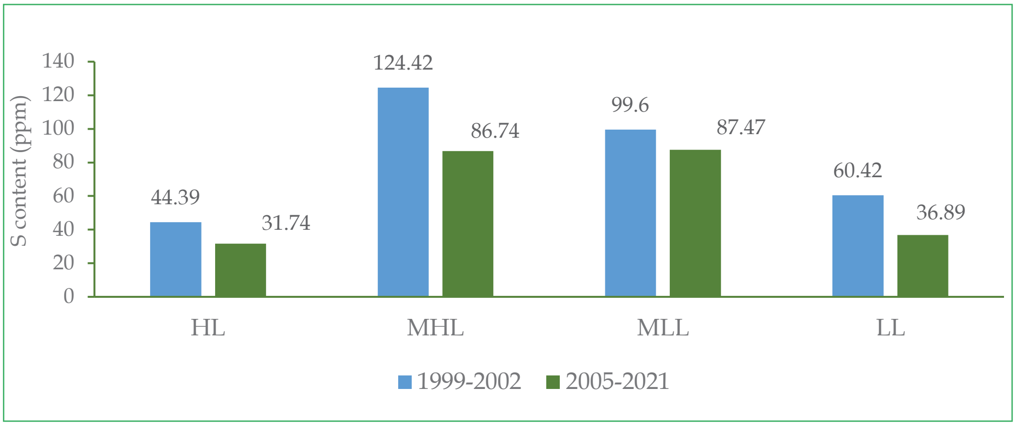


Fig. 5.9. Available S content (ppm) in soils of coastal zone (Source: BARC 2022)

In soil analysis at different times during 1999-2002 and 2005-2021, the available zinc (Zn) content in soils of the coastal zone has been found to vary from 0.67 to 1.49 ppm across HL, MHL, MLL and LL (Fig. 5.10). The soils are Zn deficient having an available Zn content less than 2.0 ppm which is the critical level. Widespread Zn and copper deficiencies in soils were observed in the coastal region (Karim et al. 1990). The availability of Zn decreases as soil pH increases. Adsorption of Zn on carbonate surfaces in calcareous soils also reduces Zn availability to plants. The available Zn content in soils of the coastal zone appears to have increased with time from 0.79 to 1.04, 0.90 to 0.93, 0.69 to 1.17 and 0.67 to 1.49 ppm in soils on HL, MHL, MLL and LL, respectively (Fig. 5.10).

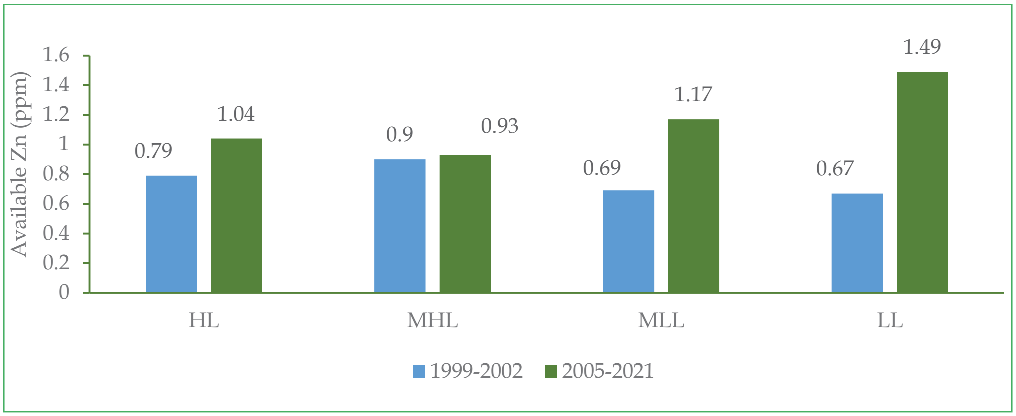


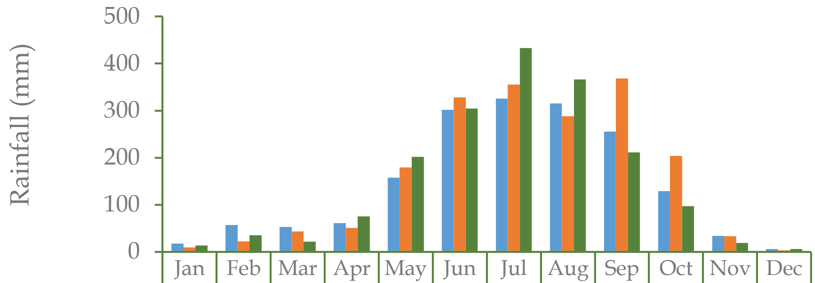
Fig. 5.10. Available Zn content (ppm) in soils of coastal zone (Source: BARC 2022)

5.2.2 Climate

A subtropical monsoon climate prevails in the coastal zone. It has more sharply defined seasons than the tropical climate. Climate variability in the coastal areas from available data during 1991-2020 has been extensively studied. The annual rainfall in the coastal districts is high with a considerable variation across the region. Global climate change which has induced an alteration in the frequency of some climatic extreme events has been increasingly impacting the environment, agriculture and livelihood in the coastal areas of Bangladesh.

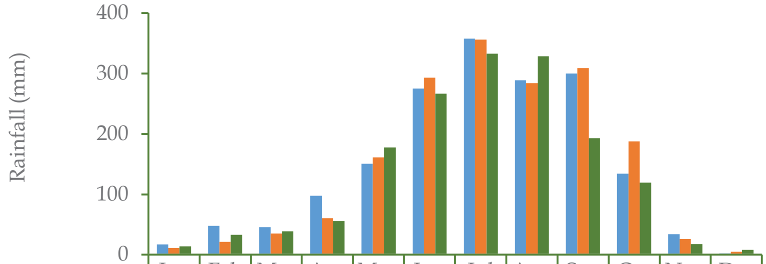
Rainfall

The Mongla meteorological station, which provides climate data for the coastal district of Khulna, recorded increasing rainfall starting with the Kharif-I season was observed for monthly rainfall in May (202 mm), June (305 mm), July (433 mm), August (366 mm) and September (211 mm) during 2011-2020 (Fig. 5.11). In the past, a similar monthly rainfall pattern was observed in this coastal district for 10-year averages of 2001-2010 and 1991-2000. The monthly rainfall in July and August averaged 433 and 366 mm during the last 10 years (2011 to 2020) and 326 and 316 mm during 1991-2000, respectively indicating that rainfall has been increasing in Khulna in these two peak wet season months. Too much rainfall in the months of July and August could be a disadvantage for the planting of T. Aman rice, Kharif-II vegetables and other crops. But at the same time well distributed moderate rainfall extending up to October could be a blessing for T. Aman rice in respect of suppressing soil salinity. To the contrary, monthly rainfall declined during the most part of the Rabi season (Fig. 5.11) indicating intensified drought and salinity stress for Rabi crops. A similar trend was observed in Satkhira district (Fig. 5.12) except that the amounts of rainfall in November and December were very poor (18 and 8 mm, respectively) during 2011-2020 compared to the same months (34 and 2 mm, respectively) in the past (1991-2000).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg Rainfall during 1991-2000	18	57	53	61	157	302	326	316	256	129	34	6
Avg Rainfall during 2001-2010	9	23	44	51	179	328	355	289	368	204	33	4
Avg Rainfall during 2011-2020	14	35	22	76	202	305	433	366	211	97	19	6

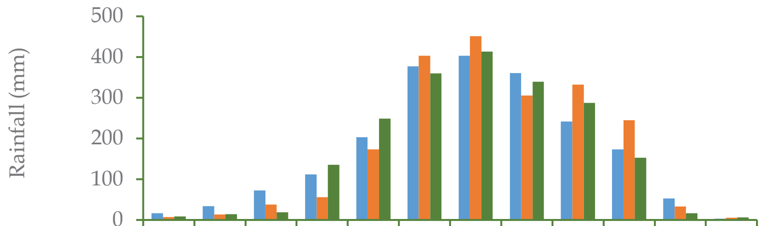
Fig. 5.11. Long-term trend of monthly rainfall in Khulna district (Source: BARC 2022)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg Rainfall during 1991-2000	17	48	46	97	151	275	358	289	300	134	34	2
Avg Rainfall during 2001-2010	11	21	35	60	161	293	356	284	309	188	26	5
Avg Rainfall during 2011-2020	14	33	39	56	178	267	333	329	193	119	18	8

Fig. 5.12. Long-term trend of monthly rainfall in Satkhira district (source: BARC 2022)

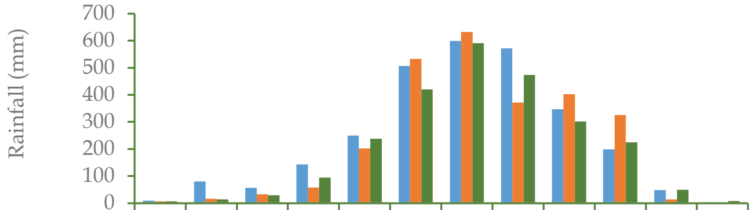
Data collected by the Barishal meteorological station indicated an increasing trend in rainfall in Barishal district during April through July regardless of the periods, 1991-2000, 2001-2010 and 2011-2020 (Fig. 5.13). There was an increase in rainfall in April (135 mm) and May (249 mm) during 2011-2020 compared to the rainfall in the same months (112 and 204 mm) during 1991-2000. In particular, high rainfall in April-May could be critical for the safe harvest of Boro rice, and planting of Kharif-I vegetables and other crops. On the other hand, there has been an undesirable reduction in rainfall (Fig. 5.13) during the Rabi months (November-March) which could adversely affect Boro rice and non-rice Rabi crops.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg Rainfall during 1991-2000	17	34	72	112	204	377	403	361	242	174	53	3
Avg Rainfall during 2001-2010	7	14	38	56	173	403	451	306	332	245	33	6
Avg Rainfall during 2011-2020	9	14	19	135	249	360	413	339	288	153	17	6

Fig. 5.13. Long-term trend of monthly rainfall in Barishal district (Source: BARC 2022)

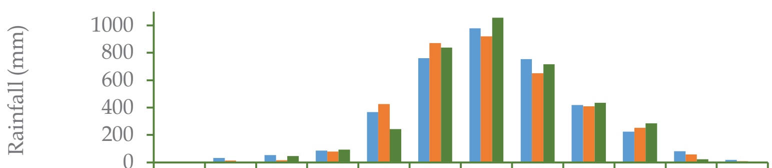
Similar changes in the amount and distribution occurr in Patuakhali district (Fig. 5.14) as indicated by climatic data recorded by the Patuakhali meteorological station, particularly when the rainfall in April and May during 2011-2020 and 2001-2010 is compared. It implies similar risks and vulnerabilities for crop production as those observed in Barishal.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg Rainfall during 1991-2000	10	81	57	143	249	507	598	572	347	198	48	4
Avg Rainfall during 2001-2010	7	17	33	58	203	532	632	372	402	326	14	1
Avg Rainfall during 2011-2020	6	14	30	95	237	421	591	474	302	225	49	9

Fig. 5.14. Long-term trend of monthly rainfall in Patuakhali district (Source: BARC 2022)

The Teknaf meteorological station provides climate data for the coastal district of Cox's Bazar. An increasing trend in rainfall with a sharp rise was observed for the months of June (838 mm), July (1057 mm) and September (435 mm) during 2011-2020 (Fig. 5.15). The average amounts of rainfall in these months during the past 10 years (2011-2020) were 838, 1057 and 435 mm, respectively) and those during 1991- 2000 were 762, 980 and 419 mm, respectively. In particular, unusually high rainfall in the months of July and September would be deleterious to the safe planting of T. Aman rice, Kharif-II vegetables and other crops. In contrast, as in the western coastal districts (Khulna, Barishal etc.) monthly rainfall has decreased severely in the Rabi months during 2011-2020 (4-23 mm rainfall from November to March) (Fig. 5.15) compared with range of 6-82 mm, respectively during 1991-2000. Consequently, severe drought struck the eastern coastal areas, greatly hampering the planting of Boro rice (winter rice) and other winter crops, and partially damaging these crops if planted at the start of the winter.



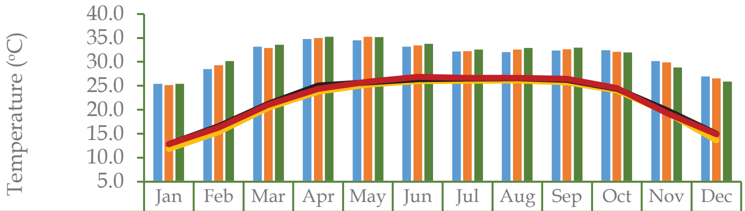
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg Rainfall during 1991-2000	6	32	54	87	366	762	980	753	419	225	82	18
Avg Rainfall during 2001-2010	5	15	16	78	425	870	921	651	409	254	59	10
Avg Rainfall during 2011-2020	7	4	45	94	242	838	1057	718	435	285	23	8

Fig. 5.15. Long-term trend of monthly rainfall in Cox's Bazar district (Source: BARC 2022)

Temperature

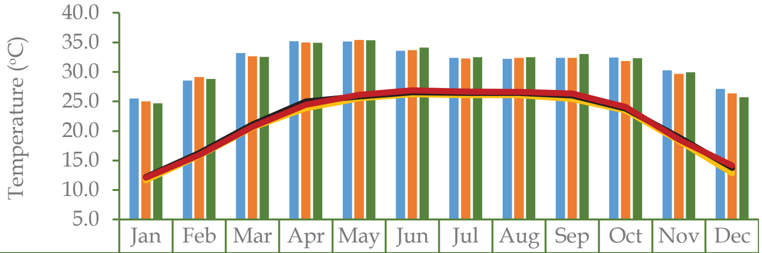
The monthly maximum temperature averaged over the last 10 years (2011-2020) ranged from 25.4°C in Janyary to 35.2°C in May (Fig. 5.16) in Khulna district. The maximum temperature has increased by the range of 0.4 to 1.7°C in all the months except from October to January averaged over the period, 2011-2020 compared with that averaged over the period, 1991-2000. The monthly minimum temperatures averaged over 10 years (2011-2020) ranged from 12.82°C in January to 26.9°C in June (Fig. 5.16). The minimum monthly temperature has also increased by 0.5 to 1.3°C in all the months of the year except in November averaged over the last 10 years (2011-2020) compared with that averaged over the period, 1991-2000. Similar increasing trends of temperature were observed in the other coastal districts, too (Figs. 5.17-5.20).

Such temperature increases are probably contributing to climate change impacting agriculture and lives and livelihoods of the millions of inhabitants in the coastal zone. Warmer climate will increase the flood risks (Hirabayashi and Yukiko 2013). The coastal zone is particularly vulnerable to climate change impacts. It is predicted that global warming will cause an annual temperature rise of 0.4°C in Bangladesh and result in a greater frequency and intensity of cyclonic storms in the coastal zone. At least 70 major cyclones hit the coastal belt of Bangladesh in the past 200 years (Islam 2004). About a million people died in the last 35 years owing to catastrophic cyclones in the coastal districts (Islam 2004). The Noakhali-Chattogram coast is the most vulnerable area for landfall of cyclones receiving 40 % of the cyclones in the past. The



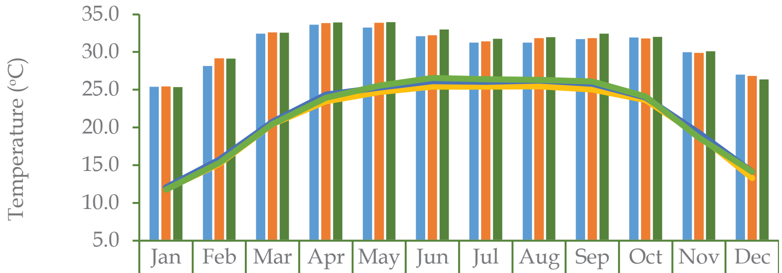
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg Max Tduring 1991-2000	25.4	28.5	33.1	34.8	34.5	33.2	32.2	32.0	32.4	32.4	30.2	27.0
Avg MaxT during 2001-2010	25.1	29.3	32.9	35.0	35.3	33.4	32.2	32.6	32.7	32.1	29.9	26.5
Avg MaxT during 2011-2020	25.4	30.2	33.6	35.2	35.2	33.8	32.6	32.9	33.0	32.0	28.9	25.9
Avg MinTduring 1991-2000	11.8	15.4	20.4	23.8	25.2	26.0	26.1	26.1	25.7	24.0	19.4	13.6
Avg MinT during 2001-2010	12.8	16.5	21.2	25.0	25.7	26.4	26.5	26.6	26.2	24.4	19.9	14.9
Avg MinT during 2011-2020	12.8	16.3	21.1	24.4	25.8	26.9	26.7	26.6	26.4	24.5	19.3	14.9

Fig. 5.16. Long-term trend of monthly maximum and minimum temperatures in Khulna district (Source: BARC 2022)



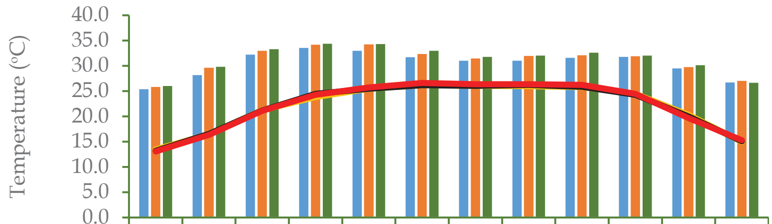
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg MaxT during 1991-2000	25.5	28.5	33.2	35.2	35.1	33.6	32.4	32.2	32.4	32.4	30.2	27.1
Avg MaxT during 2001-2010	25.0	29.1	32.7	35.0	35.4	33.7	32.3	32.4	32.4	31.8	29.7	26.3
Avg MaxT during 2011-2019	24.7	28.8	32.5	34.9	35.4	34.1	32.5	32.5	33.0	32.3	29.9	25.7
Avg MinT during 1991-2000	11.7	15.8	20.6	23.9	25.5	26.2	26.1	26.0	25.4	23.5	18.3	12.8
Avg MinT during 2001-2010	12.2	16.2	21.1	25.0	25.8	26.6	26.5	26.4	26.0	23.8	18.9	13.8
Avg MinT during 2011-2019	12.1	15.9	20.7	24.5	26.1	26.9	26.7	26.6	26.4	24.1	18.6	14.2

Fig. 5.17. Long-term trend of monthly maximum and minimum temperatures in Satkhira district (Source: BARC 2022)



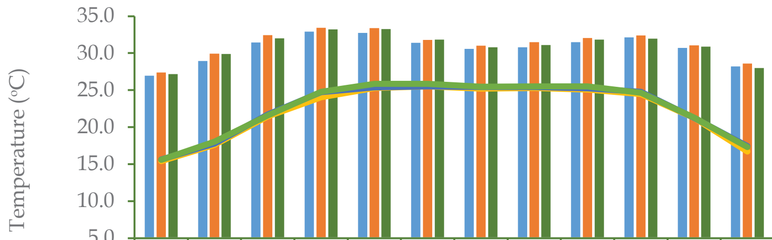
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg MaxT during 1991-2000	25.4	28.2	32.4	33.6	33.3	32.1	31.3	31.2	31.7	31.9	30.0	27.0
Avg MaxT during 2001-2010	25.4	29.2	32.6	33.8	33.9	32.2	31.4	31.9	31.9	31.8	29.9	26.8
Avg MaxT during 2011-2020	25.4	29.1	32.6	33.9	34.0	33.0	31.8	32.0	32.5	32.0	30.1	26.4
Avg MinT during 1991-2000	11.8	15.2	20.4	23.5	24.7	25.4	25.4	25.4	25.0	23.6	19.0	13.3
Avg MinT during 2001-2010	12.1	15.8	20.8	24.4	25.3	26.1	26.0	26.2	25.8	24.0	19.3	14.1
Avg MinT during 2011-2020	11.8	15.3	20.5	24.0	25.5	26.6	26.4	26.3	26.1	24.1	18.6	14.1

Fig. 5.18. Long-term trend of monthly maximum and minimum temperatures in Barishal district (Source: BARC 2022)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg MaxT during 1991-2000	25.4	28.2	32.2	33.5	33.0	31.7	31.0	31.0	31.6	31.8	29.5	26.7
Avg MaxT during 2001-2010	25.8	29.6	32.9	34.2	34.2	32.3	31.4	32.0	32.1	31.9	29.8	27.0
Avg MaxT during 2011-2020	26.0	29.8	33.2	34.3	34.3	32.9	31.8	32.0	32.5	32.0	30.1	26.6
Avg MinT during 1991-2000	13.4	16.5	21.2	23.8	25.5	26.1	26.0	26.0	25.8	24.5	20.3	15.0
Avg MinT during 2001-2010	13.2	16.6	21.2	24.5	25.5	26.2	26.1	26.2	25.9	24.2	20.0	15.1
Avg MinT during 2011-2020	13.1	16.3	21.1	24.2	25.7	26.6	26.4	26.4	26.2	24.4	19.6	15.3

Fig. 5.19. Long-term trend of monthly maximum and minimum temperatures in Patuakhali district (Source: BARC 2022)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg MaxT during 1991-2000	26.9	28.9	31.4	32.9	32.7	31.4	30.6	30.8	31.5	32.1	30.7	28.2
Avg MaxT during 2001-2010	27.4	29.9	32.5	33.5	33.4	31.8	31.0	31.5	32.1	32.4	31.0	28.6
Avg MaxT during 2011-2020	27.2	29.9	32.0	33.2	33.3	31.8	30.8	31.1	31.8	32.0	30.9	28.0
Avg MinT during 1991-2000	15.4	17.6	21.5	24.0	25.3	25.5	25.2	25.3	25.1	24.5	21.2	16.7
Avg MinT during 2001-2010	15.6	17.8	21.7	24.7	25.4	25.5	25.4	25.4	25.3	24.8	21.3	17.4
Avg MinT of last 10 years	15.6	18.0	21.6	24.8	25.9	25.8	25.5	25.5	25.5	24.6	21.3	17.3

Fig. 5.20. Long-term trend of monthly maximum and minimum temperatures in Cox's Bazar district (Source: BARC 2022)

Chattogram-Cox's Bazar cast received around 27% whereas the Khulna/Sundarban and Barishal-Noakhali regions are less susceptible (Rahman 2001). Some notable examples of the tropical cyclones are the Bakerganj cyclone of 1876, the 12 November, 1970 cyclone in the Bhola-Barishal region, the May 1985 cyclone in the Urir Char area and the April 1991 cyclone in the Chattogram-Cox's Bazar area.

5.2.3 Water regime

Salt intrusion

In coastal zone, tidal water pressure is high during June-October especially at the full and new moon times. The drainage channels cannot fully and quickly drain out excess water accumulation from rains and tides in the wet season. In the dry season (November to March), however, tidal water does not enter crop fields and this period is also mostly rainless due to which drought conditions occur from December/January to March. Irrigation requirement is high in this period for Boro rice and other Rabi crops. But river and canal waters have high salinity, and thus, stored non-saline surface water remains the only source of water for crops in the Rabi season. Kharif crops including T. Aman rice must depend on monsoon rains. With the projected sea level rise (SLR) due to global warming low-lying coastal areas would be increasingly inundated with saline water gradually contaminating the soil. In addition, climate change is increasing the frequency and severity of extreme weather events, including droughts and heat waves. These would lead to more intensive use of groundwater for drinking and irrigation resulting in increasing intrusion of seawater and soil salinization.

The coastal water resources system has an extensive range of water bodies including water resources sub-systems. These are an interlinked system of tidal rivers and channels; riverine flood plains including wetlands; intertidal lands along the coast and estuary branches; lakes and man-made ponds; the groundwater aquifer; and the sea (Islam and Ahmed 2004). The Bay of Bengal is the reservoir of seawater (saline water) along the Bangladesh coast. The main sources of fresh surface water are the Ganges, Brahmaputra and Upper Meghna. These mighty rivers drain a large basin, which provides more than 92% fresh surface water to the coastal zone of Bangladesh (Islam and Ahmed 2004). The coastal zone has a capillary network of rivers and channels, most of them under a season-dependent tidal regime with twice daily variations of water levels and salinity. Man-made ponds of different sizes, shapes and depths serve as reservoirs of freshwater, are common features in the coastal zone of Bangladesh. They are used for fish culture and sources of potable water.

Brackish water aquaculture, waterlogging, storm surges, salinity in groundwater etc. have created water crises for crop agriculture in the coastal zone. Farmers are being increasingly compelled to use poor quality water for irrigation which seriously affects crop yields to the extent that the farmers are losing interest in cultivating crops. The groundwater is affected by sodium (Na) and continuous use of such high-Na irrigation water breaks down the soil structure, reduces soil aeration and water infiltration (Rahman et al. 2011). Rainwater is the only source for irrigation of T. Aman rice for most farmers, and heavy rains are required to wash out the salts, but, in recent years the rainfall pattern has changed. Rainfall has become erratic and there is a decreasing pattern of rain in the early monsoon which is unfriendly to crop agriculture.

In the past, farmers used canal water, which was usually fresh, for irrigation, but, of late canal water has become mostly saline and cannot be used for irrigation. This situation has arisen from indiscriminate use of saline water for shrimp culture (Fig. 5.21).

Fig. 5.21. Integrated rice-fish (*bagda* shrimp) culture in a high-salinity situation of coastal zone

The ponds and canals are occupied by shrimp farm owners and all they care for it's profits without any concern for the harmful effect of increasing water salinity on crops in the crop fields nearby. One alternative source of freshwater is groundwater, which is not easily available in the coastal zone. The freshwater table is so deep (250–350 meters) that the cost of installing a deep tube well (DTW) is forbidding and, thus, DTW water remains mostly unavailable for most farmers (Datta and Ghosh 2015). Big farmers privately install DTW and supply irrigation water to others on payment, which is also expensive for the medium and small farmers and sharecroppers. The consequences of the excessive groundwater exploitation without adequate recharge, on the other hand, increases the risk of saltwater intrusion into freshwater aquifers (Rahman et al. 2011).

Waterlogging and floods

Bangladesh contains one of the largest, most densely populated and heavily farmed deltas of the world which is at great risk of increased flooding and submergence from SLR (Syvitski et al. 2009). There are forecasts of stronger-than usual backwater effect owing to SLR induced high oceanic stage in the coastal areas predominantly along the convergence points of the major rivers (Ahmed 2006). The risk of riverine and rainfall-induced high-intensity prolonged flooding (Fig. 5.22) as that in 1998, has increased. It is feared that SLR would not only submerge low-lying areas along the coast, but would also create undesirable conditions for saline waters to submerge the coastal flood protection embankments and spill over into the hinter and especially when driven by strong winds (CEGIS 2006). With increased rainfall, both the height and timing of peak flood levels might change (Warrick and Ahmed 1996).

Fig. 5.22. Flood in the coastal zone

5.2.4 Biodiversity and mineral resources

Biodiversity

The coastal zone of Bangladesh is rich in natural resources offering many tangible and intangible benefits to the nation. The mangroves (around 570,000 ha) with spectacular wildlife, wide biodiversity and fisheries (>80% of total marine catch), shrimp culture (around 11,500 ha in the coastal zone) etc. are some examples of these benefits. However, these natural resources face multiple and critical problems including non-sustainable resource uses and natural calamities.

A total of 245 genera and 334 plant species have been recorded in Sundarbans at the beginning of the 20^{th} century (Wikipedia, accessed in July 2022). Since then, there have been considerable changes in the status of various mangrove species. Differences in vegetation have been explained in terms of freshwater and low salinity influences in the northeast and variations in drainage and siltation. The Sundarbans has been classified as a moist tropical forest, comprising primary colonization on new accretions to more mature beach forests. Historically vegetation types have been recognized in broad correlation with varying degrees of water salinity, freshwater flushing and physiography. The varieties of the forests that exist in Sundarbans include mangrove scrub, littoral forest, saltwater mixed forest, brackish water mixed forest and swamp forest. Besides the forest, there are extensive areas of brackish water and fresh water marshes, intertidal mudflats, sandflats, sand dunes with typical dune vegetation, open grassland on sandy soils and raised areas supporting a variety of terrestrial shrubs and trees.

The Sundarbans flora is characterized by the abundance of *sundari (Heritiera fomes), gewa (Excoecaria agallocha), goran (Ceriops decandra) and keora (Sonneratia apetala)* all of which occur prominently throughout the area. The characteristic tree of the forest is the *sundari (Heritiera littoralis)*, from which the name of the forest had probably been derived (Fig. 5.23).

Fig. 5.23. The sundari tree, characteristic natural vegetation of the Sundarbans in the coastal zone of Bangladesh

It yields a hard wood, used for building houses and making boats, furniture and other things. New forest accretions is often conspicuously dominated by *keora* and tidal forests. It is an indicator species for newly accreted mudbanks and is an important species for wildlife, especially the spotted deer (*Axis axis*). There is abundance of *dhundul* or *passur (Xylocarpus granatum)* and *kankra (Bruguiera gymnorhiza*) though distribution is discontinuous. Among palms, *Poresia coaractata, Myriostachya wightiana* and *golpata (Nypa fruticans)*, and among grasses, spear grass (*Imperata cylindrica*) and *khagra (Phragmites karka)* are well distributed. While most of the mangroves in other parts of the world are characterized by members of the *Rhizophoraceae, Avicenneaceae* or *Combretaceae*, the mangroves of Bangladesh are dominated by the *Malvaceae* and *Euphorbiaceae* (cited from Wikipedia).

The Sundarbans is the home of the famous "Royal Bengal Tiger" (Fig. 5.24) and a host of other animals such as, monkeys, deer, reptiles, birds etc. These are remarkably resilient living beings surviving, growing and completing their life cycles in a unique environment of continuous or intermittent tidal submergence and waters with fluctuating sediment loads and salinity. Some 425 species of wildlife have been identified in the Sundarbans including 300 bird, 42 mammalian, 35 reptile and 8 amphibian species (Blower 1985, Rashid and Scott 1989). The mammals commonly attract most of the research attention, and a lot of data are available on the numbers and distribution for example, the Royal Bengal Tiger (*Panthera tigris*), for which the Sunderbans is the largest remaining natural habitat, the otter (*Lutra spp*), squirrels (*Collosciurus pygerythus, Funambalus pennati*), wild boar (*Sus scrofa*), and in rivers and the sea, a number of dolphin species. A total of 301 species of mollusks and over 50 species of commercially important crustaceans have been recorded so far in the coastal zone and the Bay of Bengal. Several 46 species of coastal wildlife are endangered with certainty and the actual number would be much more.

Fig. 5.24. The Royal Bengal Tiger in Sundarbans

The IUCN Bangladesh Red Data Book (Hilton-Taylor 2000) has listed 442 marine fishes, 22 amphibians, 17 marine reptiles, 388 resident birds, 240 migratory birds and 3 species of marine mammals in Bangladesh. There are at least 36 species of marine shrimps. Among them, the *Penaeide* shrimps are commercially important. About 336 species of mollusks; covering 151 genera have been identified. In addition, 3 lobsters and 31 species of turtles and tortoises of which 24 live in freshwater are found in Bangladesh. In addition, 168 seaweeds, 3 sponges, 15 crabs, 3 lobsters, 10 frogs, 3 crocodiles, 24 snakes, 3 otters, 1 porcupine, 9 dolphins and 3 species of whale are found in Bangladesh. According to the Red list of IUCN, among the marine and migratory species of animals, 4 fishes, 5 reptiles, 6 birds, and 3 mammals are threatened.

In addition to finfish Bangladesh also has a rich diversity of shellfish, especially of Caridean shrimps, several of which are of commercial interest and export value. A recent survey recorded 36 species of shrimps from the marine waters of Bangladesh. The brown shrimp *M. monoceros* contributes about 56% of the total shrimp catch, though P. monodon is the targeted species because of its export value. Peneaus monodon, *P. indicus, P. semisulcatus, Metapeneaus monoceros, M. brevocornis* are important penaeids. The shrimp and prawn culture sector of Bangladesh is becoming very important in economic terms contributing significantly to foreign exchange earnings and employment generation in rural areas. In addition to the finfish and shrimps, more than 300 molluskan species are recorded from Bangladesh. Two species of Trochus are recorded from the St. Martin's Island, which are disappearing worldwide. Octopus and cuttlefish (Sepia) occur in deep waters of the Bay of Bengal and are exportable commodities. A total of 234 species of fish have been identified from the St Martin's Island. Of which, 98 species are coral associated. The total number of recorded mollusk species from the St. Martin's Island stands at 187 species. Also, 7 species of crabs were recorded from the island. A preliminary survey of the St. Martin's Island and Sundarbans area revealed the occurrence of nearly 200 species of seaweeds. There are also 160 taxa of marine phytoplankton in the Bay of Bengal. Approximately 5-10% of the surface area of the sub-tidal zone of the St. Martin's Island is covered with corals. Coral collection at the present rate is detrimental for their survival. Although the St. Martin's Island is referred to as a "coral Island", no indication of coral reef formation was found in the Island. The earlier reports of "coral reefs" are in fact "boulder reefs" (Tomascik 1997). A total of 66 coral species were recorded, of which 19 are fossil corals, 36 are living coral and the rest are under 6 families of the sub-class *Octocorallia*. By shifting and overturning substrate boulders cyclonic storms and tidal surge probably cause serious damage to coral communities.

Mineral resources

Two years after independence, Bangladesh for the first time conducted a limited survey in the Bay of Bengal with the help of two the then Soviet vessels vide 'Petroleum Act 1974'. It opened up an opportunity for international oil companies (IOC) to explore oil and gas under production sharing contracts (PSC) with the Government of Bangladesh. Out of seven exploratory wells, only one gas discovery was made at Kutubdia. In 1993, two PSCs were signed for three offshore and five inland blocks. Under PSC-1993, gas was discovered in 1996 at Sangu of Chattogram, as the only offshore block. It commenced production in June 1998 with an estimated reserve of 850 billion cubic feet (BCF) (Alam 2004); but the recoverable reserve was 635.50 BCF (BER 2011a). In its best of times, Sangu produced even 160 million cubic feet/day (mcfd). The total production of this field as of 30 June 2011 was 477.80 BCF (BER 2011b).

The Geological Survey of Pakistan first discovered heavy minerals (HM) on beaches and sand dunes in the Cox's Bazar-Teknaf coastal belt in 1961. Later on, the Bangladesh Atomic Energy Commission (BAEC) installed a Beach Sand Mineral Exploitation Center (BSMEC) in 1979 with the help of the Australian government. In 1986, BAEC re-explored and found HM in 17 deposits in the area. BAEC estimated a reserve of 4.4 million tons of HM from 20 million tons of HM-bearing sands (Hasan 2012). Ilmenite, magnetite, zircon, rutile, garnet, monazite, leucoxene and kyanite were found as prominently as economic heavy minerals (EHM). These eight EHMs collectively constitute 1.76 million tons. Five of these minerals, ilmenite, magnetite, garnet, zircon and rutile, are of great economic importance. In addition, common salt is produced in huge quantities on a commercial basis in the coastal areas of Bangladesh (Alam 2004) especially in in Khulna, Satkhira, Chattogram and Cox's Bazar districts.

5.3 Demographic features

5.3.1 Population

A little over 35 million people representing 28% of the total population of Bangladesh (BBS 2003) live in the costal zone. The population density in the exposed coast is 482 persons/km^2 whereas it is 1,012 persons/km^2 in the interior areas. The average population density of the coastal zone is 743 persons/km^2 compared with the Bangladesh average of 839 persons/km^2. There are about 6.8 million households in the coastal zone (Islam 2004). About 30% of 35 million people living in the coastal zone are poor (BBS 2011). Thus, the coastal zone in terms of both area and population merits serious consideration of researchers, development workers, planners and policy makers for developing and implementing risk mitigation measures.

5.3.2 Socioeconomic situation

The coastal population faces severe multiple pressures including reduced sediment supply due to upstream dams, land subsidence due to the embankments and/or groundwater withdrawal (Adnan et al. 2019), waterlogging, salinization (Bernier et al. 2016), frequent flooding and cyclones due to climate change and SLR. These chronic and acute processes directly influence the livelihood and wellbeing of the coastal population (Adnan et al. 2020).

Fishing, agriculture, shrimp farming, salt farming and tourism are the main economic activities in the coastal zone. The Sundarbans is a major source of subsistence for almost 10 million people (Islam and Haque 2004). Main activities in the Sundarban area are fisheries, wood collection and honey collection. Almost 10,000 households in the coastal region have neither homestead land nor cultivable land. On the other hand, more than a million households in the area have only homestead but no cultivable land (Islam, 2004). Ecosystems and people's livelihoods in coastal regions are already under significant threats from climate change and variability (Ghosh et al. 2020). Another important source of income and employment in the coastal area is shrimp farming in ghers, crop production and natural resource exploitation (Ghosh et al. 2020). The coastal region is home to a large section of the country's poor. Hossain et al. (2019) in a survey found that among the coastal people, 62.46% were farmers, 3.84% on-farm laborers, 0.81% industrial workers, 12.20% engaged in commerce and 10.35% working in the services sector.

Scarcity of safe drinking water has been historically the number one issue in the daily life of the coastal population. Their drinking water sources include tube wells (90.11%), tap water (0.40%), pond water (7.53%), and others (1.86%) (Mohiuddin et al. 2021). The water supply sector, over the last few decades, has achieved commendable success so that about 95% of the population now has access to water from tube wells, taps or ring wells. Rural water supply is mainly dependent on tube wells. Pond water is also in use, especially where groundwater is either saline or expensive. Also, in recent years groundwater-based water supply in coastal areas has suffered setbacks like arsenic (As) contamination, lowering of the water table, salinity intrusion and non-availability of suitable aquifers. In a survey of water samples from 51,000 tube wells in 61 districts including coastal districts of Bangladesh, high As concentrations in water collected from tube wells <200m were observed (BGS and DPHE 2001).

Access to local government is considered a valuable asset. Proximity to the Union Parishad (UP) is positively correlated with the availability of essential services. In the coastal zone, the average area under a UP is 35 km^2, which is larger than that in other regions outside the coastal zone (32 km^2). Many households in the coastal zone consider membership of NGO groups an important asset. Within the coastal zone, however, the NGO coverage is poor in Lakshmipur, Chattogram and Chandpur (less than 25% households), and quite high in Shariatpur and Gopalganj (above 50% households). Physical facilities like markets and marketing infrastructure are critically important for economic life. The density of growth centers is relatively low in the coastal zone. The average service area per growth center in and outside the coastal zone is 80 km^2 and 66 km^2, respectively. Within the coastal zone, Bhola, Noakhali and Patuakhali have a lower density of growth centers, over 100 km^2 per center. The lower density of growth centers is also a disincentive to women's market access, economic participation and mobility.

5.4 Agricultural systems

5.4.1 Land use patterns

The 19 coastal districts comprise an area of about 1.65 million ha with a net agricultural land of about 920,652 ha (BARC 2022). Agricultural lands account for 27.82% of the total coastal area (3,309,029 ha) and constitute 6.36% of the total agricultural land area in Bangladesh (Fig. 5.25), i.e., 14,486,269 ha (BBS 2020). Rivers, canals and lakes occupy 23.79% while mangrove forests and plantations account for 13.73% of the total coastal area (Table 5.5). Brackish water aquaculture and fresh water aquaculture are the other major land uses occupying 4.50% and 3.38%, respectively, of the total coastal area. At some places integrated rice-fish culture is practiced. Special efforts are needed to bring more floodplain (both non-tidal and tidal lands) of the coastal zone into brackish water and fresh water aquaculture.

