

FARMING SYSTEMS OF BANGLADESH

Poverty Escape Pathways and Livelihoods Improvement

M Yusuf Ali, Ph.D.

Editor:

Dr. Chris Johansen

*Consultant in Agricultural Research
and Development*

&

Adjunct Professor

University of Western Australia

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Year of Publication: 2014

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Published by

Anjuman Ara
D-186/7 (2nd Floor)
Nazrul Sarani
Middle Sayabithy, Joorpukur
Gazipur-1700, Bangladesh

Printing

Idea Printers

ISBN

Price: BDT 250
USD 20

Dedication

**To My Esteemed Teacher
Dr Chris Johansen and his
Wife Mrs Lutfi Johansen**

EDITORIAL

Compared to most countries, Bangladesh is well endowed with fertile soils, water from rainfall and rivers and a benign sub-tropical climate allowing cultivation of a wide range of crops, from tropical to temperate. With so many crop and seasonal options it is therefore not surprising that a diverse and complex array of cropping and overall farming systems have evolved. Moreover, in recent decades, traditional farming systems have been changing at an ever increasing rate, due to such factors as population growth, technology intervention, commercialization of agriculture, environmental deterioration, global trade in agricultural products, development of non-agricultural industries, and so on. An example of that change has been the extraordinary increase in maize cultivation across Bangladesh, primarily in response to a rapidly expanding poultry industry. On the other hand, cultivation of winter pulses has declined, despite their continued in-country demand, due to factors such as increased Boro (winter) rice cultivation and proliferation of diseases and pests of pulse crops. However, tropical pulses such as mungbean are expanding, and there are increasing prospects for soybean induced by the on-going demand for soybean in poultry feed.

The rapid deployment of two wheel tractors in Bangladesh since the 1990s has profoundly changed the agricultural landscape. Turn-around time between crops is now hastened and this machinery has opened possibilities for practise of conservation agriculture, to redress the generally deteriorating soil quality. The role of cattle has consequently changed, from draught animals to beef and dairy production. Over recent years, fish and shrimp culture and intensive horticultural production have been increasingly incorporated into the farming systems of the country.

Dr Md. Yusuf Ali has worked on research and development of farming systems across Bangladesh since the 1980s and has thus developed a profound understanding of this complex array. This book attempts to document this understanding, and proposes a means of classifying and analysing this complex and dynamic array. As farming systems in Bangladesh are increasingly dynamic, this book can only present a snapshot of the present situation. However, such a snapshot is necessary in order to examine how farming systems might further evolve towards alleviating endemic rural poverty. Thus Dr Yusuf Ali provides a description of the present situation and gives his suggestions of how farming systems could evolve so as to effectively tackle rural poverty.

This book should therefore be of value to anyone interested in the evolution of Bangladesh agriculture with the aim of making significant inroads into rural poverty. It would thus be particularly relevant to academics focusing on economic and social development, agricultural researchers and extension agents, policy makers and development funding agencies.

Chris Johansen

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ACRONYM AND ABBREVIATION

AFP	Axial Flow Pump
AWD	Alternate Wetting and Drying
AVRDC	Asian Vegetable Research and Development Center
BARI	Bangladesh Agricultural Research Institute
BARC	Bangladesh Agricultural Research Council
BRRI	Bangladesh Rice Research Institute
BLRI	Bangladesh Livestock Research Institute
BFRI	Bangladesh Forest Research Institute
BINA	Bangladesh Institute of Nuclear Agriculture
BJRI	Bangladesh Jute Research Institute
BSRI	Bangladesh Sugarcane Research Institute
BFRI	Bangladesh Fisheries Research Institute
BMDA	Barind Multipurpose Development Authority
BRAC	Bangladesh Rural Advancement Committee
BADC	Bangladesh Agriculture Development Corporation
BARD	Bangladesh Academy for Rural Development
BBS	Bangladesh Bureau of Statistics
BD	Bangladesh
BDT	Bangladeshi Taka (Bangladesh currency)
B.aman	Broadcast aman
BAU	Bangladesh Agricultural University
BSMRAU	Bangabandhu Sheikh Mujibur Rahman Agricultural University
BNF	Biological Nitrogen Fixation
CU	Chittagong University
C	Centigrade
CHT	Chittagong Hill Tracts
CIMMYT	International Maize and Wheat Improvement Centre
DAE	Department of Agriculture Extension
DU	Dhaka University
dS/m	Decisible per meter
FAO	Food and Agriculture Organization of the United Nation
FMPE	Farm Machinery and Postharvest Processing Engineering Division
GDP	Gross Domestic Product
HDSTU	Hazi Denesh Science and Technology University
ha	hectare

HYV	High Yielding Variety
IRRI	International Rice Research Institute
IARC	International Agricultural Research Centers
ICRISAT	International Crop Research Institute for the Semi-Arid Tropics
ICARDA	International Centre for Agricultural Research in Dry Areas
ICRAF	International Centre for Research in Agro-Forestry
ILRI	International Livestock Research Institute
IPNS	International Plant Nutrient System
IPM/ICM	Integrated Pest Management/ Integrated Crop Management
I & WM	Irrigation and Water Management Division
KU	Khulna University
LLP	Low Lift Pump
mm	Millimeter
m	million
MDG	Millennium Development Goal
MoA	Ministry of Agriculture
NARS	National Agricultural Research System
NGO	Non-Government Organization
OFRD	On-Farm Research Division
PSTU	Patuakhali Science and Technology University
PSO	Principal Scientific Officer
PTOS	Power Tiller Operated Seeder
RU	Rajshahi University
RMG	Ready Made Garments
RDA	Rural Development Academy
SRDI	Soil Resource Development Institute
STW	Shallow Tube Well
SAU	Sher-E-Bangla Agricultural University
t	Tonne (Metric ton)
T.aman	Transplanted aman
T.aus	Transplanted aus
USG	Urea Super Granule
UMS	Urea Molasses Straw
WB	World Bank
WFP	World Food Program
WRC	Wheat Research Centre

GLOSSARY

Bagda	Brackish water shrimp species
B.aman	The direct seeded long duration photo-sensitive rice cultivar planted at the On-set of monsoon (April-May) but harvested in December-January
Boro rice	Transplanted rice grown in Rabi and Khaif-I season with frequent irrigation
Beel	Natural depression of land. Perennial water body in the floodplain
Bawali	Wood-cutter in the Sunderban forest
Baromasi	The fruit variety which could be harvested multiple times particularly in Off-season, such as Baromasi Moringa, Baromasi Jackfruit etc
Bigha	One third of an acre or 1320m ² -widely used in Bangladesh
Char	Newly accreted land from river/sea bed
Charra	Small canal following through hilly area
Dadonder	Money lender often with conditionality of advance purchase of products/labor
Deep water aman	Direct seeded photo-sensitive aman rice grown in low lands which can cater 1-2 meter water depth, can increase its culm length with the increase of flood/monsoon water. Sown in dry conditions in April-May
District	Administrative unit comprising several upazilas
Fertigation	Fertilizer used with irrigation
Golda	Freshwater shrimp species
Golapata	Mangrove palm type plant species; leaves are used as materials for roof
Gher	Is a Bengali word means surrounded by something. Here Gher means excavated water body surrounded all sides by 1-2 meter height of polder made by soils mainly for shrimp culture, along with other fish and T.aman rice cultivation. In some Gher Boro rice is also cultivated. It is linked with nearby river/canal for entering of saline tidal water. That is water entrance and drainage is controlled by sluice gate. Within Gher there is small long canal in all sides where water remains and shrimp and fishes take their shelter. On the bank of 1-2 meter wide Gher often vegetables are cultivated; also creeping vegetables are grown on trellis made on the water body by fixing bamboo.
Kharif-I	Monsoon crop growing season: 16 March to 15 July
Kharif-II	Crop growing season: 16 July to 15 October

Haor	Natural land depression having 1-2 meter natural water in monsoon but in Rabi season water recedes when single Boro rice is grown, mostly situated in north-east Bangladesh
Mahajan	Moneylender, generally at village level
Mawali	Honey collector in the Sunderban forest
Monga	A period of food shortage in northern Bangladesh generally during September and October, exacerbated by a scarcity of agricultural job opportunities then
Non-saline tidal water	Bangladesh tidal water is divided into two parts: non-saline and saline (IRRI, 1984), (Rashid, 1978). Actually Ganges-Bramaputra-Meghna (GBM) rivers of Bangladesh is the only outlet which carries most of the Himalayan basin water to Bay of Bengal. The amount of water is so huge that it pushes the saline water of the bay and when tide come this sweet water again return to rivers, canals and creeks. Thus the tidal water of south-central region is non-saline. Even in dry season (April-May) salinity level of Barisal region river water is only 0.25-0.7 dS/m (MoA, 2013). The central south Bangladesh Barisal region is the unique example of it. It may be mentioned that Over 138, 700 m ³ /s of water flows into the Bay of Bengal during floods through a single outlet of the GBM river in Bangladesh. This is the largest in the world for a single outlet to the sea and exceeds even that the Amazon discharge into the sea by about 1.5 times (Parua, after 2001). This main outlet is situated in south-central Bangladesh.
Polder	Reclaimed land with water management system
Rabi	Winter crop growing season: 16 October to 15 March
Rainfed	Crop grown depending on natural rain or on stored soil moisture
Rayna crop	Instead of one season crop in Jhum system in Hilly area, crop continues over the seasons such as cassava, eggplant, chilli etc.
Sunderban	Name of world largest mangrove forest in southwest Bangladesh
Taka	Bangladesh currency
T. aus	Rice grown in Kharif-I season generally with irrigation
T.aman	Rice grown in Kharif-II season generally with natural rainfall but often supplementary irrigation is applied in case of drought
Upazila	Administrative unit under a district comprising several unions

SUMMARY

Different institutions of Bangladesh have worked on Farming Systems Research and development for more than three decades, however there is a clear dearth of information and including publications. To understand Farming Systems of Bangladesh is important for overall agricultural development. Moreover, it is different from other parts of the world and complex in nature. In-depth knowledge about Farming Systems would help to identify its agricultural problems and potential. We think this publication would be instrumental to researchers, development workers, academics and policy makers for pinpointing their R&D initiatives at the very beginning.

Bangladesh a South-Asian deltaic country having 160 million population lives within a small geographical area of 147, 570 square kilometer. It is blessed with hundreds of small and big rivers mostly flowing from north towards southern sea- the Bay of Bengal though some rivers are at critical stage because of undue withdrawal of excessive water by upper riparian country in dry months. Except the eastern and southern hilly area the major landmass is alluvial in nature and experienced sub-tropical hot and humid monsoon climate except the mild winter (Rabi season) of November-February. Average rainfall is about 1600 mm of which 80 percent occurred in rainy season (June-September) having wide variation among eastern to western and northern regions. The summer air temperature ranges from 30-37°C while in winter mercury goes down to 10-25°C. Still the livelihood is agrarian as 75 percent population lives in village rest 25 percent in city though in recent year's growth in readymade garment sector, manpower export and service sector are tremendous. However, till today per capita income is only US\$1500 (adjusted by purchasing power parity) and more than 30 percent population lives below poverty. As a deltaic country and a large number of population (30 million) lives in close proximity to big rivers and coastal area, it is adversely affected by natural hazards and climate change thus lives and properties are recurrently battered by cyclone/storm/tidal bore/flood and river erosion.

Despite only eight million hectares of cultivable land Bangladeshi farmers grow/rare hundreds of field crops, vegetables, variety of fruits, agroforestry species, fisheries species along with capturing of fish from river and sea, and domestic animals and poultry for their livelihoods. Farmers try to grow two or more crops per year in the same piece of land as they have small land holdings if land category or water is not limited. Where rice is the single major staple food associated with different pulses, vegetables and fishes and often supported by beef, poultry and mutton meat. With the growth of urbanization wheat flours and associated products and fast food is rapidly being popularized among the

youths and working class and shaping towards a potential small industries and service sectors. Village people lives in 20 million homesteads mostly small but all are the hub of complex farming systems where mostly men works in field and women in homestead. Major Farming systems are subsistence in nature, however commercial farming are now increasing for seed production, maize, vegetables, cattle rearing for milk and meat, poultry, fisheries and fruit gardening. Thus it is very difficult to classify the farming systems of Bangladesh. Here, Farming Systems of Bangladesh has been broadly been classified into four types as per geographical locations viz. Rice Farming Systems, Rice-Wheat Farming Systems, Coastal Artisanal Fishing Farming System, and Highland Mixed Farming Systems. Each system is characterized by its human and natural resource along with agricultural production systems. Comparative livelihoods of poor households, average households and well-off households under each Farming Systems have been described in tabular form. For each Farming System there is considerable yield gap; minimization of that could make the farm more competitive through adoption of modern technologies developed by different agricultural research institutes and farmers innovation. Through text in box some success stories for each farming Systems has been described indicating few potential technologies. Poverty escape pathways have been indicated through different measures including intensification and diversification, off farm activities, labor migration, and availability of credit/micro-credit. Additionally an array of research and developed issues has been identified for immediate and future actions. Through expert judgment potential for poverty reduction has been mentioned for each system. Coastal Artisanal Fishing Farming Systems have high potential for poverty reduction; followed by Rice-Wheat Farming Systems where there is moderate scope to reduce poverty whereas Rice Farming Systems has low to moderate and Highland Mixed Farming Systems has low scope to reduce poverty. However, scope of future agriculture growth is moderate for all the Farming Systems.

Diversification of agriculture including processing industries development and intensification along with service sector (off farm) expansion will remain as key factors for reduction of poverty in the foreseeable future for Bangladesh. Whilst exit from agriculture could be the third option as population is increasing by two million per year, on the contrary cultivable land area is decreasing at about one percent per year due to civil works. Six broad strategic initiatives are proposed for livelihoods improvement and poverty reduction namely; land zoning, improved water management, re-orient agriculture services, improved rural infrastructure, strengthening farmers group and availability of credit/micro-credit in soft term.

1. CHARACTERISTICS OF BANGLADESH (*Data source: BBS*)

Bangladesh is a deltaic country in South Asia sheltering more than 160 million people within its 147,570 km² boundary. It is one of the most densely populated countries of the world with about 1,062 people per km². Only 8 million ha of cultivable land is available for production of the country's food and fiber. The country is mostly floodplain except for the southern and eastern small hilly area comprising about 12 % of the country and the 8 % terraced land in the High Barind Tract area of NW Rajshahi and the Madhupur Tract. However, a small part of the floodplain is naturally low-lying, popularly called "beel", where cropping is limited to Boro or deep water floating rice along with sweet water fish. Bangladesh enjoys a sub-tropical monsoon climate where the three major seasons are winter (Rabi), summer (Kharif I) and monsoon (Kharif II). Winter is quite pleasant with maximum diversified cropping beginning in November and ending in February-March, when the temperature range is 7-25°C. Highest temperatures are recorded in the summer months of April-June (25-37°C) when rainfall is intermittent but the humidity gradually increases. The monsoon season usually begins in June and stays up to September, sometimes extending into October. This period accounts for 80 % of rainfall. The average annual rainfall in Bangladesh varies from 1,429 to 4,338 mm. Maximum rainfall is recorded in coastal areas of Chittagong and the northern part of Sylhet district, while the minimum is observed in the western and north-western parts of country.

For understanding Farming Systems of Bangladesh genesis of soils and agro-ecological zones are important. That information could be found in the cited literatures (Khan, F. M. 1991. Geology of Bangladesh. Univ. Press, Dhaka; FAO, 1988. Land resources appraisal of Bangladesh for agricultural development. Report. 2; Agroecological regions of Bangladesh, FAO, Rome; Brammer, H. 1996. The geography of the soils of Bangladesh. Univ. Press, Dhaka.). The Soils of Bangladesh. Series: World Soils Book Series (Huq, S. M. Imamul and Jajaluddin Md. Shoib, 2013, Springer publication).

The country has 230 large and small tributaries with a total length of 24,140 km. The major rivers are the Padma, Jamuna, Brahmaputra, Meghna, Teesta, Surma and Karnafuli. However, in the recent years many small and large rivers are drying out due to excessive withdrawal of water from upstream, siltation, climate change, and human encroachment. This devastating the livelihoods of common people dependent on those streams as well as flora and fauna, particularly inland fish populations on which many people are dependent for their basic nutrition. On the other hand, silted river beds are unable to bear the flush of monsoon water from upstream causing severe and recurrent flooding. It may be mentioned that Bangladesh rivers carry 7 % of its own water to sea and the remaining 93 % water is trans-boundary water mainly from India.

The economy of Bangladesh is largely agriculture based, with 75 % of people living in rural villages and 25 % in urban areas in 2012 (<http://kff.org/global-indicator/urban-population/>). Agriculture is the single largest producing sector of the economy and it

contributes about 19.22% to the gross domestic product (GDP) of the country. This sector also accommodates around 47.5% of labor force including women and adolescent (www.moa.gov.bd/statistics/bag.htm). GDP growth rate of Bangladesh mainly depends on the performance of agriculture sector. Due to recurring natural calamities like flood, drought and cyclones, loss of production of food and cash crops are a regular phenomenon. Yet in recent years, there has been a substantial increase in food grain production. Rice is the major food security crop, as it can be grown in all three seasons in a year. The humid and moist sub-humid agro-ecological zones, which benefit from seasonal monsoon rains and more than 180 growing days per annum are located in Bangladesh with large areas of alluvial soils and a high proportion of land under intensive rice cultivation (Dixon *et al.*, 2001), however rice could be grown in all 365 days of the year. The present estimated mean cropping intensity of Bangladesh is 191 % (BBS, 2011). Cropping intensity is the percentage of total cropped area by different crops in a given year divided by net cropped or actual cropped area of the country. That means growing of average number of crops per year in a given land. Irrigated area is more than 61 %, high adoption of recently released improved and hybrid varieties of different crops. Fertilizer use is now intensive with 3.55 m tonnes of chemical fertilizers being applied, of which the nitrogenous fertilizer urea has the bulk share (2.57 m tonnes) favoring vertical elevation of yield of major crops. Moreover, the country has made strides in diversifying farming systems with jute, wheat, potato, maize, vegetable, fruit, mango gardening, tea, and tobacco, along with marked development in the poultry, cattle and fisheries sectors. But the country is acutely deficient in pulses and oilseed production which is seriously affecting nutritional status and livelihoods of the rural and urban poor.

The shrinking of inland fisheries resources of Bangladesh due to death of the rivers, the stagnation in rice yields, and urban encroachment and pollution by industrial waste of agricultural land are affecting the natural protein supply basket of common people. As like rice and pulses (*Dal-Bhat*), rice and fish (*Mas-Bhat*) was once the common and most liked Bangladeshi diet. However, major fish production is now coming from inland and coastal fish culture, including shrimp production along with sea fishing. Bangladesh official forest area is 17% but it is assumed that effective forest area is only 8 % because of human encroachment and corruption. However, it is estimated that two million homesteads provides 80 % of total fruits and 85 % of fuel wood and timber (Islam *et al*, 2008), indicating the importance of the homestead area as a production unit in rural livelihoods.

From 1990s the country has made good progress in the industry sector, particularly in readymade garments (RMG) and textiles, the service sector, and manpower export to foreign countries, leading to a rapid reduction in poverty level. The per capita income in Bangladesh in 2012 was estimated to be US\$2070 (adjusted by purchasing power parity), significantly lower than India, Pakistan, both of which are also lower than the world average of \$10,497 (data.Worldbank.org/indicator/NY.GNP.PCAP.PP.CD). According to the gradation by the World Bank, Bangladesh ranked as the 59Th largest economy in

the world in 2012, with a gross domestic product of US\$116,355 million (data.worldbank.org/data-catalogue/ GDP-ranking-table)). The economy has grown at the rate of 6-7 % p.a. over the past few years. But still 31.5 % of population is in absolute poverty and 19.5 % people are suffering under hard core poverty (World Bank, 2012). However, one big flood, cyclone, drought or major crop loss by any other reason could substantially increase poverty levels as the bulk of the farming community lives on the verge of poverty. Thus, one of the main causes of rural poverty in Bangladesh is the erratic and extreme climate and the fact that a large proportion of the country is low-lying and vulnerable to flooding and river erosion. Many of Bangladesh's rural poor people live in areas subject to extreme annual flooding, which can destroy their crops, homes and livelihoods. They often have to resort to moneylenders in order to rebuild their lives, which pushes them deeper into poverty. For the large numbers of rural poor people whose subsistence depends on agriculture, income and food security are highly precarious. Many farmers eke out a livelihood on small and fragmented plots. For those who are landless or almost landless, the situation is even more severe. Almost half of the population falls into this category.

Another root cause of rural poverty has been the enormous population growth and the pressure this has placed on the environment; unleashing problems such as erosion, flooding, soil degradation and urbanization of agricultural land that in turn aggravates the situation of rural poor people. One could imagine this from the dynamics of historical population growth of the then East Pakistan and present Bangladesh. In 1951 population was 40.42, 50.52 in 1961, 70.64 in 1974, 80.99 in 1981, 110.14 in 1991, 130.52 in 2001 and 160 million in 2013 (BBS, 2009; 2011).

Bangladesh has made progress in developing rural infrastructure, but much remains to be done. Many poor people living in remote areas lack services such as education, health services and transport infrastructure, particularly road links to markets. Only 19 % of rural households have electricity.

Poverty continues to affect women more adversely than men. Female-headed households are still more likely live in poverty, and women are more likely to be less educated and more malnourished than their male counterparts. Extreme poverty is most evident among landless populations (TANGO, 2004).

Different institutions of Bangladesh have worked on Farming Systems Research and development for more than three decades, however there is a clear dearth of information and publication. To understand Farming Systems of Bangladesh is important for overall agricultural development. Moreover, it is different from other parts of the world and complex in nature. In-depth knowledge about Farming Systems would help to identify its agricultural problems and potential. We think this publication would be instrumental to researchers, development workers and policy makers for pin-pointing their R&D initiatives at the very beginning.

2. MAJOR FARMING SYSTEMS IN BANGLADESH

The livelihoods of 120 million rural populations are directly affected by efficiency of the adopted farming systems. Shaner *et al.* (1982) describe a farming system to be “a unique and reasonably stable arrangement of farming enterprises that the household manages according to well-defined practices in response to physical, biological and socioeconomic environments and in accordance with the household’s goal, preferences, and resources”. The farming system is part of larger systems, such as the village, district, agro-ecological zone, etc. The farming system can be divided into sub-systems like cropping systems, animal production systems, fish production systems, etc. A cropping system comprises the growing of a number of crops in a given piece of land over time or over year. The cropping system of an area in Bangladesh is determined mainly by the local climate, land type/flooding depth and time, irrigation capability, family food requirements and market opportunities for crops. Thus except for low land and drought prone rainfed land Bangladeshi farmers practice a range of cropping patterns across years and fields. The predominant cropping systems are described as sub-system. However, cropping system of an area is not a constant thing rather farmers practice a wide range of crop rotation according to his expected return, food security needs, availability of input and resources, new technology availability, and land suitability. But for ease of characterization we have designated the major cropping system as sub-system of Farming system. Farming systems of Bangladesh are rather complex compared to other parts of the world (Chowdhury *et al.*, 1993). Most rural households practice subsistence farming with the intention of becoming self-sufficient in food requirements. Thus every household is a complex hub of field crops, homestead agriculture, livestock, and fisheries (where possible) and off-farm activities, where food-security crops always get preference. However, recently commercial farming has been gradually developing and emphasizing certain enterprises such as poultry, beef fattening, vegetable and fruit production, fish production or cash crop production. Dixon *et al.* (2001) identified four major farming systems in Bangladesh along with their broad geographical boundaries. The main characteristics of the major farming systems as they now manifest themselves are given in Table 1.

Table 1. Major Farming Systems in Bangladesh and their characteristics, as of 2011

Farming System	Cultivable land area (% of BD ¹)	Population (% of BD)	Crop production (% of BD)	Production (million tonnes)	Principal livelihoods	Poverty prevalence
Rice	62.88	60.3	Rice-61.3 Wheat-38 Maize-28 Vegetable-53 Potato-40 Jute-70 Oilseeds-64.6 Pulses-59.7 Onion-78.7 Tea-89.3	20.54 0.46 0.45 1.89 3.24 0.58 0.47 0.13 0.83 0.054	Wetland rice (both season), vegetable, legumes, oilseeds, pulses, jute, fruits, spices, livestock (poultry, dairy, beef fattening), fish culture, off-farm activities	Moderate-Extensive
Rice-Wheat	29.85	25.1	Rice-33.9 Wheat-61 Maize-70 Potato-60 Pulses-40 Vegetable-40 Mango-50 Spices-35 Jute-28 Oilseed-34 Onion-20	11.37 0.74 1.15 4.96 0.09 1.41 0.40 0.47 0.24 0.25 0.21	Irrigated rice, wheat, maize, vegetable, potato, legumes, oilseeds, spices, fruits, livestock, off-farm activities, seasonal migration	Moderate-Extensive
Coastal Artisanal Fishing	5.79	13.3	Shrimp-95.83 Rice-3.81 Other fishes-22.67 Vegetable-6	0.12 1.27 0.49 0.2	Fishing, rice, vegetable, coconut, watermelon, livestock, forest works, off-farm activities, migration	Moderate-Extensive
Highland Mixed	1.48	1.3	Rice-0.97 Pineapple-24 Jackfruit-14 Banana-11 Spices-20	0.32 0.05 0.14 0.09 0.02	Cereals, fruits, agro-forestry, livestock, off-farm activities, seasonal migration	Extensive

¹BD = Bangladesh. Source: BBS, 2011

Rice Farming System

This farming system is dominated by intensive (two or three rice crops in a plot in a single year) wetland rice cultivation by farmers and sharecroppers in fragmented bunded fields with or without irrigation; however, Boro rice (winter rice) is mainly irrigated. T.aman (transplanted aman) rice is grown in Kharif-II season mainly with rainfall. By area it is the major rice crop grown across the country. Seeds are sown in seed bed and then seedlings of 20-50 days old are uprooted and transplanted in cultivated, leveled muddy soil having small water. While Broadcast aman is direct seeded long duration photosensitive local rice sown in April-May and harvested in December in medium low land and could grow in 1-2 meter deep water. Now the country has comparatively small area of Broadcast aman rice. Of the total system area of 8.9 million ha, an estimated 5.1 million ha – or more than 57 % – is under cultivation. Some 3.36 million ha, or 65.8 % of the cultivated area, is irrigated. About 60.3 % of the Bangladesh population lives under this system. The system covers much of Bangladesh but is concentrated in central, south-western and east and north-east districts. The system has 17.47 million head of bovines, used for beef, draft power, milk and manure, along with a considerable number small ruminant. Majority poor farmers operate extremely small areas, and usually rely on off-farm income for survival. Poverty is extensive and quite severe in parts. Literacy rate is low (45.3 %). The major sub-systems of Rice Farming System are (shown in Fig.1):

- a. Boro rice-T. aman rice
- b. Boro rice-Fallow/Deep water Broadcast aman rice
- c. Pulses/Wheat/Spices-Jute/T.aman rice
- d. Onion-T. aman rice/Broadcast aman rice
- e. Maize-T. aman rice
- f. Vegetable-Vegetable-Vegetable/T.aman rice
- g. Mustard-Boro rice-Fallow/T.aman rice
- h. Lathyrus/Mungbean/Fallow-T.aman

This is the major Farming System and a wide range of sub-systems are practiced here by the farmers. But we have analyzed only first two-systems in this section and rest of the crops of the sub-systems are mostly covered by following section i.e. Rice-Wheat section.

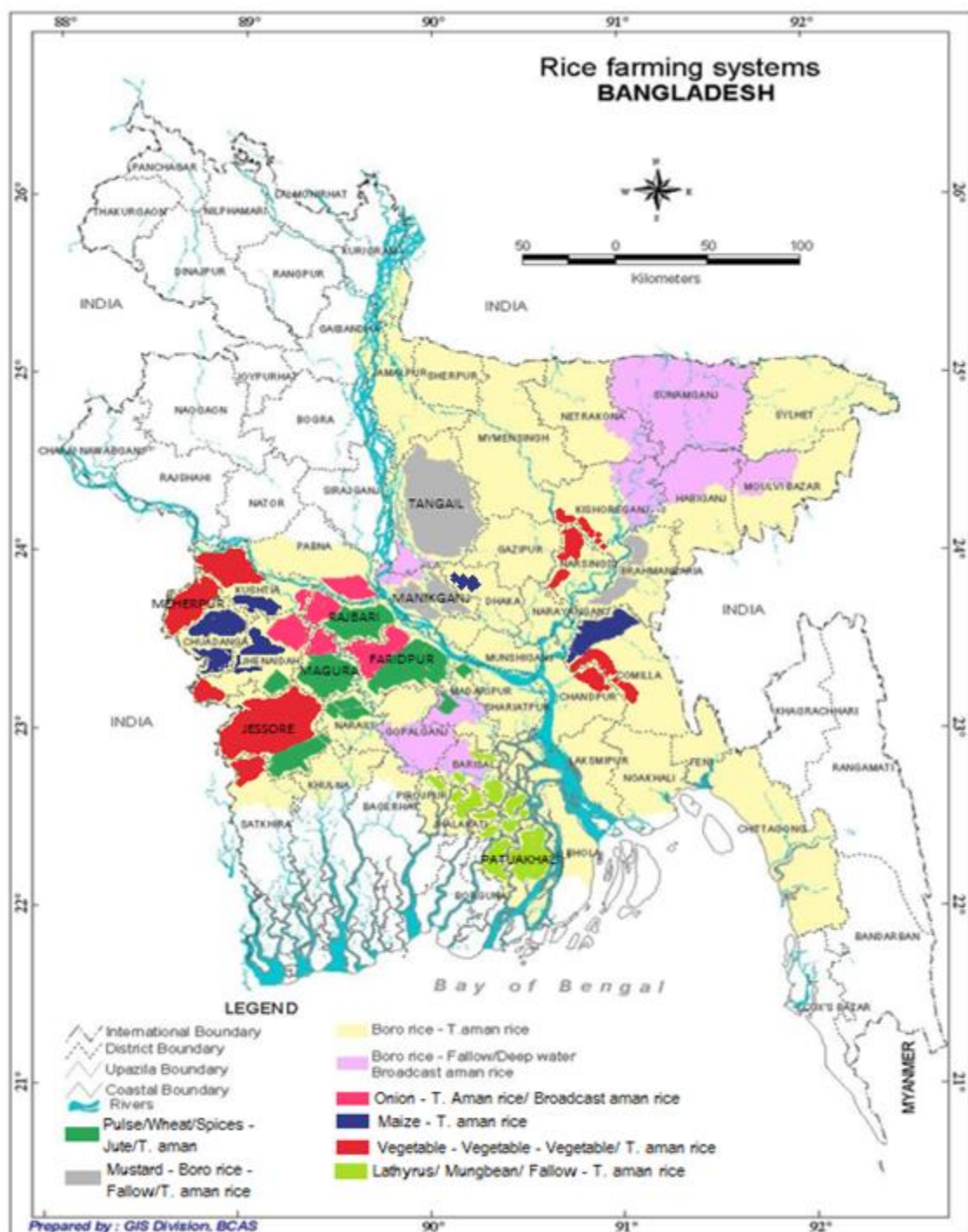


Figure 1. Rice Farming System of Bangladesh and its sub-systems, 2013.

