ASSESSMENTS OF THE MAIZE SITUATION, OUTLOOK AND INVESTMENT OPPORTUNITIES TO ENSURE FOOD SECURITY IN BANGLADESH

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ABBREVIATIONS

ACF	=	Auto Correlation Factor
ADF	=	Augmented Dickey Fuller
AEZ	=	Agro-Ecological Zone
AIC	=	Akaike Information Criterion
AIDS		Almost Ideal Demand System
AIS	=	Agriculture Information Service
ARIMA	=	Autoregressive Integrated Moving Average
BARI	=	Bangladesh Agricultural Research Institute
BADC	=	Bangladesh Agricultural Development Corporation
BBS	=	Bangladesh Bureau of Statistics
BCR	=	Benefit Cost Ratio
BRAC	=	Bangladesh Rural Advancement Committee
BRRI	=	Bangladesh Rice Research Institute
BIID	=	Bangladesh Institute of ICT Development
CCDB	=	Christian Commission for Development in Bangladesh
CHT	=	Chittagong Hill Tract
CIMMYT	=	International Maize and Wheat Improvement Center
CV	=	Coefficient of Variation
DAE	=	Department of Agricultural Extension
DAM	=	Department of Agricultural Marketing
DAP	=	Di-Ammonium Phosphate
DF	=	Dickey Fuller
DRC	=	Domestic Resource Cost
DTW	=	Deep Tube Well
EPC	=	Effective Protection Coefficient
EPDOA	=	East Pakistan Directorate of Agriculture
ERP	=	Effective Rate of Protection
FAO	=	Food and Agriculture Organization of the United Nations
FGD	=	Focus Group Discussion
FIAB	=	Feed Industry Association of Bangladesh
FMPE	=	Farm Machinery and Post-harvest Processing Engineering
GDP	=	Gross Domestic Product
GKF	=	Grameen Krishi Foundation
GMO	=	Genetically Modified Organisms
GoB	=	Government of Bangladesh
GR	=	Gross Return
Ha	=	Hectare
HIES	=	Household Income and Expenditure Survey
HPAI	=	Highly Pathogenic Avian Influenza
HYV	=	High Yielding Variety
IACIP	=	Inter Asian Crop Improvement Programme
ICM	=	Integrated Crop Management
ICT	=	Information and Communication Technology
IFDC	=	International Fertilizer Development Centre
IITA	=	International Institute for Tropical Agriculture
IPM	=	Integrated Pest Management
INFS	=	Institute of Nutrition and Food Science
IRR	=	Internal Rate of Return
ISTA	=	International Seed Testing Association
KGF	=	Krishi Gobeshona Foundation
MAB	=	Maize Association of Bangladesh

MLT	=	Multi Location Test
MoA	=	Ministry of Agriculture
MoP	=	Muriate of Potash
MT	=	Metric Ton
NAEP	=	New Agricultural Extension Policy
NARS	=	National Agricultural Research System
NGO	=	Non-Government Organization
NRP	=	Nominal Rate of Protection
NPC	=	Nominal Protection Coefficient
NPGRI	=	National Plant Genetic Resources Institute
NSB	=	National Seed Board
NSP	=	National Seed Policy
OFRD	=	On-Farm Research Division
OPV	=	Open Pollinated Variety
PACF	=	Partial Auto Correlation Factor
PCA	=	Per Capita Availability
PFAB	=	Poultry Feed Association of Bangladesh
PQR	=	Plant Quarantine Regulation
PTOS	=	Power Tiller Operated Seeder
QPM	=	Quality Protein Maize
RDRS	=	Rangpur Dinajpur Rural Service
SAAO	=	Sub-Assistant Agriculture Officer
SCA	=	Seed Certification Agency
SC	=	Schwarz Criterion
SoP	=	Sulphate of Potash
SOWT	=	Strengths, Opportunities, Weaknesses and Threats
SRDI	=	Soil Resources Development Institute
SSP	=	Single Super Phosphate
STW	=	Shallow Tube Well
TAMNET	=	Tropical Asian Maize Network
TC	=	Total Cost
TSP	=	Triple Super Phosphate
TVC	=	Total Variable Cost
USAID	=	United States Association for International Development
USG	=	Urea Super Granule
VC	=	Variable Cost
WFT	=	Whole Family Training
WTO	=	World Trade Organization

Acronyms

Aus	=	Pre monsoon rice
Bhutta	=	Maize (locally called in Bangladesh)
Boro	=	Irrigated rice in winter season
Chhatu	=	Fried rice bran mixed with fried maize bran
Don	=	A traditional irrigation equipment
Kharif-I	=	Early monsoon cropping season (16 March to 15 July)
Kharif-II	=	Monsoon cropping season (16 July to 15 October)
Khichuri	=	Boiled rice mixed with pulse and maize
Rabi	=	Winter cropping season (16 October to 15 March)
Sewti	=	A traditional irrigation equipment
T. Aman	=	Transplanted monsoon rice

Conversion rate: 1.00 USD = BDT 78.00

Some Definitions

Char: In the dynamics of erosion and accretion in the rivers of Bangladesh, the sandbars emerging as islands within the river channel, or as attached land to the riverbanks, often create new opportunities to establish settlements and pursue agricultural activities on them. Once vegetated, such lands are commonly called chars.

Chatal: A set up with open place and chimney to boil and dry crops and cereals like rice, wheat, maize, etc. In another words *Chatal* is called drying floor for cereals and many other crops.

Contract farming: Contract farming is the system of sourcing quality input for processing or sales through contracting farmers by providing them technical assistance and guidance.

Fallow land: An area of land left unseeded and uncultivated for a particular period of time or season.

Intercropping: Intercropping is the simultaneous cultivation of two or more crops in the same field. Generally short duration crops are planted between two rows of the main crop.

Relay cropping: Contrasting with mixed cropping, relay cropping is a practice of growing more than one plant in the same land, while one plant is seeded just before harvesting the other, reducing fallow period.

Value chain: It refers to all the activities and services that bring a product from conception to end use in a particular industry from input supply to production, processing, wholesale, and finally retail. It is called so because value is being added to the product or service at each step.

Faria**:** *Faria* is a non-licensed small type trader generally operating at local level. They have no fixed business premises and run their business independently. They are usually landless or small farmers having no full time work in the farm. *Farias* play a crucial role to establishing link between farmers and buyers. *Faria* informs the farmers about the current demand and price of maize. They buy small amount of maize from farmer either at farm gate or in the primary markets, and sell those to *Beparis*, and *Arathdar*.

Bepari**:** *Bepari* is comparatively a big trader who has fixed establishment in the market premise with adequate drying and storage facilities. They purchase large amount of maize from farmers and a small amount from *Farias* from farmyard and or farmers' homestead. They have both permanent and temporary staff/labour for running their business. They sell large amount of maize to Arathdar or feed mills or trader-cum-processors in local areas.

Arathdar**:** *Arathdar* is basically a commission agent in Bangladesh who operates between farmers and *Beparis* in various agricultural commodities and fish marketing. In maize marketing *Arathdar* is basically a big trader who operates between farmer and feed millers or trader cum processors. *Arathdar* has fixed establishments in the market places with adequate storage and drying facilities. They sometime offer short-term credit facility to *Faria*, *Bepari* and farmer. They perform business activities with permanent and temporary staffs.

Haor**:** A haor is a wetland ecosystem in the north eastern part of Bangladesh which physically is a bowl or saucer shaped shallow depression, also known as a backswamp. In a country where one third of all area can be termed as wetlands, the haor basin is an internationally important wetland ecosystem, which is situated in Sunamganj, Habiganj and Moulvibazar districts and Sylhet *Sadar Upazila*, as well as Kishoreganj and Netrokona districts outside the core haor area. It is a mosaic of wetland habitats, including rivers, streams and irrigation canals, large areas of seasonally flooded cultivated plains, and hundreds of haors and beels. This zone contains about 400 haors and beels, varying in size from a few hectares to several thousand hectares (http://en.wikipedia.org/wiki/Haor).

Jhum **cultivation**: Slash-and-burn system of cultivation is called shifting cultivation or *Jhum* cultivation. It involves clearing and farming land and then letting it lie fallow for some years (3-5 years). It is the primary means of food production of the ethnic groups in the hill. This cultivation has been practised for generations, with upland rice being the principal crop grown in the highlands.

Executive Summary

Maize was rarely cultivated across Bangladesh before independence. With the establishment of the Bangladesh Agricultural Research Institute (BARI) in 1976, maize research was initiated and by now eight composites and 11 hybrids of maize have been developed for the country. Maize was introduced as a relatively new crop in the rice based cropping patterns of Bangladesh. Presently maize is considered as an important cash crop to its growers. It is extensively used as one of the major ingredients of feed for poultry and fish. It is also used as an ingredient for starch production for use in textiles and other industries. Further, maize is consumed in many forms across the country. Because of its higher nutritional status, it could be a potential source of nutrition for malnourished people and as a suplimentary food for ensuring food security for the increasing population of Bangladesh, while dry maize plant is a good source of fuel for rural households.

In spite of its high genetic yield potential, current maize yield is very unpleasant. The present yield-gap is 32.7 and 41.4 per cent between on-farm research yield (10.94 t/ha) and protential yield (12.61 t/ha), respectively. The highest possible yield of a variety which is already achieved in some areas is considered as potential yield. Bangladesh still deficits in maize production and has to import large quantity every year to meet its demand. Therefore, necessary steps are needed to increase the current level of production to meet up the country's demand and save valuable foreign exchange.

Through an analysis of various data sources, the study generated information regarding the maize situation, outlook and investment opportunities. More specifically, the study generated data and information related to the current status of maize production; past trends, maize markets, maize seed; grain value chains, and available opportunities for investment in maize research and development in Bangladesh.

Both primary and secondary data and information were used in this study. Secondary data and information were collected from BBS, DAE, journal articles, MS/PhD theses, research reports, FAOStat, and internet, whereas primary data and information were gathered through focus group discussions (FGDs) with different sections of people associated with maize.

In order to estimate the costs and returns of maize production data on outputs and inputs used per hectare were collected from secondary sources like MS/PhD thesis and journals. Later this output and input data were multiplied by the current price of the respective input and output for specific area to compare the status of farm level profitability of maize cultivation in different regions of the country.

The study analyzed annual growth rates of area, production, and yield of maize through fitting a semi-log trend equation using time-series national data (1990 to 2011). The decomposition of output growth was also analyzed through Hazell's Varience decomposition procedure to find out the sources of growth. The variability in area, yield, and production of maize for the period of 1990-2011 was computed by using Cuddy Della Valle Index. Domestic resource cost (DRC) was also calculated for evaluating the comparative advantage of cultivating maize in Bangladesh. The impact of government policies on economic incentives was measured by calculating nominal and effective protection rates. Finally, ARIMA (Autoregressive integrated moving average) model was used for predicting future area, production, and yield of maize for 10 years (2014-2023) at national level. In this case, 25 years' time series data (1989-2013) from Department of Agricultural Extension (DAE) were used for this purpose.

The total area under maize cultivation is estimated to be 0.313 million ha producing 2.183 million tons with an average yield of 6.98 t/ha during 2013. The overall growth rates of area and production of maize were negative and their instabilities were medium for Bangladesh during 1990-1999. During that period, positive growth rates registered in area and production for Rangpur and Khulna division, but their instabilities were found to be high and very high, respectively. In 2000-2011, highly impressive growth rates with low instability were registered in maize area and production in all the divisions, except Sylhet due to expansion of poultry and fish farming across the country. Change in` cropped area was the principal contributor to change in the mean productions of maize in both periods.

Most agro-ecological zones (AEZs) of Bangladesh are suitable for maize cultivation. The average area, production, and yield of maize are reported to be the highest in Rangpur and Khulna division compared to that in other divisions. Dinajpur, Rangpur, Chuadanga, Thakurgaon, Lalmonirhat, Manikgonj, Panchagar, Jhenaidah, Rajshahi and Bogra district are the intensive maize growing areas of Bangladesh. These 10 districts covered more than 75 per cent of the total maize area and production in 2013. DAE reported that 84.4 per cent maize is grown in the *Rabi* season and the rest in *Kharif* (summer) season. In 2011, the change in maize area was 136 per cent and 40 per cent during summer and winter season, respectively, compared to that in 2010. This change was found to be the highest for maize compared to that of other crops grown in the same season.

Hybrid maize is generally cultivated in Bangladesh after the harvest of transplanted Aman (*T-Aman*) rice. Currently, farmers are fitting maize with a wide range of other traditional crops, such as potato, jute, and different vegetables. Maize-Fallow-*T.Aman* was the major maize based cropping pattern in different districts. The present maize-based intercropping systems are Maize+groundnut, Maize+mungbean, Maize+soybean, and Maize+tomato.

All categories of farmers are involved in maize cultivation. FGDs in two districts revealed that mostly small category farmers are involved in maize cultivation. Average size of holdings for small, medium and large category maize farmers was 0.66 ha, 1.40 ha, and 3.76 ha, respectively. They receive advices and information regarding maize production mostly from Sub Assistant Agricultural Officer (SAAO). More than 95 per cent of maize were sold by the producers and the shares of food and feed were very negligible at own farm level. The shares of income from maize were 7 per cent and 12.3 per cent of the total household income and total farm income, respectively. Women are generally engaged in various post-harvest activities like shelling of maize, sun drying, winnowing, and storing.

More than 90 per cent of the farmers used power tiller for ploughing their lands. Most of the farmers used imported hybrid maize seeds with average seed rate of 21 kg/ha. They used fertilizers at lower dose than the recommended dose. Almost all the farmers used mechanized irrigation system for maize.

The average total cost and net return of hybrid maize production was Tk 88,762 (USD 1138.0/ha) and Tk 20,004 (USD 256.5/ha) per hectare in different locations of Bangladesh during 2013. The cost of maize production was slightly higher in western part (Khulna division) of the country compared to that in northern part (Rangpur division). The costs and yields of maize for large farmers were reported to be the highest compared to that of medium and small farm. Net return was also higher for large farms compared to the other farm categories. Land preparation, fertilizer, irrigation, manure and pesticide had positive and significant effect on the gross return. Maize is relatively more profitable compared to that of the other cereal crops. Although domestic production can not meet the country’s demand, it requires substantial protection in future for import substitution and export promotion.

Both public and private sectors are involved in supplying hybrid maize seed in Bangladesh. Maize growing areas are mostly covered by a wide range of imported hybrid varieties. About 70 types of hybrid maize seed were available at seed stores across the country. The tribal people of Chittagong hilly areas are cultivating composite varieties. Bangladesh Rural Advancement Committee (BRAC), Grameen Krishi Foundation (GKF) and Rangpur Dinajpur Rural Service (RDRS) were the pioneer NGOs in maize seed production programme in Bangladesh. Bangladesh Agricultural Development Corporation (BADC) is the only public sector non-profit institution mandated to produce large quantities of seed of various kinds and distribute them to the farmers with no profit. In the private sector, there are more than 100 companies involved, with over 8000 registered seed dealers operating across the country. In the import based system of marketing, importers are importing seeds mostly from other countries and make them available to the farmers through whole-sellers and retailers.

After the independence only BADC is responsible to supply fertilizers, seed, minor irrigation equipment, and limited mechanized services to the farmers. BADC's role has diminished over the years with increasing private sector involvement during the 1990s. Private traders were given permission to have a direct access to the bulk purchase of chemical fertilizers as well as to import TSP and MoP fertilizers freely which has led to increased availability and wider adoption of chemical fertilizers at the farm level. Maize farmers are using farm machinery mainly during land preparation, intercultural operation, irrigation, and shelling. Presently, more than 40000 small and medium sized local workshops have grown up to manufacture agricultural machinery all over the country.

Access to institutional sources of credit almost tripled between 1988 and 2008.. In 2009-2010, around 375,000 farmers and 93,000 laborers were involved in the production of approximately 1.5 million tons of maize. Irrigation is mainly needed in winter maize cultivation. About 80 per cent of irrigation water stems from ground water and the rest from surface water. The Department of Agricultural Marketing (DAM) has undertaken an e-governance initiative to develop and disseminate critical agricultural market information to farmers, traders, government, policy makers, development agencies, and other stakeholders.

A large share of the innovations in the agriculture sector originates from both public and private sector. Many actors in the private sector have entered into agricultural R&D. The private sector is increasingly involved in plant breeding and seed production in response to the opportunities presented by the growing demand for new varieties and for production intensification.

The Plant Breeding Division (PBD) of BARI has a solid and systematic programme and is now leading maize research in Bangladesh. After the establishment of BARI in 1976, maize R&D programme got priorities to renew thrust with a view to developing high yielding varieties. A lot of germplasm was introduced and tested in different locations. During the period between 1986 and 2002, BARI has developed and released 8 composites including one each of popcorn and sweet corn which have got popularity among the farmers. Besides, using introduced and locally developed inbred lines, BARI has developed 11 hybrid maize varieties from 2000 to 2008 and some of them are now being cultivated commercially.

In Bangladesh, plant breeding and variety development of maize is usually carried out by plant breeders in the public research institutions and to some extent in large seed companies. BRAC receives the parent lines of hybrid maize varieties and produces the F_1 generation seed in Bangladesh. The PBD of BARI is also trying to disseminate and popularize BARI developed technologies among public and private agencies, and farmers through training, demonstrations, and field days. Whole Family Training (WFT) programme has had a substantial impact on modern maize cultivation practices, and on the promotion and increased production of maize in the mid 2000s. DAE has established maize demonstration plots across the country and thus plays a role in promoting new varieties. Besides, DAE is also monitoring the response of the farmers on existing and newly introduced varieties. BRAC also plays an important role in providing advice to the farmers on maize seed production. BARI has also developed complete package of production technologies for maize.

Maize is used as different types of foods for human consumption, feed for poultry and fish, fodder for livestock, and starch for industrial use. Maize in urban areas is mostly consumed as green cobs and popcorn. It is intensively consumed by the ethnic people of Chittagong Hill Tract (CHT) region.

The extension of knowledge through neighbouring farmers and SAAO; suppliers' of different inputs like seed, fertilizer; tillage service providers; irrigation service providers, and transport facilities like rickshaw/van, tempo (three wheeler) plays an important supporting role in maize marketing.

Organized maize marketing system to some extent has been prevailing in Bangladesh from a couple of years ago. There are different marketing channels in Bangladesh through which farmers sell their maize to different buyers. The important maize growing areas are Dinajpur, Rangpur, Kushtia, Bogra, Manikgonj, Jessore, Rajshahi, and Comilla. Important consumption areas are Gazipur, Mymensingh, Chittagong, Comilla, Bogra, Khulna, Naogaon, Narayanganj, and Jessore district because most of the feed mills and poultry farms are located in these areas. March-July is the peak period of domestic maize trade in Bangladesh.

The country needs to import some maize every year to fulfill its demand. In 2012, Bangladesh imported about 130,739 tons of maize worth USD 33,513 thousand from different countries especially from India. The highest imports occur during the months from August to October and the lowest during March-July. Recently, government of Bangladesh (GoB) has given permission to export maize on conditional basis.

The projected production and yield of maize show increasing trend over time. The maize production in Bangladesh may increase to 3128.8 thousand tons from 378.3 thousand hectares of area during 2018. The crop productivity is expected to further improve to 8.27 t/ha during 2018 and 4223.32 thousand tons of production from 442.7 thousand hectares of area under plough with a productivity of more than 9.54 tons per hectare by 2023. Future climate change, especially temperature rise will be detrimental to the maize production in many areas of Bangladesh. BARI is continuing its efforts towards developing new varieties including saline tolerant, drought tolerant, and heat tolerant maize varieties in order to mitigate current and future climate change impacts. The policy regarding maize in Bangladesh will largely depend on the demand from poultry, dairy and fish farms and the ways maize is utilized in direct human consumption. Future policy planning must be focused on diversified consumption of non-rice based cereals. Wheat and maize alone or together can play a vital role in cereal consumption diversification.

The demand for maize as human food is increasing day by day. The major divers of this increase are population and economic growth. Future demand for maize will mostly be depended on many factors, such as amount of wheat production, number of poultry and fish farms, pattern of human consumption, intensity of industrial use, price of wheat, etc. The projected requirements of maize based on demand approach are estimated to be 0.64 million tons and 0.70 million tons for the year 2015 and 2020, respectively. These figures found to be little bit low when estimating maize demand using trend approach. Future value chains of maize will be dynamic and changing due to increased demand created for its diversified use, increased number of poultry, fish & livestock farms, and food processing industries in the country.

Government policies towards increasing farmers' efficiency are very much important for maize production. Future policy must focus on farmers' capacity building and on strengthening extension services for using inputs efficiently for obtaining and sustaining higher yield levels. Both government and donor agencies should come forward to invest in maize R&D activities for Bangladesh.

A SWOT analysis was done to explore the strengths, weaknesses, opportunities and threats of maize sector in Bangladesh. The strengths behind this sector are related to technology, growing environment, institutional supports, farmers' incentives, and social benefits. The weaknesses are related to inputs, production, biotic and abiotic stresses, post-harvest management, farmers' awareness, market access, access to institutional supports, international market, and enabling environment for maize production and marketing. There are ample opportunities to develop maize sector to attain self-sufficiency in maize production, ensure food security for the growing population, livelihood development of the poor farmers, and economic development through open-up export markets. The opportunities are related to growing seasons, availability of cultivable land, availability of stress tolerant varieties, availability of technology, mechanization, post harvest activities, extension services, and opportunities relating to the establishment of maize based industries in the country. The threatening issues are emerging in the form of new biotic and abiotic stresses, deteriorating soil health, heavy and continuous rainfall, and climate variability. The other threats are heavy dependency on poultry and fish industries; high competition with other crops; high dependency on importation of hybrid seed; and adulterate maize seed.

Bangladesh has a unique opportunity to increase maize production. Different private and public organizations have been conducting research to generate suitable technologies for the farmers not only to sustain maize production but also to enhance maize productivity by minimizing the yield gap at farm level. The research thrust should be given in the areas like varietal improvement, management practices, diseases and pest management, biotechnology, farm machinery, and food processing. Besides, different research on farm economics and post-harvest management should also be conducted on priority basis. The private sector has minimal input into agricultural R&D in Bangladesh. The government has established programmes to assist private R&D, but there is room for improvement. Collaboration with the NARS should be strengthened to foster the development of improved maize germplasm.

In order to improve the performance of maize sub-sector in Bangladesh, the following steps and measures should be taken into consideration;

- Encouraging quality seed production
- Encouraging proper fertilizers dose use
- Bring suitable land (Char, saline, drought, etc.) under maize cultivation
- Provide credit facilities to the maize farmers for buying inputs
- Strengthening extension linkage between farmers and extension personnel
- Provide training to the farmers
- Promotion of intercropping and relay cropping
- Development of marketing and processing system
- Development of storage facilities for the maize farmers
- Introduction of public sector procurement
- Involvement of mass media for campaigning the benefits of maize foods

- Establishment of maize based food industries in the country
- Improvement in post-harvest operation management
- Strengthening maize research
    - Development of own hybrid maize variety programms within the country
    - Development of short-duration, dwarf, water logging, drought, and saline tolerant maize varieties with high grain yield potential
    - More QPM, fortified, micro-nutrient enriched and sticky varieties of maize
    - More research to develop low-cost drier for summer season maize
    - Post-harvest research should be strengthened for developing quality maize food and diversifying maize consumption

- Strengthening international collaboration for maize research and development
- Policy interventions: The following existing polices need to be reconsidered by the government for better results;
    - Clarity of public and private sector roles
    - Establishment of testing laboratories
    - Formulation of agricultural credit policy
    - Improvement of research and extension linkage
    - Encouraging diversified maize consumption
    - Encouraging farmers’ cooperatives

Chapter I

INTRODUCTION

1.1 Brief History of Maize in Bangladesh

The fertile alluvial soils and sub-tropical monsoonal climate make Bangladesh suitable for maize (*Zea mays L*) cultivation. Before independence in 1971, maize was rarely cultivated across Bangladesh. It was cultivated by the tribal people of the southeastern Chittagong Hill Tracts. Maize research in Bangladesh was initiated on a modest scale in the early 50s with the introduction of some popcorn and sweet corn lines from the USA with a view to popularizing maize in this region by the Economic Botany (Fibres) Division of the East Pakistan Directorate of Agriculture (EPDoA). However, after the introduction of HYV wheat and rice in the 1960s and 1970s, maize research was not considered a priority. After the establishment of the Bangladesh Agricultural Research Institute (BARI) in 1976, the authority feltit potential to develop maize as an important high-yielding cereal crop. Maize became an emerging key mandate crop of BARI and different programmes were developed for crop improvement, crop management, and subsequent area expansion. Within a few years, BARI had collected many maize germplasm from Inter Asian Crop Improvement Programme (IACIP), CIMMYT, Tropical Asian Maize Network (TAMNET), and FAO-UNDP, and tested them in different research stations (Hossain and Sarker 2001). It released its first high-yielding open pollinated variety (OPV) in 1986, and followed that with a further seven OPV releases. The Department of Agricultural Extension (DAE) mounted maize demonstration plots in farmers' fields to increase awareness about maize and expand its cultivation. In the early 1990s, due to these initiatives, only a few farmers had adopted this crop because at that time there was no market for maize and people were not accustomed to mixing maize flour with wheat for local consumption in *Chapatti* flat bread (Ali et al. 2008).

The demand for maize grain increased manifolds as one of the ingredients of poultry feed due to the rapid expansion of the Bangladesh poultry industry in the 1990s and 2000s. In this period poultry population was increased significantly at the rate of 3.14 percent (FAOStat, see Appendix A-22). This demand was initially met by grain imports from Thailand, USA, and other countries. Observing the expanding demand for maize, two private seed companies, namely Kushtia Seed Store and ICI Seed International, and International Fertilizer Development Centre (IFDC) imported a small quantity of hybrid maize seed (mainly Pacific 11) in the early 1990s (OFRD, 1993). The companies experienced an excellent high yield grown from this seed and realized the high potential and profitability of hybrid maize first in Bangladesh. During the 2000s, many other seed companies, including Bangladesh Rural Advancement Committee (BRAC), imported and marketed hybrid maize seed from Pacific Seeds in Thailand. BARI began a programme in the mid 1990 to develop its own maize hybrids in collaboration with international partners, particularly CIMMYT, and it released its first maize hybrid (BARI Hybrid Bhutta 1) in 2001. Two further maize Hybrids, BARI hybrid Bhutta 3 (released in 2002) and BARI Hybrid Bhutta 5 [quality-protein maize (QPM), released in 2004] have become very popular since they can produce up to 10-11 t/ha of grain under optimum conditions. This was comparable with or better than imported commercial hybrids, such as Pacific-11., BARI has so for released six other maize hybrids with complete management technology packages (PBD 2013).

From 2000 onwards, maize became a lucrative cash crop with a huge and expanding market demand, particularly to the farmers of northern and western Bangladesh. The crop has higher grain yield, yield stability, and profitability compared with the two other principal winter cereal crops; such as *Boro* rice (Irrigated rice in winter season) and wheat. In Bangladesh, hybrid maize is grown mostly in the *Rabi* season after the harvest of *T.Aman* rice (*Transplanted monsoon rice*). At that time, because of prevailing cool temperatures during early phases of crop development, the field duration of winter hybrid maize was long i.e., around 145 days. This and the widespread use of high rates of fertilizer along with irrigation helped ensuring high grain yields (Ali et al. 2008).

1.2. Importance of Maize in Agricultural Sector and Economy

Agriculture is an important sector of the economy of Bangladesh. This sector has contributed 20.2 per cent to the gross domestic production (GDP) and accommodates 51.3 per cent of the labour force. It comprises crop, livestock, fisheries, and forestry sub-sectors accounting for 55.7 per cent, 13.2 per cent, 22.4 per cent, and 8.7 per cent of agricultural GDP, respectively (BBS 2010). The annual growth rate of crop sub-sector decreased from 6.2 per cent in 2000/01 to 4.2 per cent in 2009/10. Its growth potential has become limited and further growth in this sub-sector will require introduction of new crops, high yielding varieties and a major improvement in the overall agricultural technology- including changes in the quality of seeds.

Agricultural land is the most important scarce means of production in Bangladesh. The total cropped area of Bangladesh is estimated to be 14.9 million hectares with cropping intensity of 191 per cent (MoA 2013). This agricultural land is decreasing year after year. A recent FAO study reveals that the annual loss of agricultural land was 13,412 ha during 1976-2000 and it reached up to 68,760 ha/year during 2000-2010. This loss was due to increase in rural and urban settlements, industrialization, forest, salt pan and aquaculture (Hassan 2013). This shifting rate is very much alarming as food security is the main concern of Bangladesh. In such a situation, agricultural lands can be utilized efficiently through cultivating high yielding crops including maize.

Maize is a versatile crop with genetic variability that can be grown in almost all types of agro-climatic conditions. It has been introduced as a relatively new crop in the rice based cropping patterns of Bangladesh, especially in the northern region. Now it has become an important cereal crop to its growers as well as in the country. The area under maize cultivation is increasing day by day due to its higher demand that has been created from its multipurpose uses. In terms of area and production, it ranks 3rd just after rice and wheat. However, maize is playing important role in the agrarian economy of Bangladesh.

Non-water logging sandy loam and loamy soils are the best for maize cultivation. Optimum temperature for its cultivation ranges from 24ºC to 29ºC. It requires less water since it is more drought tolerant than rice and wheat. When compared to other cereals, it has a wider agro-climatic adaptability and is less prone to insect and disease infestation (FGD 2013). Besides, it can be grown almost round the year. Therefore, most farmers are growing maize profitably throughout the country (Karim 2010, Ferdausi 2011; Paul 2012). They generally cultivate hybrid maize after the harvest of *T.Aman* rice. Nonetheless, they are now increasingly fitting maize with a widening range of other traditional crops including potato, jute, and different vegetables due to its genetic yield potential.

The lion share of seed requirement (85.8%) in Bangladesh is mostly met up by private seed companies through imports from other countries and the rest 14.2 per cent is met from domestic production (FGD 2013, also see Table 4.1). Therefore, government agencies and private seed companies are playing an important role in saving valuable foreign exchange through providing hybrid seed in the country.

Both farmers and seed producers are benefited through contract farming of maize. BRAC has first introduced contract farming of crops, such as fruits and vegetables. Euro Feed, Supreme Seed, East-west Seed, and many other seed companies are also involved in contract farming of maize production in northern region of Bangladesh. The risk of price falls is eliminated during over production by getting assured market for their produces from companies. They get price information earlier that helps avoiding the exploitation by middlemen. They can also receive technical services, production inputs and credit from contractors without any service charge that reduces the burden of operational expenses, increase the production due to proper use of inputs, and can help them to escape from the harms of local moneylenders.

Hossain et al. (2005) stated in their report that *Dipshikha*, a local NGO of Dinajpur district, and Doel Agro Industry provided various inputs to the maize farmers at 10 per cent service charge or interest. The farmers of Dinajpur district mentioned that local NGOs provide agricultural credits at 20 per cent interest rate. They also mentioned that Grameen Bank and Krishi Gobesona Foundation (KGF) produced maize through contract farming in this area a couple of years ago. The secretary of MAB mentioned that a couple of years ago, National Commercial Bank also provided credit to the maize farmers at 13 per cent interest. He also opined that maize production under contract farming system has already been removed from the country because of huge scattered production and the risk perceptions of bank in withdrawal of credit from maize farmers (FGD 2013).

Maize has diversified uses in home and abroad. It has high potentiality to provide feed for poultry and fish and fodder for livestock. Therefore, increase in the production of maize could enhance poultry and fish farming which will later create employment opportunities for the people of Bangladesh. Dry maize plant is a good fuel for rural households. Thus it helps reduce deforestation in the country to some extent. Maize kernel contains edible oil ranged from 7 to 12 per cent depending on the variety.

Maize is a nutritious and palatable food. It is much better than rice in terms of nutrients like protein, fat, minerals, fiber, phosphorus, carotene, and thiamine (INFS 2003). Currently maize is used to some extent as food in the form of flour (usually mixed with wheat flour[1]) and that mixed flower is used in bakery for making bread and other bakery products to reduce the cost of production. Roasted maize and fried maize are also popular in Bangladesh. Some people fry maize and then grind it together with fried rice to make *Chatu* (maize powder). Because of its higher nutritional status it could be a good source of nutrients for undernourished and malnourished people of Bangladesh. It can be considered as a substitute for both rice and wheat. Therefore, maize can be used as food for ensuring food security for the present as well as for the further increasing population of the country.

The demand for maize in Bangladesh will increase due to food and nutritional deficiency reduction programme, increasing demand by the poultry and dairy industry and increase in the per unit cereal productivity to tackle the problem of teeming population. Human consumption does not exceed 5 per cent of the total production. This means future demand for maize will largely be an outcome of the growth of livestock farms. Maize as an ingredient for starch, used in textiles and other industries, does not seem to be an important factor in an immediate future increase in the demand for local maize. The challenge to increase the rate of adoption and sustainability of maize is social acceptance and economic profitability.

[1] Most of the people of Bangladesh still consider the mixing of maize flour with wheat flour as adulteration.

However, maize is acceptable to its growers mainly due to lower cost of production and higher yield as compared to that of rice and wheat (Rahman 2011; Karim et al. 2010; Moniruzzaman et al. 2009; Uddin 2008; Mohiuddin et al. 2007). Presently maize is confined to only few pockets (4-5 districts) but otherwise it can be grown at varied agro-climatic conditions. Thus this study takes the stock of maize situation in Bangladesh with respect to major maize growing countries in Asia and suggests a pathway for increasing maize productivity and production for higher levels of indirect and direct human consumption.

1.3 Objectives

The goal of the study is to assess the maize situation, outlook, and investment opportunities for ensuring food security in Bangladesh. The specific objectives of the study are as follows.

i. To analyze the past and present situation of maize production technologies, its dissemination and consumption.
ii. To assess the outlook of maize for medium and longer term perspectives.
iii. To assess the investment opportunities for maize research and development to exploite full potential of the sector.

1.4 Scope and Significance of the Study

To attain self-sufficiency in food production to feed the growing population, since 1972 the Government of Bangladesh promoted cereal crop production with the introduction of HYVs of rice and wheat and by launching Green Revolution and Grow More Food programmes. As a result of these initiatives, cereal crop production increased manifolds, but land allocation and yields for minor crops, such as maize, pulses, oilseeds, vegetables, fruits, and spices decreased to a large extent. Despite the policy emphasis on HYV rice and wheat, demand for minor crops and livestock products increased and the government spent valuable foreign exchange to import them. In order to increase minor crop production, Bangladesh Government launched a crop diversification programme (CDP) throughout the country in 1989 with the financial and technical support from Netherlands and Canadian International Development Agency (Miah et al. 2013).

In spite of its high genetic yield potential, the current productivity of maize is very unpleasant. A big gap exists between farmers' yield and potential yield. The present yield-gap of maize is 32.70 per cent and 41.40 per cent from on-farm yield and potential yield. So, there is an ample scope of increasing the current yield in the country. Again, different studies (Uddin 2008, Ferdausi 2011, Paul 2012) show that farmers could not obtain higher yield due to different agro-socio-economic constraints that need to be solved urgently for the interest of farmers as well as for the country.

Although the growth rates of area, production, and yield of maize are excellent in Bangladesh, the country still deficits in maize production and has to import a huge quantity of maize every year in order to fulfill its demand. The average shares of net import of maize to its total availability and production were 45 per cent and 82 per cent, respectively, during 2009-2010 (FAO Stat). Therefore, immediate steps are needed to increase the current level of production to meet up the country's demand and save valuable foreign exchange.