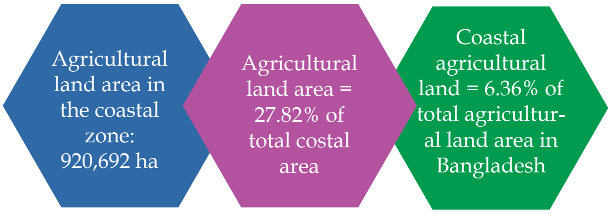


Fig. 5.25. Agricultural land area in the coastal zone as proportions of total land areas (Source: BARC 2022)

Table 5.5. Land use patterns in the coastal zone in 2022

Land Use	Area (ha)	% of total area
Agricultural Land	920692	27.82
Brackish Water Aquaculture	142361	4.30
Brackish Water Aquaculture + Rice	6589	0.20
Rice + Fresh Water Aquaculture	40426	1.22
Fresh Water Aquaculture	71445	2.16
Perennial Beels, haors and baors	8402	0.25
Ponds	953	0.03
Rivers, canals and lakes	787306	23.79
Mangrove Forest and plantation	454435	13.73
Herb and shrub dominated area	13425	0.41
Orchard + Vegetables and other plantation	5863	0.18
Rural Settlement	649981	19.64
Mud Flats or Intertidal Area	126846	3.83
Others	80305	2.43
Total	3,309,029	100

Source: BARC 2022

Among the 19 districts, Patuakhali has the largest agricultural land area (152,544ha) which constitutes 47.7% of the total coastal area of the district (Table 5.6). Barishal follows Patuakhali in terms of agricultural land area (89,562 ha) accounting for 40.9% of the coastal portion of the district. Bhola, Noakhali, Chattogram and Barguna also have substantial areas of agricultural land in their coastal areas. However, Jashore has only 5,816 ha of coastal agricultural land.

Table 5.6. Agricultural land areas in the coastal zone by district (values in the extreme right column indicate agricultural lands as proportions of the coastal area) in 2022

Division	District	Coastal area (ha)	Agriculture land (ha)	Agriculture land (%)
Khulna	Khulna	426609	74123	17.4
	Bagerhat	394955	46132	11.7
	Satkhira	333579	31624	9.5
	Jashore	5816	1779	30.6
	Narail	26169	14632	55.9
Barishal	Barishal	219011	89562	40.9
	Bhola	355871	88613	24.9
	Barguna	168133	76628	45.6
	Jhalakati	73361	34430	46.9
	Patuakhali	319653	152544	47.7
	Pirojpur	127348	49395	38.8
Chattogram	Chattogram	268334	78995	29.4
	Cox's Bazar	125127	28063	22.4
	Feni	32562	15658	48.1
	Lakshmipur	82211	27922	34.0
	Noakhali	304671	84275	27.7
	Chandpur	12107	3782	31.2
Dhaka	Gopalganj	21833	13187	60.4
	Shariatpur	11673	6195	53.1

Source: BARC 2022

The most significant land use intervention in the coastal zone has been the development of a system of polders since the 1960s, where areas of land are enclosed by embankments and the surface water levels are managed using drainage systems. The development of polders encouraged agriculture but, in the long run, has degraded soil quality by preventing the yearly accumulation of alluvium rich in plant nutrient. The embankments also resulted in land subsidence making drainage more difficult and promoting deeper flooding due to dike failures (Auerbach et al. 2015). Land use change has also disturbed the delicate balance between sea water and freshwater volumes (Lázár et al. 2015) which varies seasonally, inter-annually and spatially in response to changing patterns of precipitation, sea levels, extreme events and water management (Islam et al. 2015).

Land use patterns in the coastal zone of Bangladesh have gone through major changes over the last half century. Land is intensively used for agriculture, settlements, forests, shrimp ponds (known locally as *ghers*), water bodies and fisheries, salt production, industrial and infrastructure developments, tourism and preservation and management of environmentally important and special areas. With the continually increasing population, the following features emerged:

- demand for expansion in all land uses (urban area, settlement, shrimp, etc.),
- increasing demand for new uses (tourism, export-processing zones and others), and
- conversion of land from one use to another.

The above-mentioned circumstances call for planned management of land resources, including zoning. Natural events such as see level rise, tidal surge, flooding, climate fluctuations, and ecosystem dynamics may also initiate modifications of the land cover of coastal areas. Human/natural modifications of land cover in coastal areas have largely resulted in deforestation, biodiversity loss, global warming and increased incidences of natural disasters. Land cover changes also contribute to increasing the risk of floods in the coastal zone. Landless and marginal farmers in particular are affected by such natural calamities.

Agricultural land in coastal areas in the 19 districts has decreased by only 1.83% from 934,664 ha in 2015 (FD 2015) to 917,540 ha in 2022 (BARC 2022) (Table 5.7). The greatest decrease of agricultural land in coastal areas during the 7 years was noticed in Jashore (13.75%) followed by Chandpur (8.47%) and Lakshmipur (6.86%). However, despite an overall decrease, there was an increase in agricultural land in coastal areas of Shariatpur, Feni and Cox's Bazar districts ranging from 0.75-6.68%. The decrease in agricultural land in coastal areas could be attributed to encroachment of growing aquaculture into agricultural lands (Mukhopadhya 2018). In the lower Meghna region, saline waters intrude only during the dry season, with limited impacts on the costal environment. Even where soil and water conditions are favorable, cultivation and settlement development are constrained by frequent tidal surges and floods.

Mangrove areas have declined steadily during the last 20 years. In the 1990s, the southwestern coastal region experienced drainage congestion inside and heavy siltation outside the polders because of extensive embankment structures in a hydro-dynamically active delta, and subsequently the benefits of erecting the coastal embankments began to gradually evaporate. The area became unsuitable for agriculture and, in extreme cases, even for human habitation. On the contrary, polders have provided an opportunity for intensive shrimp farming. Many coastal polders constructed to protect agricultural land from inundation of salt water have been turned into large shrimp *ghers*. The priority is reversed, and saline water from outside the polder is purposefully introduced into the *ghers* to raise shrimp. Land previously used for agriculture and mangroves was transformed, more often than not, forcibly into shrimp *ghers.*

Table 5.7. Increase/decrease in agriculture land area in coastal zone by district

Division	District	Agriculture land (ha)		% increase/ decrease
		2015	2022	
Khulna	Khulna	74339	74123	-0.29
	Bagerhat	46181	46132	-0.11
	Satkhira	33240	31624	-4.86
	Jashore	2063	1779	-13.75
	Narail	15473	14632	-5.44
Barishal	Barishal	92221	89562	-2.88
	Bhola	92346	88613	-4.04
	Barguna	76688	76628	-0.08
	Jhalakati	34446	34430	-0.05
	Patuakhali	153420	152544	-0.57
	Pirojpur	49495	49395	-0.20
Chattogram	Chattogram	79635	78995	-0.80
	Cox's Bazar	27855	28063	0.75
	Feni	14792	15658	5.85
	Lakshmipur	29977	27922	-6.86
	Noakhali	89361	84275	-5.69
	Chandpur	4132	3782	-8.47
Dhaka	Gopalganj	13192	13187	-0.04
	Shariatpur	5807	6195	6.68
Total		934664	917540	-1.83

Source: FD 2015, BARC 2022

In Bangladesh, the coastal zone has a relatively high proportion, 48.37%, double cropped area while the national average is 50.9% (Figs. 5.26 and 5.27). Besides, there are 34.57% single cropped area and 17.06% triple cropped area in the coastal zone. This efficient land utilization in the coastal zone has been made possible by technological advancement in salinity tolerance of crops and production practices suitable for salinity affected areas.

In the coastal zone, the total areas under single, double and triple cropping are 273,117, 382,125 and 134,738 ha, respectively in 2022 (Table 5.8). Despite the dominance of double cropped areas in the coastal zone, overall, there are still relatively large areas under single cropping in Noakhali, Khulna,

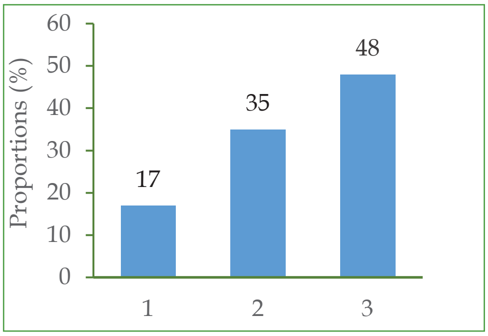


Fig. 5.26. Cropping situation in the coastal zone in 2022; 1= triple cropped area, 2= single cropped area, 3= double cropped area (Source: DAE 2022)

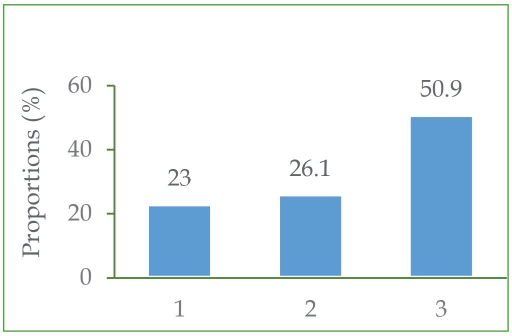


Fig. 5.27. Cropping situation in Bangladesh in 2020; 1= triple cropped area, 2= single cropped area, 3= double cropped area (Source: BBS 2020)

Table 5.8. Changes in cropping situation in the coastal areas

District	Single cropped area (ha)		% inc/ dec	Double cropped area (ha)		% inc / dec	Triple cropped area (ha		% inc / dec
	2010	2022		2010	2022		2010	2022	
Khulna	68277	37516	-45.1	39260	51753	31.8	7371	12799	73.6
Bagerhat	41670	29821	-28.4	10418	13013	24.9	1757	3270	86.1
Satkhira	51268	28055	-45.3	102650	58627	-42.9	34288	28514	-16.8
Bhola	3038	6308	108	0	12019	-	0	0	0.0
Barguna	11230	20330	81	10530	15260	44.9	19956	21911	9.8
Jhalakathi	20	60	200	0	0	0.0	0	0	0.0
Patuakhali	30120	28890	-4.1	90125	87487	-2.9	3918	10357	164
Pirojpur	792	415	-47.6	198	980	395	0	5	-
Chattogram	6945	15565	124	9200	11710	27.3	5075	7290	43.6
Cox's Bazar	4023	2648	-34.2	4402	5477	24.4	1200	2645	120
Feni	1651	2266	37.3	6467	1496	-76.9	2756	1821	-33.9
Laksmipur	5720	6760	18.2	13074	17080	30.6	4300	6190	44.0
Noakhali	76223	93512	22.7	81728	97437	19.2	45015	39560	-12.1
Gopalganj	0	10	-	0	0	0.0	0	0	0.0
Shariatpur	1830	961	-47.5	6850	9786	42.9	25	376	1404
Total	302807	273117	-9.8	374902	382125	1.9	125661	134738	7.2
Bangladesh	2439000	2110000	-13.5	3840000	4125000	7.4	1641000	1867000	13.8
inc- increase; dec- decrease									

Source: DAE 2022, BBS 2020

Bagerhat, Patuakhali and Satkhira districts. The triple cropped area has increased by 7.2% during 2010-2022 compared with 13.8% at the national level (Table 5.8). This increase occurred due to a conversion of single and double cropped areas into triple croped areas. A reduction in the single cropped area by 9.8% during 2010-2022 could have eventually led to the increase in the triple cropped area. The highest increase in triple cropping occurs in Shariatpur (1404%) followed by Patuakhali (164%) and Cox's Bazar (120%) while there is a decrease in Feni (33.9%) and Satkhira (16.8%) (Table 5.8).

The net cropped area has remained almost static during 2010-2022 although a slight decrease by 1.7% has occurred in the coastal areas (Table 5.9) which may be attributed to the utilization of some lands for development of infrastructure. Among the coastal districts, the greatest decrease in net cropped area has occurred in Feni (48.7%) followed by Satkhira (38.8%) while this decrease was negated by a significant increase in Bhola (503%), Jhalakati (200%) and Chattogram (62.9%).

Table 5.9. Changes in net cropped area in the coastal zone during 2010-2022

District	Net cropped area (ha)		% inc/dec
	2010	2022	
Khulna	114908	102068	-11.2
Bagerhat	53845	46104	-14.4
Satkhira	188206	115196	-38.8
Bhola	3038	18327	503
Barguna	41716	57501	37.8
Jhalakathi	20	60	200
Patuakhali	124163	126734	2.1
Pirojpur	990	1400	41.4
Chattogram	21220	34565	62.9
Cox's Bazar	9625	10770	11.9
Feni	10874	5583	-48.7
Laksmipur	23094	30030	30.0
Noakhali	202966	230509	13.6
Gopalganj	0	10	-
Shariatpur	8705	11123	27.8
Total	803370	789980	-1.7

inc- increase; dec- decrease
Source: DAE 2022

Among the coastal districts, the proportion of double cropped area is the highest (88%) in Shariatpur (Fig. 5.28) followed by Pirojpur (70%), Patuakhali (69%) and Bhola (66%) in 2022. Barguna has the highest proportion of triple cropped area (38%) followed by Feni (33%), Satkhira (25%) and Cox's Bazar (25%). The proportion of single cropped area is still the highest in Jhalokathi (100%) and Gopalganj (100%) followed by Bagerhat (65%), Chattogram (45%) and Feni (41%) compared to the proportions of double and triple cropped areas of these coastal districts. The predominance of single cropping in these coastal districts is primarily due to increasing salt intrusion and tidal flooding that prevent growing of crops during rainy season. Further technological advancement need to be ensured for conversion of single cropped areas into, at least, double cropped areas.

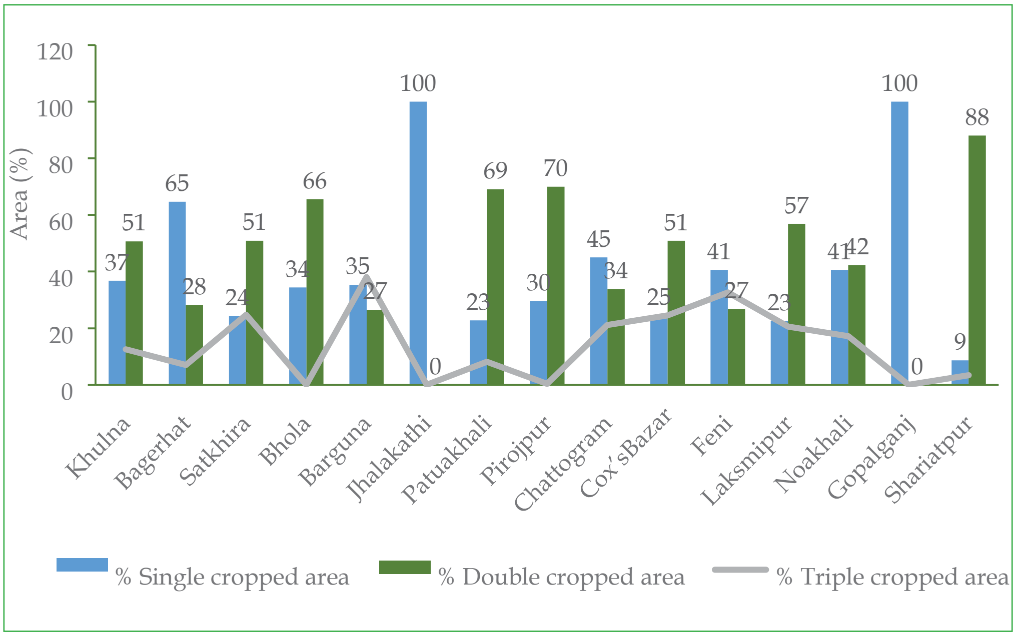


Fig. 5.28. Single, double and triple cropping proportions in coastal districts
(Source: DAE 2022)

It is interesting to note that, 14.8% of the fallow areas in the coastal zone has been vanished in 12 years from 2010 to 2022, the total fallow land area of 261,817 ha in 2010 having declined to 222,952 ha in 2022 (Table 5.10). This means that 38,865 ha of fallow land have been brought under cultivation during 2010 through 2022, which eventually has resulted in an increase in, at least, the single cropped area in the coastal zone. The deceasing trend was noticed in all the coastal districts ranging from 5.8-85.1% between 2010 and 2022 except in Lakshmipur, Feni and Satkhira which has experienced an increase in fallow land by a range of 9-32.5%. The largest decrease in fallow land (85.1%) occurs in Bhola followed by that in Shariatpur (71.6%) while the smallest is in Bagerhat (only 5.8%). There are still opportunities for the coastal zone to bring under cultivation the remaining fallow land (222,952 ha), i.e., 24% of the total agricultural land (920,692 ha), for at least a single crop during winter season. It also implies that there is enough scope of increasing the rice based cropping area and thus increasing rice cropping intensity in the coastal zone.

Table 5.10. Decrease in fallow land in the coastal areas

District	Fallow land (ha)		% inc/dec
	2010	2022	
Khulna	10967	10975	0.1
Bagerhat	7787	7332	-5.8
Satkhira	41403	45110	9.0
Bhola	12140	1807	-85.1
Barguna	260	130	-50.0
Jhalakathi	30	10	-66.7
Patuakhali	172269	146261	-15.1
Pirojpur	605	200	-66.9
Chattogram	3935	1780	-54.8
Cox'sBazar	5106	3143	-38.4
Feni	490	579	18.2
Laksmipur	1200	1590	32.5
Noakhali	4550	3720	-18.2
Shariatpur	1075	305	-71.6
Total	261817	222952	-14.8
Bangladesh	467000	431000	-7.7

inc- increase; dec- decrease

Source: DAE 2022

5.4.2 Crops and cropping patterns

Rice-based cropping is dominant in the coastal areas. Other crops like pulses, oilseed crops, watermelon, mustard, vegetables etc, are grown. In 2022, Fallow-Fallow-T.Aman is still the dominant cropping pattern in the coastal areas between 2010 and 2022 in most of the coastal districts (Table 5.11). Rice-pulse cropping is the second most prevalent cropping pattern in the coastal areas of Patuakhali, Barguna, Feni and Noakhali indicating an improvement of the cropping intensity over a 12-year period from 2010 (Table 5.11). Rice-oilseed crop-based cropping pattern is also prevalent in Lakshmipur and Shariatpur. Fallow-Fallow-T.Aman rice is a cropping pattern where crops are grown only in the Kharif II season (August-December) and land remains uncultivated during Rabi and Kharif I seasons. This narrow cropping base during Kharif season is primarily due to a rainfed situation which forces farmers to grow T. Aman rice as their major staple crop. Boro rice is practiced in the cropping patterns in Khulna, Bagerhat, Satkhira, Cox's Bazar, Noakhali, Gopalganj and Shariatpur.

Table 5.11. Changes in major cropping patterns in coastal areas

District	Major cropping patterns	
	2022	2010
Khulna	Fallow-Fallow-T. Aman (33) Boro-Fallow-T. Aman (44)	Fallow-Fallow-T. Aman (35) Boro-Fallow-T. Aman (20)
Bagerhat	Fallo- Fallo- T. Aman (45) Boro- Fallo- T. Aman (12)	Fallo- Fallow- T. Aman (43) Boro- Fallow- T. Aman (6)
Satkhira	Boro-Fallow-T. Aman (54) Fallow-fallow-T. Aman (16)	Fallow-Fallow-T. Aman (24) Boro-Fallow-T. Aman (22)
Bhola	Sweet potato- T./B. Aman (25) Chilli - T. Aman (23)	T. Aman (20)
Barguna	Mug-T. Aus -T. Aman (30) Water Melon -T. Aus-T. Aman (27)	Mug-T. Aus-T. Aman (15) Khesari-T. Aus-T. Aman (39)
Jhalakathi	Fallow-Fallow-T. Aman (86)	Fallow-Fallow-T. Aman (40)
Patuakhali	Mung-Fallow- T. Aman (42) Water melon-Fallow- Aman (16)	Mung-Fallow-T. Aman (20) Water melon-Fallow-T. Aman (18)
Pirojpur	Sweet gourd- Fallow- T. Aman (85)	Fallow- Fallow- T. Aman(80%)
Chattogram	Fallow-Fallow-T. Aman (91%)	Fallow-Fallow-T. Aman (95)
Cox's Bazar	Betel Leaf- Betel Leaf - Betel Leaf (55) Boro-Fallow-T. Aman (14)	Fallow – T. Aman- Falow (57) Boro-Fallow-T. Aman (16)
Feni	Fallow-Fallow-T. Aman (41) Pulse-Fallow-T. Aman (21)	Fallow-Fallow-T. Aman (51) Pulse-Fallow-T. Aman (16)
Laksmipur	Soyabean-Fallow-T. Aman (37) Groundnut- Fallow- T. Aman (19)	Soyabean-Fallow-T. Aman (35) Groundnut – Fallow- T. Aman (13)
Noakhali	Boro-Fallow- Fallow (29) Fallow- Fallow-T. Aman (11) Kseshri-Fallow-T. Aman (11)	Boro-Fallow- Fallow (20) Oil crop-Aus-T. Aman (18) Fallow -Fallow- T. Aman (19)
Gopalganj	Boro-Fallow-Fallow (100)	-
Shariatpur	Boro- Fallow-Fallow (19) Pepper- B. Aus- Fallow (17) Mustard- Jute- Fallow (15)	Boro- Fallow-Fallow (20) Pepper –B. Aus -Fallow (15) Mustard- Jute- Fallow (17)

Source: DAE 2022

5.4.3 Livestock and poultry

Because of environmental and social impacts associated with shrimp cultivation, farmers of the coastal areas are incorporating domestic animals into existing farming practices, integrating shrimp or prawn and fish with rice and vegetables. People of the coastal areas are trying different agricultural practices to cope with the changing environment (Mahmood 2006). In 2019, the total livestock and poultry head counts in the coastal areas were 90.1 million accounting for 22.4% of the total counts of livestock and poultry (403 million) in Bangladesh (Fig. 5.29). In 2012, the livestock and poultry head counts in the coastal areas was 77 million accounting for 22.6% of the total counts of livestock and poultry (341 million) in Bangladesh (Fig. 5.29). Thus, the livestock and poultry head counts in 2019 has increased by 17.01% compared to that of 2012. Out of the 19 coastal districts, 10 districts have experienced an increase of the total populations of livestock and poultry in their coastal areas ranging from 2.7-4.2 million in 2012 to 3.2-15.2 million in 2019, which amounted to a range of 19 – 262% increase over 7 years (Fig. 5.30). However, the coastal areas of the other nine districts have noticed a decrease of livestock and poultry ranging from 3.0-6.6 million in 2012 to 0.4-5.1 million in 2019, which amounted to a range of 22.7-86.7% decrease over 7 years (Fig. 5.30). The highest increase of the total livestock was recorded in Bhola district by 262% from 4.2 million heads in 2012 to 15.2 million in 2019 followed by Noakhali (67.7%; from 6.2 million in 2012 to 10.4 million in 2019) and Barishal (58%; from 5.0 million in 2012 to 7.9 million in 2019). On the other hand, the highest decrease of the total livestock was noticed in Gopalganj district by 87% from 3.0 million in 2012 to 0.4 million in 2019 followed by Shariatpur (72%), Feni (69%) and Satkhira (42%).

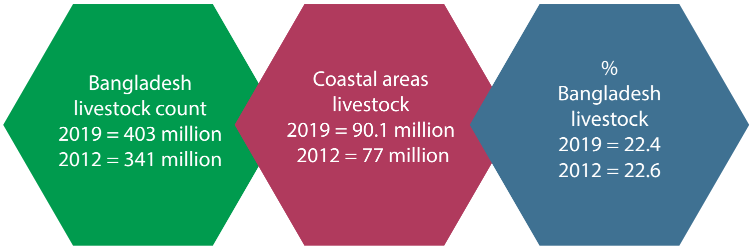


Fig. 5.29. Livestock heads in the coastal zone and in Bangladesh overall (Source: DLS 2019)

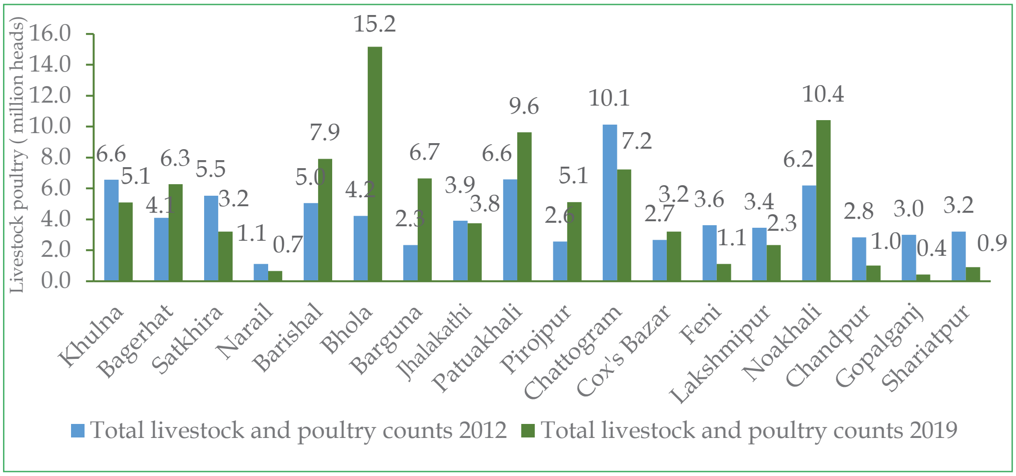


Fig. 5.30. Livestock and poultry population (in million heads) in the coastal zone by district (Source: DLS 2019)

The livestock numbers have decreased alarmingly in almost half of the coastal districts. One of the reasons for this is the continual shrinking of pastures. On the other hand, the usefulness of cattle in farm operations has diminished, farmers now can hire machines for tillage and post-harvest operations. With human population growth, homesteads are becoming smaller in size inhibiting livestock rearing, and farmers are often forced to sell livestock during crises of cash. Due to the high dependence on the salinity affected fodder crops, livestock are affected by many negative consequences such as diarrhoea, skin diseases, liver fluke, loss of body weight, and breakdown of the immune system.

In the coastal areas, between 2012 and 2019, the populations of cattle and goat have declined from 7.08 to 5.88 million and 2.92-2.81 million which amounted to 17% and 4% decreases, respectively (Table 5.12). Despite decline over time, cattle and goat currently comprised 24.3% and 10.7% of their total population in Bangladesh. However, the buffalo and sheep population have increased by 48% from 0.454 million in 2012 to 0.67 million in 2019 and 96% from 0.214 million in 2012 to 0.420 million in 2019, respectively. Buffalo and sheep

Table 5.12. Changes in livestock population (in million heads) in the coastal zone

District	Livestock count (in million heads)							
	Cattle		Buffalo		Goat		Sheep	
	2012	2019	2012	2019	2012	2019	2012	2019
Khulna	0.479	0.582	0.003	0.0009	0.219	0.373	0.023	0.019
Bagerhat	0.313	0.398	0.016	0.016	0.162	0.295	0.002	0.025
Satkhira	0.486	0.538	0.001	0.0006	0.303	0.349	0.046	0.057
Narail	0.116	0.081	0.0001	0	0.073	0.042	0.002	0.00008
Barishal	0.563	0.336	0.010	0.077	0.135	0.231	0.003	0.011
Bhola	0.384	0.965	0.091	0.222	0.205	0.448	0.013	0.039
Barguna	0.318	0.308	0.032	0.048	0.113	0.117	0.002	0.011
Jhalakathi	0.138	0.123	0.004	0.0037	0.041	0.076	0.003	0.0011
Patuakhali	0.633	0.563	0.128	0.136	0.188	0.211	0.011	0.108
Pirojpur	0.022	0.139	0.007	0.016	0.213	0.145	0.011	0.0015
Chattogram	1.255	0.978	0.079	0.0297	0.405	0.2065	0.051	0.0507
Cox's Bazar	0.445	0.227	0.035	0.0251	0.216	0.0698	0.020	0.03804
Feni	0.257	0.066	0.003	0.0047	0.072	0.0085	0.002	0.0182
Lakshmipur	0.308	0.0769	0.014	0.0254	0.085	0.021	0.003	0.0028
Noakhali	0.439	0.318	0.031	0.065	0.119	0.126	0.016	0.031
Chandpur	0.272	0.072	0.000	0.00052	0.119	0.0408	0.002	0.00227
Gopalganj	0.405	0.046	0.002	0	0.105	0.0095	0.004	0.0002
Shariatpur	0.247	0.06	0.000	0.001	0.149	0.037	0.001	0.0018
Total (in coastal areas)	7.08	5.88	0.454	0.67	2.92	2.81	0.214	0.42
Bangladesh	23.2	24.2	1.44	1.48	25.1	26.27	3.08	3.54
% of Bangladesh	30.5	24.3	31.6	45.4	11.6	10.7	6.9	11.8

Source: DLS 2019

population of coastal areas constitute 45.4% and 11.8%, respectively of their total population in Bangladesh. The cattle population has decreased in all the coastal districts between 2012 and 2019 except in Khulna, Satkhira, Bhola and Pirojpur where an increase has occurred. The goat population has also decreased in the nine coastal districts viz. Narail, Pirojpur, Chattogram, Cox's Bazar, Feni, Lakshmipur, Chandpur, Gopalganj and Shariatpur.

Coastal areas are very potentials for livestock rearing particularly cattle and buffaloes. During early eighties the southern part of Khulna, Bagerhat and Satkhira districts had enough naturally grown grasses inside the polder. The land inside the polder had been cultivated for a single crop in a year. Therefore, there were enough grazing facilities and the rich and middle-class farmers had large herd of cattle and buffaloes. But the reduction in number started with the intrusion of saline water and logging of saline water inside the polder. Intrusion was due to damage of the polder that occurred due to successive cyclone led tidal surges in 1991, and also induced for shrimp culture by the influential land owners and making the small or subsistence farmers compelled to allow their lands for shrimp culture activities.

The poultry population has, by and large, increased in coastal areas of nine districts which contributed to a 22% increase overall in coastal areas from 52.4 million in 2012 to 64.1 million in 2019 (Table 5.13). The duck population increased in coastal areas of nine districts which contributed to a 16% increase overall in coastal areas from 13.98 million in 2012 to 16.19 million in 2019. Poultry and duck population in coastal areas currently constitute 22.2% and 28%, respectively of their total population in Bangladesh. In the coastal area, poultry farming is limited to females who are also involved in duck and livestock rearing. Children from poor households are employed in herding cattle but such labor inputs reduce average literacy rates.

Duck production in the coastal districts of Bangladesh provides self-employment for landless and small farmers. There is a great opportunity for improving the productivity of ducks in coastal and haors areas through supplementary feeding. Ducks, being an important poultry species, can contribute efficiently to increasing egg and meat production than chicken in the coastal or low-lying areas in southern districts.

Poultry rearing is a supportive activity in the coastal areas and land involved in poultry farming have been increased 20 to 30 times more than the previous decades (Miah 2010). Besides, farmers in some parts of the coastal areas are also incorporating native poultry rearing on scavenging basis along with crop farming. Rahman et al. (2009) found that rearing of poultry gives the maximum return with the minimum cost. Moreover, poultry production in the coastal districts of Bangladesh provides self-employment for landless and small farmers, especially for women.

Table 5.13. Changes in poultry population (million heads) in the coastal zone

District	Poultry count (in million heads)			
	Poultry		Duck	
	2012	2019	2012	2019
Khulna	5.00	3.68	0.83	0.44
Bagerhat	3.15	4.52	0.45	1.02
Satkhira	4.37	1.88	0.33	0.37
Narail	0.74	0.36	0.18	0.18
Barishal	3.66	5.60	0.67	1.66
Bhola	2.18	9.36	1.35	4.12
Barguna	1.44	4.92	0.44	1.25
Jhalakathi	3.16	2.82	0.56	0.73
Patuakhali	3.75	6.45	1.87	2.16
Pirojpur	1.34	4.72	0.98	0.10
Chattogram	7.78	5.57	0.56	0.39
Cox's Bazar	1.74	2.74	0.22	0.10
Feni	2.55	1.00	0.73	0.02
Lakshmipur	2.35	1.94	0.69	0.27
Noakhali	3.67	7.03	1.93	2.84
Chandpur	1.51	0.69	0.94	0.22
Gopalganj	1.77	0.25	0.71	0.13
Shariatpur	2.24	0.61	0.56	0.20
Total (in coastal areas)	52.4	64.1	13.98	16.19
Bangladesh	242.9	289.28	45.7	57.75
% of Bangladesh	21.6	22.2	30.6	28.0

Source: DLS 2019

5.4.4 Fisheries and aquaculture

Coastal fish and fisheries are one of the major parts of the total country fisheries production contributing 60% of our daily animal protein (BER 2016). About 508,830 people of coastal areas are directly dependent on fisheries (FRSS 2016). About 475 coastal and marine species and 36 shrimps are available in the Bay of Bengal (BoB) (DoF 2016). At present coastal fisheries are facing many problems such as overfishing, indiscriminate killing of juveniles, pollution, disease defectives and inadequate knowledge etc.

In the coastal zone, annual fish catch area in 2022 was about 787,257 ha, 23.8% of the total coastal area (3,309,021 ha) and constitutes 20.4% of the total inland open water areas of Bangladesh (3,866,091 ha) (Table 5.14). Inland open water capture fisheries in coastal areas are, therefore, important to the country's overall economy.

Table 5.14. Fish catch areas in the coastal zone in 2022

Bangladesh inland open water area (ha)	Coastal area (ha)	Annual fish catch area (ha)	% coastal area	% Bangladesh inland open water area
3,866,091	3,309,021	787,257	23.8	20.4

Source: BARC 2022, BBS 2021

The open-water fishery is a self-sustaining system although human interventions have significantly deteriorated its health and productivity in recent years. A small improvement in the average yield of inland open water capture fisheries in coastal areas could significantly affect national fish production and consumption. Siltation and lowering water level in rivers and canals are reducing the wintering habitat for indigenous fish species. Moreover, the coastal areas came under pressure for conversion to crop fields and other infrastructures, resulting in an alarming decline in fish diversity and production.

Among the coastal districts, Bhola accounts for the highest annual fish catch area (161,457 ha) followed by Noakhali (112,325 ha), Khulna (85,501 ha) and Patuakhali (77,308 ha) comprising 45.4%, 36.9%, 20% and 24.2%, respectively of the coastal areas of the respective coastal district (Fig. 5.31).

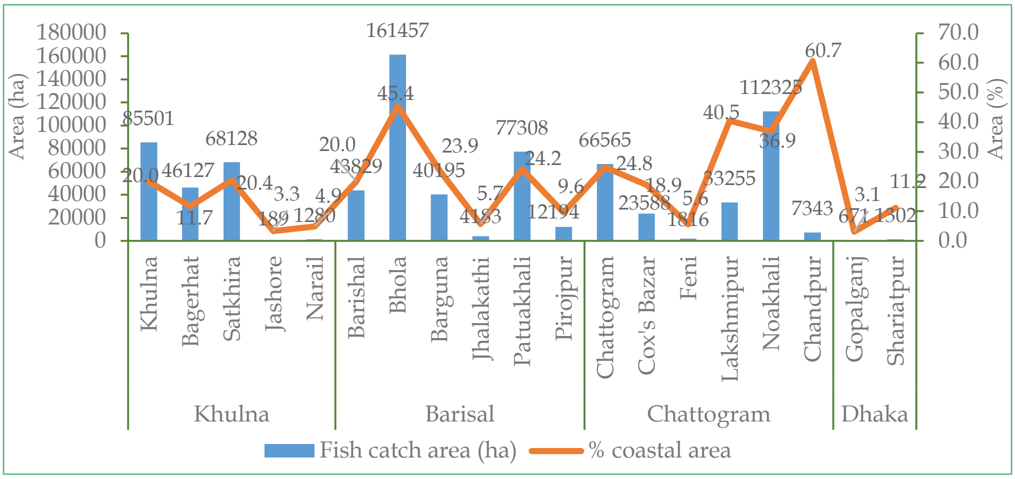


Fig. 5.31. Status of recent fish catch area in the coastal zone by district in 2022
(Source: BARC 2022)

Open water fish catch area in coastal zone is reported to have decreased by 3.89% from 819,092 ha in 2015 to 787,257 ha in 2022 (Table 5.15). On the contrary, total inland water area of Bangladesh has decreased by 1.03% during the same period. This indicates an important role the coastal zone plays in open water fish production in Bangladesh.

Table 5.15. Changes in fish catch areas in the coastal zone

Fish catch domain	Fish catch area (ha)		
	Annual fish catch area in 2015	Annual fish catch area in 2022	% increase/ decrease
Coastal area	819,092	787,257	-3.89
Bangladesh inland open water area	3,906,434	3,866,091	-1.03

Source: BBS 2015, 2020

Brackish water is water that has more salinity than fresh water, but not as much as seawater. It may result from mixing of seawater with fresh water, as in estuaries, or it may occur in brackish fossil aquifers. Thus, brackish water covers a range of salinity regimes and is not considered a precisely defined condition. It is characteristic of many brackish surface waters that their salinity can vary considerably over space and/or time. Brackish water environment includes estuaries, mangroves and brackish lakes and the species included are cultured shrimp, live crab and cuchia and to some extent, cultured coral (Sea Bens/ Vatki).

Brackish water aquaculture was practiced mainly in Khulna, Bagerhat, Satkhira and Cox's Bazar, and the total area has decreased by 5% from 156,711 ha in 2015 to 148,951 ha in 2022 (Table 5.16). All these 4 districts have experienced a decline of their brackish water aquaculture areas by a range of 1-7% except that Cox's Bazar district has got an increase of brackish water aquaculture area by 6% from 4,855 ha in 2015 to 5,159 ha in 2022. The main cultivated species is marine tiger shrimp (*Penaeus monodon*) locally called

Table 5.16. Changes in Brackish Water Aquaculture area in the coastal zone

District	Brackish Water Aquaculture (ha) in 2015	Brackish Water Aquaculture (ha) in 2022
Khulna	38556	36005
Bagerhat	35225	34845
Satkhira	78075	72941
Cox's Bazar	4855	5159
Total	156711	148951

Source: FD 2015, BARC 2022

bagda chingri. In certain geographical locations, sea level rise and tidal surge lead to frequently inundation of coastal lands that can reduce availability of brackish water aquaculture area and lead loss of shrimp stocks (Pillai and Muralidhar 2006).

Apart from *P. monodon*, giant freshwater shrimp (*Macrobrachium rosenbergii*) referred *golda chingri* also a prominent species culture was practiced in coastal freshwater environment. The ecological and climatic conditions of coastal areas are extremely suitable for shrimp culture with very low production cost (Islam and Wahab 2005). All the coastal districts except Chandpur have freshwater aquaculture areas where *galda chingri* was mainly cultured.

The total freshwater aquaculture areas in these coastal districts have increased by 9% from 102,550 ha in 2015 to 111,871 ha in 2022 (Table 5.17). The freshwater aquaculture area of almost all the coastal districts remained static except a significant increase of this area in Khulna, Satkhira and Jashore, and a slight decrease in some districts viz, Chattogram, Feni, Lakshmipur and Noakhali. Between 2015 and 2022, Khulna, Satkhira and Jashore got an increase of their freshwater aquaculture areas by 9%, 51% and 17% from 27,473 ha to 29,952 ha, 13,112 ha to 19,797 ha and 1,592 ha to 1,864 ha, respectively.