Rice-Wheat Farming System

This is one of the most intensive and diversified farming systems of the country, except in the northern part of High Barind Tract. In general it is characterized by a summer or monsoon T.aman rice crop followed by an irrigated wheat crop (and sometimes a short spring vegetable/mungbean crop). It covers most of north-western Bangladesh including the Indo-Gangetic plain and the Teesta floodplains. Total system area is 3.33 million ha with an estimated 2.42 million ha, more than 72 % of the land system under cultivation. An estimated 2.20 m ha, or 90 % of the cultivated land is irrigated. The system has a significant level of crop-livestock integration, with an estimated 6.69 million bovines which provides beef, draft power, milk, dung-often used as fuel and manure. Small ruminants (mainly goat and sheep) are reared for cash income by resource poor farmers, principally used for meat. The system has 40.2 million populations mostly agrarian and they are 25.14 percent of total Bangladesh population, indicating a better land-man ratio compared to other farming systems. It is regarded as the food basket and surplus area of Bangladesh as it supplies much of the marketed food for Dhaka and food deficit areas. The area provides 34% rice, 61 % wheat, 70 % maize, 60 % potato, 40 % pulses, 40 % vegetable and 50 % mango of total Bangladesh production. However, literacy percent is lowest (41.8%) among the systems indicating social backwardness of the area. The major sub-systems of the Rice-wheat Farming System are (shown in Fig 2):

- a. Wheat-T.aman rice
- b. Maize-T.aman rice
- c. Potato-/relay maize-T.aman rice
- d. Vegetable-T.aman rice
- e. Pulses/garlic/onion/Oilseeds-Jute/T. aus-T.aman rice/Fallow

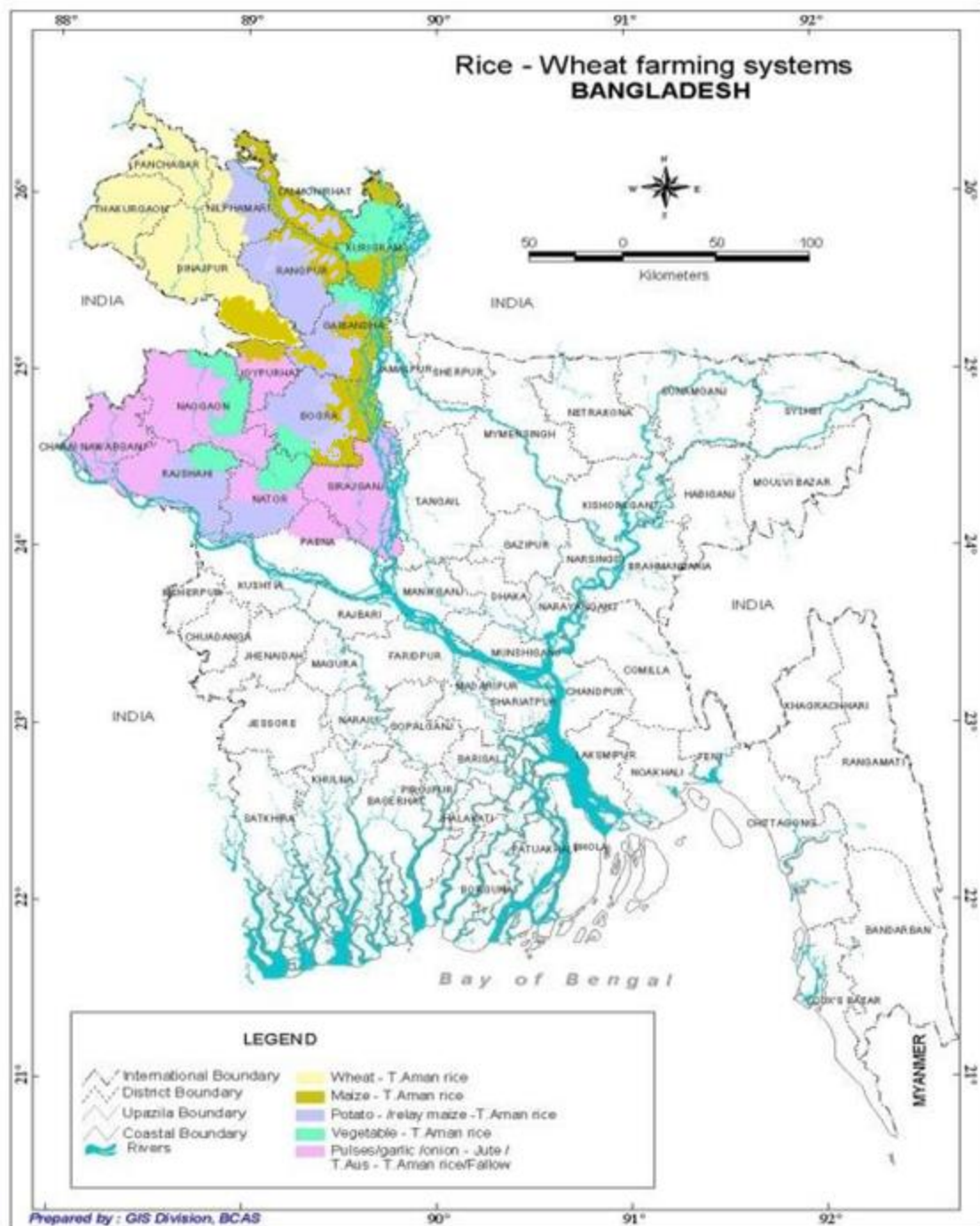


Figure 2. Rice-Wheat Farming System of Bangladesh and its Sub-Systems, 2013.

Coastal Artisanal Fishing Farming System

This system comprises only a small area of 6,701 km² along the coast of Bangladesh. The name Artisanal comes from artistic making of boat, nets and other fish catching equipment by the residents whose livelihoods depend on fishing. The south-west part is comparatively more developed in artisanal fishing, and most households supplement artisanal (inshore) fishing with rice production and cash enterprises such as watermelon, coconut, livestock and vegetables. The main livelihood is threatened by over-exploitation of the common resource, both locally and by larger well-equipped fishing boats. It is also recurrently affected by increased climate change effects like cyclones (like Cyclones Sidre and Aila), tidal bores and extreme tides. Total land area is estimated at 0.67 million ha with nearly 70 % under cultivation. Coastal land resources are under pressure from the high population density along the coastline, and from the expansion of modern and capital intensive aquaculture enterprises. Rice yield, natural grass for cattle, fruit trees' existence are threatened due to excessive soil and water salinity. About 13.55 % of Bangladesh's population lives in 5.79 % of cultivated land of coastal area, indicating the degree of population pressure. Off-farm income like catching of natural prawn fish fry and fish from coastal rivers, working in shrimp gher, boat pulling on rent, working in Sunderban forest area(for collecting honey, cutting woods and goalpata-a mangrove palm species whose leaf is used as thatching material, catching fish), etc. constitutes a significant source of livelihood, especially for poor households. A baseline survey conducted by Sunderban Biodiversity Conservation Project (SBCP, 2001)) indicates that 18 % households of 17 upzilas of five districts adjoining to Sunderban directly depend on it having a population of 3.5 million. Among them 35 % shrimp fry collector, 33% fishermen, 22% bawali, 4% boatman, 3% goalpata collector, 2% shell/crab collector, 1% mawali and medicinal plant collector. "Gher" is a Bengali word means surrounded by something. Here Gher means excavated or natural water body surrounded all sides by 1-2 meter height of polder made by soils mainly for shrimp culture, along with other fish and Boro rice and T.aman cultivation. It is linked with nearby river/canal for entering of saline tidal water. That is water entrance and drainage is controlled by sluice gate. Within Gher there is small long canal in all sides where water remains and shrimp and fishes take their shelter. On the bank of 1-2 meter wide Gher often vegetables are cultivated; also creeping vegetables are grown on trellis made on the water body by fixing bamboo.

The management of the system is complex from many points of view—the complexity associated with lying on the interface between marine and terrestrial ecosystems is aggravated by the complexity of number of stakeholders with conflicting objectives (Dixon *et al.* 2001). Poverty across the system ranges from moderate to extensive. But recent technological intervention-i.e. Gher system is helping the people to increase their income significantly from the same piece of land and moving them out of the clutch of poverty. The bovine population is about 2.65 million but they mostly suffer from poor health. However, the literacy rate is comparatively high (51.8 %). The major sub-systems Coastal Artisanal Fishing Farming System is (shown in Fig. 3):

Shrimp culture + other fishing + T.aman rice/Vegetables
Sesame/fallow-T.aman rice

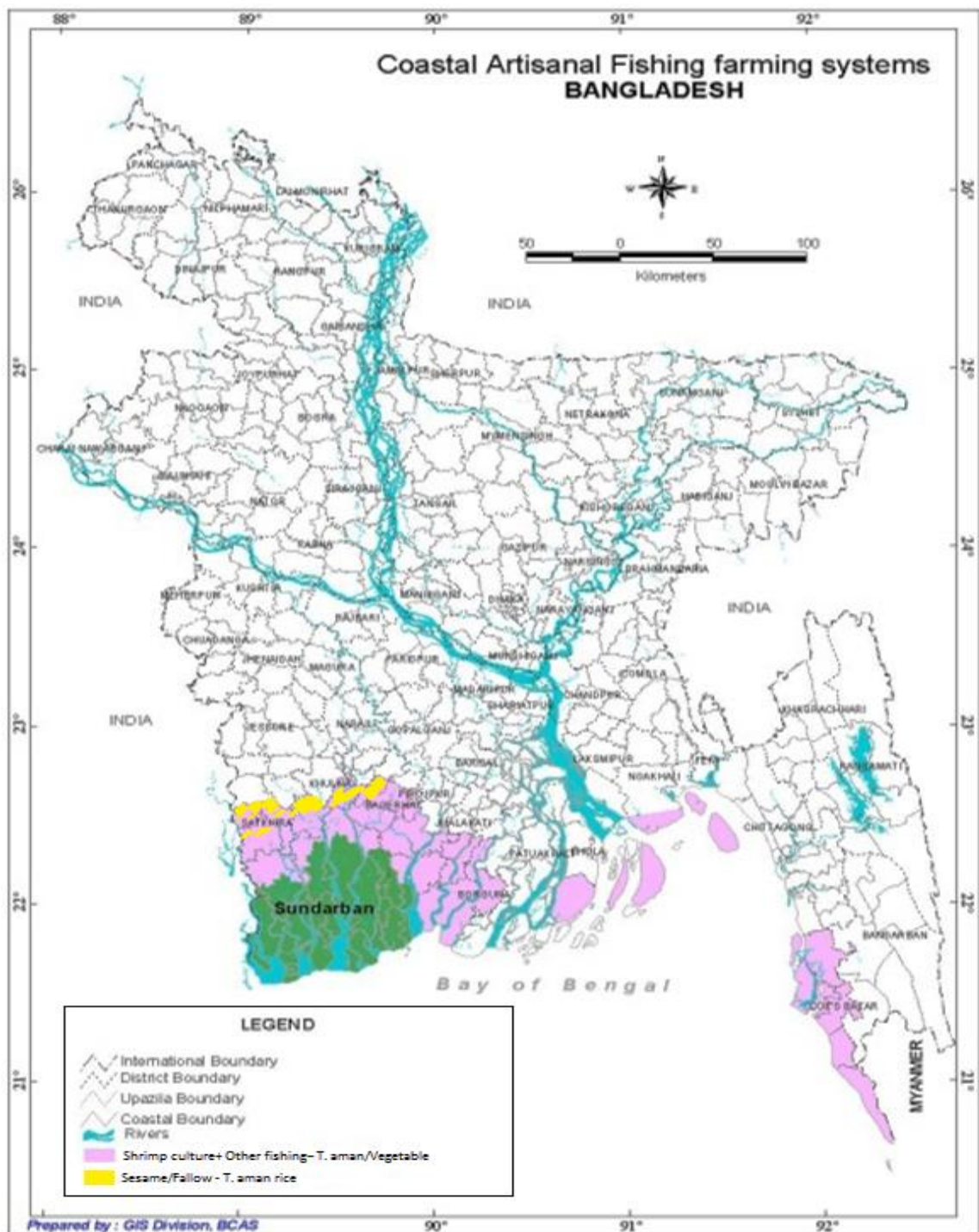


Figure 3. Coastal Artisanal Fishing Farming System and its Sub-system, 2013.

Highland Mixed Farming System

This system covers mainly the south-east and eastern small hilly areas of Bangladesh occupying about 12.6% area. It supports a population of 1.65 million on 0.16 million ha land of which 0.12 million ha, or 75%, is cultivated. In the south-east, most of the population is from tribal communities including Chakma, Marma, Tripura, Bhom, etc. along with a significant number of settler Bengali populations from main lands. They practice mainly traditional shifting or Jhum cultivation, where many crops are grown at a time but with monsoon rice as the principal crop. Soil fertility degradation and soil erosion are high due to this system of cultivation. However, settlers from the northern areas of Bangladesh and advanced tribal farmers practice modern cultivation of different crops including establishment of mixed fruit gardens. The livelihoods of the people depend on mixed culture of different crops, hunting, wood-cutting and different off-farm activities. The area produces 0.97 % of rice, 24 % of pineapple, 14 % of jackfruit, 11 % of banana and 20 % of turmeric of Bangladesh. Additionally, many other fruits, spices, tobacco, woody plants are grown here. However, due to over-exploitation by the increasing population, diversity and quantity of flora and fauna are rapidly decreasing and forcing the people to earn more from off-farm activities. Natural hilly and acidic soil limits food production and only 33 % of cultivated land is irrigated. Irrigation potential is also limited in November to April because of low water table and elevation and remoteness of the area. There area has about 0.41 million bovines along with a high population of small ruminants. Poverty is extensive, which is aggravated by remoteness, social culture, lack of social services and problems of land ownership. The major sub-systems of Highland Mixed Farming System are (shown in Fig.4):

- a. Upland rice/mixed crop Jhum cultivation
- b. Tobacco/Maize/vegetable/other crops-T.aman rice/vegetable (in valleys)

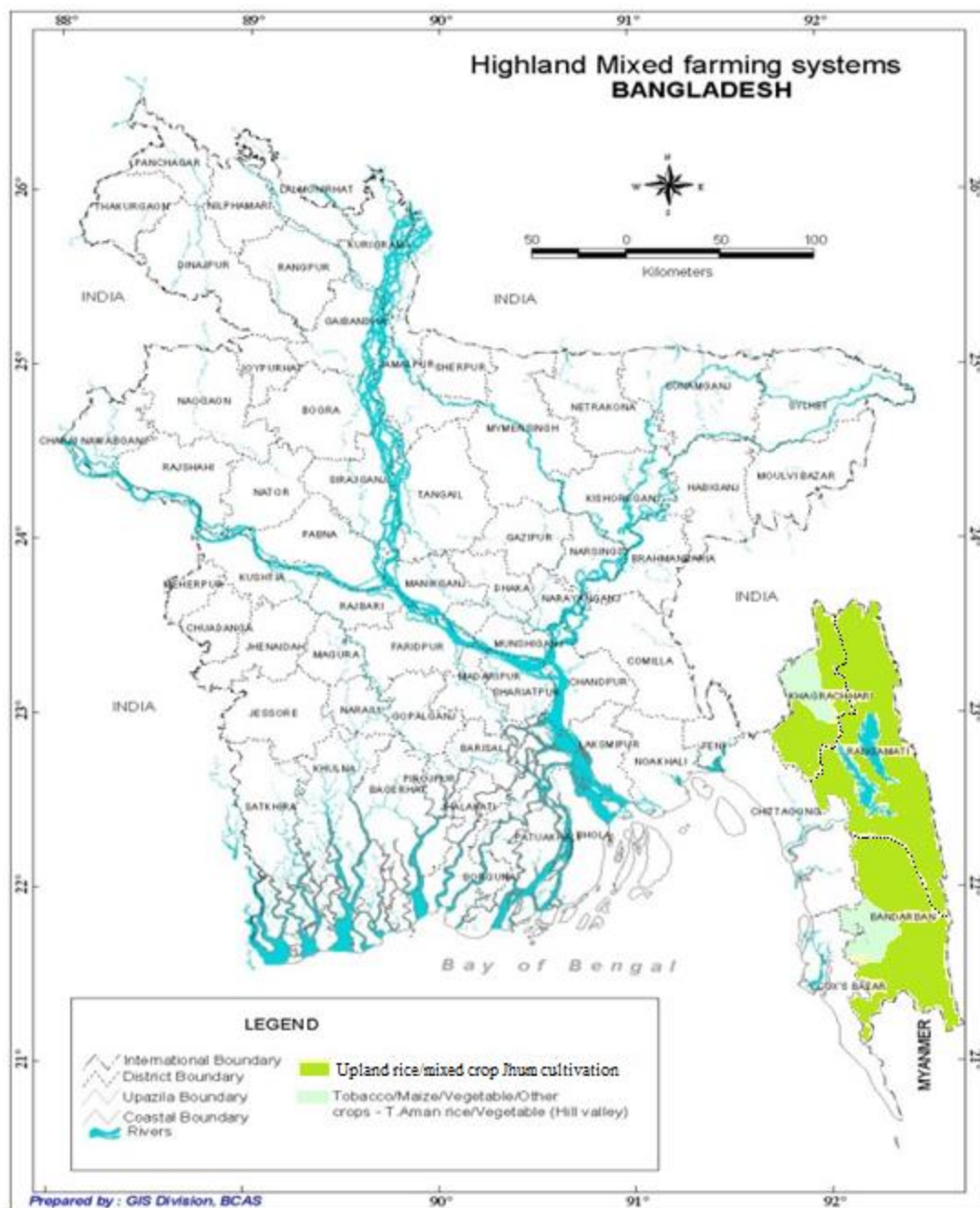


Figure 4. Highland Mixed Farming System of Bangladesh and its Sub-System, 2013.

3. TRENDS/DYNAMICS OF POPULATION, HUNGER AND POVERTY

The population of Bangladesh has been steadily increasing at the rate of 1.54 percent (BBS estimates 1.14 percent presently), which adds a formidable challenge to improving the quality of life through socio-economic development. Bangladesh remains the most densely populated country in the world, despite the efforts during the past decades of the government and development partners to reduce fertility, which has resulted in an impressive decline in the total fertility rate from 6.3 % pa in 1975 to 3.0 % pa in 2004. The current Bangladesh population of about 160 million is expected to increase by approximately 1.14 %per annum to 191.1 million by 2030 (World Bank) and to 212.5 million by 2050. The proportion of the total population living in cities (25 % in 2012) has increased markedly after 1975 and is expected to continue to expand, reaching 51.8% (99 million) by 2030 (World Bank, 2010).

A key factor affecting the pace and direction of change will be the increase in human mobility—reflected in rapid urbanization and off-farm employment particularly in service sector and especially for adult males and young women in garment factories. This mobility has already created a serious farm labor shortage in crop seasons and of female labor for household work, because a large number of young male and women have migrated to industrial areas, especially in central Bangladesh. A gap between industrial and agricultural wages has emerged, with industry paying 1.7 times higher than agriculture thus encouraging off-farm employment and urban migration (Jones, 2004). Therefore, in central Bangladesh and adjoining areas, due to higher labor cost and non-availability of labor at the proper time, rice farming has become less remunerative forcing big land owners to lease their land on a fixed amount basis. Farm households working the land for them are making good profits in enterprises such as rice, vegetable, fruits and livestock. To reduce the cost and turnaround period increased mechanization has occurred over the years particularly in tillage and post-harvest operations. As greater numbers of adult males migrate seasonally and semi-permanently in search of alternative livelihoods, it is anticipated that mechanized commercial farming will increase and women farmers will assume greater responsibilities for the management and operations of farms.

About 20 % of rural households live in extreme poverty. Chronically poor people suffer persistent food insecurity, own no cultivable land or assets, are often illiterate and may also suffer serious illnesses or disabilities. Another 29 % of the rural population is considered moderately poor. They may own a small plot of land and some livestock, but while they generally have enough to eat, their diets lack protein and other nutritional components. This segment of the rural population is at risk of sliding deeper into poverty as a result of health problems or natural disasters. Injury or crop failure caused by unexpected and severe weather conditions frequently ruins the livelihoods and the hopes of many Bangladeshis. Small-scale farmers may subsist at either of these levels of

poverty. Their livelihoods are precarious, both because of the seasonal nature of farm income and because natural disasters such as floods, river erosion, storms and drought may periodically destroy their crops and animals. Women are among the poorest of the rural poor, especially when they are the sole heads of their households, such as widows or wives of men who have migrated in search of employment. They suffer discrimination because of their gender, they have limited income-earning opportunities and their nutritional intake is often inadequate. Among extremely poor people, there are a disproportionate number of households headed by women. Fishing communities are also among the poorest and most disadvantaged groups in the country. In Bangladesh about 34.3 million people (36.80 %) are seriously undernourished, consuming only 1,805 Kcal per person per day, but it is expected to decrease malnutrition with the increase of per capita income, however the average calorie intake of Bangladesh is modest (2158 Kcal). It is estimated that until the present 26 % of the population of Bangladesh live on US\$1 per day (World Factbook, 2012). According to World Bank projections, those in dollar poverty should decline from the current level of 40 % to between 18-25 % by 2030, depending on the growth scenario selected.

Natural resource and climate

The land area under annual cultivation and permanent crops in Bangladesh is estimated 8 million ha (54 % of total land area) and is expected to reduce at a rate of nearly 1 % per year because of urban and industrial area expansion. This is an alarming situation for Bangladesh as population will definitely increase but cultivatable land will reduce, so a vertical increase of yield of crops and farming components are the only way to ensure food and nutrition security. Hence, there should be strict policies such that cultivatable lands are not unnecessarily taken for non-agricultural purpose public or private.

Soil erosion in the highland and rainfed watersheds is widespread and is being aggravated by heavy grazing and loss of vegetation from cropland/hilly areas. Severe soil management problems confront the intensive Rice and Rice-Wheat Farming Systems where yields are increasing more slowly, and even stagnating or reducing in some in some high intensity areas. This is attributed by some analysts to deteriorating soil physical conditions, declining soil organic matter and unbalanced fertilization – with over-reliance on nitrogen fertilizers, relative neglect of other major and micro-nutrients, and declining application of animal manure and crop residue compost (BARC, 1999).

Bangladesh is mainly known for periods of flooding and not so much for drought. However, a lack of water during the dry season and spells of drought at the beginning and end of the rainy season are a threat to agricultural production in Bangladesh. It is also feared that more areas will become drought prone as a result of climate change associated with global warming. During the last three decades, many hectares (ha) of land have been brought under Boro rice cultivation in the dry season by using Shallow Tube wells

(STWs) for irrigation. This is one of the main reasons that the country is self-sufficient in rice production. Boro rice receives the most irrigation water of all crops, with an estimated amount of 1,000 mm/cycle. For production one kg rice grain 3000-5000 L water is required. But in many parts of Bangladesh in the dry Rabi and Kharif-I seasons during February to May, the water table frequently falls below the reach of traditional shallow tube wells and thus irrigation fails resulting in drastic loss of rice yield. Due to partial death of the major rivers (the Padma, the Brahmaputra, the Jamuna) and many of the small rivers water scarcity (both drinking and irrigation water) is increasing across the country, particularly in the northern, south-western and hilly areas. Urban populations as in Dhaka suffer household water crises regularly in the dry season due to escalating demand of the increasing population along with severe depletions of the aquifer (Shamsudduha *et al*; 2009). Such shortage is bound to worsen overtime. It has been estimated that, if present rates of increase of overdrawing water continues, as much as one-third of irrigation blocks may be over-exploited by 2020. Already the two major river water based irrigation projects, viz. Ganga-Kobadak and Teesta, have failed in the dry period due to withdrawal of water by India from upstream. Farming systems of Bangladesh are largely governed by irrigation status of a particular location. Bangladesh irrigated land area is forecast to grow slowly, from 4.88 million ha to 6.4 million ha (80 percent of cultivated land) in 2030 at the cost of decreasing ground water table. However, excessive ground water uplifting for Boro rice is contaminating soil and water by arsenic (As) poisoning, which is rendering a heavy toll on human health and crop yield and quality (Heikens *et al*. 2007). The high cost of developing new, environmentally sustainable, irrigation systems – and the reluctance of donors to finance large irrigation projects – may lead government to place greater emphasis on modernizing existing irrigation schemes and the improvement of water use efficiency. This will involve participatory management or transfer of ownership of irrigation system to users, improved design of operating system like pre-paid system of Barind Multi-purpose Development Authority (BMDA) Rajshahi, better drainage and cost recovery. Before initiation of irrigation season farmers purchase coupon from BMDA for a certain hours according to their need, this ensures recovery of irrigation cost. Considerable potential remains for water management through better rainfall conservation and use; further development of water storage; conjunctive use of groundwater particularly following of alternate wetting and drying method (AWD) for Boro rice which could reduce water use by 30%. Increased on-farm water conservation can be achieved through proper land use planning and crop selection, conservation agriculture including crop residue retention, mulching, manuring, bunding, growing of aerobic rice and windbreaks. South-central Bangladesh has huge potential for non-saline tidal water of rivers and canals. For growing Boro rice and different Rabi crops this surface water could be effectively used by using a propeller based Axial Flow Pump (AFP) instead of traditional centrifugal pump (locally called LLP) along with drainage of water. The AFP is 30-50 %more fuel efficient than the LLP and it needs no priming. The Highland Mixed, Rice-Wheat and

even Rice Farming Systems of South-west Bangladesh will also be affected by limited availability of groundwater (surface water is already scantily available) for crop, fish and livestock production. There will be increasing demand for water from urban and industrial users in the coming decades. As a result local water markets are likely to develop, with agriculture at a disadvantage except in case of high value crops. As labor cost rises and water availability becomes scarce farmers could have to move to aerobic rice if proper technology options and machineries become available, or further diversify their cropping systems with limited water requiring crops like maize, wheat, pulses, oilseed, vegetables, etc. Increasing pressure on water resources also seems to have given rise to problems of declining quality of drinking water (including arsenic poisoning) as well as widespread pollution of rivers and other sources of water by industrial wastes adjoining major industrial zones, creating a heavy toll on the livelihoods and environment of humans as well as on all kinds of flora and fauna.

Because of high population pressure and inadequate forest management by the concerned department public forest resources are under threat. Officially Bangladesh forest area is 17 %but it believed that real forest area is only about 6.7% (World Bank Indicators-Bangladesh-land Use, 2012). While visiting the forest area including the Sunderban it is observed that the tree population is sparse and big trees are absent due to illegal logging. The pressure causing deforestation is expected to increase still further, particularly in Highland Mixed Farming System – little forest remains in most other farming systems of the region. However, about 20 million homestead areas are regularly planted with fruit and timber trees, providing major parts of household fruit, cooking fuel and timber requirements (Islam *et al*, 2008). In many instances, deforestation results from increasing pressure to obtain industrial and agricultural lands, but conflicts of interest between individuals and forest departments have also contributed. The growing realization that forest communities have to be fully involved in forest management, and that forests need to be managed for the benefit of such communities, has done much to overcome the latter factor (Dixon *et. al*, 2001).

Soil and water salinity is increasing due to decreased fresh water flow from upwards in mangrove forest area of Sunderban, is seriously affecting the eco-systems. The Sundari trees where from the name Sunderban derived are rapidly dying due to this salinity. It is assumed that low water flow from the river Padma (because of withdrawal by India through Farakka Barrage) causing excessive intrusion of sea saline water resulted in adverse effect on tree, fish and other natural species. Climate change is projected to have a significant negative effect on agricultural production in Bangladesh. The frequency of storm which batters the coastal areas of Bangladesh is expected to increase. Not only will the variability of climate cause fluctuations in yield, but average yields of rainfed crops could drop by a substantial amount (Fischer *et al*. 2001).Food security, livelihoods, and households vulnerability are frequently closely intertwined with the adverse phenomenon of natural disasters in Bangladesh, which are rooted in the nature of terrain, the physical

geographic features, its long coastline and sub-tropical climate. The increasing population density exacerbates ecological damage, adding to the misery of annual disasters. The phenomenon of global warming will also aggravate this, affecting the low lying lands of rivers and the coast.