The aim of the present study is to collect data from available sources that will assist in generating information on maize situation, outlook, and investment opportunities. More specifically, the study will generate data and information related to the current status of maize production, past trends, maize markets, value chains (e.g. seed, green maize, food, and feed industries), and available opportunities for investment in maize research and development in Bangladesh. Constraints relating to maize production and markets, opportunities and trade-offs, and their effects will also be explored. Finally, the study outputs can be used as a guide/tool for research intervention and making policy decisions that address the target needs for maize technology development to ensure food security in Bangladesh.

1.5 Organization of the Report

This report comprises eight chapters. *Chapter 1* deals with an introduction which highlights a brief overview of the rural economy of Bangladesh, importance of maize in agricultural sector and economy, objectives and significance of the study. The framework of the study, data collection and analytical procedures are discussed in *Chapter 2*. *Chapter 3* presents the importance of maize production, maize geography, maize production systems, maize technology use; factors associated with maize technology use, and economics of maize production. Maize inputs and research & development are discussed in *Chapter 4*. This chapter also presents maize seed supply system, agro-chemical supply system, supply of other inputs; maize research system, and maize development system. *Chapter 5* contains maize consumption, maize output value chains, and maize trade. Maize outlook presented in *Chapter 6* describes the outlook of maize production, outlook of maize value chains and consumption, and outlook of maize inputs, research and development (R&D), and policy. Constraints and opportunities in maize sub-sector and R&D priorities in maize sub-sector are discussed in *Chapter 7*. Finally, conclusion and policy implications are included in the last *Chapter 8*.

Chapter II

METHODOLOGY

2.1 Study Framework

The study used both primary and secondary data and information. The main categories of information used in this study were (i) Synthesis of relevant findings from existing literature, (ii) Secondary data and information from available sources, and (iii) Primary data and information obtained through focus group discussion (FGD).

2.2 Data Sources and Collection

Secondary data: In order to formulate suitable policy guidelines for strengthening current maize production in Bangladesh, the study reviewed the financial profitability of maize production along with other competitive crops, comparative advantage, SOWT of maize production, maize value chain, maize consumption, maize trade, maize research and development, and maize outlook by using different secondary sources. Data and information in these purposes were collected from national research institutes, public universities, research publications, BBS, DAE, HIES, FAOstat, and journal articles. In most cases, the study used DAE time series data for 1990-2013 and district level data (64 districts) for 2011-2013. It also analyzed the growth and instability of the area, production, and yield of maize by divisions of Bangladesh using time-series data (1990 to 2011) from BBS. It is important to state here that the amounts of area and production of maize recorded in BBS data (national) are much lower than that of DAE data. DAE data are more reliable and realistic compared to BBS data according to the opinion of extension personel, scientists, Maize Association of Bangladesh (MAB), and different seed companies of Bangladesh (FGD 2013).

Primary data: Data and information gaps were identified through synthesizing all sorts of available secondary sources. Then, a number of FGDs were conducted with maize farmers, traders, maize sheller operators/owners, flour millers, extension personnel, exporters, importers, different seed companies, the members of Feed Industries Association of Bangladesh (FIAB), members of the MAB, and the scientists of different disciplines working on maize for filling the gaps. Checklists were used in conducting different FGDs. Some snap shots are shown in the Appendix A-1 (FGD_1 to FGD_8).

2.3 Analytical Procedures

The study used different techniques and models for analyzing secondary data. A brief description on these techniques and models is given below.

2.3.1 Estimation of cost and return

The costs and returns of maize cultivation were highlighted in this study. For this purpose, various research reports, MS and PhD theses, and journal articles were taken into consideration. At first, maize output and different production inputs used per hectare were collected from the aforesaid sources and then multiplied by the current prices of the respective inputs and output for the respective district (Appendix A-2) in order to compare the status of farm level profitability of maize cultivation in different regions.

2.3.2 Estimation of compound growth rates

In order to gain some perspective on the growth rate of area, production, and yield of maize, time series data for 22 years (1990-2011) were used. The compound growth rates of area, production and yield of maize were worked out by fitting a semi-log trend equation (1) of the following form:

$$y = e^{a+bt} \text{ or } \ln y = a + bt \quad \ldots\ldots\ldots [1]$$

Where, y defines the time series data of production, area and yield of maize;'t' is the trend term (time) and 'a' is the constant coefficient. The slope coefficient 'b' measures the relative change in y for a given absolute change in the value of explanatory variable't'. If we multiply the relative change in y by 100, we will get percentage change or growth rate in y for an absolute change in variable't'. The slope coefficient 'b' also measures the instantaneous rate of growth.

2.3.3 Construction of instability index

The variability in area, yield and production of maize for the period of 1990-2011 was computed by using Cuddy Della Valle Index (Weber and Sievers, 1985; Singh and Byrlee, 1990; Deb et al. 2004). Since, the simple coefficient of variation over-estimates the level of instability in time-series data characterized by long-term trends, this index was used as it corrects the co-efficient of variation. The variability was computed for all the selected divisions for the above periods by using the following formula (3):

$$\text{Coefficient of Variation (CV)} = \frac{\text{Standard Deviation}}{\text{Mean}} \times 100 \quad \ldots\ldots\ldots [2]$$

The values for Cuddy Della Valle Index (CV*) can be calculated by using the formula as:

$$CV^* = CV \times (1-R^2)^{0.5} \quad \ldots\ldots\ldots [3]$$

Where, R^2 is the estimated coefficient of multiple determinations.

2.3.4 Decomposition of output growth

To analyze the sources of changes in maize production, Hazell's Varience Decomposition procedure[2] (Hazell 1982; Hazell 1985) was used. The relative contribution of area and yield towards the total output change can be measured through this procedure. In the literature, several researchers used this model to study growth performance of the crops (Siju and Kombairaju 2001; Akter and Jaim 2002; Kakali and Basu 2006).

$$\Delta P = \bar{A}\,\Delta\bar{Y} + \bar{Y}\Delta\bar{A} + \Delta\bar{A}\Delta\bar{Y} + \Delta Cov(A, Y)$$

$$\frac{\bar{A}\Delta\bar{Y}}{\Delta\bar{P}} \times 100 + \frac{\bar{Y}\Delta\bar{A}}{\Delta\bar{P}} \times 100 + \frac{\Delta\bar{A}\Delta\bar{P}}{\Delta\bar{P}} \times 100 + \frac{\Delta Cov(A,Y)}{\Delta\bar{P}} \times 100 = 100 \quad \ldots\ldots\ldots [4]$$

Δ represents change in the variable between two periods, P is production, Y is yield, and A is area.

Thus, the total change in production is attributed due to area and yield that can be decomposed into four effects viz: area, yield, changes in interaction between area and yield, and covariance effects. Covariance term shows the interaction between variances in areas and

[2]It allows the quantification of contribution for different sources of change in mean and sources of change in variance of the total production such as change in mean yield, change in mean area, change in yield variance, change in area variance, interaction between mean yield and mean area etc.

variances in yield because cov (A,Y) is defined as **correlation × √[(variance(A) × variance (Y)].** This is also known as **residual effect** or effects not explained by either area or yield.

2.3.5 Estimation of domestic resource cost

Domestic resource cost (DRC) was estimated for evaluating the efficiency of production of maize in relation to comparative advantage. DRC is the ratio of cost of domestic resources and non-traded inputs (valued at their shadow prices) of producing a commodity to the net foreign exchange earned or saved by producing the good domestically. Mathematically DRC is defined as:

$$DRC = \frac{\sum D_{ij} V_i}{B_i - \sum T_{ik} V_k} \qquad \text{(j = 1-------------m; k = 1-----------n)} \ \ldots\ldots\ldots.. [5]$$

Where,

D_{ij} = Quantity of j^{th} domestic resources and non-traded inputs used for producing i^{th} crop per metric ton (MT)

V_i = Price of j^{th} domestic resources and non-traded inputs (Tk/MT)

B_i = Border price of i^{th} crop (Tk/MT)

T_{ik} = Quantity of k^{th} tradable inputs for producing i^{th} crop per metric ton

V_k = Border price of tradable inputs k per metric ton.

If DRC<1, the economy will save foreign exchange by producing the i crop domestically either for export or for imports substitution. This is because the opportunity cost of domestic resources and non-traded inputs used in producing i crop is less than the foreign exchange earned or saved. In contrast, if DRC>1, domestic costs will be in excess of foreign costs or savings indicating that the i crop should not be produced domestically and should be imported instead.

2.3.6 Estimation of the impact of policies on economic incentives

A wide range of government policies influences economic incentives in agricultural production. Price and subsidy policies, import and export policies, and more general macro-economic policies, such as exchange rate and interest rate may affect relative incentives in agriculture. This effect is measured by the proportional difference between the domestic price and the border price (import or export parity price) generally at the prevailing official exchange rate. These effects can be measured by using the nominal and effective protection rates as indicators.

Nominal protection: The Nominal Protection Coefficient (NPC) is the simplest indicator of price distortion and easy to measure. It is equal to the ratio of the domestic price of a commodity i to its border price using the official exchange rate.

Conceptually, NPC is expressed as:

$$\mathrm{NPC_i} = \frac{\mathrm{P_i^d}}{\mathrm{P_i^b}} \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [6]$$

Where, $\mathrm{P_i^d}$ is the domestic producer price of a tradable agricultural commodity i and $\mathrm{P_i^b}$ is the actual border price of that commodity, evaluated at the official exchange rate, adjusted for quality, transport, storage and other margin, measured under competitive conditions and expressed in local currency.

Thus, if $NPC_i > 1$, producers are protected and consumers are taxed; if $NPC_i < 1$, producers are taxed and consumers are subsidized; and if $NPC_i = 1$, the structure of protection is neutral.

Alternatively, this can be written as the nominal protection rate (NPR), defined as the amount by which the domestic price of a tradable output deviates from its border price. It can be stated as:

$$NPR_i = \frac{P_i^d}{P_i^b} - 1 \quad \ldots\ldots [7]$$

Thus, if $NRP_i > 0$, producers are protected and consumers are taxed; if $NRP_i < 0$, producers are taxed and consumers are subsidized; if NPC>1 or NRP>0, producers receive a price which, after direct interventions, is above the border price, giving them incentives to produce more of the crop than if equilibrium prices prevailed.

Effective protection: Price distortions affect the use of inputs and output. It is often the case, for instance, that dis-protection of products is partially compensated by subsidies of some inputs (such as fertilizer, fuel and irrigation equipment). From the standpoint of incentives, it is important to capture the net effect of these distortions. For formula for calculating the effective protection co-efficient (EPC), is expressed as following.

$$EPC_i = \frac{P_i^d - \sum a_{ij} P_j^d}{P_i^b - \sum a_{ij} P_j^b} \quad \ldots\ldots [8]$$

Where,

P_i^d = Domestic price of i^{th} commodity

P_i^b = Border price of i^{th} commodity

a_{ij} = Technical coefficients measuring the number of units of traded inputs j per unit of production of output i

P_j^d = Domestic price of traded inputs j

P_j^b = Border price of traded inputs j

If EPC>1, domestic producers of the commodity i are directly protected; if EPC<1, domestic producers of i are dis-protected; if EPC = 1, the structure of prices is neutral in terms of incentives.

The study also measured this indicator in the form of effective protection rate (EPR). It is conventionally expressed as:

$$EPR_i = EPC_i - 1 \quad \ldots\ldots [9]$$

2.3.7 Share of net import to total availability

The percent share of net import of maize to its total consumption (availability) is measured using the following formula.

$$\text{Percent share of net trade of total availability} = \frac{(M - X)}{(M - X + \text{Production})} \times 100 \quad \ldots\ldots [10]$$

Where, *M* represents import and *X* represents export

2.3.8 Forecasting of maize area, production, and yield

Accurate forecast is particularly important to facilitate efficient decision making as there is considerable time lag between making output decisions and the actual output of the commodity in the market (Shamsudin and Arshad 2000). ARIMA model was used for predicting future area, production, and yield of maize in this study. Time series secondary data for the period of 1989-2013 were used and prediction was done for the period ranged from 2014 to 2023.

ARIMA modeling has three components or stages: model identification, model estimation and diagnostic checks, and forecasting (Thomas and Leatherman 2000). In the first stage, the researcher must decide whether the time series is autoregressive, moving average, or both. This is generally done by visually inspecting diagrams of the data or employing various statistical techniques. In the second stage, the researcher should verify the original model identification is correct or not. This requires subjecting the model to a variety of diagnostics. After checking the model, the researcher then proceeds to the third stage, *forecasting*.

The main advantage of using ARIMA approach is that it can generate confidence intervals around the forecasts. This in fact serves as another check of the validity of the model. If it predicts a high degree of confidence about an uncertain forecast, the researcher may have to re-specify the form of the model.

ARIMA modeling builds on the following assumptions:

- Absence of outliers in the data series.
- Data series is stationary, that is, the data series varies around a constant mean and variance. For a good model, the residuals have zero mean, constant variance, and are also uncorrelated.
- The data series is *homoscedastic*. It means that it has a constant variance. Residuals exhibit homogeneity of variance over time, and have a mean of zero.
- Residuals are normally distributed and independent.
- The presence of linear dependence in the observations of the series.
- Limitations of ARIMA include weak stationarity, equally spaced observation intervals, and a length of about 50–100 observations. It provides better formulation for incremental than for structural change.

Steps of forecasting: Forcasting through ARIMA model was done through several steps which are briefly discussed below.

Stationarity test through ACF and PACF: Before forecasting, time series data need to be tested for stationarity. It can be done through auto-correlation function (ACF) and partial auto-correlation function (PACF). The estimated ACF and PACF of original data on area, production, and yield (without differences) and the ACF & PACF of the 1st difference of original data (with differences) are shown in Appedix figure A_1. These figures focussed autocorrelations taper very slowly for the original data of area, production and yield**.** That means all the time series data were non-stationary in nature. The 1st differences of all types of data were taken and constructed the graph using ACF and PACF to examine whether they are stationary or not. Then, it is observed that the 1st difference of all data are stationary as the autocorrelaton function quickly falls off close to zero than that of undifferenced or original data.

Stationarity test through DF and ADF test**:** Before taking final decision about the stationarity of data, the study carried out formal Dickey-Fuller (DF) and Augmented Dickey-Fuller (ADF) tests by assuming without difference and 1st difference of the actual data series as dependent variabe. The formal DF and ADF test were conducted for area, production and yield data of maize and the estimates of neccessary parameters and related statistics for the time series data has been presented in Appendix A-4.

The empirical result of DF and ADF test revealed that we could not reject the null hypothesis that is $\delta = 0$ and in such cases the time series are non-stationary because the calculated value do not exceed the critical tau values. So all the undifferenced data are non-stationary and to make the data stationary, 1st difference of all types of data have been considered and after that DF and ADF test have been done in the similar manner.

After taking the 1st difference of the original data series it was observed that the data series became stationary as the tabulated values were larger than the calculated values for the respective number of samples for both DF and ADF test. So we could accept the null hypothesis that there are no autocorrelation in the data and the time series data has transformed from non-stationary to stationary.

Model selection and identification: The identification steps involve the use of the techniques for determining the values of p, d, and q. The regressor that had been chosen to form the model was selected from various lag of time of AR (p) and MA (q). As, there are several additional sets of results specific to the ARIMA analysis. The first is the Akaike Information Criterion (AIC) and the Schwarz Criterion (SC), which are often used in ARIMA model selection and identification and in this study the model was identified by observing AIC and SC values. AIC and SC are used to determine if a particular model with a specific set of p, d, and q parameters is a good statistical fit. The model with the lowest AIC and SC values were chosen and for this purpose "Risk Simulator" software was used which can generate an Auto-ARIMA result by showing AIC and SC values for different combination of **p, d** and **q** parameters for different time series data. In Appendix A-5 and A-6, the auto generation of the values of p, d and q for area, production and yield of maize were shown, respectively.

It was mentioned in previous section that all data were stationary at 1st order difference that means d =1. So the combination of p, d and q where d =1 were observed and that combination was selected whose AIC value is lowest and that combination is ***bold*** marked in each table.

Model estimation: After having the values of AR and MA, It can be defined by adding an intercept term in the model. An ARMA (*p,q*) model has the combined form of AR(p) and MA(q), and that is:

$$Y_t = (A_1 Y_{t-1} + \dots\dots + A_p Y_{t-p}) - \left(B_1 E_{t-1} + \dots\dots + B_q E_{t-q}\right) + E_t \quad \dots\dots\dots\dots[11]$$

Where, Y_t is related to both past series values and past random errors.

Ordinary Least Square Method (OLS) was used and the above equation can be written in the following format:

Forecasted result = Intercept + AR (n) +MA (n) + ε ……………………. [12]

Where, n = number of lag(s) which was chosen from the selected combination.

Diagnostic checking: How can we understand that the model selected for predicting area, production, and yield of maize provides a reasonable fit to the data? One simple diagnostic is to obtain residuals for the selected model and obtain ACF and PACF of these residuals, say up to lag 20. The estimated ACF and PACF were shown in Appendix A-7. These figures revealed that all ACs and PACs of residuals fall within 95% confidence interval levels indicating the white niose in the error term. In other words, the correlograms of both autocorrelation and partial autocorrelation gave the impression that the residual obtained from the selected forecasting model is purely random. Hence, there might not be any need to look for another ARIMA models.

Chapter III

MAIZE PRODUCTION

The main focus of this chapter is to discuss the past and present maize production situations in Bangladesh. Maize production situations include importance and geography of maize production, characteristics of maize producers, technology use, factors associated with technology use, and economics of maize cultivation. All these issues are discussed in the following sections.

3.1 Area, Production and Yield of Maize

Currently, maize is gaining popularity to its growers as a profitable cash crop rather than food crop in many parts of the country. As per statistics from the Department of Agricultural Extension (DAE), the total area under maize cultivation is estimated to be 0.3 million ha producing 2.2 million MT with an average yield of 7.0 t/ha during 2013 (DAE 2013). Table 3.1 reveals increases in both the area and production of maize during 2001-2008, but a sudden decrease was observed during 2009. The reason behind this decrease was the outbreak of bird flu during 2008. Both area and production show steady growth during 2010-2013.

Table 3.1 Area, production and yield of maize in Bangladesh

Particular	Year						
	2001	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Area (million ha)	0.02	0.22	0.17	0.20	0.23	0.29	0.31
Production (million t)	0.08	1.34	1.14	1.37	1.55	1.96	2.18
Yield (t/ha)	4.53	6.04	6.53	6.78	6.84	6.82	6.98

Source: DAE 2013

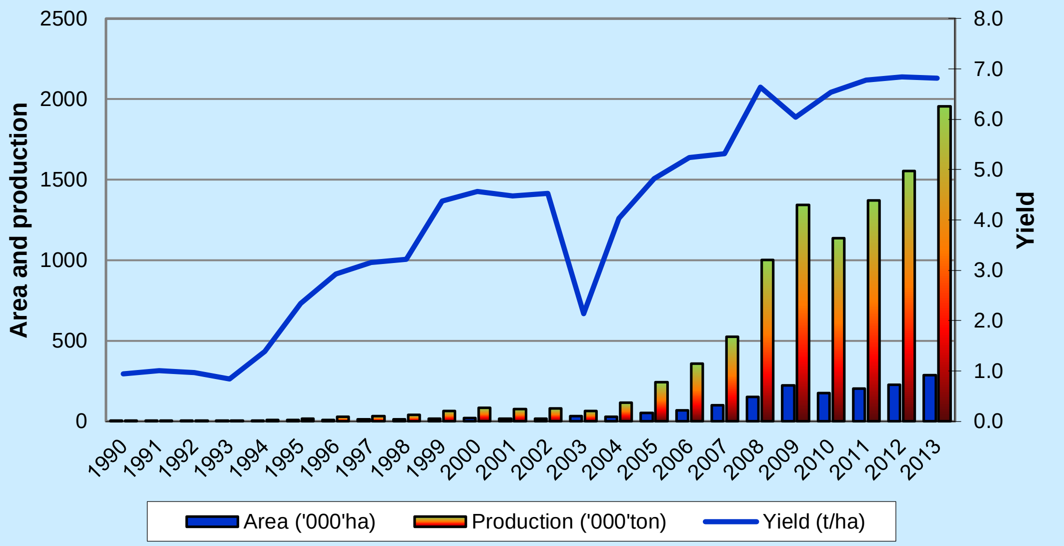
3.2 Growth Performance and Instability of Maize

It is perceived that the area and production of maize fluctuates over time and across regions. When deriving with policy advice this has to be kept into account. Therefore, the calculation of growth and instability indices for different locations and time periods can help in identifying location specific interventions/ policy measures to increase maize productivity and production.

BBS data (1990-2011) shows that the area and production of maize remained very low and more or less same during the period from 1990 to 1999, but started increasing from 2000 and continued to increase till to date. Therefore, the area and production period of maize has been grouped into two periods- Period I (1990-1999) and Period II (2000-2011). Another period (2006-2011) has also been analyzed to get some idea on growth performance during the last six years. The annual growth rates and instability of area, production, and yield of maize using BBS data are shown in Table 3.2-3.5.

DAE data (1990-2013) show that the area, production, and yield of maize remained more or less constant during the first 15 years (from 1990 to 2004). Area was stagnant around 50,050 ha till 2004. Thereafter, a sudden increase was observed. In 2013, a more than 6 times increase in maize area was observed in Bangladesh compared to 2004. Production also showed increasing trend and increase was observed from 0.24 million tons in 2004 to 2.18 million tons in 2013 (more than 9 times). Maize yield has also shown a significant increase in Bangladesh during this period (Fig 3.1). The main reason behind the sudden jump in yield during 1993-2002 and 2002-2013 was the introduction of hybrid maize accross the country.

Fig. 3.1 Area, production and yield of maize in Bangladesh, 1990-2013



Source: DAE 2013

In period-I (1990-1999), the overall growth rates of area and production of maize were negative and their instabilities were medium. Negative growth rates of area and production were found in Chittagong, Rajshahi, and Dhaka divisions. Impressive positive growth rates in area and production were registered for Rangpur and Khulna division, but their instabilities were found to be high and very high, respectively. Again, the instabilities of both area and production of maize were very high for Rajshahi, Dhaka, and Khulna divisions, whereas it was medium for Chittagong division.

In period II (2000-2011), a completely different scenario was observed for both growth rate and instability of maize area and production. In these periods, highly impressive growth rates with low instability were registered in maize area and production in all the divisions except Sylhet. Instability in area and production was observed very high only in Rajshahi division. The reason behind this increase was the development of poultry industries over the country. The growth rate of poultry population (4.29%) was positive and highly significant at 1 percent level during 2001-2013 (Appendix A-22). Increases in area and yield are also claimed to be due to the introduction of many high yielding composite varieties and hybrid maize accross the country. The lion's share of the imported seed was from India. Introduction of new seeds has resulted in higher rates of return to farmers and thus there have been some changes in cropping patterns (for details see Table 3.21-3.24). Intensive agricultural extension efforts (i.e., farmers training on production technologies, distribution of hybrid seed, and the provision of other inputs, etc.) through the Integrated Maize Promotion Project (IMPP 1997) of the Ministry of Agriculture have made a significant contribution to such a rapid rate of increase (Quasem 1999). It is noted that unlike other hybrid crops (i.e., rice, tomato, and brinjal) farmers are not able to produce hybrid maize seed; it is produced by designated 'seed growers' and so it is relatively easier to introduce hybrid maize seed among intereste farmers.

The growth performance of area and production in the last six years was very low because of lower demand for maize grain from poultry farms due to the occurance of the devastating bird flu in 2008 and higher base of area and production in 2006 (Table 3.2-3.4).

Table 3.2 Growth performance of maize in Bangladesh (in percent), 1990-2011

Division	Maize Area			Maize Production			Maize Yield		
	1990-99	2000-11	2006-11	1990-99	2000-11	2006-11	1990-99	2000-11	2006-11
Dhaka	-11.8	26.00	1.6	-8.5	31.96	0.7	3.3	5.96	-0.9
Khulna	11.2	41.74	6.3	10.8	50.02	12.8	-0.4	8.27	6.5
Rajshahi	-11.1	36.04	-10.4	-7.9	48.76	-15.0	3.3	12.72	-4.7
Rangpur	15.9	49.00	11.6	18.3	58.98	8.9	3.0	9.98	-2.7
Chittagong	-4.5	13.49	4.3	-4.4	28.61	7.3	0.1	15.12	3.0
Barisal	NA	37.37	42.3	NA	47.51	63.6	NA	10.14	21.3
Sylhet	NA	-40.6	NA	NA	-55.0	NA	NA	11.4	NA
Bangladesh	-3.7	35.43	5.9	-2.6	46.69	5.7	1.0	11.26	-0.2

Source: Calculated using data from BBS 2011; NA= Data are not available

Table 3.3 Growth and instability of maize area at division level of Bangladesh, 1990-11

Instability	Growth of area (1990-1999)			
	Negative	Slow (0-3%)	Medium (3-6%)	High (6% & above)
Low (<10%)	--	--	--	--
Medium (10-20%)	Chittagong Bangladesh	--	--	Rangpur
High (20-30%)	Rajshahi	--	--	--
Very high (>30%)	Dhaka	--	--	Khulna
Growth of area (2000-2011)				
Low (<10%)	--	--	--	Barisal, Chittagong Dhaka, Rangpur Bangladesh
Medium (10-20%)	--	--	--	Khulna
High (20-30%)	--	--	--	Rajshahi
Very high (>30%)	Sylhet	--	--	--

Source: Athor's calculation (Appendix A-8)

The growth performance of both area and production was also very low for Chittagong and Rangpur division. Medium level growth rates were observed in Dhaka and Rajshahi division. Importantly the instabilities of maize yield remained very low in all the divisions during these periods. In period-II, the growth rate of yield was double compared to the period-II (Table 3.2). Impressive growth rates of maize yield with low instabilities were also found in Chittagong, Khulna and Rangpur division. High growth rates with medium instabilities were observed in Barisal and Rajshahi division. Both growth rate and instability were very high in Sylhet division during period-II (Table 3.5). The overall productivity performance was negative during 2006-2011. Negative growth also occurred in Dhaka, Rajshahi, and Rangpur division. However, the productivity performance was found satisfactory in both Khulna and Barisal division (Table 3.2).

Table 3.4 Growth and instability of maize production at division level of Bangladesh, 1990-2011

Instability	Growth of production (1990-1999)			
	Negative	Slow (0-3%)	Medium (3-6%)	High (6% & above)
Low (<10%)	--	--	--	--
Medium (10-20%)	Chittagong Bangladesh	--	--	--
High (20-30%)	Rajshahi	--	--	Rangpur
Very high (>30%)	Dhaka	--	--	Khulna
Growth of production (2000-2011)				
Low (<10%)	--	--	--	Chittagong, Dhaka, Rangpur, Bangladesh
Medium (10-20%)	--	--	--	Barisal, Khulna
High (20-30%)	--	--	--	Rajshahi
Very high (>30%)	Sylhet	--	--	

Source: Athor's calculation (Appendix A-8)

Table 3.5 Growth and instability of maize yield at division level of Bangladesh, 1990-2011

Instability	Growth of yield (1990-1999)			
	Negative	Slow (0-3%)	Medium (3-6%)	High (6% & above)
Low (<10%)	Khulna	Chittagong Bangladesh	Dhaka Rajshahi	--
Medium (10-20%)	--	Rangpur	--	--
High (20-30%)	--	--	--	--
Very high (>30%)	--	--	--	--
Growth of yield (2000-2011)				
Low (<10%)	--	--	Dhaka	Chittagong , Khulna Rangpur, Bangladesh
Medium (10-20%)	--	--	--	Barisal, Rajshahi
High (20-30%)	--	--	--	--
Very high (>30%)	--	--	--	Sylhet

Source: Athor's calculation (Appendix A-8)

Growth decomposition of maize production: The growth analysis of maize reflected the general region and period specific patterns of growth and direction of changes in yield and area. But this analysis does not evaluate the contribution of area and yield towards production growth. Therefore, it is important to examine the sources of output growth. In order to assess the sources of output growth for maize, the change in production is divided into three effects i.e., area effect, yield effect and interaction effect. The relative contribution of area, yield, and their interaction to changes in production of maize is presented in Table 3.6.

The decomposition analysis is employed for two periods i.e., period-I (1990-1999) and period-II (2000-2011). During the period-I, positive changes in mean area and negative changes in productivity appeared to be the main responsible factors for the decreasing mean of production of maize at national level. This observation was true for Dhaka and Rajshahi divisions. For other divisions, the change in mean production was due to both the positive effects of area and productivity. In period-II, the source of change in average maize production at national level was mainly due to the positive changes in mean area (89%) and productivity (22%). The positive effect of yield change also influenced the change of maize production at national level. Similar observations were observed in Chittagong, Dhaka, Khulna, and Rangpur divisions (Table 3.6).

Table 3.6 Growth decomposition (%) in production of maize in Bangladesh, 1990-2011

Period	Effect	Divisions						Bangladesh
		Barisal	Chittagong	Dhaka	Khulna	Rajshahi	Rangpur	
1990-1999	Yield	--	13	-20	12	-40	17	-23
	Area	--	95	140	92	136	88	135
	Interaction	--	7	19	4	-4	4	10
	Residual	--	-15	-39	-8	8	-9	-22
2000-2011	Yield	-9	56	31	36	-60	15	22
	Area	79	50	87	97	125	96	89
	Interaction	-30	7	18	32	-35	11	11
	Residual	60	-13	-36	-65	70	-22	-22

Source: Author's calculation

3.3 Importance of Maize Production

Out of the total land in Bangladesh, the area under cultivation covers 57.34 per cent. Due to limited scope for increasing the net area sown, the areas sown more than once may be increased by using short duration high yielding varieties with suitable cropping patterns. This will lead to a more intensive cropping system with higher production status of Bangladesh agriculture. The availability of land per household in Bangladesh comes to only 0.297 hectares (Table 3.7). This again emphasizes that with the low per capita availability of land, Bangladesh needs to do well in agriculture sector to feed its ever-growing population. For this there is an urgent need to increase the cropping intensity and productivity thereby increasing production.

Table 3.7 Land use patterns of Bangladesh, 2013

Land use pattern	Area (million hectare)	% of total area
A. Total area	**14.860**	**100.00**
Area under forest	2.599	17.49
Cultivable land	8.520	57.34
Current fellow	0.469	3.16
Cultivable waste	0.268	1.80
Not available for cultivation	3.004	20.22
B. Total cropped area	**14.905**	**100.30**
Single cropped area	2.236	15.05
Double cropped area	4.107	27.64
Triple cropped area	1.485	9.99
Net cropped area	7.828	52.68
C. Availability of land (ha/household)	0.297	-

Source: MoA 2013

The major problem in agriculture is the shrinking agricultural land due to increased demand for housing, industrialization, and infra-structure development. Therefore, the area under all crops and fruits and vegetables is shrinking (Golder et al. 2013). In Bangladesh, rice is grown throughout the year on high to deeply flooded low land in three seasons, namely *Aus* season (March-July), *Aman* season (July-December), and *Boro* season (January-June) with overlapping or short turnover periods. There has been a very low growth in rice area during the last five years (2008/09-2012/13). However, the total rice production had an incremental growth rate of 0.02 per cent per year (Table 3.8). The increase in rice production has been possible owing largely to the adoption of modern rice varieties (HYVs) on around 73 per cent of the cultivated rice land which contributes to about 85 per cent of'the country's total rice production (Dey and Norton 1992).

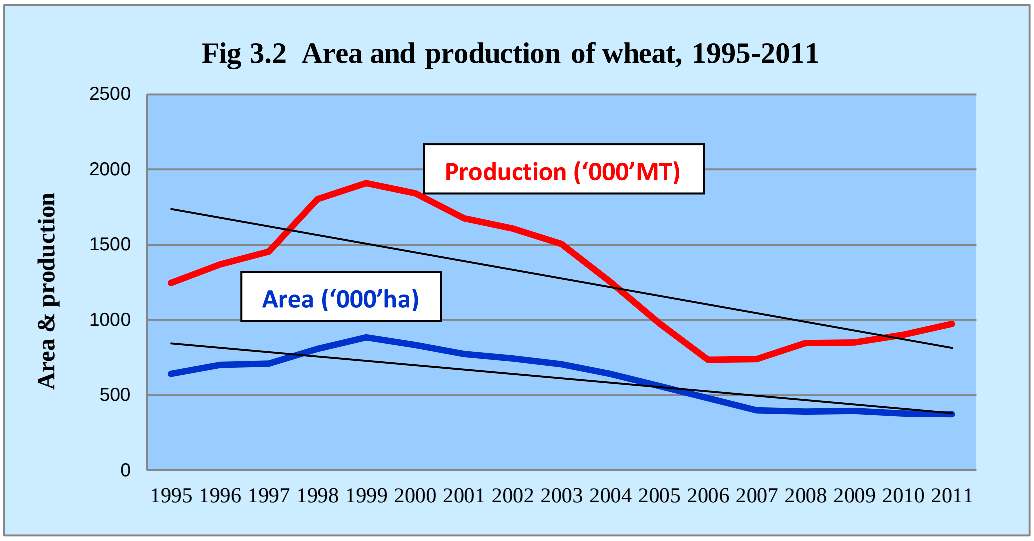
The growth rate of area under wheat crop is almost zero (0.01%), but the production and productivity growth rates are found to be positive and significant during 2008/09-2012/13 due to the adoption of high yielding varieties. It is reported that many wheat-growing farmers are now shifting to *Boro* rice because of stable and higher yield, high return and for food security (Hussain and Iqbal 2011). Nevertheless, the area under wheat is gradually replaced by maize year after year (BBS 2011). As a result wheat cultivation is reducing gradually. Figure 3.2 shows that both area and production of wheat started decreasing from 2000 and continued up to 2011. The changing scenario of area and production of maize is opposite to wheat (Fig 3.2).

The area and production of maize with its productivity are found rapidly growing at a fast pace (Table 3.8) due to its utility as feed to poultry, fish and animals as well as consumption to some extent by people mixing with wheat flour in Bangladesh. Its green parts are also used as fodder for cattle and dried parts as fuel which is becoming a scarce commodity in Bangladesh. The cultivation trends of major cereals imply that there is a vertical improvement in the cereal production where the yield component played a crucial role in increasing crop production, which is again an utmost important factor for the nation to feed its people.

Table 3.8 Annual growth rate (%) of area, production and yield of different crops in the last five years (2008/09-2012/13)

Crop	Area	Production	Yield
Cereal crops			
Rice	0.00	0.02***	0.02***
Wheat	0.01	0.08***	0.07***
Maize	0.15***	0.16***	0.02***
Cash crops	0.11	0.13	0.02***
Potato	-0.01^{ns}	0.09	0.11
Pulses	0.05**	0.06**	0.03
Oilseeds	0.01	0.02	0.01*
Spice crops	0.04**	0.14***	0.09***
Vegetable crops	0.01**	0.06***	0.04***

Source: DAE 2013
Note: *, ** and *** indicates significant at 10%, 5% and 1% level, respectively.



Source: Author's calculation using data from various issues of BBS

In Bangladesh, resource use efficiency studies (Rahman 2011, Ferdausi 2011; Paul 2012) reflect that seeds, irrigation, TSP, human labour, and land preparation contributed positively to maize production and farmers had opportunities to increase yield, thus, increasing profitability. Besides being a C_4 plant it is also climate resilient. Golder et al. (2013) suggested that efforts may be taken to expand its cultivation in southern belt; greater Sylhet region, etc. where lands remain fallow after harvest of *T.Aman* rice.

Human consumption of maize has increased to some extent due to government interventions in certain areas. But, there is no concrete and authentic data on maize consumption in Bangladesh. Different scientists have estimated maize consumption in their own ways. For instance, Bhuiyan (2005) analyzed the whole country situation of maize utilization using secondary data and stated in his MS Thesis that of total maize produced 36 per cent is utilized in poultry sector, 8 per cent starch industry, 11.67 per cent as cattle feed and fodder, 39.75 per cent as human food (including green cob), and 4.5 per cent other purposes. Rob (2010) conducted a study on maize marketing in *Char* areas and mentioned that almost 95 per cent of maize was milled for animal feed and only 5 per cent used as corn flour.