Table 5.17. Changes in Fresh Water Aquaculture area in the coastal zone

District	Fresh Water Aquaculture (ha) in 2015	Fresh Water Aquaculture (ha) in 2022
Khulna	27473	29952
Bagerhat	44159	44159
Satkhira	13112	19797
Jashore	1592	1864
Narail	667	672
Barishal	262	262
Bhola	148	148
Barguna	85	85
Jhalakathi	165	165
Patuakhali	46	46
Pirojpur	6738	6738
Chattogram	2018	1980
Cox's Bazar	4	4
Feni	787	771
Lakshmipur	210	206
Noakhali	2989	2925
Gopalganj	2019	2019
Shariatpur	76	76
Total	102550	111871

Source: FD 2015, BARC 2022

Considering high market value and growth rate, culture of sea bens has a great profitability in niche range of habitats like freshwater pond, brackish water and eggs culture in coastal areas of Bangladesh (Khan et al. 2013). Brackish water aquaculture, also known as coastal aquaculture, is a rapidly expanding farming activity and plays an important role in the overall fisheries development effort in Bangladesh. *Bagda* shrimp (black tiger shrimp, *Penaeus monodon*) is the primary target of culture species, while *bagda* fish, heterogeneous shrimp and crabs are the by-products. Brackish water aquaculture has been a definite economic activity since the early seventies when Bangladesh started exporting shrimp.

5.4.5 Forestry

Globally mangroves are important forest resources for the coastal people as it provides diversified benefits to human beings (economic, ecological, and cultural) to support their livelihood activities. Moreover, it is considered as a natural barricade against cyclones shielding lives and property of the coastal people. Unfortunately, the mangrove area experiences a sharp decrease during the last decades, and it is still declining. The reduction rate is more pronounced in developing countries due to anthropogenic pressure (Duke et al. 2007). The rapid degradation and depletion of mangroves have impacted negatively on the livelihoods and wellbeing of the local communities. The case is worse in Bangladesh as more than 35 million people live in the coastal area of Bangladesh, representing 29% of the total population (Ahmad 2019) and more than half of this coastal (nearly 52%) of people directly depend on forest resources for their livelihoods (Islam and Rahman 2015).

Only 13.99% (462,928 ha) of the total coastal areas of the 19 coastal districts (3,309,021 ha) is covered by forest in 2022 (Table 5.18) in comparison with the overall 17.78% forest area in Bangladesh. A country or any geographic area should have at least 25% forest cover to maintain a proper ecological balance, and thus, the coastal area falls far behind this threshold. Among the coastal districts Bagerhat has the highest forest cover (38%) with 150,325 ha followed by Khulna (34%) with 147,095 ha while the lowest, only 0.10%, is in Narail (26 ha). Chandpur and Lakshmipur have virtually no forest cover. Forest covers in the coastal districts shrank from 469,016 ha in 2015 to 462,928 ha in 2022 amounting to a 1.3% decline over the 7 years (Table 5.19). All the coastal districts experienced a decline in forest cover during this period except Barguna, Patuakhali and Cox's Bazar that saw a 4.6%, 0.7% and 0.6% increase, respectively, and some districts viz, Bagerhat, Jashore, Jhalakathi, Chandpur, Gopalgang and Shariatpur noticed no change.

The coastal afforestation activities started in Bangladesh back in 1965. By 2013, the Forest Department of Bangladesh established plantation in 209,140 ha of coastal area of which more than 93% was with mangrove species

(DoE 2015). The Forestry Sector Master Plan (FSMP) 2017–2036, however, noted that due to the failure and destruction from natural calamities, the actual area under coastal plantation stood 61,574 ha (BFD and UNDP 2018).

Table 5.18. Forests in the coastal districts in 2022

District	Coastal area (ha)	Forest area (ha)	% Forest area
Khulna	426609	147095	34
Bagerhat	394955	150325	38
Satkhira	333579	103497	31
Jashore	5816	9	0.15
Narail	26169	26	0.10
Barishal	219011	500	0.23
Bhola	355871	12684	3.56
Barguna	168133	5557	3.31
Jhalakathi	73361	1376	1.88
Patuakhali	319653	13400	4.19
Pirojpur	127348	2158	1.69
Chattogram	268334	5795	2.16
Cox's Bazar	125127	7906	6.32
Feni	32562	366	1.12
Lakshmipur	82211	15	0.02
Noakhali	304671	12143	3.99
Chandpur	12107	0	0.00
Gopalganj	21833	50	0.23
Shariatpur	11673	26	0.23
Coastal zone	3309021	462928	13.99
Bangladesh	14486269	2575196	17.78

Source: BARC 2022, BBS 2021

The Forest Department (FD) of Bangladesh, as a part of its annual development program, has been leading the coastal afforestation program to stabilize Bangladesh's coastline and create green belt. As a climate change adaptation measure, the BFD has started involving community people through initiatives like

a) Community Based Adaptation to Climate Change through Coastal Afforestation Project (2008−2016).
b) Climate Resilient Participatory Afforestation and Reforestation Project (2013−2016) and Integrating Community-based Adaptation into Afforestation and Reforestation (ICBA-AR) Programme in Bangladesh (2016−2020).

Table 5.19. Changes in forest cover over time in the coastal zone

District	Forest area (ha) in 2015	Forest area (ha) in 2022	% increase/ decrease
Khulna	147363	147095	-0.2
Bagerhat	150344	150325	0.0
Satkhira	103671	103497	-0.2
Jashore	9	9	0.0
Narail	27	26	-0.3
Barishal	1520	500	-67.1
Bhola	13517	12684	-6.2
Barguna	5310	5557	4.6
Jhalakathi	1376	1376	0.0
Patuakhali	13308	13400	0.7
Pirojpur	4192	2158	-48.5
Chattogram	6414	5795	-9.7
Cox's Bazar	7856	7906	0.6
Feni	511	366	-28.4
Lakshmipur	17	15	-14.1
Noakhali	13506	12143	-10.1
Chandpur	0	0	0.0
Gopalganj	50	50	0.0
Shariatpur	26	26	0.0
Coastal area	469016	462928	-1.3
Bangladesh	2574587	2575196	0.02

Source: FD 2015, BARC 2022, BBS 2015, BBS 2021

This approach was followed by "Climate Resilient Ecosystems and Livelihoods" (CREL, 2013−2018) project and is currently being followed by "Sustainable Forests and Livelihoods" (SUFAL, 2018−2023)- the largest-ever project in Bangladesh's forestry sector. Initiatives with community participation always have benefit-sharing mechanism inbuilt following the Social Forestry Rules, 2004 or similar project-specific arrangements.

National Adaptation Plan of Actions and Bangladesh Climate Change Strategy and Action Plan developed in 2009 have identified coastal afforestation with the participation of local community as top adaptation priority for coastal areas. The Seventh Five-year plan set a target of 30,000 hectares coastal afforestation between 2016 and 2020 and suggest creating 500-meter-wide permanent coastal green belt. Emphasis has also given in community participation in the coastal afforestation to adapt and mitigate the climate change impacts.

From mitigation perspective, Bangladesh sets its target to continue coastal mangrove plantation in the Intended Nationally Determined Contributions

(INDC) (MoEF 2015). In 2013, National Sustainable Development Strategy (NSDS) of Bangladesh also emphasized on continuing the existing coastal afforestation and plantation enrichment programs. Bangladesh National Conservation Strategy (2016−2031) also highlights coastal afforestation and the need to redefine the coastal forested khas (government-owned) land to manage them from leasing to other activities. The present National Biodiversity Strategy and Action Plan (NBSAP 2016−2021) also mentions about target on forestry towards biodiversity conversation and this is aligned with the SDG target 15.2.

5.5 Cross-cutting issues

5.5.1 Agricultural mechanization

Tilling, irrigation, pesticide application, and threshing operations are mostly mechanized, and transplanting and harvesting are also gaining its ground for mechanization in the northern and northeastern areas of Bangladesh. However, in the southern delta and coastal zones of Bangladesh, mechanization is lagging as well as challenging. Many lands in these areas are within polders, which are vulnerable to rising sea level and flooding. This compels farmers to grow only a single crop making agricultural productivity in these zones low. The Government of Bangladesh has approved a mega project worth around USD 360 million for popularizing and disseminating appropriate agricultural machinery for transplanting, harvesting, and drying, among other farm operations (Yadav and Jagadish 2021). The government will provide 70% subsidy on the machines in haor (low-lying area) and coastal areas; and 50% to the rest of the areas in Bangladesh. The subsidy would undoubtedly help popularize the use of appropriate machinery. But, to increase the success in machinery adoption in the polder zones the farmers and communities should be aware on the benefits of farm machines and how to operate them through field days and fairs. It also needs capacity building of operators, local workshops, demonstrations, as well as engagement of women and youth.

The early planting allows better use of the residual moisture. However, later in the season, the dry soil often cracks and ruptures roots and inhibits crop growth and productivity. It is also difficult to apply fertilizer and manage weeds if the soil is not tilled and dry. Shallow tillage using mini tillers solves these problems by pulverizing the soil between crop rows and break capillaries and thus, tilling slows down the drying of the soil. The farmers can easily incorporate fertilizer and control weeds through tillage. However, mini tillers are not readily available in the coastal zone of Bangladesh. The result of a project was a 60-cm wide mini-tractor, resembling a small version of a power tiller (Yadav and Jagadish 2021). The Mechanic bought a 5-hp diesel engine and other accessories from a local market and took help from a blacksmith to prepare the blades or tynes of the mini-tractor. The project has developed a semi mechanized cropping practice for the dry season using this mini-tiller in the polder zone. In this method, seeds of maize and sunflower (and any row crop) are sown manually by dibbling (zero tillage) on wet soil after rice harvest within the second half of December. This allows the farmers to take advantage of the residual soil moisture during the initial growth and development of rabi crops. When the soil is ready for tillage, about a month after sowing and when the crops are 15–30 cm tall, a farmer can plow the topsoil between rows with the mini-tractor. Moreover, the rabi crops established by dibbling on moist soil in the third or last week of December can be harvested within April, before the start of the cyclonic season.

5.5.2 Irrigation

About 43% (339,979 ha) of the net cropped area in the coastal zone (789,980 ha) has been brought under irrigation by 2022 (Table 5.20) while in Bangladesh, overall, almost 50% lands are now irrigated. Over the last 12 years, the total irrigated areas of the coastal zone have increased by 30.6% from 260,257 ha in 2010 to 339,979 ha in 2022. Among the coastal districts, Gopalganj has the largest (100%) irrigation acreage followed by Satkhira (91.8%) and Khulna (75.1%) while Barguna has the lowest (4.3%) acreage. Over the 12 years, Jhalakathi has the highest increase of irrigation coverage (100%) followed by Barguna (92.3%) and Chattogram 84.7%. However, scarcity of water due to

Table 5.20. Status of irrigation in the coastal areas

District	Irrigated area (ha) in 2010	% irrigated area	Irrigated area (ha) in 2022	% irrigated area	% increase/ decrease
Khulna	47810	41.6	76700	75.1	60.4
Bagerhat	4450	8.3	7320	15.9	64.5
Satkhira	94490	50.2	105720	91.8	11.9
Bhola	0	0.0	0	0.0	0.0
Barguna	1300	3.1	2500	4.3	92.3
Jhalakathi	5	25.0	10	16.7	100
Patuakhali	45757	36.9	34150	26.9	-25.4
Pirojpur	0	0.0	70	5.0	700
Chattogram	4175	19.7	7711	22.3	84.7
Cox'sBazar	4625	48.1	7305	67.8	57.9
Feni	205	1.9	445	8.0	117
Laksmipur	1250	5.4	2090	7.0	67.2
Noakhali	54430	26.8	88520	38.4	62.6
Gopalganj	0	0.0	10	100	1000
Shariatpur	1760	20.2	7428	66.8	322
Total	260257	32.4	339979	43.0	30.6
Bangladesh	7407000	48.6	7879000	49.1	6.4

Source: DAE 2022

drying up of the canals and increased intrusion of saline water due to tidal surge at the end of the monsoon season hampers irrigation. In some years, prolonged drought spells occur.

5.5.3 Agricultural marketing

The players in the fishery, livestock and crop including vegetable supply chain consisted of producers, collectors or transporters, wholesalers, *paikers*, retailers, and hypermarkets or supermarkets. The intermediaries consume a large share of the profit, and the primary producer (farmer) is left with only a marginal profit. The farmers are not satisfied with the *paikers* as at this stage of the market chain it is an almost total buyer's (*paiker's*) monopoly because the farmers are neither organized nor skilled enough for bargaining with the *paikers*. There are different types of input suppliers that are active and catering to the different kinds of crop/vegetable cultivators, seasonal and commercial agro farms and marginal farmers. The marginal farmers mostly buy their inputs, mainly seeds or seedlings, from the local bazaar, mainly from the mobile vendors/sellers who sit on the floor of main bazaars. These input sellers generally sell quality seeds and seedlings grown from unknown branded seeds. The input retailers, with their own establishments in the bazaars, tend to sell different kinds of inputs – seeds, fertilizers, and pesticides. These suppliers, who buy their products from the selected input dealers, and input suppliers have very little data on technical issues of using different inputs. However, they are interested in providing cultivation advice to market their products better. Most farmers also tend to use their own seeds for certain vegetables, like potato, brinjal, lady's finger, etc.

About 20 million coastal inhabitants are representatives of the poorest and most marginalized groups of the nation; 20% of people directly rely on the coastal and marine resources for maintaining their livelihood (Islam 2003). They live exclusively on fishing, either as boat owners or as laborers, processing, and marketing of agricultural products. The market for several of these products is promising, but the people are involved early in the production chain, in fishing, primary processing and local trading, add little value, and therefore, can make a little profit. The low returns experienced by these groups are partly related to poor product quality and partly to lack of bargaining power in the marketing networks.

The vegetable and fish producers sell the products in the nearby market and the fishery ghat (in case of captured fish). In a few belongings, the agricultural crop producers having many productions and huge amounts of catch have started to bring their products to wholesale marketing in nearby urban markets. During the peak season of agricultural product marketing, sometimes the producers are observed to go to district markets to vend their fish and vegetables having the highest quality price. Maximum vegetables and fish producers usually sell crop products to *beparies* at the fish landing station and *bazaar* points and to some extent, inter-district *aratdar* and agencies.

Demands for poultry, cattle and sheep are very high. Sheep is profitable and easy to rear compared with goat as they eat any grass, even rice straw during floods and are less susceptible to diseases. It is also reported that local improved breed of poultry Fayomi has a great potential in the market.

There are empty storage services, and an immediate requirement for financial need forces the farmers to sell the crop/vegetables instantly after the time of collection from the crop land. They carry on head loads and make use of locally available small vans to transport the crop products into the local markets from crop fields. This was found from the different documents about the supply chain of Bangladesh that nearly 66% of the crop farmers sold their product in nearby weekly markets, and almost 22% of farmers were involved in selling the products around their local daily markets (Das and Hanaoka 2010). This is a common scenario that the small size of the market and carrying process, the underprivileged condition of the different infrastructure, and inadequate condition of the storage services strengthens the value instability. Agriculture farmers generally acquire valuable information from various crop farmers, businessmen, traders, broadcasting media and print media.

Coastal people apply indigenous knowledge for quick and immediate value chain approach for better utilization of fish marketing into the local and big market of fisheries product nearby area and urban city. This process helps them for availing high-income-generating opportunities within a short time against economic losses due to natural disasters and immediate responses to upcoming natural disasters. Transportation is an elementary utility of making fishing products available in proper place and it creates place utility. Coastal people habituate to transport the culture and captured fisheries product in the market through different ways of movements in the commercial places from the producing center.

Because of a remote place, there is a lack of opportunities for the establishment of a standard value chain model in these areas. If there is certainty about their crop, farmers will stimulate large-scale fish farming. Apparently, primary fisheries markets should be made gratis from the control of *arotdars* to construct the market so that fishermen could receive a fair price to boost their sales revenue. Besides this, the fish landing center with all carrier services will create *arat* business for the advantage of fish farmers in the long run.

5.6 Advances in coastal agriculture

5.6.1 Crop

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) of Australia has been leading a research project, "Cropping System Intensification in the salt-affected coastal zones of Bangladesh and West Bengal, India" since 2015 (Yadav and Jagadish 2021). The project has been funded by the Australian Centre for International Agricultural Research (ACIAR) and Krishi Gobeshona Foundation (KGF) of Bangladesh in partnership with Murdoch University of Australia, Bangladesh Agricultural Research Institute (BARI), Bangladesh Rice Research Institute (BRRI), Institute of Water Modelling (IWM), and Khulna University from Bangladesh. In addition, ICAR-Central Soil Salinity Research Institute (CSSRI), Bidhan Chandra Krishi Viswavidyalaya (BCKV), and Tagore Society for Rural Development (TSRD) from West Bengal, India are involved as partners of this project. The project aimed to sustainably raise 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 covered three selected polders, including Amtali, Barguna and Dacope, Khulna and Gosaba Island in West Bengal, India. The project has contributed to the following lessons:

1. Surface water, groundwater, and salinity interaction models for the polders can be assisted in simulating scenarios such as saline groundwater pumping for drainage and climate change impact.
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 T. Aman rice such as BRRI dhan87, BRRI dhan77, and BRRI dhan76 for Bangladesh are suitable, profitable, and preferred by the farmers. These varieties yield half to one ton higher than existing varieties per hectare; 15–20 days shorter, which allows early sowing of Rabi crops; and provide more than 50% higher net benefit.
4. Growing T. Aus rice (BRRI dhan48) in the Kharif-I season is feasible (the average yield is more than four tons per hectare) and profitable in Bangladesh. Farmers can grow T. Aus rice in the coastal area to intensify their cropping system, an option that is becoming popular for them. Boro rice varieties (BRRI dhan67, Binadhan-10) were introduced in the project sites in Bangladesh and was found highly suitable (average yield is more than 6 tons per hectare), profitable and adopted by the farmers.
5. In Bangladesh, several new crops such as foxtail millet, English spinach, barley, garlic, along with sunflower, maize, mustard, pumpkin, among others are suitable and profitable for cultivation. The optimum sowing

time, establishment methods (zero tillage, dibbling, transplanting, use of machiner), 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 has also been successful at Dacope.
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 T. Aman rice-sunflower /maize-T. Aus rice, T. Aman rice-Boro rice, T. Aman rice-T. Aus rice, T. Aman rice-spinach/ mustard/garlic/ZT potato- T. Aus rice, among others.

5.6.2 Livestock

Native chicken has been found to outperform in the coastal areas in terms of weight gain, egg production and mortality rate. The Jinding duck performs better than local and Khaki Campbell in terms of body weight, growth rate, egg quality and mortality rate. Sheep, especially *garole* sheep grow and reproduce very well in coastal areas and they are a very good source of protein for the rural people because of their excellent body weight gain and prolific nature. The cattle fattening program offers hope for the coastal people as a good source of income. These simple livestock technologies can substantially help the coastal inhabitants with food and nutrition security, incomes, and poverty alleviation.

5.6.3 Fisheries

BFRI has been conducting applied and adaptive research on freshwater, brackish water, and coastal aquaculture; riverine and marine fisheries. Achievements of brackish water fisheries research are significant and consequently shrimp (including bagda, Microbrachium rogenbergii) culture spread over in several coastal areas. Rotational shrimp and rice-fish culture system is demonstrated by the scientists and extension personnel (Saiful 2013). Scientists have already made observation on crop diversification in coastal aquaculture, integrated crab-fish fattening, and early brooding of shrimp under 'Green House' system to develop sustainable and environment-friendly shrimp fields. Like inland capture source, the coastal and marine fisheries are of a commercial focus. The scientists have brought a notable progress in technology innovation to support the coastal and marine sector. The important achievements include:

- Culture and brood development of sea bass (*Lates calcarifer*), mullets (*Mugil* spp.)
- Development of low-cost health friendly Sun Dryer for fish drying
- Development of improved device e.g., behundi net (set-bag-net)

Further research should focus on pollution, stock assessment, breeding and culture of selected finfish, improvement of post-harvest processing, product development and socio-economic survey of fishers.

5.6.4 Impacts of technologies

Agricultural revolution has taken place in Bangladesh over the past decades through development and adoption of modern varieties and breeds, mechanization, irrigation and other management technologies. Bangladesh agriculture has been greatly influenced by research and technology development and dissemination. The organizations involved in technological development are contributing substantially in increasing area/household coverage and production of crops, livestock, fisheries and forestry through information, technology transfer, input distribution, market chain development etc.

Crops

Boro rice covered 251,740 ha in 2021-22 which was 41.1% increase over the 12 years from 2010 (Fig. 5.32). Next to rice, pulse crops are cultivated in 138,525 ha followed by oilseed crops (67,333 ha) and vegetables (41,565 ha) accounting for 12.5%, 19.5% and 40.8% increase over the last 12 years, respectively. Watermelon, however, experienced a greatest increase in cultivation area by 789% from 4155 ha in 2010 to 36,930 ha in 2022 (Fig. 5.32).

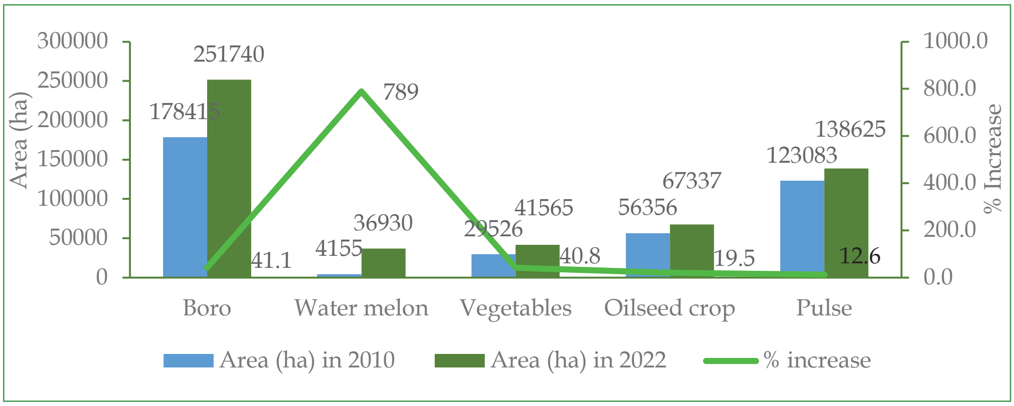


Fig. 5.32. Overall changes in area coverage of promising crops in the coastal zone (Source: DAE 2022)

Boro rice produced 1,102,709 MT in 2021-22 which was 57.7% increase over the 12 years from 2010 (Fig. 5.33). Next to rice, watermelon produced in 14,54,885 MT followed by vegetable crops (772,492 MT), pulses (161,818 MT) and oilseed crops (120,397 MT) accounting for 1176%, 61.9%, 23.5% and 39.2% increase over the last 12 years, respectively. Watermelon, however, has experienced a greatest increase in production by 1176% from 113,975 MT in 2010 to 14,54,885 MT in 2022 (Fig. 5.33).

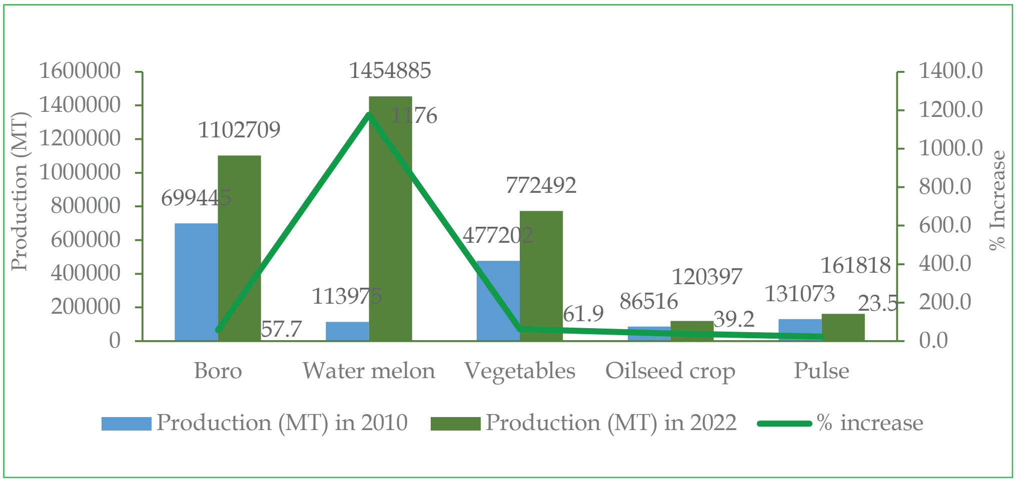


Fig. 5.33. Overall changes in production of promising crops in the coastal zone (Source: DAE 2022)

There was an increase in boro rice production in almost all the coastal based districts (Table 5.21) with the largest increase of 996% increase in Patuakhali, from 6,000 MT in 2010 to 65,775 MT in 2022 followed by a 131% increase in Lakshmipur. Watermelon production has increased sharply from only 15,750 MT in 2010 to 584,225 MT in 2021-22, a 3609% increase. Vegetable had the highest production increase in Cox's Bazar (128%) followed by Chattogram (113%) and Bagerhat (84%). The highest increase in production of pulse crop viz. mungbean was recorded in Pirojpur (3600%). Groundnut production increased steeply, by 227%, in Pirojpur followed by Chattogram (150%).

An increase in cultivation area and corresponding increase in production of some promising crops viz. watermelon, vegetables, pulses and oilseed crops despite tidal surge and salinity challenges has been a blessing for the farmers of almost all the coastal based districts. This indicates a significant breakthrough in technological advancement positively impacting incomes and livelihood of farmers in the salinity hit coastal areas of Bangladesh.

Yields of all the promising crops grown in the coastal areas have increased since 2010 which has eventually contributed to production boosts (Fig. 5.34). Watermelon has registered the highest yield increase (43.6%) from 27.4 MT/ha in 2010 to 39.4 MT/ha in 2022 followed by vegetable (18.6%), oilseed crops (16.5%), boro rice (11.6%) and pulses (9.6%).

Considering the increases in cultivation area, yield and production gains, watermelon, vegetable, oilseed crops and pulses, apart from rice, can be further promoted in the coastal zone to utilize fallow areas and to introduce these crops in single and double cropped areas where feasible.

Table 5.21. Changes in area and production of major crops in the costal zone by district during 2010-2022

District	Major crops	Area of major crops (ha) in 2010	Area of major crops (ha) in 2022	% increase/ decrease	Production of major crops (Mt) in 2010	Production of major crops (Mt) in 2022	% increase/ decrease
Khulna	Boro	47810	62730	31.2	177521	279382	57.4
	T. Amon	76770	93170	21.4	181425	278353	53.4
	B. Aman	8900	6700	-24.7	9219	8040	-12.8
	T. Aus	6036	3577	-40.7	8673	4953	-42.9
	Water melon	630	13970	2117	15750	584225	3609
	Vegetabie	8830	14835	68.0	157158	282925	80.0
Bagerhat	T. Aman	57092	59267	3.8	111849	144497	29.2
	Wheet	40	10	-75.0	72	28	-61.1
	Vegetabie	2612	4622	77.0	35525	65334	83.9
Satkhira	T. Aman	102590	89910	-12.4	232365	250428	7.8
	Boro	72975	77220	5.8	279975	309884	10.7
	T. Aus	4410	7630	73.0	10584	21996	107
	Vegetable	14365	15490	7.8	229750	309974	34.9
	Mustard	5925	12105	104	7406	16100	117
	Potato	3580	1885	-47.3	64440	32988	-48.8
Patuakhali	T. Aman	202613	199920	-1.3	455935	449798	-1.3
	Mungbean	85125	86431	1.5	86125	114089	32.5
	Watermelon	3500	22890	554	98000	869820	788
	Boro	2000	16970	749	6000	65775	996
	Maize	200	1210	505	1600	12100	656
	Sunflower	50	775	1450	7.8	1395	17785
Pirojpur	T. Aman	985	1350	37.1	2460	4050	64.6
	Mungbean	0	300	3000		360	3600
	Groundnut	150	350	133	75	245	227
Chattogram	T. Aman	18850	22359	18.6	43050	60855	41.4
	Vegetable	2280	4325	89.7	35645	75975	113
	Pulse	580	700	20.7	720	660	-8.3
	Groundnut	100	200	100	160	400	150
Cox's Bazar	T. Aman	7210	9970	38.3	20530	35855	74.6
	Vegetable	130	240	84.6	1144	2613	128
	Maize	70	120	71.4	560	1140	104
	Pepper	65	90	38.5	58	99	70.7
	W. melon	25	70	180	225	840	273
Feni	T. Aman	5278	7540	42.9	19740	28200	42.9
	Oilseed	191	273	42.9	218	311	42.7
	Pulses	1483	2119	42.9	1661	2373	42.9
	Vegetables	359	513	42.9	6105	8721	42.9
Laksmipur	Soybean	15694	21460	36.7	24125	40774	69.0
	T. Aman	19374	25220	30.2	48435	73642	52.0
	Groundnut	3000	3580	19.3	3000	6444	115
	Pulse crop	1100	9650	777.3	880	950	8.0
	Winter veg	950	1540	62.1	11875	26950	126.9
	Boro	300	550	83.3	1050	2430	131
	T. Aus	4300	6190	44.0	7310	12260	67.7

Noakhali	Boro	53600	92210	72.0	224000	431438	92.6
	T. Aus	54350	37325	-31.3	88628	85733	-3.3
	T. Aman	153480	163219	6.3	297610	437305	46.9
	Kseshri	34460	38980	13.1	41352	42866	3.7
	Ground nut	13500	13320	-1.3	21600	26640	23.3
	Soybean	15857	13207	-16.7	27750	25357	-8.6
Shariatpur	Boro	1730	2050	18.5	10899	13735	26.0
	T. Aman	1450	1890	30.3	5365	7560	40.9
	T. Aus	1510	1750	15.9	4832	5775	19.5

* T. Aus, T. Aman and Boro are rice crops

Source: DAE 2022

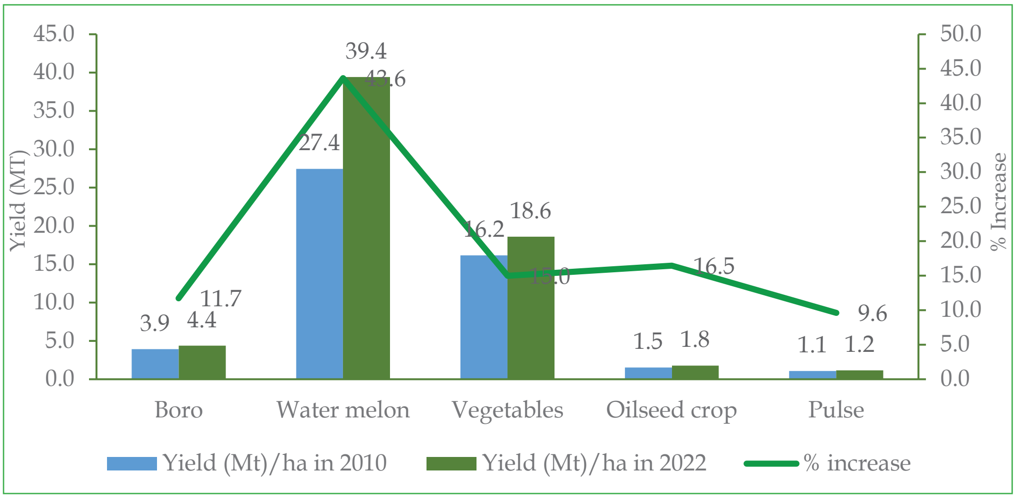


Fig. 5.34. Increase in yield of promising crops in the coastal areas during 2010-2022 (Source: DAE 2022)

Livestock and poultry

The overall livestock population density (cattle and goat) declined in the coastal areas from 2.14 to 1.78 and 0.88-0.85 per ha accounting for 16.8 and 3.4% decreases, respectively during 2012 to 2019 (Table 5.22). However, the density of buffalo and sheep population has increased by 42.9% from 0.14/ha in 2012 to 0.20/ha in 2019 and 117% from 0.06/ha in 2012 to 0.13/ha in 2019, respectively. This overall decrease in the density of cattle and goat was primarily attributed to the loss of grazing grounds to recurrent flood and tidal surge leading to increasing salinity in recent years.

Despite decreases in nine districts, the overall poultry density in the coastal areas increased by 22.4% from 15.86 to 19.41/ha when the country had a 19.1% increase during the 2012-2019 period (Table 5.23). Like poultry, the density of the duck population has decreased in nine districts while the overall duck population density in coastal areas has increased by 15,8% from 4.23 to 4.90/ha in comparison with 26.1% increase in the country during the

2012-2019 (Table 5.23). Poultry rearing has been increased by 20 to 30 times than the previous decades (Miah 2010). Besides, farmers in some parts of the coastal areas are also incorporating native poultry rearing on scavenging basis along with crop farming. The decrease of poultry and duck population density in some coastal districts could be attributed to severe scarcity of scavenging feed during summer when tidal flood is intensified.

Table 5.22. Changes in ruminant population density in the coastal zone during 2012-2019

District	Ruminant population density/ha							
	Cattle		Buffalo		Goat		Sheep	
	2012	2019	2012	2019	2012	2019	2012	2019
Khulna	1.12	1.36	0.01	0.00	0.51	0.87	0.05	0.04
Bagerhat	0.79	1.01	0.04	0.04	0.41	0.75	0.00	0.06
Satkhira	1.46	1.61	0.00	0.00	0.91	1.05	0.14	0.17
Narail	4.43	3.10	0.00	0.00	2.79	1.60	0.07	0.00
Barishal	2.57	1.53	0.04	0.35	0.61	1.05	0.01	0.05
Bhola	1.08	2.71	0.26	0.62	0.58	1.26	0.04	0.11
Barguna	1.89	1.83	0.19	0.29	0.67	0.70	0.01	0.07
Jhalakathi	1.88	1.68	0.06	0.05	0.56	1.04	0.04	0.01
Patuakhali	1.98	1.76	0.40	0.43	0.59	0.66	0.04	0.34
Pirojpur	0.18	1.09	0.05	0.13	1.67	1.14	0.09	0.01
Chattogram	4.68	3.64	0.29	0.11	1.51	0.77	0.19	0.19
Cox's Bazar	3.56	1.81	0.28	0.20	1.72	0.56	0.16	0.30
Feni	7.90	2.03	0.08	0.14	2.22	0.26	0.06	0.56
Lakshmipur	3.75	0.94	0.18	0.31	1.04	0.26	0.04	0.03
Noakhali	1.44	1.04	0.10	0.21	0.39	0.41	0.05	0.10
Chandpur	22.50	5.95	0.00	0.04	9.82	3.37	0.16	0.19
Gopalganj	18.55	2.11	0.09	0.00	4.81	0.44	0.16	0.01
Shariatpur	21.12	5.14	0.00	0.09	12.77	3.17	0.06	0.15
Coastal area)	2.14	1.78	0.14	0.20	0.88	0.85	0.06	0.13
Bangladesh	1.57	1.64	0.10	0.10	1.70	1.78	0.21	0.24

Source: DLS 2012, 2019

Table 5.23. Changes in poultry and duck population density in the coastal zone during 2012-2019

District	Poultry/ha		Duck/ha	
	2012	2019	2012	2019
Khulna	11.73	8.63	1.95	1.03
Bagerhat	7.99	11.44	1.13	2.58
Satkhira	13.10	5.64	0.99	1.12
Narail	28.40	13.57	6.77	6.84
Barishal	16.71	25.57	3.06	7.58
Bhola	6.13	26.30	3.78	11.58
Barguna	8.57	29.26	2.59	7.43
Jhalakathi	43.12	38.44	7.70	9.95
Patuakhali	11.73	20.18	5.85	6.76
Pirojpur	10.53	37.06	7.70	0.79
Chattogram	28.99	20.74	2.10	1.45
Cox's Bazar	13.91	21.91	1.72	0.80
Feni	78.29	30.56	22.37	0.64
Lakshmipur	28.54	23.55	8.35	3.27
Noakhali	12.03	23.07	6.33	9.32
Chandpur	124.55	56.91	77.65	17.76
Gopalganj	80.93	11.36	32.38	5.91
Shariatpur	192.11	51.83	47.85	17.05
Total (coastal area)	15.86	19.41	4.23	4.90
Total (country)	16.45	19.59	3.10	3.91

Source: DLS 2012, 2019

Fisheries

Annual fish catch production in coastal areas increased by 42.6% from 68,278 MT in 2010 to 97,372 MT in 2020, which greatly surpassed the status of national annual fish catch production (decreased by 21%) during the same time (Table 5.24). This dramatic increase in annual fish catch production during the last 10 years despite serious natural calamities like tidal surge and flooding was due to increased access of fishermen to modern equipment for fish catching in the open water bodies of the coastal areas and adoption of improved technologies by the farmers of the coastal areas.

Table 5.24. Changes in total annual fish catch production in coastal areas and Bangladesh during 2010-2020

Area /Country	Annual fish catch (MT) in 2010	Annual fish catch (MT) in 2020	% Increase/ decrease
Coastal area	68,278	97,372	42.6
Bangladesh	797,024	629,615	-21

Source: BBS 2012, 2021

The highest increase in annual fish catch production occurred in Satkhira by 271% from 3,360 MT in 2010 to 12,450 MT in 2020 (Fig. 5.35) followed by Khulna (157% from 7,362 MT in 2010 to 18,935 MT in 2020). The lowest increase was reported in Pirojpur (16%) from 3,173 MT in 2010 to 3,681 MT in 2020. Bagerhat and Bhola districts have experienced a decrease in annual fish catch production in the same period ranging from 28 to 29%. However, the increase of annual fish catch production in most of the coastal districts could be due to the massive adoption of improved technologies.

At present coastal fisheries are facing many problems such as overfishing, indiscriminate killing of juveniles, pollution, disease defectives and insufficient fish conservation laws, inadequate knowledge etc. Noncompliance with fishing rules and regulations and the attempts of coastal fishers to support their livelihoods by any means possible, result in increasing fishing pressure, use of destructive fishing methods, and a tendency to fish whatever is available, including larvae and juveniles. This causes serious damage not only to coastal fishery resources but also creates conflict between fishers and other resource users.