Science and technology

There have been significant impacts of agricultural research on the food and nutrition security in Bangladesh over the past 40 years through reorganization National Agricultural Research Systems (NARS) along with the establishment of central co-ordinating body. Crop, livestock and fisheries research institutes like, BARI, BRRI, BINA, BJRI, BSRI, BFRI and BLRI have played a major role in the development of modern varieties/breeds/appropriate technology along with capacity building of research, extension personnel and the farming community. BARC an apex body has coordinated many of the research and development activities of the NARS institutes. Agricultural Universities like BAU, BSMRAU, SAU, PSTU and HDSTU have also played a significant role in manpower development and science based agricultural technology generation, along with other general universities, such as, DU, RU, CU and KU. SRDI has provided valuable soil resource data suitable for characterization of particular area/site. DAE through its grass-root manpower tried to transfer NARS developed cultivars/technologies. BARD and RDA have also played role for cooperative development and technology transfer. A large number of NGOs including BRAC have also helped to disseminate modern agricultural technologies. BADC supplied modern varieties seed of rice, wheat and other crops at farmers' level along with introduction of irrigation and distribution of chemical fertilizers. Recently a good number of private seed companies and NGO-based seed company (BRAC) have pro-actively worked for production and dissemination of seeds of modern varieties of different crops. The NARS in Bangladesh has benefited greatly from the strong linkage and networks they have established with International Agricultural Research Centers (IARCs), such as IRRI, CIMMYT, ICRISAT, AVRDC, ICARDA, ICRAF, WF and ILRI, building in their participation in the development of modern technologies. However, in the recent years IARCs back-up has been weakened which has affected the advancement of NARS in their ability to address complex new challenges like climate change effects, stagnant yields, and degrading natural resource base. The high demand of agricultural research in marginal lands, the growing role of women in the farm household decision making and the emergence of new areas of integrative research (agroforestry, biotechnology, etc.) will require the development of new skills and inter-disciplinary research efforts. Although private sector research will make increasing contributions to the development of new technologies for improving the profitability of commercial ventures, the focus of public-funded agricultural research is likely to remain the resource-poor small farmers (Dixon *et al.* 2001).

Returns from the past agricultural research in Bangladesh seem to have been concentrated in certain systems (e.g. HYV-fertilizer-irrigation technology), such as Rice and Rice-Wheat Farming Systems. Emerging problems require a better mixture of upstream (basic or strategic) and downstream (adaptive and participatory, farm-level) research. Research undertaken to date has failed to address many current and long-standing issues such as: short duration, high yielding and fine quality T. aman cultivars to facilitate timely planting of Rabi crops and avoid terminal drought, short duration high yielding Boro rice cultivars to avoid seasonal storms and flash floods in low-lying areas, heat tolerant wheat varieties, virus tolerant potato and tomato, low external input requiring cultivars of different crops with minimized risk, etc. Use of chemical fertilizers in Bangladesh has expanded dramatically in recent decades, from 23 kg/ha in 1970 to 198 kg/ha in 2001 and 215 kg/ha in 2007. The rate of application is expected to increase, albeit more slowly. Application rates are high in irrigated, intensive farming systems compared to rainfed and risky production environments. In some of the more remote areas, such as in the Highland Mixed Farming System (Chittagong Hill Tracts), high transport costs can easily exceed the material cost.

Nitrogen fertilizer use efficiency is estimated at only 30-35 % in irrigated rice crops resulting in pollution of underground and surface water by nitrate through leaching and run-off, with consequent loss of poor farmers' hard earned resources. However, scientists have tried to develop technologies such as leaf color chart and urea super granule (USG) application to reduce the nitrogenous fertilizer application rate, but those technologies have had only limited success for many reasons. The future rate of increase in total fertilizer use is expected to decline, although the rate of decline will depend to some extent on progress in raising the efficiency of fertilizer use.

At present, use of fertilizer for paddy is constrained by low rice prices. The use of fertilizers in coming decades will be influenced by fertilizer prices (likely to increase in real terms), commodity prices (likely to decrease, particularly rice and wheat) and use of organic fertilizers (likely to increase). The possibility of significant contributions from the use of Biological Nitrogen fixation (BNF) cannot be discounted (FAO, 2001) including crop residue retention through practice of conservation agriculture. In parallel with the increase of fertilizer use, the demand for other types of agricultural chemicals (e.g. pesticides) has also grown, although moderated somewhat by the spread by Integrated Pest Management/Integrated Crop management (IPM/ICM).

Paddy rice is traditionally the single most important crop in Bangladesh because of its role for food security and it has increased its importance over the last 30 years – principally as a result of the green revolution. Both area and yield has increased over time, yield has increased by 3.9% from 1997 to 2011 and the country is now near self-sufficient, producing about 30 million tonnes of rice per annum (Table 2). However, it is predicted that rice area might decrease at a slow rate due to loss of cultivable land and higher economic benefit from high value crops and other farming enterprises like

fisheries, fruit gardens, etc. However, production is forecast to further increase in the period to 2030 mainly through yield increase. Wheat area in Bangladesh has decreased by 45.1 % from 1997 to 2008 because of spread of competitive Boro rice, vegetables, coupled with climatic effect, i.e. sudden rise of temperature at grain filling stage, however yield has increased by 2.4 % from 1997 to 2011. Moreover, wheat production has become less competitive due to low world price though consumption of wheat is gradually increasing due to urbanization and changing of food consumption pattern due to a geometric increase of different diseases like diabetes, high blood pressure and heart diseases.

Table 2. Trends in crop area, yield and output in Bangladesh, 1997-2011

Crop	Harvested area(m ha)	Yield (t/ha)	Production (m tons), 2011	Average change from 1997-2011(%)		
				Area	Yield	Production
Rice	11.45	2.91	33.38	3.91	47.60	5.32
Wheat	0.40	3.00	1.20	-45.10	2.42	-43.97
Maize	0.28	5.71	1.60	4927.00	170.00	13360.00
Potato	0.46	17.82	8.20	203.67	46.81	345.50
Jute	0.70	11.83	0.84	-13.08	10.00	-4.98
Sugarcane	0.118	40.44	5.34	-26.26	-10.12	-33.73
Pulses	0.253	0.91	0.205	-67.05	1.88	-60.80
Oilseeds	0.374	1.95	0.73	-36.11	129.79	46.65
Spices &condiments	0.374	5.16	0.79	106.23	111.25	335.66
Sweet potato	0.03	9.81	0.298	-30.35	1.44	-29.42
Tobacco	0.489	1.61	0.79	-19.19	26.73	2.22
Mango	0.037	27.77	0.889	-37.46	58.34	327.26
Banana	0.052	15.14	0.80	18.52	11.42	34.06
Jackfruit	0.01	90.29	0.961	-62.87	880.71	264.08
Pineapple	0.015	14.57	0.218	12.59	23.14	38.57
Vegetables	0.45	7.78	3.50	5.58	1.81	7.47
Tea	0.056	1.06	0.06	4.47	-1.81	3.38

Source: BBS, 2008, 2011

By contrast maize area has largely increased by 13360 % from 1997 to 2011 due to increasing demand from the expanding poultry industry (Table 2). It is predicted that maize area will further increase by 52 % towards 2030 (Ali, *et al*, 2008) as profitability of maize is high compared to rice and wheat along with reliable high yields of Rabi season hybrid maize. It is anticipated that area and yield of potato, banana, and other fruits and vegetables may further increase due to an expanding domestic and international market demand for processing industries and growing purchasing power of an increasing urban population. While yields of major field crops and fruit species have increased over time those of sugarcane have decreased probably due to government law on banning of making “Gur” (molasses) in mill zone areas and reduced price and management problems from sugar mills. As released HYVs of sugarcane from BSRI have yield potential of up to 100 t/ha through practicing of appropriate management, the whole issue of sugarcane should be reviewed by the government. Sugarcane is less affected by drought or flooding and is presumed to be less affected by future climate change as it is a C₄ crop. Moreover, this industrial crop played a major role in the reduction of poverty from 1970 to 1990 particularly in northern Bangladesh. The mustard (*Brassica* sp) crop is showing promising area and yield increase for fitting (as short duration crops) between two rice crops. Modern short duration mungbean (*Vigna radiata*) grown after wheat, potato, or maize or in autumn can fetch a good economic return within a 70-85 day growing period. Spice and condiment production is predicted to increase further as it has been well taken up by several processing industries for domestic and international ethnic markets. However, concern is growing among civil society, agriculturists and health professionals that tobacco area and production will further increase due to high cash return and advance loans from tobacco industries. This might have a heavy toll on people’s health and will reduce the area of essential food crops, particularly in eastern hill valleys, south-west Kushtia and north-west Rangpur region (Table 2).

A production revolution has taken place in livestock sector in the last 30 years due to high market demand, higher economic benefit within short period, low risk and it requires small space in comparison to crop production (Table 3). Government and NGO endeavor, loan and incentive availability and technology dissemination has facilitated this development. But the driving force is strong and constant market demand, peaking at Muslim festival time (Eid-Ul-Azha). However, cattle have shown a modest growth from 21.49 million head in 1983 to 22.90 million head in 2011 (6.6 % increase). While, buffalo an animal requiring less care, showed higher growth from 0.56 million head in 1983 to 1.26 million head in 2011 (125 % increase) mainly through establishing farms in char and coastal area. Even small ruminant, goat and sheep, numbers have increased, the latter showed 321.2 % increase from 1983 to 2011 (0.66 million to 2.78 million head) due to their minimal handling requirements and foraging ability. The largest increases in livestock numbers and production have occurred in poultry. Incentive, large scale demand and high profit even within 5-6 week periods have instigated many young entrepreneurs, small and large, to invest in this sector to meet the growing demand of the

urban population with its increasing purchasing power. Poultry production has increased from 73.7 million head to 252.31 million head from 1983 to 2008 period (242.3 % increases). Along with increase of livestock head numbers meat, milk and egg production have increased considerably (Table 3) even though it is still lagging far behind in meeting the needs of the total population (Table 5). Fish production has also increased from 0.72 million ton to 2.33 million tonnes from 1983 to 2010 (221.7 % production increase) (Table 4). Fortunately the fish deficit is small, as fish is a traditional and the most common source of protein for most of Bangladeshi people. Except perhaps for some cultured fish like Pangas, Tilapia, and other carps, most other fishes are more costly per unit than meat or egg. With increased incomes, meat consumption (particularly beef, poultry meat, egg and goat meat), and demand for dairy products are expected to continue increasing. However, the large ruminant population is expected to stabilize as small tractors (two-wheel power-tiller) replace the draught buffalo and oxen; but their importance for meat and milk will further increase. The management of the remaining animals will be intensified and focus would be on increased productivity for higher profitability.

Table 3: Trends in livestock population and output in Bangladesh, 1984-2011

Species	Million head 2011	Change from 1983 to 2011 (%)
Cattle	22.9	6.6
Buffalo	1.3	125
Goat	21.6	59
Sheep	2.8	321
Poultry	252: Fowl: 212 Duck: 40	242 Fowl: 248 Duck: 216
Products	Output (m tonne)	Change from 1983-2011 (%)
Total meat	2.65	178
Total milk	1.04	126
Total egg	5654 m (no.)	497

Source: BBS, 2011

Table 4: Trends in fish harvest in Bangladesh, 1983-2010

Source of fish	Amount of fish(m tonne)	Change from 1983 to 2010 (%)
Inland	2.38	217
Marine	0.52	240
Total	2.89	222

Source: BBS, 2011

Table 5. Demand and availability of meat, milk, egg and fish for Bangladesh, 2011

Product	Demand	Production	Requirement/ person /day	Availability	Deficit amount
Milk	13.01 m tonnes	2.65 m tonnes	250 ml/day	51 ml/head/day	10.36 m tonnes
Meat	6.26 m tonnes	1.04 m tonnes	120 g/day	20g/head/day	5.22 m tonnes
Egg	14,828 m no.	5,654 m no.	104 no/year	39.65 no./head/year	9,174 m no.
Fish	2.55 m tonnes	2.33 m tonnes	49.31 g/day	45.5 g/head/day	0.171 m tonnes

Source; BBS, 2011

Trade liberalization and market development

Increased liberalization would continue over the next decades, and cereals market may further decrease at least in the near future making the crops further less competitive. Global rice price index was -5.5 % down in 2012 compared to 2011(Food Outlook, FAO, November, 2012) Particularly this is true for rice price at farm-gate in Bangladesh. Thus significant diversification is expected in all the farming systems, where not limited by eco-system and environments. Bangladesh could build its position in a few niche markets such as for mango, tomato ketchup, potato chip, vegetable, shrimp and other fish products and handicrafts and other tropical products (citrus fruits such as Lotkon or Burmese grape), Pomelo, lemons etc.). Bangladesh has a large ethnic market, because a large number of expatriates live in the Middle East, Europe and America and because of the popularity of regional cuisine, it is also to be expected that considerable growth will occur in processed foods. Thus the tendency is likely to accelerate as advances in packaging and transport technology allow fresh breads, curries and other perishable products to be delivered to external markets at economical prices (Dixon *et al.* 2001).

The Bangladesh urban market is rapidly expanding and urban people are increasingly consuming imported fruit, food and other products from the regional and extra-regional countries. Peri-urban based agriculture will intensify in response to this demand. Dairying is expected to grow still further, as will processed dairy products, while poultry, beef and goat consumption will expand rapidly. Vegetable and fruit production will continue to expand, but Bangladesh will largely depend on imports for edible oil and pulses. As international labor markets develop, remittances from overseas will increase and a significant proportion will flow into housing, land purchase, commercial agriculture and rural investment in general. These cash incomes are an important source of income in many marginal rural areas, for example, in Highland Mixed, Rice and Coastal Artisanal Farming Systems.

Marketing is a serious problem for resource poor farmers, especially those in more remote areas. Although better communication development and mobile phone communication has allowed farmers to get a higher market price for some commodities, for perishable items like milk, vegetable and fruits farmers' bargaining capacity is

limited. Bangladesh imports large quantities of baby food and skimmed milk but government and private cooperative and processing industries are depriving them to get fair price. In the open market in most of the cities and villages cow milk is sold at the rate of 40-60 Taka/liter but those companies (such as Milk Vita, BARC Dairy, Pran Dairy etc.) give farmer only 16-17 BDT/liter at Tangail or Sirajgonj districts, even often they abandon purchasing incurring a big loss to the dairy farmers. Hence market development and ensuring fair price is crucial for development of dairy and other sectors.

In the same way different vegetables are selling at 30-40 BDT/kg at Dhaka but producing farmers only receive 5 BDT/kg in rural Bangladesh. Wholesalers complain that the cost difference is due to profit, transport cost and illegal toll/bribes. This situation is very common across the whole of Bangladesh, thus poor producer farmers are losing, and are often required to sell below their production cost. There is large scope for orderly market chain development.

4. RICE FARMING SYSTEM

Rice is the principal staple and food security crop for traditional Bangladeshi people. It is also an emotional crop as farmers often grow rice in such land which is not at all suitable (high land, sandy/loamy soil) for a high water requiring rice crop. The farmer's first priority is to produce the household's annual requirement of rice before considering other crops/enterprises. This emotion sometimes reduces the household income below what it could otherwise be. The Rice Farming System is the major farming system in Bangladesh, including the entire central, eastern, southern-western area (Fig. 1). The main characteristics of this system are summarized in Box 1.

Although the bovine population is mainly used for meat, milk and draft power, the dung is widely used as cooking fuel due to absence of other options, and the remainder used for compost manure. About 20-25 years ago 90 % of land was cultivated by bullock or buffalo, but now more than 85 % is cultivated by two wheel power tiller available across the country usually on a hiring basis. The small ruminants (goat and sheep) are mainly reared by landless, marginal farmers for their livelihoods. The area has a high poultry population, because surrounding Dhaka city areas there are many small and large poultry farms which supply white meat and egg to the city dwellers. Moreover, in eastern haor areas (natural depression which goes under water in the rainy season) ducks are increasingly reared with natural feeding during the monsoon periods (June to November). Literacy rate is moderate it is only higher than in the Rice-Wheat Farming

Box 1. Basic data: Rice Farming System

Total population (m)	79.82
Total area (m ha)	8.9
Agro-ecological zone	Humid
Net cultivated area (m ha)	5.10
Irrigated area (m ha)	3.36
Bovine population (m)	17.47
Small ruminants (m)	14.60
Poultry (m)	189.23
Literacy rate (%)	45.31

System. North-eastern Mymensingh and adjoining districts have the highest illiteracy and poverty levels because of mostly edaphic and climatic constraints limiting cropping to a single Boro rice crop. Rice farming of the area (Mymensingh region) is mostly done by small and marginal farmers and sharecroppers having a small operative area of about 0.3 ha. Large farmers occupy 5-7% of this area (Ali and Mondal, 2009) and operate on 5-10 ha of land. Some of this land is assigned to other crops and sharecroppers, as Boro rice production requires intensive management.

Livelihoods

Comparative livelihoods (Table 6) of poor, average and well-off farmers showed that income differences are large due to land holding and scope of higher off-farm income by well-off households. From all the household expenditure analysis it revealed that food, daily bazaar (oil, fish, meat, salt, spices, vegetable, pulses, other household items, etc.) and agricultural input costs are major. All categories of farmers use mobile phones for communication. Which indicates there is scope of transmission of important message such as BPH (Brown Plant Hopper- a serious pest of rice in Boro and Aman season) attack prevention in rice and many other things through mobile phone; however the message should be delivered in Bengali language. It is interesting that poor farmers earn much of their income (40-50 %) from selling their labor but they also hire labor particularly for rice transplanting, as it needs to be completed within a short time frame. All of the farmers' first choice is to ensure a supply of staple their food, rice, but the poor farmers face food insecurity for 5- 6 months. This puts the household in a precarious situation as family members will remain hungry if rice is not purchased from the market or borrowed from neighbors. Even the average farmers face food insecurity for 2-3 months which is managed from small business enterprises and from other off-farm income. The large farmers always have ensured food security (except in severe flood years) and generally sell their surplus rice to maintain and improve their livelihoods and increase their savings. Large farmers also usually participate in business in the local market, as they have money to invest. Poor farmers have deficit budget and rely on loans, while the small has a 6,600 BDT surplus per year, on the other hand well-off farmer have a good surplus averaging 66,800 BDT/year. Farmers expect easy loan for increased investment in commercial agriculture and off-farm income

From the dollar-a-day income poverty criterion it is evident that poor farmers live below this level, at 0.44 US\$/head/day. Average Rice Farming System farmers also live below the poverty level, at 0.79 US\$/head/day. Only the well-off farmers rise above the poverty level (US\$ 2.95/head/day). However, calculation of this income is often difficult as farmers sometimes report a lower income level than the actual level, as experienced by many researchers (WFP, 2006). Researchers have found that per-capita monthly expenditure is a proxy measure of income and that has proven to be a more reliable measure than income itself for one-time survey data. But BARI Farming System

Scientists calculated the whole income and expenditure of a family by regularly visiting and accounting during their Integrated Farming System Research and Development activities (Ali, 2001).

Table 6. Comparative Livelihoods (expenditure and income) of poor, average and well-off farmers under Rice farming system (source: survey-it was done in 2010 by the author among the farmers of different locations with the help of OFRD, BARI field staff and scientists)

Item-wise monthly expenditure	Amount (BDT)		
	Poor household	Average household	Well-off household
Food	1700	Food-2100	Food-2800
Cloth	300	Cloth-500	Cloth-900
Daily bazar	800	Daily bazar-1500	Daily bazar-2900
Health	150	Health-200	Health-700
Education	250	Education-350	Education-1000
Transport	130	Transport-300	Transport-500
Agricultural input	900	Agricultural input-1500	Agricultural input-7000
Labour	150	Labor-600	Labor-7050
Festival/guest	250	Festival/guest-500	Festival/guest-1300
Other (mobile cost etc.)	200	Others (mobile etc.)-400	Others (mobile etc.)-1700
Yearly expenditure	4830 x 12 months= 57,960	Total-7950 x 12 months= 95,400	Total-28850 x 12 months= 310,200
Income source			
Rice, wheat & other crops	32000	120000	264000
Vegetable	18000	30000	45000
Homestead fruits	1500	4000	5000
Livestock	5000	1500	5000
Labour sell & others	18000+2000	8000	-
Business	-	-	7000
Yearly total income	56,500	102000	377000
Yearly balance	-1,460	+6,600	+66,800
Income/head/day in US\$	0.44*	0.79	2.95
Rice food security(months/year)	Rice food security-6-7 months/year	Rice food security-9-10 months/year	Rice food security-12 months/year

*1 US\$ = 78 Bangladesh Taka (BDT). Five member families were considered in calculating income per day.

In the following section two sub-systems of the Rice Farming System are analyzed in terms of typical households, yield gap, adoption of modern technology, and the poverty escape pathway, other sub-systems are mostly covered by following Rice-wheat Farming Systems.

Boro rice-T.aman Farming Sub-system

This system is practiced in central, east and south-west Bangladesh but not in haor and low lands (Fig. 1). This system is the most productive for rice farming, ensuring adequate to surplus rice production for all categories of farmers. The system relies on irrigation in the Boro season and T. aman can be supplemented by irrigation when needed, but T.aman mostly relies on monsoon rain. In the Boro season one-fourth of the harvest is to be surrendered to the irrigation pump-owner as irrigation cost. Typical marginal and small farmers with 0.3 ha of land practice this system along with utilization of land on sharecropping basis (see Box. 2). Farmers grow high yielding cultivars of rice in both seasons to achieve, on average, yield of 5 t/ha in the Boro season and 3.5 t/ha in the T.aman season.

Box 2. A typical household of Rice Farming System of Bangladesh

Bharul and his family live in a typical marginal household of Vhararul village under Gazipur district following Rice Farming Systems practice on 0.3 ha of own land along with 0.4 ha of share cropping land. The family has six members, lives on a 3 decimal (120 m²) of homestead area having one small tin-shed house with mud walls comprising two rooms, a kitchen and cattle shed. Both the own and share cropping land is under an irrigation scheme. The farmer follows Boro rice (winter season)-T. aman (monsoon rice) cropping pattern. He cultivates modern varieties of rice in both seasons and gets a yield of 5 t/ha in Boro season and 3.5 t/ha in Aman season. In the Boro season farmer has to give 25 % of his harvest to the pump owner for providing irrigation. However in T.aman season irrigation rate depends on frequency, as precipitation generally provides sufficient water. In case of share cropping the land owner gets 1/3 of the rice harvest, as he provides nothing except land. Rice gives food security to the family for nearly 8 months along with feed security to his cattle by rice straw. The real economic return from rice is small because of high cost of fertilizer, seed, irrigation, pesticide, land preparation, labor in comparison to the low farm gate market price in the crop season. The farmer earns some money by selling milk, cattle calf each alternate year, and by rearing a few chickens. The family consumes little of the milk, eggs or chicken meat produced because of the need for money for other livelihood activities. The family also earns a small amount by selling wood apple, mango, bamboo and vegetables grown in the homestead. However, the family consumes most of the vegetables grown in the homestead, while selling some. The farmer also sells his labor as a helper in construction work in the off-season for additional income. He can marginally maintain the family livelihood when the crop season (environment) is satisfactory and his health is sound. But often poor health and crop damage put his family in a vulnerable situation, as he is the only earning member of his family. He desires to rear cattle for beef fattening, as his wife and mother can manage this, but he is constrained through lack of cash or availability of a loan.

However, marginal and small farmers cannot meet minimal costs of maintaining their family livelihoods by reliance on rice farming alone because of low farm gate price of rice compared to the high cost of production of modern varieties. Thus farmers have to rely on other enterprises such as livestock, homestead fruits and vegetables, and off-farm activities for a bulk of their income.

Yield gap in Boro rice-T.aman Sub-system

Achievable yield gap is shown in Figure 5. It is also observed that yield potential of different HYV is very optimistic, 9.1 t/ha in Boro rice, 6.5 in T.aman and 5 t/ha in T.aus rice where best farmers yield is 6.5, 5, 4 t/ha for Boro, T.aman and T.aus rice respectively. By contrast average farmers yield compared to best farm yield is 33 percent lower (2.2) in Boro, 35 percent lower in T.aman (1.79 t/ha) and 35 percent lower (1.4 t/ha) in T.aus rice (Satter, 2007). Physical and socio-economic factors responsible for these large yield gaps are: a) low levels of management, b) lack of price stability, c) loss of farmers' interest in investment due to an unbalanced land tenure system, and d) other socio-economic factors. The low-level management factors include: low quality seed, excessive seedling age, high plant population density inviting pests and diseases, low/non application of non-nitrogenous fertilizer (imbalanced fertilizer) as basal dose, improper irrigation management, delayed weed management, delayed or improper pest-disease management, and delayed harvest. Soil factors associated with low farm level rice yield are highly reduced organic matter content and widespread occurrence of sulphur and zinc deficiencies. Among the other physical factors that often affect rice yield are unfavorable temperature, flood and drought. Although the farm level rice yield remains below the attainable yield because of these management, their influence is often overshadowed by the most important socio-economic factors that often remain latent. Systematic field monitoring is needed to assess the actual productivity that is affected by the socio-economic factors. Such studies were very rare in the past and thus more long-term studies of this nature are essential, involving various ecosystems, farm sizes, availability and use of credit, farmers' knowledge, etc. Yield gap is often described as a knowledge gap associated with other technical, physical and logistic factors.

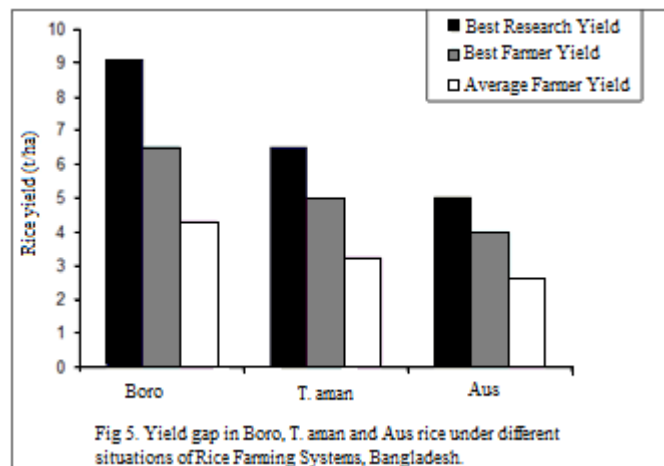
Narrowing the Yield Gap

In order to meet the food shortage, there are no other options than bridging the rice yield gap in the country on the one hand, and breaking the yield ceiling of the existing modern varieties on the other hand. The existing modern varieties of rice have come to a stage of

stagnation. Attempts are being made to break the present rice yield ceiling by developing and disseminating hybrid varieties and new ideotype rice cultivars at IRRI and China (Peng, 2008), but this will take time to achieve.. Considering the complicated maneuvers and difficulty in launching a hybrid rice program in a country like Bangladesh where most farmers lack formal education and financial resources, the immediate practical solution to the problem of food shortage would be to narrow the rice yield gap between the attainable and farmer's rice yields. This gigantic task involves, apart from applying present technological know-how, solving several physical and socio-economic constraints (Satter, 2007). The present activities for narrowing the rice yield gap in the national research institutions include:

- Development of shorter duration rice varieties with high yield potential so as to better fit into the farmer's cropping pattern. This will help farmers to free the land for the next crop in time and thus a balanced cropping scheme will be possible.
- To sustain soil productivity a program of introducing integrated use of organic and inorganic fertilizers has been gaining momentum.
- Attempts are being made to strengthen the present linkage between research and extension in order to accelerate dissemination of available technologies among the farmers.

Seedling age: Researchers recommended 40-50 days seedling age for Boro rice for achieving maximum yield, but farmers often used 70-90 days-old seedlings because of knowledge gap and non-functioning of irrigation pump for seedling raising. This situation causes the farmer to opt to sow seeds in the seedbed in November with residual water after the monsoon season. It may be mentioned that government or electricity department give an electricity connection for pumps only after December, for the purpose of preparing land and to transplant seedlings. This situation causes a big yield loss because seed to seed duration of Boro rice variety is about 170 days (depending on the cultivar); if 90 days are spent in the seed-bed then the vegetative growth period of the rice plant becomes limited resulting in lower crop yield. This situation could be avoided by preparation of common seed-beds and by revising the policy of electricity department.



Adoption of Modern Technologies in Boro rice-T.aman System

Farmers have largely accepted high yielding varieties (HYV) in the Boro season, as they give high yield along with production of good quality and amount of milled rice. The major Boro rice varieties highly accepted are BRRI dhan 28 and BRRI dhan 29 (Table 7). But for hybrid rice (such as: BRRI Hybrid 3, Taj, Tia, Hira) acceptance percentage is gradually improving (13 %) despite good yield potential, because it needs intensive management, it has coarse grain, and amylose percentage is low so boiled rice loses its eating quality quickly and its market price is low. Thus, recently, the area of hybrid rice has reduced. Hence, these problems need to be solved to improve farmer acceptance; only yield potential will not be enough. In the T.aman season acceptance of HYV is about 61 %, with the remaining area under local adapted fine quality rice varieties. Most of the high yielding aman season HYV like BR11 are long duration, often giving low yield due to terminal drought and the rice quality is a bit coarse. Moreover after harvesting sowing of winter rabi crops like wheat, potato, mustard and pulses is delayed or they cannot be sown. So farmers opt for locally improved or exotic short duration cultivars, whose grain they prefer to eat and after its harvest different Rabi crops can be sown timely. Hence, researchers should develop short duration, fine quality T.aman rice varieties. As in the Boro season acceptance of HYV in T.aus rice is also high. But acceptance of balanced fertilizer application is only 25 percent in Boro season, mostly by resourceful and knowledgeable farmers. But unbalanced application of fertilizer is seriously hampering soil and water quality and also limiting crop yield. This needs enhanced motivation, demonstration and capacity building of rice farmers. Acceptance of IPNS (Integrated Plant Nutrient System-that is supplying of nutrients from both organic and chemical sources) is also low among T.aus and T.aman farmers. Full IPM (Integrated Pest Management- managing the pest mainly by physical and biological means-where chemical control is the last option)) has been accepted by only a pocket of farmers, but it has been partially (such as bird perching) accepted by more farmers.