A variety of crops including cereals, pulses, oilseeds, spices, and vegetables are grown in Bangladesh round the year. The main food grain crops in the country are rice and wheat. Rice is the major cereal crop occupying 70.62 per cent of the total cropped area followed by other crops, vegetables, oilseeds and pulses. In spite of being a promising crop maize has still an insignificant coverage of only about 2.71 per cent of the rice area and 1.92 per cent of the gross cropped area (Table 3.9).

The farmers in the maize growing areas are very much benefiting by cultivating hybrid maize. They are switching from wheat cultivation to maize cultivation due to its higher yield potentiality and profitability. A recent field survey[3] (2012) in two maize growing districts described the average share of income from maize which was 28.5 per cent of the total annual household income of the maize farmers (Table 3.10).

[3]This survey was conducted under a FAO funded research project titled '*Policy options for supporting agricultural diversification in Bangladesh* during July-August, 2012 (Miah et al. 2013)

Table 3.9 Area and production under different crops in Bangladesh during 2012/13

Major crops	Area (Million ha)	% of cropped area	Production (Million tons)
Rice	11.42	70.62	33.83
Wheat	0.42	2.60	1.25
Maize	0.31	1.92	2.17
Pulses	0.71	4.39	0.77
Oilseeds	0.76	4.70	0.89
Spices	0.51	3.15	2.98
Potato	0.44	2.72	8.60
Vegetables	0.77	4.76	13.22
Other crops*	0.83	5.13	13.20
Total	**16.17**	**100**	**76.91**

Source: DAE 2013, *sweet potato, jute and sugarcane

Table 3.10 Annual household net incomes of the maize farmers, 2011-2012

Crop	Dinajpur *(N=30)*		Rangpur *(N=30)*	
	Amount (Tk)	%	Amount (Tk)	%
Rice	31,903	35.7	31,807	58.5
Maize	32,890	36.8	8,155	15.0
Wheat	887	1.0	--	--
Jute	1,280	1.4	1,858	3.4
Vegetables	--	--	959	1.8
Potato	7,308	8.2	2,203	4.1
Oilseed	--	--	83	0.2
Spices	2,353	2.6	907	1.7
Livestock	4,992	5.6	6,235	11.5
Poultry	460	0.5	351	0.6
Fish	7,392	8.3	1,813	3.3
Total	**89,465**	**100**	**54,372**	**100**

Source: Field survey 2012; Conversion rate 1 USD = 78.0 BDT

3.4 Maize Geography and Ecology

This section presents disaggregated statistics on maize production for different geographical locations of Bangladesh in order to identify main maize growing areas. It also highlights agro-ecological zones, soil types, rainfall, and temperature pattern over time for main maize growing regions that are important for maize cultivation.

3.4.1 Maize geography

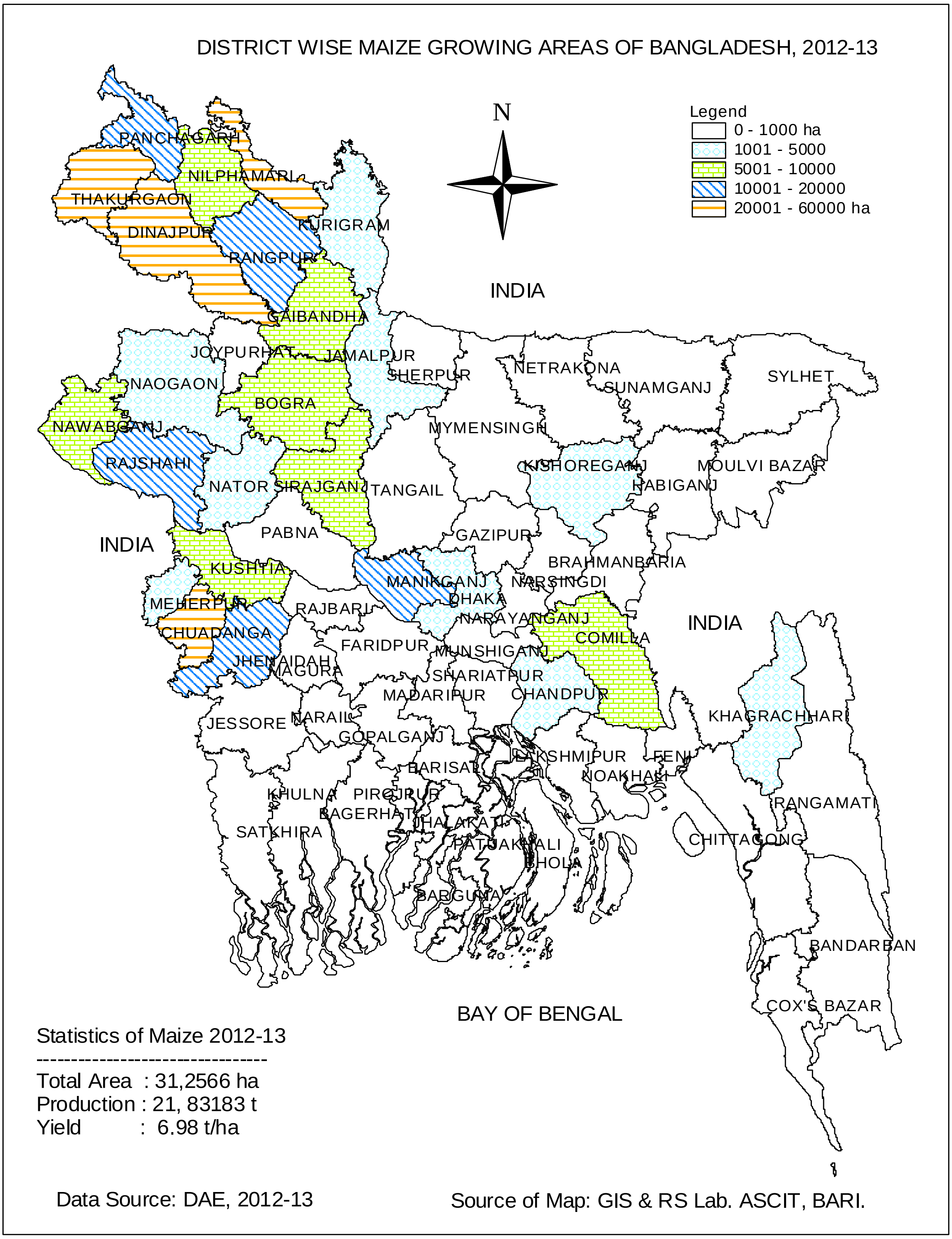
Maize is grown in most of the areas of Bangladesh. Several factors, such as higher return, lower cost of production, ready output market, and suitable weather influence farmers to cultivate maize instead of wheat, boro rice, mustard, and lentil cultivation (FGD 2013). As per the statistics of DAE, the total area under maize cultivation is 0.31 million ha with the production of 2.18 million tons during 2012-2013 (DAE 2013). The three years' (2011-2013) average of area and production of the 10 intensive maize growing districts (among 64 districts) are shown in Table 3.11. Table 3.12 shows that most of the intensive maize growing districts are under Rangpur division followed by Khulna and Rajshahi divisions. Figure 3.3 shows the spread of maize growing districts of Bangladesh for 2012-2013.

Table 3.11 Last three years (2011-2013) average of area and production of maize in the intensive growing districts of Bangladesh

Division/District	Area covered		Production		Yield (t/ha)
	'000' Ha	% of Bangladesh	'000'Ton	% of Bangladesh	
Rangpur division					
1. Dinajpur	47.09	17.1	340.58	18.0	7.23
2. Thakurgaon	26.77	9.7	183.73	9.7	6.86
3. Rangpur	13.89	5.0	89.83	4.7	6.47
4. Panchagar	11.56	4.2	79.77	4.2	6.90
5. Lalmonirhat	24.48	8.9	161.62	8.5	6.60
Dhaka division					
6. Manikganj	13.12	4.8	83.28	4.4	6.35
Khulna division					
7. Chuadanga	39.02	14.2	276.43	14.6	7.09
8. Jhenaidah	11.15	4.0	79.34	4.2	7.11
Rajshahi division					
9. Rajshahi	9.72	3.5	56.52	3.0	5.82
10. Bogra	9.18	3.3	68.58	3.6	7.47
Other divisions					
11. Other districts	69.54	25.2	477.64	25.2	6.87
Bangladesh	**275.52**	**100.0**	**1,897.32**	**100.0**	

Source: DAE 2013

Fig 3.3 District-wise maize growing areas in Bangladesh, 2012-2013



Region wise scenario of area and production is different in Bangladesh. Table 3.12 reveals the area of maize in the divisions of Bangladesh from 2011-2013 and shows that the average area of maize is more for Rangpur, Khulna, and Rajshahi divisions. Barisal and Sylhet divisions are showing very low amount of area under maize compared to other divisions. There is much variation observed in the area for Dhaka and Khulna divisions. Chittagong, Sylhet, and Rangpur divisions are showing consistency in the area. The lowest variation is observed in Barisal division (Table 3.12).

Table 3.12 Variation in maize area in different divisions of Bangladesh during 2011-2013

(Hectares)

Division	Minimum	Maximum	Mean	Std. Deviation	CV (%
Barisal	281	620	447.0	140.9	31.5
Sylhet	2	902	383.3	386.6	100.9
Chittagong	2	3804	853.7	1198.7	140.4
Dhaka	4	13118	1424.9	3213.9	225.6
Khulna	3	39015	5959.5	12223.8	205.1
Rajshahi	537	9717	4464.1	3504.7	78.5
Rangpur	3069	47089	17795.6	14435.2	81.1

Source: DAE 2013

Table 3.13 illustrates that the average production of maize is more in Rangpur, Khulna, and Rajshahi divisions. Barisal and Sylhet divisions are showing very less production compared to other divisions. There was no production at Sylhet and Barisal district before 2002 and 1997, respectively. After the development of poultry sector across the country in 2000-2001, the farmers of these two districts might have started producing maize as a cash crop. There is much variation observed in the production for Dhaka and Khulna divisions. The reason behind this variation is that the farmers of Dhaka division are more enthusiastic toward vegetable cultivation in the winter compared to Khulna division. Sylhet and Rangpur divisions are showing consistency in the production.

Table 3.13 Division-wise production (tons) of maize in Bangladesh during 2011-2013

Division	Minimum	Maximum	Mean	Std. deviation	CV (%)
Sylhet	16	4,959	1,948.3	2,158.4	110.8
Barisal	1,233	4,886	2,724.2	1,369.3	50.3
Chittagong	13	23,823	5,496.6	7,655.8	139.3
Dhaka	18	83,276	9,290.4	20,567.1	221.4
Khulna	24	276,432	42,455.7	86,596.9	204.0
Rajshahi	3,833	68,577	30,628.3	22,839.6	74.6
Rangpur	22,548	340,584	123,149.5	103,787.2	84.3

Source: DAE 2013

Division-wise yields (t/ha) of maize in Bangladesh during 2011-2013 are presented in Table 3.14 which shows that the average yield of maize is more in Rajshahi, Rangpur, and Khulna divisions, while Sylhet division is accruing low yield compared to all other divisions in the country. Much variation in the yield was observed in Barisal and Sylhet divisions and the lowest in Rangpur and Rajshahi division.

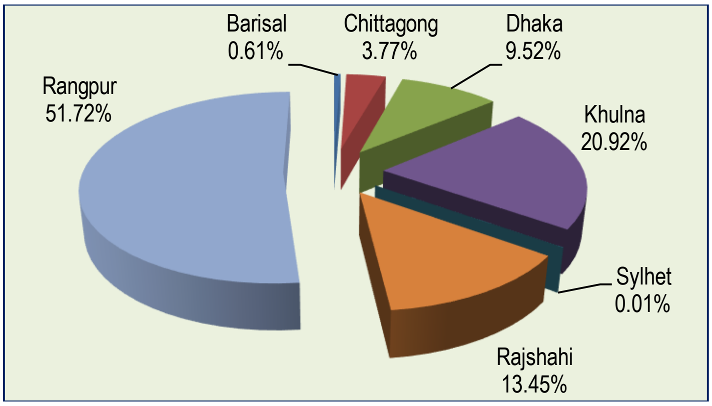
Table 3.14 Division-wise yield (tons/ha) of maize in Bangladesh during 2011-2013

Division	Minimum	Maximum	Mean	Std. Deviation	CV (%)
Barisal	4	8	5.88	1.48	25.17
Sylhet	4	7	5.33	1.23	23.08
Chittagong	5	8	5.96	0.82	13.76
Dhaka	4	8	6.18	0.89	14.40
Khulna	5	8	6.81	0.77	11.31
Rajshahi	6	8	7.15	0.71	9.93
Rangpur	6	7	6.90	0.31	4.49

Source: DAE 2013

Most of maize area is concentrated in Rangpur division which is 51.7 per cent of the total area under maize, while Khulna, Rajshahi, and Dhaka divisions are collectively contributing about 43.9 per cent to the total area during 2012-2013. Chittagong, Sylhet, and Barisal divisions are contributing only 4.4 per cent to the total area (Fig 3.4).

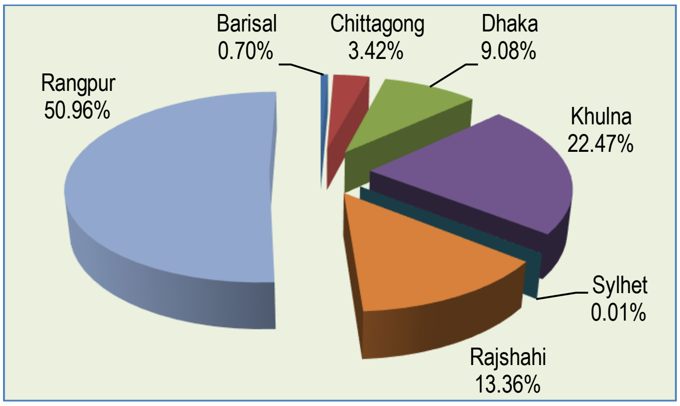
Fig 3.4 Percent distribution of maize area by divisions in Bangladesh, 2012-2013



Source: DAE 2013

Rangpur division is leading in the production of maize in the country during the cropping season of 2012-2013 and contributing about 51 per cent to the total production. Khulna, Rajshahi, and Dhaka divisions are collectively contributing about 45 per cent of total area under maize in the country (Fig 3.5).

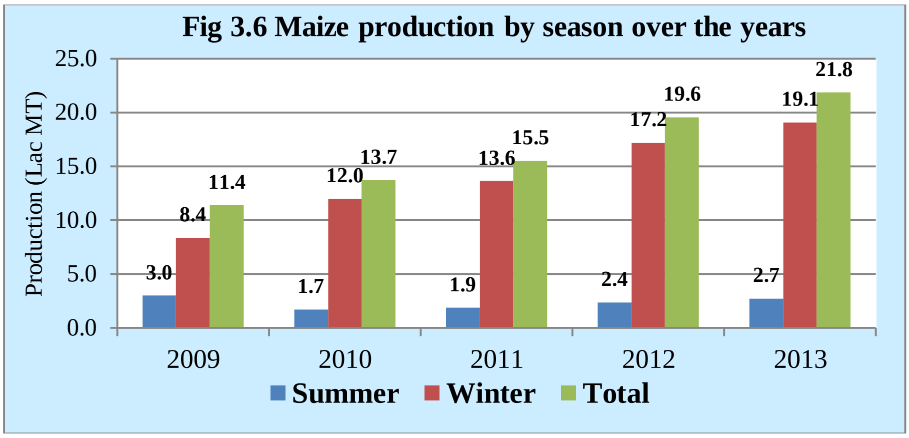
Fig 3.5 Percent distribution of maize production by divisions in Bangladesh, 2012-2013



Source: DAE 2013

Maize production by season: Maize possesses a wide genetic variability enabling it to be grown successfully throughout the world covering low land, tropical, subtropical, and temperate agro-climatic conditions. Due to its broad adaptability, it is grown in the variying environmental conditions in Bangladesh, from subtropical low land at sea level to high elevation. Maize is grown both in *Rabi* and *Kharif-1* seasons and well suited to the existing agronomic conditions. In Bangladesh, the growing period of maize in *Rabi* season is 15th November- 31st March, whereas the period 16th March -15th July for Kharif-1. Small amounts of land are also planted on hill slopes in eastern Bangladesh during *Kharif-2* (16th July-15th October). Early sowing (in September) and late sowing (in February) of maize are commonly found in Chuadanga and Dinajpur districts, respectively. Many Dinajpur farmers sow maize seeds just after potato harvest (FGD 2013). Ali et al. (2008) stated that '…while best adapted to cropping during the *Rabi* season, there is potential for it to be grown more widely in many parts of the country during the *Kharif-1* and even during the monsoon (*Kharif-2*) season on hillsides in the Chittagong Hill Tract areas'. Detailed crop growing seasons can be seen in the Appendix A-9.

DAE (2013) statistics show that the lion share of maize is cultivated in the wither season over the years. In many districts, farmers also grow maize in summer (rainy) season. The statistics also reveal that 87.65 per cent maize is grown in *Rabi* season and the rest 12.35 per cent are grown in the *Kharif-1* season in 2013 (Fig 3.6). Similar production scenarios can be found in the other years. Table 3.15 depicts that irrespective of growing season, the highest area was planted to maize in four districts, namely Dinajpur, Chuadanga, Thakurgaon, and Lalmonirhat during 2013. These four districts covered about 48.6 per cent of the total maize area and provided about 50.6 per cent of the total production of Bangladesh.



Source: DAE 2013

Table 3.15 Season-wise area and production of maize in major growing districts, 2013

Division/ district	Winter season		Summer season		Both seasons			
	Area ('000'ha)	Production ('000' ton)	Area ('000'ha)	Production ('000'ton)	Area ('000'ha)	%	Production ('000'ton)	%
Rangpur								
1. Dinajpur	51.15	383.63	5.79	38.09	56.94	18.2	421.71	19.3
2. Thakurgaon	20.89	149.92	7.43	46.04	28.32	9.1	195.96	9.0
3. Lalmonirhat	19.81	129.45	5.28	33.54	25.09	8.0	163.00	7.5
4. Rangpur	12.27	75.43	4.40	25.65	16.67	5.3	101.08	4.6
5. Panchagarh	13.80	86.88	1.15	8.14	14.95	4.8	95.02	4.4
6. Nilphamari	6.28	40.13	1.57	10.25	7.85	2.5	50.38	2.3
Khulna								
7. Chuadanga	41.25	323.25	0.25	1.50	41.50	13.3	324.75	14.9
8. Jhenaidaha	13.80	89.53	0.00	0.00	13.80	4.4	89.53	4.1
9. Kustia	6.38	47.85	0.51	2.55	6.89	2.2	50.40	2.3
Dhaka								
10. Manikgonj	10.93	75.97	5.14	29.29	16.07	5.1	105.26	4.8
Rajshahi								
11. Rajshahi	5.52	35.55	7.35	41.55	12.87	4.1	77.10	3.5
12. Bogra	8.45	66.65	0.83	5.11	9.28	3.0	71.75	3.3
13. Gaibandha	8.03	57.58	0.32	1.89	8.35	2.7	59.47	2.7
14. Nawabganj	5.31	35.03	0.42	1.83	5.73	1.8	36.86	1.7
Other divisions								
15. Other districts	43.46	312.69	4.82	28.25	48.27	15.5	340.93	15.6
Bangladesh	**267.32**	**1909.51**	**45.24**	**273.67**	**312.57**	100	**2183.18**	100

Source: DAE 2013

The perusal of Table 3.16 is that the areas under most of the crops in summer season increased to some extent in Bangladesh except rice and pulses. The decrease in pulses area was much higher than that of rice area. Similarly, the area under most of the crops increased in the winter season during 2012-2013 except the area under rice and spices crops. However, the highest positive changes occurred in the area under wheat and maize cultivation in the winter season of 2012-2013 (Table 3.16). It is noted that the overall area under wheat is decreasing over the year.

Table 3.16 Change in maize area sown during different seasons vis-à-vis other seasonal crops in Bangladesh

Major Crops	2012/13 (million ha)		% change over previous year	
	Summer	Winter	Summer	Winter
Rice	6.66	4.76	-1.19	-0.83
Wheat	--	0.42	--	+16.67
Maize	0.04	0.27	+9.75	+12.50
Pulses	0.05	0.66	-8.16	+2.31
Oilseeds	0.09	0.67	+7.89	+4.01
Potato	--	0.44	--	+2.33
Vegetables	0.27	0.50	+1.50	+6.38
Spices	0.03	0.48	+6.25	-3.25

Source: DAE 2013

On the other side, the scenarios of different crop productions presented in Table 3.17 discusses the growth performances of all the crops are found to be positive for the last five years (2008/09-2012/13)**.** But the highest growth performance was found in the production of winter maize (0.20%) followed by that of wheat (0.08%) and winter vegetables (0.08%). The annual growth performances of winter spices (0.14%) and potato (0.09%) productions are also observed to be impressive in Bangladesh.

Table 3.17 Production level of different crops in Bangladesh, 2008/09-2012/13

(Million tons)

Crops	Season	2008/09	2009/10	2010/11	2011/12	2012/13	GR (%)
Rice	Summer	13.53	13.92	14.92	15.13	15.05	0.03***
	Winter	17.81	18.34	18.62	18.76	18.78	0.01***
	Total	31.33	32.26	33.54	33.89	33.83	0.02***
Wheat	Winter	0.85	0.97	0.97	1.00	1.25	0.08***
Maize	Summer	0.30	0.17	0.19	0.24	0.27	0.01
	Winter	0.84	1.20	1.36	1.72	1.90	0.20***
	Total	1.14	1.37	1.55	1.95	2.17	0.16***
Pulses	Summer	0.04	0.04	0.05	0.06	0.06	0.01***
	Winter	0.55	0.60	0.67	0.61	0.71	0.05*
	Total	0.59	0.65	0.72	0.67	0.77	0.06**
Oilseeds	Summer	0.09	0.09	0.08	0.08	0.09	-0.01
	Winter	0.75	0.70	0.76	0.77	0.80	0.02
	Total	0.84	0.79	0.84	0.84	0.89	0.02
Potato	Winter	5.27	8.17	8.33	8.21	8.60	0.09
Vegetables	Summer	3.70	3.59	3.49	3.75	3.99	0.02
	Winter	6.93	7.28	7.70	8.83	9.23	0.08***
	Total	10.62	10.87	11.19	12.58	13.22	0.06***
Spices	Summer	0.06	0.05	0.05	0.05	0.06	0.00
	Winter	1.61	2.24	2.53	2.91	2.92	0.14***
	Total	1.67	2.29	2.57	2.97	2.98	0.14***

Source: DAE 2013
Note: *, ** and *** indicates significant at 10%, 5% and 1% level, respectively.

3.4.2 Seasonality in maize trade and price

Maize trade at producing centers starts immediately after harvesting (April). The majority of the farmers generally do not store maize for higher price due to many socio-economic reasons. The major reasons are immediate cash needs of the farmers, lack of adequate drying floor and lack of storage facility. Different middlemen traders and feed millers' agents buy maize directly from farmers' homesteads. A delegate of maize traders estimated that the production of maize at Chuadanga district for 2012 to be 357 thousand metric tons of which 55 per cent was sold to different traders within three months (March-May) and the rest was sold in the following five months (June-December). It is important to mention here that the entire maize is handed over from farmers to traders within 3-4 months. Maize trade generally takes place between July-December among different traders. Normally, *Arathdars* and *Beparis* store big amounts of maize and maintain proper moisture content during this period. The highest farm gate prices prevailed in the months of November and December due to low supply of maize at this time. Again, the lowest prices were prevailed in the months of April and May which are the months after harvesting (Table 3.18).

Table 3.18 Seasonality in maize trade and price in major markets during 2012

Month	Producing area: Chuadanga district		Consuming area: Quality Feed Industry, Gazipur district			
	Volume traded ('000'ton)	Farm gate price ('000' Tk/ton)	Domestic supply ('000'ton)	Importation ('000'ton)	Domestic price ('000' Tk/ton)	Import price (USD/ton)
January	--	--	--	0.90 (13.6)	27.00-28.00	290-300
February	--	--	--	1.00 (15.2)	27.00-28.00	300-310
March	89.25 (25)	17.50-18.75	2.70 (17.5)	--	22.00-23.00	300-310
April	71.40 (20)	12.00-12.50	3.50 (22.7)	--	18.00-20.00	240-280
May	35.70 (10)	12.00-12.50	3.40 (22.1)	--	18.00-20.00	240-280
June	17.85 (5)	12.50-13.75	3.40 (22.1)	--	21.00-22.00	240-280
July	17.85 (5)	13.75-15.00	2.40 (15.6)	--	22.00-23.00	240-280
August	17.85 (5)	13.75-15.00	--	1.00 (15.2)	22.00-23.00	240-280
September	17.85 (5)	16.25-18.75	--	1.00 (15.2)	23.00-24.00	240-280
October	17.85 (5)	20.00-21.25	--	1.00 (15.2)	28.00-29.00	240-280
November	35.70 (10)	22.50-25.00	--	0.90 (13.6)	28.00-29.00	280-290
December	35.70 (10)	22.50-25.00	--	0.80 (12.1)	28.00-29.00	290-300
Total	357.0 (100)	--	15.40 (100)	6.60 (100)	--	--

Figures in the parentheses indicate percent of total maize traded
Source: FGD 2013 with traders and FIAB

Different feed industries are the prime consumers of maize grain. According to the opinion of the Feed Industries Association of Bangladesh (FIAB), domestic production can't fulfill the total requirement of the feed industries. Therefore, feed millers have to import maize grain from India. It was also mentioned that Quality Feed Industry (QFI) procured 22,000 tons of maize in 2012 of which it procured 70 per cent from the domestic market and imported 30 per cent from India. QFI bought domestic maize grain during the months of March-July because of its availability. It imported maize during the rest of the year. An assessment of the price scenario at the consuming centres reveals that the lowest buying price of domestic maize was found during the months of May-June, whereas it was highest during the months of October-December. The price of maize at consuming centres is mostly determinated by its availability and transportation costs. The import price of maize remained unchanged (USD 240-280/ton) throughout the months of April to October. Import price usually increases during November and March (Table 3.18).

3.4.3 Maize ecology

An agro-ecological zone (AEZ) indicates an area characterized by homogenous agricultural and ecological characteristics. This homogeneity is more prominent in the sub-region and unit levels. The AEZs of Bangladesh have been identified on the basis of hydrology, physiography, soil types, land levels in relation to flooding, cropping patterns, and seasons (www.banglapedia.org). There are 30 AEZs in Bangladesh which are shown in Fig 3.7.

Most of the AEZs of Bangladesh are suitable for maize cultivation. It is depicted from Table 3.19 that major ten maize-growing districts are under 19 AEZs. The AEZs are 1-12, 14-15, 19, 22, and 25-28. The major soil types of these AEZs are non-calcareous (NC) brown, NC alluvium, NC gray, NC dark grey, acid basin clays, calcareous grey, calcareous dark grey, shallow grey terrace, and deep grey terrace.

Table 3.19 Soil charecteristics of the selected AEZs in different maize growing districts

District	AEZs	Main soil type
Dinajpur	1, 3, 25 & 27	Grey floodplain; non-calcareous brown floodplain; and black Terai and grey terrace soils
Rangpur	2, 3 & 27	Non-calcareous alluvium; grey floodplain; and non-calcareous brown floodplain
Kushtia*	11	Silt loam, silty clay loam in ridges and dark grey clay soils in basins; Most ridge soils are calcareous and basin soils are non-calcareous.
Dhaka	7, 8, 9, 15, 19 & 28	Grey floodplain and non-calcareous grey floodplain soils. Red brown terrace soil.
Bogra	3, 4, 5, 7, 25 & 27	Non-calcareous alluvium and grey terrace soils.
Rajshahi	5, 10, 11 & 26	Calcareous dark grey floodplain soils and calcareous brown floodplain soils.
Comilla	19 & 22	Grey floodplain and non-calcareous dark grey floodplain soils.
Jessore	11 & 14	Silt loam and silty clay loam. On basin margins grey and dark grey acidic heavy clay overlies peat.
Pabna	7, 11 & 12	Non-calcareous alluvium. Calcareous dark grey floodplain and calcareous brown floodplain soils.
Jamalpur*	7, 8, 9 & 28	Soils are mixture of sandy and silty alluvium which occupies most char land. Dark grey floodplain soils are also found.

Source: Bhuiyan and Bhuiya (undated), BBS (2010a)
Note: * due to non availability of data rainfall of adjacent district was taken into consideration.

Short-term rainfall patterns recorded during maize growing season (*Rabi*) for different maize growing areas reveal that the average rainfall recorded in 2010 for most of the maize growing districts was much higher compared to the rainfalls recorded in 2009 and 2011. In 2010, the highest rainfall (305 mm) was recorded in Comilla district and the lowest (83 mm) in highly maize growing district Dinajpur. Again, the average rainfalls recorded in the *Kharif-1* season ranged from 419 to1,402 mm in 2010 and 714 to1,133 mm in 2011. In 2010, the highest rainfall (1,402 mm) was recorded in Rangpur district and the lowest (419 mm) in Rajshahi district during Kharif-1 season (Table 3.20).

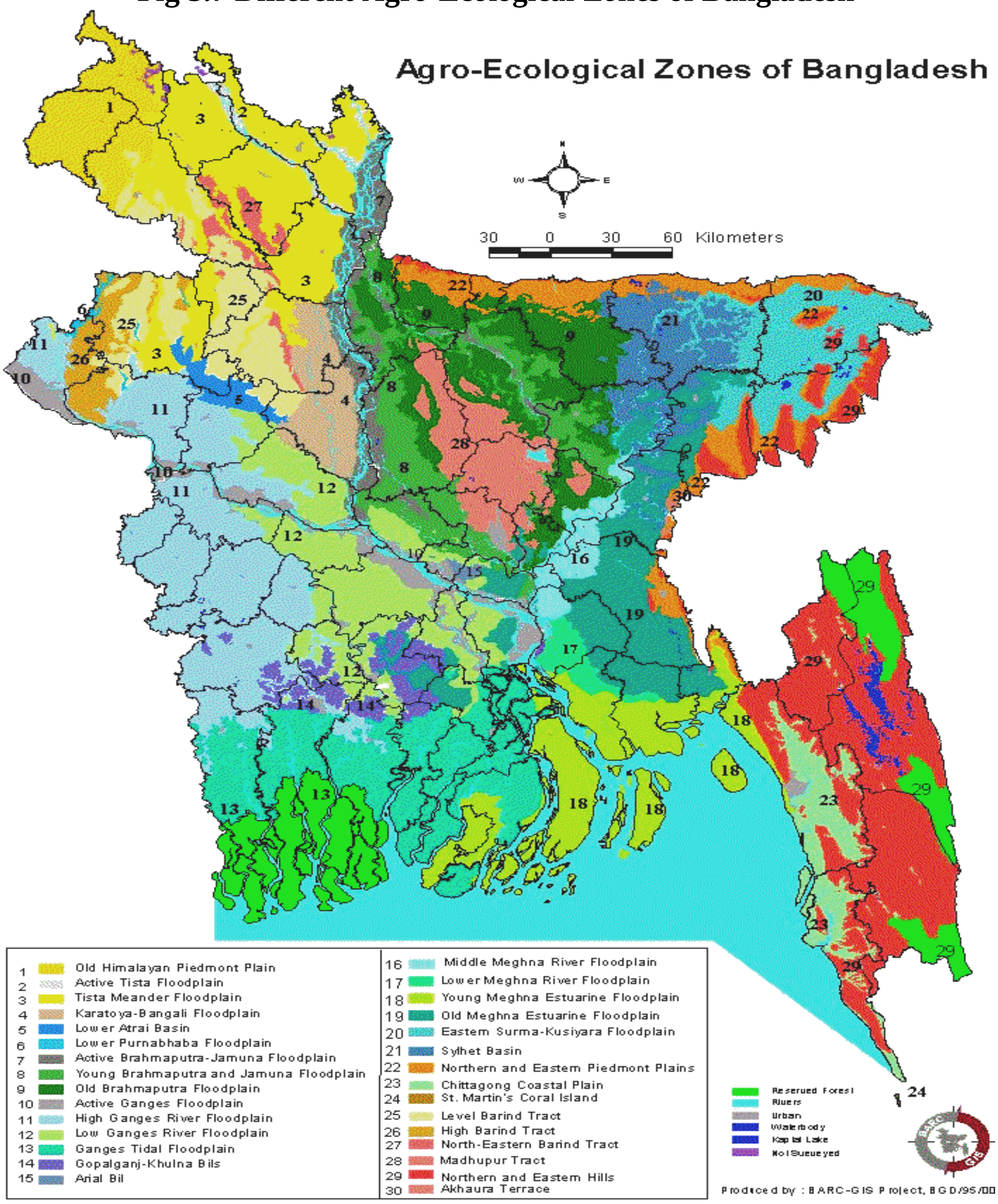
Long-term (1991-2011) rainfall pattern show a decreasing trend for all the maize growing districts except Dhaka and Jessore districts (Appendix A-10). Similarly, the growth rates of rainfall are negative for all the maize -growing districts except Dhaka and Jessore (Appendix A-11).

Table 3.20 Average rainfall (mm) in different maize growing areas during maize growing seasons (2009-2011)

District	Rabi season (October-February)			Kharif-1 season (March-July)		
	2009	2010	2011	2009	2010	2011
Dinajpur	268	83	31	1158	1161	971
Rangpur	231	128	27	1077	1402	997
Kushtia*	96	135	20	511	440	957
Dhaka	80	303	112	1071	711	1048
Bogra	92	213	12	579	589	714
Rajshahi	53	171	42	468	419	776
Comilla	98	305	76	1154	907	1074
Jessore	74	269	19	910	736	809
Pabna	71	174	7	593	483	823
Jamalpur*	29	198	31	1043	1318	1133

*Rainfall of the adjacent district is considered
Source: BBS 2011

Fig 3.7 Different Agro-Ecological Zones of Bangladesh



Source: http://www.apipnm.org/swlwpnr/reports/y_sa/z_bd/bdmp231.htm

Beside management practices, maize production depends on environmental conditions. The main environmental factors influencing maize growth are temperature and moisture. The optimal average temperatures for maize growth range between 20°C (68°F) and 22.8°C (73°F). Maize can survive short exposure to low and high temperatures of 0°C (32°F) and 44.4°C (112°F), respectively. Temperatures between 32-35°C are considered to cause heat stress which is harmful to maize production. Cooler temperatures slow down the growth of plants and stunted once the temperature drops to about 5°C (41°F). Extremely low temperatures cause freeze damage, the severity of which will depend on the temperature, duration, and maize growth stage (Wiatrak 2013).

Temperature variations in different maize-growing seasons are presented in Table 3.21. The overall short-run maximum and minimum temperature during *Rabi* season prevailed in different maize growing districts in 2009 and 2011, respectively show a decreasing trend over the time. Again in *Kharif-1* season, the overall maximum and minimum temperatures prevailed in the different maize growing districts in 2010 and 2009, respectively show fluctuating trends over the *Kharif-1* season. The important observation is that the maximum temperature rose above 35ºC in Kustia, Rajshahi, and Pabna district during 2010. In 2009, the maximum temperature was also recorded above 35ºC in Rajshahi and Jessore district. Temperatures above 35ºC are harmful for successful maize cultivation in Bangladesh.

The long-term temperature scenario reveals that minimum tempertature registered positive and significant growth rates over 1991-2011. It implies that the the temperatures in maize growing districts are increasing year after year. Again, maximum temperature is also increasing but not significant at all (Appendix A-12). The trends of minimum and maximum temperature in the last decade (2002-2001) also show similar patterns as discussed above (Appendix A-13 & A-14).