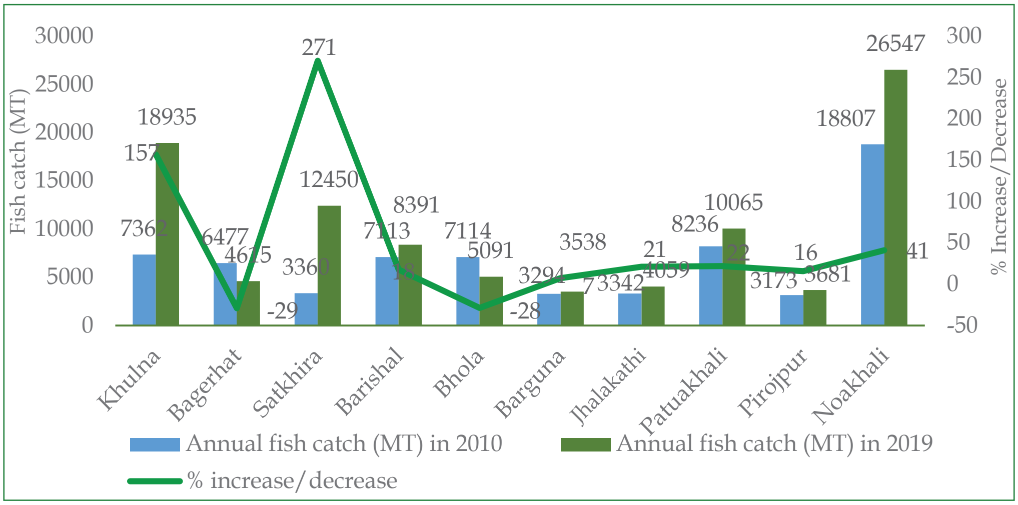


Fig. 5.35. Changes in annual fish catch production in coastal areas by district during 2010-2020 (Source: BBS 2012, 2020)

5.7 Strategic investment Opportunities for Coastal Ecosystem

Attempts to introduce area specific strategy for the coastal ecosystem have been taken through a number of 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)

All these initiatives eventually prepared the ground for the Government Initiative in 1999 to embark on a process of ICZM. In that year, 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.

Climate resilience and agricultural development strategies should, therefore, be adopted for coastal areas based on the following plans/policies of the Government currently in place:

- Bangladesh Delta Plan 2100
- Vision 2041: Perspective Plan of Bangladesh (2021-2041)
- Eight Five Years Plan (2020-2025)
- Sustainable Development Goals (2016-2030)
- National Agricultural Policy (2018)
- Master Plan for Agricultural Development in the Southern Region of Bangladesh 2012
- Agricultural Research Vision 2030 and beyond

Strategy A: Addressing salinity for sustainable crop production year round

Soil salinity in drier months (February to May) affects crop growth, which reduces yield and in severe cases causes a total loss. Presence of saline ground water table within one meter throughout the year affects crop production. So, alternative ways should be adopted to address these problems.

Sub-strategy A.1: 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 rain water. Vast opportunities still exist in all the coastal areas, where the remaining fallow land (222,952 ha) i.e., 24% of the total agricultural land area (920,692 ha) can be brought under cultivation of at least a single crop during the winter season using irrigation of fresh water from rain water harvest reservoirs.

Sub-strategy A.2: Salinity management options

Saline tolerant varieties: Farmers have access to saline tolerant varieties of different crops being available in NARS institutes. Bangladesh Rice Research Institute (BRRI) has already developed different climate resilient rice varieties. BRRI dhan40 and 41 are saline tolerant rice varieties which grow during Aman season. It can tolerate salinity up to 8 ds/m during its reproductive stage. BRRI dhan47, BRRI dhan67 and BRRI dhan99 are Boro season saline tolerant rice varieties which can tolerate salinity up to 14 ds/m during seedling stage and 6 ds/m during other growth stage. BRRI dhan55 can tolerate 8-10 ds/m and BRRI dhan61 can tolerate salinity 12-14 ds/m. BRRI dhan53 and 54 are also saline tolerant short duration Aman season rice varieties which can be harvested 12-41 days earlier of BRRI dhan41 variety. It can also tolerate 8-10 ds/m during its reproductive stage. Binadhan-8 and Binadhan-10 can tolerate EC 8 -10 ds/m at mature stage with 6.0 MT/ha yield potentiality. Groundnut saline tolerant varieties are Binachinabadam-1, Binachinabadam-2. Salt tolerant species like chilli, methi, water melon, cucumber etc. should be cultivated in saline prone areas. One potato variety named “Saikat” has been recommended by BARI for cultivation in saline belt (up to 8 ds/m).

Management technologies: Farmers should be trained on using aged rice seedling (40 days’ old) and 3-4 seedlings per hill with foliar spray of Zn-sulphate solution @ 2 g /1 L water 5-7 days before seedling uprooting. They should be aware of application of manure for improving soil health and preventing soil crack. Gypsum @15 kg/bigha (33 decimal) should be applied. Soils should be flashed with fresh water or mild saline water for irrigation with <3.0 dS/m salinity before plantation. Application of increased dose of muriate of potash or ash would be very effective.

Sub-strategy A.3: Alternate cropping management

Development of coastal agriculture has potential to improve sustainable livelihood and congenial environment. The rigorous effort to develop the coastal agriculture focuses mainly on flood protection and crop production in the recent past.

- Watermelon could be cultivated using surface water of earthen well (patkua). Use of underground/surface sweet water of earthen well reduce the soil salinity levels and increase the yield of watermelon. Pyramid type of raised pit protects the vegetable crop from tidal water and thus utilizes the land for vegetables cultivation all the year round.

- Development of intervention such as soil less agriculture can work without altering the natural environment and also promote the conservation of wetlands. Soil-less cultivation system (hydroponics system) has been traditionally practiced in the southwest region of the coastal areas for more than two centuries. More than 20 different kinds of vegetables and five different types of spices are cultivated in this hydroponics system. In view of the above, the proposed strategy aims at: increasing agricultural production, adapting management practice for producing crops in saline soil, promotion and dissemination of soil-less cultivation system, proper utilization of wetlands, and development of agro-based industries. The major activities include: baseline survey, development of Knowledge base and Agricultural Information System (AIS), development of infrastructure and physical facilities, expansion of soil-less agriculture, financial assistance to the beneficiaries, capacity building and training.

Sub-strategy A.4 Up-scaling of innovative technologies

Scientists of different agricultural research organizations (BARI, BRRI, BINA etc.) and also local farmers have developed a good number of innovative technologies to combat the salinity stress condition for successful crop production. These technologies should be promoted, where feasible. Some of these technologies are mentioned below:

- 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 Barisal-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.
- Sorjan system: Farmers are practicing sorjan system 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 region of Patuakhali. Bangladesh Agriculture Research Institute (BARI) has developed this technology through a series of testing in its Farming Systems Research

(FSR) site, Lebukhali, Patuakhali. Vegetable gardening in sorjan system is applicable in lands that go under water for most time of the year. Much efforts should be taken to promote this innovative technology in the coastal areas.

- Floating agriculture: In Barisal, Gopalganj, Madaripur and Pirojpur, the farmers have been practicing floating agriculture. 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 grow different crop seedlings and vegetables on these buoyant platforms. This system can be integrated with fish culture, where a raft is made with bamboo and is kept suspended above the water by plastic containers as floats. Earthen or plastic pots with soil placed on the frame are used to grow vegetables. A net cage is installed beneath the floating structure to culture fish. It is a useful adaptive option in low-saline areas as it uses a small amount of non-saline soil to grow vegetables and culture salt-tolerant fish, like tilapia. Thus, this technology warrants special efforts to get it disseminated widely in the coastal areas.
- Hanging agriculture: Hanging garden, an innovation of the communities of south western Bangladesh enables cultivation of vegetables in water-logging and salinity situations. This technology can be promoted extensively in coastal areas. In this technology, an earthen platform is set over a triangular bamboo frame. The raised platform is made of an earthen pot which is filled with fertile surface soil, cowdung and fertilizers. Usually, the platform is raised by 5-6 feet (1.52 m - 1.83 m) above the ground depending on the depth of water stagnation in the locality. The major cultivable crops could be country bean, sweet gourd, bottle gourd, wax gourd, cucumber, ribbed gourd and Indian spinach.

Sub-strategy A.5: Enhancing breeding of salinity tolerant and short duration varieties of crops

Variability and uncertain rainfall, cyclone, storm etc. delays sowing/ transplanting, and flooding damages aus and aman crops. Narrow technological and germplasm bases of salt tolerant crops limit crop choices. Late harvest of T. Aman rice with short winter season restricts rabi crop cultivation. Therefore, the strategy should emphasize on developing short-duration rice varieties that are tolerant to salinity both at the seedling and reproductive stages to avert damage from floods.

Strategy B: Management of polder and sluice gate in coastal areas

Soil salinity in the coastal areas is developed due to tidal flooding during wet season (June-October), direct inundation by saline water, and upward or lateral movement of saline ground water during dry season (November-May). Salinity causes unfavorable hydrological situation that restricts the normal crop production in this area. To address this problem, the GoB has constructed polders or embankments surrounding low-lying areas. The regional workshop in Khulna organized in August 2022 indicated that there are about 139 polders in coastal zone of Bangladesh constructed in 1960s and 1970s to protect farm lands from saline water intrusion and tidal floods. Out of the 2.8 million ha in the coastal zone, almost half (1.2 million ha) of the areas are protected by polders. Sluice gate is also constructed by a gate or lock to control water levels and flow rates in rivers and canals so as to regulate 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 dykes do not cover the entire sea coast, 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 dykes is very high and presently the embankments are in a terrible state of disrepair. Given these vulnerabilities, it is imperative to strengthen and maintain these dykes. Measures should be the risk analysis of sea dykes against the projected climate change scenario; to prioritize the intervention measures and locations; construct new sea dykes, if necessary (with relevant structures), regular maintenance program, etc.

Based on the success of Land Degradation Neutrality Target Setting Program (LDN-TSP) during December 2016 through February 2018 with the support of United Nations Convention to Combat Desertification (UNCCD), Bangladesh put further commitment to achieve LDN leverage plan to efficiently manage polders in the coastal areas. According to the target 5 of LDN, the Government of Bangladesh will protect non-saline land areas from salinity intrusion in 1200 km^2 in coastal zone area by 2030. 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 value salt-tolerant crops; increase surface (fresh) water reserve in channels and ponds and establish community-based polder management. This investment plan of LDN as committed by the Government of Bangladesh through UNCCD should be widely implemented in the coastal areas in support of effective management of polders and sluice gates.

Strategy C: Development and settlement of accreted land

Protection from cyclone damage afforded by the Sundarbans natural mangrove forests led the Forest Department in 1966 to commence a program of afforestation over the greater districts of Chattogram, Noakhali, Bhola, Barisal and Patuakhali. Mangrove plantation in the newly accreted Char lands, not only stable lands at the quickest possible time but also help enlarge the accreted areas. The success of the plantation program resulted in setting some additional objectives like stabilization of land for agriculture, production of timber, pole and fuelwood, creation of employment opportunity and development of suitable environment for wildlife, fishes and other estuarine and marine fauna. People in that area continuously become landless facing erosion. There is no established system of providing stabilized

- lands and sustain living to these people. The proposed strategy aims at: Establishing criteria for identification of land (different types), which are mature for agriculture and suitable for rehabilitation of land-less people;
- Identification of newly accreted land along the waterline suitable for plantation and create/enhance plantation coverage;
- Newly accreted land in the form of mud shall be utilized for planting mangrove plants;
- Existing mangrove forests shall be managed through participatory way;
- Degraded/depleted forests land shall be planted and which will act as green wall/wind break.

Strategy D: Livestock improvement

Sea level rise due to climate change results in flooding and salinity intrusion, and thus reduces grazing ground and fodder production. Flooding, water logging, erosion and siltation also result in the scarcity of free grazing area. High soil and water salinity, poor drainage and congestion lead to sanitation and drinking water problems for livestock. There exists an inefficient land use for production of fodder without undermining crop production. Expanding economic opportunities and increasing incomes through livestock production is a potentially promising strategy to enhance livelihood development and poverty reduction in the coastal areas.

Sub-strategy D.1: Utilizing fallow land for fodder production with fresh water irrigation from rain harvest reservoirs

Huge fallow land and water provide the natural resources base for the intensification of livestock production. Land can be used for grass production for forage using fresh water irrigation from rain harvest reservoirs. Cattle fattening program opens up a new hope for local people in coastal areas, gaining a noticeable financial support. Sheep rearing especially *garole* sheep could be strengthened for incomes and protein supplements for the rural people in coastal areas as they are tolerant to harsh environment like drought, salinity etc.

Sub-strategy D.2: Enhancing breeding for improvement of local animals and fodders

Breeding program should be strengthened to develop saline, drought and water logging tolerant fodder varieties and modern feeding management practices. Conservation and improvement of potential indigenous fodder germplasm should be given a priority. Coastal ecosystem-based fodder germplasm conservation and improvement is essential to make germplasms fit into the local context. Quality breeding animals or semen should be used to improve indigenous animals.

Potential local indigenous breeds should be conserved. Further, use of Artificial Reproductive Technology (ART) should be strengthened at the coastal villages to improve local breeds and thereby increase production year-round.

Sub-strategy D.3: Expanding disease control mechanisms at local level

Livestock in the coastal areas are threatened by Lumpy Skin Disease (LSD), Blood Protozoa in high yielding animals and AI viruses (H5N1, H9N2). Mastitis, repeat breeding, and metabolic problems hamper livestock production. Therefore, various disease control models (FMD, PPR, Deworming, Community poultry biosecurity, availability of vaccine seed, PPR/FMD/goat pox, Rapid antibody test kit-RBT, ELISA kit) need to be expanded in the vicinity of coastal villages. There should be development and application of the methodology to link coastal climate data with animal disease surveillance system. Development of updated vaccines and therapeutics combating endemic and emerging diseases should be taken into account as the top priority for such a remote coastal area.

Strategy E: Improvement of aquaculture

Increase of salinity coupled with inadequate water management affects freshwater aquaculture. Drought and tidal wave, rain and flood affect fish culture round the year. Upstream water flow and siltation reduce reservoirs for fish culture.

Sub-strategy E.1: Enhancing breeding program

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 for endangered fish propagation and mass seed production and for development of Fish Live Gene Bank in the coastal areas.

Sub-strategy E.2: Environmental and socially responsive shrimp farming

Unplanned practice of shrimp farming has been causing a great harm to the environment as well as creating social conflict in many coastal regions of Bangladesh. The situation is not yet that alarming but it needs to make more investments in socially responsive shrimp farming following recent global trends that favor semi-intensive shrimp aquaculture practices. The proposed strategy will encourage socially responsive shrimp farming by inculcating semi-intensive farming practices and greater social cohesion also hygienic and safe sea food supply from farm to plate. The activities will be baseline situ ation assessment, aquatic and terrestrial biodiversity study, water management and soil quality study in shrimp farms within polders, study on major social issues and development of management tools for environmental and social responsible shrimp farming. For this purpose, pilot projects should be taken in several coastal districts.

Strategy F: Introduction and expansion of solar, tidal and wind energy in the remote coastal areas

In remote coastal areas, especially islands and chars, normal electrification is a distant reality but expansion of renewable energy has potential. The strategy is designed to ensure generation and distribution of energy in selected islands and chars by utilizing solar energy. By adopting appropriate modes encompassing public-private partnerships, the strategy should be to establish some Photo Voltaic Installations and to form and maintain user groups. Similarly, the possibility of power generation and distribution by using wind energy at suitable locations in the CZ should be tested. LGED has developed a model of green energy development for the St. Martin's island. PDB has also been implementing a pilot project. The possibility of electricity generation using tidal fluctuations at suitable locations in the CZ can be tested.

Strategy G: Enhancing private sector opportunities for investment in agribusiness

Private sectors should be involved in agri-input sectors like seed, fertilizer, pesticide, irrigation and farm machinery. Production of high value-added safe and nutritional foods for local and export, including vegetables, fruits, spices, nuts and pulses should be increased. Post-harvest processing should be strengthened for pulses (mungbean), oil seeds (soybean, sunflower), vegetables, tuber crops (potato, sweet potato), fruits (guava, watermelon, hog plum, coconut), spices (chili, Bombai chili) etc. Cold storage facilities should be strengthened to establish the supply chain, especially fresh produce for local and export markets.

References

Adnan MSG, Haque A and Hall JW (2019) Have coastal embankments reducedflooding in Bangladesh? Sci Total Environment, 682:405 –416. https://doi.org/10.1016/j.scitotenv.2019.05.048

Adnan MSG, Abdullah AYM, Dewan A and Hall JW (2020) The effects of changing land use and flood hazard on poverty in coastal Bangladesh. Land Use Policy, 99. https://doi.org/10.1016/j.landusepol.2020.104868

Ahmed AU (2006) Bangladesh climate change impacts and vulnerability. Climate change cell, Department of Environment, Comprehensive Disaster Management Programme, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh.

Ahmad H (2019) Bangladesh Coastal Zone Management Status and Future Trends. Journal of Coastal Zone Management, 22: 1-7.

Alam K (2004) Bangladesh's Maritime Challenges in the 21st Century, op. cit., pp. 176-81.

Allison (1998) Historical changes in the Ganges–Brahmaputra delta front, Journal of Coastal Research, 14 (1998): 1269-1275.

Auerbach LW, Goodbred SL, Mondal DR, Wilson CA, Ahmed KR, Roy K, Steckler MS, Small C, Gilligan JM and Ackerly BA (2015) Flood risk of natural and embanked landscapes on the Ganges-Brahmaputra tidal delta plain, Nature Climate Change, 5 (2): 153–157. https://doi.org/10.1038/nclimate2472.

Banglapedia (2021) Coastal Zone. https://en.banglapedia.org › index.php › Costal Zone.

BARC (Bangladesh Agricultural Research Council) (2022) Computer and GIS Unit, BARC, Farmgate, Dhaka.

BBS (Bangladesh Bureau of Statistics) (2003) Year Book of Agricultural Statistics 2003. Ministry of Planning, Government of the People's Republic of Bangladesh.

BBS (Bangladesh Bureau of Statistics) (2011) Report of the household income & expenditure survey 2010, Bangladesh Bureau of Statistics, Statistical Division, Ministry of Planning.

BBS (Bangladesh Bureau of Statistics) (2012) Year Book of Agricultural Statistics 2012, Ministry of Planning, Government of the People's Republic of Bangladesh.

BBS (Bangladesh Bureau of Statistics) (2020) Year Book of Agricultural Statistics 2020, Ministry of Planning, Government of the People's Republic of Bangladesh.

BBS (Bangladesh Bureau of Statistics) (2021) Year Book of Agricultural Statistics 2021, Ministry of Planning, Government of the People's Republic of Bangladesh.

BER (Bangladesh Economic Review) (2011a) Economic Adviser's Wing, Finance Division, Ministry of Finance, 2011, p. 138.

BER (Bangladesh Economic Review) (2011b) Finance Division, Ministry of Finance, Government of the People's Republic of Bangladesh. Op Cit, p. 138.

BER (Bangladesh Economic Review) (2016) Finance Division, Ministry of Finance, Government of the People's Republic of Bangladesh, retrieved from http://www.mof.gov.bd/en/index.php?option=com_co ntent&view=ar ticle&id=367&Itemid=1

Bernier Q, Sultana P, Bell AR, Ringler C (2016) Water management and livelihood choices in southwestern Bangladesh. Journal of Rural Studies, 45:134–145. https://doi.org/10.1016/j.jrurstud.2015.12.017

BFD and UNDP (2018) Co-management and benefit-sharing from coastal afforestation. Integrating Community-based Adaptation into Afforestation and Reforestation (ICBA-AR) Programme in Bangladesh, Dhaka: Bangladesh Forest Department, Ministry of Environment, Forest and Climate Change and UNDP Bangladesh.

BGS and DPHE (2001) Arsenic Contamination of Groundwater in Bangladesh, Vol 1: Sum- mary. Kinniburgh, D.G. and Smedley, P.L. (eds), Project for Ministry of Local Govern- ment, Rural Development and Co-operatives of Bangladesh, Department of Public Health Engineering (DPHE); funded by Department for International Development (DFID). British Geological Survey Report WC/00/19, British Geological Survey, Keyworth.

Blower JH (1985) Sundarbans Forest Inventory Project. Bangladesh Wildlife Conservation in the Sundarbans, ODA.

Brady NC and Weil RC (2013) The Nature and Properties of Soils. 14th Ed. Published by Pearson Education, Inc. Publishing as Prentice Hall. pp. 381-382.

Brammer H (2014) Bangladesh's dynamic coastal regions and sea-level rise, In: Climate Risk Management, 1: 51-62.

Alam MK, Hasan AKMS, Khan MR and Whitney JW (1990) Geological map of Bangladesh, Geological Survey of Bangladesh, Dhaka, Bangladesh.

CEGIS (2006) Impacts of Sea Level Rise on Land use Suitability and Adaptation Options, Draft Final Report. Submitted to the Ministry of Environment and Forest, Government of Bangladesh and United Nations Development Programme (UNDP) by Centre for Environmental Geographic Information Services (CEGIS), Dhaka.

DAE (Department of Agricultural Extension) (2022) Unpublished data, Field Services Wing, Khamarbari, Farmgate, Dhaka-1215

Das R and Hanaoka S (2010) Perishable Food supply chain constraints in Bangladesh, International Journal of Food Supply Chain, 5(2): 13-29.

Datta DK and Ghosh PK (2015) Groundwater of the municipalities of southwestern coastal Bangladesh, In: Subramaniam, V. (Ed.) Surface and Sub-surface Water in Asia: Issues and Perspectives, IOS Press, The Netherlands.

DLS (Department of Livestock Services) (2012) Unpublished data regarding statistics on livestock and poultry in Bangladesh, Ministry of Fisheries and Livestock, Government of the People's Republic of Bangladesh.

DLS (Department of Livestock Services) (2019) Unpublished data regarding union-wise statistics on livestock and poultry in Bangladesh, Ministry of Fisheries and Livestock, Government of the People's Republic of Bangladesh.

DoE (2015) Fifth National Report of Bangladesh to the Convention on Biological Diversity, Dhaka: Department of Environment (DoE), Ministry of Environment and Forests, Government of the People's Republic of Bangladesh.

DoF (2016) National Fish Week 2016 Compendium (In Bengali). Department of Fisheries, Ministry of Fisheries and Livestock, Bangladesh, Retrieved from http://www.fisheries.gov.bd/site/page/cc02ff66-b470- 4b76-aadd -25c7f18a09a7/Sonkolon

Duke NC, Meynecke JO, Dittmann S, Ellison AM, Anger K, Berger U, Dahdouh-Guebas F et al. (2007) A World without Mangroves? Science, 317, 41-42. https://doi.org/10.1126/science.317.5834.41b

FD (Forest Department) (2015) Land cover atlas of Bangladesh, 2015, Forest Department, Ministry of Environment, Forests and Climate Change, Government of the People's Republic of Bangladesh.

FRSS (2016) Fisheries Statistical Report of Bangladesh. Fisheries Resources Survey System, Department of Fisheries, Bangladesh, BG Press. 32, p. 57.

Ghosh DK, Hossain MN, Sarker MNS and Islam S (2020) Effects of land-use changes pattern on tree plantation: Evidence from gher land in Bangladesh, International Journal of Agricultural Policy and Research, 8(3), 56-65, https://doi.org/10.15739/IJAPR.20.007

Hasan HM (2012) Mining: Chorus of Disapproval, Energy & Power, 01 December 2012, p. 15.

Haque SA (2006) Salinity problems and crop production in coastal regions of Bangladesh- A Review Article, Pakistan of Journal of Botany 38(5): 1359–1365.

Hilton-Taylor C (Compiler) (2000) IUCN Red List of Threatened Species. IUCN (International Union of Conservation of Nature and Natural Resources), Gland, Switzerland and Cambridge, UK. http://www.iucn.org, www.iucnredlist.org

Hossain MS (2001) Biological aspects of the coastal and marine environment of Bangladesh, Ocean and Coastal Management. Ocean & Coastal Management, 44(3-42): 261–282.

Hossain MN, Saifullah ASM, Bhuiyan S, Uddin N and Rahman M (2019) Effects of climate change on rice production at Khulna district, Bangladesh, Environment, Earth and Ecology, 3(1):42– 54, https://doi.org/10.24051/eee/110398

Hirabayashi and Yukiko (2013) Global flood risk under climate change, Nature Climate Change, 3: 816.

Iftekhar MS. 2006. Conservation and management of the Bangladesh coastal ecosystem: Overview of an integrated approach, Natural Resources Forum 30(3): 230–237.

Islam AJMA (1977) Sulphur deficiency- a new problem coming up in rice cultivation of Bangladesh, Paper presented at BRRI sulfur seminar in December. p. 3 1.

Islam MR (2004) Living in the coast: Problems, opportunities and challenges, Working Paper WP011, Dhaka. 2004, Programme Development Office (PDO) and Integrated Coastal Zone Management Plan (ICZMP), pp. 13-15.

Islam MR (ed.) (2004) Where Land Meets the Sea: A Profile of the Coastal Zone of Bangladesh, The University Press Limited, Dhaka.

Islam MR and Ahmad M (2004) Living in the Coast: Problems, Opportunities and Challenges, PDOICZMP, WARPO, Ministry of Water Resources, Government of Bangladesh. Available at: http://www.warpo.gov.bd/rep/liv/living2.pdf. pp. 33,42,47,130

Islam MS (2003) Perspectives of the coastal and marine fisheries of the Bay of Bengal, Bangladesh, Ocean and Coastal Management, 15(2):35-50.

Islam MS and Haque M (2004) The mangrove-based coastal and nearshore fisheries of Bangladesh: ecology, exploitation and management, Reviews in Fish Biology and Fisheries, 14: 153-180.

Islam MS and Wahab MA (2005) A review on the present status and management of mangrove wetland habitat resources in Bangladesh with emphasis on mangrove fisheries and aquaculture, Hydrobiologia, 542: 165-190.

Islam MS, Ahmed MK, Al-Mamun MH and Masunaga S (2014) Trace metals in soil and vegetables and associated health risk assessment, Environment Monitoring and Assessment, 186: 8727-8739.

Islam GMT, Islam A, Shopan AA, Rahman MM, Lázár AN and Mukhopadhyay A (2015) Implications of agricultural land use change to ecosystem services in the Ganges delta, Journal of Environmental Management, 161: 443–452. https://doi.org/10.1016/j.jenvman.2014.11.018.

Islam SA and Rahman MM (2015) Coastal Afforestation in Bangladesh to Combat Climate Change Induced Hazards, Journal of Science Technology and Environment Informatics, 2:13-25.https://doi.org/10.18801/jstei.020115.12

Karim Z, Saheed SM, Salauddin ABM, Alam MK and Huq A (1982)

Coastal saline soils and their management in Bangladesh, Soils publication no.8, BARC, p. 33.

Karim Z, Hussain SG and M Ahmed (1990) Salinity problems and crop intensification in the coastal regions of Bangladesh, Soils publication No. 33. BARC, p. 17.

KGF (Krishi Gobeshona Foundation) (2020) Annual Report for 2018-19. pp 110

Khan NA, Khan SR and Faisal M (2013) Vatki Culture in the Coast: A New Horizon in Aquaculture, A popular article edited in National Fish Fortnight Week, DoF, Ministry of Fisheries and Livestock, 2-8 July, 2013.

Lázár AN, Clarke D, Adams H, Akanda AR, Szabo S, Nicholls RJ, Matthews Z, Begum D, Saleh AFM, Abedin MA, Payo A, Streatfield PK, Hutton C, Mondal MS and Moslehuddin AZM (2015) Agricultural livelihoods in coastal Bangladesh under climate and environmental change – A model framework, Environmental Science-Processes and Impacts 17 (6): 1018–1031. https://doi.org/10.1039/c4em00600c.

Mahmood N (2006) Prawan (Changri), Banglapedia - the National Encyclopedia of Bangladesh, Asiatic Society of Bangladesh. Dhaka, Bangladesh.

MoEF (2015) Intended Nationally Determined Contributions (INDC). Dhaka: Ministry of Environment and Forest (MoEF), Government of the People' Republic of Bangladesh.

Miah MMU (2010) Assessing Long-term Impacts of Vulnerabilities on Crop Production Due to Climate Change in the Coastal Areas of Bangladesh, Final Report PR No. 10/08. Bangladesh Center for Advanced Studies. National Food Policy Capacity Strengthening Program.

Mohiuddin MS, Hossain MN, Sarker MNI, Nayeem MAR, Islam S and Salehin F (2021) Climate Change Vulnerability and its Impacts on Live and Livelihood Patterns in the South-Middle Coastal Areas of Bangladesh, Alam GMM, Erdiaw-Kwasie MO, Nagy GJ, Leal Filho W (eds) Climate Vulnerability and Resilience in the Global South. Climate Change Management, Springer, Cham, https://doi.org/10.1007/978-3-030-77259 -8_25

Mukhopadhyay A, Duncan D H, Craig WH, Attila NL, Fiifi AJ and Tuhin G (2018) Land Cover and Land Use Analysis in Coastal Bangladesh, https://link.springer.com/book/10.1007/978-3-319-71093-8

Naher N, Uddin MK, Alam AKMM (2011) Impacts of salinity on soil properties of coastal areas in Bangladesh, Agrivita, 33(2): 3–10.

Najnin A (2014) Integrated approach to assess vulnerability of the coastal region of Bangladesh due to climate change. MS (Geospatial Technologies) Thesis. Universidade Nova de Lisboa (UNL), Lisbon, Portugal. http://hdl.handle.net/10362/11748

Pillai SM and Muralidhar M (2006) Survey and de marcation of seawater inundated areas for eco-friendly aquaculture in Andaman and Nicobar Islands, Report submitted to Andaman and Nicobar Administration, Port Blair, Central Institute of Brackishwater Aquaculture, Chennai, pp. 69-74.

Rahman MS (2001) Tropical cyclones of Bangladesh. Quarterly Nirpad Newsletter, 4th issue, Dhaka, Bangladesh.

Rahman MH, Lund T and Bryceson I (2011) Salinity impacts on agro-biodi versity in three coastal, rural villages of Bangladesh, Ocean & Coastal Man agement, Volume 54, Issue 6, June 2011, pp. 455-468. Available at: http://www.sciencedirect.com/science/article/ pii/S0964569111000317

Rahman MM, Khan MJ, Chowdhury SD, Akbar MA (2009) Duck Rearing System in Southern Coastal Districts of Bangladesh, Bangladesh Journal of Animal Science, 38: 132-141.

Rashid SMA and Scott DA (1989) Some waders of the Sundarbans mangrove forest, The Stilt: Newsletter of RAOU and AWSG.

Saiful (2013) Fisheries in Bangladesh – Technological Advancement https://agricultureandfarming.wordpress.com/2013/09/05/fisheries-in-bangladesh-technological-advancement/

Syvitski JPM, Kettner AJ, Overeem I, Hutton, EWH, Hannon MT, Brakenridge, GR, Day J, Vorosmarty C, Saito Y, Giosan L and Nicholls RJ (2009) Sinking deltas due to human activities, Nature Geoscience, 2(10): 681–686. https://doi.org/10.1038/ngeo629

Tomascik T (1997) Management Plan for Resources of Narikel Jinjira (St. Martin's Island), National Conservation Strategy Implementation Project 1, Ministry of Environment and Forest, Government of Bangladesh. pp. 125.

UNCCD Bangladesh (2018) National Report on Land Degradation Neutrality Target Setting Program (LDN-TSP) of Bangladesh 2018. United Nations Convention to Combat Desertification (UNCCD). https://www.unccd.int/sites/default/files/ldn_targets/2019-

Warrick RA and Ahmad QK (1996) The implications of climate and sea-level change for Bangladesh. Kluwer Academic Publishers, Dordrecht, Boston, London. pp. 415.

Yadav S and Jagadish SVK (2021) Working together for a resilient agri-food systems in coastal Bangladesh. Polder Tidings, 3 (2): 11-13.

Chapter 6 Hill Ecosystem

6.1 Extent and distribution

The only extensive hill area in Bangladesh is Chattogram Hill Tracts (CHT), which spreads over the southeastern part of the country (21°25'N to 23°45'N latitude and 91°54'E to 92°50'E longitude) bordering Myanmar on the southeast, the Indian state of Tripura on the north, Mizoram on the east and Chattogram district on the west (Banglapedia 2021). The mountainous rugged terrain with deep forests, lakes and falls including human habitat gives it a different character from the rest of Bangladesh (Fig. 6.1).

Fig. 6.1. A habitat in Chattogram Hill Tract

Historically, in the year 953 a king of Arakan occupied the present districts of Chattogram Hill Tracts and Chattogram. King of Tripura occupied this region later in 1240. The Arakanese King recaptured the district in 1575 and continued possession till 1666. The Mughals controlled the area from 1666 to 1760. Then, the area was ceded to East India Company In 1760. After that this area became a part of British India when the British occupied the Chattogram Hill Tracts in 1860. They named it 'Chittagong Hill Tracts' (Parvatya Chattogram) (Nazila 2005, Danilo 2008).

The AEZ-29 (Northern and Eastern Hills) includes the country's hill areas. This AEZ spreads mainly over Rangamati, Khagrachhari, Bandarban, Chattogram, Cox's Bazar, Habiganj and Moulvibazar districts, small areas along the northern border of Sherpur, Netrakona, Jamalpur, Mymensingh,

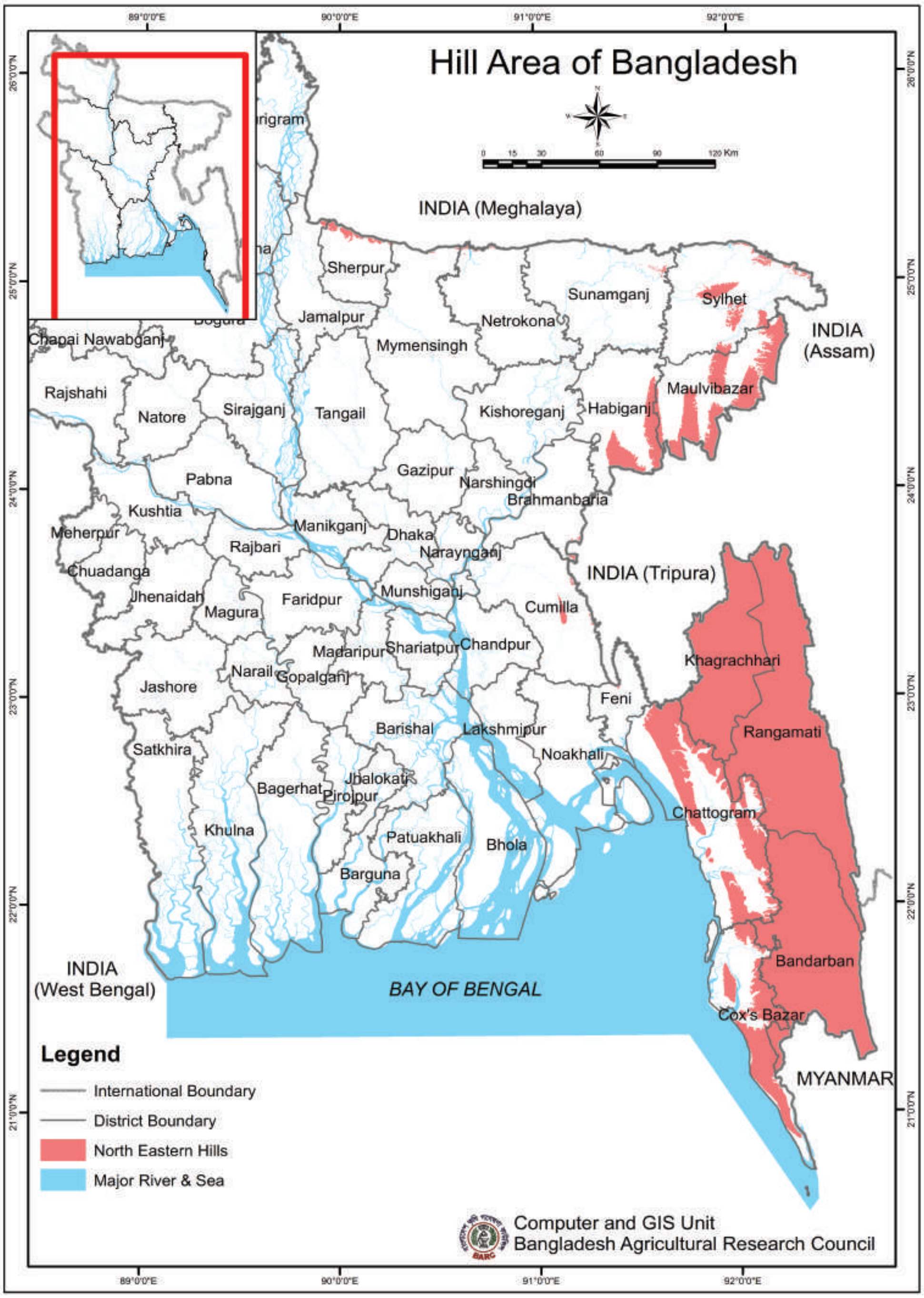


Fig. 6.2. Map of Chattogram Hill Tracts in Bangladesh (Source: BARC 2022)

Sunamganj and Sylhet districts in central and south eastern Sylhet and in the east of Brahmanbaria, Comilla and Feni districts (Fig. 6.2)

The CHT is originated as a result of the collision between India and Asia. Indo-Australian plate moved southeasterly of about 1750 km at a drift rate of 6 cm/yr, after the break-up of Gondwanaland (Banglapedia 2021). Later, India broke apart from Australia and started to drift northeasterly. From this time, eventually the history began for the CHT.

Out of the 159 upazilas of the hill-based districts, 90 are in the hilly areas. These 90 upazilas comprise 18.2% of the total 495 upazilas of Bangladesh (Table 6.1). All upazilas of Bandarban (7), Khagrachhari (9), Rangamati (10) and Moulvibazar (7) districts, and also most upazilas (14 out of 15) of Chattogram district are parts of the hilly areas. Names of the upazilas of the hill-based districts situated in the hilly areas are listed in Table 6.2.

Table 6.1. Number and proportion of hill upazila

Division	District	Upazila (no)	Hill Tract Upazila (no)	Proportion of Hill Tract upazila (%)
Chattogram	Bandarban	7	7	100
	Khagrachhari	9	9	100
	Rangamati	10	10	100
	Chattogram	15	14	93.3
	Cox's Bazar	9	7	77.8
	Cumilla	17	5	29.4
	Brahamanbaria	9	1	11.1
	Feni	6	4	66.7
Sylhet	Moulvibazar	7	7	100
	Habiganj	9	5	55.6
	Sylhet	14	8	57.1
	Sunamganj	12	5	41.7
Mymensingh	Sherpur	5	3	60.0
	Netrakona	10	2	20.0
	Jamalpur	7	1	14.3
	Mymensingh	13	2	15.4
	Total	159	90	57
	Bangladesh	495	90	18.2

Source: BBS 2021, BARC 2022

Table 6.2. Upazilas under the domain of hilly areas

Division	District	Upazila containing hilly areas
Chattogram	Bandarban	Bandarban Sadar, Lama, Naikhongchhari, Rowangchhari, Ruma, Thanchi and Alikadam
	Khagrachhari	Guimara, Khagrachhari Sadar, Lakshmichhari, Mahalchhari, Manikchhari, Matiranga, Panchhari, Ramgarh and Dighinala
	Rangamati	Barkal, Belai Chhari, Jurai Chhari, Kaptai, Kawkhali (Betbunia), Langadu, Naniarchar, Rajasthali, Rangamati Sadar, Baghai and Chhari
	Chattogram	Banshkhali, Boalkhali, Chandanaish, Fatikchhari, Hathazari, Karnaphuli, Lohagara, Mirsharai, Patiya, Rangunia, Raozan, Satkania, Sitakunda and Anowara
	Cox's Bazar	Cox'S Bazar Sadar, Maheshkhali, Pekua, Ramu,Teknaf, Ukhia and Chakaria
	Cumilla	Burichang, Chauddagram, Cumilla Adarsha Sadar, Cumilla Sadar Dakshin and Barura
	Brahamanbaria	Kasba
	Feni	Feni Sadar, Fulgazi and Parshuram
Sylhet	Moulvibazar	Juri, Kamalganj, Kulaura, Moulvibazar Sadar, Rajnagar, Sreemangal and Barlekha
	Habiganj	Chunarughat, Madhabpur, Nabiganj, Shayestagang and Bahubal
	Sylhet	Companiganj, Fenchuganj, Golabganj, Gowainghat, Jaintiapur, Kanaighat, Sylhet Sadar and Beani Bazar
	Sunamganj	Dowarabazar, Madhyanagar, Sunamganj Sadar, Tahirpur and Chhatak
Mymensingh	Sherpur	Nalitabari, Sreebardi and Jhenaigati
	Netrakona	Kalmakanda and Durgapur
	Jamalpur	Bakshiganj
	Mymensingh	Haluaghat and Dhobaura

Source: BARC 2022

The Hill areas occupy 1,836,605 ha (Fig. 6.3) which is 37.31% of the total area (4,922,648 ha) of the 16 hill-based districts and 12.7% of the total area of Bangladesh (14,486,269 ha). Among the hill-based districts, Rangamati contains the largest Hill areas of 565,076 ha out of the total district area of 565,302 ha (Fig. 6.4). Next to Rangamati, Bandarban, Khagrachhari, Chattogram, Moulvibazar and Cox's Bazar districts account for 458,756 ha, 297,838 ha, 181,663 ha, 118,617 ha and 111,723 ha, respectively, of the Hill areas. In comparison, the other ten districts possess small areas of the hilly areas.