Table 7. Adoption of modern technology in Boro-T.aman system (%area coverage)

Crop season	HYV	Hybrid variety	Balanced fertilizer/IPNS	IPM
Boro	97	13	25	3
T.aman	61	4	15	2
T.aus	95	3	18	2

Poverty Escape Pathway for Boro-T.aman Sub-system

As the person to land ratio is so small (1 person/0.06 ha) it is difficult to achieve a poverty escape pathway for all classes of farmers. However, by adopting different possible options poverty could be reduced to some extent. As the Boro-T.aman system is irrigated and land elevation is comparatively high, there is ample scope for intensification and diversification, emphasizing in livestock/fisheries along with off-farm activities and labor migration.

Intensification and diversification: Yield potentiality could be achieved through following block approach under the supervision of public and NGO field workers. Cultivation of same variety of crop under similar management in a large area by many farmers instead of doing in a small plot by one or two farmers is the block approach. More attention needs to pay to selection of appropriate land for rice, avoiding high land sandy soils. Without increasing per unit yield profitability of rice crops cannot be achieved because of low farm gate price often fixed by the government so as to benefit the urban population. Many farmers of Manikganj and Tangail districts are diversifying the two rice system by adopting another short duration oil crop like mustard (*Brassica* sp.) for increasing the system productivity and profitability. They are growing short duration T.aman and then sowing mustard in November and harvesting the 75-85 days crop in late January, and then transplanting Boro rice seedlings. By this way farmers are realizing 1 t/ha mustard seed having a high economic return (31, 200 BDT/ha) without losing significant yield in rice. Mustard straw is used for cooking fuel and mustard cake (after crushing to get oil) is used as high quality animal/fish feed. Thus it helps to optimize the farmers' income, paving a pathway for poverty reduction. Recently BARI has released some short duration, higher oil content and high yielding mustard cultivars (BARI Sharisa 14 and 15) which could double the mustard productivity as well as economic return (ORC, 2009). Other short duration vegetable and spice crops could also enhance farmers' income for this sub-system. Even some farmers are growing a short duration potato crop before planting of Boro rice.

Maize and Soybean Potential high value crop: In the Central-south region and in other parts a large area remains fallow after T.aman rice (Rawson *et al.*, 2007). Among this fallow land some are fertile char lands where non-saline tidal water is available. In those areas hybrid maize (Box 3) could substantially increase the income of farmers instead of keeping the land fallow or growing low priced pulse, such as grass pea (*Lathyrus sativa*) or even Boro rice. Moreover, for a low production cost enterprise soybean is a prospective crop as it has good sale value and also could be consumed by making different highly nutritious soya-food items. Soybean (*Glycine max*) is a legume crop, which in general does not require fertilizer or irrigation and can yield 2-2.5 t/ha within four months (January-April/ Mid-May). Its production cost is about 25, 000 BDT/ha

while its return is about 60,000-75,000 BDT/ha. Hybrid maize is highly profitable compared to Boro rice or a local pulse crop like grass pea, or just keeping the land fallow. Even maize planting during late December to early January gives reasonable yield and income.

Box 3. Hybrid maize cultivation-Means of food security and Cash earner for Marginal farmers of Barisal

Abul Hossain (60) a marginal farmer cum trader cum fisherman lives on the bank of Kirtonkhola river with his wife and two sons in a tin shed bamboo fenced house in the village Taltoli of Barisal Sadar sub-district which is just 10 kilometer from Barisal city. His family has 50 decimal of land. He grows T.aman in the monsoon season but the Rabi season remains mostly fallow, except for sometimes a low quality pulse cum fodder, grass pea. He and his fellow farmers had never considered that a bumper crop could be grown on this land in the Rabi season by using fresh water from the Kitonkhola river, perhaps because of the initial investment required.

Along with other farmers, Abul devoted his 15 decimal lands (0.06 hectare) for maize cultivation. He learned from CIMMYT workers about using a bed planter for sowing, plowing and leveling with one pass instead of 2-3 passes as needed for normal 2-wheel tractor tillage. For tillage and maize seed sowing by bed planter he just paid 300 BDT (4940 BDT/ha) to a local service provider instead of 500 BDT (8233 BDT/ha) to a 2-wheel tractor service provider. Abul planted seed on 6 December, 2012 and harvested his maize crop on 20 May, 2013. Most of the farmers were reluctant to irrigate crops with river water though Axial Flow Pumps, as they rarely irrigate Rabi crops except Boro rice. But Abul and a few other farmers were convinced through CIMMYT discussion and an exposure visit to Chuadanga. So, they asked the local service provider to irrigate their field through hose pipe. Abul paid 1500 BDT (24700 BDT/ha) to service provider for three irrigations and he was rewarded with the highest yield among his fellow maize farmers, 600 kg (9.8 t/ha). Abul knew about maize sheller but to save cost he did hand shelling with his family members. He has seen the CIMMYT video on the use of maize grain as human food. So he consumed 120 kg after mixing with wheat at 50:50 ratio, and also distributed few kilograms among his relatives. Thus maize helped him to increase his food security, as he mostly relies on purchasing rice from the market. Abul, having good business sense, looked for the market where highest price of maize could be obtained. He sold his 480 kg maize to a nearby cattle=cum-chicken farm and received 27.5 BDT/kg and earned 13,200 BDT. Abul had a healthy return of 18,900 BDT (311220 BDT/ha) from sale of grain and stover whereas his production cost was 5,440 BDT (89,578 BDT/ha), so his net benefit was 13,460 BDT (221,642 BDT/ha). Abul, his sons and neighbors were astonished to see the high profit from maize from where mostly nothing was harvested in previous years.

Production cost reduction by following conservation agriculture: Conservation agriculture could be another option to reduce the cultivation cost of labor intensive Boro/T.aman rice. Through one pass two-wheel tractor (WRC, 2009) cum seeder (PTOS) dry seeding of rice could be done, which could reduce the cultivation and transplanting cost by about 70% without any significant yield loss. Moreover bed planting facilitates better water management and reduces the irrigation requirement in rice cultivation. With aerobic rice production soil quality improves, water requirement decreases and field duration of rice is shortened. Through using a bed planter for Rabi season crops like maize, wheat, soybean and pulses land preparation and sowing cost could be reduced by 40-60 %ensuring better irrigation and drainage. AWD (Alternate Wetting and Drying) method of irrigation could easily reduce the irrigation cost for Boro rice by 25-30% along with yield increase by 3-4%. However farmers are sometimes reluctant to follow AWD because of flat irrigation costing system (see Box 4) for electricity charge from the government department. Flat system electric billing- bill is equal per season per Shallow Tube Well not on the amount of electricity used.

Box 4. Ensure policy to prevent misuse of irrigation water and proper land use planning

Rice crops need at least 3,000 L water to produce one kg of paddy rice. As farmers usually consider rice as a food security crop, they generally ignore its production cost and misuse water. Farmers in many areas cultivate Boro rice in light soil or in char area soil, where the farmer has to irrigate almost daily to keep the soil moist and to reduce the weed population. Actually the land is not at all suitable for Boro rice cultivation, but better suited for other low water requiring crops like maize, vegetables and others. However, farmers continue Boro rice cultivation because of their mind set about food security. Presently the government fixes a common charge for each tube well; whether it irrigates 10 or 50 ha land, not on the amount of electricity used. Alternate Wetting and Drying (AWD) method of irrigation in Boro rice could easily reduce irrigation cost by 30 % along with yield increase of 3-4 %. But farmers are often over-irrigating Boro rice because of this electric revenue collection policy. Also, in many areas of Bangladesh the water table is receding, creating many environmental problems such as arsenic contamination in water and soil. Thus proper land use planning must be ensured in each block and electricity revenue collection should be on use basis by setting a meter. This would definitely compel farmers to select suitable crops depending on land quality and apply AWD method. However, farmers' motivation for rational use of water is also important.

Through using a propeller based Axial Flow Pump (AFP) instead of the traditional centrifugal pump (called LLP or Low Lift Pump) for surface water farmers could largely reduce the diesel fuel cost even by 30-50% depending on lift height. Moreover, the AFP could discharge 115,000-125,000 L water/hour for a 6 inch diameter pump having 10-12 HP engines which is 1.5 times more than LLP (Ali *et al*, 2012). Additionally, unlike LLPs, AFPs do not require any priming to start the pump and engine; priming is an irritant and time consuming deed for pump operators (see Box 5). AFPs could be ideally

suited for tidally flooded (non-saline water) central-south districts of Bangladesh where surface water is available in dry months also (December-May).

Box 5. Axial Flow Pump – an Environment Friendly and Cost Saving Surface Irrigation device for Boro Rice Block in Tidally Inundated Southern Bangladesh

Alim Khan (45) a marginal farmer cum rice irrigation block manager lives with his wife and children in the tidally flooded village Harinafulia under Barisar Sadr sub-district, which is just 5 km from Barisal city. Each year he is kept busy in the rabi and kharif-I seasons with boro rice irrigation. He has centrifugal pump to irrigate boro crops, which need 25-30 irrigations per season. As a block manager he gets one-fifth of the harvested rice as payment for irrigating the lands of 35 farmers. His block area is 4.45 ha. Boro rice is the only crop of this area. His major cost is diesel fuel for pumping of water by centrifugal pump, which is locally called LLP (Low lift pump).

In 2012, diesel requirement for this Boro rice block was 500 liters and its cost was 34,250 BDT, considering diesel cost @ 68.5 BDT/liter. Over time, the diesel cost is increasing but the market price of rice is decreasing. Until recently Alim was unable to find any answers to his declining profitability. But in January, 2013 he suddenly heard from another local rice block manager, Faruque, that there is a propeller based new pump called Axial Flow Pump (AFP) which requires less fuel and has greater water discharge per hour in comparison to LLP. CIMMYT is promoting this pump. Alim communicated CIMMYT and obtained a pump to set up in this block. CIMMYT gave him training on setting and managing and the AFP. He was astonished to see the amount of water discharge. He was convinced by CIMMYT staff and set an AFP instead of the LLP in the nearby tidally flooded canal which is adjacent to his rice block. For adjusting with the huge discharge (125,000 liter/hour) Alim had to increase the depth and height of his irrigation channel. At the end of the season Alim calculated that 350 liter diesel fuel was required for the AFP to irrigate the same Boro rice block where last year 500 liter fuel was required for LLP. So, he saved 150 liter diesel fuel, equivalent to 10,275 BDT, just by using the AFP. Moreover, Alim was relieved of the painstaking physical effort needed for priming of the LLP, as the AFP needs no priming. Additionally, he needed comparatively less time for irrigating with AFP. Twelve hours are needed to irrigate his block with the LLP and only 8 hours with the AFP. For his own curiosity Alim compared this AFP performance with another adjacent (Jalal Chowdhury block) rice block performance where LLP was used for irrigation. Alim discovered that Jalal's block of same area required 513 liter diesel fuel for irrigating the Boro rice crop. People of the locality named the AFP as "Auto pump" as it required no priming whereas for the LLP several times priming is necessary.

Emphasize on other enterprises of the Farming System: Areas following the Boro rice-T.aman farming subsystem have comparatively higher purchasing power, because of the adjacent urban population and scope of more off-farm income. Thus a large poultry industry has developed in this area to improve the livelihoods of all walks of people including the educated young generation. For marginal and small farmers beef fattening and small ruminants could be useful enterprises to supplement their income as household women and children could play a major role in rearing these animals. This activity is done mostly in the homestead area and it needs a small area for each animal. Normal market demand of beef and goat meat, outside of festival times when there is very high demand, is quite high across the country because of acute deficit of protein production in comparison to population and their purchasing power. Moreover, traditional inland fish has become costly compared to beef. Thus beef fattening particularly before festival time could bring a good income for the farming community (see Box 6). Culture fisheries in excavated ponds also bring more ensured profit than rice production. Thus on-farm commercial fisheries are expanding in north-eastern Mymensingh district in rice land.

Box. 6. Beef fattening for Income enhancement and Poverty Reduction

Beef fattening may be regarded as the single most popular technology among all classes of farming community across Bangladesh because of its simplicity and huge market demand of beef. Generally 2-5 years age male calf is reared for 3-6 months period targeting towards rapid development of body weight for commercial meat purposes, particularly for the Muslim annual festival (Eid-ul-Azha) market. Beef fattening is done by providing a nutritious and balanced ration (BLRI, 2008) in stall feeding conditions in the homestead area. Thus women play a big role in managing and rearing the cattle. As comparatively small space is required, the technology is applicable for poor or rich alike although well-to-do farmers rear more number of cattle. From a single calf purchased for 20, 000 BDT a farmer could earn up to another 20, 000 BDT within 5-6 months at a cost of only 5, 000-7, 000 BDT. That is a net benefit of 13, 000-15, 000 BDT per cattle can be earned. Some farmers also rear cattle only for 3-4 months targeting the Eid festival. More income could be generated within an 8-9 months period by selecting better cattle, even up to 75, 000 BDT net benefit could be earned from a single cross-breed. Many landless and marginal farmers are benefited by this technology; they purchase cattle though loan money obtained from NGO/private lenders/relative help and even on a sharing basis. Beef fattening is playing an important role in uplifting farmers' income even in remote char areas.

Off-farm: For poor and small farmers income only from the land would not be sufficient to lift them out of poverty due to small land area in relation to family size (Table 6-shown above). Even big farmers have to supplement their income by business as often crop yield is affected by flood and other natural calamities, including pests and diseases of rice. This double cropping rice area has considerable scope for off-farm activities as most of the industry is situated in this region and each year there is high labour demand for civil

works such as buildings and transport infrastructure. Women in particular have good scope for work in the garments industry. However, to productively participate in these off-farm employment opportunities rural dwellers need good health and training to increase their work efficiency. Government and NGOs have a role to play in providing adequate and low-cost health facilities, to support this off-farm work. Government also has a role in ensuring fair terms and conditions of employment for these workers.

Labor Migration: Both internal and external migration is important to enhance the income level of landless, small and other categories of farmers. Generally landless and small farmers migrate to nearby urban and other areas as laborers of agriculture, civil works, garment factories (mostly women), and also as rickshaw-pullers and other odd jobs. This provides a major income for their livelihoods along with their small scale farming. Some well-off farmers try to send their family members son or brother to overseas countries for improvement of income and livelihoods. From 1980 to 2005 (25 years) millions of young people migrated to different countries particularly in Middle-East to improve their income prospects. Thus, still today the highest overseas remittances come from the labor export sector. However, this has also created many social problems, as there is much fraud involved in raising the cash necessary to send a worker abroad. Village people can be cheated by brokers, after selling their land and any other assets for this purpose, thus pushing them further into poverty. Government intervention is also required here to ensure a fair process, and also adequate training and supply of information for prospective overseas workers. As an overpopulated country labor migration will remain a viable option for improving livelihoods.

Credit/Micro-credit: This is important for fulfilling the immediate cash needs of farmers to purchase inputs or cattle, to pay laborers, for medical treatment or marriages. Government bank based credit is cumbersome, time consuming and informal cost (bribe) is high although interest rate is low compared to NGO or Cooperative or private money lenders. Moreover, many landless or marginal farmers or women have no collateral which is essential for the traditional state-based banking system. This failure has prompted the development of micro-credit systems over the last three decades, initiated by Dr. Muhammad Yunus of Grameen Bank. The micro-credit industry has played an important economic role as an instrument for achieving the objective of poverty alleviation in Bangladesh. The success of micro-credit has been mainly due to its ability to address the credit needs of the poor, as no collateral is required. However, its interest rate is high (30-45 %) even though less than that of private money lenders. Only good entrepreneurs are benefited by this loan with many poor farmers falling into a debt trap, taking additional loans from other sources to meet the repayment of installments from the original lender. Refinement of currently operating micro-credit schemes is required to ensure provision of small loans without collateral and at reasonable interest rates. Muslim Aid -UK provides credit without interest, which is helping resource poor farmers and

landless people to become self-reliant within 2-3 years period, however, it is limited to a few areas of Bangladesh. A study revealed that in rural Bangladesh 80 % loan is provided by non-institutional actors, 15 % by micro-finance institution and rest 5 % by public sector (MoA, 2013). The non-institutional sources are dominated by *mohajans* and *dadanders*. They charge on loan at high rates, generally 10% per month. This indicates that there is ample scope for micro-finance institutions (mostly by NGOs) and public Banks to cater need of rural people to provide credits at reasonable rates.

Boro rice-Fallow/Deep water Broadcast aman rice Farming Sub-System

This Farming Sub-System is practiced in a comparatively small area, 10-12 % (Fig. 1), of the Rice farming system. The area is low-lying and goes under water from June to November. In the dry season (December to May) HYV boro rice is cultivated with irrigation. A typical small farmer has about 0.4 ha of cultivable land from which he gets eight months of food security (Box. 7).

Box 7. A typical household of Boro-Fallow Farming Sub-System

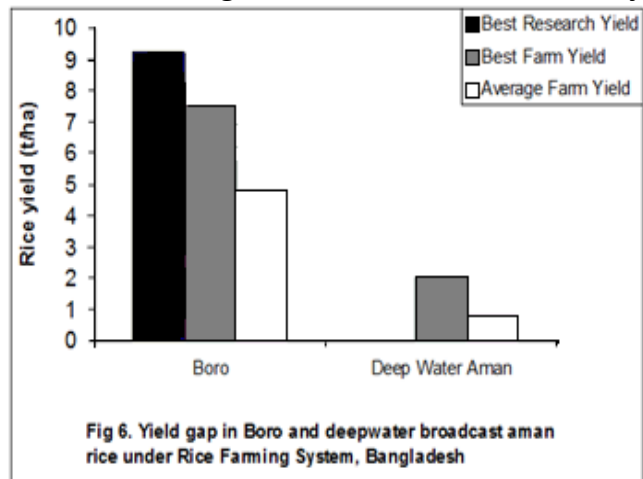
A typical small farmer of Kishoreganj district haor (natural depression) area lives in a raised tiny homestead with his wife, mother and two minor children. He grows a single Boro rice crop in the winter season when the flood water recedes from his land. He gets a yield of 5.5-6.0 t/ha by cultivating high yielding varieties of rice. The land requires less nitrogenous and other fertilizers because of natural fertility of the basin land. However, paddy price is always lower compared to peri-urban or well-connected areas because of remoteness of the area. He earns a good amount of cash by rearing ducks in the nearby haor land during May to November. However, his livelihood is always under threat due to flash flooding from the hills of Maghalaya state, India. It comes often before the harvesting rice, on average once in 3-4 years, and destroys nearly all the means of livelihood pushing the family into greater poverty and often hunger or malnutrition. However, his duck rearing enterprise and fishing allow the household to persist.

In some parts of the country in central area, in Tangail and Sirajganj districts, rain or flood water rises slowly, and after harvesting of Boro rice farmers sow the seed of Broadcast Deep Water Aman rice. Its yield is low, at only about 1.5-2.5 t/ha but it has the capacity to grow with rising water level. Thus, it is sometimes called floating rice. It has a long culm, producing a high amount of straw which is often used as fodder and mulch material for Rabi crops like potato. To all people this rice is regarded as tasty and used for preparing puffed rice (Muri). Still no HYV variety has been developed for this type of cultivation. However, to increase the system productivity farmers always try to sow grass pea (*Lathyrus sativus*) by zero tillage surface seeding method as the water recedes, which may give yields up to 1.5 t/ha with a good amount of fodder for cattle. But in some years

delayed rain hamper sowing of grass pea. To increase productivity of low-lying land farmers dig a small ditch in one corner of the land, so that natural fish can live there. However, this fish production is seriously compromised due to excessive use of pesticide and fertilizer along with excessive catching of small fish by fine nets.

Yield gap in Boro-Fallow/ deep water Broadcast aman rice

For Boro rice in this sub-system the yield gap (Fig 6) is low compared to other sub-systems because of high fertility of haor soils, minimal growth of weeds and availability of irrigation water. Each year natural soil fertility of the haor area is replenished by new siltation carried by flood water. The yield gap between best research yield and best farm yield is only 18 % (1.7 t/ha) but the yield gap between the best farm to average farm yield is fairly large, at about 36 % (2.7 t/ha) There is scope to these yield differences though ensuring good quality seed, proper seedling age and other recommended management practices.



To the present no superior cultivar of deep water Broadcast aman rice has been released. The yield gap between best farm and average farm is about 60 % (1.2 t/ha) in Broadcast aman rice could be minimized through proper weed and plant population management.

Adoption of Modern Technologies in Boro-Fallow/Deep water broadcast aman rice

Adoption of improved technology is very high for Boro rice (Table 8), because farmers rely on this crop as their predominant source of food security and income. To date, hybrid rice has had little impact in low lying areas, even though it has high yield potential. For deep water rice there is no high yielding variety, rather farmers select their preferred varieties, such as Chamara, Digha and others.

Table 8. Adoption of modern technology in Boro-Fallow/Deep water broadcast aman rice system in percent area

Crop	HYV	Hybrid variety	Balanced fertilizer/IPNS	IPM
Boro	99	0.5	30	3
Deep water Broadcast aman	N/A	N/A	N/A	0

Poverty Escape Pathway

Comparatively little room is available for productivity improvement in this sub-system. Despite that there is scope of intensification and diversification, emphasizing livestock/fisheries along with off-farm activities and labor migration, to ease the grip of poverty particularly among the marginal and small farmers.

Intensification and diversification: It is possible to further improve the average Boro rice yield by timely transplanting of seedlings, application of balanced fertilizer particularly phosphorus and potassium fertilizers, employing IPM to control pests and diseases, but this needs capacity building of the farming community including hands-on training.

Practice of conservation agriculture: Farmers of Narayanganj and Chadpur districts are diversifying this sub-system through practicing unique conservation agriculture. They are directly seeding mustard and Boro rice at the same time in November after the recession of flood water. Mustard grows very quickly and is harvested within 75-85 days and Boro rice remains in a suppressed condition. After harvesting of mustard, farmers weed, irrigate and fertilize Boro rice and can get yields comparable to traditional transplanted Boro rice. Farmers thus harvest an extra mustard crop with a high economic return (see Box 8). However, preliminary research finds that this mustard + Boro rice system is only possible where weed population is less or if there is effective weed control in the direct seeded Boro rice.

Box 8. Science behind the success of Direct Seeded Boro rice + Mustard) is:

- Selection of short duration mustard (75-85 days) and long duration rice-BRRI dhan29
- Farmers sow both rice and mustard at the same time in November
- After the harvest of mustard in late January farmers weed, irrigate and fertilize the rice crop. At this time seedling age is around 90 days. Across Bangladesh most farmers also use 80-90 day-old seedlings for transplanting Boro rice particularly in the case of BRRI dhan29. So seedling age of both direct seeded (DS) Boro and transplanted Boro is similar.
- Transplanted seedlings can face cold injury and they have at least 10 days transplanting shock. On the other hand, DS Boro seedlings are comparatively healthy with prolific root systems, even though suppressed by vigorous growth of mustard. Thus DS Boro rice recovers very quickly after harvest of mustard and produces similar yields to transplanted Boro rice.
- In this way farmers get an additional mustard crop (1-1.5 t/ha) having good market price along with quality fuel (by-products) for cooking. From one tonne mustard 31, 200 BDT can be earned which is a big income compared to what can be obtained from rice.
- Moreover through practice of DS Boro rice, seedling raising and transplanting is not required and cultivation and irrigation costs, particularly the labor component can be significantly reduced. It may be mentioned that labor availability is a problem in this season.
- Thus system productivity and profitability are greatly increased along with conservation of thus natural resource base (soil, water).

Emphasis on other enterprises of the Farming System: Cattle, poultry, including ducks, have some scope in these low lying areas. Ducks in particular have good scope for improving livelihoods of farmers because of an expansive foraging area available for 6-7 months in the haor water. Introduction of improved duck breeds with proper management could improve the survivability percentage as well as productivity. From 100 ducks, 2,500-3,000 BDT could be earned per month (BLRI, 2004) from sale of eggs -with very little feeding cost in the haor area. Moreover, farmers could earn a good amount by selling their ducks. It has been reported by BLRI scientists that duck rearing improves the protein intake and nutrition of family members and could enhance their income by 67%.

Through community fish farming, fish productivity could be improved to a significant extent. But this needs some investment and rules for sharing the products among the cooperators, for which government, NGO and the local community may come forward in a more effective way.

Off-farm: For all categories of farmers (Table 6) off-farm activities could play a major role in supplementing the income from agriculture. Particularly for landless, marginal and small farmers a large part of earnings need to come from off-farm otherwise poverty

cannot be significantly reduced. Farmers of this sub-system are vulnerable to recurrent flash flood and crop loss and there is little scope for other crops except rice.

Labor migration: Internal labor migration regularly occurs but this relies on sound health of the migrating farmers. The return from local selling of labor is small and often no work is available. Overseas employment offers best prospects for improving livelihoods in this system but this requires appropriate Government and NGO facilitation.

Credit/micro-credit: Credit and micro-credit facilities are particularly needed in this farming sub-system area, as discussed in previous section.

Trends and issues in the Rice Farming system

In the coming years Bangladesh will be facing three dimensional challenges (population increase, land area reduction and climate change effect) in supplying the required amount of rice for its ever increasing population. The population will increase by two million/year but the area of land on which to grow rice may decrease by 0.5 %/year, resulting in a reduction of rice production (Table 9). Although it is widely estimated that total Bangladesh agricultural land will decrease by 1 %per year, it is believed that as rice land is at comparatively lower elevation its loss will be less – at about 0.5 %. Moreover, it is predicted that due to climate change 20 %of coastal area land might be affected by salinization and river erosion. Furthermore, climate change induced effects of higher temperatures and more flooding and cyclones would adversely affect rice production. The effects of temperature on yield of Boro rice have been assessed using the DSSAT (Decision Support System for Agrotechnology Transfer, version 4) model for the years 2020, 2030, 2040 and 2050 respectively (J. K. Basak, Unnayan.org/reports/climate.change.and.food.security.repport.pdf). The study has been conducted on the basis of IPCC fourth assessment report (temperature is projected to rise in a range from 1.8°C to 4.0°C by 2100) and a considerable yield reduction (1.5%, 2.5%, 4.4% and 5.4%) was found for the years specified (base year 2008). There would be a shortfall of about 2.59, 2.24, 2.62 and 3.43 million tones in Boro rice production in 2020, 2030, 2040 and 2050 respectively only due to the temperature effect. Consequently, there could be a rice shortage of 7.68, 8.25, 10.40 and 13.93 million tonnes in the targeted years for the combined effect of temperature and population. However, the land reduction factor was not considered in this modeling study. After 1975 Bangladesh has been able to contain its rice deficit within 1 million tonnes/year except in severe flood or cyclone years. But it is assumed that at current productivity rate (Table 9) each year food deficit will increase due to the cumulative effect of land loss and population growth along with the projected effect of climate change. In 2025 rice deficit will be 16.63 million tonnes and reaching a shortfall of 26.07 million tonnes in 2050, if the projected population growth and land loss

rate is considered. It is only possible to contain this level of shortfall by increasing per unit average yield. To maintain the present level of rice per capita, Bangladesh has to increase its per ha yield to 2.5 t/ha in 2025 and 4.0 t/ha in 2050, from the present yield level of 2.04 t/ha. To increase average yield at this level is a daunting task but not impossible as technology is available but it has to be employed with seriousness. Otherwise, per capita availability of rice may decrease further.

Table 9. Population, land availability and rice requirement projection for Bangladesh

Year	Population* (million)	Land availability for rice** (m ha)	Rice production*** (m ton)	Rice yield**** (t/ha)	Rice requirement/ year (m ton)	Surplus/ deficit per year (m ton)
2012	161.08	11.45	23.36- 10% =21.02	2.04	28.63	-7.61
2025	190 (projected)	9.34	19.05- 10% =17.14	2.04	33.77	-16.63
2050	231(projected)	8.17	16.66-10% = 14.99	2.04	41.06	-26.07

* International Monetary Fund, 2009, World Economic Outlook

** Considering 0.5 % loss of rice land per year

*** 10 % production is for seed and others

**** Clean rice. Requirement was calculated at 487 g rice/head/day (Source, DAE)

However, with increased urbanization and enhancement of income dietary habits of a large number of people would substantially change, towards consuming more vegetables, fruit, broiler chicken, bread-based fast food and other diversified food. This may lead to a reduction of rice intake to perhaps half of the present level. Moreover, increasing water scarcity in agriculture is expected, as demand for water grows in domestic and industrial sectors. However, some market-driven land consolidation can also be expected together with gradual reduction of sharecropping. Education levels for both men and women are expected to increase substantially. Widespread adoption of hybrid rice is expected, except in deep water and other unfavorable ecologies (Dixon *et al*, 2001). The terms of declining trade for rice, and increasing cost of production, will induce diversification of production, vegetable, fruits, poultry, dairy, beef fattening and aquaculture. Increased labor cost will favor conservation agriculture and farm mechanization. The gradual decline in rice profitability, and increasing population pressure, will force many male household members, including women, to seek an increasing part of their income from off-farm sources. In this situation, women will shoulder an increasing burden of farm management. However, there may be a gradual improvement in food security and a modest reduction in poverty because of diversification of the agricultural systems and overall economy.

It is envisaged that there will be significant improvement in public infrastructure, transport, communications, health facilities, credit/micro-credit facilities, marketing and other aspects of socio-institutional environment affecting agriculture production. Decentralization in decision making may be improved in the near future. The prevailing feminization of poverty in large areas of Bangladesh will probably begin to be reduced.