Table 3.21 Temperature variation during maize growing seasons in Bangladesh

District	Rabi season (October-February)						Kharif-1 season (March-July)					
	2009		2010		2011		2009		2010		2011	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
Dinajpur	27.3	15.3	26.9	14.9	26.5	14.9	32.5	22.5	32.9	23.1	32.0	22.8
Rangpur	27.1	15.7	26.8	15.3	26.2	15.5	32.0	22.5	31.9	22.8	31.5	22.7
Kushtia*	16.1	15.7	28.1	15.1	27.8	14.7	24.6	24.2	35.4	24.9	33.9	23.5
Dhaka	28.8	17.9	28.2	17.6	27.8	17.5	30.0	24.5	34.0	25.3	32.7	24.4
Bogra	28.5	16.0	28.2	15.9	27.7	16.0	33.5	23.2	33.7	24.2	32.7	23.7
Rajshahi	28.2	14.9	27.6	14.8	27.3	14.7	35.1	23.2	35.8	24.1	34.0	23.3
Comilla	28.7	16.4	28.3	16.4	27.9	16.7	32.9	23.3	32.6	24.2	32.0	23.5
Jessore	29.9	15.1	29.1	15.2	29.0	15.0	35.6	23.5	35.5	24.8	34.2	23.7
Pabna	28.3	15.0	27.7	14.9	27.3	14.6	34.9	23.3	35.3	24.3	33.7	23.4
Jamalpur*	28.1	16.3	27.5	16.2	27.0	16.0	32.1	23.1	32.1	23.6	31.4	23.4

Note: Max and Min indicate Maximum and Minimum, respectively
*Due to non-availability of data, temperature of the adjacent district is considered
Source: BBS 2011

3.5 Maize-rice Cropping System

Rice is the staple cereal crop in Bangladesh which is grown throughout the country year round. *Rabi* season maize is grown in rotation after the traditional monsoon *Aman* rice crop. In almost all the regions, maize is grown as a high-input (hybrid seed, high doses of fertilizer, sufficiently irrigated) crop, especially in Northwest and West central Bangladesh, where it is replacing mostly wheat, chili, mustard, or vegetables, or *Boro* rice in some areas

(Waddington et al. 2006; 2007 as cited in Ali et al. 2008, P. 5). Maize is most commonly grown in maize-fallow-*T. Aman* rice; potato-maize/relay maize-*T.aman*; maize-relay jute/jute-*T.aman*; maize-*Aus* rice-*T.aman* rice; or maize-vegetables-vegetables cropping patterns (CIMMYT 2005; 2006 as cited in Ali et al. 2008, P. 5).

Maize cultivation is less detrimental to the environment than *Boro* rice cultivation. With increasing concerns about arsenic contamination in *Boro* rice (Heikens et al. 2007 as cited in Ali et al. 2008, P.5), maize offers an attractive alternative cereal crop that has already been shown to contain lower concentrations of arsenic. Again, it requires much less water for irrigation than *Boro* rice which ultimately reduces the risk of arsenic accumulation in the soil and crop. In areas, where soils are already contaminated with arsenic, maize can be grown instead of *Boro* rice as an arsenic management option. Additionally, the high financial and environmental costs of irrigating *Boro* rice with large amounts of water from electric or diesel pumps is of increasing concern. Maize needs only around 850 liter water per kg grain production (with 2-4 irrigations) compared with 1,000 liter/kg for wheat grain (1-3 irrigations) and over 3,000 liter/kg rice grain (with 20-35 irrigations) for *Boro* rice (Ali et al. 2008).

3.6 Maize-based Cropping Patterns

Ali et al. 2008 described maize-based cropping patterns as:

> Hybrid maize was promoted as a winter crop and is generally cultivated in Bangladesh after the harvest of traditional *T. Aman* rice. But now farmers are increasingly fitting maize with a wide range of other traditional crops, such as potato, jute, and various vegetables. This indicates that hybrid maize cultivation in Bangladesh is becoming increasingly integrated by farmers into their cropping systems. In Bogra [(Table 3.22)], for example, one of the first areas where maize expanded-20 different maize-based cropping patterns were found. In some cases, two maize crops (both *Rabi* and *Kharif-I* season) were grown on the same piece of land in a large portion of the maize area (about 28.5%). In most of the areas of Rangpur, Maize-Fallow-*T. Aman* was the major cropping pattern followed by Potato-Maize-*T.Aman* pattern.

Maize was sown as a relay crop 20-35 days after planting potato or it was grown after the early harvest of potato in late February/early March. The scientists of PBD of BARI opined that the potato-maize relay cropping system is expanding very fast in different districts. Many maize farmers of Nowabgonj *Upazila* under Dinajpur district, and two *Upazilas* of Chuadanga district are practicing this potato-maize relay cropping system (Table 3.23 and 3.24). The current maize-based cropping patterns observed in different divisions are shown in Table 3.24 and 3.25. All these observations imply that hybrid maize cultivation is becoming more diversified from the initial system and maize cultivation is increasingly accepted by different types of farmers in Bangladesh.

Table 3.22 Maize-based cropping patterns of different district, Bangladesh, 2005-2006

Cropping pattern	Bogra district		Rangpur district[4]		Kushtia Sadar	
	Land area (ha)	% of maize area	Land area (ha)	% of maize area	Land area (ha)	% of maize area
Maize-Fallow-T.Aman	4,415	40.6	2,037	44.3	4,500	64.1
Maize-Jute-T.Aman	551	5.1	150	3.3	1,500	21.4
Maize-Vegetables-Fallow	530	4.9	--	--	200	2.9
Maize-Maize-Fallow	3,098	28.5	--	--	--	--
Maize-T.Aman seed-Fallow	1,158	10.7	--	--	--	--
Maize-T.Aman seed-T.Aman	250	2.3	211	4.6	--	--
Potato-Maize-T.Aman	234	2.2	1,180	25.6	--	--
Maize-T.Aus-T.Aman	110	1.0	183	4.0	--	--
Maize-Vegetables-Vegetables	50	0.5	500	10.9	--	--
Potato-Maize-Fallow	30	0.3	200	4.3	--	--
Maize-Jute-Fallow	109	1.0	--	--	390	5.6
Maize-Vegetables-T.Aman	86	0.8	--	--	350	5.0
Maize-Mungbean-T.Aman	--	--	--	--	85	1.2
Vegetables-Maize-Fallow	70	0.6	--	--	--	--
Vegetables-Maize-T.Aman	63	0.6	--	--	--	--
Potato-Maize-Vegetables	45	0.4	--	--	--	--
Blackgram-Maize-Fallow	22	0.2	--	--	--	--
Wheat- Maize-Fallow	20	0.2	--	--	--	--
Maize-T.Aman-Fallow	20	0.2	--	--	--	--
Vegetab-Maize-T.Aman seed	5	0.04	--	--	--	--
Maize-Vegetab-T.Aman seed	3	0.03	--	--	--	--
Mustard-Maize-T.Aman	--	--	10	0.2	--	--
Maize-Maize-T.Aman	--	--	20	0.4	--	--
Onion-Maize-T.Aman	--	--	6	0.1	--	--
Garlic-Maize-T.Aman	--	--	4	0.1	--	--
Wheat-Maize-T.Aman	--	--	100	2.2	--	--
Total	**10,869**	**100**	**4,601**	**100**	**7,025**	**100**

Source: Ali et al. 2008

Table 3.23 Maize-based cropping patterns at two *Upazilas* of Dinajpur district, 2013

Cropping pattern	Ghoraghat		Nawbabgonj	
	Land area (ha)	% of maize area	Land area (ha)	% of maize area
Maize-Fallow-T.Aman	2,000	93.4	92	1.9
Maize-Summer vegetables-T.Aman	100	4.6	--	--
*Potato-Maize - T.Aman	42	2.0	1,140	23.6
Maize-T.Aman-Vegetables	--	--	3,220	6.8
Maize -T.Aman-Mustard	--	--	368	7.6
Maize-Jute-T.Aman	--	--	3	0.1
Total	**2,142**	**100**	**4,823**	**100**

Source: FGD 2013; *Relay cropping

[4] The cultivated land area is the sum of three Upazilas, namely Sadar, Mithapukur, and Pirgonj.

Table 3.24 Maize-based cropping patterns at two *Upazilas* of Chuadanga district, June 2013

Cropping pattern	Chuadanga Sadar		Damurhuda	
	Land area (ha)	% of maize area	Land area (ha)	% of maize area
Maize-T.Aus-Vegetables	3,500	23.5	--	--
Maize-Jute-Vegetables	2,000	13.4	--	--
Maize-Jute-Fallow	1,700	11.4	4,000	33.3
Maize-T.Aus-Fallow	1,500	10.1	3,000	24.9
Maize-Fallow-T.Aman	1,400	9.4	1,000	8.3
Maize-Mungbean-T.Aman	1,200	8.1	1,500	12.5
Maize-S.gourd-Vegetables	1,100	7.4	--	0.0
Maize-Vegetables-T.Aman	1,000	6.7	--	0.0
Maize-Sweet gourd-T.Aman	500	3.4	--	0.0
*Maize- Aroids/vegetables-Fallow	350	2.3	20	0.2
Maize-Sesame-T.Aman	300	2.0	1,000	8.3
Maize-Maize-Fallow	150	1.0	--	0.0
*Potato-Maize-Fallow	150	1.0	10	0.1
Vegetables-Maize-Vegetables	50	0.3	--	0.0
Maize-Summer vegetables-Pulses	--	--	1,000	8.3
Maize-T.Aus-Pulses	--	--	500	4.2
Total	**14,900**	**100**	**12,030**	**100**

Source: FGD 2013; *Relay cropping

Maize intercropping: The cultivation of *Rabi* season hybrid maize requires about 145 days, but small and marginal farmers want quick returns from their investment. In the case of intercropping, the space between two rows of maize is 70-75 cm and canopy closure happens after 45-50 days. During this early period of maize crop development, the production of quick growing vegetables, such as spinach, lafa *shak* (Fig. 3.8), and red amaranth (Fig. 3.9) is very feasible and economical; it provides early additional income without reducing maize grain yield. Again, relay cropping of maize 20-35 days after the planting of potato (Fig. 3.10) can bring very high profit (CIMMYT 2005; 2006 as shown in Ali et al. 2008, P.16). Thus intercropping and relay cropping are gaining popularity among the subsistence farmers in different regions of Bangladesh. The current maize-based intercropping systems are opined to be maize+groundnut, maize+mungbean, maize+soybean, and maize+tomato. Ali (2006) showed that relay cropping of maize with potato provided 20-21 t/ha maize equivalent yield within five months (Table 3.26). The pictorial view of intercropping and relay cropping of maize can be seen in Figures 3.8 to 3.10 (Ali et al. 2008).

Fig. 3.8 Maize + lafa shak intercropping

Fig. 3.9 Maize+red amaranth intercropping

Fig. 3.10 Maize + potato relay cropping

Table 3.25 Maize-based cropping patterns of different divisions, Bangladesh, 2011-12

Division/District	Maize based cropping patterns *(Rabi-Kharif 1-Kharif 2)*
A. Dhaka Division	
1. Dhaka	Potato – Maize – T.Aman; Groundnut – Maize – Fallow
2. Manikgonj	Maize–T.Aus rice -Fallow; Maize-Boro-Fallow; Maize-Fallow-Jute, Maize-Boro-T.Aman; Maize-Jute-Fallow (low land); Maize-Maize-T.Aman; Vegetables-Maize-Fallow
3. Tangail	Maize-Aus-Blackgram; Maize-Jute-Fallow (low land)
B. Rangpur Division	
1. Dinajpur	Maize –Fallow-T.Aman; Maize-Radish-T.Aman; Potato – Maize – Aus rice; Maize-Jute-T.Aman; Potato-Maize-Local T. Aman; Potato – Maize – Fallow
2. Thakurgaon	Maize-Jute-T.Aman; Potato-Maize-T.Aman; Mustard-Maize-T.Aman; Maize-Vegetables-T.Aman
3. Lalmonirhat	Potato-Maize-T.Aman; Maize-Vegetables-T.Aman
4. Rangpur	Maize-Fallow-Aman; Maize-Taro-Fallow; Maize-Fallow-T.Aman
5. Gaibandha	Maize-Groundnut-Fallow; Maize-Fallow-Fallow; Maize-Fallow-T.Aman; Maize-Jute-T.Aman
6. Nilphamari	Maize – Fallow – Local T. Aman; Maize – Jute – Local T. Aman
C. Rajshahi Division	
1. Rajshahi	Lentil-Maize-T.Aman, Onion-Maize-T.Aman/Aus; Potato-Maize-Aus; Potato-Maize-Fallow; Potato-Maize-T.Aman; Wheat-Maize- Fallow
2. Bogra	Maize-Radish-T.Aman; Maize-Aus-T.Aman; Maize-Jute-Fallow; Maize-Fallow-Maize; Fallow-Fallow-Maize; Maize-Fellow-T.Aman
D. Khulna Division	
1. Jessore	Maize -T. Aman-Aus; Maize– Boro rice - Fallow
2. Kushtia	Maize-Fallow-T.Aman; Maize-Jute-T.Aman; Maize-Jute-Fallow
3. Chuadanga	Maize-Jute-Fallow; Maize-Aus rice-Sweet gourd; Maize-Fallow-T.Aman rice; Maize- Sweet gourd-T.Aman rice; Maize- Aus rice-Fallow

Source: FGD 2013; Rahman 2011; Paul 2012; Annual reports of Breeding Division (2008-12), and personal communications with Agriculture Officers of DAE

Table 3.26 Yield of potato, maize and maize equivalent yield as relay crops

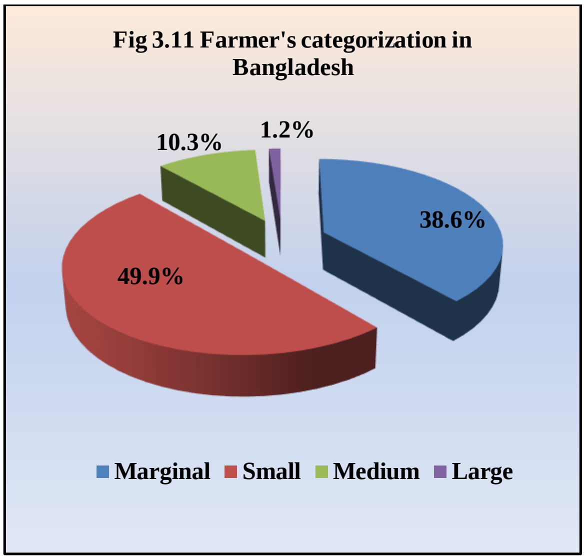
Treatment	Potato yield (t/ha)		Maize yield (t/ha)		Maize equivalent yield (t/ha)		
	Rangpur	**Pabna**	**Rangpur**	**Pabna**	**Rangpur**	**Pabna**	**Mean**
Same day potato + maize planting	15.8	10.9	8.3	8.7	17.9	18.4	18.2
Potato planting 20 days before maize	17.7	12.4	9.9	8.1	21.7	19.1	20.4
Potato planting 35 days before maize	20.1	15.4	9.4	7.3	22.6	21.0	21.2
Sole maize	--	--	10.4	9.2	10.4	9.2	9.8

Source: Ali 2006

3.7 Maize Producers

Socio-economic characteristics of the farmers influence their production behavior and decision-making. Therefore, it is useful to get an insight into the profile of the maize growers which might help in planning development interventions. It can also be used as important indicators in comparing different categories of maize farmers. The socio-economic profiles of the maize producers are discussed below.

Farmers' category: All categories of farmers are currently involved in cultivating maize throughout the country. But national level statistics on maize producers by farm category are not available. Based on operated land holdings, the major farm categories in Bangladesh are marginal, small, medium, and large farmer. The lion's shares of farmers belong to the category of small and marginalfarmers (Fig-3.11). The share of different farmers varies from region to region. Marginal farmers vary from 34.7 to 47.1 per cent and small farmers vary from 39.3 to 53.0 per cent in different regions (Table 3.27).



Source: BBS 2010

Table 3.27 Percentage distribution of farm households in Bangladesh

Division	Marginal (0.02-0.20 ha)	Small (0.20-1.01 ha)	Medium (1.01-3.03 ha)	Large (3.04 ha+)	All category
Barisal	47.1	39.3	11.9	1.6	100
Chittagong	43.0	49.0	7.3	0.6	100
Dhaka	37.3	53.0	8.9	0.8	100
Khulna	40.2	48.2	10.5	1.1	100
Rajshahi	34.7	51.9	12.0	1.5	100
Sylhet	35.4	46.9	15.2	2.5	100

Source: BBS 2010

Recent FGD (2013) with farmers and extension personnel revealed that the involvement of small category farmers in maize cultivation is reported to be the highest at both Ghoraghat and Nawbabgonj *Upazila* under Dinajpur district. Involvement of large category farmers is higher at Ghoraghat *Upazila* compared to Nawbabgonj *Upazila* (Figs. 3.12a and 3.12b) due to higher selling facility directly to CP-Bangladesh (a Thailand based multi-national company) at higher price. The involvement of small category farmers in maize cultivation is much higher in Chuadanga district compared to that in Dinajpur district (Figs 3.13a and 3.13b).

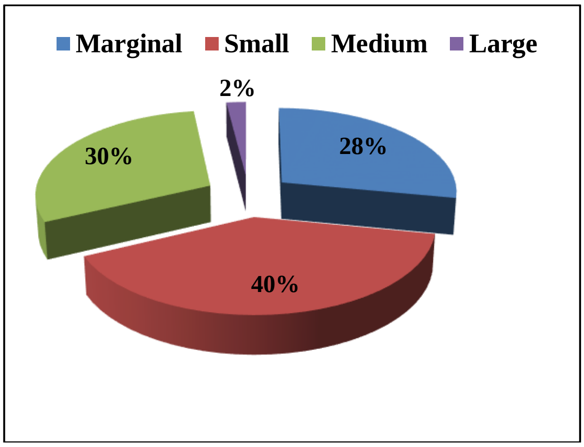


Fig 3.12a. Categorization of farmers involved in maize cultivation, Nawbabgonj, Dinajpur district

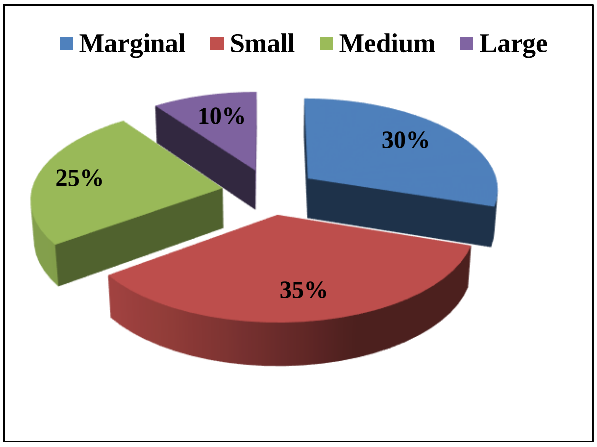


Fig 3.12b. Categorization of farmers involved in maize cultivation, Ghoraghat, Dinajpur district

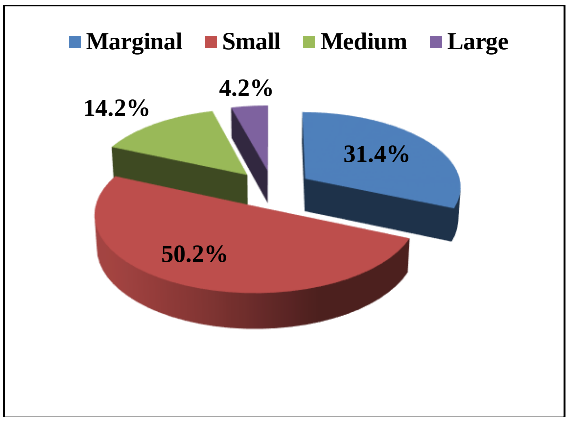


Fig 3.13a Categorization of farmers involved in maize cultivation, Sadar *Upazila*, Chuadanga district

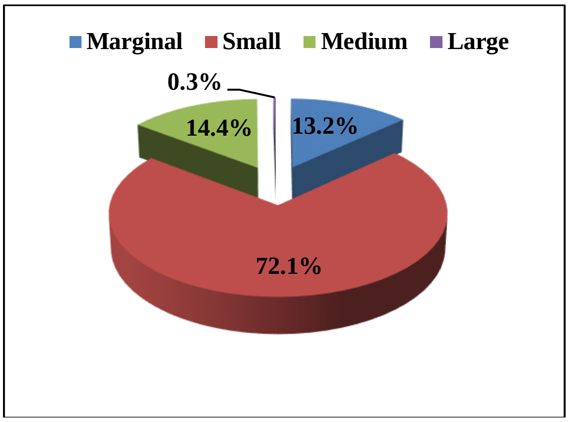


Fig 3.13b Categorization of farmers involved in maize cultivation, Damurhuda, Chuadanga district

Literacy level: Education is considered as a crucial factor for progressive attitude of the farmers towards the adoption of modern technology. A recent study showed that irrespective of farm categories, 81 per cent of the maize farmers were literate in which 38 per cent had primary level education, 34 per cent secondary level, and 9 per cent above secondary level of education (Table 3.28). The highest share of literate maize farmers was found in Dinajpur district followed by that in Chuadanga and Bogra district. Rahman (2011) found a positive relationship between the level of education and farm category. It implies that farmers with larger land holdings are able to afford higher levels of education. Paul (2012) found significant positive relationship between the level of education and maize technology adoption in Lalmonirhat district.

Table 3.28 Distribution of maize farmers according to educational levels

District	Farm category	Sample Size (n)	Literacy level (%)				
			Illiterate	Primary (I-V)	Secondary (VI-X)	Above secondary	Total literate
Bogra	Small	34	26	39	26	9	74
	Medium	39	38	26	23	13	62
	Large	27	11	38	44	7	89
	All	**100**	**27**	**33**	**30**	**10**	**73**
Chuadanga	Small	48	27	35	25	13	73
	Medium	34	12	44	41	3	88
	Large	18	11	44	34	11	89
	All	**100**	**19**	**40**	**32**	**9**	**81**
Dinajpur	Small	36	19	50	25	6	81
	Medium	37	8	43	49	-	92
	Large	27	4	22	52	22	96
	All	**100**	**11**	**40**	**41**	**8**	**89**
All area	Small	118	25	41	25	9	75
	Medium	110	20	38	37	5	80
	Large	72	8	34	44	14	92
	All	**300**	**19**	**38**	**34**	**9**	**81**

Farm category: Small (0.20-1.01 ha), Medium (1.01-3.03 ha) and Large (3.04 ha+)
Source: Rahman 2011

Occupational status: Occupational status presented in Table 3.29 reveals that the principal occupation of most maize farmers was agriculture in all three districts. Business ranked second position among different occupations. Similar observations were made in different farm categories. Occupational status slightly varied from study area to area (Table 3.14).

Table 3.29 Occupational status of maize farmers in three districts

District	Farm category	Occupation type				
		Agriculture	Business	Service	Others	Total
Bogra (2011)	Small	26 (87)	4 (13)	-	-	30 (100)
	Medium	25 (83)	3 (10)	2 (7)	-	30 (100)
	Large	5 (100)	-	-	-	5 (100)
	All category	56 (86)	7 (11)	2 (3)	-	65 (100)
Lalmonirhat (2012)	Small	27 (75)	9 (25)	-	-	36 (100)
	Medium	17 (85)	2 (10)	1 (5)	-	20 (100)
	Large	4 (100)	-	-	-	4 (100)
	All category	48 (80)	11 (18)	1 (2)	-	60 (100)
Kishoregonj (2008)	Small	32 (80)	1 (3)	-	7 (17)	40 (100)
	Medium	25 (48)	10 (19)	12 (23)	5 (10)	52 (100)
	Large	12 (43)	10 (36)	4 (14)	2 (7)	28 (100)
	All category	69 (58)	21 (17)	16 (13)	14 (12)	120 (100)

Note: Figures in the parentheses indicate the percentages of total
Farm category: Small (0.20-1.01 ha), Medium (1.01-3.03 ha) and Large (3.04 ha+)
Source: Ferdausi 2011, Uddin 2008, Paul 2012

Land holdings and land tenure**:** Land is one of the important assets of the farm families in Bangladesh since most of them depend mainly on land resources. Rahman (2011) estimated the size of land holdings of the maize farmers based on farmers' category in three maize growing districts. The average sizes of holdings for small, medium, and large category maize farmers were 0.66 ha, 1.40 ha, and 3.76 ha, respectively. The farm size of large category farmers was much higher in Dinajpur area compared to other districts (Table 3.30).

Table 3.30 Land holdings (ha) of maize farmers by farm category in different locations

District	Small farmer	Medium farmer	Large farmer	All category
Bogra	0.70 (34)	1.40 (39)	3.78 (27)	1.81 (100)
Chuadanga	0.65 (48)	1.45 (34)	3.47 (18)	1.43 (100)
Dinajpur	0.62 (36)	1.36 (37)	3.93 (27)	1.79 (100)
All districts	0.66 (118)	1.40 (110)	3.76 (72)	1.67 (300)

Note: Figures in the parentheses are respondent farmers
Farm category: Small (0.20-1.01 ha), Medium (1.01-3.03 ha) and Large (3.04 ha+)
Source: Rahman 2011

Islam (2006) also estimated the average farm size of different categories of maize farmers of Lalmonirhat district (Table 3.31) which was more or less similar to the farm size estimated by Rahman (2011). The land tenure system presented in Table 3.31 represents the cultivated land of maize growers included own land, mortgaged in and rented in land (for share cropping). Some maize growers also mortgaged out and rented out their lands to other farmers.

Table 3.31 Land tenure status of the maize growers in Lalmonirhat district

Farmers' category	No. of farmer	Homestead area (ha)	Others (ha)	Cultivated land (ha)					Farm size* (ha)
				Own	Mortgaged in	Rented in	Mortgaged out	Rented out	
Small	8	0.07	0.03	0.40	0.01	0.05	0.02	-	0.54
Medium	15	0.11	0.06	1.06	0.04	0.07	0.02	0.02	1.30
Large	7	0.38	0.09	2.73	0.09	-	0.02	0.07	3.20
All types	30	0.18	0.06	1.27	0.04	0.04	0.02	0.03	1.68

*Farm size = (Homestead + Others + Own land +Mortgaged in + Rented in) – (Mortgaged out + Rented out)
Farm category: Small (0.20-1.01 ha), Medium (1.01-3.03 ha) and Large (3.04 ha+)
Source: Islam 2006

Livestock and poultry: Livestock and poultry are integral parts of the rural households in Bangladesh. Hence, most of the maize growers own livestock and poultry resources. A recent survey of two districts reveals that a maize growing household owned, on an average, three cattle, one goat, and six poultry. Livestock and poultry holdings were found higher in Dinajpur district as compared to that in Rangpur district (Table 3.32).

Table 3.32 Livestock and poultry resources of the maize farmers

Type	Dinajpur (*n=30*)		Rangpur (*n=30*)		Both districts (*n=60*)	
	No./family	Value (Tk)	No./family	Value (Tk)	No./family	Value (Tk)
A. Cattle	**3.76**	**43840**	**2.17**	**40650**	**3.00**	**42712**
Bull/Ox	0.73	9207	0.67	13667	0.74	12437
Cow/ heifer	1.70	26200	0.97	22333	1.33	23733
Calf	1.33	8433	0.53	4650	0.93	6542
2. Goat	**2.03**	**3990**	**--**	**--**	**1.02**	**1995**
3. Poultry	**7.96**	**1362**	**4.6**	**845**	**6.28**	**1103**
Chicken	5.93	897	3.23	540	4.58	718
Duck	2.03	465	1.37	305	1.70	385

Source: Field survey 2012; Conversion rate 1 USD = 78.0 BDT

***Extension contact*:** Farmers in general receive advices and information regarding production inputs from various sources. Table 3.33 reveals that maize growing farmers receive advices and information with respect to maize production mostly from extension personnel, namely SAAOs (formerly called block supervisors), neighbouring farmers, and fertilizer/pesticide dealers. Different programmes broadcasted through television and radio also play an important role in disseminating maize related information in the country.

Table 3.33 Level of extension contact of maize farmers with different Medias

Extension media	**Dinajpur district** (n=30)	**Rangpur district** (n=30)	**Both district** (n=60)
SAAO	3.03	2.97	3.00
Neighbouring farmer	2.37	1.97	2.17
Dealer	1.63	0.80	1.22
TV/Radio	1.63	0.77	1.20
Block demonstration	0.47	0.87	0.67
Newspaper	0.57	0.43	0.50
Agricultural fair	0.73	0.10	0.42
Research institutes	0.07	0.20	0.13
Booklet	0.10	0.07	0.08

Note: Level of extension contact (Score: 0-4), 4 = Very high, 3 = High, 2 = Medium, 1 = Low, 0 = No contact.
SAAO = Sub-Assistant Agricultural Officer
Source: Field survey 2012

***Factors impacting maize cultivation*:** As stated earlier, maize is one of the promising crops in Bangladesh, but different factors influence farmers to cultivate maize instead of other crops. Respective factors could be: profitability of maize production, suitability of maize within the cropping system practiced by the farmer, better resistance to stresses then competing crops. A recent survey explored different sources of influence that encouraged farmers to cultivate maize. The most important source of influence came from neighbouring farmers followed by extension personnel (SAAO), family member, and local credit facility. Other sources of influence were mass media, output sale facility, and agricultural training (Table 3.34).

Table 3.34 Level of influence by different factors for cultivating maize

Source of influence	Dinajpur (n=30)	Rangpur (n=30)	Both districts (n=60)
Neighbouring farmer	2.76	2.47	2.61
SAAO	2.80	2.17	2.48
Family member	2.40	2.20	2.30
Credit facility in the area	1.20	1.87	1.54
Mass media	0.46	0.24	0.35
Sale facility in the area	0.54	0.10	0.32
Agricultural training	0.50	0.13	0.32

Note: Level of influence (Score: 0-4), 4 = very high, 3 = High, 2 = Medium, 1 = Low, 0 = No influence
Source: Field survey 2012

***Societal membership*:** Like many other farmers, maize growers are also involved with different social organizations although there is no direct relationship between societal membership and maize cultivation. However, a recent household survey revealed that 23.33 per cent and 16.67 per cent respondent maize farmers in Dinajpur district were engaged with the local mosque managing committee and school managing committee, respectively. Farmers' cooperative societies are not running well in most of the areas. The involvement of maize farmers in the ICM/IPM club, market development committee, and union council was reported to be very negligible (Table 3.35). Farmers' motivation towards productive and beneficial activities in the organizations may be the solution of making these organizations active in the society.

Table 3.35 Percent distribution of maize farmers according to societal membership

Membership with	**Dinajpur** (n=30)	**Rangpur** (n=30)
Mosque managing committee	23.33	3.33
School managing committee	16.67	6.67
Farmers' cooperative society	3.33	3.33
ICM/IPM club	3.33	--
Market development committee	3.33	--
Union council	3.33	--

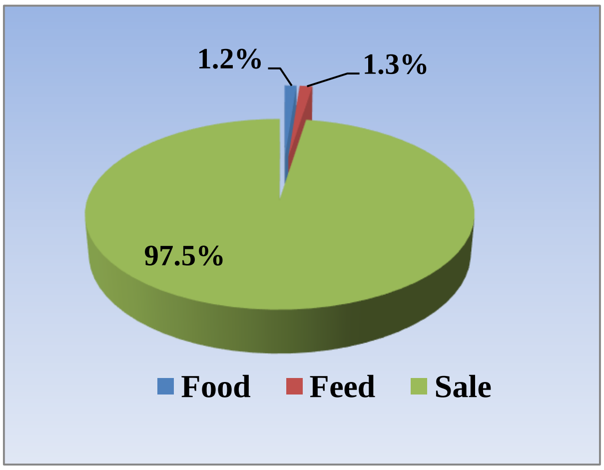
Note: ICM = Integrated crop management, IPM = Integrated pest management
Source: Field survey 2012

***Production and use of maize*:** Quashem (1999) estimated an average production of maize at 1.98 tons per household in four districts. The highest production was found in Dhaka district followed by that in Dinajpur and Nilphamari districts. This information is back dated. Current production scenario is opposite to this information (DAE 2013).

Disposal pattern shows that the lion's share of their production was sold to local traders (*Faria* & *Bepari*), poultry farms, and feed millers. The shares of food for household consumption and feed for own livestock were very negligible (Fig. 3.14). More than half of the maize produced in Dhaka was sold to poultry farms and feed mills, whereas it was sold to traders in the case of other districts.

In Nilphamari and Jessore district, no consumption was reported at all. Dinajpur farmers mostly consumed maize in the form of fresh cobs and flour (Table 3.36).

Fig. 3.14 Disposal pattern of maize at farm level



Source: Quashem 1999

Table 3.36 Production and disposal pattern of maize at household level

Study area	Production (kg/HH)	Quantity retained for HH consumption (kg)		Quantity sold (kg) to:	
		Food	Feed	Local traders	Poultry farms & millers
Dinajpur	2,120	70	83	1,967	--
Nilphamari	1,550	--	--	1,550	--
Jessore	1,240	--	--	1,240	--
Dhaka	3,000	21	12	1,539	1,428
All areas	1,978	26	24	1,588	340

Source: Quashem 1999

Recent FGD (2013) with maize farmers and extension personnel revealed that more than 95 per cent of maize is sold for cash and the rest is used for food and feed. The popular maize food is reported to be *Chattu* at Dinajpur and Chuadanga districts (Table 3.37).

Table 3.37 Disposal pattern (%) of maize at farm household level

Disposal pattern	Dinajpur district		Chuadanga district	
	Ghoraghat	Nawbabgonj	Sadar	Damurhuda
Grain sale	97.00	98.00	98.00	95.75
Use as food	1.00	1.00	--	0.25
Use as feed	2.00	1.00	2.00	4.00
Total	100	100	100	100

Source: FGD 2013

Household income: The income of a farm household generally comes from different sources. The main source of income is farm income. Islam (2006) showed in his study that the average annual income of the maize farmers was Tk 114,819 (USD 1,472.04) of which 57 per cent come from farm income and 36 per cent from non-farm income. The trend of income shares from different sources was found to be more or less similar among farm categories. Again, the average shares of household income from maize were 7 per cent and 12.3 per cent of the total household income and total farm income, respectively (Table 3.38).

Table 3.38 Annual incomes (Tk/household) of maize farmers in Lalmonirhat district

Source of income	Small farmer	Medium farmer	Large farmer	All category
Maize income	4139 (6.3)	7,525 (6.7)	12,542 (7.6)	8,069 (7.0)
Farm income	33,650 (51.0)	69,700 (61.8)	92,850 (56.0)	65,400 (57.0)
Non-farm income	28,220 (42.8)	35,500 (31.5)	60,330 (36.4)	41,350 (36.0)
Total income	66,009 (100)	112,725 (100)	165,722 (100)	114,819 (100)

Figures within parentheses are the percentages of total income. Conversion rate 1 USD = 78.0 BDT
Source: Islam 2006

Recent FGD (2013) also revealed that most of the maize farmers could improve their livelihood constructing new houses, sending their children to school, having better food and cloths, buying motor cycles, etc. due to cultivating maize. For instance, a farmer of Birgonj *Upazila* under Dinajpur district became self-sufficient in maintaining his family through cultivating hybrid maize using one hectare of land. He has received Tk 143,000 (USD 1,833.3) as net profit incurring Tk 37,000 (USD 474.4) per hectare (Daily *Bangladesh Protidin*, 15 June 2013).