In terms of proportions of total district areas in the Hill ecosystem, Bandarban, Khagrachhari and Rangamati districts have the highest proportion (each district with 100%) followed by Cox's Bazar (48.3%), Moulvibazar (44.4%) and Chattogram (37.2%) compared with the other districts containing parts of the hilly areas (Fig. 6.5). A negligible proportion is in Sunamganj, Netrakona, Jamalpur, Mymensingh and Brahmanbaria ranging from 0.2-0.8%.

Fig. 6.3. Areas of hills relative to those of hill-based districts and Bangladesh (source: BBS 2021, BARC 2022)

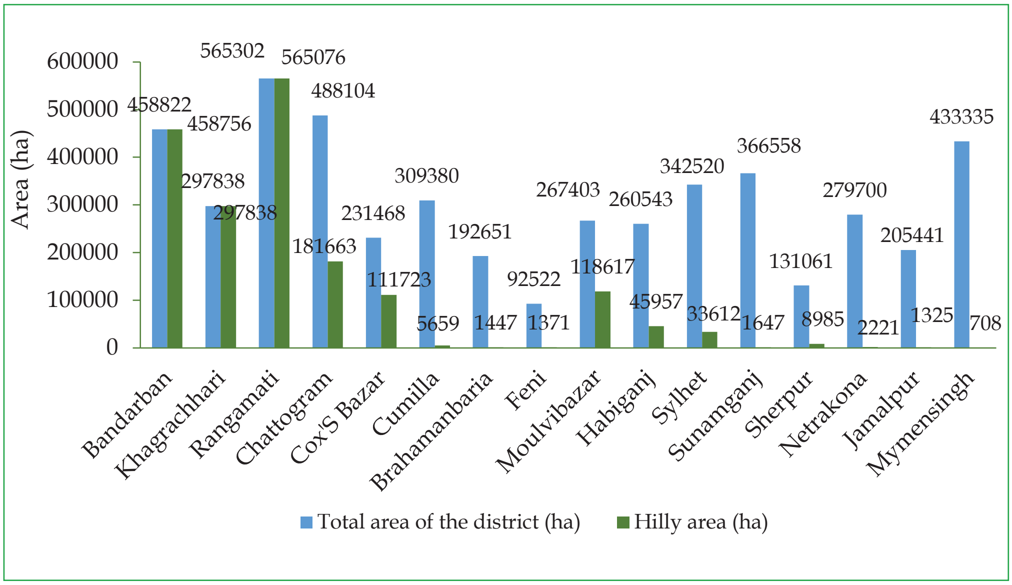


Fig. 6.4. Hilly areas in different districts in 2022 (source: BARC 2022)

Earlier communications indicate that CHT account for about 13,184 sq km, which is approximately one-tenth of the total area of Bangladesh (Banglapedia 2021). The CHT comprises 70% of the hilly areas of Bangladesh and covers 13,184 km^2 (10% of total country area), of which 90% are sloping lands (Hossain et al. 2017).

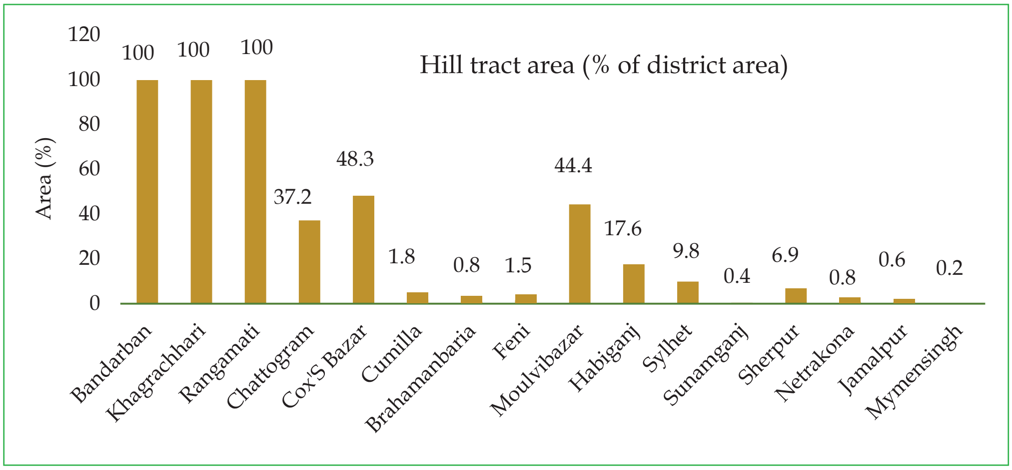


Fig. 6.5. Proportions of district areas occupied by the Hill Tracts

6.2 Biophysical characteristics

6.2.1 Land and soil

Hills have been dissected to different degrees over different rocks. 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. There are extensive stretches of low hills and hillocks within the high hill ranges (Anonymous 1996). The hill ranges and the river valleys are longitudinally aligned generally. Four ranges, with an average elevation of over three hundred metres, strike in a north-south direction in the northern part of the hill based districts. These are Phoromain range (Phoromain, 463 m), Dolajeri range (Langtrai, 429 m), Bhuachhari (Changpai, 611 m) and Barkal range (Thangnang, 735 m). There are seven main mountain ranges within the CHT. These are: Muranja range (Basitaung, 664m), Wayla range (most of this range is in Myanmar), Chimbook range (Tindu, 898 m), Batimain range (Batitaung, 526 m), Politai range (Keokradang, 884m; Ramiu Taung 921m, Saichal-Mowdok range (Bilaisari, 669m) and Saichal range. Saichal range contains the highest peaks of Bangladesh. These are Waibung (808m), Rang Tlang (958m), Mowdok Tlang (905m), and Mowdok Mual (1,0 03m) which are on the border with Myanmar (Nazila 2005, Danilo 2008). Saka Haphong was belived to be the highest peak in Bangladesh. It is situated between Thanchi, Bandarban and the Chin State of Myanmar on the Bangladesh-Myanmar border (Fig.6.6). Now officially, Tazing Dong (also known as Bijay) is the highest mountain in Bangladesh with the height of 1,280 m (4,200 ft) (21º47′11″N 92º36′36″E) (Fullen 2014). It is located on Saichol Mountain ranges, Ruma Upazila of Bandarban District, southeast of Bangladesh. Saka Haphong has an elevation of 1,052 metres (3,451 ft) (Nazila 2005; Danilo 2008; Life is not Ours Land and Human Rights in the Chittagong Hill Tracts, Bangladesh 2000).

Fig. 6.6. Tazing Dong, Bandarban – the highest Mountain Peak of Bangladesh

The thick sediments deposited in the Irrawaddy Basin during Miocene and Lower Pleistocene time are exposed in the Chattogram and Tripura hills. In the Chattogram Hill Tracts, the Upper Tertiary sandy-argillaceous sediments have been folded into a series of long sub meridional anticlines and synclines represented in the surface topography by elongated hill ranges and intervening valleys. The folded flank is divided into three parallel almost N-S trending zones from west to east as: (a) the Western Zone is characterized by simple box-like or similar shaped anticlines with steep flanks and gentle crests separated by gentle synclines, viz. Matamuhuri anticline, Semutang anticline, etc.; (b) the Middle Zone is characterized by more compressed structures, other than just simple box-like folds, with ridge like asymmetric anticlines frequently associated with faults and separated by narrow synclines. There are Sitapahar anticline, Bandarban anticline, Gilasari anticline, Patiya anticline, Changohtung anticline, Tulamura anticline, Kaptai syncline, Alikadam syncline, etc; (c) The Eastern Zone is characterized by highly disturbed narrow anticlines with steep clipping flanks and mostly associated with thrust faults. There are Belasari anticline, Subalong syncline, Utanchatra anticline, Barkal anticline, Mowdac anticline, Ratlong anticline, Kasalong syncline, Sangu Valley syncline and few others (Nazila 2005, Danilo 2008).

The major hill soils are yellow brown to strong brown, permeable, friable loamy, very strongly acidic, and low in moisture holding capacity. However, soil patterns generally are complex due to local differences in sand, silt, and clay contents of the underlying sedimentary rocks and in the amount of erosion that has occurred. Erosion on steep slopes of high hills constantly removes the weathered material on the hills. Thus, it keeps the soils young on the high hills. The soils on the low hills are older as erosion is less severe. Hence, soil materials can easily accumulate. Brown Hill Soils is the predominant General Soil Type of the area. Organic matter content and general fertility level is low. Chattogram Hill Tracts, Chattogram, Sylhet, Moulvibazar, Mymensingh etc. contain hill soils. The soils consist of hard red clay with a mixture of fine sand of the same color and nodules containing a large percentage of sesquioxides. The soils are highly leached and have a low natural fertility. The hill soils (dystric cambisols) are mainly yellowish brown to reddish brown loams which grade into broken shale or sandstone as well as mottled sand at a variable depth (Nazila 2005, Danilo 2008). The soils in the area develop from semi-consolidated to consolidated shales and sandstones on very undulating relief in a tropical climate with heavy rainfall concentrated in the monsoon. The parent materials are low in weatherable minerals. The area was earlier covered by dense tropical rainforests that suffered extensive deforestation during the recent past.

Shifting cultivation by ethnic minorities is contributing to major deforestation and subsequent land degradation in the Hill Tracts though it is their only farming activity. Many scientists have reported that shifting cultivation causes land degradation by encouraging erosion of fertile topsoil with ultimate exposure of rocks. A considerable amount of nutrients is also washed away from the upper 10 cm soil with run off sediments as an outcome of shifting cultivation (Gafur et al. 2003).

6.2.2 Soil fertility

Soil pH and soil organic matter (SOM)

Soil pH values observed in three periods, 1985-1999, 1999-2002 and 2003-2021 are presented in Table 6.3. The minimum soil pH values averaged over the 2003-2021 period ranged from 3.6 to 4.9 (extremely acidic to strongly acidic) tending to be higher at the lower land elevations (Table 6.3). The maximum observed soil pH ranged from 5.9 to 6.8, and unlike in case of the lower pH range, the soils appeared to be less acidic (higher pH) on higher land than on lower land. Soil acidity may have arisen from the release of hydrogen ions upon oxidation of the soils (upland condition at higher elevations). The hydrogen ions attack clay minerals releasing aluminum which, upon hydrolysis acidifies the surface soil (Brammer 1996). Over time (1985-2021), there was no significant changes in soil pH (Table 6.3).

Table 6.3. Soil pH in the hilly areas during 1985-1998, 1999-2002 and 2003-2021

Soil pH (1985-1998)			
Land type	HL	MHL	MLL
Min	3.9	4.3	4.9
Class	Extremely acidic	Extremely acidic	Extremely acidic
Max	7.3	6.7	5.9
Class	Neutral	Neutral	Moderately acidic
1999-2002			
	HL	MHL	MLL
Min	3.6	3.9	4.4
Class	Extremely acidic	Extremely acidic	Extremely acidic
Max	7.3	7	5.1
Class	Neutral	Neutral	Strongly acidic
2003-2021			
	HL	MHL	MLL
Min	3.6	3.8	4.9
Class	Extremely acidic	Extremely acidic	Strongly acidic
Max	6.8	6.5	5.9
Class	Neutral	Moderately acidic	Moderately acidic

Here, HL- High Land; MHL- Medium High Land; MLL- Medium Low Land

Source: BARC 2022

Available evidence indicates that the hill soils have derived from highly weathered parent materials (tertiary semi-consolidated to consolidated sediments) on precipitous steep slopes. They are severely surface-drained and leached. The resulting soils are, therefore, naturally moderate to strongly acid (SRDI 1976). Another study also indicate that soil pH varies within a narrow range from 4.56 (forested sites) to 4.77 (two years after shifting cultivation) (Biswas et al. 2012).

The SOM level (averaged over three periods, 1989-1998, 1999-2002 and 2003-2021) across HL, MHL, MLL and LL, ranged from 1.74% to 2.92% in the hilly areas (Fig. 6.7). In general, soils on MLL have a higher organic matter content than those on HL and MHL during 1999-2002 and 2003-2021. However, SOM in the hilly areas has historically remained above the critical level of 2% needed for good crop production although soils on MHL and MLL during 1989-1998 had a relatively low SOM content (below 2%). A comparison of the three periods indicates that SOM increased over time on all land types. The reason for this increase might be due to decaying residues of forest trees that are extensively grown in the Hill areas. This implies an improvement in fertility of the Hill soils which Biawas et al. (2012) had in the past found to be moderately fertile due to a low soil organic carbon content (0.54 %) in slashed and burnt sites to 1.55% in forest sites.

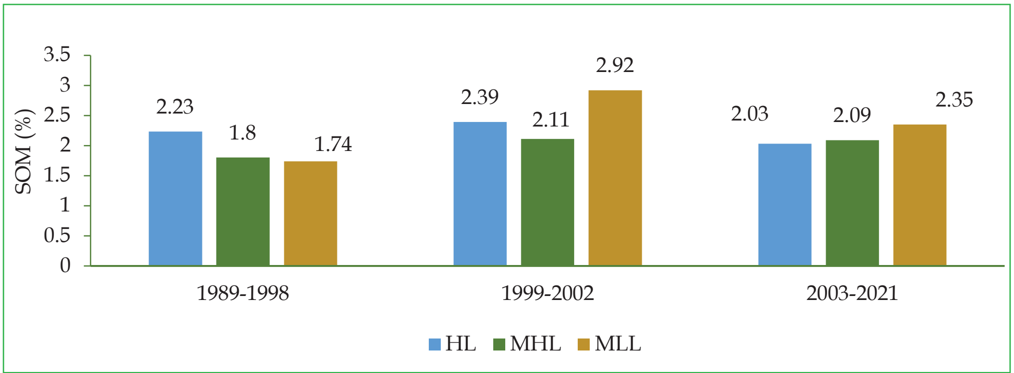


Fig. 6.7. Organic matter content of soils in the hilly areas (Source: BARC 2022)
Here, HL- High Land; MHL- Medium High Land; MLL- Medium Low Land

Nutrient contents

During 1999-2002 and 2003-2021, the available phosphorus (P) levels in soils of the hilly areas across land types (HL, MHL and MLL) ranged from 5.19 to 5.34 ppm and 4.38 to 6.88 ppm, respectively which were much below the optimum level of 20 ppm for crops. Available P in soils across HL and MHL appeared to increase with time between 1999 and 2021 (Fig. 6.8). The reason probably is increasing application of P fertilizer as crop production intensity and acreage has been increasing in the hilly areas.

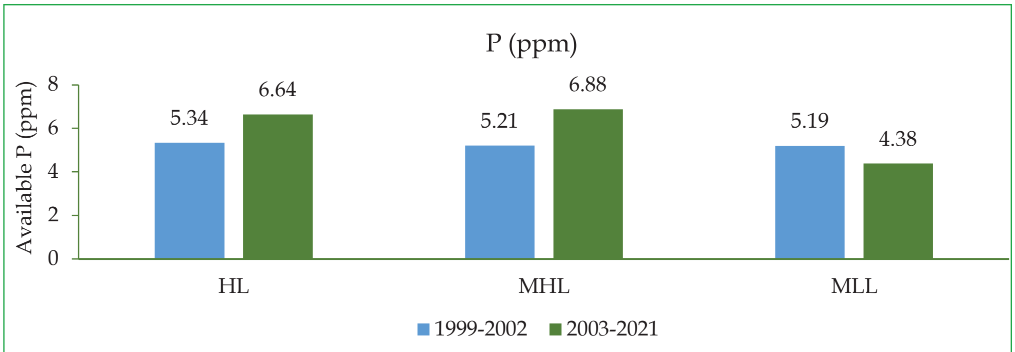


Fig. 6.8. Available P in soils of the hilly areas (Source: BARC 2022)
Here, HL- High Land; MHL- Medium High Land; MLL- Medium Low Land

The available potassium (K) levels in soils of the hilly areas, averaged over two periods, 1999-2002 and 2003-2021, measured as exchangeable K, ranged from 0.11 to 0.23 meq/100g and 0.17 to 0.22 meq/100g, respectively (Fig. 6.9). The K level is generally higher on higher land than that on lower land. Soils on HL and MHL had an exchangeable K level ranging from 0.17 to 0.23 meq/100 g compared with 0.11-0.22 meq/100 g in soils on MLL. The available K level in soil has increased with time on MLL while it remained almost static on HL and MHL. However, at no time the exchangeable K level was sufficient (0.5 meq/100g or higher) for crops.

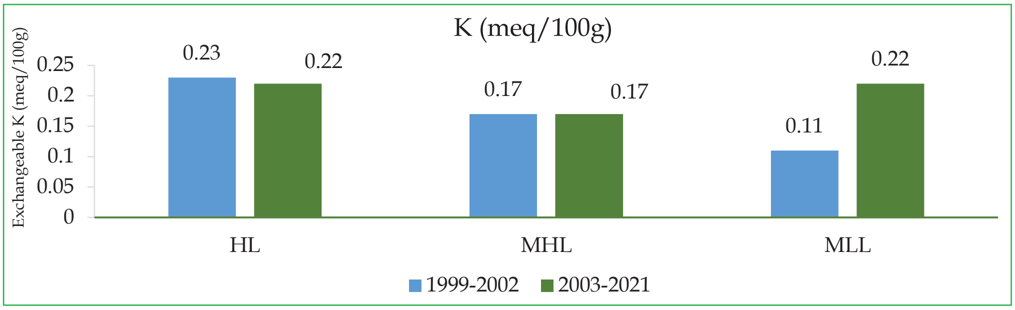


Fig. 6.9. Exchangeable K in soils of the hilly areas (Source: BARC 2022)
Here, HL- High Land; MHL- Medium High Land; MLL- Medium Low Land

Available sulphur (S) in soils of the hilly areas across land types (HL, MHL and MLL) has remained generally above the critical level (12 ppm) during the last two decades (1999-2021) but the values have been much below the optimum level of 20 ppm (Fig. 6.10). During 1999-2001, the available S content in the soils was 11.19-21.82 ppm which declined significantly to 10.13-14.82 ppm during 2003-2021. The decrease in the available S content of soils is attributed mainly to an increased cultivation of crops applying high-analysis S-free fertilizers over the years. The crops which absorbed large amounts of S from soils were not adequately replenished with S addition.

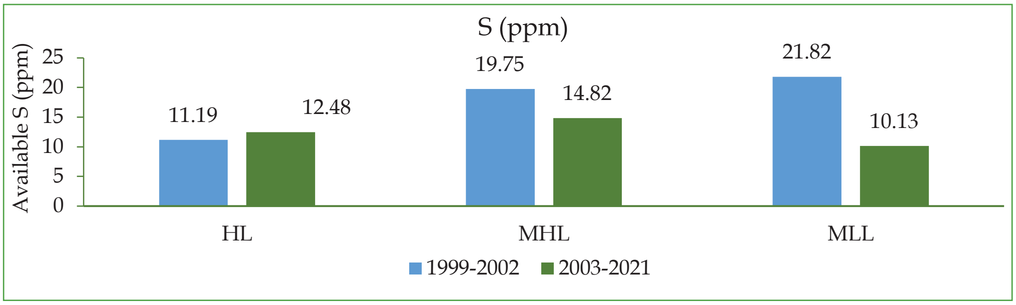


Fig. 6.10. Available S in soils of the hilly areas (Source: BARC 2022)
Here, HL- High Land; MHL- Medium High Land; MLL- Medium Low Land

The available zinc (Zn) content in soils of the hilly areas ranged from 0.86 to 1.96 ppm during 1999-2021 (Fig. 6.11) which was above the critical level of 0.6 ppm indicating mostly Zn sufficiency for crops. Soils on HL contained a deficient Zn level than those on any of the other land types. Appropriate soil and crop management including the application of adequate amounts of Zn fertilizer are required for optimum crop growth and yield on Zn deficient soils.

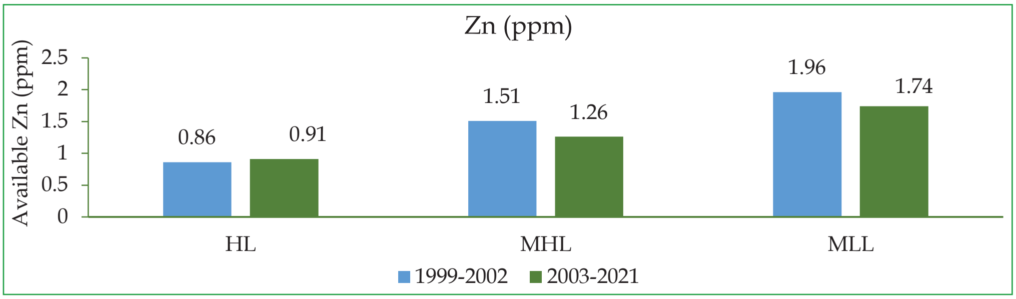


Fig. 6.11. Available Zn in soils of the hilly areas (Source: BARC 2022)
Here, HL- High Land; MHL- Medium High Land; MLL- Medium Low Land

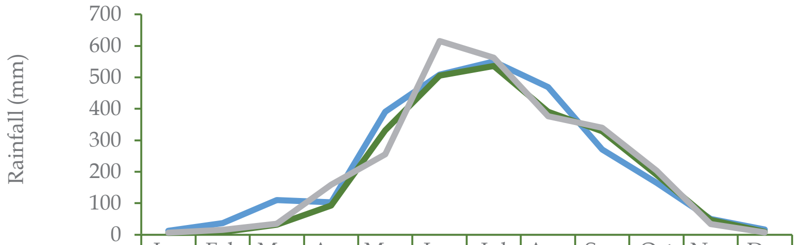
Gafur et al. (2000) found nutrient losses due to burning prior to shifting cultivation. They observed annual losses per ha of 61 kg Ca, 13 kg Mg, 13 kg K, 0.14 kg P, 0.20 kg S, 0.05 kg Cu, 6.7 kg Fe, 6.1 kg Mn and 0.065 kg Zn corresponding to 8% Ca, 3% Mg, 17% K, 11 %P, 27% S, 4% Cu, 8% Fe, 14% Mn and 5% Zn of the nutrient content before burning. Nutrient depletion will likely continue as long as the present cultivation systems will continue with little regard for recycling of crop residue and addition of organic amendments.

6.2.3 Climate

Rainfall

Unlike the relatively low-lying central and southern parts of Bangladesh, the hilly areas are not expected to be affected by excess water problems due to its elevation above flood levels. The CHT has never been a national disaster hotspot until very recently. In recent years, flash flood and landslide have captured disaster headlines. On 13 June 2017, non-stop rains and heavy landslides devastated the Rangamati, Bandarban and Khagrachari hill districts, killing 131 people. Hundreds were injured and around 15,000 families were affected, having lost most of their belongings. Landslides wiped out agricultural lands and crops and destroyed most of the roads and electrical installations. The story of land-use change, deforestation, land degradation, heavy rain, flash flood, and landslide are interlinked and needs a holistic view to understand the interconnections of development, hazard, and climate change.

The Rangamati Meteorological Station recorded monthly precipitations in the Rangamati-Khagrachhari-Bandarban districts. From the data, a 10-year set of monthly average of three periods viz. 1991-2000, 2001-2010 and 2011-2020 were derived (Fig. 6.12). The months receiving the highest precipitation were, obviously, the Kharif months of May to September irrespective of the period. The average rainfall in May, June, July, August, and September amounted to 391, 509, 550, 469 and 277 mm in 1991-2000 and 256, 616, 562, 376 and 340 mm, respectively, during 2011-2020. Apparently, precipitation tended to increase slightly over time. However, the rainfall in June, July, and September during 2011-2020 was much higher than the average precipitation in the corresponding months of 1991-2000. This could be interpreted as an increasing trend of rainfall in this part. In particular, an increase in rainfall in the months of June and July has been critical for the safe harvest of Boro rice and planting of Kharif-I crops. An increase in rainfall in September, on the other hand, is potentially damaging to T. Aman rice.

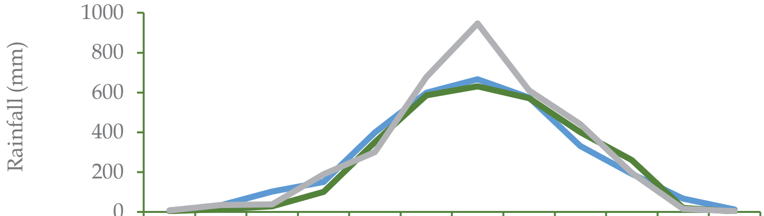


	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg Rainfall during 1991-2000	13	37	111	103	391	509	550	469	271	165	50	16
Avg Rainfall during 2001-2010	6	8	32	93	331	506	536	391	329	190	47	9
Avg Rainfall during 2011-2020	6	15	35	159	256	616	562	376	340	204	34	7

Fig. 6.12. Monthly rainfall in the Rangamati-Khagrachhari-Bandarban districts (Rangamati Meteorological Station) during 1991-2000, 2001-2010 and 2011-2020 (Source: BARC 2022)

In the hilly areas of Chattogram district, average amounts of rainfall in the months of June, July, August and September during 2011-2020 amounted to 677, 946, 610 and 440 mm, respectively as recorded by the Sitakundu Meteorological Station (Fig. 6.13). Average amounts of rainfall in the same months during 1991-2000 were 599, 666, 574 and 331 mm. A comparison of average rainfall during 1991-2000 with that during 2011-2020 indicates an increasing trend in rainfall during June through September i.e., during Kharif season. However, rainfall decreased generally consistently in the Rabi season

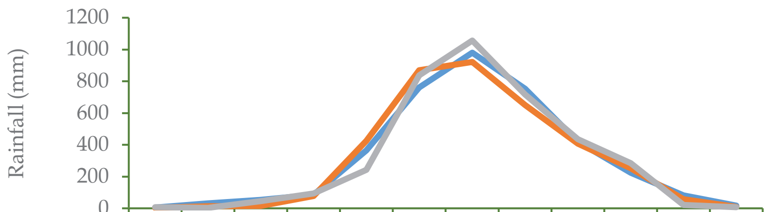
(November-March) ranging from 5-38 mm, 2-29 mm and 12-103 mm, respectively during 2011-2020, 2001-2010 and 1991-2000. This indicates increasing dryness and probable drought spells in the peak dry months of the year which could adversely affect T. Aman rice and Rabi crops.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg Rainfall during 1991-2000	8	33	103	151	399	599	666	574	331	192	67	12
Avg Rainfall during 2001-2010	4	15	29	102	351	586	631	571	400	260	20	2
Avg Rainfall during 2011-2020	7	35	38	189	301	677	946	610	440	196	16	5

Fig.6.13. Monthly rainfall covering major hilly areas of Chattogram district in the Fatikchhari-Sitakundu-Raozan-Rangunia upazilas (Sitakundu Meteorological Station) during 1991-2000, 2001-2010 and 2011-2020 (Source: BARC 2022)

The Cox's Bazar Meteorological Station recorded relatively high rainfall in June (838 mm), July (1057 mm), August (718 mm) and September (435 mm) during 2011-2020 in the hilly areas of Cox's Bazar district (Fig. 6.14) compared to the rainfall of the same months (762, 980 753 and 419 mm, respectively)

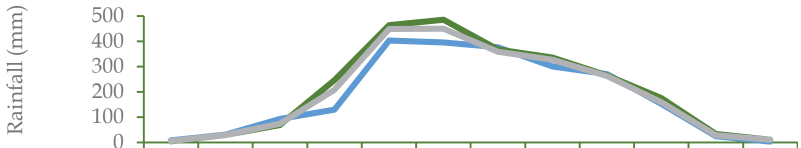


	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg Rainfall during 1991-2000	6	32	54	87	366	762	980	753	419	225	82	18
Avg Rainfall during 2001-2010	5	15	16	78	425	870	921	651	409	254	59	10
Avg Rainfall during 2011-2020	7	4	45	94	242	838	1057	718	435	285	23	8

Fig.6.14. Monthly rainfall covering major hilly areas of Cox's Bazar district in the Cox's Bazar sadar-Ramu-Ukhia-Moheshkhali-Chakaria upazilas (Cox's Bazar Meteorological Station) during 1991-2020 and 2011-2020 (Source: BARC 2022)

during 1999-2000. This comparison of average rainfall during 1991-2000 with that during 2011-2020 indicates an increasing trend in rainfall during June through September i.e. during Kharif season. Like Chattogram, similar increase in dry spell occurs in the peak dry months (November-March i.e. Rabi season) in the hilly areas of Cox's Bazar.

Data collected by the Sreemangal meteorological station indicated an increasing trend in rainfall (Fig. 6.15) in the Moulvibazar-Habiganj region. There was an intense rains during April (208 mm), May (449 mm), June (450 mm) and August (328 mm) during 2011-2020 in comparison with the rainfalls in the same months during 1991-2000 (130, 403, 395 and 301 mm, respectively). In particular, the increasing trend in the months of April and May has been critical for the safe harvest of Boro rice, and planting of Kharif-I vegetables and other crops. The high rainfall in April and May causes frequent flash floods in this region. The monthly rainfall has, however, decreased severely in November- March during 2011-2020 (0, 4, 1 and 0 mm, respectively) compared to the average rainfall during 1991- 2000 (29, 11, 7 and 30 mm, respectively). This sharp decline in rainfall in these dry months brings about drought that delays planting of Boro rice and other winter crops with resultant yield losses.



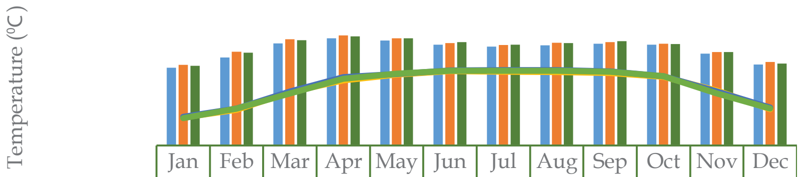
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg Rainfall during 1991-2000	8	31	93	130	403	395	377	301	270	152	24	3
Avg Rainfall during 2001-2010	5	30	69	246	464	485	368	336	265	175	33	11
Avg Rainfall during 2011-2020	7	30	74	208	449	450	359	328	262	159	29	11

Fig.6.15. Monthly rainfall in the Moulvibazar-Hobiganj region (Sreemangal Meteorological Station) during 1991-2000, 2001-2010 and 2011-2020 (Source: BARC 2022)

Chattogram Hill Tracts is affected by climate-induced events, particularly hydro-climatic events like heavy and frequent rainfall and storms. Besides, the same amount of rainfall in the past three decades would have very different consequences because of massive change in CHT's topography and land use over time. For example, Rangamati had similar magnitudes of heavy rainfall in 1998, 1999, 2004 and 2017, and all of them were above 300 mm (MJF 2020). There was a mass scale landslide in 2017. One of the major discourses emerging following this event is massive deforestation and land-use change which, coupled with heavy rainfall, causes landslide. Besides, changing pattern of rainfall, particularly during crop seasons, causes water scarcity which in turn raises cost of irrigation. Thus, local farmers point out myriad ways in which slight changes in rainfall are challenging local agricultural harvests. As a result, dependence on hybrid seeds, pesticides, and chemical fertilizers are mounting day by day. These chemicals are washed onto the water bodies and adversely impact aquatic ecosystems. Inappropriate land use not only reduces soil fertility but also causes soil erosion, runoffs into water bodies and rivers and reduces their capacity to accommodate surface runoff and eventually causes flash flood.

Temperature

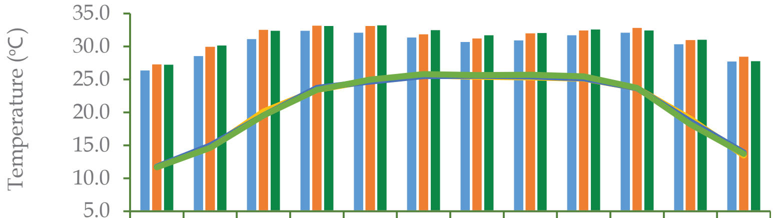
The average monthly maximum temperature (T_{max}) for the three periods viz. 1991-2000, 2001-2010 and 2011-2020 was collected from the Rangamati Meteorological Station for the Rangamati-Khagrachhari-Bandarban region. The trend indicated an increase in T_{max} with time in all months of the year except January (Fig. 6.16). The magnitude of T_{max} increase was 0.2-1.3° C. Likewise, the minimum monthly temperature (T_{min}) during the same 30-year period also increased (Fig.6.16). In 2011-2020, T_{min} ranged from 14.8° C in February to 24.6° C in September while in 1999-2000 T_{min} values, 14.5° C in February to 24.3° C in September were recorded. Thus, T_{min} increased by 0.3° C.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg MaxT during 1991-2000	25.6	28.4	32.2	33.5	32.9	31.8	31.3	31.6	32.0	31.8	29.4	26.6
Avg MaxT during 2001-2010	26.4	29.9	33.3	34.3	33.5	32.2	31.7	32.3	32.5	32.1	29.9	27.2
Avg MaxT during 2011-2020	26.2	29.7	33.0	34.0	33.5	32.5	31.8	32.3	32.7	32.0	29.8	26.8
Avg MinT during 1991-2000	12.5	14.5	19.2	22.3	23.8	24.8	24.6	24.5	24.3	23.2	19.6	14.7
Avg MinT during 2001-2010	12.6	14.9	19.3	23.1	24.0	25.0	25.0	25.0	24.7	23.4	19.3	15.1
Avg MinT during 2011-2020	12.2	14.8	18.8	22.7	24.1	24.9	24.9	24.8	24.6	23.5	18.8	14.8

Fig. 6.16. Monthly maximum and minimum temperatures in the Rangamati-Khagrachari-Bandarban districts (Rangamati Meteorological Station) during 1991-200, 2001-2010 and 2011-2020 (Source: BARC 2022)

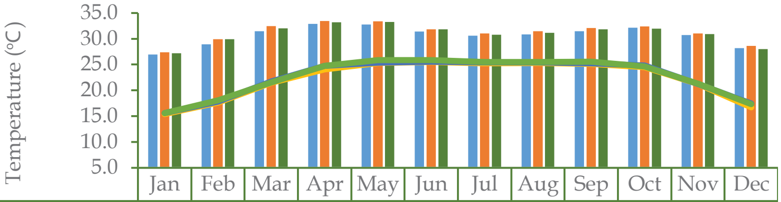
In the Chattogram region, according to average monthly temperature data recorded by the Sitakundu Meteorological Station, the monthly T_{max} in 2011-2020 ranged from 30.2° C in February to 32.6° C in September (Fig. 6.17). In the 1991-2000 period, T_{max} ranged from 28.5° C in February to 31.7° C in September. There was generally an increase in T_{max} by 0.9-1.7° C, the increase being most marked, by >1° C in the months of February, March, May, June and August. The recorded average T_{min} for the periods of 2011-2020 and 1991-2000 amounted to 25° C in May to 23.7° C in October and 24.8° C in May to 23.7° C in October, respectively (Fig. 6.17). The data indicated an increasing trend of T_{min} over time in the Chattogram hilly areas, the magnitude of increase being 0.0 to 0.2° C. The greatest increase in T_{min} occurred in the month of August and September for which the average recorded T_{min} during 1991-2000 was 25.3° C and 25.1° C, respectively which increased to 25.7° C and 25.4° C during 2011-2020.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg MaxT during 1991-2000	26.4	28.5	31.1	32.4	32.1	31.3	30.7	30.9	31.7	32.1	30.4	27.7
Avg MaxT during 2001-2010	27.3	30.0	32.5	33.1	33.1	31.8	31.2	32.0	32.4	32.8	31.0	28.4
Avg MaxT during 2011-2020	27.2	30.2	32.4	33.1	33.2	32.5	31.7	32.0	32.6	32.4	31.0	27.8
Avg MinT during 1991-2000	11.8	14.7	20.1	23.4	24.8	25.6	25.4	25.3	25.1	23.7	19.0	13.4
Avg MinT during 2001-2010	11.7	15.0	19.6	23.7	24.7	25.5	25.5	25.5	25.2	23.7	18.6	13.9
Avg MinT during 2011-2020	11.6	14.6	19.5	23.4	25.0	25.8	25.7	25.7	25.4	23.7	18.2	13.7

Fig.6.17. Monthly maximum and minimum temperatures covering major hilly areas of Chattogram district in the Fatikchhari-Sitakundu-Raozan-Rangunia upazilas (Sitakundu Meteorological Station) during 1991-2000, 2001-2010 and 2011-2020 (source: BARC 2022)

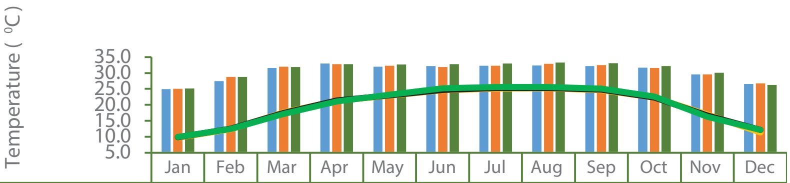
The average T_{max} in the Cox's Bazar district during 1991-2000 as recorded by the Cox's Bazar Meteorological Station ranged from 26.9° C in January to 32.7° C in May (Fig. 6.18). During 2011-2020 , January was the coolest (27.2° C) and May was the warmest (33.3° C) month. In hilly areas of Cox's Bazar, T_{max} has increased in all the months of the year except in October and December as is revealed by a comparison of the average T_{max} values during 1991-2000 and 2011-2020 (Fig. 6.18). The T_{max} rise with time in this part of the Hill Tracts ranged from 0.3° C to 0.6° C in 10 months of the year. T_{min} during 1991-2000 ranged from 15.4° C in January to 25.5° C in June, and during 2011-2020 from 15.6° C in January to 25.8° C in May (Fig. 6.18). Over time, like T_{max}, the monthly T_{min} had also increased to various extents in all months of the year. For example, in the last 10 years (2011-2020), the average T_{min} in January was 15.6° C and that in May was 25.9° C increasing from 15.4° C and 25.3° C, respectively, during 1991-2000 (Fig. 6.18).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg MaxT during 1991-2000	26.9	28.9	31.4	32.9	32.7	31.4	30.6	30.8	31.5	32.1	30.7	28.2
Avg MaxT during 2001-2010	27.4	29.9	32.5	33.5	33.4	31.8	31.0	31.5	32.1	32.4	31.0	28.6
Avg MaxT during 2011-2020	27.2	29.9	32.0	33.2	33.3	31.8	30.8	31.1	31.8	32.0	30.9	28.0
Avg MinT during 1991-2000	15.4	17.6	21.5	24.0	25.3	25.5	25.2	25.3	25.1	24.5	21.2	16.7
Avg MinT during 2001-2010	15.6	17.8	21.7	24.7	25.4	25.5	25.4	25.4	25.3	24.8	21.3	17.4
Avg MinT of last 10 years	15.6	18.0	21.6	24.8	25.9	25.8	25.5	25.5	25.5	24.6	21.3	17.3

Fig.6.18. Monthly maximum and minimum temperatures covering major hilly areas of Cox's Bazar district in the Cox's Bazar sadar-Ramu-Ukhia-Moheshkhali-Chakaria upazilas (Cox's Bazar Meteorological Station) during 1991-2000, 2001-2010 and 2011-2020 (Source: BARC 2022).