Public sector research and extension investment will be needed well into the future until private sector investment can take hold. However, NGOs, the private sector and farmers' organizations will increase their activity in quality seed production and retailing, and some degree of research, extension and adaptation activities across the country, particularly in coastal belt. The main issues driving the evolution of the system are: declining per capita land, low and declining paddy prices combined with increasing labor cost and high market demand and higher profitability of other products such as vegetable, fruits, meat, milk, fish and other processed products.

Priorities for Rice Farming System

Poverty could be significantly reduced for this farming system by following strategies in the following order: diversification, increased off-farm income, intensification of the existing production systems and exit from agriculture. However, facilitating the implementation of all these strategies needs development of government facilities, including infrastructure, marketing, health services and availability of credit/micro-credit. For intensification and diversification, management of the natural resource base including soil, water and synergistic interactions with other enterprises is important for long term sustainability. One of the major problems is the low and progressively declining producer price for rice resulting from unfavorable terms of trade. This can be minimized in the long run by using more efficient production practices, thereby increasing the competitive advantage of local rice production. An effective research and extension service is needed to improve the labor and factor productivity. Conservation agriculture and dry direct seeding of rice could have a role in reducing the cost of production in rice. However, to maintain adequate incentives to farmers it will be necessary to avoid urban bias in trade and economic policy.

The productivity of rice could be improved through intensification, following the whole recommended production packages particularly in irrigated Boro rice. However, this needs investment, capacity building of farmers and field workers, development of new rice cultivars with higher yield potential under unfavorable conditions, supervision of knowledgeable workers and overall policy support of government. Particularly, the government should ensure development of efficient irrigation systems along with proper land delineation for irrigated Boro rice. For T.aman more short duration and fine quality rice cultivars are needed to facilitate timely planting of Rabi crops and to avoid terminal

drought in rice. Submergence tolerant T.aman rice cultivar could help to minimize the effect of flash and short-time floods. Some local cultivars such as Bhusiara, Kalomota , Sadamota, Lalmota, Chulamata, Lalpakkaya are potential under tidal submergence conditions. For Aus and Aman rice direct seeding with one pass machine (PTOS-power tiller operated seeder/trip tillage) could effectively reduce production costs and ensure early land release for Rabi crops.

Poultry and dairy farming have a tremendous role to play in reducing poverty and malnutrition in central Bangladesh, because of industrialization and enhanced purchasing power of city and peri-urban residents. Both layer and broiler chickens can play a major role in meeting the household protein demand as well providing a quick cash return (see Box 9). Moreover, a comparatively small area is needed for poultry rearing, as land area is scarce in Bangladesh.

Box 9. Layer chicken rearing a viable option for poverty reduction and livelihood improvement

In the small village of Sukundi in Gazipur district Lokman and his wife started chicken rearing with 200 layers after he returned from Saudi Arabia. At 22 week age chickens began laying eggs and he earned a net benefit of 46,000 BDT /year with an initial investment of 156,000 BDT, managed from his overseas income. Now he has increased his layer flock up to 4,000 with support from a local bank which was needed for shed fabrication, purchasing feed and buying of one-day old hybrid chicks. Now he is earning about 400,000 BDT per month after the expenditure. His poultry farm has created employment for five persons. He is also selling poultry litter to a fish farm in Mymensingh. Now Lokman is living happily with his wife and three children and his poultry farm is earning more income than he could obtain from working in an overseas country. He is paying his bank loan installment regularly and saving money for future investment.

Research and Development needs for the Rice Farming System

- Rice Farming has a tremendous impact on livelihoods and poverty reduction of large number of Bangladesh people. Emphasis should be given to the following aspects of research and development issues:
- Development of more hybrid rice varieties having good cooking quality and market price
- Development of short duration Boro rice to avoid flash flooding in April-May for haor and low lying areas
- Development of rice varieties for dry direct seeding for facilitating conservation agriculture

- Submergence tolerant T.aman rice cultivars to be promoted in flood prone areas
- Development and calibration of machineries for one pass PTOS/ strip tillage for sowing of seeds at proper depth and rate
- Better calibration of bed planter for simultaneously making bed and sowing of seeds of different dry land crops such as rice, maize, wheat and pulses
- Ensure development of short duration, high yielding and high quality fine rice for T.,aman season, ensuring timely planting of Rabi crops
- To improve the total system productivity sustainable management of multiple cropping should be developed along with proper crop rotation, except for the low land
- Develop rice varieties with good quality straw for livestock fodder
- Appropriate rice-fish culture should be patronized through mobilization of communities
- Quality rice seed production should be ensured through research-extension-private companies and farmers' linkage on a block basis.
- Arsenic tolerant rice varieties should be developed for arsenic affected areas
- Low water requiring Boro rice varieties should be developed with low nitrogen requirement and having prolific deep root systems
- Drought tolerant Aus and Aman rice varieties need to be developed
- Government may introduce pre-paid irrigation systems like BMDA (Barind Multipurpose Development Authority) to avoid loss of irrigation water; Electricity department should revise the flat billing system (common for all) and should give electrical connection to irrigation pump at seedling raising stage also
- For reduction of yield gap target would be fixed for each block with assignment of responsibility
- Ensure disbursement of credit and micro-credit at proper time with a soft interest rate, and even at zero interest rate
- If keeping the rice market price low remains as a government de-facto policy, then subsidy should be provided to farmers to compensate the loss
- For tidally flooded non-saline areas system productivity of medium high land could be increased through growing Rabi crops like, maize, wheat, pulses and soybean
- Axial Flow Pump instead of LLP should be promoted to irrigate non-saline tidal water affected area and other areas where surface water is available

5. RICE-WHEAT FARMING SYSTEM

Characteristics of the System

The Rice -Wheat Farming System covers 30 % of cultivable land of Bangladesh (see Box 10). Of the total area of 3.33 m ha, 2.42 m ha is under cultivation and 90 % of that is irrigated. The system covers the Gangetic floodplains, Teesta floodplains and Barind Tract area (Fig. 2). Except for the High Barind Tract area it is a very intensive area with high production potential. The lowest rainfall area of the country, the High Barind Tract, falls under this area but elsewhere has moderate rainfall and it faces a comparatively cooler winter than other farming system areas.

Box 10. Basic data: Rice-Wheat Farming System

Total population (m)	33.30
Total area (m ha)	3.33
Agro-ecological zone	Dry-Humid
Net cultivated area (m ha)	2.42
Irrigated area (m ha)	2.20
Bovine population (m)	6.69
Small ruminants (m)	7.88
Poultry (m)	47.93
Literacy rate (%)	41.81

The farming system is characterized by a summer (monsoon) crop of generally T.aman rice followed by a winter (cool, dry season) crops of wheat/maize/vegetable/potato/pulses/other crops. Crop diversification is high in this system in most of the land except low and medium low land. Poverty, household food insecurity and malnutrition are widespread, principally among landless agricultural workers, marginal farmers and sharecroppers. The system has lower population density but due to less industrial development along with river erosion and recurrent flooding in the northern districts of Rangpur, Gaibandha, Kurigram and Lalmonirhat a large section of the people suffer acute poverty. Particularly when laborers do not get jobs starvation, popularly known as “Monga”, can threaten. This happens generally in September to October when there is less agricultural work available. Due to serious poverty the literacy rate of the people is the lowest (41.8 %) among all the farming systems.

Being away from the sea, temperature extremes are the highest in the country. There is a sudden rise of temperature in February often affecting the yield of wheat crop and this is perhaps one reason for the significant reduction of wheat area after 2000. Moreover, wheat is facing competition from other remunerative crops like maize, potato, vegetable, onion and other crops. Wheat yield potential is limited by the short winter and prices are kept low due to wheat imports. Wheat consumption has increased markedly over the years due to urbanization and change of food habit. Thus every year Bangladesh has to import additional quantities of wheat. In 2012-13, it is estimated that Bangladesh imported three million tonnes of wheat, which was 11 % more than in 2008 (USDA, 2012).

Livelihoods

Major household expenditure in this system is for food, daily bazaar and agricultural inputs (Table 10). However, well-off households spend 2,000 BDT per month for mobile phone usage which is more than poor household food cost, indicating the importance of communication in village people's livelihoods also. There are large differences in income and expenditure among poor, average and well-off households. Poor farmers have an income of 76,400 BDT/year against their 70,680 BDT expenditure per year, leaving a small yearly balance of 5,720 BDT. Their major income comes from selling proceeds from crops and the second highest from selling labor. They also earn some money from vegetables, homestead fruit and livestock. However, flood, drought, pest attack or poor health of farmers can change this balance to negative, as the poor are on the verge of absolute poverty. Major income for average households comes from sale of different crops, followed by sale of vegetables. Household total yearly income is 159,500 BDT against 144,432 BDT expenditure, with a yearly balance of 15,068 BDT. Similarly well-off households' major income also comes from sale of different crops and then vegetables, indicating dependency on agriculture. Off-farm income is small. Well-off households spend 297,480 BDT/year against 326,000 BDT incomes, having a marginal yearly balance of 28,520 BDT. This yearly balance is comparatively less compared to coastal or rice farming systems because of less income from off-farm activity. Northern Bangladesh has less scope for off-farm work because of limited industrialization there. Rice food security is a key and prestigious issue in traditional Bangladesh society. The poor have only 6-7 months food security, while average households have 9-10 months food security and well-off households have year-long food security. According to the "dollar-a-day" poverty criterion, only poor households fall into this category, and both average and large household farms are above this level. Except for the landless, diversified agriculture has helped the northern Bangladesh farmers to safely live on their own income, although the majority of them are far away from prosperity. More income from off-farm can bring respectable solvency.

Table 10. Comparative Livelihoods (expenditure and income) of poor, average and well-off farmers under Rice-Wheat farming system (source: survey as like Rice farming system)

Item-wise monthly expenditure	Amount (BDT)		
	Poor household	Average household	Well-off household
Food	1800	2700	3000
Cloth	400	600	1000
Daily bazar	1250	2000	3000
Health	200	500	750
Education	250	1000	1200
Transport	150	300	500
Agricultural input	1000	1850	7800
Labour	140	1416	4040
Festival/guest	300	670	1500
Other (mobile cost etc.)	400	1000	2000
Yearly expenditure	5, 890 x 12 months = 70, 680	Total-12, 036 x 12 months= 144, 432	Total-24, 790 x 12 months= 297, 480
Income source			
Rice, wheat & other crops	32000	120000	264000
Vegetable	18000	30000	45000
Homestead fruits	1500	4000	5000
Livestock	5000	1500	5000
Labour sell & others	18000+2000	8000	-
Business	-	-	7000
Yearly total income	76400	159500	326000
Yearly balance	+5, 720	+15, 068	+28, 520
Income/head/day in US\$	0.59	1.24	2.55
Rice food security (months/year)	6-7	9-10	12

*1 US\$=78 Bangladesh Taka (BDT). Five member families were considered in calculating income per day.

In the following section the major sub-systems of the Rice-Wheat Farming System are analyzed in terms of typical household, yield gap, adoption of modern technology and poverty escape pathway.

Wheat-T.aman Farming Sub-System

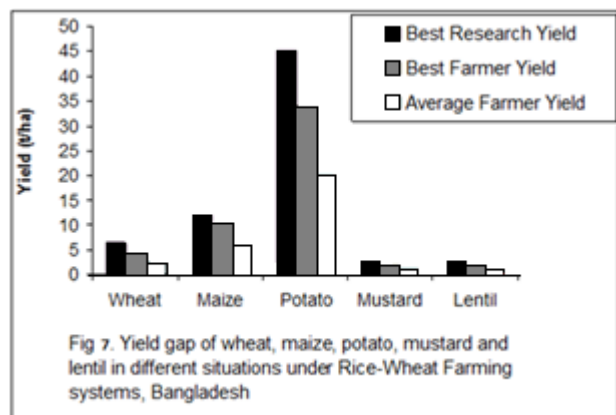
This is one of the major sub-systems of northern Bangladesh (Fig. 2). About 61 % of wheat produced in the country comes from this sub-system. Wheat is one of the preferred crops by the farmers as it need less water and care although in recent years its yield potential has been hampered by high temperature (Rahman *et al.*, 2005). Wheat flour has become an essential part of many Bangladeshi people's life, particularly for city dwellers. After milling for flour, wheat bran is widely used as livestock feed and its price is near that of wheat flour. Wheat straw is used as cooking fuel and thatching material, but not as livestock feed. A typical small farmer cultivates 0.53 ha land of which 0.38 ha is under

the wheat-T.aman system, realizing a moderate yield of 3.5 t/ha paddy rice and 3 t/ha wheat grain (see Box 11).

Box 11: A typical household of Rice-Wheat Farming Systems of Bangladesh

A typical small farm household, having two adults and two children, under the Rice-Wheat Farming System at Paba, Rajshahi district cultivates 0.53 ha of land of which 0.15 ha is devoted to round the year vegetable cultivation and the remaining 0.38 ha under wheat-T.aman rice system. In addition the family lives on 0.02 ha of homestead area having a small tin shed bamboo-fenced dwelling house along with a small kitchen and cow shed. The surrounding area is covered by a few mango and other fruit trees, *Moringa* tree and plantain banana. Through cultivation of modern rice cultivars the farmer gets about 3.5 t/ha paddy rice and from following wheat harvests about 3 t/ha wheat grain which ensures his food security for the whole year, in an environmentally normal year. Rice straw is mostly used as cattle feed and wheat straw for thatching and cooking fuel. Cash income for other aspects of livelihoods comes from cultivation of vegetables in a loamy textured high land plot having an irrigation facility. Vegetables grown there include amaranth, spinach, radish, cabbage, bottle gourd, snake gourd, wax gourd, tomato, etc. The household earns about BDT 30,000/year net from sale of vegetables. Vegetables are sold at the local market, obtaining high prices early in the season but low prices at optimum harvest time. This income supports children's education costs, festival costs and purchases of other consumer goods. However, livelihoods of this household become precarious when excessive rain, drought, storm and serious pest attack occurs. Household ambitions are to purchase a few cows along with initiation of a small business for livelihood diversification to escape the clutch of poverty.

Yield gap: The yield gap (Fig. 7) between best research yield and best farm yield for wheat is 38 % (2.5 t/ha) while the difference between best farm and average farm yield is 40 % (1.6 t/ha). Wheat yield gap has been critically analyzed by (Hasan *et al.* 2008). The major bio-physical factors responsible for the wheat yield gap are lack of good quality seed, non-application of recommended fertilizers, poor germination, weed infestation and irrigation problems. Delayed planting due to late release of land from the previous T.aman rice crop also causes drastic reduction of yield because of high temperature at flowering and grain filling stages. The socioeconomic constraints for yield reduction are lack of proper knowledge about modern technology, high price and spot scarcity of



fertilizer, shortage of human labor and animal power, dearth of cash and low price of product. To improve yield of wheat, short duration T.aman rice with fine quality grain should be developed, so that land is released before the optimum time of planting wheat. Hasan *et al.* (2008) opined that existing yield gap could be reduced through policy intervention and adoption of modern technology.

In mustard the yield gap between best research and best farm yield is 23 % (0.5 t/ha) while the yield gap between best farm and average farm yield is quite large, at 41 % (0.7 t/ha). Yield gaps of maize, potato and lentil described in following sections.

Adoption of Modern Technologies in Wheat-T.aman rice Sub-system

There is about 95 % adoption of modern wheat varieties with the remaining 5 % being the previously recommended variety Kanchan (Table 11). Thus, although area of wheat has decreased the yield has increased by 2.42 % compared to 1997, mainly because of release of several high yielding varieties and also increased availability of that seed at block levels. However application of balanced fertilizer is meager, which is one of the causes of the large yield gap. For T.aman adoption of modern varieties is to still 55%, because of existing variety is long duration or coarse grain size or taste are less (such as the modern varieties BR10, BR 11, BRRI Dhan 49 while traditional farmers preferred cultivars are Swarna, Parija). Farmers prefer T.aman for home consumption, so quality is an important factor. Balanced fertilizer use in T.aman is also not encouraging, with only 10 % of farmers practicing it, as an excessive proportion of nitrogenous fertilizer is used. Motivation, training and result demonstration is important to convince a significant number of farmers to accept recommended fertilizer application, which is also crucial for future soil health. Acceptance of IPM, apart from bird perching, is also negligible. So, continuous hands-on training is important for promoting this technology.

Table 11. Adoption of modern technology in Wheat-Rice Sub-system in percent area

Crop	HYV	Balanced fertilizer/IPNS	IPM
Wheat	95	5	-
T.aman	55	10	2

Poverty Escape Pathway

Some of the poorest areas of Bangladesh fall under this farming sub-system (WFP, 2006). There are a large number of landless and marginal farmers having little scope for off-farm activities. Agriculture alone cannot reduce their poverty, and so multiple approaches should be taken. Some of the options are discussed below:

Intensification and diversification: As the land in this sub-system is medium high to high land with widespread irrigation facilities, considerable intensification and diversification is possible. Through selection of short duration T.aman rice like BINA-7/ BRRI Dhan 39 (fine quality rice having shorter growth duration) and adoption of balanced fertilizer along with application of irrigation at critical stages like Crown Root Initiation and flowering yield of both T.aman and wheat could be improved. Considerable scope has been created by the release of short duration (70-75 days) summer mungbean (*Vigna radiata*). After harvest of a wheat crop a mungbean crop could be grown producing at least 1 t/ha grain and 4-5 t/ha brown manure (plant residue) for mixing with the soil before the planting of T.aman rice. As mungbean is a legume crop its roots and leaves contain higher amounts of nitrogen along with other nutrients, and thus mixing of residues with soils can markedly improve its fertility. Moreover mungbean is a high value pulse in Bangladesh, but its production cost is minimal (see Box 12). Thus farmers' income and nutrition is greatly improved by the introduction of mungbean in the Wheat-T.aman system.

Box 12. Introduction of mungbean after wheat in Wheat-T.aman Farming System: sustainable improvement of productivity and profitability

A small farmer of Dinajpur Sadar planted mungbean for the first time in 0.4 ha area after the harvest of wheat in late March, 2010, following the advice of the Wheat Research Centre of BARI. The farmer prepared the land in the same day with a two-wheel power tiller and sowed the seed of mungbean cultivar BARI Mung 6. He was astonished that pods formed within 45 days and he could harvest them within 75 days, to achieve a yield of 1.1 t/ha. Following the researchers' advice he ploughed the mungbean stover into the soil to improve soil fertility. From this mungbean crop he earned 44,000 BDT/ha, from an outlay of 10,000 BDT/ha. In July, he planted T. aman rice in that same land and achieved about 0.8 t/ha higher yield compared to another plot where mungbean was not cultivated. He estimated that he would need 25 % less fertilizer for T.aman rice due to the effect of mungbean biomass in the soil. Thus introduction of mungbean has increased the profitability of the existing Wheat-T.aman system along with sustainable soil management. By observing the mungbean crop yield many farmers of the locality have decided to cultivate mungbean after wheat.

Conservation agriculture for cost saving and production enhancement: For wheat it has been well demonstrated that bed planting, strip tillage and one pass full tillage by PTOS greatly reduces the turnaround period and permits sowing of seed before residual soil moisture dries up (BARI, 2011). Through bed planting wheat yield could be increased by 20-30% and the system helps to reduce water requirement both in wheat and T.aman rice. Further, the rat problem is solved in wheat because of better light penetration through the spacing between two beds. PTOS sowing also helps to reduce

cultivation cost in wheat by 30%. Thus through adoption of conservation agriculture concepts and use of PTOS or bed planting input costs can be reduced and yields increased. In bed planting conditions, summer mungbean crops also performed better because of optimized plant population and superior water management (BARI, 2011).

Emphasis on other enterprises of the farming system: This system also has potential for homestead gardening, commercial fruit gardening, beef fattening, sheep rearing and poultry production. Particularly, litchi gardening has helped many people to increase profitability in high land light soil of Dinajpur and other areas. Unlike mango it gives production each year (see Box 13)

Box 13. Litchi gardening, a step forward to defeat poverty

Litchi is a very popular and high income generating drought-tolerant fruit tree. From the 5th year of plantation about 592,800-624,000 BDT/ha/year net return could be earned at an initial cost of 54,600-62,400 BDT/ha. Over time, the tree canopy increases and bearing of fruit also increases markedly up to a certain age, fetching more profit with less cost. At the seedling stage (up to 5th year) farmers cultivate different field crops and turmeric as intercrops between the rows of litchi trees. Across the country, particularly in northern and south-west regions, pockets of villages have been converting to “litchi villages”. For example, one litchi village of Dinajpur district was producing litchi worth 78 million BDT/year within a very short time. Similarly, another big litchi village of Pabna district-Jainagar produced litchi worth 1,115 million BDT/year, bringing a huge cash return for the gardener and supporting a big back-up business for packaging and marketing of the fruits, thus creating many seasonal jobs. Additionally, gardeners are also earning money by selling litchi saplings. In contrast, field crops, except maize, only return 23,400-39,000 BDT/ha/year. Moreover, fruit trees like litchi are assured crops (as they give fruit every year) whereas field crops often suffer from climatic hazards. Along with litchi many other fruit gardens like mango and papaya are helping farmers to enhance income and escape the notorious cycle of poverty. However, only land owners and lessee businessmen are getting this benefit directly.

Off-farm: Scope of off-farm activity is lower in comparison to other Farming Systems. As the area is mostly agrarian, virtually no big industries have been developed, except some mechanized rice-mills and potato cold storage. So different services jobs like seasonal farm labor, work in mango and litchi gardens, small business, rickshaw pulling is available but not sufficient for the whole year. Moreover the wage rate is also lower than in industrialized areas.

Labor Migration: Labor migration takes place to other parts of the country, because the area has little scope for jobs. Rickshaw pulling in districts and big cities is one of the lucrative jobs for the able bodied young, as it can bring a good daily income, helping the family to survive and building savings for other small investments. However, as the level

of education in this sub-system is low, people are deprived of opportunities of working overseas. Thus national facilities should be created so that young people from this sub-system have opportunities for foreign employment, to help raise their families out of poverty. Foreign remittance has a major role to markedly increase family income and to defeat poverty.

Credit/Micro-credit: A good number of farmers have been trained by WRC of BARI on wheat production technology and use of balance fertilizer, particularly in Dinajpur area, but farmers are not adopting this. One of the important reasons for non-adoption is severe dearth of cash for purchasing of fertilizer at the proper time along with other reasons. So, timely credit with reasonable interest (discussed in earlier section) rates have a crucial role to play in increasing crop productivity and reducing poverty.

Maize-T.aman rice Farming Sub-system

Hybrid maize is an emerging high-value cereal crop in Bangladesh. Economically, hybrid maize is by far more profitable than Boro rice, wheat, or most other competing winter season Rabi crops. Maize cropping is expected to expand by about 15 % per year, driven by a booming poultry industry, although that industry faced a temporary setback in 2007-2008 due to avian flu (Ali *et al*, 2008). Moreover, alternative uses of maize may increase in future. Maize-T.aman (monsoon) rice is the major cropping system. Maize has played a major role in boosting farm productivity where other crops have yielded poorly due to light soil and water crisis. Maize cropping helps a large number of north-west area farmers escape poverty, this region being one of the most poverty-affected areas, of Bangladesh (WFP, 2006). All categories of farmers have come forward to cultivate maize considering it as a best bet for the area and as a cash crop. A typical farmer of Lalmonirhat cultivates 0.5 ha Rabi hybrid maize and gets an average yield of 6.2 t/ha (see Box 14). Additionally its huge biomass (10 t/ha) supplies high quality cooking fuel for the family, because fuel is a scarce resource in this farming sub-system.

Box 14. Hybrid maize cultivation for boosting production and poverty reduction in NW Bangladesh

Farmers of Patgram, Lamoniirhat generally grow some vegetable, jute/aus rice in Kharif-I and T.aman or peanut in Kharif-II season but this has very low productivity because of high land light soil and excessive weed infestation. Except for big farmers nobody has food security or economic solvency. Suddenly, hybrid maize cultivation was introduced through BARI, CIMMYT and Doel, a business farm, and greatly changed the economy of the locality, because of high productivity of maize with a high market price. A typical farmer of Patgram planted hybrid maize in his 0.5 ha of land in November and harvested 6.2 t/ha maize grain in early April. By selling it in the local market he earned 27,900 BDT/ha, this being a very big income to receive at one time. To get this income his cost was 15,000 BDT/ha. From the proceeds of maize he purchased 700 kg paddy rice for 5,600 BDT for his family food security, and procured a heifer (female calf) for 8,000 BDT as a future investment. The remaining money was utilized for his family and purchasing inputs.

In the following section the Maize-T.aman Sub-system is analyzed in terms of yield gap, adoption of modern technology, poverty escape pathway.

Yield gap: Among Asian countries, Bangladesh has the highest average maize yield. Yield gap (Fig. 9) between best research yield and best farm yield is only 17 % (2 t/ha), however, the difference between best farm yield and average farm yield is large, at 41 % (4.1 t/ha). Crop models indicate that Rabi maize in Bangladesh has the potential to yield up to 23 t/ha under non-limiting resource supply and by advancing the planting time (Ali *et al.*, 2008). The reasons for the yield gap in hybrid maize is summarized by Ali *et al.* (2008) as; late planting of Rabi season maize, use of recycled hybrid seed, unsustainable soil management in maize-rice systems, soil fertility depletion, irrigation difficulties and drought, high price of mineral and organic fertilizers, high cost of hybrid maize seed and credit shortage, often low market price of grain due to bird flu of poultry and lack of information and training. Through timely planting (before 15 December), use of balanced fertilizer including boron (B) application, timely irrigation and weed management, quick sun drying and selling/storing of maize grain yield gap could be reduced substantially, because the environment and market is quite encouraging for advancing maize. For improving soil fertility, summer mungbean could be cultivated for both grain and brown-manuring purposes. Brown manuring improves soil fertility and facilitates better yield in succeeding T.aman rice and maize crops. Through minimization of the yield gap farmers could have a crop of 8 t/ha (average farm) under the existing technology. However, this needs a block approach from sowing to harvesting under the supervision of knowledgeable persons.

Adoption of Modern Technologies in Maize-T.aman rice Sub-system

Maize is a fortunate crop in Bangladesh, as from the beginning farmers have widely accepted hybrid maize due to its high yield, ease of cultivation, less disease and pest incidence and high market demand for supplying feed to rapidly expanding poultry farms (Table 12). However, due to high price of hybrid seed some farmers are not using quality seed, sometimes using recycled hybrid seed. However, it is assumed that farmers are applying balanced fertilizers only 30 % of the maize area, which has a negative impact on the yield of maize. In light soil regions like Rangpur and Lalmonirhat application of boron (B) is crucial to get optimum yield (OFRD, 2007). Even for other soils application of 2 kg B/ha also increases maize yield, as probably most of the available hybrid maize is susceptible to B deficiency.

In the case of T.aman, HYV varieties have been adopted over only 55 % of the area because of its long duration and coarse quality grain. Many farmers prefer fine quality traditional T.aman which has better taste than HYV even though it's yield is a bit low. Application of balanced fertilizer in T.aman is very low; rather farmers mostly use

nitrogen fertilizer only. Quality seed is in short supply, and farmers do not do rouging to get quality seed from their own fields. Hence, farmers' motivation is important to produce quality seed, as government agencies have only limited capacity to supply quality seed in the T.aman season.

Table 12. Adoption of modern technology in Maize-T.aman rice Sub-system in percent area

Crop	HYV	Hybrid variety	Balanced fertilizer/IPNS	Quality seed
Maize	0	100	30	80
T.aman	55	N/A*	5	20

* Not available

Poverty escape pathway

One of the poorest and Monga-affected areas is located in this farming sub-system (WFP, 2006). Land distribution is uneven. There are a large number of landless and marginal farmers having little scope for off-farm activities. As agriculture alone cannot reduce their poverty, multiple approaches should be taken. Some of the options are discussed below.

Intensification and diversification: By reducing the yield gap and sustainable management of soil yield of maize could be improved further. For sustainability and productivity inclusion of mungbean is important as a succeeding or relay crop within maize. This would bring a substantial change in productivity, profitability and household diet pattern. Even cultivation of short duration yard long bean (*Vigna unguiculata, subspecies-sesquipedalis*) in maize fields as a relay crop using left-over maize plants as stakes could improve household diets and bring additional income. Experimental results suggest that both mungbean and yard long bean could fetch a good income paving the path of enhanced system productivity and poverty reduction (OFRD, 2008). Moreover, it has been clearly demonstrated, and adopted by a large number of farmers, that cultivation of short duration vegetables at the time of maize planting as an intercrop is remunerative. As maize is a spaced crop its two line canopy covers the inter-row space only after 45-50 days age. In the meantime a short duration vegetable like red amaranth, spinach, French bean, coriander leaf as vegetable could easily be grown and harvested (Ali, 2008). Use of maize shellers has helped many small farmers-cum-businessmen to increase their income significantly in maize growing areas.

Conservation agriculture for cost saving: By using one pass PTOS seeds of maize could be sown very quickly before drying of post-rainy season residual soil moisture. The inclined plate device in the seed box helps to sow the maize seed without any damage (Dr

A Wahab, FMPE Division, BARI, personal communication). Bed planting of maize also reduces cultivation cost and facilitates better water management, resulting in increased yield (personal communication Dr M Israil, Dr A Khalaque and Dr M Illias, WRC, Rajshahi). Use of appropriate machinery helps to reduce cultivation cost as well as to sow the seed timely.

Emphasis on other enterprises of the farming system: The area also has potential for homestead gardening, bamboo production, commercial fruit gardening, beef fattening, sheep and goat rearing and poultry farming. In the light soils of the homestead area nothing grows more vigorously than bamboo (see Box15).