3.8 Maize Technology Use

Land preparation**:** Farmers in general use both country plough (CP) and power tiller (two wheel tractors) for land preparation across the country. A study conducted in the northern part of Bangladesh showed that 47 per cent of maize farmers used country plough and 35 per cent used PT for land preparation. At present, majority of the land preparation is done by PT which is mostly done on hire basis. Farmers at Dinajpur used more PT, than that of Panchagarh (Table 3.39). FGD (2013) reveals that the scenario of land preparation has changed to a great extent. Currently more than 90 per cent farmers of Dinajpur and Chuadanga districts are using power tiller for ploughing their maize lands.

Table 3.39 Percent distribution of maize farmers using different mode of ploughing

District	% of farmers			
	Country plough	Power tiller	Both	Total
Dinajpur	32	46	22	100
Panchagarh	62	24	14	100
Overall	47	35	18	100

Source: Hasan 2008

Use of seed: Most of the maize farmers in Bangladesh generally used different types of imported hybrid seed. They do not use recycled (retained) seed as some of them have experienced very low yield from it. The indigenous farmers of hill districts, namely Bandarban, Rangamati, and Khagrachari cultivated composite varieties of maize mostly for consumption purpose. These tribal communities use retained seeds. Different studies showed that most of the farmers (33%) cultivated 900M hybrid followed by NK-40 (22%) and Pacific-11 (18%). NK-40 and Pacific-11 were the most common and popular varieties cultivated in all the study areas (Table 3.40). BARI has developed seven open pollinated varieties (composite varieties) and 11 hybrid maize. Although the yield potential of BARI released varieties (7.4-12.0 t/ha) is encouraging, but their farm level adoption is not very satisfactory. The main reasons opined by the concerned BARI scientists about this low adoption are non-availability of BARI maize seed is the lack of seed production and lower productivity at farm level compared to many other imported hybrid maize seeds.

Table 3.40 Distribution of farmers according to maize variety

(Per cent of total maize growers)

Variety	Study area (Districts)						All areas
	Chuadanga	Dinajpur	Rangpur	Bogra	Kushtia	Lalmonirhat	
1. 900 M	42	48	3	46	--	60	33
2. Pacific 11	6	2	17	2	47	6	18
3. Pacific 60	24	2	10	50	--	34	14
4. Pacific 984	8	--	--	--	--	--	1
5. NK 40	20	48	33	2	23	--	22
6. NK 46	--	--	17	--	27	--	7
7. NK 48	--	--	7	--	--	--	1
8. NK 60	--	--	6	--	--	--	1
9. BARI 5	--	--	7	--	--	--	1
All variety	100	100	100	100	100	100	100

Source: Karim et al. 2010; Moniruzzaman et al. 2009

A recent study (Karim et al. 2010) conducted in the intensive maize growing areas revealed that 24 types of imported hybrid maize varieties were used by the maize farmers. Among the varieties, NK-40 occupied the highest (37%) area of the total maize growing areas. The second and third positions were secured by Pacific-984 (24%) and 900M (17%) variety, respectively (Table 3.41). The extent of using maize variety by the farmers depends mainly on the availability of seed at local level.

Table 3.41 Area coverage (ha) by different maize varieties

Maize Variety	Study area (Districts)			Area covered	
	Manikgonj	Thakurgaon	Lalmonirhat	Hectare	%
1. NK40	250	995	341	1586	36.9
2. Pacific-984	709	308	2	1019	23.7
3. 900M	259	176	289	724	16.8
4. 749	142	--	--	142	3.3
5. EM Fortun	--	--	127	127	3.0
6. AP-100	--	82	--	82	1.9
7. Bekalb-981	--	--	72	72	1.7
8. SP-100	--	67	--	67	1.6
9. Karnal	--	--	70	70	1.6
10. Kanak	--	--	65	65	1.5
11. HP-100	--	50	--	50	1.2
12. CP-818	--	50	--	50	1.2
13. 900K	--	35	--	35	0.8
14. Pacific-11	--	35	--	35	0.8
15. Miracle	--	--	35	35	0.8
16. NK-6621	--	--	25	25	0.6
17. 717 K	--	--	25	25	0.6
18. 827K	--	22	--	22	0.5
19. Badsha	--	--	17	17	0.4
20. P-3637	--	15	--	15	0.3
21. Bekalb-962	--	--	12	12	0.3
22. 900M Gold	--	--	12	12	0.3
23. 987 K	--	--	9	9	0.2
24. 700K	1	--	--	1	0.0
Total	**1361**	**1835**	**1101**	**4297**	**100.0**

Source: Azimuddin et al. 2012

Input use pattern**:** Human labour is one of the most important inputs in maize production. Human labour is employed in land preparation, fertilizerand pesticide application, intercultural operations, irrigation, crop harvesting, and post-harvest activities. The average human labour used for producing maize was 161 man-days/ha in all the study areas. The farmers of Kishoregonj district used more human labour compared to that of other districts. On an average, the quantity of seed used by the farmers was 21 kg/ha, which was more or less similar for other districts except Dhaka. This rate is lower than that of recommended rate of 25-30 kg/ha. Manure is the most important source to increase organic matter in the soil. The average quantity used of cowdung was 5 t/ha. The highest (9.3 t/ha) use of cowdung was found in Dinajpur district, while farmers of Dhaka did not use any cowdung at all. The reason might be due to having more cattle by the Dinajpur farmers.

Maize is called to be a fertilizer loving crop. Maize growers used different types of chemical fertilizers, namely urea, Triple Super Phosphate (TSP), Murate of Potash (MoP), gypsum, and zinc sulphate. Fertilizer doses in maize cultivation vary among geographical locations. Even fertilizer dose is not same in the winter and summer season. The average quantities of urea, TSP, MoP, gypsum, zinc sulphate, and borax used in maize cultivation were found to be 462, 192, 146, 52, 5, and 3 kg per hectare, which were lower than the recommended doses (Appendix A-15). It is implied that farmers generally use imbalanced doses of fertilizers in maize cultivation. Farmers also applied pesticides valung Tk 419 (USD 5.37) per hectare. Maize fields were also irrigated and its average cost was Tk 2,925 (USD 37.5) per hectare (Table 3.42).

Table 3.42 Input use pattern per hectare in maize production in different districts

Input	**Study area (Districts)**								**All area**
	Bogra	Chua danga	Dinaj pur	Lalmoni rhat	Kishore gonj	Dhaka	Rangpur	Kustia	
H. labour (m-d)	168	172	113	121	247	227	118	122	161
Tillage cost (Tk)	3,382	3,342	2,646	2,876	2,117	1,850	2,562	3,360	2,767
Seed (kg)	21.36	20.62	20.38	18.92	14	32.93	20.22	20.52	21
Cowdung (ton)	3.36	3.20	9.24	6.2	5.5	--	7.8	2.4	5
Urea (kg)	444	463	443	507	263	519	419	638	462
TSP (kg)	119	180	137	233	124	296	226	218	192
MoP (kg)	113	84	110	229	86	162	168	218	146
Gypsum (kg)	18	67	95	177	--	61	--	--	52
Zinc sulphate (kg)	2	12	5	12	--	--	7	4.65	5
Borax (kg)	2	0.35	5	10	--	--	5	--	3
Pesticides (Tk)	668	202	51	534	--	485	469	945	419
Irrigation (Tk)	2,639	3,669	2,766	5,400	1,100	600	3,330	3,897	2,925

Source: Chowdhury 1995; Karim et al. 2010; Moniruzzaman 2009; Mohiuddin et al. 2007
Conversion rate 1 USD = 78.0 BDT

Input use pattern by farm size**:** The use of different inputs in maize production varies among locations, periods of cultivation, cropping patterns, and farm categories. It is evident from different studies (Uddin 2008; Ferdausi 2011; Paul 2012) conducted in different districts (Bogra, Kishoregonj and Lalmonirhat) of Bangladesh indicate that the uses of human labour (125 man-day/ha) and total fertilizers (279 kg/ha) shown in Table 3.43 are much lower compared to the uses of human labour and fertilizers shown in Table 3.42. This is mainly due to differences in study locations, cropping patterns, and study periods.

However, large category farmers used more human labour (136 man-day/ha) compared to small and medium category farmers. Medium and large category farmers used more seed per hectare than small farmers (20 kg/ha). Total fertilizer use was found higher for medium category farmers (294 kg/ha) compared to that of other two categories of farmers (Table 3.43).

Table 3.43 Input use pattern per hectare by different categories of maize farmers

Input	Category of farmers			All category
	Small	Medium	Large	
H. labour (m-d)	108	132	136	125
Tillage cost (Tk)	2,674	2,958	2,922	2,851
Seed (kg)	20	21	21	21
Cowdung (ton)	4	6	5	5
Urea (kg)	168	172	162	167
TSP (kg)	53	73	66	64
MoP (kg)	21	31	31	28
Gypsum (kg)	18	17	22	19
Borax (kg)	1	1	2	1
Pesticides (Tk)	447	515	485	482
Irrigation (Tk)	2,464	2,891	2,771	2,709
Average yield				

Farm category: Small (0.20-1.01 ha), Medium (1.01-3.03 ha) and Large (3.04 ha+)
Source: Uddin 2008; Ferdausi 2011; Paul 2012; Conversion rate 1 USD = 78.0 BDT

***Mode of irrigation*:** Maize farmers in Bangladesh use both ground water and surface water for irrigating their crops. Surface water is generally lifted by *Don* and *Sewti* (traditional small irrigation instrument) and watering cane. On the other hand, shallow tube well (STW) and deep tube well (DTW) are used for lifting ground water (Table 3.44). At present, almost all the maize farmers (99%) in Bangladesh used mechanized irrigation (i.e., STW & DTW) systems for maize (Hasan 2008). The recent statistics of BADC (2012) reveal that 83.1 per cent STW and DTW pumps run on diesel and the remaining 16.9 per cent run on electricity in Bangladesh. Although the cost of electricity is much lower than that of diesel in Bangladesh, the use pattern is mainly due to the non-availability of electricity in the rural areas.

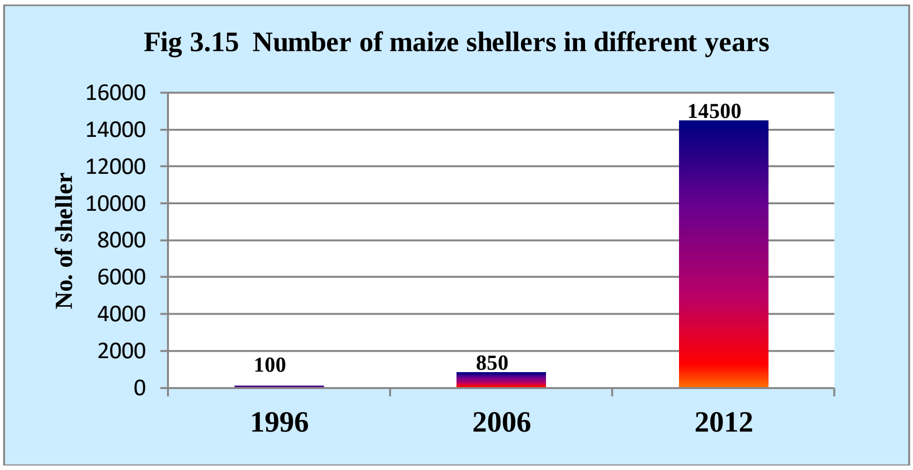
Table 3.44 Distribution of maize farmers according to mode of irrigation

(in per cent)

District	Mechanized irrigation			Traditional irrigation
	STW	DTW	Both	
Dinajpur	100	--	100	--
Panchagarh	78	20	98	2
All areas	89	10	99	1

Source: Hasan 2008

***Harvesting and maize shelling*:** Maize cobs are usually harvested by hand. Initially farmers used to shell maize grain from cob with hand operated shellers. Power operated maize shellers were available in local market since 2001-2002, thereafter farmers started using this machine which can save more time and labours in maize shelling. Scientists of BARI claimed that one of the reasons for increasing maize cultivation is due to the use of electric maize shellers (FGD 2013). The use of maize shellers is increasing rapidly year after year (Fig. 3.15).



Source: Roy and Sing 2008

The average operating use of maize shellers was 103 hours per year serving 23.5 ha/year which included farmers' own land and rented land in Bogra, Dinajpur, Rangpur, Kustia, and Mymensingh districts (Roy et al. 2007).

Women role in maize cultivation**:** Maize is a labour intensive crop. The tribal women in three hill districts, namely Bandarban, Rangamati, and Khagrachari are generally involved in the entire process of maize cultivation. Womenin the hills make a good contribution towards maize cultivation. They are involved in maize harvesting, processing, marketing and other related activities. Women in the hills were involved in maize harvesting (23.08%), which was followed by maize processing (17.57%) and intercultural operations (17.07%). A significant percentage of them were also involved in irrigation and land preparation (Ali et al. 2010). The women belonging to lower caste and indigenous communities (tribes) spread across the country also work in the crop field. Rahman (2011) found that womenwere commonly engaged with various post-harvest activities like de-husking and shelling of maize, sun drying, winnowing, and storing. The only activity which is solely a woman's task is drying (Morgan 2006).

FGDs conducted in the study with farmers and extension personnel revealed that women's role in maize cultivation is related to seed planting, maize cob harvesting (Fig 3.16), cob cleaning (Fig 3.17), cob drying, and maize shelling in Dinajpur district. This scenario is a little bit different in Chuadanga district. In Chuadanga, female farmers mainly work in post-harvest activities (Table 3.45). This difference is mainly due to the long lasting social and cultural norms in the area. The shelling of maize is done by electric maize shellers. The female labourers of Dinajpur generally help their male counterparts in shelling maize.


Fig 3.16 Women harvesting maize, Ghoraghat, Dinajpur


Fig 3.17 Woman cleaning harvested maize, Ghoraghat, Dinajpur

Table 3.45 Division of labour in maize cultivation at two *Upazilas* of Dinajpur district

(Figure in %)

Activity	Dinajpur district				Chuadanga District			
	Ghoraghat		Nawbabgonj		Sadar		Damurhuda	
	Female	Male	Female	Male	Female	Male	Female	Male
Land preparation	--	100	--	100	--	--	--	100
Seed purchase	5	95	--	100	--	--	--	100
Seed planting	50	50	40	60	1	99	--	100
Weeding	--	100	--	100	--	--	--	100
Buy fertilizer/pesticide	5	95	--	100	--	--	--	100
Fertilizer/pesticide application	--	100	--	100	--	--	--	100
Cob harvesting	90	10	60	40	10	90	1	99
Cob cleaning	100	--	80	20	20	80	95	5
Drying	50	50	60	40	90	10	60	40
Maize shelling	60	40	100	--	--	100	--	100
Crop or grain sale	--	100	5	95	--	100	--	100

Source: FGD 2013

3.9 Factors Associated with Maize Technology Use

***Factors of maize cultivation*:** Rahman et al. (2012) showed that the gross return from maize production and subsistence pressures (persons per household) were the important factors that significantly influenced farmers in cultivating winter maize. The soil suitability also significantly influenced the choice of winter maize cultivation which implies that environmental factors within which the farmers operate do play an important role in their decision-making processes. However, extension contact negatively influenced the adoption of winter maize cultivation, the reason of which is not clear (Table 3.46). This finding is quite opposite to the finding of Rashid (2006) presented in Table 3.47.

Table 3.46 Factors affecting the adoption of winter maize cultivation at Kushtia, Bogra and Dinajpur districts: probit estimates

Variables	Coefficient	t-ratio
Constant	-13.72***	-8.56
Gross return per hectare	0.0002***	9.78
Irrigation cost	0.0016	1.24
Farm operation size	-0.0769	-1.16
Farmer's age	0.0081	0.52
Farmer's education	-0.0813	-1.05
Farmer's education squared	0.0161*	1.71
Farmer's experience	0.0069	0.21
Farmer's experience squared	-0.0005	-0.91
Subsistence pressure	0.3649**	1.97
Subsistence pressure squared	-0.0127	-0.92
Extension contact	-1.919***	-7.20
Soil suitability index	0.4289***	2.15
Log likelihood	-126.84	
McFadden R^2	0.55	
Chi squared	308.88***	
Observations (n)	450	

Note: ***, **, and * indicate significant at 1%, 5% and 10% level of significance, respectively

Dependent variable: Farmers' season selection criterion (if a plot is planted with winter maize 1, Otherwise 0).

Source: Rahman et al. 2012

***Factors influencing maize technology adoption*:** The annual household income and extension contact had positive and significant relationship with the adoption of maize technologies in different study areas (Rabbi 2006; Rashid 2006). It implies that the more extension contact the farmers had, the more was their adoption because farmers with higher extension contact receive more information regarding modern technologies (Rashid 2006). Organizational participation and knowledge about maize cultivation play a positive and significant role in adoption of maize production technologies in Thakurgaon district. In Lalmonirhat district, the adoption of maize production technologies was found higher for those farmers who had higher level of education, while age had negative relationship with adoption (Table 3.47).

Table 3.47 Relationship between selected respondent's characteristics and maize technology adoption

Characteristics	Value of correlation coefficient	
	Thakurgaon *(n = 90)*	**Lalmonirhat *(n = 100)***
Age	0.073	-0.258**
Education	0.027	0.264**
Family size	-0.010	-
Farm size	0.903*	0.048
Farming experience	-0.009	-
Annual household income	0.663*	0.201*
Extension contact	0.580*	0.380**
Knowledge of maize cultivation	0.257**	0.051
Organizational participation	0.209**	-
Area under maize cultivation	-	0.995**
Cosmopoliteness	-	0.055

Note: ** and * indicate significant at 1% and 5% level of significant, respectively.
Source: Rabbi 2006; Rashid 2006

It implies that young farmers had positive tendency to adopt modern maize production technologies. Focus Group Discussion (2013) revealed that higher profitability, suitable weather, availability of hybrid seeds, and ready market for the product are the divers of promoting maize cultivation in Dinajpur.

***Factors affecting maize yield*:** The productivity of maize depends on various factors. The scientists of BARI opined in an FGD meeting that yield gap existed between winter and summer maize due to different weather and rainfall condition and varietal differences. BARI scientists observed yield differences that ranged from 2.5 to 3.0 t/ha between BARI maize and imported maize mostly due to varietal differences. Generally, the yield of winter maize is higher than summer maize. The reasons of higher yield of winter maize are favourable weather that facilitates longer duration of growth, higher sunshine hours, higher respiration, efficient use of fertilizers and water, and higher net physical accumulation (FGD 2013).

The productivity of maize generally depends on many other agro-socio-economic and environmental factors, such as type of variety, soil type, fertilizer use, planting time, planting methods, extent of labour use, farm size, training, and different climatic factors. The yield of winter maize is positively influenced by various factors, such as seed, urea, MoP, gypsum, and irrigation (Rahman 2011). The negative coefficients of human labour and TSP indicate inefficient use of these inputs. On the contrary, the regression coefficients of human labour, urea, irrigation, and land rent in summer maize cultivation were found to be negative which implied that summer maize growers did not apply this inputs judiciously (Table 3.48).

Table 3.48 Coefficients and related statistics of Cobb-Douglas production function model

Variables	Winter maize		Summer maize	
	Coefficients	Standard error	Coefficients	Standard error
Intercept	0.973***	0.137	0.088	0.279
Human labour (m-day/ha)	-0.059***	0.009	-0.271***	0.043
Power tiller cost (Tk/ha)	0.131***	0.010	0.614***	0.050
Seed (kg/ha)	0.054***	0.016	0.140	0.156
Urea (kg/ha)	0.066***	0.007	-0.049*	0.027
TSP (kg/ha)	-0.026***	0.005	--	--
MoP (kg/ha)	0.052***	0.005	--	--
Gypsum (kg/ha)	0.002**	0.001	--	--
Zinc sulphate (kg/ha)	0.001	0.001	--	--
Borax (kg/ha)	0.003*	0.002	--	--
Cowdung (kg/ha)	0.004***	0.000	--	--
Irrigation cost (Tk/ha)	0.044***	0.005	-0.037	0.029
Pesticides cost (Tk/ha)	-0.001**	0.000	--	--
Land rent (Tk/ha)	-0.082***	0.010	-0.114***	0.037
Land type (high land and MHL=1, Otherwise 0)	0.006	0.006	-0.150**	0.076
Soil type (sandy loam, loamy, clay loam=1, Otherwise 0)	-0.012	0.009	0.121***	0.035
Sowing time (15 Nov-15 December =1, otherwise 0)	-0.003	0.003	0.008	0.041
Variety (900M = 1, otherwise 0)	0.008***	0.003	-0.081***	0.020
Adjusted R^2	0.750		0.880	
F-value	54.64***		107.14***	
Observations (N)	300		150	

Note: Dependent variable = Yield (t/ha); '***' '**' and '*' represent 1%, 5% and 10% level of significance.
Study area: Winter maize- Kushtia, Bogra, & Dinajpur districts
Summer maize- Manikgonj, Bogra, & Thakurgaon districts
Source: Rahman 2011

***Factors affecting the yield of winter maize by farm size*:** Maize yield is influenced by different factors including farm size. Table 3.49 exibits that different factors like tillage cost, amount of urea, MoP, and manure used had positive and significant effect on maize yield for small and medium farms, while application of urea, boron, and irrigation positively influenced the yield of winter maize for large farms. Negative coefficient for human labour for all types of farms indicated that all farms used excess amount of human labour for maize cultivation. Besides, negative and significant coefficient of zinc sulphate and TSP indicated over use of these inputs by small and medium farms, respectively.

Table 3.49 Coefficients of farm size specific stochastic Cobb-Douglas frontier production function

Variables	Small category		Medium category		Large category	
	Coefficient	Std. error	Coefficient	Std. error	Coefficient	Std. error
Intercept	1.826***	0.53	0.360	0.50	1.888	1.32
Human labour (m-d/ha)	-0.069*	0.04	-0.017	0.04	-0.046	0.05
Power tiller cost (Tk/ha)	0.092**	0.03	0.096**	0.04	0.074	0.06
Seed (kg/ha)	-0.038	0.06	0.124*	0.06	0.009	0.12
Urea (kg/ha)	0.050*	0.02	0.054**	0.02	0.070**	0.03
TSP (kg/ha)	-0.009	0.01	-0.035**	0.01	0.012	0.03
MoP (kg/ha)	0.041***	0.01	0.043**	0.01	-0.005	0.01
Sulfur (kg/ha)	0.002	0.005	0.007	0.005	0.005	0.01
Zinc sulphate (kg/ha)	-0.015**	0.008	0.004	0.008	-0.015	0.01
Borax (kg/ha)	0.002	0.01	-0.024	0.01	0.063***	0.02
Cowdung (kg/ha)	0.004***	0.001	0.004***	0.001	0.00	0.002
Irrigation cost (Tk/ha)	0.063***	0.02	0.030	0.02	0.044*	0.02
Pesticides cost (Tk/ha)	0.000	0.002	-0.001	0.002	-0.002	0.002
Land rent (Tk/ha)	-0.100***	0.03	-0.009	0.03	-0.101**	0.04
Land type (high land and MHL=1, Otherwise 0)	0.039*	0.02	0.054	0.03	-0.002	0.02
Soil type (sandy loam, loamy, clay loam =1, Otherwise 0)	0.011	0.04	0.050*	0.02	-0.006	0.03
Sowing time (15Nov-15Dec =1, otherwise 0)	0.011	0.01	0.006	0.01	-0.022*	0.01
Variety (900M=0, Otherwise 0)	0.013	0.009	0.012	0.01	0.022*	0.01
Observations (N)	118		110		72	

Note: Dependent variable = Yield (t/ha)

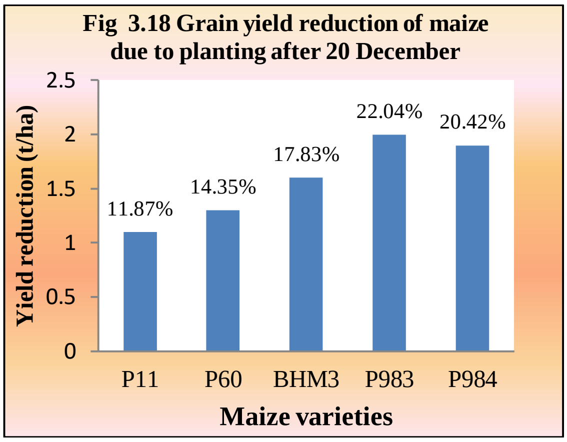
*** Significant at 1% level, ** Significant at 5% level, * significant at 10% level.

Farm category: Small (0.20-1.01 ha), Medium (1.01-3.03 ha) and Large (3.04 ha+)

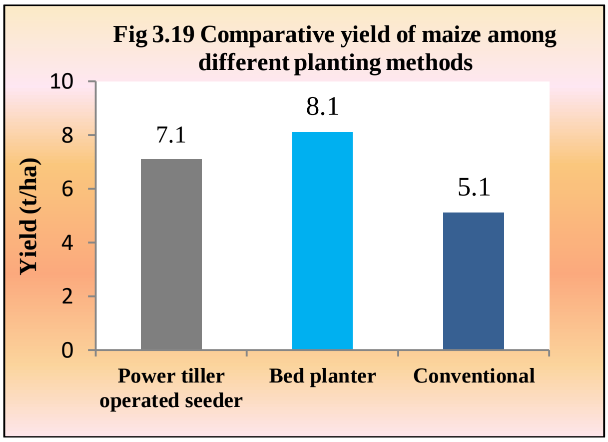
Source: Rahman 2011

Impact of planting time on yield: In Bangladesh, most of the winter season maize is planted after the harvest of *T. Aman* rice. Thus the planting of maize depends on the harvest time of rice and the speed of drying of the soil just after rice harvest. Ali (2006) showed that late planting (20 December onwards) might cause yield losses of 11 to 22 per cent or more for various maize varieties (Fig 3.18).

Impact of bed system planting on maize yield: Planting methods significantly affect maize yield. Bed planting method of maize is **e**specially popular in Dinajpur area. Waddington et al. (2006) showed that bed planting method received higher yield compared to other two methods of planting in Dinajpur district of Bangladesh (Fig 3.19). Miah et al. (2011) showed that on an average, 56 per cent of the farm families of Durgapur *Upazila* under Rajshahi district adopted raised bed technology for cultivating different crops including maize. The number of male members in the household, level of extension contact, and status of societial membership significantly influenced farmers to adopt this technology.



Source: Ali 2006



Source: Waddington et al. 2006

***Impact of producer types on maize yield*:** The farm management, cultivation technique, and farm decision may vary from one farmer category to another which ultimately influences the productivity of crop. It is evident from Table 3.50 that on an average, large producers received little bit higher yield compared to small and medium farmers in the study areas. This might be for applying a proper seed rate, high fertilizers use, and intensive management practices.

Table 3.50 Yield of maize according to producer category

Producer type	Districts			
	Bogra	Chuadanga	Dinajpur	All district
Small	7.99	7.84	7.91	7.91
Medium	8.15	8.00	7.86	8.00
Large	8.15	8.14	8.01	8.10

Farm category: Small (0.20-1.01 ha), Medium (1.01-3.03 ha) and Large (3.04 ha+)
Source: Rahman 2011

***Impact of climate risk on maize yield*:** Miah (2010) conducted a number of FGDs with maize farmers for an FAO funded study at six districts in order to assess the long-term impacts of various climatic factors on maize production. Farmers' perceptions revealed that three climatic vulnerability factors, namely severe drought, rainfall variation, and high wind affect maize production to a great extent. The yield reduction due to negative impacts of these factors opined to be ranged from 40 to 60 per cent in the study areas (Table 3.51).

Table 3.51 Reduction in maize yield due to climatic risks/vulnerability factors

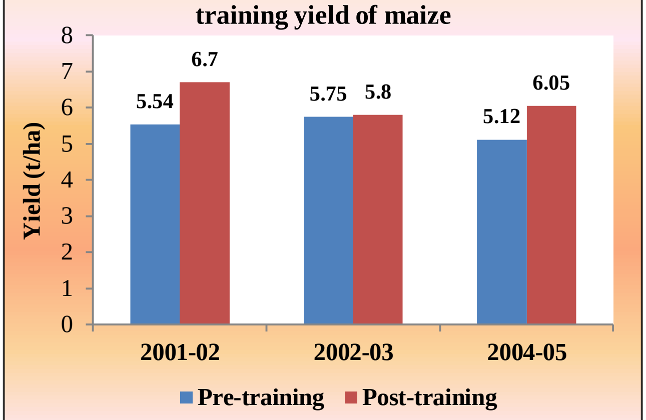
Risk factors	Ranges of reduction in yield (%)					
	Cox's bazar	Patuakhali	Satkhira	Pirojpur	Borguna	Barisal
Drought	40-60	40-60	40-50	>60	40-60	30-40
Rainfall	40-60	40-60	40-50	>60	40-60	30-40
High wind	40-60	40-60	40-50	>60	40-60	30-40

Source: Miah 2010

A recent FGD (2013) with farmers and extension personnel at Dinajpur and Chuadunga districts also pointed out that severe wind is detrimental to maize cultivation since it lays the maize plant down and by this reduces yield by 20-25%. They had no experience on any yield reduction due to drought and heavy rainfall since available irrigation facility could meet up drought problem. Water logging is a serious problem to the farmers of low lying areas of Bangladesh, especially at Jamalpur, Mymensingh, Rajshahi, Dhaka, Chittagong, and some other coastal districts, namely Barisal, Noakhali, and Khulna.

Impact of information and training on maize yield: Training and information regarding crop production can play a crucial role in attaining higher yield. For the cultivation of a new crop like hybrid maize, information and technology need to flow to among farmers. A study conducted by CIMMYT (2006) shows (Fig. 3.20) that the farmers after receiving training on maize cultivation obtained 17.31 per cent and 15.4 per cent higher yield during 2001-2002 and 2004-2005, respectively compared to pre-training period.

Fig 3.20 Comparison between pre and post training yield of maize



Source: CIMMYT 2006

3.10 Recommended Agronomic Practices

Land, soil and land preparation: A deep loamy soil, high in organic matter and plant nutrients is the best soil for maize cultivation. However, with proper management and fertilizer practices, maize can be grown successfully on any soil from loamy sand to clay. The soil should be free from salinity and water logging. It can be grown successfully on soils with a pH from 5.0 to 8.0, but 6.0 to 7.0 is optimal. If the soil pH is low, liming might be necessary. Under normal condition 4-5 ploughings followed by laddering are adequate for seed sowing (Salahuddin 2003).

Seed rate and seed treatment: The recommended seed rate is 20-22 kg/ha. The most common fungicides used for seed treatment are Furadan and Arasan M. Seed can be treated by 50 ml of Furadan 30 per cent (seed treater), 2g of Arasan 75 per cent (wettable powder) and 12 ml of water per kilogram of seeds. Seed can also be treated by Provax 200 WP @ 2.5g/kg seed (Quayyum 1993, Salahuddin 2003).

Time of sowing and sowing method: Sowing dates should be chosen to avoid risky environmental conditions, such as excessively cool or hot temperatures and during heavy shower. Optimum time of sowing in *Rabi* season is from mid October to 1st week of December in Kharif-I from mid February to end of March and in Kharif-II from mid July to mid August.

Seeds should be sown in rows. Usually, sowing is done in furrows in light textured soils and in ridges in heavy soils. In flood prone areas sowing can be done by dibbling method under zero tillage conditions after receding of flood water. In Bangladesh, it is recommended to plant in rows 75 cm apart with a plant to plant spacing of 20 cm with one plant per hole which gives 66,666 plants/ha.

Fertilizer application: Fertilizer application depends on fertility status of the soil, where the crop will be grown and nutrient requirement of the variety. However, irrespective of locations the following per hectare doses of N, P_2O_5, K_2O, S, Zn, and B are recommended for maize cultivation, respectively (Quayyum 1993, Salahuddin 2003):

i. for hybrids : 250, 120, 120, 40, 5, and 1kg
ii. for composite and inbreeds: 120, 80, 80, 20, 5, and 1kg

The time and method of fertilizer application influence maize yield. One-third of N and other fertilizers should be applied at the time of seed bed preparation. The remaining two-third of N should be applied in two installments: One-third at floral initiation (knee height stage/8-10 leaf stage) and the rest at about one week before silking or when the male flower is just visible. In case of dibbling method of planting, initial dose of fertilizers can be applied in the pits, 10 cm apart from the plants. The second and third doses of N can be applied as mentioned in two installments. For better yield, 5-7 tons of cowdung per hectare should be applied.

Irrigation: There is no need to irrigate in summer, but if the crop is sown before rains, a pre-sowing irrigation is required for germination and good subsequent growth. Under heavy rainfall conditions, drainage would be needed. One irrigation at each of the growth stages i.e. within a day of planting; at knee height stage; a week before silking or when male flower is visible; and about two weeks after silking or grain filling stage, are necessary for high yield. Water logging at any stages of growth is harmful (Quayyum 1993, Salahuddin 2003).

Intercultural operation: For a good stand of maize, over planting and then thinning at crop establishment stage may be practice. In case of over-planting, thinning to a desired number should be done within two weeks of germination or when the seedlings are about 15 cm tall. Care should be taken not to disturb standing plants at the time of thinning operation.

Earthing up of plants is one of the most important operations in maize cultivation. It means placing of soil near the base of the plant collected from the space between the rows. This operation helps to provide anchorage of the lower whorls of adventitious roots above the soil which then begin to function as absorbing roots. This operation also prevents the plants from lodging. The furrows made out of this operation could be used as drainage or irrigation channels, depending on the needs. This operation can be performed with the help of spade at the time of application of the second dose of N at knee height stage of the crop (Quayyum 1993, Salahuddin 2003).

Weed control is essential to ensure good harvest. In Bangladesh, weeds are not a serious problem in the winter season, but in the summer season, weeding is necessary. When the seedlings are about two weeks old, first weeding should be done. Further, 2-3 weedings may be required depending on the degree of weed infestations during different life cycle stages of the crop. The maize farmers of Bangladesh practise hand weeding when weed infestation is very high.

Pest management: The important diseases appear during seedling, growing, and maturity stages of maize are 1) Seed rot and seedling blights, 2) Leaf blight, 3) Yellow leaf blight, 4) Stalk rots, and 5) Ear rot and kernel rots. Application of proper fungicide will help control these diseases. For example, Tilt 250 EC @ 0.05 per cent may be applied to control leaf blight disease, when lesions are first observed. Control of both above and below ground insects is essential in maize for good crop production. Those most likely to develop as key insects are 1) maize aphid, 2) corn earworm, 3) cut-worms, 4) stem borer, 5) seedling maggot, and 6) hairy caterpillar. For controlling cutworm field infestation, application of poison bait or application of granular insecticides @ 1.5 kg a.i./ha are effective. Application of any granular insecticides in a dry field must be followed by irrigation or watering for uptake of insecticides by the plants from the soil. Dursban, Pyrifos 20 EC @ 5 ml/litre of water may be sprayed to control soil borne insects. For controlling stem borer, Marshall 20 EC or Diazinon 60 EC @ 2ml/litre water could be sprayed properly to control the pest. For ear worm, the larvae could be killed after collecting from the infested cobs. Cypermethrin (Ricord 10 EC/ Cymbush 10 EC/ Fenom 10 EC) @ 2ml/litre water could be sprayed to a control this pest (Quayyum 1993, Salahuddin 2003).

Harvesting and seed preservation: Harvesting should be done when plants show distinct signs of drying, the husk cover is completely dry and the grains are fully mature. Grain maturity could be identified from the milk line of kernels or the formation of a black layer at the junction of grain and placenta. Premature harvesting reduces the yield. If possible, a prompt harvest of the maize crop at physiological maturity is recommended, as delays will unduly expose the grain to possible undesirable occurrences in the field including temperature extremes, rainfall, diseases and insects, bird damage, and theft may happen. It is commonly harvested with 15 to 25 per cent moisture content (Salahuddin 2003). Harvesting fully mature grain will result in maximum yield, improved appearance and reduced susceptibility to injury from high drying temperatures. In Bangladesh, harvesting is done by hand. The cobs are separated from the stem and the plants are cut near the ground. Soon after harvesting, the cobs should be dehusked and sundried for about 2-3 days. Dried cobs are shelled either by corn sheller or by hand. The use of power operated sheller is mostly used for shelling dried cobs throughout the country.