The average monthly T_{max} in the Moulvibazar and Habiganj region as recorded by Sreemangal Metrological station has increased in all the months of the year except in April and December as compared between the average T_{max} values of during 1991-2000 and 2011-2020 (Fig. 6.19). The average monthly T_{max} has increased by the range of 0.2-1.3^{o}C over the 10 months of the year. T_{min} has also increased in all the months of the year except in February, March, April and November. During 2011-2020, T_{min} ranged from 9.9^{o}C in January (the lowest) to 25.6^{o}C in July (the highest) and similarly T_{min} ranged from 9.7^{o}C in January to 25.1^{o}C in July. Thus, the average monthly T_{min} has increased by the range of 0.2 to 0.5^{o}C.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg MaxT during 1991- 2000	24.9	27.4	31.5	32.9	32.0	32.2	32.2	32.4	32.2	31.6	29.5	26.6
Avg MaxT during 2001-2010	25.0	28.8	32.0	32.8	32.2	31.9	32.2	32.8	32.5	31.6	29.6	26.8
Avg MaxT during 2011- 2020	25.1	28.7	31.9	32.8	32.7	32.8	33.0	33.2	33.1	32.2	30.0	26.3
Avg MinT during 1991- 2000	9.7	12.3	17.7	21.3	22.9	24.6	25.1	25.2	24.6	22.2	17.0	11.4
Avg MinT during 2001-2010	9.9	12.6	17.5	21.4	23.0	24.7	25.3	25.3	24.7	22.3	16.7	12.1
Avg MinT during 2011- 2020	9.9	12.4	17.2	21.0	23.1	25.1	25.6	25.5	25.1	22.6	16.2	12.1

Fig.6.19. Monthly maximum and minimum temperatures in the Moulvibazar-Habiganj region (Sreemangal Meteorological Station) during 1991-2000, 2001-2010 and 2011-2020 (Source: BARC 2022)

6.3 Biodiversity

Flora

Hill forests are mostly mixed-evergreen forests which are mostly situated in the northeast and southeast parts of Bangladesh. The forests of northeast are mostly fragmented, and some relatively large patches of mixed-evergreen forests still exist in the CHT in the southeast. The dominating plants in these forests are *Dipterocarpus turbinatus, D. pilosus, Swintonia floribunda, Hopea odorata, Syzygium grande, Salmalia insignis, Lophopetalum fimbriatum, and Duabunga sonnerationides*. Evergreen plants dominate the mixed-evergreen forests; however, deciduous plants are quite common and abundant (Mukul et al. 2008). Some of the major species in the forests in Hill Tracts grow to gigantic heights and diameters. The tallest part of the canopy is generally formed by deciduous and semi-deciduous trees while the understory is of evergreen type. Bamboo formations and savannah are also present. The hills, rivers and cliffs are covered with dense bamboo breaks, tall trees and creeper jungles. The valleys are covered with thick forest. The vegetation is characterised by semi-evergreen (deciduous) to tropical evergreen dominated by tall trees belonging to *dipterocarpaceae, euphorbiaceae, lauraceae, leguminacae and rubiaceae (*Banglapedia 2021*)*. Most of the hills are covered with forests containing valuable timber trees, bamboos, canes and a kind of grass known as shan.

Fauna

The mixed-evergreen forests of Bangladesh support large populations of wild mammals including Asian elephants, Asiatic black bear, hoolock gibbon, sambar deer, wild dog, leopard, and other globally threatened species (Khan 2018). Birds like the imperial pigeon, the green pigeon, and the white winged wood duck are also present. Amphibians like tree frog, toad, python, cobra, monitor lizard are found in the forests. Among mammals big rat, bat, monkey, entellus, leopard, gibbon, bear, elephant and gaur are found to live here. Elephant is the largest mammal amongst the terrestrial animals. In forest, birds like Moutusi, Doyel (*Copsychus saularis*) [the national bird of Bangladesh], parrot, woodpecker and some others. The fauna mainly includes monkey, fox, jungle cat, fishing cat, wild boar, land turtle, king cobra, reticulated python, rat snake and other non-poisonous snakes together with large number of species of lisards and amphibians like frog and toad, and tree frogs. The bird life of the CHT is wonderfully rich. More than 60 families of birds are found (Nazila 2005, Danilo 2008). The gaur, also known as the wild cattle, is the largest of the bovines (Fig. 6.20). It is a native species of South and Southeast Asia. The gaur was declared vulnerable in 1986 due to their declining numbers, limited range, and degradation of their natural habitat. A few animals are found in the CHT of Bandarban district, Bangladesh. Over the past three decades, the population has declined significantly due to deforestation and hunting by the native people of Sangu Matamuhuri forest despite a ban on poaching. They prefer evergreen, semi-evergreen, and deciduous forests but can occasionally be seen in deciduous forests. Gaurs are also found in Vietnam, Laos, Cambodia, Myanmar, Malaysia, India, China, Nepal, and Bhutan. It plays an important role by modifying its habitat by way of resetting succession of a forest habitat to grassland and spreading the propagules of numerous plants.

Fig. 6.20. Photo of Gaur or wild cattle in the hilly areas of Bandarban

The forests of CHT are ecologically classified as Tropical wet-evergreen, Tropical semi-evergreen, Tropical moist-deciduous, Tropical open deciduous and Savannah forests. The important reserve forests of CHT are Kassalong reserve forests (159,449.7 ha), Raingkheong reserve forests (76,331.0 ha), Sitapahar reserve forests (5,876.5 ha), 235.79 ha of Barkal reserve forests; and Sangu and Matamuhury reserve comprises about 74,500 ha (Chowdhury 2006). There are three protected areas, e.g. Pablakhali Wildlife Sanctuary, Kaptai National Park, and Sangu Valley Wildlife Sanctuary. The CHT in Bangladesh supports almost 80% of the country's total biodiversity (Jashimuddin and Inoue 2012). Rampahar along with Sitapahar were declared as the first reserve forest in the CHT region in 1875 (Anonymous 1960). Presence of 85 different tree species having dbh ≥10 cm was reported from the Sitapahar reserve forest is comparable to other rich tropical forests (Nath et al. 2000). Since much of the biodiversity in tropical forests resides in herbs, shrubs and small trees, Uddin et al. (1998) recorded 332 species (248 dicots and 84 monocots) from this area. Harun-Ur-Rashid and Chowdhury (2013) later on added 43 taxa (38 dicots and 5 monocots) from this forest. A survey from 2001 to 2008 revealed 89 monocots (Uddin and Hassan 2012) and 500 dicot species from Rampahar area (648 ha) under Kaptai Forest Range. Uddin and Hassan (2012) also reported 41 pteridophyte species belonging to 26 genera from Rampahar and Sitapahar area, which constitutes 21% of total fern flora of the country. Similarly, the status and distribution pattern of natural regeneration of Sitapahar reserve forest reported 62 identified tree species and another

20 unidentified tree species with an average density of 15,618 seedlings/ saplings per ha indicating the rich soil seed bank of the native tree species (Hossain et al. 1999).

Commercial tree plantations, illegal logging, dam mega-projects, and forced displacement are responsible for the accelerated destruction of those precious ecosystems, which means the destruction of their biodiversity. Rubber, teak and eucalyptus monocultures for export have provoked negative ecological effects by the substitution of part of the forest, as well as conflicts between local communities belonging to the 13 ethnic groups that inhabit the region.

6.4 Demographic features

6.4.1 Population, social structures and facilities

The peoples of Chattogram Hill Tracts (CHT) are quite different from rest of the majority population of Bangladesh in all respects that feature 'a people' with regard to social, economic, cultural, so on and so forth. It is a land of at least 11 multilingual indigenous peoples consisting of Chakma, Marma, Tripura, Mro, Bawm, Pangkhu, Khyang, Khumi, Chak, Lushai, Tanchangya including Assamese, Gurkha and Saontals, collectively known as Jumma. The indigenous Jumma peoples mainly practice Buddhism, Hinduism and Christianity as their religion. Each group has distinctly different language, culture, religions, tradition, customs, practices, and lifestyle but still then they lead a common culture of livelihood. Despite all this, the indigenous peoples have been living in peaceful co-existence with their traditional economic system and develop their own socio-economic-cultural and political system under the umbrella of their traditional "Jum economy". The indigenous Jumma peoples are of Mongoloid origin belonging to the Tibeto-Burman or Mon-Khmer group although there are some Indo-Aryan traces visible in them. The original languages of the different ethnic's groups belong to the various branches of different language families. The languages of Bawm, Chakma, Khumi, Khyang, Lushai, Marma, Mro, Pangkhu, Chak, Tanchangya are Kuki-Chin branch of Tibeto-Burmese family. Kokbarak (Tripura) language is Bodo branch of Tibeto-Burmese family. The Chakma and Marma have their own scripts.

During the partition of India and Pakistan, the total population of CHT was only 247,053 out of that only 2.5 percent Bengali including 1.5 percent Bengali Muslims. According to the census report of 1991, total population was 974,445 (including ethnic Bengali and settlers) out of that 501,144 were Jumma and 473,301 were Bengali (means 49% of total Population). The total population was further increased to 15,98,231 as per population census report of 2011, where 845,541 (52.90%) were Jumma and 752,690 (47.10%) were Bengali (BBS 2011). The population of the CHT makes the population density roughly 120 per km^2. About 54.5% of the population is tribal people. They are mainly followers of Theravada Buddhism (44%), 6.5% Hindus (mostly Tripuris), 3% Christians (mostly in Bandarban) and 1% animists; 45.5% of the inhabitants are Bengalis (42% Muslims and 3.5% Hindus). Muslim population was 50.75% in Bandarban, 44.67% in Khagrachari and 35.28% in Rangamati (cited from Wikipedia 2022).

6.4.2 Socioeconomic conditions

In Bangladesh, the main terms that are used to indicate indigenous people are: 'Upojati' (indicates the tribal people) and 'Adibashi' (equivalent to the words 'indigenous' or 'aboriginals') (Roy 2010). As mentioned earlier, at present, 45 different indigenous groups are living both in the plain lands and on the hills. The highest number of indigenous people lives in the southeastern border region of CHT. Dhamai (2006) mentions that the social, political, cultural, and economic situation of those indigenous people living on the hills, is much different from the situations of the people living in the plain lands and on the hills. The highest number of indigenous people lives in the southeastern border region of CHT. These 'Jumma' people settled in this land before the 16th century. Later in the 19th century, the Bengali people (the dominant ethnic group of Bangladesh) started settling in these highlands. Over the years, the number of Bengali settlers increased in this area. Barkat et al. (2009) characterized the Chattogram Hill Tracts of Bangladesh as 'one of the most vulnerable' because of its income and employment opportunities, poverty, housing, health, water, sanitation, education, and intercommunity confidence. Dhamai (2006) commented that the main problems of the indigenous people are land dispossession (through development and forestry projects), limited access to education and other social services, and discrimination from the part of the non-indigenous people.

As the CHT is a hilly area, the opportunities for diverse kinds of occupation are very limited. The scope of cultivation and agriculture is also dependent mainly on the primitive techniques and technologies. From a survey of 400 households in the CHT areas, Dutta (2000) has identified the followings as the main occupations of the households of the indigenous people in CHT:

i. Agriculture;
ii. Business;
iii. Service/professional;
iv. Agricultural labor;
v. Tenant farmers;
vi. Fishing.

The main occupation of these households is agriculture (64%). This is followed by agricultural labor (12.5%), business (8.5%), service/professional (7.8%), fishing (4.8%) and tenant farmer (2.5%). From this Figure, it can be concluded that the main attribute of the indigenous economy in the CHT is agriculture. The main form of cultivation is the Swidden/Slash and Burn cultivation or shifting agriculture. In local indigenous language, this cultivation is called 'Jhum'. This special form of cultivation is common in several hilly areas of different parts of the world. The hill dwellers cut a good number of trees and burn them to clear the land for cultivation. They produce several kinds of crop on that land. The main crops that are cultivated include rice, maize, millet, sesame, cotton, ginger, cucumber, pumpkin, melon and some others (Karim and Mansor 2011). This is a thousand-year-old cultivation tradition and is the main source of sustenance for these indigenous people. But these days it has been found that because of the burning of the trees, the hill areas are facing huge environmental damage. Moreover, the lands are becoming infertile. Because of this burning process, the land becomes incapable of producing crops after this has been done a few times. As a result, new forest lands are cleared for cultivation. Again, trees of new areas are destroyed. It results in greater environmental damage.

Cultivation on the hills results in landslides that increase the siltation of the nearby lakes and cause floods. Because of the growth of population and infertility of land these people are shifting their occupations. The status of entrepreneurship among the indigenous people of CHT is poor. The indigenous people face huge barriers in entering non-agricultural trades, which are largely controlled by a few families based cartels (water transport, bamboo/ timber trades, trucks). Only traditional textiles and bamboo crafts are there for indigenous entrepreneurs, who are slowly entering into construction industries. However, there is an increasing trend for large farmers to also become involved in agricultural business enterprises, such as retail of agricultural inputs (seeds, fertilizers, agro-chemicals, etc.). This system aggravates social inequity and is not conducive to long-term sustainability of the land resource. These are the reasons for which it is commonly said that the most horrible poverty conditions prevail among the indigenous people and most of these people can be classified either under the poor or the extreme poor (Asian Indigenous Peoples Pact 2007). Land Dispossession and Migration due to land dispossession is one of the main problems of the indigenous people in Bangladesh. In 1960, the then Pakistan Government built the Kaptai hydroelectric project on the river Karnafuli and as a result the lands of indigenous people were flooded, and they had to migrate to other places including Myanmar and India (Dhamai 2006). Later, and many times, the Government has taken land for creating reserve forests and protected areas, building national parks and eco parks (Asian Indigenous Peoples Pact 2007).

According to Mullah et al. (2007), despite considerable improvement in the spread of education in Bangladesh, level of educational attainment is still very low amongst the Tribal people, with a strong differential persisting between males and females. It was found that the literacy rate in CHT is lower than the national literacy. Although the number of primary schools is adequate, they are not well managed. They really suffer from lack of number of teachers. The school facilities are shanty and the communications to the schools are not good. The schools are often far from their homes. Another problem of education is the language. According to Dhamai (2006), the most important limitation of the education system is that these indigenous children have to study in Bengali (the national language) which is not their mother tongue. In many cases, the indigenous children face learning difficulties and thus get dropped out. Barakat et al. (2009) commented that the indigenous children in CHT are in a disadvantageous position as they have to start school with a different language. That is why, it has now become important to introduce their local language as a medium of instruction. For many years, because of armed conflicts, the education of children was hampered. Chowdhury and Hossain (2010) found that conflict had a negative impact on the schooling of the household members. In 1974, after the independence of Bangladesh, the ethnic people of CHTs started an armed struggle for autonomy. The 23-year-long struggle ended with the signing of a peace accord on 2 December 1997 between the Government of Bangladesh and the Parbattya Jana Samhati Samiti (PCJSS), the political front of the armed group. Nearly two and a half years later, the armed members of the PCJSS have deposited their arms and returned to normal life. After the signing of the peace accord, the situation has improved. The extension of formal and informal education programs from the part of the Government, nongovernment organizations (NGOs) and international agencies also helped in this development of educational conditions of the people in the CHT.

Although in Bangladesh, many health and welfare services are provided by both Governmental agencies and the NGOs, in hill areas, these services are not that much available like those in the plain areas. Barakat et al. (2009) put comment that in many areas they did not avail the service due to lack of knowledge and in many other areas, service providers did not visit their houses, or they could not approach service providers due to geographical obstacles. Sultana (2011) identified the following main health problems prevailing in the CHT:

a. The poor health status is an underlying factor for its very low participation in economic development.
b. There are Government health care centers and private clinics but, in many cases, these are inaccessible as the transports are irregular and costly. That is why, in many cases, these people depend on the traditional healers.
c. The most common diseases are malaria, diarrhea, acute respiratory tracts infections, malnutrition, and poor pregnancy.
d. Infant mortality is higher than the national figure. The main reason for this is the lack of knowledge.
e. Waterborne diseases, basic sanitation and hygiene remain the most common problems in the CHT.

The hill women are very hard working at home and outside. Women work during jhum cultivation-from plantation to harvest. Every woman prepares their cloths by weaving in handloom at home. They prepare threads from their own produced cotton. They also make color of the cloths from the cultivated jhum plants, seeds, and bark etc. In case of handicrafts, they make food preparing materials from bamboo, leaves and woods. The plantation and intercultural management of field crops are also done by the woman laborers. They bring hygienic drinking water from the different *chharas (canals)* and *kua* (well) at the bottom of the hills. They also take care of homestead poultry, pig, goat, and cattle rearing. They carry their product to the nearer market and sell it to the consumers.

6.5 Agricultural systems

6.5.1 Land use pattern

The 16 districts have a total Hill areas of about 1.84 million ha. The agricultural land including shifting cultivation, tea garden and orchard in the Hill areas totals about 0.26 million ha (Fig. 6.21). Agricultural lands in the hilly areas account for 14.25% of the total hilly areas and 2.97% of Bangladesh agricultural land area. The total agricultural land of Bangladesh is 8,800,810 ha (BBS 2020).

Fig. 6.21. Agricultural land in the hilly areas (Source: BARC 2022)

Different land use patterns of the Hill areas spread over 16 districts (Table 6.4 and Fig. 6.22). Hill forest, scattered trees and other plantation occupy 74.86% area of the total hilly areas, which follows the agricultural land (14.25%). Lake, rivers and canals occupy 3.17% area of the hilly areas.

Among the 16 districts, the highest coverage under agriculture (55,629 ha) is in the hill areas of Moulvibazar occupying 46.9% of the total hilly areas of the district (Fig. 6.23). Rangamati Hill Tract areas follows Moulvibazar in terms of its agriculture land (39,954 ha). Next to this, Khagrachhari, Bandarban, Chattogram, Cox's Bazar, Habiganj and Sylhet have substantial amount of agriculture land in their hilly areas ranging from 7.5-47%. However, Jamalpur and Netrakona districts are constrained by the presence of only 138 ha and 178 ha, respectively agriculture lands in their total hilly areas (1,325 and 708 ha, respectively).

Table 6.4. Land use pattern in the hilly areas in 2022

Land use	Area (ha)
Agricultural Land	153355
Shifting Cultivation (with agriculture)	34761
Hill Forest	700699
Shrubs with scattered trees	604077
Forest Plantation	40115
Bamboo Forest	5664
Rubber Plantation	24269
Orchards and Other Plantations (Trees)	4870
Tea Garden	68648
Lake	47127
Rivers and Khals (Canals)	11021
Rural Settlement	129476
Others	12525
Total	1836605

Source: BARC 2022

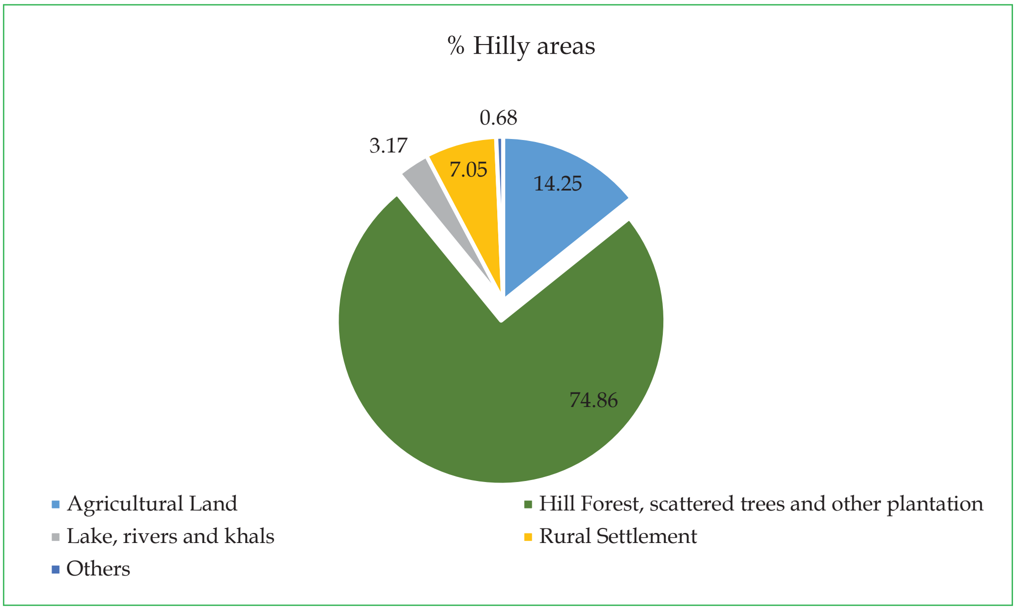


Fig. 6.22. Proportion of land use pattern in the hilly areas
(Source: BARC 2022)

The Hill Tract region is different in terms of physical, geomorphic and soil characteristics to the rest of Bangladesh. The main land types are high and medium hills and there is a small area of low land valleys and plain lands (Khan et al. 2007). Forests including timber/fruit tree farming and shifting cultivation are the major land covers on the hills. Paddy cultivation largely occurs in the valley parts or the plain land areas of the region. Hills cover most of the land types with medium to steep slopes, so conventional agriculture is limited and instead shifting cultivation is convenient (Islam et al. 2007). Agroforestry practices with intensive fruit cultivation have also increased as another land-use practice.

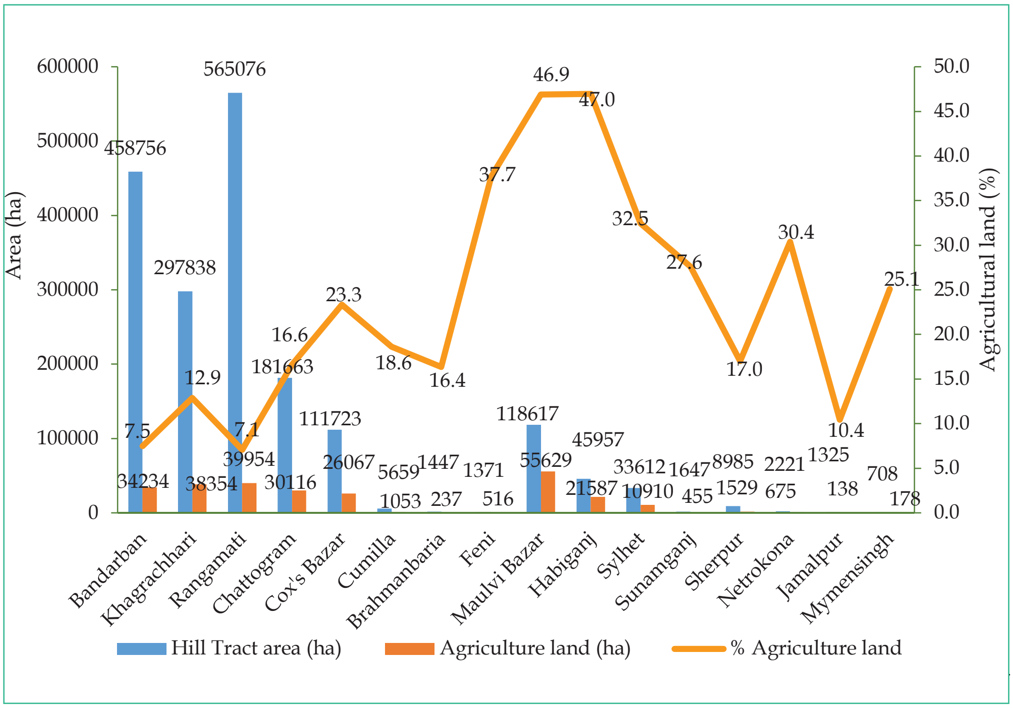


Fig. 6.23. Agricultural land in the hilly areas by district in 2022 (Source: BARC 2022)

In the last 7 years (2015-2022), there has been no significant increase or decrease in agricultural land area (Table. 6.5). There has been only a 0.30% increase from 260,878 ha in 2015 (FD 2015) to 261,633 ha in 2021-2022 (Table 6.5). The greatest decrease of agricultural land in the hilly areas during the 7 years was noticed in Feni (24.7%) followed by Mymensingh (10.6%). The decrease in agricultural land in the hilly areas could be attributed to the conversion of agricultural lands into infrastructure e.g., rural settlements, roads etc.

Higher population growth in the region will cause direct and indirect pressures on forests and agriculture land uses for food production. Forest uses may be higher among the ethnic people in this region compared to other areas of the country. A range of traditional forest uses exists in the region for energy, wild foods, shelter, and water.

Table 6.5. Changes in agricultural land area of the hilly areas during 2015-2022

District	Agricultural land (ha)		
	2015	2022	% Increase/ decrease (+/-)
Bandarban	34233	34234	0.0
Khagrachhari	38369	38354	0.0
Rangamati	39573	39954	1.0
Chattogram	29129	30116	3.4
Cox's Bazar	26375	26067	-1.2
Cumilla	1110	1053	-5.1
Brahmanbaria	204	237	16.1
Feni	686	516	-24.7
Moulvibazar	55426	55629	0.4
Habiganj	21668	21587	-0.4
Sylhet	10981	10910	-0.6
Sunamganj	495	455	-8.2
Sherpur	1613	1529	-5.2
Netrakona	678	675	-0.4
Jamalpur	140	138	-1.1
Mymensingh	199	178	-10.6
Hill Tract	260878	261633	0.3

Source: FD 2015, BARC 2022

6.5.2 Crops and cropping patterns

The hilly area has a single crop coverage of 68.1% which is more than double of the national average for single cropping (26.1%) (Fig 6.24 and 6.25). Double cropping and triple cropping account for 28.3% and 3.6%, respectively, of the agricultural land in the hilly areas. The reasons for lower number of cropping can be attributed to hill slope, lack of irrigation water and remoteness. Diversified cropping pattern may be resort for the farmer as a coping strategy with flood related risk but scope of diversification is limited due to biophysical and climatic condition of the hilly areas.

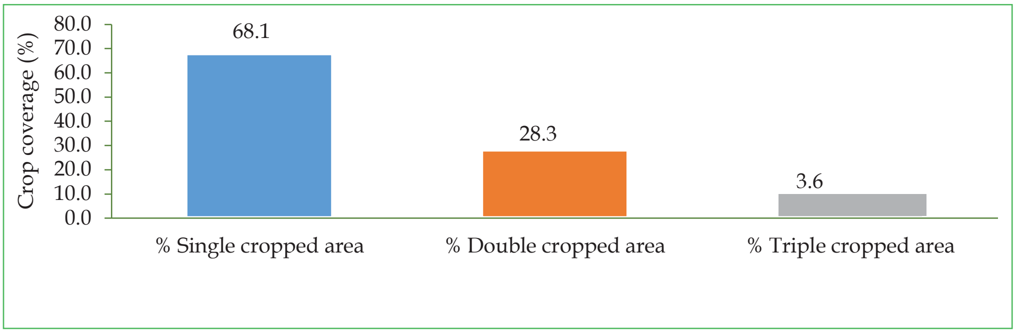


Fig. 6.24. Cropping situation in the hilly areas in 2022 (Source: DAE 2022)

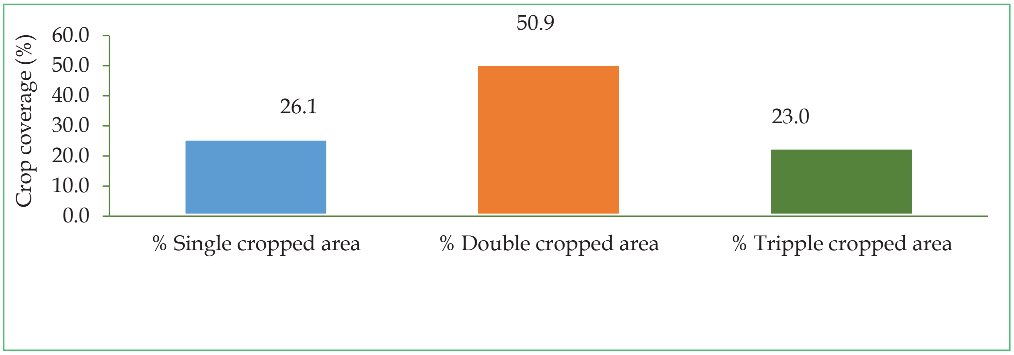


Fig. 6.25. Cropping areas in Bangladesh in 2020 (source BBS 2020)

In the hilly areas of 12 hill districts, single cropped area is 213,222 ha, double cropped area is 88,726 ha and triple cropped area is 11,076 ha during 2022 (Table 6.6). All the 12 hill districts have the higher single cropped area in their hilly areas except Sherpur, which possesses higher double cropped area (5,492 ha) than the single cropped area (1,055 ha). The single cropped area has increased by 23% during 2010-2022 compared with the decrease by 13.8% at the national level (Table 6.6). This increase has occurred due to a conversion of fallow areas into single cropped areas couple with conversion of forest areas into agriculture through deforestion. There is also an increase in double cropped area by 7% and triple cropped area by 33% during the same period. Among the hill districts, the highest increase in single cropping has occurred in Cox's Bazar (424%) followed by Khagrachari (114%) and Sunamganj (80%)

Table 6.6. Changes in cropping status in the hilly areas during 2010-2022

District	Single cropped area (ha) in 2010	Single cropped area (ha) in 2022	% Increase / decrease (+/-)	Double cropped area (ha) in 2010	Double cropped area (ha) in 2022	% Increase / decrease (+/-)	Triple cropped area (ha) in 2010	Triple cropped area (ha) in 2022	% Increase / decrease (+/-)
Bandaraban	41717	52911	27	20359	18609	-9	1021	1958	92
Khagrachari	23809	50951	114	1 4684	14212	-3	2165	2624	21
Rangamati	38740	36390	-6	15540	17829	15	1136	1853	63
Chattogram	25089	29339	17	16481	19284	17	2470	3089	25
Cox's Bazar	63	330	424	0	0	0	0	0	0
Cumilla	108	190	76	22	74	236	17	69	306
Moulvibazar	19727	20273	3	7207	7585	5	457	558	22
Habiganj	11640	9650	-17	5860	5623	-4	0		0
Sylhet	11124	11570	4	3	5	67	0	0	0
Sunamganj	250	450	80	0	0	0	0	0	0
Sherpur	1485	1055	-29	3055	5492	80	1032	925	-10
Netrakona	92	113	23	10	13	30	0	0	0
Hill Tract	173844	213222	23	83221	88726	7	8298	11076	33
Bangladesh	2439000	2110000	-13.5	3840000	4125000	7.4	1641000	1867000	13.8

Source: DAE 2022, BBS 2020

while there is a decrease in sherpur (29%) and Habiganj (17%). The highest increase in double cropping occurrs in Cumilla (236%) followed by Sherpur (80%) and Sylhet (67%). Despite the overall poor coverage of triple cropping, Cumilla has noticed the highest increase in triple cropping (306%) followed by Bandarban (92%) and Rangamati (63%). Agroforestry practices with different fruit species (i.e. banana, jackfruit, mango and litchi) along with annual crops have gradually replaced shifting cultivation due to increasing demand for cash incomes. This could contribute to increasing double and triple cropping in the hilly areas of the above districts.

Shifting cultivation, known as 'slash and burn agriculture' and referred to locally as 'Jhum cultivation', is a traditional land-use practice of ethnic populations in CHT. About 16% of land is cultivated with this traditional system each year (Bala et al. 2012). Following a certain fallow cycle (3–8 years), farmers cultivate a plot of hill lands in different years. The main feature of this land use is a combination of diverse crops for cultivation in one season (March–May) and harvesting gradually to secure food for the rest of months (August–December). The extent of shifting cultivation agriculture is higher in Rangmati and Bandarban districts than in Khagrachari district (GoB and FAO 2013). The size of shifting cultivation practices ranges from 0.5–3 ha in a family. Shifting cultivation activities also comprise the planting of different fruit species. Traditional forms of shifting cultivation were based on only annual crops and retaining trees largely available in remote areas. Intensive forms of agriculture (i.e. mix of fruit trees and teak plantations) are now increasing in areas closest to markets and roads (Thapa and Rasul 2005).

Ploughing agriculture is the most common type of farming in the plain lands of Bangladesh. The CHT region has much less area of plain lands and ploughing practices. Traditional practices by ethnic people involve digging soil with spades for cultivation instead of ploughing lands in their shifting cultivation plot. Ploughing was introduced by a small number of the lowland Bangalee migrants during the 1870s (Islam et al. 2007). With higher amounts of food production, plough cultivation expanded in all plain lands of hilly areas and ethnic people since that time. Ploughing agriculture is only prevalent in valleys, riverbanks, and lower slopes of the region. The total cropped area under plough cultivation is much less in CHT compared to the other plain land regions of Bangladesh. Valleys and floodplains suitable for plough agriculture covered only 3.2% (270,812 ha) of the total land in the region. Less than one-fifth of these lands could be cultivated through ploughing for producing rainfed and irrigated agricultural crops (GoB and FAO 2013). The size of plain land declined in CHT due to submersion of the cultivable lands after establishment of a hydroelectric dam resulting in approximately 21,850 ha of plain lands (which covered 40% of the best productive lands) being inundated (Olarieta et al. 2007).

The net cropped area has increased by 16% during 2010-2022 from 270,252 ha in 2010 to 313,023 ha in 2022 (Table 6.7) which may be attributed to conversion of current fallow land and some forest lands into agriculture. Among the hill based districts, the greatest increase in net cropped area has occurred in Cox's Bazar (424%) followed by Cumilla (127%) and Khagrachhari (67%). However, hilly areas of Sherpur and Habiganj districts have noticed a slight decrease in net cropped area (30% and 13%, respectively).

Table 6.7. Changes in net cropped area in hilly areas during 2010-2022

District	Net cropped area (ha) in 2010	Net cropped area (ha) in 2022	% increase/ decrease (+/ -)
Bandaraban	63097	73477	16
Khagrachhari	40658	67787	67
Rangamati	55416	56072	1
Chattogram	44060	51712	17
Cox's Bazar	63	330	424
Cumilla	147	333	127
Moulvibazar	27391	28416	4
Habiganj	17500	15273	-13
Sylhet	11127	11575	4
Sunamganj	0	450	0
Sherpur	10691	7472	-30
Netrakona	102	126	24
Hill Tract	270252	313023	16
Bangladesh	7838000	8106478	3.43

Source: DAE 2022, BBS 2020

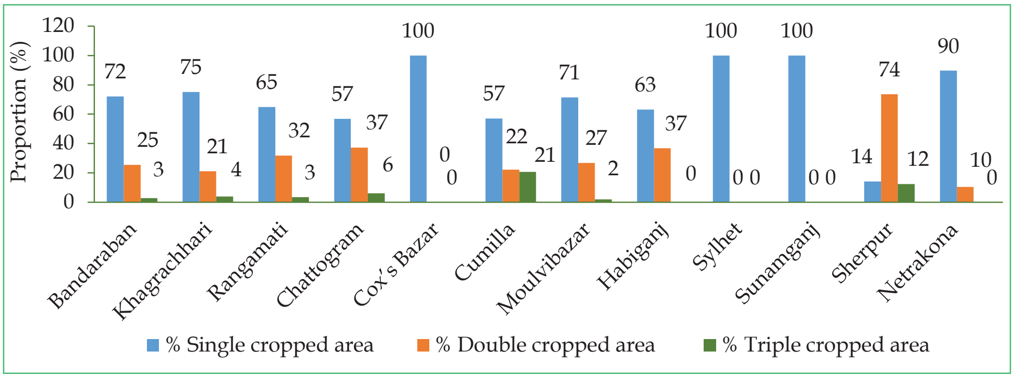


Fig. 6.26. Single, double and triple cropping proportions in hilly areas in 2022
(Source: DAE 2022)

Among all the hill districts, the proportion of single cropped area is the highest (100%) in Cox's Bazar, Sylhet and Sunamganj (Fig. 6.26) followed by Netrakona (90%), Khagrachhari (75%) and Bandarban (72%). Sherpur has the highest proportion of double cropped area (74%) followed by Chattogram (37%) and Habiganj (37%).

It is interesting to note that about one-fifth (19.7%) of the fallow land in the hilly areas has decreased in 12 years (2010-2022) compared to the national average of 7.7% decrease in fallow land (Table 6.8). In effect, the 167,464 ha of fallow lands in 2010 decreased to 134,432 ha in 2022. This means that 33,032 ha fallow lands were brought under cultivation during 2010 through 2020, which eventually resulted in increasing the net cropped area in the hilly areas (Table 6.8). The deceasing trend is noticed in all the hill districts ranging from 13.5-67.2% between 2010 and 2022. The greatest decrease in fallow land (67.2%) occurred in Cumilla followed by Sunamganj (46.9%) and Moulvibazar (38.2%) while the lowest was in Chattogram (only 13.5%). There are still opportunities of converting the remaining fallow land (134,432 ha) to cultivated lands by growing at least single crop during the rainy season. This opportunity exists particularly in Bandarban (51,414 ha), Chattogram (42,980 ha) and Rangamati (23,121 ha).

Table 6.8. Decrease/increase in fallow land areas in hilly areas during 2010-2022

District	Fallow land area (ha)		% Decrease/ Increase (+/-)
	2010	2022	
Bandarban	69362	51414	25.9
Khagrachari	4609	5697	-23.6
Rangamati	30542	23121	24.3
Chattogram	49668	42980	13.5
Cox's Bazar	2005	1675	16.5
Cumilla	540	177	67.2
Moulvibazar	2726	1685	38.2
Habiganj	3400	2700	20.6
Sylhet	2157	1478	31.5
Sunamganj	535	284	46.9
Sherpur	1810	3140	-73.5
Netrakona	110	81	26.4
Hill Tract	167464	134432	19.7
Bangladesh	467000	431000	7.7

Source: DAE 2022, BBS 2020

More than 35 different types of crops are cultivated in CHT annually. Agriculture crops including fruits and trees provide both subsistence uses and cash incomes for local ethnic groups. But the main cultivated crops are limited to seven including rice, turmeric, ginger, and banana. Cotton and sesame were once valuable cash crops but have gradually declined in recent years due to a decrease in productivity. Different fruit species (i.e. banana, jackfruit, mango and litchi) have gradually replaced shifting cultivation crops due to increasing demand for cash incomes.