Box 15. Bamboo cultivation in unused homestead and marginal land for income generation

A bamboo clump can give at least 20-25 salable bamboo poles each year having a value of 2,000 BDT/year. A Patgram farmer earns about 20,000 BDT from his 10 bamboo clumps on his 0.026 ha homestead area. Moreover he gets most of his cooking fuel from bamboo branches and fallen leaves. However, bamboo has been recently affected by a fungal disease affecting growing tips. Application of fungicide at the base of the bamboo clump after cleaning and subsequently applying fresh soil in March-April can alleviate this problem (BFRI, 2013). A huge amount of bamboo is exported to Dhaka and construction sites of different areas, so this has also created a good effect on off-farm employment around the year. Thus bamboo cultivation and the business it generates have a role in reducing poverty under this sub-system.

Off-farm: Scope of off-farm income is very limited except for some seasonal work in agriculture, some jobs in rice mills, small business, extracting small stones from rivers and rickshaw pulling. Some jobs have been created in maize procurement, processing and grading by a private company, Doel, with private bank finance. However, a few people are also working in nearby Burimari land port, where Indian and Bhutanese goods (mainly fruits) are imported. As the land distribution is uneven, there is a large number of jobless youth. Creation of maize based poultry feed industry could be a viable option in this area, because of ready availability of maize.

Labor migration: This should be seriously looked into for employment of a large number of jobless youths. Hands-on training and other facilities should be created by the government and large NGOs, so that the young could compete for overseas jobs. Seasonal and permanent/semi-permanent migration within the country occurs for agricultural labor, construction work, rickshaw pulling and other small jobs, which can contribute to a good proportion of family income.

Credit/micro-credit: Due to poverty and a serious dearth of cash many landless and marginal farmers sell their labor in advance at 50 % less than market price. Moreover,

sometimes they become bound to take loans from private money lenders, which often leads to keeping them permanently under extreme poverty. Credit and supervised micro-credit with soft conditions could have a role to engage the people in some income generating activities. It is reported that a huge amount of agricultural loan money is sitting idle in the national bank and private banks for lending to small farmers.

Potato-/relay maize-T.aman rice Farming Sub-system

In NW Bangladesh use of potato is next to rice in the daily diet. It has a high economic value, having a good tuber yield in light alluvial soils under dry winter weather conditions. In winter, potato gets the highest preference from farmers. Its production cost is high and is probably the highest seed (tuber)-requiring field crop (1,500-1,800 kg/ha). For commercial purposes exotic Holland varieties released by BARI are cultivated but in a sizeable area different local cultivars are grown for home consumption and the latter has higher keeping quality under ambient temperature. Farmers generally cultivate potato after the harvest of T.aman rice or jute, in areas ranging from 0.02 to 2-3 ha land. Big businessmen and potato cold storage owners also cultivate potato by taking seasonal leases in a large area (see Box 16). Potato employs a large number of people for its production and cold storage. In NW Bangladesh the potato cold storage business is one of the viable agriculture based industries, but it is often hampered by acute electricity shortage. Potato is the only vegetable which is used around the year by both poor and rich people.

Box 16. Potato, a short duration remunerative crop for livelihoods improvement and poverty reduction

A small farmer of Rangpur planted 0.3 ha of potato after harvest of T.aman rice in early December. By borrowing from a relative he purchased seed of Cardinal variety and fertilizers from the local market. He had to spray fungicides five times to control early and late blight of potato and he irrigated eight times in the crop season. He harvested the potato tuber manually in late February (88 days) and got a yield of 29 t/ha. He earned 232,000 BDT/ha at a cost of 100,000 BDT /ha, having a net return of 147, 030 BDT /ha within 88 days. After selling he returned the loan money to his relative. This sale proceeds has helped him a lot to reduce poverty and to invest in future cropping and livestock farming. Thus potato is a key crop contributing to the livelihoods of the many people in this farming sub-system. In this part of the world the potato crop dominates the Rabi season economy.

In the following section the Potato-/relay maize-T.aman rice Farming Sub-system is analyzed in terms of yield gap, adoption of modern technology, poverty escape pathway.

Yield gap: In potato (Fig 9) the difference between best research yield and best farm yield is relatively small, at 24 % (11 t/ha), but the gap between best farm and average farm yield is 41 % (14 t/ha). The latter gap is attributed to low quality seed, unbalanced use of fertilizer, untimely irrigation and inadequate fungicidal spraying against late blight disease. High quality tissue-cultured virus-free potato seed should be ensured at reasonable price. More hands-on training could be arranged for sanitation and the complete production package. Endeavors to develop virus and late blight resistant potato cultivars should be strengthened at public and private level.

Adoption of Modern Technologies in Potato-/relay maize-T.aman rice Farming Sub-system

Potato is a highly deserving cash crop to farmers. They try to collect quality seed and plant it for better yield and to avoid disease infestation, but there is a dearth of quality seed in the market. Virus and disease free seed production is a challenge even for public institutions under Bangladesh conditions. About 50 % of farmers use quality seed (Table 13). For cultivars, 80 % farmers use HYV and the remaining 20 % prefer different types of local varieties. Those local varieties are lower yielding but their taste is preferred by local people; moreover their keeping quality under ambient conditions is quite satisfactory. Farmers can keep seed tubers of local varieties in their houses, so they can avoid dependency on the market. Farmers often use excessive fertilizer in potato to get higher yield, but it has been shown that over-fertilization is not profitable. For T.aman rice, farmers have adopted HYV in 60 % of the area, including short duration coarse grain variety BRRI Dhan 33. However, most farmers do not apply balanced fertilizer, and quality seed is used only in 20 % of the area.

Table 13. Adoption of modern technology in Potato-/relay maize-T.aman rice Farming Sub-system in percent area

Crop	HYV	Balanced fertilizer/IPNS	Quality seed
Potato	80	30	50
T.aman	60	5	20

Poverty escape pathway

Intensification and diversification: The sub-system has scope to intensify the production of potato by better adjusting with short duration T.aman rice. Early planting favors better vegetative growth and ultimately higher tuber yield. Quality seed use is crucial for potato, but it needs joint efforts of government and commercial seed producers. Balanced fertilizer application will lower costs without significant yield loss.

Researchers and farmers are intensifying and diversifying this sub-system by relaying of hybrid maize or planting Kharif maize after the harvest of potato. Potato gives 20-21 t/ha maize equivalent yield instead of 9 t/ha maize (see Box 17). Kharif maize is harvested within 110 days with only urea application due to the residual effect of P and K applied

Box 17. Significant enhancement of total productivity through relay cropping of maize with potato

Growing of maize with potato as a relay crop is gaining popularity among the farmers. By this method farmers are utilizing time, space and residual effects of phosphorus and potash fertilizers. Only urea is applied to maize. They plant maize seed after potato crop is 35 days age old. After harvest of potato at 85 days maize continues to grow and is harvested in April. If sole potato is grown the farmer gets 29 t/ha yield and if sole maize is grown the farmer gets 9 t/ha. But when both are grown as relay or intercrop the farmer gets 27 t/ha potato plus 8 t/ha maize. Thus total productivity as well as profitability of the land is increased substantially with small additional cost (Ali *et al.*, 2008; Islam *et al.* 2008). This significantly improves system productivity and profitability.

to potato. Thus about 4-6 t/ha maize is obtained with small cost within 110-120 days.

Emphasis on other enterprises of the farming system: As the land and homestead areas are comparatively bigger than in central Bangladesh there is substantial scope of beef fattening, small dairying and goat and sheep rearing. Recently, a market for broiler chicken has been created in these villages. Small and moderate scale broiler chicken could bring substantial change to farmers' income. By rearing 500 broiler chicken per batch a five member family could easily cover their livelihoods (BLRI, 2008), as broiler chicken becomes marketable within 5-6 weeks. Moreover there is scope for fish culture in ponds and seasonally inundated lands. Banana production has become a source of income for many farmers. It has high market demand around the year and is mainly transported to Dhaka and other cities in central Bangladesh.

Off-farm: Compared to other sub-systems this sub-system has more scope for off-farm income, including service, small engineering industry, potato cold storage, transport including rickshaw pulling and small business. However, as wage rate is low, families could not be supported by this income. With illness or other problems families may easily fall into hard core poverty. Thus wage rate should be just and fair and free health care facilities are very important to maintain human labor productivity.

Labor migration: Labor migration would continue to play an important role in increasing farmers' income and reduction of poverty. Due to excess population there is seasonal job scarcity and the local wage rate is also low. In particular, overseas migration could bring a big change in the income and livelihoods of families. Government/NGO

should provide hands-on training, including language training for the target country. This would improve wage prospects of overseas workers, and hence their level of remittance.

Credit/Micro-credit: This facility needs further promotion and implementation, as discussed previously.

Vegetable-T.aman rice Farming Sub-system

Vegetables are part of the daily diet for Bangladeshi rich or poor alike. Vegetables are palatable, affordable and easy to grow in crop fields, homesteads and even on trees/roofs around the year in Bangladesh environments. Moreover due to an increase of different health problems urban people's diet has substantially changed, such that they are taking more vegetables and salad to remain healthy. Vegetables also play a major role in the livelihoods of a large number of farming families. Vegetable crops can produce yields within a very short time (25-30 days), while long living vegetables like pointed gourd continue to give fruit as the vine grows. Early vegetables realize a good profit within a short time (see Box 18) contributing substantially to farmers' livelihoods. In general, farmers cultivate T.aman rice during the monsoon season and in Rabi and Kharif-I seasons farmers plant different types of vegetables after the harvest of rice. Rice ensures cereal food security and vegetables improve the household diet and contribute to cash income to support livelihoods.

Box 18. Early vegetable a great stride to defeat poverty

A farm family of Bogra, comprising husband, wife and three children, has 0.5 ha of cultivated land of which 0.12 ha is located near a small river having sandy loam flood free soil. Here the family cultivates early vegetables. They plant cabbage in September and harvest it at the end of October to early November. They only get one-fourth (20 t/ha) of normal season yield but market price is 10 times higher (30 BDT/kg) during this period. The wholesaler procures the cabbage heads from the field and sends them to Dhaka for marketing. The family earns 600,000 BDT/ha with a cost of 110,000 BDT/ha and gets a net benefit of 546,000 BDT/ha within 60-70 days. However, production cost of early cabbage is 40-45 % higher than in the normal winter season. For managing excessive rain and pest and disease attack the crop needs to be sown on beds with good drainage, shading and increased pesticide application. This income from early cabbage brings great relief to this family, allowing them to afford required inputs, meet children's education needs and purchase livestock. Vegetable farming has helped this family escape poverty.

Yield gap: In brinjal (eggplant) the yield gap (Fig. 8) between best research yield to best farm yield is 40% (20 t/ha), while the gap between best farm to average farm is 43% (13 t/ha). Pests, weeds and nutrient deficiencies contribute to the yield gap.

For tomato the difference between best research yield to best farm yield is 30% (30 t/ha), while the gap between best farm to average farm is 62% (50 t/ha).

The gap is mainly attributed to time of planting and crop management. Often virus attack causes major yield loss.

In cabbage the yield gap between best research yield to best farm yield is 28% (35 t/ha), while the gap between best farm to average farm is 44% (40 t/ha), with time of planting and management being key factors for this large yield gap.

In cauliflower the yield gap between best research yield to best farm yield is 22% (10 t/ha), while the gap between best farm to average farm is 49% (17 t/ha).

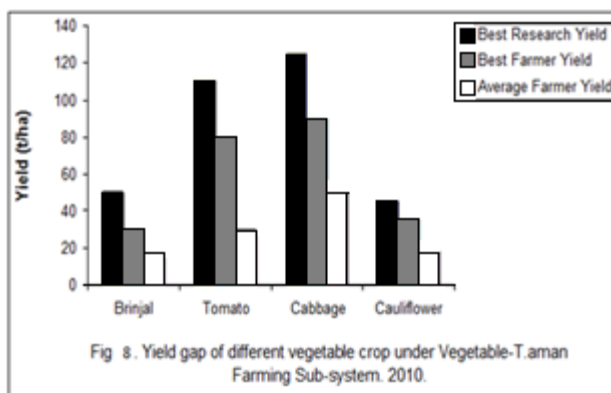
Moreover, sometimes environmental effects, such as sudden excessive rainfall, can markedly affect vegetable yield, which is one of the causes of low average farm yield.

Adoption of Modern Technologies in Vegetable-T.aman rice Farming Sub-system

Vegetable farmers try to procure hybrid and good quality seeds so that maximum yields can be harvested. Hybrid vegetable and water melon seeds have a big market in Bangladesh. Each year Bangladesh imports much vegetable seed from different countries including Japan, Thailand, Taiwan and India. Thus adoption is high for hybrid seed of tomato, cabbage and cauliflower when it is available to farmers (Table 14). But for brinjal no hybrid seed is available yet. Balanced fertilizer application is also encouraging in vegetable as it is regarded as cash crop with high incentives. Very few farmers have accepted IPM for vegetables but recently use of sex-pheromone for different cucurbits and brinjal has increased through the efforts of different research and development agencies. Its success depends on availability of pheromone traps in the local market.

Table 14. Adoption of modern technology in Vegetable-T.aman rice Farming Sub-system in percent area.

Crop	HYV	Hybrid	Balanced fertilizer/IPNS	IPM/ICM
Brinjal	100	-	60	3
Tomato	20	80	70	1
Cabbage	-	100	60	2
Cauliflower	20	80	65	2



Poverty escape pathway

Intensification and diversification: Early and timely planting is important to get higher yields and market prices. Late sown vegetables often become unsalable or bring a negative income. Hence, for intensification, T.aman should be planted earlier and preferably using a short duration variety like BINA7 (fine rice) and BRRI Dhan 33/39. For maximizing vegetable production from the same land innovative farmers plant sweet gourd after one month of cabbage planting, then sow stem amaranth/red amaranth two times and after harvesting of amaranth they sow a short duration T.aman rice crop. In this way farmers are getting higher income from the same land, but it needs intensive supervision and suitable soil management including application of compost.

Use of IPM: IPM is more important for vegetable production than for other crops, as vegetables are consumed with less boiling and often without cooking, such as in salad. Use of long lasting pesticides may affect human health. Pheromone traps in cucurbits (a major vegetable group) works excellently: it reduces pest control cost, increases yield and ultimately permits a very lucrative return (see Box 19).

Box 19. Pheromone trap for effective controlling of pest in sweet gourd – a way of safe food production and income maximization

A farmer of Rajshahi District planted sweet gourd in his 0.36 ha land, used pheromone traps in 0.26 ha and in the remaining 0.13 ha he used his usual pesticide to control fruit fly. He was astonished to see the dramatic result. He got 37 t/ha in the pheromone trap-fitted field and only 20 t/ha in the pesticide sprayed plot. Fruit flies destroy the small growing fruits and often small deformed fruits are obtained in non-pheromone plots. But in pheromone trap field most flies are trapped and killed, so there is limited effect of the pest on fruit. His production cost was 44,616 BDT/ha for the usual pesticide treated plot and 43,446 BDT/ha for the field with pheromone traps. Thus he got 162,084 BDT/ha net return from pheromone trap plot and only 66,846 BDT/ha from pesticide applied plot. Farmers are very enthusiastic to use pheromone traps for cucurbits and thus government services and businessmen should ensure their availability and quality at the local level.

Bed planter for land preparation: Vegetables are usually planted on beds, particularly where seedlings are transplanted. By using a power tiller operated bed-former, beds can be formed in single/double pass operation. This would reduce land preparation cost and thus increase profitability of vegetable production. Government support to promote availability of good quality bed-formers is needed.

Emphasis on other enterprises of the farming system: Beef fattening, poultry rearing for eggs and meat, dairying, fish culture, fruit production, fruit and timber tree nursery all

could bring increased returns to the farm family. It would also diversify and minimize risk of total dependence on vegetable or field crop production.

Off-farm: Off-farm employment will remain a key contributor to the income of landless, marginal and small farmers. As land holding size will likely further decrease off-farm opportunities should be promoted. However, with the improvement of overall livelihoods and per capita income off-farm scope will increase and wage rate will also be increased. Presently, major off-farm activities are for agricultural labor, construction work (both public and private), small industry, rickshaw pulling, other service sectors and small business.

Labor migration: As earlier discussed this could bring substantial increases in farm household income and contribute to poverty reduction.

Credit/Micro-credit: Increased availability of credit on reasonable terms will also assist income generation and employment creation, as earlier discussed.

Pulses/garlic/onion-Jute/T. aus/Fallow-T. aman rice/Fallow Farming Sub-system

North-west area farmers try to cultivate different types of crops on their land. Crop type varies due to price of products and also for the sake of crop rotation to optimize crop yield. Pulses are regarded as protein for poor people, but irrigated agriculture, particularly Boro rice, has replaced most of the pulses creating nutritional imbalance in the diet of the general population. Presently, the daily per capita pulse availability is only 4g as against the FAO-recommended 45 g. A large part of Rajshahi District, including the High Barind Tract (HBT) area follows this farming sub-system (Fig. 2). In the drought prone HBT area monsoon T. aman is the major crop, followed by chickpea grown on residual soil moisture or the land remains fallow. In irrigated areas onion/garlic is preferred in the Rabi season and this is regarded as a cash crop. Garlic is also grown under zero tillage mulched conditions. Per unit return from pulse is very high, as input costs for rainfed legumes are low – they need little or no fertilizer application. In the floodplain area pulse crops are often followed by jute or Aus rice. Returns from jute can be high, and the fallen jute leaves improve soil fertility. An example of a small farmer growing chickpea is given in Box 20.

Box 20. Chickpea– a miracle crop for drought prone rainfed area: crucial to livelihoods and sustainability

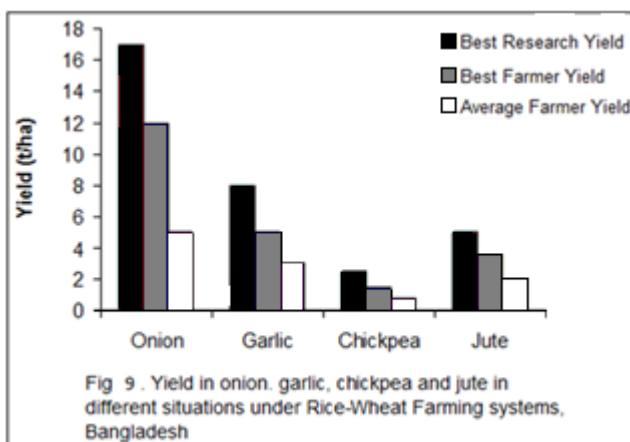
A typical small farmer of the High Barind Tract area, Naogaon District lives in a mud wall, tin-roofed house and cultivates 0.5 ha of land. He has a five member family of which his two children attend the local primary school. His lands are rainfed, but he can partially irrigate from an adjacent pond. But in summer, as most of the pond dries up water become a serious problem even for household needs. He mainly cultivates T.aman rice during the monsoon season and tries to sow 0.3 ha chickpea in the post-rainy season relying on residual soil moisture. As chickpea is a deep rooted crop, once germinated and established it gives some yield. His family loves chickpea; they use its leaves and young shoots as a vegetable and they get about 1 t/ha grain yield. Chickpea by-products are used as palatable cattle and goat feed. His cultivation cost is only 13,338 BDT/ha and return is 60,528 BDT/ha. Being a legume chickpea cultivation also improves soil quality. But its cultivation is often hampered when the monsoon ceases earlier than normal. The family uses chickpea in different forms, such as for dhal and for frying in the month of Ramadan. The farmer keeps one-third of the chickpea grain for his family's consumption and the rest is sold in the market. The farmer believes that for this rainfed dry area chickpea is a miracle crop.

Yield gap: In onion the yield gap (Fig. 9) between best research yield to best farm yield is 29% (5 t/ha), while a large yield gap of 58 % (7 t/ha) remains between best farm to average farm yield. Minimizing this gap is crucial to reduce import of onion.

In garlic the yield gap between best research yield to best farm yield is 38 % (3 t/ha), while the gap between best farm and average farm yield is quite large, at 67 % (2 t/ha).

For chickpea, the yield gap (Fig. 7, shown above) between best research yield to best farm yield is 40 % (1 t/ha), while the gap between best farm to average farm is 47 % (0.7 t/ha). Yield gap is due to late planting, poor plant stand, drought stress, molybdenum deficiency in acidic HBT soil (Johansen *et al.*, 2007), Botrytis Grey Mould and pod borer attack (Ali and Rahman, 2006.)

In jute the yield gap between best research yield to best farm yield is 30 % (1.5 t/ha), while the gap between best farm to average farm yield is 43 % (1.5 t/ha).



In lentil the yield gap (Fig. 7, shown above) between best research yield to best farm yield is 27 % (0.6 t/ha), while the gap between best farm to average farm yield is 50 % (0.8t/ha).

Good seed and planting time advancement through cultivation of short duration T.aman rice along with application of recommended fertilizer, disease and pest management could minimize the yield gap in lentil (BARI, 2011). Chickpea pod borer could be managed by using IPM including use of bird perching (Ali *et al.*, 2006).

Adoption of Modern Technologies in Pulses/garlic/onion-Jute/T.aus/Fallow-T.aman rice/Fallow Farming Sub-system

Except for lentil and garlic acceptance of modern released varieties in different crops is encouraging (Table 15). Seed of officially released lentil varieties are generally not available at field level across the country. For onion use of balanced fertilizer is higher and sometimes excessive fertilizer is applied because it is a cash crop and good yielder. However, use of *Rhizobium* inoculum in chickpea or lentil is rare, as inoculum is not available at farmers' level; moreover, often its effectiveness is not clearly observed. For different disease and pest control farmers still depend on chemical pesticides. But for pod borer control in chickpea a few farmers use bird perching.

Table 15. Adoption of modern technology Pulses/garlic/onion-Jute/T.aus/Fallow-T.aman rice/Fallow Farming Sub-system in percent area (data source: local farmers and scientists)

Crop	Modern variety	Balanced fertilizer/IPNS	IMP/ICM
Onion	70	60	3
Garlic	5	40	1
Chickpea	70	10	2
Lentil	30	20	2
Jute	70	30	5

Poverty escape pathway

Intensification and diversification: There is considerable scope for intensification and diversification within this farming sub-system. Onion production is considered by farmers as a profitable enterprise within a short time, so they try to take proper care of the crop through applying fertilizer and irrigation. Innovative farmers produce onion seed as this is a costly item and it brings a large profit compared to onion bulb production for consumption (see Box 21).Chickpea and lentil yields could be increased by adjusting time of planting by cultivating short duration rice varieties. Management of pod borer

could increase chickpea yield by 15-20%. Bird perching can reduce the larval population markedly with small cost compared to pesticide spray. Chickpea intercropped with linseed and/or barley can also reduce pod borer attack and minimize risk. Need-based spraying of fungicide in lentil could reduce fungal disease attack and ensure reasonable yield. Many people abandoned pulse production due to its yield instability and risk of yield loss. But risk could be minimized if recommended practices are followed (Johansen *et al.*, 2008). For garlic, mulching, balanced fertilizer with irrigation and proper fungicide spray ensure good crop growth as well as yield level. Particularly, application of sulphur fertilizer has a good effect on yield of both onion and garlic.

Box 21. Onion seed production for boosting income

A farmer of Godagari, Rajshahi District cultivated onion for seed production in 0.26 ha. Onion seed production needs much care and cost of cultivation is also higher compared to bulb production. The farmer could get 600 kg seed/ha having a sale value of 668,538 BDT/ha and incurring a cost of 132,600 BDT/ha. Whereas, when he cultivated onion for bulb he used to get 12 t/ha yield with a sale value of 160,446 BDT/ha at a cost of 78,000 BDT/ha. Thus his profitability jumped to 453,492 BDT/ha more in comparison to normal bulb production. This helps him a lot to purchase food, inputs, and other necessities, and to invest more in his children's education.

Conservation agriculture for cost reduction and less turnaround time: By using one pass PTOS/ zero/strip tillage planter/ bed planter turnaround time could be effectively reduced. This is because timely planting before the soil dries is crucial for proper seed germination in rainfed areas. Different crops including jute, lentil, chickpea and onion could be sown by PTOS, and it would reduce the cultivation cost by one third compared to normal tillage. However, better calibration capability of seed metering devices and availability of quality machinery is important for large scale adoption. Along with reduction of cultivation cost, machinery use also increases yield as it permits uniform germination.

Emphasis on other enterprises of the farming system: As the sub-system is located in the low rainfall and driest part of Bangladesh different fruits like mango, ber, litchi perform well here (Fig. 2). Ber is a drought tolerant fruit tree and bears fruit each year, including the year of planting. (see Box 22). Drumstick (*Moringa oleifera*) is miracle tree due to its medicinal and nutritive value. Although its leaves are more nutritious than pods, pods have an export market and throughout the country it is liked and sold at a high price. It is a drought tolerant tree and could be grown anywhere except moist land without much care. Drumstick can also bring good income for the household, as this sub-system area has Baromasi (multiple time harvest) cultivars, bearing pods when they are not available in other parts of the country. Beef fattening, poultry rearing both for egg and

meat, dairying, pond fish production, fruit production, fruit and timber tree nursery all could bring good returns to the farm family.

Box 22. Creating ber garden and nursery businesses to reduce poverty

In highland and drought prone areas, creation of fruit gardens is gaining momentum rather than traditional field crops. Because of high population growth and rapid income enhancement of a significant number of people (mainly urban) demand for fruit has greatly increased. However it needs 0.012 ha to a large area of land for establishing a mono/mixed garden. Improved Ber (cv. Apel Kul and BAU kul) cultivation has attracted a large number of youth and farmers due to its quick production and good market demand. From a one ha Ber garden 156,000 -163,800 BDT/year net benefit could be obtained, at a cost of only 78,000 - 85,800 BDT/ha. Fruit bearing starts even from the first year, and profit gradually increases and production cost reduces. Additionally, the gardener also gets a good income (15,600-31,200 BDT/ha/year) by selling seedlings (graft). Each year after fruit harvest branches are pruned, providing cooking fuel for the household.

Off-farm: In drought years agricultural productivity sharply decreases resulting in reduction of seasonal labor opportunities. Drought also reduces the productivity of widely reared animals like cattle, goat and sheep because of scarcity of natural grass and feed. More mango juice processing could easily be established in this part, but probably this needs government patronization. Off-farm income will remain as a key contributor to income of the landless, and marginal and small farmers. As land holding size is likely to further decrease off-farm opportunities should be promoted

Labor migration: As discussed earlier, this could bring substantial change in farmers' income and greatly helps in poverty reduction.

Credit/Micro-credit: The benefits of more accessible microcredit were discussed earlier.

Infrastructure and market development: Farmers often lose income because of poor infrastructure, remoteness of the area and unfair marketing. Bangladesh is still lagging far behind in development of fair marketing channels, so that both grower and consumer are benefited. Presently, major profits go to wholesalers.

Trends and Issues in Rice-Wheat Farming System

Average farm size will continue to decrease with fragmentation of land among the family members along with utilization of land for civil works. The number of absentee land owners will further increase, as wealthy and powerful urban citizens purchase village land to enhance their power base and as an investment option. Due to land scarcity, land price is increasing dramatically every year. Instead of sharecropping, there will be a preference for cash lease arrangements, as this benefits and satisfies both parties.

Through the lease process more commercial and big farms may develop in future leading to commercial agriculture. Sharecroppers and marginal farms will be reduced if not diminished. The practice of sharecropping has some advantage for poor farmers, but has the disadvantage of perpetuating traditional and subsistence operating systems where promotion of innovation is difficult.

In general soil fertility decline will continue due to unbalanced use of mineral fertilizers, non/sub-optimal application of organic manure and complete removal of crop-residue from the field. Yield of rice, wheat, potato and maize may decrease due to declining soil fertility. Both surface and underground water resources will decrease due to decreased flows of major rivers, siltation of big ponds and excessive use of groundwater for Boro rice cultivation. Moreover due to urbanization and industrialization water requirement will largely increase in urban and peri-urban areas. It is assumed that due to climate change rainfall of the area is also decreasing; in particular its distribution is becoming uneven causing sudden floods, drought and crop loss. There will be increasing levels of mechanizations for tillage, harvesting and processing. Already most land tillage is done by two wheel power tiller and small area by tractor. The typical crop based enterprise is expected to shift towards horticulture, poultry, dairy, sheep and feed production. Because of rapid urbanization, even at sub-district levels, demand for these products would be more remunerative. Private entrepreneurs and big NGOs would come forward in those sectors targeting both the domestic and export markets. Already BRAC, Grameen Bank and other big NGOs undertake different agricultural and food processing businesses. Moreover, wheat area may further decrease due its susceptibility to high temperature at the reproductive stage, unless heat tolerant varieties are developed. On the contrary, maize area may further expand, the main driver being the development of the poultry and fish culture sectors. Different agro-forestry species are likely to spread due to their increasing demand, use and profitability. This would also facilitate the development of more off-farm work with increased wage rates.

Overall, most farmers are expected to achieve both food security and increased household incomes by the year 2030 (Dixon *et al.*, 2001). There may be a gradual decline in poverty among the landless and marginal as wage rates rise, even if opportunities for agricultural employment are reduced. Continuous improvement in infrastructure, particularly roads and markets, will occur. Decentralization will bring decision making closer to farm, and women would have a greater role in local governance. Funding of public sector research and extension will continue until the development of private and NGO research capabilities. But NGO and private sectors may play a bigger role in seed production, adaptive and participatory experimentation, advisory services and policy making, which may improve the efficiency of the dissemination of technical information. Mobile phone based technology may play a greater role in disseminating important messages and technology among the people. Moderate growth of the off-farm rural economy is expected.