The shelled kernels should be dried again before storing at optimum moisture level of 12 to 13 percent. Drying is important before storage to avoid deterioration, reduction of seed borne insect and disease attacks. Almost all the maize is sun dryed on concrete *chatal* (drying floor) since mechanical drying is not available in Bangladesh.

3.11 Economics of Maize Production

3.11.1 Cost of maize production

The average cost of maize production was found to be Tk 88,762/ha (USD 1,138.0/ha) at different locations of Bangladesh of which 83.4 per cent and 16.6 per cent was variable cost and fixed cost, respectively. Among different cost items, human labour was the most important one followed by fertilizer cost. On an average, the cost of human labour was Tk 36,500/ha (USD 467.9/ha) which was more than 41 per cent of the total cost. The price of family labour was calculated based on opportunity cost principle. Generally, prevailing local labour wage is taken into consideration in this case. Fertilizer cost was more than 20 per cent of the total cost. The results of the different studies suggest that the cost of maize production was slightly higher in the western part (e.g., Chuadanga, Kustia district, etc.) of the country compared to northern part due to higher prices of different inputs like irrigation, seed, etc. (Table 3.52).

Table 3.52 Cost of maize production in different geographic locations

(Tk/hectare)

Cost items	Bogra	Chua-danga	Dinaj-pur	Lalmo-nirhat	Kishor-egonj	Dhaka	Rangpur	Kustia	All
A. Variable cost (VC)									
H. labour	42,000	43,000	33,900	24,200	49,400	45,400	23,600	30,500	36,500
Tillage cost	5,239	4,692	5,614	5,988	4,491	4,117	4,892	7,485	5,315
Seed	6,408	6,392	5,299	4,919	3,500	5,733	6,066	6,566	5,610
Cowdung	1,680	1,600	4,620	3,100	2,750	0	3,900	1,200	2,356
Urea	8,880	9,260	8,860	10,140	5,260	10,380	8,380	12,760	9,240
TSP	2,975	4,500	3,425	5,825	3,100	7,400	5,650	5,450	4,791
MoP	1,808	1,344	1,760	3,664	1,376	2,592	2,688	3,488	2,340
Gypsum	144	536	760	1,593	0	488	0	0	440
Zinc sulphate	240	1,440	600	1,440	0	0	840	558	640
Borax	320	56	800	1,600	0	0	800	0	447
Pesticides	1,497	898	1,310	1,123	0	524	1,123	1,871	1,043
Irrigation	3,742	5,239	6,785	2,994	2,620	2,994	4,117	5,614	4,263
Int. on OC	989	1,042	973	879	957	1,051	819	996	963
TVC	75,923	80,000	74,706	67,465	73,454	80,678	62,875	76,489	73,948
B. Fixed cost									
Land use cost	14,970	13,722	14,970	13,722	12,475	16,217	16,217	14,970	14,814
Total cost	90,893	93,722	89,675	81,187	85,928	96,895	79,092	91,458	88,606

Source: Karim et al. 2010; Moniruzzaman 2009; Mohiuddin 2003; Chowdhury 1995
Conversion rate 1 USD = 78.0 BDT, OC = Operating capital

3.11.2 Productivity and yield gap of maize

The average farm level yield of hybrid maize is 7.4 (t/ha) which ranged from 6.6 to 8.0 t/ha. The yield is more or less similar in different districts of Bangladesh. The On-farm Research Division (OFRD) of BARI conducted a number of yield trials in different locations/districts for different BARI along with other imported hybrids of maize during 2010-11 and 2011-12. The mean yield and mean potential yield of these hybrids were 11.0 t/ha and 12.6 t/ha, respectively. Therefore, the yield gap between farmer's yield and experimental and potential yield were 32.7 per cent and 41.4 per cent, respectively (Table 3.53). This observation clearly indicates that government intervention is necessary for improving farmers' capability towards maize cultivation. Government interventions may be on supplying quality maize seed to the farmers and their capacity development through hand-on training on different aspects of maize cultivation.

Table 3.53 Productivity and yield gap of maize in Bangladesh

Yield level	Yield (t/ha)	Yield gap	
		(t/ha)	%
Average yield of the districts (farm level yield)	7.39	--	--
Average experiment trial yield	10.98	3.59	32.70
Average experimental potential yield	12.61	5.22	41.40

Note: For details, see Appendix A-16

3.11.3 Return from maize cultivation

Maize is a profitable crop in Bangladesh. The average gross return was calculated at Tk 108,611/ha (USD 1,392.5/ha). The average gross margin and net return were Tk 34,662 (USD 444.4) and Tk 20,004 (USD 256.5) per hectare, respectively. Due to lower cost of production, the farmers of northern Bangladesh received higher gross margin compared to other part of the country. The average BCRs were 1.48 over variable cost and 1.23 over total cost basis (Table 3.54).

Table 3.54 Return from maize production in different districts of Bangladesh

(per hectare)

Particulars	Bogra	Chuad -anga	Dinaj-pur	Lalmo -nirhat	Kishor -egonj	Dhaka	Rang-pur	Kustia	All
Yield (t/ha)	8.00	7.69	7.99	7.91	6.70	6.83	7.41	6.55	7.39
Price (Tk/kg)	14.5	13.75	13.25	14.8	16.15	17.25	14.15	14.25	14.76
Gross return (Tk)	116,000	105,738	105,868	117,068	108,205	117,818	104,852	93,338	108,611
Total variable cost (TVC)	75,923	80,000	74,706	67,465	73,454	80,678	62,875	76,489	73,949
Total cost (TC)	90,893	93,722	89,675	81,187	85,928	96,895	79,092	91,458	88,606
Gross margin	40,077	25,738	31,162	49,603	34,751	37,140	41,977	16,849	34,662
Net return	25,107	12,016	16,193	35,881	22,277	20,923	25,760	1,879	20,004
BCR on TVC	1.53	1.32	1.42	1.74	1.47	1.46	1.67	1.22	1.48
BCR on TC	1.28	1.13	1.18	1.44	1.26	1.22	1.33	1.02	1.23

Source: Chowdhury 1995; Karim et al. 2010; Moniruzzaman 2009; Mohiuddin 2003
Conversion rate 1 USD = 78.0 BDT

3.11.4 Economics of maize production according to farm category

3.11.4.1 Cost of maize production

The production cost of maize for large farmers was the highest (Tk 67,940/ha or USD 871.0) and the lowest for small category farmers (Tk 58,977/ha or USD 756.1/ha) (Table 3.55). Irrespective of farm categories, the human labour cost was the most important cost among different cost items. Considering farm categories, human labour incurred the highest cost (Tk 29,017/ha or USD 372.0/ha) for large category of farm compared to other categories.

Table 3.55 Cost of maize production (Tk/ha) by different farm categories

(Taka per hectare)

Cost items	Farm category			All category
	Small	Medium	large	
A. Variable cost				
Human labour	22,850	28,183	29,017	26,683
Tillage cost	5,738	5,738	5,738	5,738
Seed	5,252	5,640	5,631	5,508
Cowdung	1,922	2,484	2,433	2,280
Urea	3,353	3,440	3,233	3,342
TSP	1,325	1,825	1,658	1,603
MoP	332	501	496	443
Gypsum	142	135	178	152
Borax	133	213	261	202
Pesticides	1,372	1,372	1,372	1,372
Irrigation	2,245	3,493	3,493	3,077
IOC	590	700	706	665
Total variable cost	45,255	53,725	54,218	51,066
A. Fixed cost				
Land use cost	13,722	13,722	13,722	13,722
Total cost (A+B)	58,977	67,447	67,940	64,,788

Farm category: Small (0.20-1.01 ha), Medium (1.01-3.03 ha) and Large (3.04 ha+)
Source: Uddin 2008; Ferdausi 2011; Paul 2012; Conversion rate 1 USD = 78.0 BDT

3.11.4.2 Return from maize cultivation

The average yield was higher (5.6 t/ha) for large category of farmers compared to small (4.7 t/ha) and medium (5.5 t/ha) farmers. These yields were much lower than the yields shown in Table 3.50. These variations might be due to difference in study areas, management practices, and maize varieties. However, the average gross returns ranged from Tk 69,412 to Tk 82,480 (USD 889.9 to USD 1,057.4) per hectare in the study areas. Again, large category farmers received higher gross margin and net return compared to small and medium category farmers. The net return was Tk 14,540/ha (USD 186.4) for large farmers, while it was Tk 13,149 (USD 168.6) and Tk 10,435 (USD 133.8) for medium and small category farmers, respectively (Table 3.56). Therefore, it is clearly observed that there was a positive relationship between farm size and profitability. This might be due to the fact that large category farmers used higher inputs and received higher yield and output price compared to other categories of farmers. Again, large category farmers can enjoy possible economics of scale in production.

Table 3.56 Cost and return of maize cultivation by different farmers' category

(Taka per hectare)

Items	Small	Medium	large	All category
Yield (t/ha)	4.69	5.45	5.57	5.24
Price (Tk/ton)	14,800	14,788	14,808	14,799
Gross return (Tk)	69,412	80,596	82,480	77,496
Total variable cost (TVC)	45,255	53,725	54,218	51,066
Total cost (TC)	58,977	67,447	67,940	64,788
Gross margin (GR-TVC)	24,157	26,871	28,262	26,430
Net return (GR-TC)	10,435	13,149	14,540	12,708
BCR on TVC	1.53	1.50	1.52	1.52
BCR on TC	1.18	1.19	1.21	1.20

Farm category: Small (0.20-1.01 ha), Medium (1.01-3.03 ha) and Large (3.04 ha+)
Source: Uddin 2008; Ferdausi 2011; Paul 2012; Conversion rate 1 USD = 78.0 BDT

3.11.4.3 Factors affecting gross return

The gross return of maize production may be influenced by various costs spend for various factors of production, such as human labour, land preparation, irrigation, seed, and fertilizer. The results of two studies showed that most of the coefficients possessed positive sign implying positive influence of different factors on gross return (Table 3.57). The coefficients of land preparation, fertilizer, irrigation, manure, and pesticide were found to be positive and significant which indicated that more use of these inputs, with all other factors remaining constant, would increase the gross return from maize cultivation. However, the coefficient of seed cost was found negative and significant in both the studies which implies inefficient or over use of seed. Gross return from maize may be increased by using appropriate amount of seed in the study areas.

Table 3.57 Coefficients and related statistics of Cobb-Douglas revenue function model

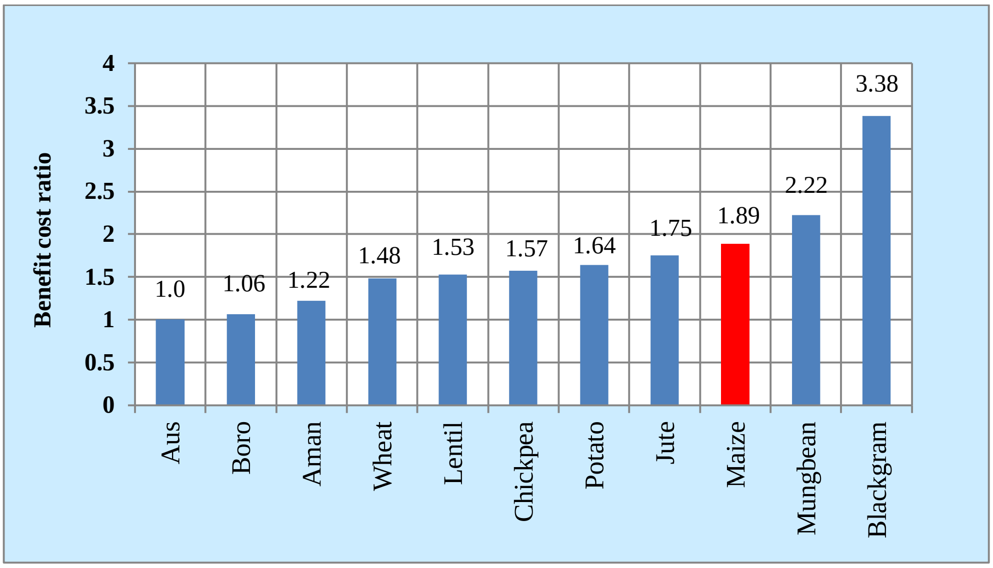
Explanatory Variable	Study-1 (Year 2012)		Study-2 (Year 2011)	
	Coefficient	Std. error	Coefficient	Std. error
Intercept	10.36	1.32	9.48	0.476
Farm size (ha)	--	--	-0.01	0.016
Human labour cost (Tk/ha)	0.25	0.29	0.05	0.053
Seed cost (Tk/ha)	-0.10*	0.04	-0.27***	0.071
Land preparation cost (Tk/ha)	0.20***	0.04	0.02	0.042
Fertilizer cost (Tk/ha)	0.13**	0.05	0.07*	0.060
Manure cost (Tk/ha)	0.17***	0.04	0.14***	0.026
Irrigation cost (Tk/ha)	0.18***	0.02	0.11***	0.028
Pesticides cost (Tk/ha)	0.16**	0.05	0.04*	0.033
R^2	0.73		0.66	
F-value	13.36***		11.77***	
Observations (N)	60		65	

Note: Dependant variable = Gross return (Tk/ha); ***, ** & * represent significant at 1%, 5%, and 10% level.
Source: Ferdausi 2011; Paul 2012

3.11.5 Relative profitability of maize cultivation

Maize cultivation is more profitable compared to many other competing crops including rice and wheat. In order to compare the relative profitability of maize cultivation, Miah et al. (2013) used secondary data on different competing crops for the year 2009-2010. However, given the prices in 2009-2010, the following figure explains the relative profitability of maize in Bangladesh. Among the cereal and fiber crops, blackgram is the best due to lower cost of production, and maize stands at the third position (Fig 3.21).

Fig 3.21 Relative profitability of maize, 2009-2010



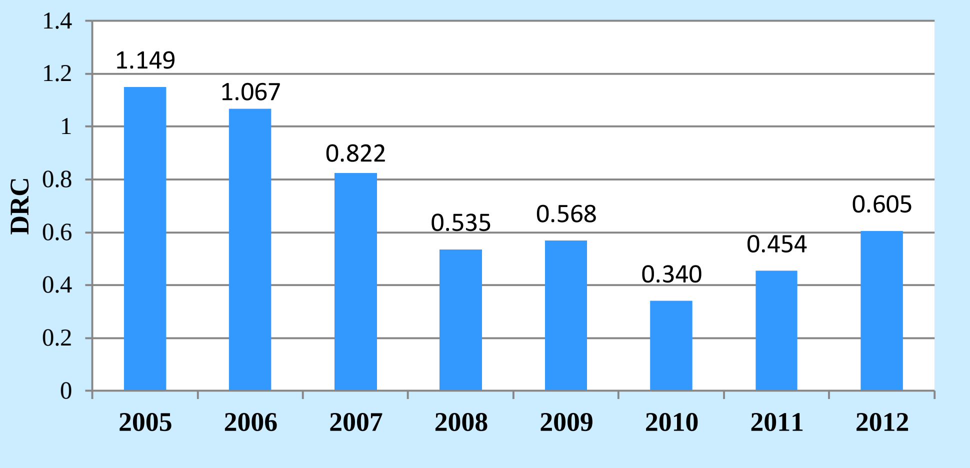
Source: Miah et al. 2013

The farmers of Ghoraghat and Nawbabgonj *Upazila* under Dinajpur district also mentioned various positive sides of maize cultivation compared to other crops. They mentioned that the profit of maize cultivation is about double that from rice and wheat. Maize farmers mentioned some problems, such as requirement of higher amounts of fertilizers, storing problem unlike wheat and paddy, and low bargaining option in determining the conditions during maize sales (FGD 2013).

3.11.6 Domestic resource cost of maize production

Domestic Resource Costs (DRCs) for maize production in Bangladesh were estimated at import parity prices for the period from 2005 to 2012 (Fig 3.22 and Appendix A-17). The estimated DRCs were less than unity during 2007-2012 under import parity prices implying that the country had comparative advantage in maize production for import substitution and export promotion. DRCs were higher than unity implying that the country had no comparative advantage in maize production during 2005-2006. Again, the value of DRC gradually increased from 2010 which was due to increase in the cost of production.

Fig 3.22 DRC of maize production, 2005-2012



Source: Rashid et al. 2009; Author's calculation for the year 2010-2012

3.11.7 Impact of policies on agricultural incentives

Impact of government policies on the financial incentives was estimated for the last 8 years (2005-2012) of maize production by calculating Nominal Protection Co-efficient (NPC), Nominal Rate of Protection (NRP), Effective Protection Co-efficient (EPC), and Effective Rate of Protection (ERP). Hence, f.o.b. world prices at the port of a significant exporting country were taken into consideration and these prices were brought to the import parity level assuming that imports compete with domestic production at the producer level. A NPC of greater than one indicates that the government has protected domestic production by raising its financial price in the domestic market above its economic price. Again, an EPC of less than one implies that the domestic market of a crop is not protected and the crop requires substantial protection in future for import substitution.

Table 3.58 shows that the estimated NPCs and NRPs over the period 2005-2012 for maize were less than one and negative for all the years at import parity level. It means that domestic maize production was taxed and consumers were subsidized. Again, the border price of maize at producer level measured at official exchange rate was mostly higher than the domestic producer price. Rashid et al. (2009) re-examined the estimated NPCs by working out EPCs. The EPCs were also less than one and ERPs were negative for maize production during 2005-2012. This also implies that the domestic market of maize was not protected. Domestic production of maize may require substantial protection in future for import substitution and export promotion.

Table 3.58 Nominal rate of protection and effective rate of protection for maize production at official exchange rate

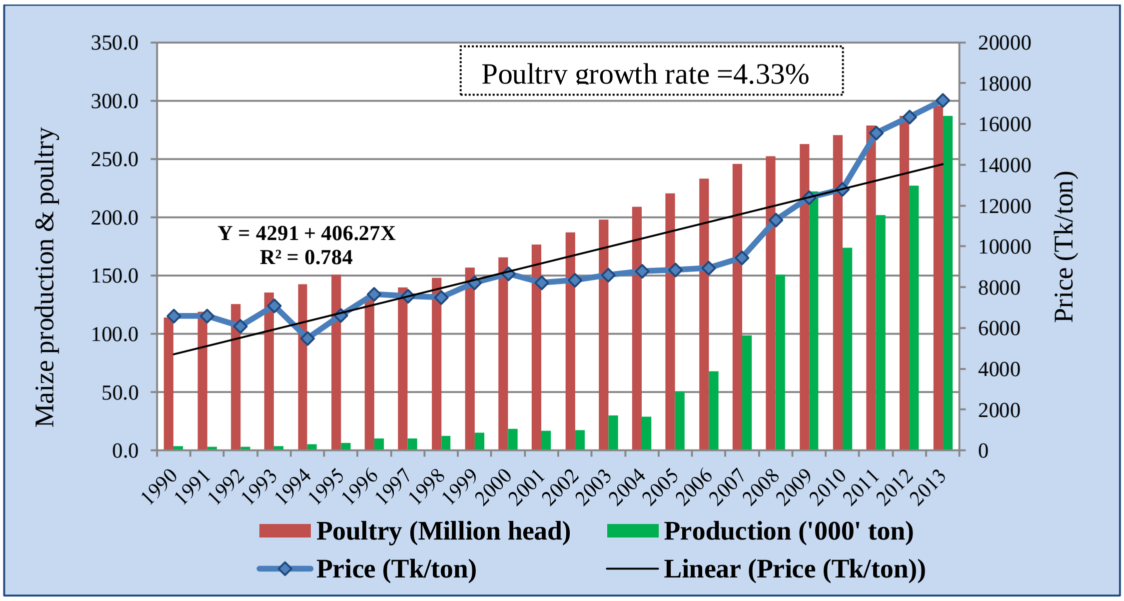
Year	NPC	NRP	EPC	ERP
2005	0.892	-0.108	0.94	-0.05
2006	0.908	-0.092	0.95	-0.04
2007	0.790	-0.210	0.79	-0.20
2008	0.583	-0.417	0.55	-0.44
2009	0.595	-0.404	0.54	-0.45
2010	0.792	-0.208	0.85	-0.15
2011	0.861	-0.139	0.89	-0.12
2012	0.829	-0.171	0.85	-0.15

Source: Rashid et al. 2009; Author's calculation for the year 2010-2012 (Appendix A-18)

3.11.8 Farm gate price of maize

The farm gate prices of maize were more or less static and below the price of Tk 7,000 per ton during 1987-1995 mainly due to less demand. During next five years (1996-2000), maize price increased gradually but fluctuated due to the introduction of poultry farming in some parts of the country. The major demand for maize started increasing from 2002 owing to the increase in the demand of poultry growth rate and fish feed across the country. During this period, a steady growth was observed in maize production, poultry (chicken and duck) production, and the price of maize due to huge demand from poultry and fish sector across the country. However, the overall price shows an increasing trend over the years (Fig 3.23).

Fig 3.23 Farm gate price of maize in Bangladesh



Source: Production data from DAE, Price data from BBS, and Poultry data from FAOStat

Chapter IV

MAIZE INPUTS AND RESEARCH & DEVELOPMENT

4.1 Introduction

The current situation of maize input provision and Research & Development (R&D) including recent past are discussed in this chapter. It also highlights the main features of the supply of maize related inputs, including input product characteristics, supply characteristics (e.g. availability, access, and cost), supplier characteristics, market differentiation/ segmentation, and related policy aspects.

4.2 Maize Seed Supply

Seed is a key agricultural input and its quality has a significant effect on crop yields. Providing farmers with a steady supply of quality seed can significantly improve both the quantity and quality of agricultural production and increase the prospect of attaining food security for Bangladesh's growing population (www.katalyst.com.bd/op_ai_Seed.php). In Bangladesh context, seed is one of the main limiting factors for expansion of maize areas in the country. The Government of Bangladesh considers the seed sector a high priority area, and developmental activities targeting strengthening of the seed sector have been supported by several donors during the past decades including Holland, USA, Germany, Australia, EU, Belgium, Denmark, and FAO (Huda 2001 as in Bødker et al. 2006).

The demand for good quality seed is very high, but its supply is low from both public and private sector. In the seed sector, both public and private sector companies are operatingthis business. Specifically each type of seed company maintains their own mandate with defined roles and objectives. The mandate of public companies like Bangladesh Agricultural Development Corporation (BADC) differs widely from those of private companies. The vision of BADC is the development of agriculture through supply of agricultural inputs and dissemination of technologies among the farmers to ensure national food security, whereas private companies are mostly profit oriented. After the adoption of National Seed Policy (NSP) in 1993, the emerging private seed sector and NGOs have played an increasing role in the seed production and seed supply (GOB 1993).

4.2.1 Type of maize seed supplied

In Bangladesh, maize growing areas are now mostly covered by a wide range of foreign hybrids of normal maize (non-QPM) type. Only the tribal people in Chittagong hilly areas are cultivating composite varieties. Most of the cultivated hybrid varieties are single cross and a few of them are three way and double cross hybrids. These hybrids are being sold in the market between Tk 150 (USD 1.88) and Tk 450 (USD 5.63) per kilogram. BADC is selling their hybrid seeds at Tk 75 (USD 0.94) per kg, while the price of BARI composite (pop corn) variety is Tk 37 (USD 0.46) per kg.

Private companies have introduced hundreds of cultivars, but there is no centralized record of what has been introduced. However, a non-systematic survey of seed stores throughout Bangladesh in 2008–2009 found 70 types of maize hybrids of which 20 hybrids accounted for most of the sales (Rashid et al. 2012). At present, more than 70 types of hybrids of maize are available in the market (Appendix A-23). Most private maize hybrids come from the companies in China, India, Thailand, and other regional countries.

4.2.2 Main seed suppliers

In 1990s, two seed companies, Kushtia Seed Store and ICI Seed International and the International Fertilizer Development Center (IFDC) imported small amounts of seed of hybrids for testing. One of these was Pacific-11, imported from Thailand, which yield was higher than the yields of BARI composite varieties (Chowdhury and Islam 1993). Other seed companies subsequently imported hybrid seeds, as did BRAC for use in its poultry programme. BRAC, Grameen Krishi Foundation (GKF), and Rangpur Dinajpur Rural Service (RDRS) were the pioneer NGOs in maize seed production programme in Bangladesh. At present, except BRAC, rests of the NGOs are not playing an active role. In 1996, BRAC started producing high quality maize seed with the objective to supply farmers. Currently, two seed producing farms are working for maize seed production.

BADC is the only public sector mandated entity to produce large quantity seed of various kinds and "still supply the majority of the high volume/low profit seed which include the cereals (rice, wheat, and maize), pulses, jute, and oilseeds, whereas the private seed companies are mostly confined to low volume/high value seed e.g. hybrid seed of maize, rice, and vegetables" (Bødker et al. 2006). BADC supplies about 20 per cent of the country's cereal seed requirements and about 2–5 per cent of other crops (Bødker et al. 2006). Shortly after the Government of Bangladesh removed controls on the introduction of new cultivars for all but five crops (notified), private companies, and NGOs began to produce maize hybrids (Kabir and Huda 2009). In some cases, farmers are cheated by those hybrids which are not good performers and are being sold without any quality testing in the local environment. Besides, poor viability of the imported seeds has also been noticed (FGD 2013).

BADC has established a system of seed multiplication of different (except sugarcane and cotton) crops by the engagement of approximately 57,025 smallholders as contract farmers, 54 (of which 23 are cereal seed production farms) seed production farms, 75 contract grower zones, 100 seed sale centers and connections with more than 1,000 registered private seed dealers (www.badc.gov.bd). In the current year, BADC is producing BARI hybrid maize seed covering 97.28 ha of land under 9 seed producing farms, and 8 contract farmers *Khoi Bhutta* is produced in another 3 seed production farms covering an area of about 8.10 ha.

The PBD of Bangladesh Agricultural Research Institute (BARI) with its limited resources is producing small quantities of seeds of its own released hybrids for demonstration and other purposes. Large scale seed production of the BARI released hybrids started recently with the establishment of MoUs with public and private seed entrepreneurs and some progressive farmers to facilitate them to get parental lines of BARI developed hybrids. Total hybrid seed requirement in the country is estimated to be 6,552 tons in 2013, of which only 933 tons (14.2% of total) is being produced locally mostly by BRAC (640 tons), BADC (257 tons) and negligible amount by ACI seed and Supreme Seed Company. The rest amount of seed requirement (85.8% of total) was met from imports mainly from Thailand, India, and Vietnam. However, the dependency of seed import was higher in 2012-13 compared to 2011-12 (Table 4.1). BRAC is producing hybrid seeds of its own developed varieties and using parental lines of Pacific Seed Company. Currently, BADC, ACI seed, , and Supreme Seed are producing hybrid seeds of BARI developed varieties through contract growers. Every year, the country has to import a huge amount of hybrid seeds to meet the local demand. BADC is also producing foundation seed of *Khoi Bhutta* (a composite pop corn variety) from breeder seed supplied by BARI.

Table 4.1 Production and import of hybrid maize seed by different organizations

(Metric ton)

Organization	2012-2013			2011-2012		
	Production	Import	Total	Production	Import	Total
ACI Seed	7	300	307	--	--	-
BADC	257	--	257	184	--	184
BRAC	640	400	1,040	783	400	1,183
Supreme Seed	29	40	69	22	40	62
Syngenta	--	1,500	1,500	--	1,500	1,500
Quality Asurance	--	1,100	1,100	--	800	800
Petro Chem (BD) Ltd.	--	475	475	--	350	350
Agro Services Ltd.	--	580	580	--	450	450
Other organisations	--	1,224	1,224	--	239	239
Total	933 (14.2)	4,395 (85.8)	5,328 (100)	989 (20.7)	3,779 (79.3)	4,768 (100)

Note: Figures within parentheses are percent of total
Source: FGD (2013) with the representatives of different seed companies

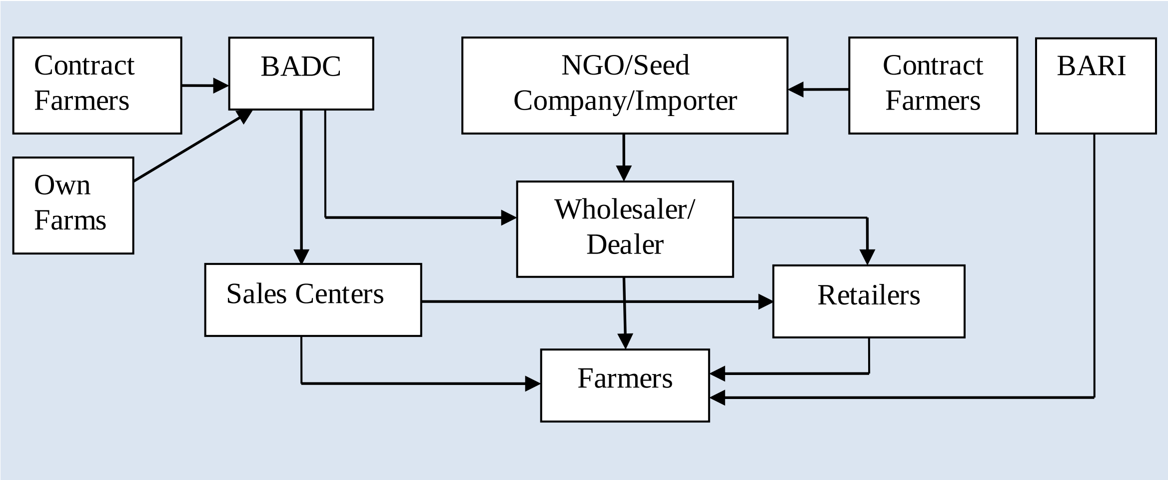
The emerging private seed sector includes both multinational companies and domestic seed businesses. The leading seed companies in Bangladesh are Monsanto (Bangladesh) Limited, Syngenta (Bangladesh) Limited, BRAC, Pioneer, Advanta, National Agri Care, CP seed, Alfa Seed International, Rashel Seed, Lal Teer Seed Limited, ACI Seed, Auto Equipment Ltd., Kushtia Seed Store, Siddiquis Seeds, Supreme Seed Company Ltd., Alpha Agro Limited, Getco Agro Vision Ltd., United Seed Store**,** Agri Concern, etc. Most of the world's seed multinationals get cultivars into Bangladesh through locally owned collaborating companies.

4.2.3 Seed marketing and distribution

In Bangladesh, there are more than 100 private companies involved with over 8,000 registered seed dealers operating across the country (http://www.katalyst.com.bd). BADC distributed seed by seed-sales centres and through private seed dealers. The private sector is a mix of small farmer seed entrepreneurs, one-man owned wholesalers/ importers, international seed companies, and joint venture companies. The private sector is increasingly involved in plant breeding and seed production in response to the opportunity presented by growing demand for new varieties and for production intensification. Seed dealers as defined in the Seed Amendment Act 1997, are required to register with the Seed Wing of the Ministry of Agriculture.

In the import based system of marketing, distributors/importers are importing seeds directly from foreign countries and make them available to farmers or seed users through whole-sellers and retailers. In the local production based system of marketing, distributors/ marketing organizations are producing seeds through contract farmers or procuring seeds from the reliable seed producers of selected areas, and after cleaning, grading, and processing preserving in seed stores. These seeds are made available to the farmers through wholesalers and retailers. BRAC has set up 50 marketing outlets in different parts of Bangladesh through which they distribute maize seeds (BRAC 2005). BADC distributed seed through seed sales centres and private seed dealers. A flow diagram of these channels is presented in Fig 4.1.

Figure 4.1 Flow diagrams of seed marketing and distribution in Bangladesh



Source: Created by authors

4.2.4 Seed policy in Bangladesh

This section is based on the overview of seed systems in Bangladesh prepared by Danish International Development Assistance (DANIDA) for its Agriculture Sector Support Programme. Bødker et al. 2006 describe the legal and regulatory framework regarding seed: (i) The National Seed Policy (1993); (ii) The Seed Ordinance 1977 (Amendments in 1997 and 2005), and (iii) The Seed Rules 1998. As they further elaborate: "The *Plant Quarantine Regulation* is considered part of the regulatory framework as it also affects the seed sector. The *Plant Variety and Farmers' Rights Protection Act, 2009*, which is awaiting final approval by Parliament, and the proposed National Plant Genetic Resources Institute (NPGRI) are also critical components of plant breeding and the seed system in Bangladesh" (Bødker et al. 2006).

Bødker et al. 2006 present the following overview:

> *The National Seed Policy 1993*
>
> The National Seed Policy (NSP) was declared in 1993 … with the objectives of (i) promoting balanced development of public and private sector seed enterprises; (ii) simplifying the import of seeds and planting material; (iii) providing training and technical support for seed stakeholders in topics related to seed production, processing, storage, and use of high quality seed and (iv) monitoring, controlling and regulating the quality and quantity of seed produced in Bangladesh.
>
> *The Seed Ordinance 1977 (The Seed Act Amendments in 1997 and 2005)*
>
> The Seed Ordinance 1977 stipulates the role and function of the National Seed Board (NSB) and the Seed Certification Agency (SCA). It also provides clauses for the import and export of seeds, the representation of Board members, regulations of standards for quality of seed, approval, and registration of new varieties, labeling of seeds and the functions of SCA and penalties for violating the ordinance or rules. The Seed Amendment Act 1997 provides definition of seed dealers and changes in the structure of the NSB. The Seed Amendment Act 2005 incorporates clauses for non-notified crops and for increasing penalties for violation.

Seed Rules 1998

The Seed Rules elaborate on the role and function of the NSB and on the procedures for registration of seed dealers, registration of varieties, and labeling of the seed offered for sale in sealed containers or packets. The functions of the SCA and its seed inspectors are highlighted. The seed rules also describe in more detail the seed regulatory framework and stipulate the forms and procedures in relation to application for variety registration, field inspection, seed certification, and market control.

Plant Quarantine Regulation (PQR)

The PQR is regulated by the "Destructive Insects and Pest Rules", 1966 amended in July 1989. The aim of PQR is to ensure safe importation of plant products, including seed, into the country without creating obstacles to international agricultural trade and international transfer of germplasm. A new PQR was framed in 2005 and submitted to the Government for approval which is at present under consideration.

Genetically Modified Organisms (GMO)

Currently, there is no law to regulate GMO in Bangladesh. GMO is not allowed for cultivation. There is a considerable pressure from the emerging private seed sector to instate modalities for assessment and approved GMOs because of the release of GM cotton in India.

Seed import and export

To import any type of seed to Bangladesh, an import permit and a phytosanitary certificate are required. The import permit is issued by the Plant Protection Wing of the Department of Agricultural Extension (DAE) under the Ministry of Agriculture (MoA), while the phytosanitary certificate is provided by the exporting country (Huda 2001). International Seed Testing Association (ISTA) orange certificate is not yet mandatory but quality certificate from the seed certification authority of the exporting country is needed. In addition, imported varieties of the five notified crops (rice, wheat, jute, potato, and sugarcane) must be listed on the Official National List of Varieties and comply with crop-specific standards.

Documentation required to export seed is issued by the Plant Protection Wing of DAE in the form of an export permit and a phytosanitary certificate. At present, it is difficult to export seeds from Bangladesh because of lack of an internationally accredited laboratory which can issue seed quality certificates. The private seed sector is pushing hard to get an accredited laboratory in the country, either as a private initiative or as a part of SCA.