Basically, non-rice-based agriculture is dominant in the hilly areas. Non-rice crops vegetables, citrus, pineapple, banana, ginger, turmeric, cassava, sugarcane, betel leaf, tea etc. are grown in the hilly areas. Currently, there are 18 major cropping patterns and only 3 of them are rice-based (Table 6.9). Fruit is a major component of 7 cropping patterns while vegetable is grown in 3 of the 18 major cropping patterns. Ginger/turmeric, pulse, cassava, and betel leaf are introduced in 4 cropping patterns (each crop in one pattern) next to fruits, rice, and vegetables. This indicates that cropping in hilly areas is highly diversified with different crops. However, this diversity of crops is high in the Kharif season (7 fruit, 3 vegetables and 2 rice based cropping patterns). This high cropping base during the Kharif season is primarily due to a rainfed situation which forces farmers to grow fruit, vegetable, and T. Aman rice as their major crops. There were no significant changes in major cropping patterns during 2010 through 2022 although 17 major cropping patterns were practiced during 2010 instead of 18 during 2022. However, area coverage of the orchard has increased from 49.9% to 56.9% of the net cropped area during 2010 through 2022 in Bandarban district. Similarly, the Pulse-Fallow-T. Aman rice in Chattogram and Tea garden area in Habiganj have increased from 7% to 12% and 66.9% to 75.1%, respectively of the net cropped area during the same period.

Table 6.9. Changes in major cropping patterns in the hilly areas

District	Major cropping patterns	
	2021-2022	2010-2011
Bandarban	Orchards year-round (56.9)	Orchards year-round (49.9)
	Boro-Fallow-T. Aman (5.9)	Jhum cultivation (13.4)
	Banana+Jhum (5.5)	Boro-Fallow-T. Aman (8)
Khagrachari	Fruit garden year-round (27.2)	Fruit garden year-round (28.8)
	Fallow-Fallow-T. Aman (20)	Fallow-Fallow-T. Aman (15)
	Boro-Fallow-T. Aman (14)	Boro-Fallow-T. Aman (12)
Rangamati	Fruit garden year-round (45.3)	Fruit garden year-round (46.2)
	Boro-Fallow-T. Aman (7.4)	Aush (Jhum)+Others (11.3)
	Banana+Aus (Jhum) (5.8)	Boro-Fallow-T. Aman (7.5)
	Spices (Ginger) year-round (9.3)	Spices (Turmeric/Ginger) year-round (10.3)
Chattogram	Fallow-Fallow-T. Aman (43)	Fallow- Fallow- T. Aman (39)
	Boro- Fallow- T. Aman (33)	Boro- Fallow- T. Aman (46)
	Pulse- Fallow- T. Aman (12)	Pulse- Fallow- T. Aman (7)
	Fruit garden year-round (2.7)	Fruit garden year-round (1.8)
Cox's Bazar	Fruit garden year-round (100)	Fruit garden year-round (100)

Cumilla	Fruit garden year-round (55.6)	Fruit garden year-round (72.1)
	Vegetable year round (33.3)	Vegetable year round (12.9)
	Cassava-Turmeric/Ginger (8.1)	Vegetable-Turmeric/Ginger (13.6)
	Cassava-Vegetable (3.9)	
Moulvibazar	Tea garden year-round (68)	Tea garden year-round (65)
	Citrus (Lemon) year-round (3)	Citrus (lemon) year-round (1)
	Pineapple year round (2)	Pineapple year round (1)
Habiganj	Tea garden year-round (75.1)	Tea garden year-round (66.9)
Sylhet	Tea garden year-round (79)	Tea garden year-round (76)
	Fruit garden year-round (4)	Fruits garden year -round (2)
	Betel leaf year-round (1.7)	Betel leaf year-round (1.5)
Sunamganj	Fruit garden year-round (86.7)	
	Pineapple year-round (13.3)	
Sherpur	Boro-Fallow-T. Aman(24.7)	Fallow- Vegetables-Fallow (40.8)
	Fallow- Vegetables-Fallow (9.9)	Boro-Fallow-T. Aman(3.6)
	Fallow- Fallow-T. Aman (6.8)	Fallow- Fallow-T. Aman (6.1)
	Sugarcane-Fallow (4.7)	Sugarcane-Fallow-Fallow (3.1)
Netrakona	Fruits + Vegetable(55.6)	Fruits + Vegetable (63.7)
	Vegetable year round (4)	Vegetable year round (3.9)

Figures in parentheses indicate % of the net cropped area
Source: DAE 2022

Fruit is extensively cultivated in hilly areas year round in 10 out of 12 hilly districts. Boro-Fallow-T. Aman rice cropping pattern is grown in hilly areas of 5 districts viz, Bandarban, Khagrachhari, Rangamati, Chattogram and Sherpur. Vegetable based cropping pattern is practiced in hilly areas of Cumilla, Sherpur and Netrakona districts. Fallow-Fallow-T. Aman rice pattern is grown in the hilly areas of Khagrachhari, Chattogram and Sherpur districts. Tea garden is prominent in hilly areas of Moulvibazar, Habiganj and Sylhet districts.

6.5.3 Livestock and poultry

Cattle, buffalo, goat, sheep, chicken, and duck are the most popular livestock in the Hill areas. In 2022, livestock and poultry heads numbered 29.085 million accounting for 7.23% of the total livestock and poultry (402.5 million) in Bangladesh (Fig. 6.27). This indicates a significant contribution to the livestock of Bangladesh.

Fig. 6.27. Livestock in the hilly areas as a proportion of that in Bangladesh
(Source: DLS 2019)

In 2022, livestock population is the highest in the hilly areas of Chattogram district (5.794 million) followed by Moulvibazar (3.138 million) and Rangamati (2.982 million) (Table 6.10). Among livestock, cattle population is the highest (2.81 million) followed by goat (1.23 million) in the hilly areas. It is noteworthy that the highest share of cattle (11.60%) of the Bangladesh population exists in the Hill Tract areas followed by buffalo (8.94%) and goat (4.68%). There is a good opportunity of promoting cattle, buffalo and goat as they grow well in dense vegetation areas like the hilly areas. Cattle population (0.855 million) is the highest in the hilly areas of Chattogram while buffalo, goat and sheep populations are the highest in Moulvibazar, Khagrachhari, and Sylhet, respectively. The poultry population is 21.25 million, and ducks number 3.54 million (Table 6.10). However, the livestock and poultry population density (15.84 /ha) in the hilly areas is below the national average (45.74 /ha) in Bangladesh (Table 6.10). The highest population density of livestock in the hilly areas is recorded in case of cattle (1.53/ha) followed by goat (0.67/ha). Then poultry population density (11.57/ha) is very high compared with that of duck (1.93/ha). However, the buffalo population density in the hilly areas is low (0.07/ha) compared with the national average of Bangladesh (0.17/ha).

Table 6.10. Status of livestock and poultry in the hilly areas by district in 2019

District	Cattle	Buffalo	Goat	Sheep	Poultry	Duck	Total
	Head counts in million						
Bandarban	0.115	0.018	0.060	0.004	1.23	0.05	1.475
Khagrachhari	0.182	0.004	0.253	0.004	2.22	0.08	2.742
Rangamati	0.174	0.015	0.163	0.002	2.45	0.18	2.982
Chattogram	0.855	0.014	0.220	0.003	4.31	0.39	5.794
Cox's Bazar	0.205	0.025	0.083	0.010	2.45	0.07	2.846
Cumilla	0.132	0.0002	0.017	0.0007	1.76	0.39	2.297
Brahamanbaria	0.001	0.0004	0.0004	0.002	0.15	0.04	0.194
Feni	0.075	0.0001	0.085	0.0005	1.64	0.21	2.011
Moulvibazar	0.448	0.032	0.136	0.026	1.73	0.77	3.138
Habiganj	0.114	0.0007	0.062	0.012	1.02	0.21	1.415
Sylhet	0.353	0.019	0.075	0.038	1.26	0.85	2.593
Sunamganj	0.031	0.003	0.010	0.011	0.30	0.12	0.475
Sherpur	0.051	0.00	0.032	0.007	0.23	0.02	0.341
Netrakona	0.034	0.0006	0.015	0.001	0.10	0.06	0.209
Jamalpur	0.008	0.0002	0.004	0.002	0.04	0.01	0.059
Mymensingh	0.030	0.0002	0.016	0.001	0.38	0.09	0.513
Hill Tract Area Total	2.81	0.13	1.23	0.12	21.25	3.54	29.085
Bangladesh Total	24.2	1.48	26.27	3.54	289.28	57.75	402.5
% Bangladesh	11.60	8.94	4.68	3.44	7.35	6.14	7.23
Livestock/ha (Hill Tract area)	1.53	0.07	0.67	0.07	11.57	1.93	15.84
Livestock/ha (Bangladesh)	2.75	0.17	2.99	0.4	32.87	6.56	45.74

Source: DLS 2019

Emphasis has been given to livestock development to meet the growing demand for milk, meat, and eggs, and to create employment and generate income for the rural poor (Rasul and Tripura 2016). The CHT has the potential for livestock development for a number of reasons, e.g. availability of land for grazing and fodder production, natural water resources, hard working population, changing lifestyles of the hill people, and presence of suitable indigenous breeds of different species of livestock and poultry. The lakes in the CHT can be used for duck farming with minimum investment. The CHT is suitable for sustainable poultry farming, especially broilers and layers, goat farming as there are abundant scavenging areas. Considering the potential for livestock development in the CHT, both the public and private sectors should need to undertake special initiatives, and livestock can be one of the key livelihood options for disadvantaged ethnic communities.

Among the hilly chickens, reddish brown type produces more eggs than spotted black and desi white type. All types of chickens produce similar weight eggs, but mature live weight differs between types. The lighting group hilly chickens produce more number of eggs than heat stress group. Hilly chickens are more susceptible than non-descriptive desi for heat stress. Therefore, in consideration of the effects of temperature and humidity index, lighting duration and productivity, the reddish-brown hilly type has been identified better than all available types of chicken in hilly areas of Bangladesh. The selected types of hilly chicken (reddish brown and spotted black and white) can be incorporated in the structured genetic improvement program for dual (egg and meat production) purpose. Such research would be helpful for researchers, academics, farmers and policy makers for undertaking research and developmental work on chickens for egg and meat purposes.

6.5.4 Fisheries and aquaculture

The fisheries area in the hilly areas is reported to increase slightly by 0.27 % from 59,117 ha in 2015 to 59,279 ha in 2022 (Table 6.11). The highest increase (13.35%) has been recorded in freshwater aquaculture followed by lake (0.29%), and river and canals (0.06%). However, areas of perennial beel and pond have decreased by 18.57% and 1.07%, respectively.

The Hilly region of Bangladesh is blessed by various aquatic ecosystems such as rivers, streams, creeks, and reservoirs (Hossain and Wahab 2010) (Fig. 6.28). The CHT is characterized by a huge network of trellis and dendritic drainage consisting of some major rivers draining into the Bay of Bengal. Karnaphuli, Sangu, Matamuhuri and Feni are the major rivers. The Karnaphuli has several important tributaries within the hill areas, of which Chengi, Kasalong and Rainkhiang are the main ones. There are two natural lakes (Rainkhiangkine lake and bagakine lake) and one artificial lake (Kaptai lake).

Table 6.11. Status of fisheries in the hilly areas in 2019

District	Lake	Pond	River and canal	Fresh Water Aquaculture	Perennial Beel/Haor	Total
Area (ha)						
Bandarban	132	323	2744	0	0	3199
Khagrachhari	448	135	2261	0	0	2844
Rangamati	44793	47	3985	0	0	48826
Chattogram	1199	262	820	87	1	2370
Cox's Bazar	90	8	614	81	0	793
Cumilla	0	3	1	2	0	6
Brahmanbaria	0	0	0	6	0	6
Feni	2	2	2	0	0	6
Moulvibazar	311	0	247	44	24	626
Habiganj	60	12	158	9	0	239
Sylhet	78	11	89	44	8	232
Sunamganj	0	0	5	5	1	11
Sherpur	13	0	69	11	0	93
Netrakona	0	1	19	0	0	21
Jamalpur	0	0	0	2	0	2
Mymensingh	0	0	5	0	0	5
Total (2022)	47127	805	11021	292	35	59279
Total (2015)	46989	813	11014	258	43	59117
% Increase (+)/decrease (-)	0.29	-1.07	0.06	13.35	-18.57	0.27

Source: BARC 2022

Fig. 6.28. A stream of hill forest, Rangamati

The Kaptai lake covers an area of about 767 sq km in dry season and about 1,036 sq km in the monsoon (Banglapedia 2021). A total of 1200 creeks were constructed surrounding Kaptai lake, and these have created huge potentiality of aquaculture in the hill (Rahman et al. 2017). To date, aquaculture activities have not been popular in CHT regions. Fish farming in creeks has a lot of potentials (Basak et al. 2017). CHT produces 14773.46 MT (metric tonnes) of fish per year, including culture, capture, and output from the Kaptai lake (DoF 2014). With 12,696 MT of fish produced in 2019–20, the Kaptai lake is the most important contributor to CHT's fish production (DoF 2020). Small-scale aquaculture can significantly improve the livelihoods of marginalized peoples, including ethnic minorities. For this, expansion of aquaculture is necessary with due consideration for social, economic, and environmental aspects.

6.5.5 Forestry

Forest and trees provide direct and indirect economic benefits to local communities in CHT, as well as to the national economy. Timber, bamboo, rattan, fuelwood, fruits, and different types of grasses are the major sources of forest-based annual income. In CHT, more than 60% of forest products are used at the household level and the remaining 40% are sold at local markets to generate cash income (Misbahuzzaman and Smith-Hall 2015). Timber is largely collected from planted forests. Natural forests still provide the largest stocks of bamboo, which are a potential source of forest-based economic activities in the region. Forested areas in CHT make up almost 43% of total forestlands in Bangladesh (FD 2015). In terms of forest types, natural forests and plantation forests cover more than 70% of land areas in all three districts. The total forest area managed under the Bangladesh Forest Department in CHT is 483,000 ha, with 86,000 ha designated as plantation land (BBS 2015). The major plant species in the region are tropical wet evergreen/semi-evergreen and deciduous and are classified as ‘hill forests.’ Among the plantation covers, teak (*Tectona grandis*) is the dominant type of plant in both Government and private forestlands.

During the last century, commercial plantations with largely teak (*Tectona grandis*) plants increased in the region. Teak was primarily introduced as an exotic species in small patches of Kaptai National Park around 1920. One of the reasons was that the region had a major push for the harvesting of valuable forest timbers during British regimes. This was one of the reasons that commercial plantations preceded at the expense of natural forest coverage. Throughout the 19th century, planted forests replaced a large portion of natural forests. Along with these, commercial plantations with fast growing species, such as *gamar*, used for raw materials in paper and pulp making industries also expanded. The CHT region is a large source of plant-based industries managed under the Bangladesh Forest Industries Development Corporation.

In 2022, 73.6% (1,351444 ha) of the total hilly areas (1,836,605 ha) of the 16 hill districts is covered by forest (Table 6.12) in comparison with the overall 17.78% forest area in Bangladesh. A country or any geographic area should

Table 6.12. Forest cover in the hilly areas in 2022

District	Hill Tract area (ha)	Forest area (ha)	% Forest area
Bandarban	458756	407573	88.8
Khagrachhari	297838	239170	80.3
Rangamati	565076	463301	82.0
Chattogram	181663	117369	64.6
Cox's Bazar	111723	60229	53.9
Cumilla	5659	2251	39.8
Brahmanbaria	1447	449	31.1
Feni	1371	365	26.7
Moulvibazar	118617	33308	28.1
Habiganj	45957	13941	30.3
Sylhet	33612	5976	17.8
Sunamganj	1647	172	10.4
Sherpur	8985	5365	59.7
Netrakona	2221	858	38.6
Jamalpur	1325	963	72.6
Mymensingh	708	155	21.8
Total	1836605	1351444	73.6
Bangladesh	14486269	2575196	17.78

Source: BARC 2022, BBS 2021

have at least 25% forest cover to maintain a proper ecological balance, and thus, the hilly areas fall far above this threshold. Among the hill districts, Bandarban has the highest forest cover (88.8%) with 407,573 ha in its hilly areas followed by Rangamati (82%) with 463.301 ha while the lowest, only 10.4% is in Sunamganj (172 ha). Forest covers in the hill districts shrank slightly from 1,363,900 ha in 2015 to 1,351,444 ha in 2022 amounting to a 0.91% decline over the 7 years (Table 6.13). All the hill districts experienced a decline in forest cover during this period ranging from 0.08-34.99% except Sunamganj and Feni that showed a 89.34% and 55.92% increase, respectively.

Historically, CHT was designated for forest resources, particularly as a source of timber harvesting in Bangladesh (Rasul 2007). But most of the forestlands are barren, covered with grass or with scattered trees and bamboo. Forest areas cover almost 70% of the total lands that are either natural, planted or grasslands with scattered timber trees and bamboo in the region. Natural forest only covers approximately 72,000 ha or only 15%–20% of the total forestlands in CHT. The remaining area is largely secondary forest with mixed

Table 6.13. Changes in forest cover over time in the hilly areas

District	Forest area (ha) in 2015	Forest area (ha) in 2022	% Increase/ decrease
Bandarban	409670	407573	-0.51
Khagrachhari	239517	239170	-0.15
Rangamati	463686	463301	-0.08
Chattogram	120650	117369	-2.72
Cox's Bazar	61879	60229	-2.67
Cumilla	2327	2251	-3.24
Brahmanbaria	525	449	-14.38
Feni	234	365	55.92
Moulvibazar	33473	33308	-0.49
Habiganj	16756	13941	-16.80
Sylhet	6970	5976	-14.26
Sunamganj	91	172	89.34
Sherpur	6044	5365	-11.23
Netrakona	876	858	-2.14
Jamalpur	964	963	-0.10
Mymensingh	238	155	-34.99
Hill Tract	1363900	1351444	-0.91
Bangladesh	2574587	2575196	0.02

Source: FD 2015, BARC 2022, BBS 2015, 2021

natural and planted forests (i.e. a mix of naturally regenerating bamboo and planted timber species) and monoculture planted forests. Most of the primary forest declined between 1700 and 1800 in the region, although there is no accurate information available on forest cover change for that period. Limited information on CHT for the periods 1960–1980 and 1990–2005 show that natural forest cover declined during this time (FAO 2010). Data on historical changes in Kassalong and Rankhiang, the two major reserves in the region, showed that in 1963, natural forest cover was 172,000 ha, which declined to 84,000 ha in 1990 and to 70,000 ha in 2005 (FAO 2010). Forest cover changes in CHT are due to the conversion of large areas into non forest lands (i.e., agriculture, grassland, and scattered tree patches). Tree harvesting and shifting cultivation has caused degradation of the forest landscape in CHT (Rahman et al. 2012). A gradual loss of trees either for revenue generation or through illegal felling and clearing/burning practices in shifting cultivation has increased the area of non-forestlands. Encroachment and illegal felling has caused the loss of 21,000 ha of planted forests and valuable trees of regenerating capacity in natural forests (e.g. garjan – *Dipterocarpaceae* spp.) throughout the region (Khan et al. 2012).

Deforestation is still higher in CHT compared to other forested areas of Bangladesh, although areas of monoculture plantations have increased or remained stable since the 1990s (FAO 2010). Altogether, approximately 90,000 ha of forested land (either natural or planted with timber and bamboo forests) have been converted into agriculture lands or grasslands (Khan et al. 2012). But the forest cover change on barren land is much higher at about 287,461 ha of lands (GoB and FAO 2013).

6.6 Cross-cutting issues

6.6.1 Irrigation

About 31% (98,300 ha) of the total net cropped area in the hilly areas has been brought under irrigation by the year 2022 compared with 49.1% of Bangladesh overall (Table 6.14). Over the last 10 years the irrigation area in the hilly areas increased by 29.2% from 76,065 ha in 2010 to 98,300 ha in 2022. In terms of irrigation coverage Cox's Bazar and Sunamganj with 100% topped the list of the 16 hill districts followed by Sylhet (91%) and Habiganj (64%) while the lowest was 10% in Netrakona. All the hill districts experienced an increase in irrigation coverage in 2010 through 2022 except Netrakona, the greatest increase (705%) being in Cox's Bazar followed by Cumilla (197%) and Rangamati (105%).

However, the land productivity of hilly areas is very low due to rain-fed agriculture. Jhum cultivation is the prime cultivation method practiced by the farmers. The cropping intensity is only 153.3% (Dasgupta et al. 2008) compared to that of 191% of the country. The main drawback in the development of hill agriculture is the crisis of water in the lean period (November to March). In addition, steep hill slope, low soil fertility and small water holding capacity of soil can also be regarded as the other associated constraints to agricultural development in the region (Brammer 1997). The CHT has enormous potentials for fruit production, especially, mango, malta, lemon, pineapple, banana, guava, and similar other fruits. Demand of these fruits is increasing day by day in the hilly areas for commercial cultivation. Successful production of quality fruits warrants good management practices of which availability of soil moisture during flowering and fruiting stages ensure sufficient fruit retention through reducing fruit and flower drop. However, in hilly areas, there is a huge water crisis during dry months (November to March) and farmers of the hilly areas do not have adequate water for irrigation. In CHT, 80% crop lands are under rain-fed condition. Irrigation is mainly done by surface water sourcing from perennial creeks/ chharas or lakes/ponds (BADC 2014). The average annual rainfall of CHT amounts 2500 mm which is quite sufficient for year-round irrigation but the erratic distribution of rainfall-too much in rainy season (June to October) and too less in dry season (November to March) leads to water scarcity in dry season for both irrigation and human consumption. Thus, without efficient water distribution and application method, it is almost impossible to irrigate fruit gardens adequately.

Table 6.14. Status of irrigation in hilly areas

District	Irrigated Area (ha) in 2010	Irrigated Area (ha) in 2022	% Increase/ decrease (+/-)
Bandarban	11945 (19)	13061 (18)	9.3
Khagrachari	14945 (37)	16417 (24)	9.8
Rangamati	5780 (10)	11870 (21)	105
Chattogram	17040 (39)	27962 (54)	64.1
Cox's Bazar	41 (65)	330 (100)	705
Cumilla	39 (27)	116 (35)	197
Moulvibazar	4700 (17)	5790 (20)	23.2
Habiganj	8900 (51)	9700 (64)	9
Sylhet	10440 (94)	10545 (91)	1
Sunamganj	250 (100)	450 (100)	80
Sherpur	1970 (18)	2047 (27)	3.9
Netrakona	15 (15)	12 (10)	-20
Total	76065 (28)	98300 (31)	29.2
Bangladesh	6843724 (45.8)	7879000 (49.1)	15.1

Figures within parentheses indicate % irrigated area
Source: DAE 2022, BBS 2012 and 2021

In the Hill Tract areas, many springs are dried. It is assumed that about 200,000 springs were flowing over the CHT areas before 100 years ago (Alam and Mong 2004). The vital spring located at Ghagra, on the way to Chittagong and Rangamati, now simply becomes a remnant of the forceful spring of 7-8 years back which had a mentionable depth of water flowing all year round. A pretty good numbers of springs on the way of Rangamati and Mohalchhari have damaged in the recent years. The famous Nyoungmrong spring at Raikhali union under Rangamti district that has been providing water for irrigation and field work for hundreds of people round the year is now waterless. Even the Brimong spring which becomes the sole water source after the death of the Nyoungmrong spring is also on the wane (Alam and Mong 2004). So, the natural water sources are dying day by day and the water scarcity is rapidly increased with its severity. CHT are inhabited by the people of Garo, Monipuri, Khasia, Chakma, Marma and Mog tribes and Bengalis. They also try to practice various methods to conserve water for agricultural purposes. For irrigation purpose, indigenous cross-dam and retention ponds are used in Kaptai and Bandarban.

There is rainwater potential in the hilly areas to harvest for irrigation purpose because of its high annual average rainfall and availability of suitable landscape. Under this condition, developing rainwater harvesting technologies for irrigation would be very useful for local agricultural production (Zhang et al. 2014). By constructing small water reservoirs in upstream hilly canyon, rainwater can be harvested to irrigate hilltop and hill slope areas by pumping, and the valley areas by gravity flow.

6.6.2 Agricultural marketing

Mango, jackfruit, litchi, papaya, and watermelon have been the fruits of choice for mass-scale production in the Hill Tracts areas of Bandarban, Rangamati, and Khagrachhari districts for the past decades. The area has turned into a seasonal fruit hub with vast potentiality for expanding a food-processing sector. However, there is still a reliance on a centuries-old practice of intermediaries in the fruit trade (Anonymous 2020). The dealers go out to the cultivators a few weeks before harvest to negotiate prices for all products. They transport the produce to cities, where it is sold to smaller vendors. This strategy restricts the options available to farmers. At the same time, urbanites continue to charge exorbitant rates, implying that a significant portion of the fruits' value is pocketed somewhere along the road (Anonymous 2020).

Fruit growers make a sizeable contribution to fruits production. Low volumes (minimal marketable surplus), poor quality, inconsistent supplies, and other factors limit their access to formalized markets. Simultaneously, local markets for the products are limited, forcing them to sell their products in far-flung urban and export markets, adding to their expensive transportation and marketing costs. Intermediaries such as assemblers, wholesalers, sub-wholesalers, commission agents, and retailers control existing supply chains. Producers can get as little as one-third to one-half of the final price in some instances, reflecting substantial marketing costs and margins. Institutions such as cooperatives and commodity associations reduce marketing and transaction costs and risks by providing "markets" to the producers at their doorsteps. Transforming smallholder self-sustaining (non-market-oriented) agriculture into dynamic market-oriented sectors can create multiplier effects towards other sectors. This transition can enhance the non-farm sector by creating jobs and boosting income. Presently, the rising demand for these seasonal commodities is allowing producers, particularly smallholder farmers, to diversify into commodities with a significant possibility of increased returns on land, labor, and capital. Nevertheless, due to lack of access to inputs, capital, technology, extension services, skills, land, water, etc; there is concern regarding smallholder producers' ability to participate in market-oriented production.

Market actors play a crucial role in ensuring a smooth marketing system, and their role is undoubtedly significant in the market development of any commodity. Dewan (2015) found four types of intermediaries involved in the fruit marketing system. The study revealed that the production growth rate for mango was highest, whereas banana recorded the negative growth rate in the hilly area (Dewan 2015). Farmers with limited resources invest less in farming inputs such as insecticides and fertilizers, resulting in poorer yields and inferior quality goods. Due to lack of storage and transportation facilities, substantial post-harvest losses occur, reducing supply and putting increased pressure on pricing. Lack of transportation, exploitation by intermediaries, and market information impeded the feasibility and profitability of businesses. Producer groups are linked to formal and informal market places through marketing models relevant to all actors in the value chain to overcome these flaws.

Most of the market actors depend mainly on agricultural activities and engage themselves thoroughly in the production and marketing of seasonal fruits. The most common mango variety transported to various markets is the Rangui type, as the displays of other varieties are in short supply. Other fruits, such as jackfruit and litchi, are also more popular at the local market than in the distant market. For mango (Rangui variety), the retailer's net margin or profit is more significant than the other actors. In contrast, the net marketing margin of *Faria* (middleman) is higher when they supply jackfruit in the market. Also, the highest net margin is received by *Bepari* for litchi trading. The most efficient marketing channel for mango is "farmer-*Bepari*-*Aratdar*-retailer-consumer." Whereas for jackfruit, (farmer-*Bepari*-*Aratdar*-consumer) is an efficient channel, and for litchi, (farmer-*Faria*-consumer) has the highest marketing efficiency.

Several marketplaces are available in the Hill Tract areas where seasonal fruits are rigorously sold. In the case of mango for Bandarban, the local markets where Faria and Bepari bring and sell their product is Bandarban Sadar market and Balaghata Bazar. The Bepari brings the product to different parts of Chattogram city: Satkania, Keranihat, Dohazari, BRTC market, etc. Farmer and the market actors could not profit, sending this to the other remote markets as the marketing costs demand more for these fruits than its production. In Rangamati, demand for mango variety like Amrapali is more as it is produced more in number. There are other mango varieties that are sold in the local markets, such as Rangamati Banarupa Bazar, Ranirhat Bazar, Rauzan market, etc. Market actors like Faria and Bepari are more in Ghagra Bazar for selling jackfruit and pineapple. Most of the fruit growers bring these fruits directly into the market to sell. The other seasonal fruits (especially jackfruit and pineapple) from Rangamati through Bepari come to the market like Chattogram Amin market, Bohoddar hat Bazar, Firingi Bazar, BRTC market, etc. Some market actors (specially Bepari), both from Bandarban and Rangamati, sell their fruits in the Feni and Dhaka markets. Though this number is not so high, they send more to this distant market if the market actors get some incentives.

6.7 Agricultural advancement

6.7.1 Crops and cropping patterns

Hill agriculture can be broadly classified into five viz. (i) upland agriculture-Jhum and horticulture based; (ii) valley or plough land agriculture (iii) Agro-forestry, (iv) animal husbandry and (v) fish farming in Jhiri or lake. Jhum or shifting cultivation is the major source of livelihood for most tribal communities in the remote places. Due to low yields of Jhum crops and lack of sufficient land for jhum cultivation, many tribal are now moving away from jhum farming and turning to mixed fruit orchards or other occupations. The potential crops of Jhum includes local rice such as cockroah, gallon, sherray. HYV rice like BRRI dhan28, BRRI dhan48, BRRI dhan55 are very popular. There are other crops like sweet gourd, marfa (cucumber), chinal, arahar (pulse), bean, cucumber, yam, sesame, maize, chilli, millet, yard long bean, cotton, and marigold, etc. Mixed fruit orchards are currently dominating as an alternative to shifting cultivation in the hills and it covers vast areas of upland agriculture.

Valley agriculture has a significant potentiality for growing high value crops. The main cropping patterns here are Boro-Fallow-T. Aman rice and Vegetable- T. Aus- T. Aman. Aus rice is mainly cultivated in jhum farming. In valley, mainly cultivates Aman, Boro, cotton, sugarcane, maize and winter and summer vegetables. Most of the valley lands of the river basins have come under tobacco cultivation. In the case of hill agriculture model, in the nineties by stepping on the slopes of the hills, which is called the SALT method called Slopping Agricultural Land Technology for Hill. In this method, steps were made on the hill and saplings were planted step by step. In this way, it would have cost about 50-60 thousand BDT per acre to make a step on the hill. Even without technical and skilled people it could not be done. For this reason, the next time it did not advance. The Hill Agriculture Research Station, Ramgarh, Khagrachari developed MATH (Modern Agricultural Technology in Hill) as another model. Although the design and purpose of the model is excellent, it could not be expanded due to various reasons. After that the Hill Agriculture Research Station, Khagrachari developed another model called Multi-Strata Fruit Orchard and this model is promoted widely in the Hill Tract areas.

extension project are being jointly implemented by BARI and DAE in the hilly areas of Bangladesh. Another potentiality of hill agriculture can be production of value-added products by processing more productive fruits like mango, banana, jackfruit, pineapple, papaya, watermelon, olive, etc.

BARI Aam-3, BARI Aam-4, BARI Aam-8, BARI Banana-3, BARI Litchi-2, BARI Litchi-3, BARI Malta-1, Pineapple, Papaya, Dragon fruit, year round Jackfruit, BARI Guava, hybrid cotton, sugarcane and citrus are the most potential crops in the hills. For remote areas, spices crop such as bay leaves, black pepper, cinnamon, common plum (Alu Bokhra) and cardamom should be encouraged for cultivation. BARI Malta-1 is a high yielding malta variety developed by Hill Agricultural Research Station, BARI, Khagrachari. Demand of these varieties is increasing day by day in the hilly areas for commercial cultivation. Successful production of malta with quality fruits warrants good management practices of which availability of soil moisture during flowering and fruiting stages ensure sufficient fruit retention through reducing fruit and flower drop. However, in hilly areas, there is a huge water crisis during dry months (November to March) and farmers of the hilly areas do not have adequate water for irrigation. Drip irrigation technology has been developed for not only saving production costs but also for reducing water loss in crop field. So, this drip irrigation technology helps determine the appropriate irrigation scheduling for malta cultivation during dry season.

KGF (Krishi Gobeshona Foundation) sponsored research projects (the six-year trial ended in 2019) developed saveral transferable tecnologies for Hill Tracts. Some promising tecnologies are given below:

a) Khagrachari model was developed to promote assorted vegetables growing year round in the homesteads. Bamboo fencing is used to grow vegetables in a sequence of yard long bean (Kharif)- hyacinth bean (Rabi)- bittergourd (Kharif)- bottlegourd (Rabi),
b) Summer tomato (var. BARI Hybrid Tomato-4) was introduced through improved production tecnology although tomato is cultivated by the farmers of CHT during winter season,
c) BARI Shim-6 (country bean) variety was introduced and proved to be the double yielder compared to the local varieties in CHT,
d) BARI Malta-1 and BARI Kola-3 (Banana), popularly known as Bangla kola was proved suitable for cultivation in CHT through improved fertilizer, insect and pest management and
e) Weed control of maize using standard mulch technology was proved successful and may be disseminated widely in CHT.

Farming practices in the CHTs have undergone significant changes with the incorporation of new techniques into existing practices. The households that have wet-rice plots often move away from jhuming to plantation cultivation of timber or fruit trees on the hill slopes. Ploughing using draught animals has also been substantially replaced by mechanization. Pumps are also used to lift water from the valleys into surrounding terraces. In the background of land and forest degradation along with demographic pressure, three tree based sustainable farming models i.e. Multistorey Agroforestry System (MAFS), Multi-strata Fruit Orchards (MSFO) and complex fruit and timber-based mixed agroforest are developed and promoted for hilly areas to maintain agricultural production and environmental gradient. Multistorey Agroforestry System (MAFS) is already practiced by many farmers in CHTs and is well suited for regeneration of forest vegetation in the jhum fields. The system is based on fruits and timber trees in upper storey, shrubby and medium sized fruit species in middle storey together with vegetables, medicinal plants, and tuber species in lower storey. Multi Strata Fruit Orchards (MSFO) are practiced by arranging pineapple and papaya in lower strata, lemon, orange and guava in middle strata, mango and litchi in upper strata, and coconut and betel nut in top strata. The other is the complex fruit and timber-based mixed conservation agroforestry, which is established in the large, depleted landscapes. Timber species with bamboo preserve hilltops by forming a mini forest with hydrological functions. Fruit trees are planted next to the natural forest. For food security, upland rice and maize can be intercropped with acacia, teak, and fruit trees for the first 6 years. Subsequently, shade tolerant pineapple is planted under fruit trees which produces fruits after one year. Papaya, banana, lemon, guava, orange, etc. are planted next to fruit tree plantation. Mung bean and black beans are intercropped at the foot of the hilly slope.

The agricultural research centers located in the three hill districts have developed a lot of technology. Strengthening research-extension linkages is essential to disseminate the developed technologies at the field level. Popularization of mushroom and beekeeping is very essential. Setting up of genetic resource centers, collection centers and pack-houses, facilities of storage and value addition are urgently needed. Export opportunities need to be created through branding of many potential local fruits.

6.7.2 Livestock and poultry

The rearing of livestock has received repeated consideration as an important option for investment in the CHT. The local market, as well as that on the Bangladesh plains, is very large. Additionally, there is the prospect of exports to both India and Myanmar. As well as being a source of income, livestock can also function as a safety-reserve asset for farmers. Finally, it is possible to take livestock to the market even from remote areas. Livestock farming in the CHT differs from that on the plains in terms of the number of species reared. On the plains, there are religious objections to pig farming, but this is a highly profitable pursuit in the CHT that boasts the highest growth rate of all livestock farming in the region. CHT pig farmers supply to both the domestic and international markets. The CHT is also home to a type of bison, the mithun, which is still in the process of domestication. Earlier, mithun was reared by Mro farmers in forest enclosures, but other communities have now entered the field.

6.7.3 Fisheries

In terms of its potential for developing aquaculture, the CHT has the advantage of the Kaptai reservoir. Fisheries production from the reservoir has increased over time, but its potential is more than the current achievement. To raise this production capacity, floating aquaculture technologies may be used, such as cages and pens.

Department of Fisheries (DoF) implemented a project in the mid-1990s "Fish Culture Development and Extension in hills." This project has created 11.5 ha of nursery ponds and 92 ha of other water bodies by modifications of creek flows and construction of small dams, and these were brought under fish culture. Training of farmers about aquaculture was given special attention under this project. Department of Fisheries (DoF) has implemented a project entitled"Improvement and extension of fish culture by developing creek in the CHT from 2000 to 2010". By this project, Department of fisheries developed 287 creeks and established 3 mini hatcheries in CHT. Third phase will repair 903 creeks and establish 1 hatchery by five years.

6.7.4 Impact of technologies

The major public agricultural extension organizations involved in agricultural development in the hilly areas are i) Department of Agricultural Extension (DAE), ii) Department of Livestock Services (DLS), iii) Department of Fisheries (DoF) and iv) Forest Department (FD) apart from NARS institutes. All these organizations are contributing greatly to increasing production of crops, livestock, fisheries and forestry through technology dissemination and transfer, input distribution, market chain development etc.

Crops

Rice covered 57,953 ha in 2021-22 which was only 0.8% of the total rice area in Bangladesh (Fig. 6.29). Next to rice, fruits are cultivated in 65,234 ha followed by vegetables (54,740 ha) and the lowest area cultivated by spices (8,910 ha) accounting for 16.2%, 12.1% and 2.1% of the areas in Bangladesh, respectively. Although rice has the highest coverage in area, fruit cultivation becomes prominent due to its highest proportion of area coverage (16.2%) of the total fruit growing areas in Bangladesh.

Fruit production in the hilly areas has toppled the highest and amounted to 1.12 million MT in 2021-2022, which was 21.9% of the total fruit production in Bangladesh (Fig. 6.30). Vegetables produced 0.42 million MT and spices 0.32 million MT covering 9.1% and 8.8% of the total Bangladesh area, respectively.

It is noteworthy that citrus production is overwhelming due to its highest proportion (39.9%) of the total production in Bangladesh. This advancement of fruit production including citrus considering total production of the country has resulted from varietal improvement, increased irrigation coverage and better soil-water-crop management.