Priorities for Rice-Wheat Farming System

In order to make substantial progress in reducing poverty in this system, the following household strategies to escape poverty need to be supported (in order of importance): diversification, increased off-farm income, intensification of the present system and exit from agriculture. There are a number of worthwhile options for supporting these poverty reduction pathways that will also have direct impacts on agricultural growth, although the opportunity cost of labor will be a critical determinant of the variability of interventions.

Of high priority is to tackle the resource conservation issues, such as declining soil fertility, and surface and ground water depletion particularly in Boro rice land. Research is being conducted to develop technologies that can improve the level of soil fertility, which has fallen as a result of the continuous, intensive cereal production practiced for a long time (Dixon *et al.*, 2001). However, governments sometimes pursue policies that work at cross-purposes with such research efforts. For example, government is heavily subsidizing urea fertilizer whereas price of P, K and other fertilizer is high and their quality is not often satisfactory. This causes a serious imbalance of fertilizer application among most of the farmers resulting in severe mining of other nutrients, particularly K, which may damage long term soil productivity. In the Boro rice growing areas aquifers are continuously receding causing failure of many pumps in drought years, and aquifers are not recharging from rain water (Sevaraju *et al.*, 2006). So, irrigation costs are increasing with serious concerns for the future because of predictions of low rainfall and high temperature due to climate change. But using the AWD method in Boro rice could reduce irrigation cost by 30 %. Through direct seeding of rice, particularly Aus and Aman, by strip tillage/PTOS, irrigation requirement may be substantially reduced. Practice of bed planting, strip tillage, zero tillage, use of plastic pipes to reduce water loss, residue retention, mulching, etc. could reduce the water requirement of different crops. Greater cultivation of deep rooting crops like chickpea, barley and linseed could effectively reduce the irrigation needs with a reasonable yield along with sequestration of carbon deep into the soil (Ali *et al.*, 2009). Government policy on electricity charge for irrigation should be revised to reduce water loss in Boro rice (discussed in Rice Farming chapter).

Most of the developed resource-management technologies are scale-neutral, so both small farmers and sharecroppers will be benefited by their adoption. Integrated Crop Management (ICM) is an example. Conservation agriculture (CA) will reduce production costs and conserve the natural resource base. By adoption of both ICM and CA farmers may benefit but they need to choose the practices best suited to their situation. Use of CA machinery will boost the rural economy, in terms of its sale and maintenance. However, for promotion of machinery more public and private research, development and adaptation are needed along with strong participation of the national government to encourage its use.

There are good opportunities for greater integration of ruminant livestock into smallholders' farming systems; with profitable conversion of crop by-products, increased use of manure and increased income from beef production and dairying. Modern technology application on feed processing for livestock such as Urea Molasses Straw (UMS) and silage making will give better unit return due to expected higher demand of animal protein. Halal (blast) beef export to the middle-east and other countries may be strengthened because of low production cost compared to other countries. The expansion of livestock enterprises will stimulate development of the feed industry. It will be desirable to locate the feed industry in the production zone to minimize transport costs and to contain environmental problems involved in processing. However, the poor may not be benefited so much from this livestock industry but off-farm jobs will be created and increased money flow may benefit the local economy.

It is expected that the system will aggressively incorporate many forms of diversification, such as fruit gardening, vegetable production, agroforestry, fruit and timber tree nursery, ornamental plants and flowers and different cash crops, by the land owner or through leasing to businessmen-cum-farmers. Diversification will generally require investments in marketing, transport, infrastructure, research, extension and support services. Government agencies will continue to supply more modern cultivars, management technologies, post-harvest processing techniques but the private sector, NGOs and farmers' cooperatives would progressively come forward. Similarly the demand for technical and market information could be addressed through public-private partnerships (Dixon *et al.*, 2001). The system has greater potential to foster more economic growth because large areas of the Rice-Wheat Farming System are flood free and less hazardous compared to other parts of the country.

Research and Development Needs for Rice-Wheat Farming System

- Heat and drought tolerant wheat varieties having high yield to be developed
- Short duration drought tolerant T.aman cultivars with fine quality grain to be developed on priority basis
- New cold storage for potato should be built, with reliable electricity supply
- Local potato varieties with improved storage quality to be improved along with disease management
- Drought tolerant, less N and B requiring maize hybrids to be developed
- Research and development for pulses and spices to be taken on priority basis
- Research and development on conservation agriculture should be taken up with emphasis including modification of different relevant machineries
- Conjunctive water management technology to be promoted for saving natural resources and biodiversity

- Surface water management and fish culture promotion should come into effect with development of appropriate technology options
- Cultivation and brown manuring of mungbean residue to be promoted on a large scale to increase pulse availability and improve of soil quality and fertility
- IPM to be promoted for vegetable, fruits, rice and pulses cultivation
- Research on post-harvest processing to be strengthened for different fruits like mango, papaya, banana, litchi and ber
- Tomato ketchup and juice industry to be developed for tomato
- Government/bank/donor agency should support the establishment of mango processing industries for preserving pulp for further industrial uses to reduce the loss of mango within short time periods and for creating job opportunities.

6. COASTAL ARTISANAL FISHING FARMING SYSTEM

The coastal area has attracted many people because of fish and other natural resources, including forest products, honey and deer of mangrove forest Sunderban. Thus 17.7 million people live in 6,701 km² area having 0.47 m ha of cultivated land of which 0.20 m ha is irrigated (see Box 23).

The area is characterized by salinity affected tidal water during the dry season (December to May), however, water becomes almost non-saline in the monsoon season due to rainfall and water flow from inland rivers. The area is mainly in the form of polders, protected from the sea and saline water by earthen

Box 23. Basic data: Coastal Artisanal Fishing Farming System

Total population (m)	17.69
Total area (m ha)	0.67
Agro-ecological zone	Humid
Net cultivated area (m ha)	0.47
Irrigated area (m ha)	0.20
Shrimp (million tonnes)	0.12
Bovine population (m)	2.65
Small ruminants (m)	1.46
Poultry (m)	12.61
Literacy rate (%)	51.8

barriers. However, these are regularly breached by powerful cyclones and tidal bores, causing loss of life and having a long term devastating effect on trees, the wider ecology and overall livelihoods of the people. All sources of freshwater become polluted by saline water, causing drinking water to become unavailable and cropping not possible. Before the 1980s, the production practice of the area was only local T.aman rice in the monsoon season having a low yield with some naturally occurring fish, leaving most of the people under food insecurity. However, after introduction of the “Gher” system of land use people are converting their crop land to Gher and cultivating shrimp, other fish and Boro and T.aman rice in the monsoon season. “Gher” is a Bengali word meaning surrounded by something. Here Gher refers to an excavated water body surrounded on all sides by 1-

2 meter high dykes made of soil, used mainly for shrimp and fish culture, along with Boro and T.aman rice cultivation. It is linked by a sluice gate with a nearby river or canal for access to saline tidal water.. Within the Gher there is small long canal in all sides where water remains and shrimp and fish can take shelter. On the 1-2 meter wide bank of the Gher vegetables can be cultivated; also creeping vegetables are grown on bamboo trellises made over the water. Some progressive farmers, adopting advice from research institutions, can fetch high returns from such vegetable cultivation (Personal communication, S. K. Zaman, PSO, OFRD, BARI, Jessore). Consequently, there has been a significant improvement in the livelihoods of the rural population practicing this farming system. This breakthrough has occurred through the introduction of culture shrimp, as it is a high value export commodity. However, it has some environmental costs as Gher owners let in saline water for the growth of specific species of shrimp, causing changes to the long term ecology of the area. Despite that inhabitants are trying to convert more of their crop lands to the Gher system of land utilization. About 0.12 million tonne per annum of shrimp is produced under this farming system. The region has 2.65 million head of bovines, but they have poor health because of scarcity of straw and natural grass, 1.46 million small ruminants (goat and sheep) and 12.61 million poultry. The area has the highest literacy rate (51.8 %) in the country. Because people of this area are always under climatic threat, they try to educate themselves and migrate to other parts of country for better and safer livelihoods.

Livelihoods

As per expenditure and income balance (Table 16) it has been observed that livelihoods of all categories of farmers have improved over other farming systems because of changing of land use pattern and introduction of shrimp culture. Labor wages are at least 30 %higher shrimp culture than for normal rice farming works, providing greater opportunity for livelihood improvement of poorer households As the system includes only a single T.aman crop, rice food security is precarious for poor and average farmers, although well-off farmers are buffered by having larger land area and higher overall income. Nevertheless, even poor farmers can have a positive income balance at the end of year (4, 992 BDT), because of the opportunity to sell labour and fish for shrimp fry and local fish in rivers and inlets. An average farmer can have a cash return of 133, 692 BDT from his one bigha (1320 m²) small Gher to provide an income balance of 20, 748 BDT at the end of the year. Well-off households can earn about 390, 000 BDT/year from 3 bigha (4000m²) shrimp Gher to provide a yearly balance of 153, 738 BDT. Such households usually also earn extra income from off-farm activities. Thus change of land utilization has helped the people of this farming system to rise out of poverty; along with the contribution of off-farm earnings in poverty reduction.

Table 16. Comparative Livelihoods (expenditure and income) of poor, average and well-off farmers under Coastal Artisanal Farming System (source: survey as like Rice farming system)

Item-wise monthly expenditure	Amount (BDT)		
	Poor household	Average household	Well-off household
Food	2000	2500	3500
Cloth	500	900	1500
Daily bazar	1380	1800	2800
Health	400	600	1100
Education	250	400	600
Transport	150	400	700
Agricultural input	900	2500	7500
Shrimp production cost	00	1666	4750
Labour	80	Labor-1250	4150
Festival/guest	500	Festival/guest-1000	2000
Other (mobile cost etc.)	300	Others (mobile etc.)-600	900
Yearly expenditure	Total-6460 x 12 months= 77520	Total-13616 x 12 months= 163392	Total-29500 x 12 months= 354000
Income source			
Rice & other crops	15000	25000	40000
Vegetable & Homestead fruits	5000	10000+7000	20000+12000
Livestock	2000	10000	10,000
Fish fry and fish catching	10000	-	-
Labour sell & others	50000	-	-
Small business/shop fare	-	25,000	60,000
Gher fish selling	-	120,000	350,000
Yearly total income	Total income-82,000	Total income-182,000	Total income-492,000
Yearly balance	+4,480	+18,608	+138,000
Income/head/day in US\$	0.64	1.42	3.85
Rice food security (months/year)	Rice food security-3-4 months/year	Rice food security-8-9 months/year	Rice food security-12 months/year

*1 US\$=78 Bangladesh Taka (BDT). Five member families were considered in calculating income per day.

The major sub-system of the Coastal Artisanal Fishing Farming System is discussed as follows:

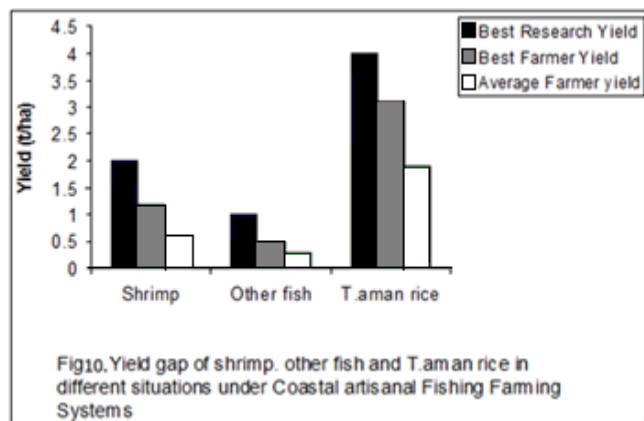
Shrimp culture + other fishing-T.aman/vegetable Sub-system

This sub-system now plays a major role for food security and livelihoods of the coastal region of Bagerhat, Khulna, Satkhira and part of Bhola, Patuakhali, Borguna, Pirojpur and Cox-Bazar districts (Fig.3). In this sub-system, income from shrimp culture dominates over other forms of income. T.aman rice does not ensure food security because it is a single crop, generally of low yield. Along with shrimp, farmers also get some income from carp fish which is popularly known as “white fish” in this locality. Except for rejected shrimp farmers rarely consume shrimp, but rather sell it to local frozen food traders for export. However, income of many Gher farmers has been improved through the systematic cultivation of vegetables around the year on the Gher banks (see Box 24). As the Gher bank is above flood or tide level, vegetables can be cultivated there without any disturbance. Farmers are even cultivating creeper vegetables like bottle gourd on bamboo trellises fitted over water bodies with rope or metallic coir. The area is an acutely vegetable deficit area, so there is ample scope of marketing. Vegetable cultivation also helps farmers to improve their household nutrition security by changing a rice dominated diet to a more balanced diet.

Box 24. A typical household of Coastal Artisanal Fishing Farming Systems

A typical small household of Coastal Artisanal Fishing Farming systems has 0.4 ha land supporting five family members, three adults and two children. They live in a small tin shed built on 0.016 ha of homestead area surrounded by coconut, betel nut, sapota and hog plum trees. Change of land use pattern since 2005 has almost revolutionized the agriculture and livelihoods of farmers of Fakirhat upzila, Bagerhat district. The change is the cultivation of shrimp-T.aman rice and vegetable by constructing “Gher”. Gher refers to a land area encircled by 2-3 m high and 1.5-2.0 m wide bank of soil excavated from within the boundary so as to hold water for cultivation of shrimp and other fish, along with T.aman rice cultivation in the monsoon season (July-November). The quantity of water in a Gher is controlled by a sluice gate which links to a local canal or river. Before introduction of the Gher system the farmer produced only 3 t/ rice from a single T.aman crop, as it was not possible to grow Aus or Boro rice due to excessive soil and water salinity. Thus food security was not ensured and farmers and their families had to live in extreme poverty. But now through the Gher system farmers can earn about BDT 100,000/ year from his one bigha (0.132 ha) Gher with an outlay of about BDT 50,000/ year, including own labor costs. Additionally, from about the last two years, with the encouragement and advice of BARI researchers, farmers have been getting a good vegetable harvest from the Gher boundary and profit from it is gradually increasing. Market price of vegetables is high in Bagerhat as this is an acutely vegetable deficit area. This has allowed poorer households to climb out of poverty. Now farmers of the area are planning to build better houses and can afford the required expenditure for festivals and children’s education. A typical farmer’s next target would be to bring another one bigha of land under the Gher system, at a cost of about 20,000-25,000 BDT.

Yield gap: Shrimp culture in crop land started from local innovators and businessmen using local technology, thus yield and quality of shrimp produced was very low. But observing export potential and worldwide demand, research and development institutions came forward to develop and improve the whole production package for shrimp, including production of shrimp fry in hatcheries. Also, foreign importers promoted scientific production of shrimp and prawn. From semi-intensive farms higher production was thus achieved. For shrimp, from best research yield to best farmers yield the gap (Fig. 10) is 40 % (0.8 t/ha) while from best farm to average farm the yield gap is 51 % (0.61 t/ha). Through adoption of semi-intensive and intensive cultivation yield of shrimp could be improved further. However, there are many biosafety measures required for producing export quality shrimp. For other fish, from best research yield to best farmers yield the difference is 50 % (1.0 t/ha) while from best farm to average farm the yield gap is 39 % (0.12 t/ha) (Fig. 10). Yield gap in T.aman is quite high among the three levels, farmer's average yield 50% less than best farm yield and 100% less than best research yield. Vegetable yield on the Gher boundary also has a big yield gap due to quality of seed/seedlings, and management problems. For vegetable, from best research yield to best farmers yield the difference (data not shown) is 40 % (4.4 t/ha) while from best farm yield to average farm yield the gap is also 40 % (2.6 t/ha). On Gher boundaries high yield is obtained from the Kangkong-Tomato pattern, and also good yield of sweet gourd, bottle gourd, bitter gourd is harvested from trellises (Zaman and Hossain, 2007). Through proper management and application of IPM quality vegetables can be produced on Gher boundaries. Increasing numbers of farmers, particularly from average households, are cultivating vegetables to improve their income and livelihoods. Those not wishing to undertake intensive vegetable cultivation plant such crops as papaya and aroids as they need less management and attention.



Adoption of Modern Technologies in Shrimp culture + Other fishing-T.aman rice/ Vegetable Sub-system

As shrimp culture earns hard cash most cultivators try to collect high quality shrimp fry, to avoid virus infection. However, the semi-intensive method of management has been accepted by only 20 % of farms. Other fish cultured in the pond are considered as supplementary, so they receive less husbandry; moreover carps are less disease

susceptible. For T.aman, 90 % of farmers have accepted modern variety BR 23 (Table 17) as it has late planting potentiality, but balanced fertilization is not undertaken as farmers assume that rice receives adequate nutrients from the preceding shrimp culture. Farmers try to collect vegetable seeds from research institutes or seed companies as officially released seed promises higher yield and only small quantities of seed are required.

Table 17. Adoption of modern technology in Shrimp culture+other fishing-T.aman rice/vegetable Sub-system in percent area

Crop season	HYV/ breeds	Hybrid variety	Balanced fertilizer/IPNS/ semi-intensive	IPM
Shrimp	90	-	20	-
Other fish	20	N/A	15	-
T.aman	90	N/A	-	-
Vegetable on Gher boundary	80	60	20	5

Poverty Escape Pathway

Among the various farming systems of Bangladesh, poverty has been reduced to a greater extent in this sub-system. However, scope still remains in this system to further enhance income, improve livelihoods and reduce poverty through intensification and diversification of shrimp farming, emphasis on other enterprises of the farming system, off-farm income, labor migration and credit/micro-credit.

Intensification and Diversification: Most Bangladesh shrimp cultivation is under the extensive method resulting in low yield (0.5 t/ha) with low production cost (78-234 BDT/kg live shrimp), while only 20 % farms have adopted semi-intensive methods. Through semi-intensive methods yield could be 2-6 t/ha but with comparatively higher production cost (234-468 BDT/3kg live shrimp). Shrimp is the second largest source of export income for Bangladesh, earning as much as US\$ 430 million in 2011 (CBI, 2012). This sector employs about 0.9 million persons directly or indirectly. Through intensification and adoption of the semi-intensive method of cultivation production could be doubled and further employment generation would be possible. Semi-intensive cultivation involves stocking densities beyond those that the natural environment can sustain without additional inputs. Consequently these systems depend on a reliable shrimp post-larval supply, and a greater management intervention in the pond's operation compared to extensive ponds. Semi-intensive shrimp aquaculture relies on water pumps to exchange up to 25 % of pond volume daily. With stocking rates of 3-10 shrimp post-larvae per m², farmers are completely dependent on formulated feeds to augment natural food in the ponds. The post-larvae are usually raised in nursery ponds until they are large

enough to be stocked at lower densities in grow-out ponds. Maximum annual yields range from 2 to 6 t/ha. The risk of crop failure increases with increasing farming intensity, which is mainly due to the impact on water quality exerted by the high stocking densities and supplementary feeding. All of the costs associated with semi-intensive production are much higher relative to those for extensive production, including a more complex system of ponds, installation of a pump system to regulate water exchange, skilled management, labour, purchase of feed and seed stock and increased energy usage. The higher the culture intensity, the higher the capital required and the higher the risks involved. Thus, the increased capital inputs required for semi-intensive culture often preclude its adoption by small-scale producers. Intensive grow-out systems have evolved primarily in countries with high land costs, ample supplies of clean sea water, adequate infrastructure, and well-developed hatchery and feed industries. Intensive shrimp farming introduces small enclosures (down to 0.1 ha), high stocking densities (10-50 hatchery-produced shrimps/m²), around-the-clock management, very high inputs of formulated feeds, and aeration. Aeration – the addition of oxygen to the water – permits much higher stocking and feeding levels. The water exchange rate in intensive ponds is usually more than 30 % per day. Frequently conducted in small ponds, intensive farming is also practised in tanks, which may be covered or located indoors. Construction costs range from US \$10,000 to \$35,000/ha. Sophisticated harvesting techniques and easy pond clean up after harvest permit almost constant production. Yields range from 7 to 15 t/ha/year, and production costs range from 390-546 BDT per kg of live shrimp. The risk of disease can be serious in intensive culture, especially if water discharge from one pond or farm is reused in another pond.

A greater area is coming under production of improved shrimp species such as Galda or Bagda species. Galda is cultivated in lesser saline and fresh water. There is good scope for increased vegetable cultivation of on Gher boundaries. With the release of saline tolerant rice varieties by BRRI and BINA (BRRI Dhan 47, BRRI Dhan 53, BRRI Dhan 55 and BINA Dhan 8) boro rice could be cultivated under this farming system. However, those varieties can only grow under moderate soil salinity (4-8 dS/m). Several farmers have already started boro rice cultivation within Ghers by retaining fresh water within the Gher canal in the dry season.

Emphasis on other enterprises in the farming system: There is scope for improvement in the production of homestead tree species which are adapted to excessive soil moisture and modest salinity, such as coconut, hog plum, sapota, mango, ber, date palm and palmyra palm. Those trees will also protect against excessive wind and reduce soil erosion. Moreover, forest species adapted to tidal and saline soil and water have large potential because of high demand within the country. Homestead vegetables could be successfully grown (see Box 25) with raised beds and selection of saline tolerant crops (Ali, 2009). It would bring income from un-used/under-used homestead land and would create women's employment along with improving family nutrition. Increased duck

farming is possible because of availability of water bodies, although a section of the community of that area do not consume duck meat and eggs for cultural reasons. Sheep have good scope because of their foraging ability and beef fattening may also be another means for increasing farmers' income. Crab farming also has good scope to expand, as it has an export market. With the clearing of forest area honey collection from Sunderban is decreasing. However, it is an important source of livelihood for many people and so promotion of modern apiculture has potential in this area.

Box 25. Homestead vegetable gardening for family nutrition and women empowerment

Sriti Rani, wife of a small farmer of Laudove village, Dakope Upazila, Khulna district produced homestead vegetables on 0.012 ha of her 0.04 ha of homestead land. With the advice of BARI researchers she prepared the soil in a ridge and furrow system and prepared beds ensuring drainage of excessive soil moisture and for reduction of soil salinity. She was largely successful in producing both Kharif and Rabi vegetables and produced 160 kg. Vegetable intake was increased more than three times (69 g/head/day) from the bench mark (20 g/head/day) through vegetable gardening, though it was far less than the recommended adult requirement of 200 g/head/day. Females contribute most in homestead vegetable production, from land preparation to intercultural managements, but not in marketing. This is because most male partners are out of the home attending to activities like fishing, forest related business and other off/non-farm activities in the surrounding Sunderban. Economic analysis clearly showed that vegetable gardening is quite profitable bringing a gross margin of 1,560 BDT/homestead but costing only 312 BDT/homestead. The amount of profit might be small but homestead vegetable gardening has a profound impact on Sriti Rani's five member family in respect of food habit, nutrition, consuming a balanced diet in a carbohydrate (rice) dominated daily diet. She produced kangkong, spinach, red beet, turnip, stem amaranth, lady's finger, tomato, sweet gourd. Among the vegetables produced, farmers consumed 52 %, freely distributed 18 % among relatives and neighbours and sold 30 % for cash income, which they needed for purchasing small items including children's school needs and other items. Most of the earned money was held by women. Female members of more households are becoming interested in homestead gardening and want to pursue it into the future.

Off-farm: This farming system has a greater scope for off-farm activity including fish and shrimp fry catching in nearby canals and rivers, collection of forest products and honey from Sunderban, water and road transport like boat and rickshaw-van operation, small business related to different commodities but, most importantly, work in shrimp Ghers. However, work in the Sunderban is risky, due to the threat of tiger and crocodile attack. The amount of work available is quite high in this system but population pressure is more compared to other systems. Thus, the livelihoods of landless and marginal people can be adversely affected in lean seasons. With the increase of income of many people

through shrimp cultivation the scope for more and better paid off-farm activity has broadened.

Tourism has great scope in this area. Each year a large number of visitors travel to the mangrove forests of the Sunderban, the long sea beach at Cox's Bazar and Kuakata (Patuakhali district) sea beach from where both sunrise and sunset can be observed. However, visits to Kuakata are hampered by poor road communication. Eco-tourism has the potential to create many service jobs and enhance the local economy.

Labor Migration: Migration is a key option for this system because of vulnerability of this geographical residence of many people on risky areas like river banks, sea side, etc., which are regularly battered by cyclonic storms incurring heavy loss of life and property. For example, in cyclone "Sidre" in 2007, 8.9 million people were affected with 3,363 killed, 1.7 million livestock were killed or washed away, 1.4 million houses damaged, and 0.7 million ha of crops affected across the whole coastal and adjoining areas (BBS, 2008). People of many areas have still not been able rebuild their homes because saline water entered and remained because of breaking of polder walls. So, both in-country and foreign migration is crucial for livelihood improvement and poverty reduction for the people of this system. Seasonal labor migration could also help poorer people to get employment.

Credit/micro-credit: For both shrimp cultivation and off-farm activity such as preparing boats and fishing items, soft and easily available credit could help farmers of this system invest further and reduce the adverse effect of local money lenders (discussed in detail previously). Due to poverty, fishermen sell their projected fish catch in advance to the wholesaler at a very low price and their life becomes ever more miserable.

Trends and issues in Coastal Artisanal Fishing Farming system

The area under this system will continue to grow. It is estimated that it will increase at a rate of 15-20 % per annum because of higher productivity and profitability of the Gher system of shrimp culture. This land use pattern has dramatically increased the farm income by 10-12.5 times compared to previous reliance on a single Aman rice crop. However, there is concern about the loss of biodiversity and environmental cost on the whole ecosystem along with the extended inundation effect (by saline water) on human and animal health. Moreover, sometimes small farmers are uprooted from their land by unfair practices of big farm owners. However, huge employment opportunities have been generated by shrimp farming along with the general economy of the region. Adoption of semi-intensive and intensive farming may increase in future to enhance yield within a limited land area, maximizing profit particularly in big investors' farms. However, extensive shrimp farming will continue to grow in small farms also so as to maximize

land productivity through technical intervention. This would help reduce poverty in a large section of people and allow them to invest more in children's education, better housing, diversified recreation and travel to nearby cities. But from a short- and long-term perspective, environmental effects need to be minimized by imposing strict regulations and adoption of scientific methods.

The Bangladesh Shrimp and Fish Foundation estimate that there are over 600,000 people employed directly in shrimp aquaculture who support approximately 3.5 million dependents (Islam *et al.*, 2011). As shrimp farming offers significant employment opportunities, it may help alleviate the poverty of the local coastal populations in many areas, if it is properly managed. In general, intensive shrimp farming requires more labor per unit area than extensive farming. Extensive farms cover much more land area and are often but not always located in areas where no agricultural land uses are possible. Supporting industries such as feed production or storage, handling, and trade companies should also not be neglected, even if not all of them are exclusive to shrimp farming.

Typically, workers on a shrimp farm can get better wages than with other forms of employment. A global estimate from one study is that a shrimp farm worker can earn 1.5-3 times as much as in other jobs (www.vertie.org/commodities/Shrimp).

NGOs have frequently criticized that most profits go to large conglomerates instead of to the local population. While this may be true in certain regions, where most shrimp farms are owned by large companies, it does not apply in all cases. Whether the local population benefits from shrimp farming is also dependent on the availability of sufficiently trained people. Extensive farms tend to offer mainly seasonal jobs during harvest that do not require much training. More intensive farms have a need for year-round labor in more sophisticated jobs.

Shrimp farming in many cases has far-reaching effects on the local coastal population. Especially in the boom years of the 1980s and 1990s, when the business was largely unregulated in many countries, the very fast expansion of the industry caused significant changes that sometimes were detrimental to the local population. Conflicts can be traced back to two root causes: competition for common resources such as land and water, and changes induced by wealth redistribution.

A significant problem causing much conflict in some areas has been land use rights. With shrimp farming, a new industry expanded into coastal areas and started to make exclusive use of previously public resources. In some areas, the rapid expansion resulted in the local coastal population being denied access to the coast by a continuous strip of shrimp farms, with serious impacts on the local fisheries. Such problems were compounded by poor ecological practices that caused a degradation of common resources (such as excessive use of fresh water to control the salinity of the ponds, causing the water table to recede and leading to the salinization of fresh water aquifers by an inflow of salt water). With growing experience, countries have usually introduced stronger governmental

regulations and have taken steps to mitigate such problems, for instance through land zoning legislation, but Bangladesh lags far behind with respect to legislation and implementation. It has only just begun policy planning (MoA, 2013).

In general, it has been found that shrimp farming is accepted best and introduced most easily and with the greatest benefits for the local communities if the farms are owned by local people instead of by a few remote elites or large companies. This is because local owners have a direct interest in maintaining the environment and good relations with their neighbors, and because it avoids the formation of large-scale landholdings.

Priorities for Coastal Artisanal Fishing Farming System

In order to make substantial progress in reducing poverty in this system, the following household strategies to escape poverty needs to be supported (in order of importance): exit from agriculture, intensification of the present system, diversification, increased off-farm income and increased farm size (mainly through leasing of lands for commercial cultivation). Many people in this region are climate refugees and it is apparent that they face further danger from severe cyclones, and perhaps tsunamis, because of the geography of coastal Bangladesh. Hence, some of the landless people should be shifted to safer areas to reduce future loss of lives and property. Climate refugees should get proper training in appropriate disciplines to enable them to get employment elsewhere in the country or overseas. Government and NGOs should come forward in this respect with assistance from donor and developed countries, as developed countries have a responsibility to compensate climate refugees due to their disproportionate contribution to climate change. Diversification of the crop and fish based system could minimize risk and would contribute in increasing income and dietary diversity of rural people along with women empowerment. Examples would be raising of small ruminants, homestead gardening, duck rearing, bee keeping, etc. The system could be diversified with planting of “Golpata” in tidally flooded canal and polder banks, for use as a housing material (leaves like coconut tree used for thatching of house) as it has a high demand beyond the region. Also other timbers and saline tolerant trees have great scope in property development and income generation as well as for protection against storms and soil erosion.