Variety approval, release and intellectual property rights

As a non-notified crop, prior to variety approval and release, new varieties of maize need not to undergo two types of variety tests: (i) test for Distinctness, Uniformity, and Stability, and (ii) test for Value, Cultivation, and Use which is obligatory for notified crops. New varieties can freely be marketed in Bangladesh after the acquirement of a registration number, which is issued without testing by the NSB of MoA (Huda 2001). Bangladesh maintains a list of released varieties. Newly released varieties are added to this list. There is no fee to keep the variety on the list of released varieties.

Bangladesh has signed the Agreement on Trade Related Aspects (Plant Variety Protection) of International Property Rights of the World Trade Organization (WTO) and the International Treaty on Plant Genetic Resources for Food and Agriculture (Farmers' Rights). Bangladesh is, therefore, committed to implement the obligations arising from these agreements or any requirements concerning maintenance of the variety into national law (Bødker et al. 2006).

4.3 Agro-input Supply (non-seed)

"Although a successful maize crop requires high inputs, it also provides several advantages. Maize is more than two times as economical in terms of yield per unit of land as wheat or *Boro rice* (winter season rice). It also requires less water than *Boro* rice and encounters fewer problems with pests and diseases" (www.katalyst.com.bd). The government has removed many agricultural subsidies, eliminated quantitative restrictions, reduced tariff levels, and created an open-market economy that makes agricultural inputs readily available for farmers and guarantees fair commodity prices.

Maize farmers use locally available seeds, fertilizers, and pesticides from retailers either on cash or credit. These inputs are mostly imported from different countries by large companies. The retailers sometimes suggest farmers about which seed to buy because farmers are lacking proper information about quality seeds. Most retailers try to sell seed to companies that offer more commission. Rob (2010) mentioned in his report about the typical system of fertilizer and pesticide distribution as follows:

> ''Government enlisted dealers collect fertilizers from nearby government or importers' warehouse. They supply the fertilizers to enlisted sub-dealers or rural retailers. Farmers buy from these retailers. Private importers control the whole pesticides import and distribution system. The importers through their representative distribute pesticides to retailers. Farmers buy from them. Quality control is a big issue as different types of pesticides are available in the market. Adulteration of pesticides is a common feature in rural areas''

Among the non-seed inputs, fertilizer plays the vital role but agrochemicals and agricultural machinery also have an important role in crop production in general and maize production in particular. The supply systems of these non-seed inputs are briefly discussed below.

Fertilizer*:* "Fertilizer is a key input in crop production, and its judiciuous use can return optimal yields and higher profits to the farmers. Conversely, indiscriminate use leads not only to lower productivity but also the deterioration of soil health. The supply and availability of quality fertilizer at the farmer's doorstep, coupled with its balanced usage and application, is a critical issue in sustaining crop productivity" (http://www.katalyst.com.bd). BADC was established in 1961 (as the East Pakistan Agricultural Development Corporation) primarily to supply fertilizers, seed, minor irrigation equipments, and limited mechanized services to farmers. It has played a major role in distributing chemical fertilizers and seed and installing irrigation equipment, which in turn facilitated the expansion of HYV rice cultivation during the 1970s and 1980s. BADC's role has diminished over the years with increasing private sector involvement during the 1990s. Fertilizer distribution was first put into the hands of private wholesalers in 1975-1977. Controls on farm-level sale prices were removed in 1982–1983. The government's monopoly on fertilizer import was lifted in 1991. In the first 5 years after fertilizer price controls were removed, farmers gained significantly as the marketing margin between wholesale and farm-level prices decreased by 29 per cent (Samad 1999). Private traders/distributors were given permission to have a direct access to the bulk purchase of chemical fertilizers as well as to import TSP and MoP fertilizers freely which has led to increased availability and wider adoption of chemical fertilizers at the farm level.

Hybrid varieties of maize are highly responsive and need adequate supply of fertilizer to achieve targeted production. In maize, fertilizer consumption began to increase rapidly with the introduction of hybrid varieties. There is no statistics of the amount of fertilizers used in maize production. Farmers often do not use recommended and balanced fertilizers which hamper the production. The total urea fertilizer production in 2009-10 was 11 lac tons in six urea factories and total demand was 29.5 lac tons. Domestic production covered 37 per cent of the total demand of urea. Similarly, domestic production of TSP was 0.76 lac tons, which covered 8.8 per cent and domestic production of 0.38 lac tons of DAP covered only 6.9 per cent to the total demand. Moreover, the demand of 3.18 lac tons of MoP was completely imported from foreign countries (Table 4.2).

Table 4.2 Fertilizer production, demand, sales and import, 2008/09-2009/10

Types	**Domestic production** ('000'ton)	**Import** ('000'ton)	**Availability** ('000'ton)	**Estimated demand** ('000'ton)	**Deficit** ('000'ton)	**Total sales** ('000'ton)
2006/07						
Urea	1,816.86	775.00	2,591.86	-	-	2,515.00
TSP	500.00	290.00	340.00	-	-	340.00
MoP	--	230.00	230.00	-	-	230.00
DAP	--	125.00	125.00	-	-	115.00
2007/08						
Urea	1,474.88	1,161.35	2,636.23	-	-	2,762.78
TSP	47.17	254.04	301.21	-	-	381.97
MoP	--	224.60	224.60	-	-	274.00
DAP	--	10.00	10.00	-	-	89.00
2008/09						
Urea	1,200.00	1,375.00	2,575.00	2,818.00	243.00	2,533.00
TSP	45.00	300.00	345.00	475.00	130.00	161.00
MoP	--	235.00	235.00	400.00	165.00	82.00
DAP	28.00	18.00	46.00	250.00	204.00	18.00
2009/10						
Urea	1,100.00	1,465.00	2,565.00	2,951.00	386.00	2,406.00
TSP	76.00	376.00	452.00	670.00	218.00	420.00
MoP	--	318.00	318.00	497.00	179.00	263.00
DAP	38.00	149.00	187.00	263.00	76.00	136.00

Source: BBS 2010

Imports and use of fertilizer increased substantially in the 1990s compared with the early 1980s. It is quite evident that demands of fertilizer are heavily dependent on imported fertilizer. Therefore, any disruption in the supply chain is quite possible to affect the total production system. Zaman (1987) and Shah et al. (2008) reported that three forths of total fertilizers were consumed for rice production and the rest for other crops. Well-timed supply and availability of fertilizer should receive top priority to sustain maize production in Bangladesh.

The price of non-urea fertilizers per ton was more than USD 1,000 in the last season, whereas the current price of these fartilizers is less than half. This is because of government initiative and subsidy. At present, the farmers are buying 1kg of Triple Super Phosphate (TSP) at Tk 40

(USD 0.51), Murate of Potash (MoP) at Tk 35 (USD 0.45) and Di Ammonium Phosphate (DAP) at Tk 45 (USD 0.58) from dealers and their agents at the union parishad level. They can buy urea fertilizer at the previous price of Tk 12/kg (USD 0.15/kg). Besides, diesel price cut down by Tk 2 per litre to Tk 44 on sharp fall of crude oil in the international market (Ahmed et al. 2009). The prime minister assured that her government would continue to provide fertilizers, seeds, diesel, electricity, and other inputs at subsidised rate (www.newagebd.com/detail.php?date=2012-05).

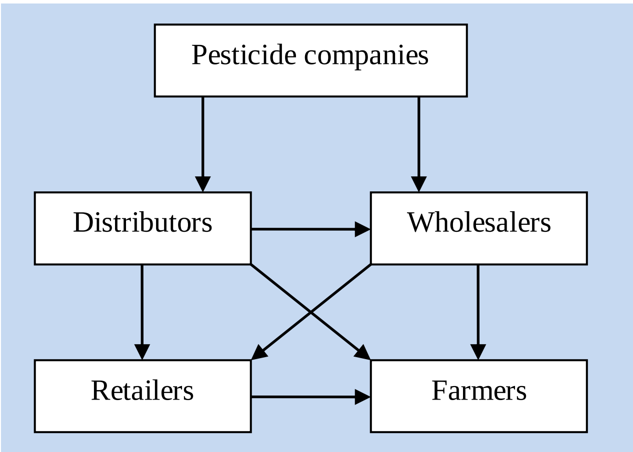
Agro-chemicals: "Bangladesh does not produce any active ingredients, it only imports and formulates. The marketing channel of pesticides in Bangladesh consists of pesticide companies, distributors, wholesalers, wholesaler cum-retailers, retailers, and farmers (Sabur and Molla 2000). There exist approximately 66 officially registered companies, with 6 of these being multinational in nature" (Dasgupta et al. 2005, p.6). Some of the leading pesticide companies are ACI Ltd, Alif Chemical Co, Alpha Agro Ltd, Auto Equipment Ltd., Bayer Crop Science Ltd., Ciba Geigy (Bd) Ltd, McDonald Bd (Pvt) Ltd, M/S Quazi Enterprise, M/S Map Agro industries, Monsanto Bd Ltd, Novartis Bd Ltd, Syngenta Bangladesh Ltd, Padma Agro Spayers, Globe Insecticide Ltd, Pioneer Equipment & Chemical co., Shetu Pesticides Ltd., Square Pharmaceuticals Ltd., Agri Tech, Hossain Enterprise C.C. Ltd, and Reckitt & Benckiser (Bd) Ltd.

Dasgupta et al. (2005) further elaborate that:

> Distributors buy almost all of their products from pesticide companies. However, the pesticide companies also directly sell to wholesalers. Distributors, in turn, sell their products to the wholesalers-cum-retailers, retailers and large farmers. Wholesalers sell to retailers as well as farmers. Retailers, in turn, sell their product to farmers, but farmers frequently buy directly from the distributors as well as wholesalers.

A simplified representation of these channels is presented in the following Fig-4.2.

Figure 4.2 Pesticide marketing channels in Bangladesh



Source: Dasgupta et al. 2005

According to an estimate, annual yield loss due to insect pest alone is 16 per cent for rice, 25 percent for vegetables crops in every year (http://www.moa.gov.bd/advertisement/IPM.htm). The government of Bangladesh also promotes the use of pesticides to expand its agricultural frontiers and increase output per unit of land. As a result, pesticide use in general is increasing. According to national statistics, the consumption of pesticides increased from 17,392.24 metric tons in 2002 to 34,011.26 metric tons in 2011, about doubled in the past decade (BBS 2011). Insecticides and fungicides account for 97 per cent of pesticide use and have registered a steady growth over the years (Meisner 2004).

As in many developing countries, Bangladesh lacks sufficient information on pesticide use, even at the regional level. Although maize insects and diseases are still not a serious problem in the country, the situation is changing with the increase in area and intensity of cultivation. Farmers generally use chemicals to control some below ground insects (e.g., Cut worm) and foliar diseases (e.g., Leaf blight). The consumption of year wise different types of pesticides is shown in Table 4.3. Although there are no statistics of the total amount of pesticides used in maize, but it is seen that until 2008, the trend was increasing and then gradually decreased.

Table 4.3 Consumption of pesticides (in Metric tons or Kilo litres)

Year	Insecticides			Fungicides (All types)	Herbicide	Rodenticide	Public hygiene	Total
	Granular	Liquid	Powder					
2002	12,334.54	1,496.85	142.12	2,418.80	963.60	36.33	--	17,392.24
2003	11,781.36	1,830.82	155.02	2,940.68	1,354.02	18.56	--	18,080.46
2004	12,113.40	2,008.27	229.04	4,279.23	3,462.83	23.08	--	22,115.85
2005	14,061.65	2,511.05	323.51	5,771.74	2,774.94	23.54	--	25,466.43
2006	1,518.46	3,159.63	514.26	8,710.02	3,205.40	14.93	--	17,122.70
2007	19,963.28	3,104.17	581.46	10,227.56	3,825.26	10.35	--	37,712.08
2008	25,221.58	4,190.40	694.20	63.68	14,426.78	4,024.77	68.18	48,689.59
2009	22,118.87	4,274.89	606.80	55.97	14,353.67	3,697.86	62.38	45,170.44
2010	11,163.00	2,115.85	306.59	6,599.09	1,206.17	39.97	34.13	21,464.80
2011	16,815.50	2,520.30	516.77	11,835.38	2,222.15	40.33	60.83	34,011.26

Source: BBS 2011; BBS 2010

Agricultural machinery: Introduction of agricultural machinery in the agriculture sector of Banglsadesh is very much important for increasing production and cropping intensity. It will also reduce the post-harvest losess of agriculture produces. Islam (2009) stated in his report that:

> Replacing the traditional inefficient agricultural tools, efficient mechanized cultivation must be introduced and extended. The government has already attributed due importance to agricultural mechanization in the National Agricultural Policy (MoA 2009). In the Policy (Draft 5) it was included that "The government would encourage production and manufacturing of agricultural machinery adaptive to our socio-economic context. Manufacturing workshops and industries engaged in agricultural mechanization activities will be provided with appropriate support".

In maize cultivation, farmers are using farm machinery mainly during land preparation, intercultural operation, irrigation, and shelling. In 2000, for all crops, the land preparation was done almost 70 per cent by machine (Farouk et al. 2007 as cited by Islam, 2009) which has now been raised to about 80 per cent. But, bed makers, seeders and weeders, all have limited uses (Islam 2009). However, shelling of maize is accomplished almost 100 per cent by power and hand maize sheller. In 2007-2008, the irrigated area coverage by different irrigation equipment was 61 per cent of the net cultivable area (8.29 million hectares). Irrigation pumps are produced locally in Bangladesh, but the engines or motors to drive them are imported. During the last few years, the pump market (including shallow tube well pumps) has experienced a 15-20 per cent growth (http://www.katalyst.com.bd). Though, tractors, power tillers, and other farm machinery like threshers and weeders increased with time, irrigation equipment increased at much faster rates (Table 4.4). A list of farm machinery used all over the country in 2012 is provided in Table 4.5. Again, the status of manufacturing units of agricultural machinery in the country is presented in Table 4.6.

Table 4.4 Number of different farm machineries over years

Name of machine	Year				
	1977	*1984*	*1989*	*1996*	*2006*
Tractor	300	400	1,000	2,000	12,500
Power tiller (2-wheel tractor)	200	500	5,000	100,000	300,000
Maize Sheller	-	-	-	100	850
Thresher (open drum)	-	500	3,000	10,000	130,000
Thresher (closed drum)	-	100	1,000	5,000	45,000
Deep tube well	4,461	15,519	22,448	24,506	28,289
Shallow tube well	3,045	67,103	223,588	325,360	1,182,525
Low lift pump	28,361	43,651	57,200	41,816	119,135

Source: Roy and Singh 2008

Table 4.5 Statistics on farm machinery in Bangladesh, 2012

Farm machinery	No. of unit	Farm machinery	No. of unit
Power tiller	450,000	Reaper	120
Tractor	30,000	Open drum thresher	250,000
High speed rotary tiller	3,000	Closed drum thresher	40,000
Weeder	200,000	Winnower	2,000
Seeder, PTOS	500	USG Applicator	12,000
Sprayer	1,250,000	Hand maize sheller	12,000
Combine harvester	60	Power maize sheller	2,500

Source: FMPE 2013

Table 4.6 Status of manufacturing units of agricultural machinery in 2013

Manufacturing Units	Number
1. Foundries	50
2. Agri-machinery manufacturing workshops	500
3. Spare parts manufacturing workshops	250
4. Repair and maintenance workshops	10,000
5. Village artisans	100,000

Source: FMPE 2013

With the collaboration of CIMMYT, farm mechanization and resource conservation technologies were developed and tested through collaborative adaptive research programmes with BARI, BRRI, several public universities, NGOs, and with farmers. These included maize sheller, a multi-crop seed drill, power-tiller-operated bed planter with universal tool bar frame, seed-drill-operated bed planter for permanent soil beds, strip till seed drill, zero till seed and fertilizer drill, cone type seed-drill operated bed planter, high speed rotovator, rice-wheat reaper, rice-wheat thresher, mobile pump for irrigation, winnowers, and 4m boom sprayers. CIMMYT's work has successfully created far greater awareness on the benefits of small-scale farm mechanization in Bangladesh and there has been tremendous interest by farmers (CIMMYT 2008).

Farm mechanization in Bangladesh is constrained by various socio-economic factors. Islam (2009) stated the following in these regards.

> Mechanization in the country is always associated with some inherent drawbacks like fragmented lands, poor buying capacity of farmers, lack of

quality machines for farm operation, inadequate knowledge of the users about machines, and insufficient awareness building activities. The rural people are mostly poor and hardly can buy a costly machine individually. Some moneyed farmers having a large quantity of agricultural lands possess some costly machines like, tractors, power tillers, power tiller operated seeders, combines, etc. They use these machines in their own lands and also operate them on hiring basis in others lands and earn a substantial income. But, the number of such farmers is very limited. Due importance was not given to farm mechanization until the beginning of the century. Earlier, only a few manufacturers came up to fabricate simple manually operated machinery like weeder, sheller, etc. Presently, more than 40,000 small and medium sized local metal working workshops have grown up to manufacture agricultural machinery across the country (Farouq et al. 2007).

4.4 Supply of Other Services and Production Factors

Credit/finance: Agricultural credit is very much important to all categories of farmers in Bangladesh. Generally farmers receive agricultural credit from both institutional and non-institutional sources. Institutional sources mostly comprised banks and NGOs, whereas non-institutional sources are moneylenders (locally called *Mohajons*), friends, relatives, traders, and landowners. Most farmers have no or little access to bank credits due to lack of adequate information and collateral. In 1988, only 13 per cent of households had access to institutional credit. However, access to institutional sources of credit increased to 40 per cent during the past two decades. Following the success of the Grameen Bank, a large number of NGOs stepped into supplying rural credit in remote areas as part of their social development programmes. The lion's share of the incremental institutional contribution came from NGOs. By and large, informal sources no longer play the dominant role as in the distant past. The reason behind this could be the presence of more cost-effective NGO sources which created a condition of somewhat competitive environment in rural credit markets (Bayes 2012).

“Maize requires a higher investment than many other crops, especially at the beginning of the season” (http://www.katalyst.com.bd). Farmers need credit mostly to buy inputs like hybrid seed and fertilizers. Organizations like Katalyst (a multi donor development initiative) are promoting partnerships between input companies and the Department of Agriculture Extension (DAE) to promote maize-based cropping patterns in locations with potential. Such long-term partnerships will ensure the sharing of resources among the public-private organizations in these areas, and increase farmer’s adoption of maize in their crop cycle. Katalyst is also trying to promote the contract farming system which enables farmers to link with traders who can provide them with know-how regarding maize production, access to larger buyers (i.e., the feed mills), and credit to buy inputs. District-wise disbursement of agricultural credit is shown in Table 4.7, but no data was recorded for maize.

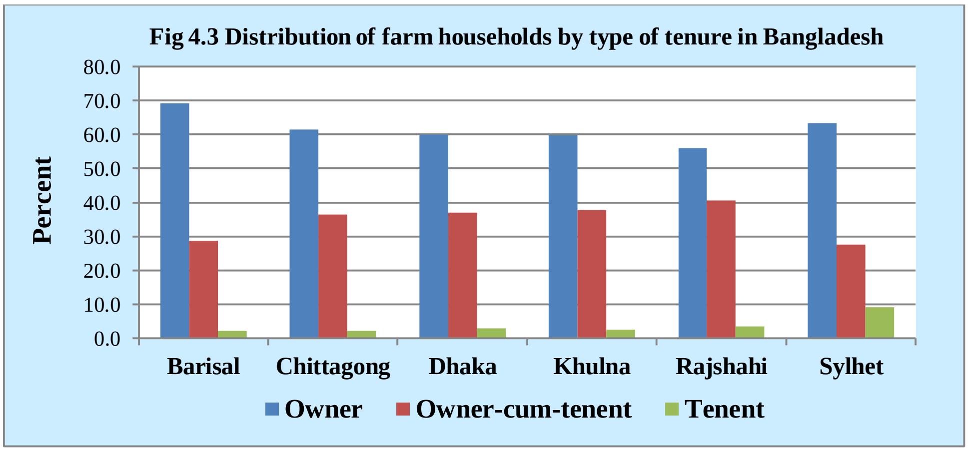
Small and marginal maize farmers generally have little purchasing power or own little working capital for buying quality seed, fertilizer, and insecticides. In this context, poor maize farmers need credit support to continue production and sustainable livelihood. Bangladesh Bank (Central Bank) has directed most public and private banks to provide credit to these poor and marginal farmers. But in practice, the banks (commercial and nationalized) have high risk perception of poor farmers regarding repayment capacity of the borrowers. On the other hand, some NGOs have already started disbursing seasonal loan to meet the requirement of poor farmers, but their repayment schedules are opined to be inappropriate to the farmer (Rob 2010).

Table 4.7 Agricultural credit disbursement in Bangladesh over years *(In lac taka)*

District	Year					
	2005	2006	2007	2008	2009	2010
Bandarban	607	816	836	759	974	323
Chittagong	30,146	44,116	44,913	48,767	54,636	2,075
Comilla	13,197	15,311	16,942	16,115	16,009	4,730
Khagrachhari	996	1,139	1,443	1,642	1,582	498
Noakhali	7,739	8,349	7,535	6,914	6,823	2,679
Rangamati	1,809	3,232	1,814	1,657	1,577	868
Sylhet	14,715	17,054	16,987	17,389	19,596	1,856
Dhaka	64,258	96,204	97,348	27,963	129,940	6,711
Faridpur	12,931	19,650	16,568	25,412	24,622	14,637
Jamalpur	6,904	9,079	10,154	8,562	11,180	258
Kishoreganj	5,904	5,833	6,095	5,629	5,803	671
Mymensingh	11,886	12,962	18,788	18,799	21,529	348
Tangail	6,115	6,585	6,399	7,242	6,051	3,061
Barisal	3,138	3,788	4,161	4,876	3,581	1,314
Jessore	13,223	15,429	18,161	17,740	18,242	2,192
Khulna	16,839	17,893	71,571	27,786	24,931	5,413
Kushtia	9,103	11,444	13,575	16,209	18,550	1,924
Patuakhali	12,137	15,940	16,064	18,651	18,276	1,855
Bogra	964	817	959	972	--	3,062
Dinajpur	193	167	152	170	--	914
Pabna	354	394	432	451	--	1,495
Rajshahi	1,026	1,129	1,225	1,154	--	5,127
Rangpur	657	511	358	403	--	2,215
Bangladesh	**234,842**	**307,841**	**372,481**	**275,263**	**383,902**	**64,226**

Source: BBS 2010

Land tenure system: Land is one of the most essential assets for the rural people in Bangladesh to overcome poverty (Uddin and Haque 2009). If households are unable to cultivate their own land, sharecropping (*Barga*) and leasing, on a seasonal or more permanent basis, is widespread. A variety of land tenancy and sharecropping systems exists in rural Bangladesh. Three typical types of farm holdings found in Bangladesh- these are operated by the owners, owner cum tenant farms, and tenant farms. The land distribution pattern by types of tenure of the six divisions in Bangladesh is shown in Figure 4.3.



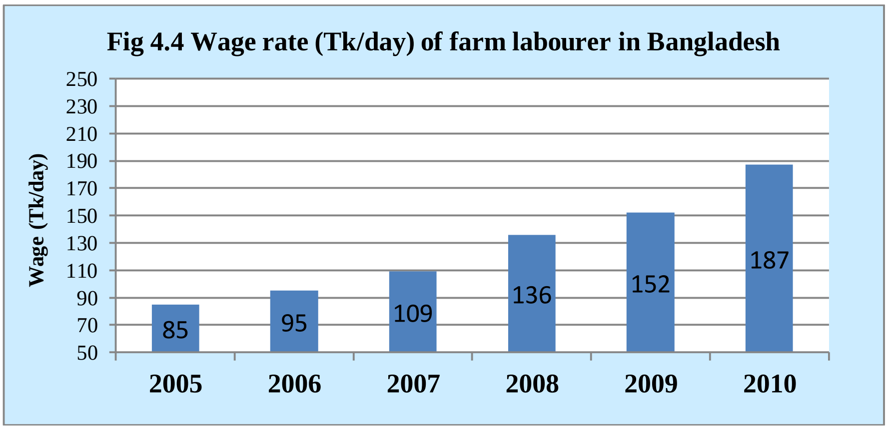
Source: Using data from BBS 2010

Small and marginal farmers generally grow maize as sharecropper or take lease of land from large category farmers. There are four types of land leasing systems which are (1) If land owner shares 50 per cent of the cultivation cost, lessee gets half of the share of total crops produced, (2) If land owners do not share cultivation cost, lessee gets 1/3 parts of total crops produced, (3) Farmer cultivates lands in agreement with land owner and pays fixed amount of money [(i.e., Tk 5,000 to Tk 8,000 or USD 64.1 to USD 102.6 per *Bigha* (33 decimal or 0.134 ha)] for one year. The rates of leasing land depend on land quality and areas, and (4) Farmer cultivates land in agreement with land owner and pays a big amount of money (i.e., Tk 50,000 to Tk 100,000 or USD 641.0 to USD 1,282.1) for minimum one crop. In this case, lessee stops cultivation if the land owners return back the money after season. Otherwise lessee can continue production until the land owner returns the money back to the farmer. In most cases, these leasing and land use systems are operated without any written agreement. In fact, policy and practice related to land lease allow marginal and small farmers to use the land at a limited scale (Rob 2010).

Tillage services*:* Tillage is required two times for land preparation in maize cultivation. Power tiller services are available throughout the country. Large farmers prepare lands by their own power tiller. Small category farmers generally purchase tillage service from large category farmers or commercial power tiller service providers. The demand for mechanized tillage service is rising as farmers are moving away from traditional ploughing (Rob 2010).

Labour: Maize is a labour-intensive crop employing a good number of labourers every growing season, with women making up an overall of 33 per cent of the waged labourers involved (www.katalyst.com.bd). Different studies (Karim et al. 2010 Moniruzzaman 2009, Mohiuddin 2007, Chowdhury 1995) revealed that the average use of labour in maize cultivation was 161 man-days per hectare (Table 3.42). In 2009-2010, around 375,000 farmers and 93,000 labourers were involved in the production of approximately 1.5 million tons of maize.

It may safely be said that the expansion of maize cultivation is not going to replace any labour; rather it would absorb more labour particularly if women are involved in its shelling operation. However, the supply of human labour in agriculture is shrinking over time due to increase of non-farm activities and the wage rate (Tk/day) is also increasing along with its scarcity (Fig 4.4).



Source: Using data from BBS, 2010

Irrigation services: Irrigation is an integral part of crop production and as a result of climate change and the need to produce HYVs for food security, its significance to agriculture has increased manifolds. The lack of timely irrigation leads to a 37 per cent decrease in the yields of rice, maize, potato, and vegetables. Conversely, efficient irrigation can increase both the productivity and profitability of these crops (http://www.katalyst.com.bd). High yielding crop varieties, modern technology, new management practices, such as irrigation, fertilizer, crop management, etc., are used to improve the production rate which gradually increases the irrigated area (Table 4.8).

Irrigation is mainly needed in *Rabi* (winter) maize cultivation when the crop compete with *Boro* rice, potato, and vegetables. About 78.7 per cent irrigation is done by ground water and the rest 21.3 per cent by surface water (BADC 2012). Canals, rivers, ponds, etc. are the major sources of surface water. In Bangladesh, there has been widespread use of both shallow tube wells (STW) and deep tube wells (DTW) for irrigation. Irrigation water was ensured through removing the restriction on the imports of small diesel engines, withdrawal of customs duty, and the abolition of tube-well setting restriction in non-surface irrigation areas, which led to a tangible effect on the demand for irrigation equipment and an increase in area under minor irrigation. BADC continues to play in expansion of small-scale irrigation through public projects. Besides, farmers use low cost diesel engine to irrigate maize field, but traditional method of irrigation is also practiced in many areas.

Table 4.8 Irrigated area (‘000’ ha) by sources of irrigation in Bangladesh

Year	Power pump	Tube-well			Total Tube-well	Canal	Traditional Method	Total Means
		DTW	STW	HTW				
2000-01	757	694	2,438	30	3,162	177	325	4,421
2001-02	768	678	2,593	32	3,303	163	324	4,558
2002-03	782	698	2,768	26	3,492	146	307	4,727
2003-04	785	719	2,970	26	3,715	145	291	4,937
2004-05	802	717	3,002	27	3,746	--	489	5,037
2005-06	887	801	3,462	22	4,285	--	432	5,604
2006-07	960	852	3,645	22	4,519	--	420	5,898
2007-08	1,036	911	3,773	22	4,705	--	390	6,132
2008-09	1,094	911	3,979	21	4,911	--	354	6,359
2009-10	1,091	991	4,094	24	5,109	--	353	6,553

Source: BBS 2010

Most large maize farmers own irrigation devices. Small category farmers usually purchase irrigation services from large farmers or ‘water sellers’ who have invested in shallow bore-holes and water-pumps. The command area of their water-pumps ranged from 5 to10 hectares of land. There are a growing number of irrigation service providers throughout the country, and farmers appear to have some choice and ability to negotiate reasonable prices (Rob 2010).

Transport services: Farmers and local traders (*Faria* and *Bepari*) hire rickshaw, van, tampo, motor driven trolley, and bicycle pullers to transport harvested maize to the local markets. This transportation contributes to excessive marketing cost. Hiring of bicycle pullers are commonly found in Char areas since rickshaw and other suitable means of transportation services are not available. In some areas, farmers and local traders also hire boat to transport maize in the primary assembling markets (Rob 2010).

Extension knowledge: The main sources of extension related knowledge for maize households are fellow farmers. They gather knowledge on maize cultivation by observing and discussing with their neighbouring farmers. Maize farmers also gather maize related knowledge from local SAAO, fertilizer dealers, and seed traders. Sometimes, they use own ideas in applying fertilizers and insecticides depending on the conditions of maize on field. They also confirm their ideas with other knowledgable farmers through discussion. They are not fully aware of appropriate fertilizer dose, sowing, spacing, timing of irrigation and other management aspects (Rob 2010). Farmers need knowledge and information in these areas.

Department of Agricultural Extension (DAE) has not sufficient manpower, especially in the *Char* areas to provide proper extension service to scattered maize farmers. Nonetheless, farmers are lacking of voice to demand better public extension services for maize and high value crop cultivation (Rob 2010).

Market information: The Department of Agricultural Marketing (DAM) of MoA, GoB has undertaken an e-government initiative that would utilize the power of Information and Communication Technology (ICT) to develop and disseminate critical agricultural market information to farmers, traders, government, policy makers, development agencies, and other stakeholders. "Seed companies particularly the private sector have spent large amount of money in the promotional activities of their products. Companies use quality posters, catalogues and leaflets and distribute them to attract farmers to inform the characteristics of seeds. Large billboards, banners are now commonly visible. Private companies are spending in advertisement in newspapers, radio, and television networks" (BARCIK 2012). Sometimes farmers get information about new technologies from progressive farmers.

Maize farmers have no organization and therefore, are unable to bargain with landowners, buyers and inputs suppliers. ''Weak competition among maize buyers and input suppliers (in some seasons) put farmers in this situation. Informality of land ownership/leasing gives power to land-owners and make poor farmers vulnerable and compel them to accept unfair terms of share-cropping arrangements" (Rob 2010). In most cases, feed millers or the agents of feed millers control maize price at farm level.

Information and communication technology (ITC): It has huge potential as a tool to facilitate access to updated information on production technologies for all categories of farmers. Access to information is a vital input to any business, and lack of it acts a major constraint to small and medium enterprises. "Timely and accurate dissemination of information helps farmers to protect themselves from potential losses, while learning and applying new production techniques mean they can make optimum use of limited resources, thereby increasing productivity and production. At the same time, ICT through its expert judegment can also help in reducing business costs, leading to improved overall competitiveness and the growth" (http://www.katalyst.com). Using this technology maize farmers can reduce the cost of production and increase maize productivity through collection and judicious use of hybrid seed and other production inputs.

WIN **Incorporate** established in 2006 in order to develop information and advisory services on small businesses and social issues including wide range of agriculture business."In December 2008, *WIN* Incorporate and Bangla link, one of the leading telecom companies in Bangladesh launched '*Jigyasha 7676 Mobile Phone Service'* as the first mobile based agro info service in Bangladesh" (www.global1.youth-leader.org/2010/12/kashfia-making-e-agriculture-work-successfully-through-public-private-partnership-in-bangladesh/).

The Bangladesh Institute of ICT in Development (BIID), in collaboration with Katalyst and Grameen Phone (a leading telecom operator), launched the *e-Krishok*, an e-agriculture initiative in 2008. *E-Krishok* aims to bridge the information gap that exists in the agriculture sector and builds awareness and capacity of the farmers to use ICT-enabled information and advisory services. *E-Krishok* offers information and advisory services through mobile phones (call back and SMS) and email at an affordable cost[5] (E-Krishok 2012). Government agencies, such as the Agriculture Information Service (AIS) and the Soil Resource

[5]Through the 'push pull' service, farmers receive two SMS messages on a particular topic they request, at a cost of USD 0.03 per SMS. A second service enables farmers to receive a call from a BIID information officer to respond to their immediate needs (USD 0.07 per minute), and four SMS messages, containing relevant information about the topic in question.

Development Institute (SRDI) are also playing a role in dissemination of agricultural information. AIS under the Ministry of Agriculture signed MoU with *WIN* Incorporate**.** Recently AIS has piloted 10 farmers community based call centers in rural areas.

http://www.katalyst.com.bd:

> Mass media, especially print and broadcast media, plays a vital role as change agent in Bangladesh. It can assist the poor through providing information service as well as advocacy service. Research has proven the semi literate or illiterate poor in Bangladesh actively collect information through broadcast media. Experience with the print media industry also shows media can raise the voice of the poor and advocate for their critical issues.

4.5 Maize Research System

Public research institutions are no longer the only source of innovation. A large share of the innovations in the agriculture sector is now originating from other sources. Many actors in the private sector have entered into agricultural R&D. Commercial enterprises, NGOs, universities, and public sector research organizations are real and definable entities of innovation systems. The partnerships and linkages among these organizations are in fact very poor. The private sector is increasingly involved in plant breeding and seed production in response to the opportunity presented by growing demand for new varieties and for production intensification. The PBD of BARI has a solid and systematic programme and is now leading the maize research in Bangladesh. Different universities, NGOs, and private companies are conducting maize research in sporadic manner and in a limited scale. Universities research is mainly confined by the MS or PhD students. Because of fund limitation, the universities focus more on teaching than on research. All the seed organizations reported employing research staff. In 2008, “the combined number of professional research staff (researchers, research technicians, and administrators) totaled 1,101 individuals, including 19 with Ph Ds, 74 with M Scs, and 242 with B.Scs” (Rashid et al. 2012, p. 2) and a very few of them are working in maize. BARI has more than 25 plant breeders directly involved in maize breeding at head quarters and different regional stations. Besides, a good number of scientists are working in different disciplines of maize like agronomy, pathology, entomology, soil science, seed technology, post harvest processing, and farm machinery to develop suitable technology in the respective areas, but there is a lack of co-ordination among them (FGD 2013).

4.5.1 Activities in research institutes

Maize research in Bangladesh was initiated on a modest scale in the early fifties with the introduction of some popcorn and sweet corn lines from the United States with a view to popularizing maize in this region by the Economic Botany (Fibres) Division of the East Pakistan Directorate of Agriculture (EPDOA). However, after the introduction of HYV wheat and rice in the 1960s and 1970s, maize research was not considered a priority. After the establishment of BARI in 1976, maize research and development programme got renewed thrust with a view to developing high yielding varieties. Many germplasm from Inter Asian Crop Improvement Programme (IACIP), CIMMYT, Tropical Asian Maize Network (TAMNET) and FAO-UNDP were introduced and tested in different research stations of BARI (Hussain and Sarker 2001). Initial thrust was given for the development of composite varieties as they have an advantage over hybrid in greater convenience of seed multiplication. Some of the composites were identified for their reasonably good yield potential and wider adaptability. During the period between 1986 and 2002, BARI has developed and released 8 composites including one each of popcorn and sweet corn of which some have got popularity among the farmers (Table 4.9).