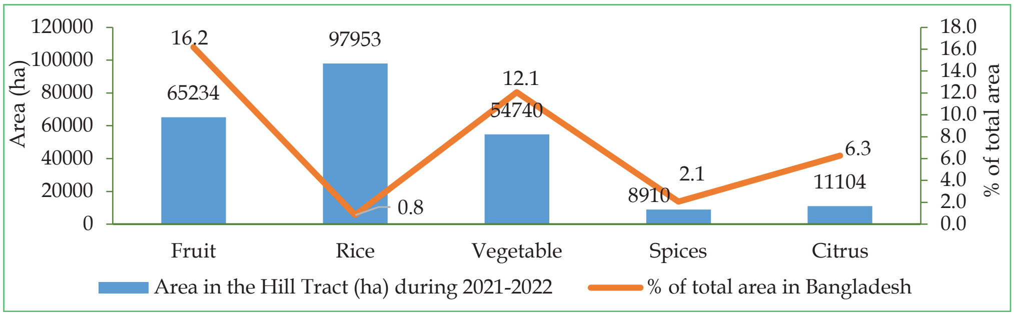


Fig. 6.29. Areas under major crops: Hill Tract and Bangladesh overall during 2021-2022 (source: DAE 2022 and BBS 2021)

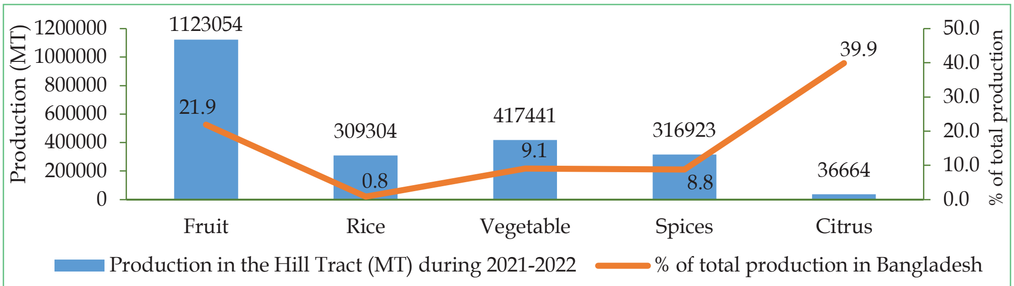


Fig. 6.30 Production of major crops: Hill Tract and Bangladesh overall during 2021-2022 (source: DAE 2022 and BBS 2021)

District-wise (Table 6.15), the increase in rice area has been: Bandarban (1.12%), Khagrachhari (2.2%), Rangamati (5.0%) and Sherpur (60.6%) during 2010-2022 except that Boro and T. Aman area in Rangamati has decreased by 0.5% and 5.8%, respectively. Fruits registered the biggest jump in area coverage by 84.6% in Sylhet followed by Sunamganj (77.3%), Cumilla (74.5), Rangamati (61.5%) and Chattogram (61.5%). The highest increase in area of vegetable occurred in Rangamati (582%) followed by Cumilla (197%) and Chattogram (152%). There was a huge expansion of the papaya and mango acreage in Chattogram by 525% and 272% increase, respectively. The increase in area of non-rice crops in the Hill Tracts may be attributed to adoption of improved varieties and management technologies.

There was an increase in rice production in almost all the hill districts (Table 6.15) with the largest increase of Boro (60.6%) and T. Aman (57.6%) in Sherpur followed by a 16.2% increase in Bandarban and a 14.2% increase of Aus rice in Rangamati during 2010-2022. However, T. Aman in Rangamati experienced a decrease in production by 3.3%. Fruit production increased sharply by 809% in Sylhet followed by 122% in Sunamganj, 114% in Cumilla, 95.1% in Chattogram and 83.5% in Khagrachhari. Vegetable had the highest production increase in Cumilla (377%) followed by Chattogram (277%) and Khagrachhari (67.3%). The phenomenal highest increase in production of papaya (2457%) and mango (1968%) was recorded in Chattogram.

Table 6.15. Changes in area and production of major crops in the hilly areas by district during 2010-2022

District	Major crops	Area (ha)		%Inc/dec (+/-)	Production (MT)		%Inc/dec (+/-)
		2010-11	2021-22		2010-11	2021-22	
Bandarban	Rice	29647	30006	1.2	78192	90854	16.2
	Vegetables	5107	6615	29.5	83051	113550	36.7
	Turmeric	1700	1730	1.8	23200	27010	16.4
Khagrachhari	Fruit	11700	18434	57.6	183476	336681	83.5
	T. Aman	27900	28510	2.2	78921	79200	0.4
	Boro	11360	11463	0.9	45591	48823	7.1
	Winter Vegetable	3625	4954	36.7	50750	84909	67.3
	Turmeric	4605	3867	-16.0	27718	15503	-44.1
Rangamati	Fruit	22020	35565	61.5	400243	608383	52.0
	Boro	8090	8053	-0.5	32730	34708	6.0
	Aus	6270	6581	5.0	8770	10016	14.2
	T. Aman	10240	9650	-5.8	28216	27282	-3.3
	Vegetable	5550	37825	582	76599	112740	47.2
	Ginger	2850	3100	8.8	33950	39771	17.1
	Turmeric	2750	2110	-23.3	3575	7526	110.5
Chattogram	Fruit	2912	4702	61.5	30238	58988	95.1
	Pineapple	145	220	51.7	971	1710	76.1
	Cassava	0	145	100	0	1980	100
	Vegetable	1435	3617	152	19956	63325	217
	Citrus	310	1089	251	2258	9539	322
	Mango	390	1450	272	1460	30200	1968
	Papaya	60	375	525	400	10225	2456
	Guava	105	250	138	552	1320	139
	Banana	105	105	0.0	295	1600	442
	Oilseed crop	140	270	92.9	265	530	100
	Mungbean	8	12	50	20	34	70
	Potato	170	230	35.3	2550	3850	51
	Green chili	185	225	21.6	1295	1575	21.6
	Lemon	4520	8050	78.1	145	400	176
	Spices	375	561	49.6	4701	8065	71.6
	Litchi	550	1200	118	1750	5400	209
	Jackfruit	300	250	-16.7	5000	4500	-10.0
	Malta	0	80	100	-	1440	100

Cox's Bazar	Lemon	40	40	0.0	5	10	100
	Mango	30	30	0.0	8	18	125
	Banana	60	60	0.0	2	8	300
	Guava	110	110	0.0	1	5	400
Cumilla	Vegetable	39	116	197	1208	5760	377
	Spices	22	32	45.5	147	220	49.7
	Fruit	106	185	74.5	1539	3300	114
	Casava	0	40	100	0	880	100
Moulvibazar	Pineapple	1004	1200	19.5	17068	20587	20.6
	Lemon	1600	1900	18.8	24000	28080	17.0
	Spices	150	350	133.3	600	1750	192
	Vegetable	645	1010	56.6	11610	18180	56.6
Sylhet	Tea	10130	10250	1.2	43559	44588	2.4
	Fruit	260	480	84.6	8450	76800	809
	Betel leaf	195	220	12.8	642	756	17.8
Sunamganj	Fruit	220	390	77.3	1760	3900	122
	Pineapple	30	60	100	450	1200	167
Sherpur	Boro	1130	1815	60.6	6215	9983	60.6
	T. Aman	1190	1875	57.6	5355	8438	57.6
	Vegetable	235	373	58.7	4935	7833	58.7
	Citrus	10	25	150	80	300	275
	Spices	27	35	29.6	363	710	95.6
	Fruit	17	13	-23.5	102	118	15.7
Netrakona	Banana	65	75	15.4	960	1500	56.3

Source: DAE 2022

An increase in cultivation area and corresponding increase in production of almost all the major crops has been a blessing for the farmers of almost all the

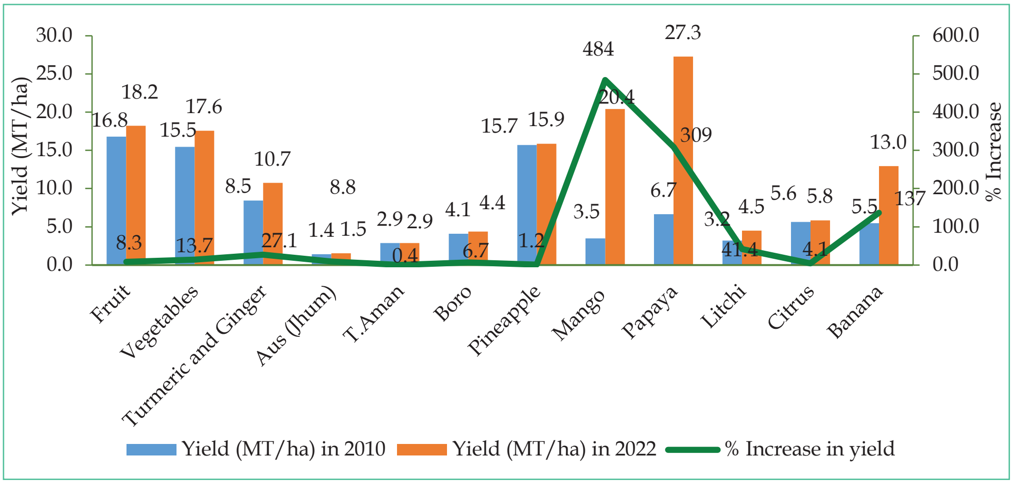


Fig. 6.31. Increase in yield of major crops in the hilly areas during 2010-2022: the bars represent yield in MT/ha and the line represents % increase in yield (source: DAE 2022)

hill districts. This indicates a significant breakthrough in technological advancement positively impacting incomes and livelihood of farmers in the hilly areas of Bangladesh.

Yields of all the major crops grown in the hilly areas increased since 2010 which has eventually contributed to production boosts. (Fig. 6.31). Mango registered the highest yield increase (484%) from 3.5 MT/ha in 2010 to 20.4 MT/ha in 2022 followed by papaya (309%), banana (137%), turmeric and ginger (27.1%) and vegetables (13.7%). The lowest yield increase was noticed in T. Aman rice (0.4%).

Considering the increases in cultivation area, yield and production gains, mango, papaya, other fruits, vegetables, and spices, apart from rice, can be further promoted in the Hill Tracts by utilizing fallow areas and introducing these crops in single and double cropped areas where feasible.

Livestock and poultry

The overall livestock and poultry population increased in the CHT districts (Bandarban, Khagrachhari and Rangamati) from 2.94 to 7.19 million heads accounting for 145% increase during 2007 to 2019 (Table 6.16). The population of all the livestock and poultry species increased in the CHT and the highest increase occurred with Buffalo by 398% from 0.007 to 0.037 million heads followed by poultry (177%) from 2.13 to 5.89 million during the same time. Rangamati hill district had the highest increase in total livestock and poultry population by 166% followed by Khagrachhari (134%) and Bandarban (124%). This overall increase in the livestock and poultry population was

Table 6.16. Changes in livestock and poultry in the Chattogram Hill Tracts during 2007-2019

District	Cattle	Buffalo	Goat	Sheep	Poultry	Duck	Total
	Head counts (million)						
Bandarban							
2007	0.095	0.002	0.056	0.002	0.468	0.027	0.649
2019	0.115	0.018	0.060	0.004	1.23	0.05	1.475
% Increase	21	740	8	129	162	95	127
Khagrachhari							
2007	0.135	0.003	0.109	0.003	0.851	0.070	1.171
2019	0.182	0.004	0.253	0.004	2.22	0.08	2.742
% Increase	35	28	131	5	161	10	134
Rangamati							
2007	0.120	0.002	0.107	0.003	0.811	0.078	1.122
2019	0.174	0.015	0.163	0.002	2.45	0.18	2.982
% Increase	44	533	52	-45	202	130	166
Total							
2007	0.350	0.007	0.272	0.008	2.131	0.175	2.943
2019	0.471	0.037	0.476	0.009	5.897	0.310	7.199
% Increase	35	398	75	12	177	77	145

Source: BBS 2008, DAE 2019

primarily due to the abundant grazing grounds and technological advancement.

Fisheries

Inland water (river, lake, pond, floodplain etc.) fish production in Rangamati hill district increased by 51.7% from 9,624 MT in 2010 to 14,598 MT in 2020 followed by Khagrachhari (36.3%) and Bandarban (15.5%) (Fig.6.32). This increase greatly surpassed the status of national annual fish catch production (decreased by 21%) during the same time. The dramatic increase in inland water fish production during the last 10 years was due to the massive adoption of improved technologies.

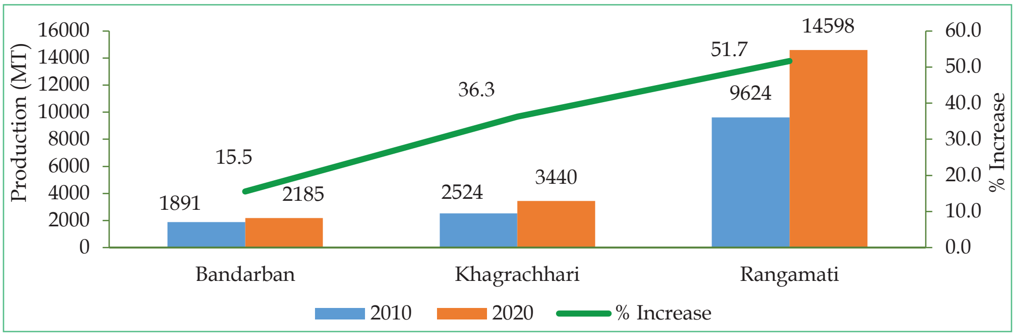


Fig. 6.32. Changes in production (MT) of inland water fishes in the Hill Tracts by district during 2010-2020 (Source: BBS 2012 and 2021)

6.8 Strategic investment opportunities for Hill Ecosystem

All categories of stakeholders such as researchers, extension experts, planners, policy makers, agribusiness entrepreneurs etc. need to rationally think about the strategic investments for agricultural development in the hilly areas of Bangladesh. Agricultural development strategies for hilly areas should be undertaken based on the following plans/policies of the Government:

- Bangladesh Delta Plan 2100
- Vision 2041: Perspective Plan of Bangladesh (2021-2041)
- 8th Five Years Plan (2020-2025)
- Sustainable Development Goals (2016-2030)
- National Agricultural Policy (2018)
- Plan of the Chattogram Hill Tracts Development Board
- Agricultural Research Vision 2030 and beyond

The major strategies that need special attention are discussed below.

Strategy A: Increasing water use

Hill farming is constrained by long dry season leading to severe crisis of water coupled with very poor irrigation system. Erratic rainfall in terms of both volume and distribution, because of climate change, is one of the major challenges for agricultural enterprises in the hilly areas during Rabi season. It has, therefore, become increasingly important, in view of the changing weather patterns induced by climate change, to make optimum use of available water primarily from current rainfall.

Sub-strategy A.1: Watershed management and rainwater harvesting

There is a need for irrigation-based project 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 single crop. This fallow land especially exists in Bandarban (52,414 ha), Chattogram (42,980 ha) and Rangamati (23,121 ha). This will also help increase cropping intensity.

Sub-strategy A.2: Irrigation management

Traditional methods of flood irrigation from a channel allow less flexibility in timing and amount of irrigation and it results in water loss. Boro rice cultivated in the valleys of Hill Tract areas is by far the biggest user of irrigation water as farmers try to maintain 4-10 cm of water in the rice field, during the hottest period of the year. This is not only wastage of water but also hampers tillering. Use of PVC and plastic pipes permits implementation of the alternative wetting and drying (AWD) method for increasing WUE in Boro rice.

Sub-strategy A.3: Crop choice and zoning

- Due to the increasingly erratic rainfall and limited surface water resources of the Hill Tracts, special consideration needs to be given to low water requiring crops and crop rotations.
- Considering the water limitation of the Hill Tracts, it is proposed that Boro rice cultivation should be restricted to 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.
- The development strategy for the valleys should discourage the farmers in monoculture plantations of timber or fruit trees on the hills. Instead, farmers should be encouraged to adopt mixed plantations. The other is that 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.
- Introduction of drip irrigation, sprinkler irrigation, buried pipe, mulching film etc. will help reduce water loss and increase water use efficiency.
- With the residual soil moisture after the rainy season, it is possible to grow short-duration rice, vegetable crops etc. using irrigation water from creaks, streams and rain harvest reservoirs.
- Hill Tract areas can grow high-value fruits e.g., mango, papaya, citrus.
- There is a huge potential for production of spices (zinger, turmeric, tezpata, alach, black pepper etc.) and other crops in fringe lands using surface irrigation from creaks, streams etc.
- Along with improved water capture and water use, the improved soil management techniques and good choice of crops, crop rotation etc. are necessary.

Sub-strategy A.4: Enhancing breeding of drought tolerant HYVs of crops

Inadequate HYVs of crops for jhum cultivation and inadequate research activities pose challenges for effective cultivation of hilly areas. There are insufficient short-duration drought tolerant/low water requiring varieties of rice, vegetables and other crops. Since long dry season with high temperature causes serious crop losses in most years, planting early maturing (short-duration) drought tolerant rice and other crop varieties is desirable to escape crop damage from drought. Thus, there is a dire need to enhance breeding of drought tolerant HYVs of different crops.

Strategy B: Afforestation and agroforestry

Traditionally, the communities in the hilly regions practice a farming method called jhum. This 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, population pressure and the inclusion of jhum land in reserved forest has necessitated higher production from an ever-shrinking land base. This has gradually shortened the fallow period to as little as two or one years, contributing to a sharp decline in productivity and deterioration of forest ecosystem. Particularly as the Hill Tracts have been denuded of trees over time, it is important to return them to the extent possible to improve the ecosystem in various ways. This can involve all kind of trees, from orchards to trees providing building materials, fuel, and fodder. This includes bamboo clumps, which should get preference due to their drought tolerance, low management requirement and multiple uses as construction material, fuel, trellises, and cash value. All land not allocated for cropping or infrastructure should be considered in a multi-strata agroforestry farming approach. Government Horticulture Center, DAE, should be established in all hilly upazilas, if not available yet, to ensure a constant supply of saplings and seedlings to the agroforestry farmers. Farmers need to be trained in establishing and managing tree nurseries to provide saplings of good quality.

Strategy C: Addressing soil erosion

Land preparation prior to establishment of monoculture plantations involves uprooting of tree stumps and burning of debris on the forest floor which leads to serious soil erosion and depletion of soil moisture. The most serious problem regarding gardening, particularly of pineapple citrus fruits, and some root crops such as ginger and turmeric, is the direct exposure of the soil surface to heavy downpour and surface runoff. This results in topsoil erosion, which causes gradually diminishing harvests of the concerned crops, and ultimately also renders the land virtually useless for further cultivation or plantation purposes. To address these constraints, the following strategies should be taken into account:

Sub-strategy C.1: Promoting Village Community Forest (VCF) in the hilly areas

Since 1900, Village Community Forests (VCFs) have presented excellent examples of traditional forest management by the indigenous communities in the CHTs. The presence of good understorey vegetation consisting of many herbs and other plants is the primary indicator of good site conditions prevailing in the VCF areas. These understoreys are helpful to soil and water conservation. In some places, communities are totally dependent on VCFs to sustain water flow of perennial streams so as to meet year-round water requirements. Besides VCF management, the 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. Therefore, there is a huge potential for promoting VCFs in the conservation of forest, soil, and water in some critical locations of hilly areas. Moreover, there is a wealth of indigenous knowledge and cultures involved in management of these resources. VCFs could certainly act as models of resource conservation in the degraded hilly landscapes. Thus, further investment should be provided to promote VCF model extensively in the critical hilly areas of the country.

Sub-strategy C.2: Effective management of slopping land

Based on the success of Land Degradation Neutrality Target Setting Program (LDN-TSP) during December 2016 through February 2018 with the support of United Nations Convention to Combat Desertification (UNCCD), Bangladesh put further commitment to achieve LDN leverage plan to reduce soil erosion in hilly areas. According to the target 4 of LDN, the Government of Bangladesh will reduce soil erosion in hilly areas in 600 km^2 area by 2030. 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 should be taken to establish agroforestry/horticulture, no tillage on slope, introduce hedgerow across the slope by leguminous shrubs/trees. This investment plan of LDN as committed by the Government of Bangladesh through UNCCD should be widely implemented in the hilly areas in support of effective management of slopping lands.

Sub-strategy C.3: Manipulated fallow management

Tribal people in the CHT practice jhum or shifting cultivation in an area for one year and keep the land fallow after that to allow it to rejuvenate. But short fallow period is not able to restore the soil fertility. The use of "manipulated" or improved fallows provides a range of techniques which make better use of the ecological processes, leading to more sustainable practices. Some of the improved techniques that have been observed being used by the farmers in the CHT are using mulch as soil protection. The farmers follow this technique for growing ginger and taro in hilly areas. According to farmers, mulch controls weed, minimizes soil erosion and adds humus after decomposition. The use of mulch safeguards the topsoil against excessive soil temperatures and favors seed germination. Thus, this manipulated fallow management technique should be widely promoted for effective shifting/jhum cultivation.

Strategy D: Reverting land degradation

Ethnic communities are encouraged to implement monoculture farming strategies through land allocation policies. Subsequent unsystematic tillage on the hill slopes for establishment of monoculture plantations has led to serious land degradation. Land degradation is undermining the long-term capacity of the Hill Tract agro-ecosystem to deliver in terms of agricultural production. Although nutrient inputs and technologies may offset a decline in soil health, the long-term implications need to be addressed especially in the face of increasing peoples' demands for food and other necessities. Hilly lands contain sandy-loam fertile soil and there is no water logging situation as about 97% land are high to medium low. Soils and weather are very much suitable for fruit production in the hills. So, much more orchards with multistorey of different fruits instead of monoculture can be established in different hill slopes to revert land degradation.

Strategy E: Improvement of livestock

The main challenges in livestock rearing are lack of modern husbandry technologies. In addition, lack of quality veterinary facilities and physical infrastructure, and insufficient scientific and technical innovations hinder livestock production. The rearing of livestock has received consideration as an important option for investment in the CHT. The local market, as well as that on the Bangladesh plains, is very large. Additionally, there is the prospect of exports to both India and Myanmar. As well as being a source of income, livestock can also function as a safety-reserve asset for farmers. It is also possible to take livestock to the market even from remote areas.

Sub-strategy E.1: Diversified livestock farming with improved veterinary services

Farmers' livelihoods could be diversified with intensive livestock farming including beef and cattle fattening, sheep & goat raising, poultry farming and dairying. Ability to sell livestock provides insurance against crop failure, or other crises. However, to be viable, veterinary services would need to be markedly improved across the hilly areas, with creation of para-vets at community level.

Sub-strategy E.2: Improving animal feeding

Returns from livestock can be increased by improving animal feeding. Most animals in the CHT are grazed, usually watched over by children. Stall feeding would improve the medical condition of animals and reduce the incidence of parasites both in animals and humans. In addition, it would have an added advantage of keeping children in 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. A move away from grazing to stall feeding would also require a collective decision to be made at village level and enforcement of the decision. The successful enforcement of collective decisions about stall feeding has been observed across the border, in the Indian states of Mizoram and Nagaland.

Strategy F: Improvement of fisheries

There are numerous small waterways in hilly areas, although most are seasonal and are dried during winter. It should be 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 pangus (*Pangasianodon hypophthalmus*) or tilapia. However, to promote it in the CHT would require backward-linked investments in rearing fry and fingerlings. Such investments could initially come from a private-public partnership. The CHT has the advantage of the Kaptai reservoir, which has a maximum surface area of almost 70,000 ha. Fisheries production from this reservoir has increased over time, but its full potential has not yet reached. To raise this production capacity, floating aquaculture technologies may be used, such as cages and pens. There is a risk that increasing aquaculture will compete with indigenous species for space and resources. In order to preserve biodiversity, development of aquaculture needs to be combined with the establishment of sanctuaries.

Strategy G: Agricultural mechanization

Rural labor force has started to shift from agricultural to industrial sector and service sector, creating an acute agricultural labor shortage during peak planting and harvesting times. This situation necessitates introduction of farm mechanization. But hill agriculture is constrained seriously due to lack of irrigation machineries. Therefore, to increase the efficiency of surface irrigation from creeks, streams etc. irrigation pumps should be available to the hill farmers on subsidized rate.

Strategy H: Strengthening agricultural marketing

Very poor marketing facilities exist in the hilly areas. There are a few numbers of collection points and storage facilities with no cool chamber advantage. Inadequate seed supply and faulty seed delivery system have negative impact on crop production. Farmers have poor access to agricultural inputs, technologies, extension services, marketing etc. due to remoteness. The main constraint of agriculture in the hilly areas is the high price of inputs (fertilizer, seed, labor etc.). Transportation of the produce after harvesting also appears to be a major problem due to lack of sufficient road networks.

Sub-strategy H.1: Improving market facilities

To ensure proper marketing of agricultural products, processing plant unit and cool camber should be established for different fruits and vegetables. Farmer market needs to be grown for increasing access of farmers to the local markets. Community based agriculture marketing system should be established, and agriculture inputs should be made available in the remote hilly areas.

Sub-strategy H.2: Establishing effective market zoning for well-connected and remote hill villages

In villages located on metalled roads, motor transport can be used to take goods to markets, but farm produces in remote villages are usually not much so that transportation would not be cost effective. Consequently, the availability and cost of motor transport are factors limiting the participation of hill farmers in wider markets. Farmers in remote villages are forced to produce more of what they require for their own consumption than villages with easy access. Thus, they are unable to benefit from schemes promoting specialized or larger-scale production. In addition, there are likely to be fewer traders in any single commodity in remote village markets than those in larger towns. With a greater degree of monopoly, the prices that sellers receive are likely to be lower in distant village markets. Therefore, in well-connected villages, the agricultural development strategy should be to promote multi-strata fruit production. The Bangladesh Agricultural Research Institute's Hill Agriculture Station in Khagrachari district reports that pineapple-based multi-strata fruit cultivation could suit these well-connected villages. Furthermore, pineapples could perform a dual function of not only providing income, but also reducing soil erosion. On the other hand, fruits are highly perishable and only limited quantities can be carried to market. Therefore, cash crops in the remote villages should include not just the traditional ginger and turmeric, but also the less demanding chili and even hybrid maize. Hybrid maize has a yield that is about 50% higher than that of conventional maize, but it is used mainly for processing into animal feed. Therefore, marketing channels would need to be established. Initially, the maize might have to be taken to the nearest market, for instance, to Chattogram. But growing volumes would eventually encourage traders to buy it from the production areas.

Strategy I: Linking hill farmers with digital platforms

Farmers of the Hill Tracts should be equipped and linked with digital platforms serving the agricultural sector. As per the National Agricultural Policy (2018), Farmers' Information and Advice Centers (FIAC) housed in Union Parishad premises have been spreading across the country through DAE. This facility should be rapidly extended to all unions of the hilly areas in Bangladesh.

References

Alam MF and Mong N (2004) 'Indigenous people in CHT face worst water crisis', The Daily Star, 18 June 2022, p. 5.

Anonymous (2020) 'CHT fruit growers given short end of the stick', The Daily Star, Retrieved from https://www.thedailystar.net/business/news/cht-fruit-growers-given-short-end-the-stick-1895824, ".

Anonymous (1996) Banglapedia: Encyclopedia of Bangladesh. Asiatic Society of Bangladesh, Dhaka. www.Banglapedia. com.

Anonymous (1960) Working plan of the Chittagong Hill Tracts North and South Forest Division for the period from 1953-54 to 1972-73, Vol. 2. Working Plan Division, Forest Department, the Government of East Pakistan, pp. 1-89.

Asian Indigenous Peoples Pact (2007) A Brief Account of Human Rights Situation of the Indigenous Peoples in Bangladesh, AIPP, Chiang Mai, Thailand.

BADC (Bangladesh Agricultural Development Corporation) (2014) Minor Irrigation Survey Report 2013-14, Ministry of Agriculture, Government of the People's Republic of Bangladesh.

Banglapedia (2021) Hill Tract. Retrieved from https://en.banglapedia.org/index.php/Chittagong_Hill_Tracts

Bala BK, Majumder S, Altaf Hossain SM, Haque MA and Hossain MA (2012) Exploring development strategies of agricultural systems of Hill Tracts of Chittagong in Bangladesh, Environment, Development and Sustainability 15(4): 949–66.

Barakat A, Halim S, Poddar A, Badiuzzaman M, Osman A, Khan M S, Rahman M, Majid M, Mahiyuddin G, Chakma S and Bashir S (2009) Socio-economic Baseline Survey of Chittagong Hill Tracts, Human Development Research Center, Dhaka.

BARC (Bangladesh Agricultural Research Council) (2022) Computer and GIS Unit, BARC, Farmgate, Dhaka.

Basak SS, Rahman MM, Bashar MA, Khan MMH and Mahmud MY (2017) Production and growth performance under carps polyculture with different stocking densities in hilly creeks of Kaptai lake, Rangamati, MOJ

Ecology and Environmental Sciences, 2 (4) (2017), pp. 158-163. Retrieved from http://doi.org/10.15406/mojes.2017.02.00029

BBS (Bangladesh Bureau of Statistics) (2021) Year Book of Agricultural Statistics 2021, Ministry of Planning, Government of the People's Republic of Bangladesh.

BBS (Bangladesh Bureau of Statistics) (2015) Year Book of Agricultural Statistics 2015, Ministry of Planning, Government of the People's Republic of Bangladesh Accessed 10 June 2015. http://www.bbs.gov.bd/home.aspx

BBS (Bangladesh Bureau of Statistics) (2020) Year Book of Agricultural Statistics 2020, Ministry of Planning, Government of the People's Republic of Bangladesh.

BBS (Bangladesh Bureau of Statistics) (2012) Year Book of Agricultural Statistics 2012, Ministry of Planning, Government of the People's Republic of Bangladesh

BBS (Bangladesh Bureau of Statistics) (2022) Year Book of Agricultural Statistics 2008, Ministry of Planning, Government of the People's Republic of Bangladesh.

BBS (Bangladesh Bureau of Statistics) (2008) Year Book of Agricultural Statistics 2008, Ministry of Planning, Government of the People's Republic of Bangladesh.

Brammer H (1997) Agricultural Development Possibilities in Bangladesh, University Press Limited, 114 Motijheel C/A, Dhaka, Bangladesh, pp. 103.

Brammer H (1996) The Geography of the Soils of Bangladesh, University Press Limited, Dhaka, Bangladesh.

Biswas A, Alamgir M, Haque SMS, and Osman KT (2012) Study on soils under shifting cultivation and other land use categories in Chittagong Hill Tracts, Bangladesh, Journal of Forestry Research 23(2): 261−265.

Chowdhury MJA and Hossain DM. 2010. Conflict and Schooling of Household Members: Experience from the Chittagong Hill Tracts (CHT) Region in Bangladesh, Journal of Asian Studies for Intellectual Collaboration, Rikkyo University AIIC, pp. 30-42.

Chowdhury JA (2006) Towards Better Forest Management, OITIJJHYA, p. 336.

DAE (Department of Agricultural Extension) (2022) Unpublished data. Field Services Wing, Khamarbari, Farmgate, Dhaka-1215

Danilo G (2008) Frontier Encounters: Indigenous Communities and Settlers in Asia and Latin America, International Work Group for Indigenous Affairs, p. 487.

Dasgupta S, Ghosh SP and Pillai KG (2008) Chittagong Hill Tracts (CHT), Growth Potential in High Value Agriculture, Dhaka, Bangladesh.

Dewan B (2015) Scenario of major fruits production and marketing system in Chittagong hill tracts: Study based on Khagrachari Hill District, Bangladesh, International Journal of Economics, Commerce and Management, 3: 966-977.

Dhamai BM (2006) Migration and Indigenous People: A Perspective of Bangladesh, Presented in the Expert Workshop on Indigenous Peoples and Migration, Geneva, 6-7 April.

DLS (Department of Livestock Services) (2019) Unpublished data regarding union-wise statistics on livestock and poultry in Bangladesh, Ministry of Fisheries and Livestock, Government of the People's Republic of Bangladesh.

DoF (2014) Fisheries statistical report of Bangladesh 2014, Fisheries resources survey system (FRSS) Vol. 30, Department of Fisheries, Bangladesh.

DoF (2020) Yearbook of fisheries statistics of Bangladesh 2020, Fisheries resources survey system (FRSS) Vol. 37, Department of Fisheries, Bangladesh.

Dutta JP (2000) Impact of Development Programmes on Environment and Demographic Phenomena of the Ethnic Minorities of Chittagong Hill Tracts, Center for Policy Dialogue, Dhaka.

FAO (Food and Agriculture Organization of the United Nations) (2010) Global Forest resources assessment country report: Bangladesh, Rome: FAO.

FD (Forest Department of Bangladesh) (2015) Forest cover of Bangladesh. Accessed 20 June 2015. http://fd.portal.gov.bd/

FD (Forest Department) (2015) Land cover atlas of Bangladesh, 2015, Forest

Department, Ministry of Environment, Forests and Climate Change, Government of the People's Republic of Bangladesh.

Fullen G (2014) World peaks climbed, Archived from the original on 29 July 2014.

Gafur A, Borggaard OK, Jensen JR and Peterson L (2003) Run off and loses of soil and nutrients from watershed under shifting cultivation (Jhum) in the Chittagong Hill Tracts of Bangladesh, Journal of Hydrology, 279: 293-309.

Gafur A, Borggaard OK, Jensen JR and Petersen L (2000) Changes in soil nutrient content under shifting cultivation in the Chittagong Hill Tracts of Bangladesh, Geografisk Tidsskrift, 100: 37–46.

GoB (Government of Bangladesh) and FAO (Food and Agriculture Organization of the United Nations) (2013) Support to preparation of an integrated project for environment friendly agriculture in the Chittagong Hill Tract, Technical Report, Dhaka, Bangladesh: GoB; FAO.

Harun-Ur-Rashid M and Chowdhury MAI (2013) Additions to the angiosperm flora in the Sitapahar Reserve Forest of Kaptai, Rangamati, Bangladesh, Bangladesh Journal of Plant Taxonomy, 20(2): 255-257.

Hossain MA, Jashimuddin M, Nath TK and O'Reilly P (2017) Spiny coriander (Eryngium foetidum L.) cultivation in the Chittagong Hill Tracts of Bangladesh: Sustainable agricultural innovation by indigenous communities, Indian Journal of Traditional Knowledge 16(1): 59-67.

Hossain MA and Wahab MA (2010) The diversity of cypriniforms throughout Bangladesh: Present status and conservation challenges, Nova Science Publishers (2010), (Chapter 4), Google Scholar.

Hossain MK, Azad AK and Alam MK (1999) Assessment of natural regeneration status in a mixed tropical forest at Kaptai of Chittagong Hill Tracts (South) Forest Division, The Chittagong University Journal of Science, 23(1): 73-79.

Islam MS, Alam M and Mantel S (2007) Land use planning and environmental control in the Chittagong Hill Tracts, CHARM Project Report No. 3. Dhaka, Bangladesh.

Jashimuddin M and Inoue M (2012) Management of Village Common Forests in the Chittagong Hill Tracts of Bangladesh; Historical Background and

Current Issues in Terms of Sustainability, Open Journal of Forestry, 2(3): 121-137.

Karim SMR and Mansor M (2011) Impact of Jhum Cultivation on the Agro-ecology of Mountains and Socio-economy of Tribal Peoples, Asian Journal of Agricultural Research, 5 (2): 109-114.

Khan MMH (2018) Photographic Guide to the Wildlife of Bangladesh. Dhaka, Bangladesh: Arannayk Foundation, p. 488.

Khan MH, Aziz MA, Uddin M, Sharif S, Chowdhury SU, Chakma S, Chowdhury GW, Jahan I, Akter R, Myant MH and Mohsanin S (2012) Community conserved areas in Chittagong Hill Tracts of Bangladesh, In: Islam, MA, ed. Wildlife Trust of Bangladesh, Dhaka, Bangladesh.

Khan MFA, Mantel S and Choudhury EH (2007) State of the environment of Chittagong Hill Tracts, CHARM Project Report No. 2. Dhaka, Bangladesh.

Life is not Ours Land and Human Rights in the Chittagong Hill Tracts, Bangladesh (2000) Copenhagen: Chittagong Hill Tracts Commission, 2000, pp. 4–7. OCLC 67231760.

Misbahuzzaman K and Smith-Hall C (2015) Role of forest income in rural household livelihoods: The case of village common forest communities in the Chittagong Hill Tracts, Bangladesh, Small-Scale Forestry, 14(3): 315–30. doi:10.1007/s11842-015-9290-1

MJF (Manusher Janno Foundation) (2020) Climate Change Trends, Situation and Impacts in Chittagong Hill Tracts of Bangladesh, Climate Change Report 2020. http://www.manusherjonno.org/wp-content/uploads/2021/01/Climate-Change-Report-2020.pdf

Mukul SA, Uddin MB, Uddin MS, Khan MASA and Marzan B (2008) Protected areas of Bangladesh: Current status and efficacy for biodiversity conservation, Proceedings of the Pakistan Academy of Sciences 45(2): 59-68

Mullah MAS, Parveen N and Ahsanullah M (2007) Tribal People and their Socio-economic Characteristics in Rangamati Sadar Thana, BRAC University Journal, IV(1): 7-58.

Nath TK, Hossain MK and Alam MK (2000) Assessment of tree species diversity of Sitapahar forest reserve, Chittagong Hill Tracts (South) Forest Division, Bangladesh. The Indian Forester, 126(1): 16-21.

Nazila G (2005) Minorities, Peoples and Self-Determination. Martinus Nijhoff Publishers, p. 117. ISBN 9004143017.

Olarieta JR, Rodriguez-Ochoa R and Ascaso E (2007) Land management in the Chittagong Hill Tracts and sustainable alternatives, CHARM Project Report No. 4. Dhaka, Bangladesh.

Rahman MM, Islam AS, Uddin KB, Alam MA and Mahmood Y (2017) Creek's aquaculture techniques in Rangamati hill tracts of Bangladesh, Annual Research & Review in Biology, 13 (2017): 1-10, 10.9734/ARRB/2017/33657

Rahman SA, Rahman MF and Sunderland T (2012) Causes and consequences of shifting cultivation and its alternative in the hill tracts of eastern Bangladesh, Agroforestry Systems, 84(2): 141–55.

Rasul G and Tripura NBK (2016) Achieving the sustainable development in the Chittagong Hill Tracts – Challenges and opportunities, ICIMOD Working Paper 2016/12. Kathmandu: ICIMOD.

Rasul G (2007) Political ecology of the degradation of forest commons in the Chittagong Hill Tracts of Bangladesh, Environmental Conservation, 34(2): 153–63.

Roy RD (2010) Country Technical Notes on Indigenous Peoples' Issues: Bangladesh, IFAD, Italy.

SRDI (2018) Annual Report 2017-18, Soil Resource Development Institute, Ministry of Agriculture, Government of the People's Republic of Bangladesh, Dhaka.

SRDI (1976) Reconnaissance Soil Survey Reports of Chittagong North and Sadar Subdivision (1971-1973), Soil Resources Development Institute, Dhaka, Bangladesh.

Sultana N (2011) Community Health Program at Remote Hill District, Bangladesh, ACCESS Hill International Bangladesh, Bangladesh.

Thapa GB and Rasul G (2005) Patterns and determinants of agricultural systems in the Chittagong Hill Tracts of Bangladesh, Agricultural Systems, 84(3):

Uddin SN and Hassan MA (2012) Angiosperm flora of Rampahar Reserve Forest under Rangamati district in Bangladesh, *I. Liliopsida* (Monocots). Bangladesh Journal of Plant Taxonomy, 19(1): 37-44.

Uddin SN, Khan MS, Hassan MA and Alam MK (1998) An annotated checklist of angiospermic flora of Sitapahar at Kaptai in Bangladesh. Bangladesh J.ournal of Plant Taxonomy, 5(1): 13-46.

UNCCD Bangladesh (2018) National Report on Land Degradation Neutrality Target Setting Program (LDN-TSP) of Bangladesh 2018, United Nations Convention to Combat Desertification (UNCCD). https://www.unccd.in t/sites/default/files/ldn_targets/2019-

Zhang B, Wu P, Zhao X, Gao X and Shi Y (2014) Assessing the spatial and temporal variation of the rainwater harvesting potential (1971–2010) on the Chinese Loess Plateau using the VIC model, Hydrology Process, 28: 534–544.

Wikipedia (2022) Hill Tracts. https://en.wikipedia.org/wiki/chittagong _Hill_Tracts.