For intensification of shrimp farming high priority should be given to conservation of natural resources, such as soil and water quality and biodiversity. Appropriate models should be developed for the containment of salinity level. Bagda species of shrimp should be cultivated only in naturally existing saline soil and water, and Golda species should be promoted in less saline land. In this respect local people should be motivated in conserving biodiversity and proper zoning should be enforced for shrimp cultivation. Long term research and development works need to be initiated to help the local people

in cultivating shrimp in an environment friendly way. Long term effects of shrimp farming need to be monitored to measure its effects on human, animal health and biodiversity. For reduction of water salinity the government should take initiative to increase the water flow of the Padma (Ganges) and its tributaries. Moreover, crop fields and settlements should be protected from saline water by maintaining strong barriers and saline water intrusion must be checked within polders in the dry season by means of sluice gates. For this work responsibility must be specifically assigned, along with participation of the local community.

A comprehensive model should be developed to utilize the Gher area around the year by cultivating shrimp, other fish, T.aman where applicable and vegetables on Gher banks and on trellises. This would help to maximize income and reduce risk and would automatically promote consumption of balanced diets, as vegetables are scarce and costly in this tidally flooded saline area.

Research and Development needs for Coastal Artisanal Fishing System

- An integrated model should be developed on Gher system of land use applicable to small farmers for cultivating shrimp + other fish + T.aman rice + vegetable
- Cost-effective and environment friendly semi-intensive and intensive shrimp culture methods should be investigated and developed
- Strict environment protection rules should be enforced to protect the ecology from destruction caused by secondary salinity (artificial salinity created by shrimp farming through forced intrusion of saline water)
- T.aman rice cultivars should be developed with higher yield potential and better adaptation to late planting
- More saline tolerant Boro and T.aman rice varieties need to be developed
- Participatory research and training on apiculture needs to be initiated
- Homestead vegetable and fruit tree cultivation needs to be promoted following ridge and furrow system and through selection of saline tolerant cultivars
- For winter cash crops like water melon, chilli and other crops production research and development initiatives are needed to ensure fresh water for irrigation and its conjunctive use
- Credit/micro-credit facilities with easy terms should be made available by government banks and NGOs to the farming community and fishermen for enhancing fish capture/production and employment
- Infrastructure, cyclone shelter-cum-school, roads and waterways should be developed on a priority basis so that people (development workers) can have ready access and safe accommodation in the region

- Rain water harvesting should be strengthened to ensure safe drinking water for all people
- Eco-tourism development should receive high priority to create more off-farm jobs
- Strong polder barriers and paved roads need to be built and/or repaired on a priority basis to protect the coastal area people from saline tidal water. Polder protection should be ensured by active participation of the local community

7. HIGHLAND MIXED FARMING SYSTEM

Characteristics of the System

The Highland Mixed Farming System is completely different from farming systems on the plane lands. Traditional tribal farmers cultivate many crops, with rice as the main crop mixed with legumes, tubers, aroids, vegetables, cotton, banana and other crops. A method of shifting cultivation, called Jhum, is practiced whereby crops are sown on small hill tops and slopes with the onset of monsoon. Previously, when the population was much less, land would only be cultivated for a few years before farmers would move onto new land cleared from the natural vegetation, and allowing the previously cultivated land to return to natural vegetation. However, with increasing population, the sustainability of this system has declined, with shorter periods of re-vegetation and hence increased soil erosion and fertility loss. Total population of the area is 1.65 million distributed on 0.16 m ha land of which 0.12 ha is under different forms of cultivation (see Box 26).

There is little scope for irrigation in the dry season except for a small area from hilly “Charra (small canal flowing through hill areas). Irrigated area is only 0.04 m ha. Bovine population is also comparatively small, at 0.41 m head. However, literacy rate is higher compared to the Rice Farming System due to increased budget allocation for education from local and national

Box 26. Basic data: Highland Mixed Farming System

Total population (m)	1.65
Total area (m ha)	0.16
Agro-ecological zone	Hot-Humid
Net cultivated area (m ha)	0.12
Irrigated area (m ha)	0.04
Bovine population (m)	0.41
Small ruminants (m)	0.80
Poultry (m)	2.52
Literacy rate (%)	46

governments. Nevertheless, there are wide differences in literacy rate, with Chakma people more educated than other tribes. The settled Bengali population is also less educated; they are more engaged in selling their labor, modern farming (cultivation of improved rice and vegetables cultivars with the application of fertilizers and irrigation) in valleys, gardening and off-farm jobs. A tribal farmer practices Jhum cultivation on about 1 ha to several ha and usually achieves low yields but from many different crops.

Livelihoods

The livelihoods of Highland Mixed Farming farmers are marginal compared to other farming practices because of land topography, traditional agricultural practices having low production and cultural norms of the tribal people. As productivity is low under the Jhum cultivation system, poor farmers have only 2-3 months food security, average farms have 4-5 months and the well-off farms have 7-8 months (Table 18). Main expenditure of

Table 18. Comparative Livelihoods (expenditure and income) of poor, average and well-off farmers under Highland Mixed Farming System (source: survey as like Rice Farming System)

Item-wise monthly expenditure	Amount (BDT)		
	Poor household	Average household	Well-off household
Food	Food-750	Food-900	Food-1200
Cloth	Cloth-80	Cloth-100	Cloth-250
Daily bazar	Daily bazar-400	Daily bazaar-650	Daily bazaar-900
Health	Health-50	Health-90	Health-200
Education	Education-40	Education-60	Education-300
Transport	Transport-200	Transport-70	Transport-250
Agricultural input	Agricultural input-200	Agricultural input-350	Agricultural input-1000
Labour	Labor-00	Labor-80	Labor-800
Festival/guest	Festival/guest-100	Festival/guest-170	Festival/guest-800
Other (mobile cost etc.)	Others (mobile etc.)-30	Others (mobile etc.)-50	Others (mobile etc.)-300
Yearly expenditure	Total-1690 x 12 months= 20280/year	Total-2520 x 12 months= 30240/year	Total-6000 x 12 months= 72000/year
Yearly income source			
Rice & other crops	10000	15000	20000
Fruits	2000	3000	7000
Livestock	1000	2000	3000
Labour sell & others	5000	-	-
Wood collection & selling	2000	2500	-
Small business/business	-	10000	60000
Yearly total income	20,000	32,500	90,000
Yearly balance	-280	+2,260	+18,000
Income/head/day in US\$	Income/head/day in US\$-0.15	Income/head/day in US\$-0.25	Income/head/day in US\$-0.70
Rice food security (months/year)	Rice food security-2-3 months/year	Rice food security-4-5 months/year	Rice food security-7-8 months/year

*1 US\$=78 Bangladesh Taka (BDT). Five member families were considered in calculating income per day.

poor households is for food, daily bazaar and agricultural input. But large farms have a sizeable expenditure in festival/guest occasions, payment for labor, children's education and mobile phone, besides basic living costs. The hill people's economy is diversified and they thus receive income from many sources, including crops, fruits, livestock, forest

wood and off-farm sources. The well-off households receive their highest income from off-farm sources, followed by agriculture. Yearly total income of poor farm households is only 22,308 BDT while the average household earns 36,192 BDT and large farm income is 100,308 BDT. The poor have a negative income balance while average households have a small positive balance and the large farm balance is also low (20,046 BDT/year). In terms of US\$1 /day/ capita income none of the households have crossed this level. The apparent savings of the average and well-off are for future security and they live under extreme austerity. Actually livelihoods of hill people cannot be explained only by their farming systems; their food habits and culture dictates that they collect different roots, fruits, animals and plants which contribute to their livelihoods but are not easily measurable. However, due to serious exhaustion and degradation of hill forests these natural resources are disappearing fast.

The dominant sub-system of the Highland Mixed Farming System is the, Upland rice/mixed crop Jhum cultivation sub-system (Fig 4). This is analyzed in the following in terms of typical household, yield gap, adoption of modern technology and poverty escape pathway.

Upland rice/mixed crop Jhum cultivation sub-system

Jhum cultivation is an age-old rainfed hill farming practice in the hill slopes in the Chittagong Hill Tracts (CHT) practiced by the tribal people. Under this practice a piece of land is selected, cleared of the natural vegetation by slash-and-burn, and seeds of different crops are mixed together and sown in the field after the first shower of pre-monsoon rain during the months of April to May. In selecting Jhum sites, religious and cultural beliefs play an important role. The size of the Jhum plot depends on the size of the family and the availability of suitable sites. Weeding and/or other different management practices are followed based on their traditional knowledge. The field crops are harvested within 8-9 months in a sequential manner. After harvesting, the lands are kept fallow for 2-5 years for natural re-vegetation. But in some cases, after harvesting the Jhum crops, the farmers plant pineapples, fruit and timber trees or continue planting annual crops in the next season. Sometimes, crops like chili, eggplant, cassava and other seasonal crops are harvested from the left over Jhum known as *ranya* cropped for one or two years and then allowed to revert to natural vegetation (M Mohiuddin, BFRI, Chittagong).

Due to this traditional system, poor management and soil fertility degradation, yield of Jhum cultivation is rarely economic; sometimes farmers earn less than production cost if their personal labor value is considered. For the 8-9 month period they get a total yield of

around 1.5- 2.2 t/ha from different mixed crops (see Box 27). Nath *et al.* (2005) summed the yield of 14 different crops under Jhum system in a ha of land in CHT to get a total

Box 27. A typical household of Highland Mixed Farming Systems of Bangladesh

A typical small household of Banderban sadar upazila of Chittagong Hill Tracts cultivates 1 ha of small hill and valley land. This Chakma family includes two children along with an aged mother. Both wife and husband practice Jhum cultivation with the onset of the monsoon (April-May). They clear the hill top and slope of natural vegetation and burn it and prepare the land by spade and sickle. They dibble Aus rice seed as the main crop and a variety of crops as mixed crops or intercrops which are harvested sequentially. The intercrops include maize, sesame, bean, brinjal, cotton, banana, turmeric, aroid, cucumber (locally called Marfa) and many other crops sown at low population density. They can only harvest up to 1.2 t/ha paddy rice and achieve low yields from the other crops. From the proceeds of these crops they can earn about 20,000 BDT/ha/year at a cost of 16,000-18,000 BDT/ha. The livelihood of the family remains under hardship as they often have to cope with the situation of food insecurity by reducing meal number or quantity. The female often needs to get a day laborer job in a nearby brickfield or on construction work to supplement the income from agriculture. The male partner sometimes conducts a small trade of agricultural goods in the local market to obtain small cash income. The female partner is more active and often collects wood from the forest to sell it in the local market. They family has a few chickens and a cow which act as a safety net in time of need. They also have a few pineapple plants, and olive and jackfruit trees whose fruits are both consumed by themselves and sold. Their children attend a local community school free of cost, where a meal is also served. The family desires to purchase more cattle and a few goats to improve their livelihoods.

yield of 1.48 t/ha. The yield of different crops was: rice-1,035, barley-15, maize-17, linseed-44, ginger-42, turmeric-77, arum-25, cassava-27, chilli-22, brinjal-17, snake gourd-17, beans-10, cucumber-40, marfa-7, khira-20, sweet gourd-40, cotton-45 kg. For tribal people, culture and physical livelihood are closely interwoven and their economic well-being is thus a bit difficult to quantify. Among the tribes there are differences in economic productivity and its interaction with culture. For example, the Murong achieve higher Jhum yields because of better crop management, including use of manure and fertilizers, and the Boom tribes have adopted mixed gardening to improve their economic well-being (Personal communication, M Jamal Uddin, Scientific Officer, OFRD, BARI, Banderban).

Yield gap: No systematic research has been conducted into crop yields under Jhum cultivation as research and development workers believe Jhum cultivation is unscientific, unproductive and exacerbates soil erosion and low productive. However, it is estimated that the yield gap between best farm and average farm is 33 % for rice and 40 % for the other mixed crops (data not shown).

Adoption of Modern Technology: Under Jhum cultivation tribal farmers mostly use their own seed of traditional and locally adapted varieties of different cereals, vegetables and fruits. Adoption of any modern cultivars in Jhum cultivation is rare. But some farmers, such as in the Murong tribe, apply chemical fertilizers in their cultivation.

Poverty escape pathway

Intensification and diversification: Scientists have suggested a modified Jhum cultivation (see Box 28) and mixed fruit garden (BARI, 2005) instead of traditional Jhum

Box 28. Modified Jhum cultivation for improvement of productivity, profitability and sustainability

Farmers of Nutunpara, Khagrachari district, have practiced a modified form of Jhum farming since 2000 in transition to innovative agroforestry practices. Modified Jhum (short rotation shifting cultivation practice) is characterized by a short rotation cycle, use of fewer crops and more intensive farm inputs than in the traditional Jhum system. In the long term it will lead to non-rotational or permanent agroforestry. This modified Jhum is now being practiced along the roads and in accessible areas of the CHT. Improved fallow management can be achieved by growing nitrogen fixing plant species, introduction of high value cash crops and medicinal plants, early harvesting of forest crops, domestication of important minor forest species, pollarding of trees instead of removing them, ensuring off-farm income opportunities and awareness and capacity building. In terms of soil fertility, the fallow vegetation can be used to improve soil structure, prevent erosion, and after burning add to soil fertility. Additionally controlled burning helps to suppress weeds and pests. The usual 'remedy', chemical fertilizer, is a meager replacement. There will be less and less room for traditional crops. This has implications both for food security and soil fertility management. Farmers will require support to establish reliable market linkages, access credit, and make other adjustments in order to deal with the increased market dependency (Source: M. Mohiuddin, Scientist, BFRI, Chittagong).

to increase productivity and reduce soil erosion. In the mixed fruit garden different fruit trees like mango, olive, lemon, papaya and pineapple are intercropped in the concept of agroforestry. Mulching is done in summer to conserve soil moisture. The system also could check soil erosion by ensuring round the year soil coverage. Management in jackfruit can increase productivity and income from this traditional fruit tree of the area.

Emphasis on other enterprise of farming system: Ramgui mango (Burmese poly-embryonic variety) and orange garden has high potential for giving better yield and income. A Government project on mango and orange is helping the local residents to accept these high value fruits. However, in remote areas there is lack of ready access to markets. In valleys and barren hill areas cattle and sheep have better scope to bring good income to farmers. Chittagong Red cattle are highly productive and are the preferred

breed in this region. Their widespread rearing is expected to increase farmers' income (Personal communication, Dr Nathuram Sarker, BLRI).

Off-Farm: Creation of off-farm activities is crucial for the area because of limited scope of different field crops. However, off-farm job creation depends on overall economic growth of the area. Pineapple and jackfruit based food processing could create many jobs as well as help farmers to get a better price for their products. Government and NGO relief and rehabilitation activities are presently helping the area people to get some rations and also some jobs are being created through food for work programs. The locally made colored cloths, boutique (cloth designing), and handicrafts have a good market and could create more jobs but this needs soft cash flow to the poor weavers and other artisans.

Labor migration: As the area has limited scope to improve people's overall livelihoods, labor migration both inside and outside the country is necessary.

Credit/micro-credit: Like other farming systems of the country, its importance is equally applicable for the hill tract people. Without easy and soft credit/micro-credit the poor cannot improve their livelihoods in a reliable and dignified manner. For development of small scale fruit and spices processing industries supervised credit could play an important role. Government agencies and NGOs should be proactive in this regard.

Better infrastructure, market development and tourism: For farmers income generation there is no alternative to these factors. Often farmers do not get a fair price for their fruits, spices and local handicrafts. Sometimes even fruit like pineapple, lemons and jackfruit remain unsold or handed over at a nominal price.

A large number of in-country and foreign visitors are attracted to the scenic beauty of the CHT, tribal culture and tribal made handicrafts and colored cloths. This needs to be promoted with public-private partnership as tourism would greatly contribute to income enhancement of local residents.

Trends and Issues in Highland Mixed Farming System

Land ownership and land dispute is preventing the acceptance of many promising technologies. It is feared that the local elite or vested interest group will try to undermine government efforts to settle issues. Conflicts within the tribal and Bengali population and within different tribal groups along with political rivalry of different tribal groups are inhibiting development of the area. All effort should be given to improving social cohesion so as to pave a pathway to development. There is huge degradation and deterioration all manner of natural resources, such as land, water, forest, biodiversity, due

to human encroachment, population pressure and Jhum cultivation. Corrupt forest employees are also responsible for denuding the hills of big trees. The hill people have virtually no cash income and women have to walk progressively further to secure water in the dry season and fuel-wood needs. Soil and water conservation under these conditions is generally poor, and erosion and the decline of soil fertility can pose grave threats to household survival.

As local off-farm opportunities are few, the young are temporarily migrating to find jobs elsewhere, leaving the ageing resident population. The difficulties experienced by shifting cultivators in adapting to sedentary cultivation have also been a factor (Dixon *et al.*, 2001).

Despite these problems some promising developments have been made such as rapid acceptance of modern orange and mango gardens and their scientific management. Farmers are inspired by getting good yields as well as market access. It may be mentioned that each year Bangladesh imports a large quantity of oranges from neighboring countries. Large scale adoption of modern turmeric cultivation on hill tops and slopes with other tree species is also noteworthy. Spices processing companies are ordering turmeric fingers in advance. Due to improved road communication and availability of mobile phones farmers are getting better prices for their products, and this will be further strengthened into the future. Sheep and cattle farming also have scope to develop. In valleys, exportable items like French bean and Bilati Coriander leaves could be produced. Moreover, agroforestry with watershed management could improve resource conservation and management and overall production. There are prospects for more investment in tourism, facilitating higher earnings for local people.

Priorities for Highland Mixed Farming System

In order to make substantial progress in reducing poverty in this system, the following household strategies to escape poverty need to be supported (in order of importance): exit from agriculture, diversification, increased off-farm income and intensification of the existing production system. Emigration can be facilitated by measures to improve rural and urban labor market function and the provision of basic and vocational skills, focused on poorer households (Dixon *et al.*, 2001).

For diversification and intensification, mango, orange and mixed fruit gardening would get high preference along with their post-harvest processing. For high value fruits and vegetables drip irrigation and fertigation (fertilizer applied with irrigation water) could bring a revolution in productivity, and more efficient use of water and nutrients (Mr. Abdur Razzaque (personal communication), PSO, I&WM, BARI, Gazipur). Agroforestry with modern watershed management, mulching and legume cover must get preference for arresting soil erosion and loss of soil fertility. In hilly areas, reversal of land and soil fertility degradation and soil moisture conservation should get strategic importance. Safe

road and waterway development will remain as key determinants for better marketing and faster development of socio-economic conditions for the hill people.

All programs need to be implemented in a participatory manner with the full involvement of local communities, government agencies and NGOs. Capacity building of the community should be specifically targeted so that they can take their own decisions, particularly in remote hilly areas. Government agencies may act as a moderator and continue to provide technical assistance. Participatory research and extension will be needed to support households and communities during the adoption and adaptation process. Better service facilities must be ensured by government, such as vocational school, health clinic, plant nursery and faster and less costly communication systems. Considering the remoteness of the area private entrepreneurs may not be interested to invest in different fruit processing industries. Therefore, government agencies should intervene to establish such industries. The tourism industry needs to be further developed without jeopardizing the local ecology and cultures.

Research and Development Need for Highland Mixed Farming

- Development of better roads, water ways, tourist spots and marketing systems across the hill area.
- Development of suitable and sustainable models such as multi-layer gardens for the hill region.
- Development of watershed management along with soil and water conservation strategies and options.
- Pineapple based fruit processing industry to be developed through government patronization or as a public-private partnership.
- High value vegetable crops may be cultivated in valleys by ensuring premium price, such as by Hortex Foundation.
- Red Chittagong Red cattle should be promoted in hilly areas by local and national government funding and through bank credit.
- Pen culture of fish and appropriate fisheries technologies could be promoted in hill canals and rivers through adaptive research and development.
- Spices drying and processing machinery could be developed along with introduction of quality and higher yielding turmeric and other spice crops.
- Suitable mango and litchi cultivars for hilly regions should be selected.

8. STRATEGIC PRIORITIES FOR BANGLADESH

Agriculture will remain as a key means of livelihood for the majority of people in Bangladesh although expanding service and light manufacturing sectors will play increasingly greater roles. Bangladesh has little potential for expansion of agricultural land, rather it will shrink at about 1 % per year as urban and industrial areas expand. Nevertheless Bangladesh has relatively fertile soils, being a delta region, and is well endowed with water resources through rainfall and irrigation. However, agricultural productivity faces recurrent risk of flood, drought and cyclone. Despite all odds – during the past 30 years – the agricultural research and support services of the country have generated growth in food production matching the increasing population with declining agricultural land area per capita. The proportion of people living in poverty has been markedly reduced. The opening of the Bangladesh economy has had a profound effect on farming system dynamics in the past decade. In the next 30 years farming may gradually change from subsistence to commercial forms, dictated by population pressure, technological support and market demand. Thus farming systems in Bangladesh are likely to evolve rapidly during the coming 30 years, as technologies, institutions and markets change, and the pace of change is expected to accelerate.

Available projections suggest that hunger and poverty will slowly reduce in the coming years. Bangladesh experienced a uniform and steady decline in poverty rates between 2000 and 2010. Poverty declined 1.8% annually between 2000 and 2005, and 1.7% annually between 2005 and 2010. There was a continuous decline in the number of poor people, from nearly 63 million in 2000, to 55 million in 2005, and then 47 million in 2010. Despite a growing population, the population of poor people declined by 26 % in 10 years. The Bangladesh poverty assessment shows that during the period 2000-2010 poverty reduction was closely linked to the growth in labor income and changes in demographics. Labor income, both formal and informal, was the dominant factor in higher incomes and lower poverty rates. Parallel to this, fertility rates have been steadily dropping over the last several decades which have resulted in lower dependency ratios thereby increasing income per-capita and reducing poverty. The potential to benefit from the demographic dividend will continue in the short to medium term. But to continue to reap the benefits from the demographic changes, Bangladesh will need policies that respond to the needs of the growing population of young adults. It is projected that within 2013 poverty level is expected to go down to 28.5 % (World Bank, 2013).

However, localized poverty may increase such as occurred when a large number of people were affected by cyclone “Aila” in 2009 in the coastal belt of Satkhira and Khulna, turning them into asset-less climate refugees. Therefore, the rate of poverty reduction will depend on how Bangladesh is able to manage such large natural disasters, which are likely to increase in frequency and intensity with climate change. But the projected halving of poverty by 2015 (from 2002 levels), as per Millennium

Development Goals (MDG) may not be achieved. In order to meet those goals, increased effort by public and private organizations and farming communities is required. Potential for growth and poverty reduction within each farming system is shown in Table 19. It projects that only moderate growth is possible in different farming systems. Table 19 also indicates the relative importance of five household strategies for escape from poverty. Strong support will be needed both for small farm diversification and for growth in employment opportunities in the off-farm activities.

Table 19. Potential and relative importance of rural household strategies for poverty reduction in Bangladesh

Farming System	Potential for agricultural growth	Potential for poverty reduction	Strategies for poverty reduction				
			Intensification	Diversification	Increased farm size	Increase off-farm income	Exit from agriculture
Rice	Moderate	Low-Moderate	2	3	0	3	2
Rice-Wheat	Moderate	Moderate	2	3	0	3	2
Coastal Artisanal Fishing	Moderate	High	2	2	1	2	3
Highland Mixed	Moderate	Low	1	3	0	2	3
Mean score for all Farming Systems	-	-	1.75	2.75	0.25	2.5	2.5

Note: Total score for each farming system equals 10. Assessments refer to poor farmers only.

The first priority for poverty reduction is the diversification of agriculture (Table 19), second is the increased income from off-farm and third priority will be measures that help people leave agriculture. Intensification of existing farming systems could also potentially reduce poverty, largely through adopting a systems approach, and adoption of improved technologies and water management. The strategic priorities for actions, under areas of policies, market, information, technologies and natural resources have been described extensively for South Asia by Dixon *et al.* (2001).

9. CONCLUSIONS

The agricultural sector will continue to remain an important component of the poverty reduction program for the foreseeable future in Bangladesh. Along with successful management of natural calamities and climatic effects there are some major degradation challenges, as well as linkages to the off-farm rural economy, to be taken into account. The major means of hunger and poverty alleviation and risk reduction will be through diversification to high value enterprises including local processing for value addition. Similarly, the rapidly growing service and manufacturing sectors (off-farm) would bring formidable changes in job opportunities with higher wages and this could result in a significant reduction in poverty. Due to ever increasing population growth and reduction of land area exit from agriculture will be third option for poverty reduction. Intensification of the existing production systems also has the potential to reduce poverty. Six broad strategic initiatives are proposed:

Land zoning: Due to sensitivity to rice food security many farmers are growing Boro rice in areas which are not at all suitable for this water hungry crop. Land zoning would help the farmers to opt for alternative and better options. Ultimately it would also help to develop specialized processing and other back-up industries in certain potential areas. It may also be helpful for the wholesaler and exporter to maintain quality and reduce transport cost.

Improved water resource management: Water is becoming a prime concern in the dry season not only for agriculture but also for household use, industry and biodiversity. Water quality aspects, such as arsenic and industrial waste contamination, pose a great threat to health, life and property of millions of people. Improved water management is essential to support the intensification and diversification of production and to reduce resource depletion, for both surface and underground water projects. However, there should be certain restrictions on the use of ground water, otherwise in coming years ground water availability will be critically reduced, particularly in the dry season. Components of improved water use efficiency include: selection of low water requiring crops in high land, char and light soil areas in the dry season (November to May), efficient resource conserving technologies, conjunctive water use, availability of electricity for water pumps and use-based pricing, application of alternative wetting and drying (AWD) method for Boro rice, formation of water users associations, and watershed protection. Conjunctive water use refers to simultaneous use of surface water and groundwater to meet crop demand. It is suggested that the best way to optimize conjunctive water use is to concentrate on capacity building of irrigation system managers to improve system management and reshape hydraulic infrastructure of large and small-surface systems. To sustain groundwater use in tube well-irrigated areas, enhancing recharge from precipitation and surface water imports is necessary. None of

these improvements can be made without the proper institutional and organizational development, including investment in the capacities of local governments to lead on participatory groundwater management and integrated water resources management ([http:// documentsworldbank.org/curated/en/2006/02/7104292-use-groundwater-surface-water](http://documentsworldbank.org/curated/en/2006/02/7104292-use-groundwater-surface-water)). For irrigation and drainage from surface water sources propeller based Axial Flow Pumps should be promoted instead of centrifugal pumps, so as to reduce fuel costs by 30-40 %.

Re-orient agricultural service: Public agricultural institutions including research, extension, education and other supporting departments should come under revolutionary change to cater for the present and future challenging needs of farmers. Those institutions must involve farmers fully to underpin the drive for intensification and enterprise diversification and promote sustainable resource management. Components include: working models for joint public-private-NGO service provision, multiple advisory services, need based location specific research and extension based institution development, organization of collection centers in remote areas for ensuring better technology transfer and market price for the producers, mobile phone and internet based delivery of technical and market information to small farmers, multidisciplinary learning approaches in higher education and provision of internship for agricultural graduates and diploma degree holders.

Improved rural infrastructure: Returns to education, electricity, transport and health investments are high and beneficial to the poor as well as to all categories of households. Bangladesh is lagging far behind in those basic prerequisites to reach its development goals Components include: electricity, roads, water ways, schools (including vocational), health facilities and more effective and justified models for private sector participation.

Strengthened farmers' groups: This is one way to redress the extensive degradation of land, water, fish and forest resources across Bangladesh. Components include: resource management groups for watershed management in hill, char, haor, drought prone highland areas, and policies to encourage common property resource management.

Availability of credit/micro-credit on soft terms: Credit for investment particularly for agriculture and small off-farm activities should be regarded as the people's right. Quick and easy loan disbursement has a tremendous impact on modern technology adoption and diversification of farmers' income sources. As a majority of Bangladesh farmers live hand-to-mouth, it is difficult for them to bear the upfront cost of recommended packages of input. In this situation, NGOs and government and private banks could ensure supervised credit without collateral at least up to a certain limit. Credit on soft terms could increase investment in agriculture resulting in higher rural incomes. This would definitely help farmers to reduce poverty and improve overall livelihoods.

10. ACKNOWLEDGEMENTS

All praises belongs to Almighty Allah Subhanutala for making me successful to complete the manuscript of this book. I would like to thank John Dixon, Mohammad Zainul Abedin, Md. Badirul Islam, Md. Mohi Uddin, Md. Akkas Ali, Sheikh Mostafa Zaman, Md. Shofiqul Islam, Md. Shakawat Hossain, Md. Jamal Uddin, Md. Sirajul Islam, Md. Altab Hossain, Md. Nurul Islam , Md. Kamrul Hasan, Md. Khairul Alam, Nathuram Sarker, Md. Delwar Hossain Mollah and Md. Raiqul Islam for some helpful contributions to this book. I also thank Md. Golam Arif and Md. Mostafijar Rahman of FSRD site Kadamsahar, Rajshahi and K M A Aziz Talukder and Md. Afaz Uddin of FSRD site, Palima, Tangail, Bangladesh for their help in collecting information. I am grateful to the farmers of Palima, Tangail, Bangladesh for providing information on their livelihoods. The author is also thankful to Helen Kilborn and Henry Lee for their help in conducting this study. I would like to thank Australian Centre for International Agricultural Research (ACIAR), Canberra for initially funding the present study. I am grateful to my colleague Shah-Al-Emran for modifying Farming Systems maps and formatting graphs and to P. K. Raptan for kind help. Lastly the author is immensely grateful to his mother Mohterema Halima Khatun and Uncle Abdus Satter for their all sorts of effort to be an educated human being. The author recognizes the help and cooperation of his spouse Anjuman Ara and children Humira Hoq and Miah Ahmad Zubair.

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