Table 4.9 List of composite maize varieties developed by BARI

Sl.No.	Composite variety	Yield (t/ha)	Maturity	Year of release	Grain colour and texture
1	Barnali	5.5-6.0	140-145	1986	Golden yellow, semi flint
2	Shuvra	4.5-5.5	135-145	1986	Golden white, semi flint
3	Khoibhutta	3.5-4.0	125-130	1986	Bright yellow, flint
4	Mohar	5.0-5.5	135-145	1990	Bright yellow, flint
5	BARI Maize 5	5.0-5.5	145-155	1997	Bright yellow, flint
6	BARI Maize 6	6.5-7.0	145-150	1998	Yellow, semi flint
7	BARI Maize 7	6.5-7.5	145-155	1998	Yellow, dent
8	BARI Sweetcorn 1	10.0-10.5 (without husk)	113-120 (Green cob)	2002	Light yellow

Source: PBD 2013

Since the early nineties, the research strategy of this division was directed from composite and synthetic varieties towards the development of hybrids. Inbred lines were introduced from different international research organizations like CIMMYT, CIMMYT-ARMP (CIMMYT Asian Regional Maize Programme, Thailand), IITA (International Institute for Tropical Agriculture, Nigeria) and KU (Kasetsart University, Thailand) and evaluated for the development of hybrid varieties. The long-term inbred lines are being maintained and early generation lines have been advanced. Programmes have also been taken up for the local development of inbred lines using hybrids and OPVs. Promising single crosses are being recycled for extraction of superior inbred lines (Hussain and Sarker 2001).

In the mean time, both exotic and locally developed lines are being used for development of single cross and top cross hybrids and a good success has been achieved. Beside inbred line development, the maize improvement programme of BARI has also been testing exotic hybrids through international trials with a view to identifying better performing hybrids under Bangladesh conditions. Using introduced and locally developed inbred lines, BARI has so far developed 11 hybrid maize varieties from 2000 to 2008 of various kinds and some of which are now being cultivated commercially. Yield potential of the released hybrids ranges from 10.5 to 12.5 tons/ha under favourable conditions (Table 4.10). Recently a programme has been initiated to develop base population as a source of elite inbred lines from promising hybrids of different origins. Research is now going on to find high yield potential, short duration, and medium tall varieties for wider agro-climatic conditions.

Table 4.10 List of hybrid maize varieties developed by BARI

Sl.No.	Hybrid Variety	Yield (t/ha)	Maturity	Year of release	Grain colour and texture
1	BARI hybrid *Bhutta* 1	8.5-9.5	140-150	2000	Orange yellow, flint
2	BARI hybrid *Bhutta* 2	8.0 -9.0	145-150	2002	Yellow, semi flint
3	BARI hybrid *Bhutta* 3	9.5 -10.0	144-150	2002	Yellow, dent
4	BARI hybrid *Bhutta* 4	7.5 - 8.5	142-146	2002	Orange yellow, flint
5	BARI hybrid *Bhutta* 5	9.5 - 10.5	140-145	2004	Orange yellow, flint
6	BARI hybrid *Bhutta* 6	9.8 - 10.0	140-145	2006	Yellow, semi flint
7	BARI hybrid maize 7	10.5-11.2	140-145	2006	Yellow, flint
8	BARI hybrid *Bhutta* 8	10.5 -11.5	142-146	2007	Yellow, semi flint
9	BARI hybrid *Bhutta* 9	11.5-12.5	145-150	2007	Yellow, dent
10	BARI hybrid *Bhutta* 10	9.0 -11.5	145-150	2008	Yellow, flint
11	BARI hybrid *Bhutta* 11	10.5 -12.5	147-153	2008	Yellow, flint

Source: PBD 2013

Pictorial view of some BARI hybrid and local maize

4.5 BARI Hybrid maize-7

4.6 BARI Hybrid maize-8

4.7 BARI Hybrid maize-9

4.8 Local variety in hills

Source: PBD 2013

Maize production in Bangladesh is almost dependent on poultry and fish feed which makes this sector very vulnerable. All the maize varieties cultivated in Bangladesh are yellow seeded and are not well-suited for human consumption as flour. To overcome this, BARI has initiated work for the development of white grain QPM (Quality Protein Maize) for making *Chapati*. Research work is also focusing the development of high yielding exportable quality baby corn, good quality popcorn, and sweet corn varieties. The PBD of BARI is now also giving thrust to develop different abiotic stress tolerant maize varieties to address problems of excess water, heat, drought, and saline soils. Recently biotechnological interventions, such as marker-assisted selection have also been adopted to develop maize varieties targeting specific objectives.

Recently, the Agronomy Division of BARI started research on maize cultivation as fodder. Many farmers of Kushtia district are cultivating maize as fodder. They mentioned that fodder production generally reduces the yield due to de-topping of the plant. But the ultimate profit is not hampered because the value of fodder. This division also developed maize intercropping (with spinach, chickpea, bush bean, lafa shak, etc.) and relay cropping (with potato) systems. Soil scientists developed and recommended 2 tons of boron and lime per hectare for successful grain formation and minimizing soil pH. The PBD is providing *whole family training* to the maize-growing families in order to expand maize cultivation in the county since such training has positive impact on maize yield.

4.5.2 Activities in NGOs and private seed companies

"Beginning from the late-1980s, liberalizing reforms established the framework for private companies and NGOs to introduce agricultural technology" (Rashid et al. 2012, p.vi). Private agricultural R&D in Bangladesh has expanded rapidly in recent years. Much of this expansion occurred in the seed industry. For example, competing companies not only assess imported cultivars, but also breed maize hybrid from both imported and local genetic material for local markets. The Bangladesh Rural Advancement Committee (BRAC), Lal Teer Seed Ltd. and Supreme Seed Company Ltd. have the largest programmes (Kabir and Huda 2009). BRAC (a NGO) started maize research activity since early 1996 at a limited scale in cooperation with CIMMYT. With their small effort it has so far released three maize hybrids (Uttaran, Uttaran-2, and Uttaran-3) by the Seed Board of the government. Out of the three hybrid maize varieties, one (Uttaran-3) is white grain QPM although their main thrust was in hybrid seed production. Government and donors not only support public-sector agricultural research, but also extend assistance to private research and technology introduction. Companies are now also introducing new varieties from imported seed. It is not surprising that most of the private sector seed companies prefer importation rather than production of seed and R&D. Basically; it all depends on the incentives and profitability of seed importation and production. There is a lack of regulation to this effect.

4.6 Maize Development System

In Bangladesh, plant breeding and variety development of maize is usually carried out by plant breeders in the public research institutions and to some extent in large seed companies. BARI has received support from CIMMYT in the development of maize varieties. BRAC has an extensive collaboration with Pacific Seed Company in Australia and Thailand and works more or less on commercial basis. BRAC receives the parent lines of hybrid maize varieties and produces the F_1 generation seed in Bangladesh. BRAC pays royalties to the foreign breeders of the parental lines based on production figures. Most of the companies are doing adaptive trials of maize hybrids for commercial purposes. There is an urgent requirement for varieties which are adapted to low-input farming and tolerant to biotic and abiotic stress conditions e.g. water-logging, drought, and salinity (FGD 2013).

BADC is the only organization having significant cleaning and storage facilities for seed though BRAC is currently upgrading its capacity. Under the provision of the NSP, the private seed enterprises and NGOs can lease these storage facilities on a commercial basis. However, according to the private sector, BADC still prioritizes their seed production. “Seed production, processing and storage require elaborate infrastructure and sizeable capital, beyond the capacity of most NGOs and private sector enterprises” (Ahmed et al. 2012, p.2).

The PBD of BARI is also trying to disseminate and popularize BARI developed technologies among public and private agencies and farmers through training, demonstrations, and field days. Back in 2001, with CIMMYT’s concept and financial support, PBD of BARI in collaboration with DAE has started whole family training (WFT) approach to train up farmers on modern methods of producing maize. WFT programme has had a substantial impact on modern maize cultivation practices, and on the promotion and increased production of maize in the mid 2000s in Bangladesh. This training approach is still continuing with the financial support from MoA, GoB, and by the scientists of PBD all over the country. Besides, the scientists of PBD are also organizing training programmes for the officials of BADC, NGOs, and private seed companies on hybrid maize seed production technology to increase maize production using locally developed quality hybrid seeds which has become a serious concern of the government. The scientists of BARI are also conducting training programme on modern maize cultivation practices for DAE and NGOs personnel.

DAE, under MoA, is one of the largest public sector service providers in Bangladesh. DAE is being regarded as an organization that should have close contacts with the farming community. DAE established maize demonstration plots in various places in the country some years ago thus it plays a role in promoting new maize varieties. BRAC also plays an important role in providing advice to farmers on maize seed production. “BRAC has a broad-based extension programme involving about 10,000 agricultural extension workers in 64 districts of Bangladesh” (World Bank 2005 as shown in Bødker et al. 2006, p.40).

“Combining collective wisdom and knowledge of potential actors in maize sector, with hands-on-experience, would be a new way of generating innovation” (Ahmed et al. 2012, p.2). These developments will bring change the context of maize research which hopefully will help towards self sufficiency and ultimately future food security in Bangladesh.

Chapter V

MAIZE CONSUMPTION AND OUTPUT VALUE CHAINS

5.1 Introduction

This section discusses consumption and the maize value chains in Bangladesh. Importance of maize consumption including role of maize vis-à-vis other foods and political economy considerations are highlighted in this section. A brief historic overview of maize consumption with emphasis on recent past and drivers of change and geography of maize consumption is given in this section.

5.2 Maize Consumption

Maize is a diversified crop which has multipurpose uses. It is used as different types of foods for human consumption, feed & fodder for poultry and livestock, and starch for industrial products (Kaul et al. 1987). In the past, maize was specially consumed by the tribal people of the hill areas of Bangladesh. The people of plain areas occasionally consumed it in roasted and fried form. Due to population pressure and higher price of flour, maize is more often used as flour (mixed with wheat flour). Till to date, the mixing of maize with wheat flour is considered as an adulteration in Bangladesh. Disseminating the information on nutritional value of maize through different mass media and include it in the course of school level study may be the best measure to overcome the problem. However, the demand for maize and soybeans has been increasing to a large extent in the country from last decade due to increasing demand for poultry and fish feed and high gluten flour for baked goods.

The scientists of BARI opined that about 85 per cent maize are used for preparing poultry and fish feed and the rest 15 per cent are used as human food and other purposes. According to Poultry Feed Association of Bangladesh (PFAB) the current demand for feed is 30 lac tons in the country. Based on this information the amount of maize used in feed industries is 16.50 lacs tons. The demands for maize as seed, food, and other purposes are 5,328 tons and 2.5 lacs tons, respectively. Again, about 10,000 tons of maize was also exported during 2012. Therefore, the national demand for maize is estimated at 19.15 lac tons per year (FGD 2013). On the other side, the domestic production of maize is estimated at 21.83 lac tons (DAE 2013). This estimation indicates that local production of maize exceeds its local demand and the opportunity of maize export is becoming bright in the country.

There is a contradiction in the production and the use of maize in Bangladesh. The impored amount of maize was about 0.131 lac tons in 2012 (Bangladesh Bank 2013). The imported amount in 2013 is not less than the amount imported in 2012. This scenario indicates that Bangladesh is not self-sufficient in maize production and basically a net imported of maize.

5.2.1 Importance of maize consumption

Maize is a high energy rich food which contains high digestible carbohydrate and protein. It also contains amino acids which are essential for human nutrition, cholesterol free edible oil, vitamin A, and a good quantity of trace minerals (Martin and Leonard 1967 in Islam et al. 2011).

The Institute of Nutrition and Food Science (INFS) under the University of Dhaka analyzed the nutritional value of some cereal foods (Table 5.1) and found that maize is much better than rice in terms of nutrients like protein, fat, minerals, fiber, phosphorus, carotene and thiamine (INFS 2003; Islam and Kaul 1986). With the great effort of CIMMYT, a quality protein maize (QPM) has already been released for farm level use that will increase the content of lysine and easily digestible protein tryptophane. The level of adoption of QPM (BARI Hybrid 5) is very low. The area under QPM is 7.14 thousand hectares in the country since BADC produced and distributed about 150 tons of QPM seed (seed requirement is 21 kg/ha) during 2012-2013 (FGD 2013). This will uplift the food value of maize and helps the poor to eradicate nutrition deficiency. Nevertheless, it can also be an important cereal to reduce food insecurity of Bangladesh where 31.5 per cent of the population at national level, 35.2 per cent at rural level, and 21.3 per cent at urban level live below the poverty line (HIES 2010). So, there is a wide scope of utilizing this grain as an alternative food to reduce the pressure on rice. Hence, maize is becoming a substitute for both rice and wheat. The scientists relating to plant breeding and food nutrition, and consultants of FAO-Bangladesh start thinking about maize to be a potential source of nutrients for the malnourished population of Bangladesh. Attempt was also made from FAO-Bangladesh to find out policy measures for popularizing maize foods among indigenous people in the Hill Tract Region of Bangladesh (Ali et al. 2010).

Table 5.1 Comparative nutritive values of maize, wheat and rice food

(per 100 grams of edible grain)

Composition	Maize		Wheat flour	Rice
	Dry	Tender	(Whole)	Milled
Energy (kcal)	342.0	125.0	341.0	346.0
Protein (g)	11.1	4.7	12.1	6.4
Fat (g)	3.6	0.9	1.7	.04
Minerals (g)	1.5	0.8	2.7	0.7
Fiber (g)	2.7	1.9	1.9	0.2
Carbohydrates (g)	56.2	24.6	69.4	79.0
Calcium (mg)	10.0	9.0	48.0	9.0
Phosphorus (mg)	348.0	121.0	355.0	143.0
Iron (mg)	2.0	1.1	11.5	4.0
Carotene (mg)	90.0	32.0	29.0	-
Thiamin (mg)	0.4	0.1	0.5	0.2
Riboflavin (mg)	0.1	0.2	0.2	0.1
Niacin (mg)	1.8	0.6	4.3	3.8
Vitamin C (mg)	0.0	6.0	0.0	0.0
Moisture (g)	14.9	67.1	12.2	13.3

Source: Islam and Kaul 1986; INFS 2003

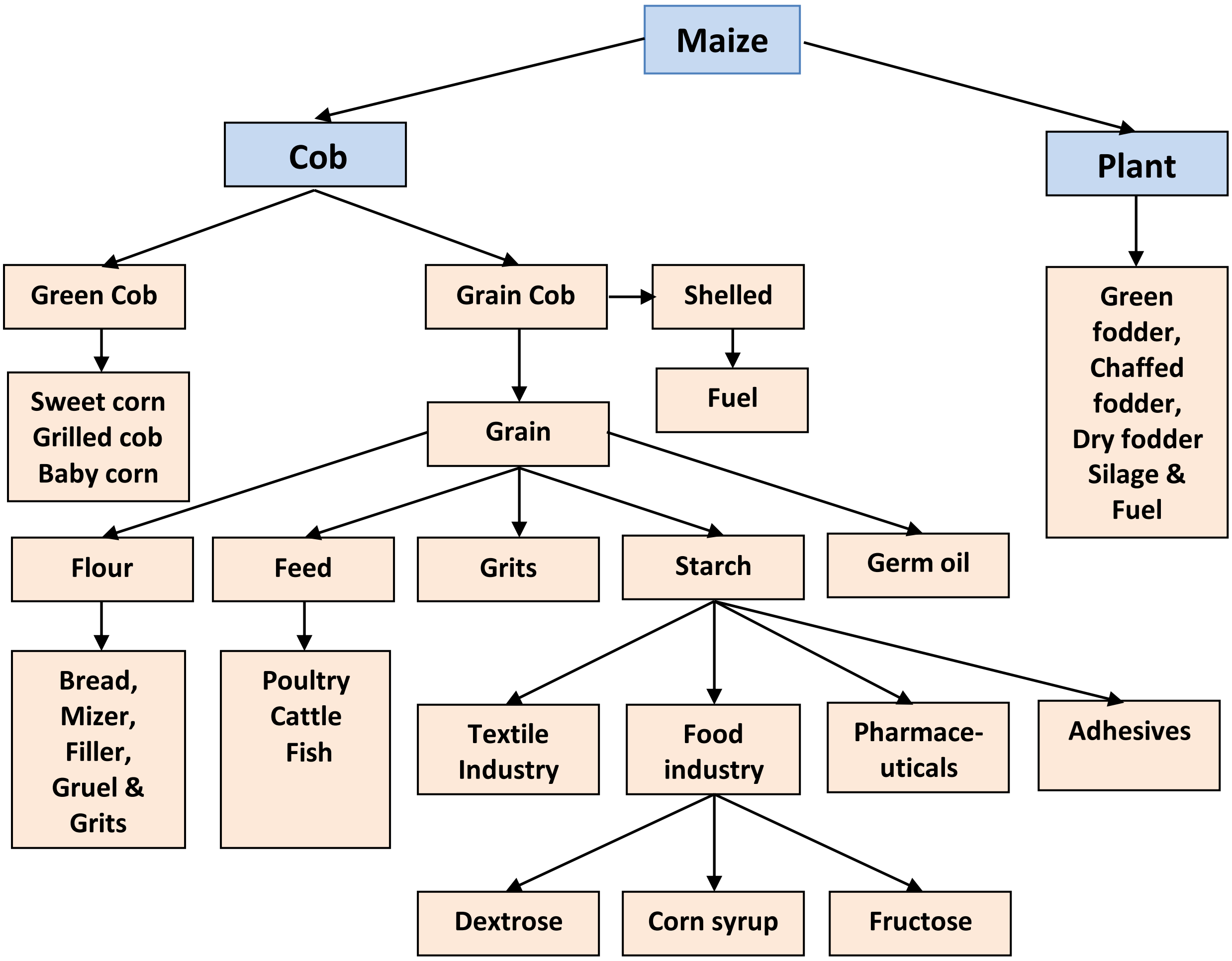
Maize can be a food securing cereal in Bangladesh where producing rice is comparatively not easy due to adverse land and soil conditions. The hilly area of Bangladesh is one of the less suitable areas for producing rice or wheat like plain irrigated land. Maize is a C_4 plant which needs less water and to some extent it is drought resistant. Irrigation facilities are not available in the hilly areas. Besides, it is grown and consumed in the Chittagong hill tract (CHT) as the second most important cereal crop. Therefore, maize production and consumption can reduce the food insecurity of the people of CHT region.

In CHT region, tribal farmers are cultivating maize from time immemorial. They cultivate maize as both sole crop and intercrop through *Slash-and-burn* (*Jhum*) cultivation system. Maize has an important role in securing their food and nutrition. Maize farmers in the CHT opined that their health condition improved to some extent due to the consumption of maize and maize cultivation ensured their household food security through buying other foods with maize income (Ali et al. 2010). The author also identified that people who consumed maize daily are more food secure than the people who never consumed maize or consumed it once or 2-3 times a week.

5.2.2 Type of maize consumption

Maize is consumed by both humans and livestock directly and indirectly. Though there is a lot of diversified use of maize as food in the world, but it is not much diversified for human consumption in Bangladesh. Maize is consumed by humans through incorporating it in many types of processed food. It is also consumed indirectly when it is mixed with wheat for flour production. Maize is largely used for preparing poultry and fish feed (Ali et al. 2008). It is one of the important ingredients of fish feed and frequently used by fish farmers in Bangladesh (Dongmeza et al. 2010). Maize is also widely consumed by ruminant livestock as forage and feed. Maize consumption and use are shown in Figure 5.1.

Fig 5.1 Flow chart of maize consumption and use by humans and animals



Human consumption: The consumption pattern of maize is changing gradually with the change in domestic production of maize in Bangladesh. IMPP (2001) estimated the share of maize use or consumption in different sub-sectors. They showed that the share of maize use was 8 per cent as green cob, 3 per cent as farmer's home consumption, 2 per cent as snacks, 9 per cent by flour mills and processing industry, 48 per cent as poultry feed, 9 per cent as cattle feed, 14 per cent as cattle fodder, 4 per cent as starch, and 3% as relief and rehabilitation (Table 5.2). Hasan (2008) found that 90 per cent of maize available (production and import) in the country are utilized for poultry feed production and 10 per cent is used for fish feed and human consumption. The study conducted by Gmark Consultancy firm for Oxfam (2013) revealed that in adjacent *Char* areas, the local bakeries and confectioneries are using maize flour as raw materials of finished flour, biscuits, and other backary products. The present share of maize used for preparing feed and food might be higher than the share estimated during 2001 and 2008.

Many farmers of Ghoraghat and Nawbabgonj *Upazila* consume maize as *Chhatu* (ratio of maize and rice is 50:50) and green cob (after roasting). A small portion (1-2%) of the maize farmers consumes maize as flour (maize and wheat ratio is 30-40:70-60). Flour millers also support these mixing ratios and opined that local flour traders do not crush wheat with maize together. Some farmers experienced a bitter taste of mixed flour. Most maize farmers prepare cattle feed by crushing poor quality maize and paddy (ratio is 50:50). The consumption scenario is different in Chuadanga district. Consumption of maize is rare in this district, but use as *Chhatu* (ratio of maize, wheat and rice is 50:25:25) and cattle feed is very common (FGD 2013).

Table 5.2 Distribution of maize demand in the year 2000-2001 in Bangladesh

Items	Total demand (ton)	% of total demand
Green cob	23,600	8
Farmer home	8,850	3
Snacks products	5,900	2
Flour mills & proc. industry	26,550	9
Poultry feed	141,600	48
Cattle feed	26,550	9
Cattle fodder	27,000	14
Starch factory	11,800	4
Relief and rehabilitation	8,850	3
Total demand	295,000	100

Source: IMPP 2001

Consumption by poultry, fish, and livestock**:** Maize is largely used by the poultry feed industry of Bangladesh. Among the various types of animal feeds, maize ranks first considering its nutritious value. Shaha and Asaduzzaman (1998) pointed out that “Barnali” and “Khoibhutta” variety of maize can be a better replacement of wheat based poultry feed since maize-based feed helps producing eggs with yellow yolks and harder shells. The poultry industry consumes one-fourth of the total maize production. Maize is also used as fish and cattle feed. Maize based poultry feed is extensively used in poultry industry where feed is consumed by 234.7 million chickens and 44.2 million ducks (FAOStat 2011).

The actual statistics on the number of poultry birds or poultry firms, and their feed requirements are not available. It was estimated that about 52 per cent of poultry feed (for 18% layer and 90% broiler) was produced by feed mills in year 2005 and the rest feed was prepared by farmers themselves using locally available ingredients (BPBD 2007). Another source of statistics reveals that there are 0.15 million commercial poultry farms in Bangladesh and the requirements of poultry feed of those farms are 2.0 million tons which are supplied from domestic sources (Chakma and Rushton 2008).

The use of maize is increasing year after year due to increase in the number of poultry and fish farms. The time series data showed that the use of maize as poultry and fish feed increased from 706 tons in 1991-1992 to 2711 tons in 2001 (Mutalib 2001). Table 5.3 also reveals that the use of maize as poultry, fish, and cattle feed increased at the rate of 9.17 per cent per year. An impressive change in the use of maize was found during the period from 1998/99 to 2000/01. Although the statistics on maize consumption in poultry and fish sector are not available, the rate of change in maize use in these sectors must be much higher in the periods after 2000/01 as the maize boom just started after this period due to increase in the number of poultry and fish farms.

Bangladesh experienced Highly Pathogenic Avian Influenza (HPAI) outbreaks during 2007 and 2008. A total of 547 commercial and 42 backyard flocks were culled with over 1.6 million birds being destroyed (Fig 5.2). Among the culled birds, 78 per cent were from layer flocks and 22 per cent from broiler flocks. Therefore, the demand of maize for feed industry decreased from 3.0 million tons to 2.0- 2.2 million tons, which were due to close a significant number of poultry farms (Chakma and Rushton 2008). According to the opinion of MAB, Bangladesh is producing a surplus of maize. Therefore, they are planning to export surplus maize to other countries. The statement is controvercial according to FIAB because Bangladesh is importing maize from other countries every year (FGD 2013).

Fig 5.2 Commercial birds affected by Highly Pathogenic Avian Influenza (Bird Flu)

http://m.theepochtimes.com/n2/images/stories/large/2010/03/15/ubanga79518923.jpg

Table 5.3 Uses of maize as poultry and livestock feed from 1991-1992 to 2000-2001

Year	Poultry &fish feed (ton)	% change per year	Cattle feed & fodder (ton)	% change per year	Total (ton)
1991-92	706	-	602	-	1,308
1992-93	707	0.14	602	0	1,309
1993-94	738	4.38	628	4.32	1,366
1994-95	695	-5.83	591	-5.89	1,286
1995-96	693	-0.29	591	0	1,284
1996-97	699	0.86	595	0.68	1,294
1997-98	690	-1.29	587	-1.34	1,277
1998-99	771	11.74	657	11.92	1,428
1999-00	1 ,056	36.96	900	36.99	1,956
2000-01	2,711	156.72	2,310	156.67	5,021
GR (%)	9.17**	--	9.17**	--	9.17**

Note: '**' represents significant at 5% level, Source: Mutalib 2001 and Bhuiyan 2005

***Production of starch*:** Starch is widely used in different industries: paper-making, textile, food-processing, chemistry, pharmaceutical and medicine, building materials, and casting. It is also used in the deep-refining industries as raw materials to produce modified starch, ethanol, sweetener, organic acid, antibiotic substance, and amino acid. Dry maize contains about 66 per cent starch. It can be observed from Table 5.4 that the use of maize in starch industry was 273 tons in 1991-1992 which was increased to 1,046 tons in 2000-2001. This means use of maize in starch industries has increased about 74 per cent during this period and rate of increase was 9.16 per cent annually.

Table 5.4 Use of maize in starch industry from 1991-1992 to 2000-2001

Year	Quantity (Ton)	% Change per year
1991-92	273	-
1992-93	273	0
1993-94	284	4.03
1994-95	268	-5.63
1995-96	268	0
1996-97	269	0.37
1997-98	265	-1.49
1998-99	298	12.45
1999-00	408	36.91
2000-01	1,046	156.37
Growth rate	9.16**	

Note: '**' represent significant at 5 per cent level
Source: Husain 2001 and Bhuiyan 2005

5.2.3 Geography of maize consumption

It is stated earlier that Bangladeshi people consume maize in a very limited form. They mainly consume it in roasted (Fig 5.4) and fried form. Maize is also consumed as green cobs (Fig 5.3) and popcorn (*Khoi*) mostly in urban areas. Popcorn (imported from Australia) is prepared by street hawkers through locally made small machine (Fig 5.5). The livelihood of many destitute families depends on popcorn business. Many children from poor families sell popcorn mainly to the travelling customers (Fig 5.6). Some small-scale industries also come foreward to prepare popcorn and market it apparently in a good form (Fig 5.7). Maize consumption through mixing with wheat flour (ratio =1:3) is increasing in Bangladesh.

Fig 5.3 Selling green cobs on the street
Source: http://blog.cimmyt.org/wp-content/uploads/

Fig 5.4 Tribal woman selling boiled cobs on street
Source: PBD, BARI, Gazipur, 2013

Fig 5.5 Making popcorn on the street
http://www.infokosh.bangladesh.gov.bd

Fig 5.6 Selling popcorn on the street
http://static.flickr.com/66/179585122

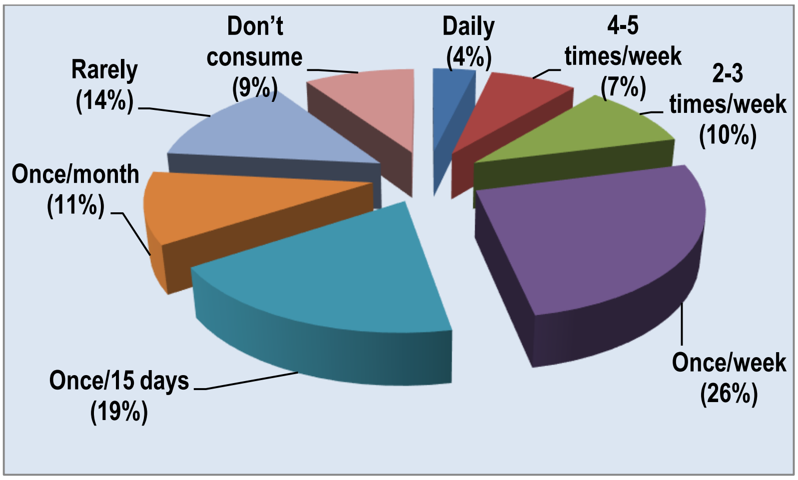
Fig 5.7 Commercial popcorn
http://www.facebook.com/FaatafatCar

Data and information of maize consumption by different districts are very limited in Bangladesh. Elias et al. (1985) studied the consumption pattern of maize at Ishurdi *Upazila* under Pabna district and found that 48 per cent of the farmers used maize to make *Chapati* by mixing with wheat flour, 16 per cent farmers prepared *Chhatu* (powder of fried maize), 10 per cent farmers made *Khichuri* (mixed with rice), 14 per cent of the farmers made cake (mixed with rice flour), 4 per cent of the farmers made *Khoi* (fried maize), and 8 per cent of the farmers roasted green cob.

Quasem (1999) studied the production and marketing of maize at four districts of Bangladesh, namely Dinajpur, Nilphamari, Jessore, and Dhaka. The disposal pattern of maize of this study revealed that 1.3 per cent of farmers consumed maize as food, 1.3 per cent farmers used it as feed, 80.3 per cent farmers sold maize to the traders, and 17.1 per cent farmers sold maize to poultry farms and millers. The people of Jessore district prepare *Khoi* through frying maize in sand. In the Char areas of Jamalpur district, maize is consumed as *Chapati* and *Chatu*.

Maize is intensively consumed by the ethnic people of Chittagong Hill Tract (CHT) region which comprised three hill districts of Bangladesh, namely Bandarban, Rangamati, and Khagrachari. The details of maize production and consumption in hill areas were studied by Ali et al. (2010). Their studies revealed that about 45 per cent of the farmers cultivated maize only for own consumption and only 8.11 per cent cultivated it for sale. Consumption scenario revealed that about 91 per cent people ate maize during the growing season and the rest 9 per cent did not consume it. Figure 5.8 shows that 4 per cent people ate maize daily, and 7 per cent and 10 per cent people ate maize 4-5 times, and 3-4 times per week, respectively. The highest number of people (26%) ate maize once a week and 11 per cent once a month.

Fig 5.8 Frequency of maize consumption by percentage response



Source: Ali et al. 2010

Ali et al. (2010) also identified that people in hilly areas were not aware of multipurpose uses of maize. They eat boiled maize at the early/milk stage (before full maturity). Over matured maize is not used by them. Consumption of maize based food like hotchpotch, *chapati*, vegetables, soup, and baby corn were limited in those regions. A small percentage of people had knowledge about use of maize as fish feed, baby corn, fodder, oil source, vegetable, fuel, organic fertilizer, maize flour, poultry feed, and other foods. A demonstration programme on different types of food prepared by maize was held in order to attain food security through popularizing maize in hill areas. People in the hills make and eat different maize-based dishes as shown in the following photographs (Ali et al. 2010).

Fig 5.9 Making chapati ruti

Fig 5.10 Making *Piaju*

Fig 5.11 Making *Khoi*

Fig 5.12 Delevering *Khituri*

Fig 5.13 Eating boiled cob

Fig 5.14 Eating *Khoi*

5.3 Maize Output Value Chains

This section discusses maize marketing systems, channels through which maize reaches the ultimate consumers, characteristics of the main actors involved in maize marketing, different marketing functions, and the profit shares for different actors.

5.3.1 Main value chain actors and their importance along the chain

Different types of actors are involved in the process of maize marketing. These actors are farmers, input suppliers (land, farm machineries, seed, fertilizers, pesticides, credit, etc.), *Farias, Beparis, Arathdar*-cum-wholesalers, *Paikers* (wholesaler), trader-cum-processors, feed millers, importers, retailers, and consumers.

Farmers: The farmer is the first link of the maize marketing channel. Different categories of farmers, such as marginal, small, medium, and large farmers are involved in maize cultivation. Maize farmers generally sell their products to *Farias, Beparis*, and wholesalers. They have little or no access to maize processors, millers, and poultry farms. Some contact growers can sell maize to their respective institutions (i.e., NGO). The study conducted by Matin et al. (2007) revealed that farmers sold 19 per cent of the harvested maize to *Beparis*, 29.11 per cent to *Farias* (Local small trader), 20.45 per cent to *Arathdars* (commission agent), 4.2 per cent to BRAC (an NGO), and 1.05 per cent to retailers. Most of the farmers of

Dinajpur and Chuadanga district sell maize grain to *Beparis* and feed mill agents (CP Bangladesh), stockiests, and *Chatal* owners at home. CP Bangladesh procures the lion's share of the local production and controls maize price in the area (FGD 2013).

Faria*: *Farias are non-licensed small type traders who generally operate at local level. They have no fixed business premises and run their business independently. They are usually landless or small farmers having no full time work in the farm. *Farias* play a crucial role to establishing links between farmers and buyers. The *Faria* informs the farmers about the current demand and price of maize. They buy small amounts of maize from farmers either at farm gate or in the primary markets, and sell those to *Beparis*, and *Arathdar-cum-wholesalers.*

***Bepari*/*Chatal* owner:** *Bepari* is comparatively a big trader who has fixed establishment in the market premise with adequate drying and storage facilities. They purchase large amounts of maize from farmers and small amounts from *Farias* from farmyard and or farmers' homestead. They have both permanent and temporary staff/labour for running their business. They sell large amounts of maize to Arathdar-cum-*Bepari* or feed mills or trader-cum-processors (i.e., CP Bangladesh) in local areas.

Arathdar: *Arathdar* is basically a commission agent in Bangladesh who operates between farmers and *Beparis* in various agricultural commodities and fish marketing. In maize marketing, *Arathdar* is basically a big trader who operates between farmer and feed millers or trader cum processors. *Arathdar* has fixed establishments in the market places with adequate storage and drying facilities. They sometimes offer short-term credit facility to *Farias*, *Beparis*, and farmers. They perform business activities with permanent and temporary staffs.

Feed miller: Most commercial hatchery farms have feed mills. They have sophisticated crushing machines and enough storage facilities. They use modern processing technology for preparing poultry feed. Maize is the main ingredient of poultry feed (share of maize is 65%). Feed millers purchase maize mainly from *Arathdar* and *Bepari*. They also collect maize from farmers through their purchasing centres. Feed mill owners sell their finished product to poultry, dairy, and fish farms through sales centres. All the activities are performed by permanent labour and educated organized official staff. Matin et al. (2007) identified some feed mills which were Kazi feed Mill, Universal feed mill, National feed mills, Paragoan feed mill, Quality feed mill, Agro-industrial Trust, Aftab Bohumukhi feed mill, and Saudi Bangla feed mill. There are 70 feed mills in Bangladesh. The names of some other feed mills are CP Bangladesh Ltd., BRAC-RENATA Agro Inds Ltd., Holy Poultry and Fish Feed Industries Ltd., Phoenix Feed Mill Ltd., Shapla Poultry Feed Mill Ltd., Muyang Poultry Feed Mill, Rifad Poultry Feed Mill, Aive Feed Mills, Excel Feed Ltd., Euro Feeds Ltd., Savar Co-operative Poultry Feed Ltd., and Toyo Feed Ltd. (FGD 2013).

Trader-cum-processor: Most of the traders-cum processors have their own crushing machine. They purchase different crops including maize and soybean from *Bepari* and crush it. The crushed product is sold to the poultry farm owner as a separate ingredient of poultry feed. CP Bangladesh is one of the prominent trader-cum-processors in Bangladesh.

5.3.2 Post-harvest processing and core functions in maize marketing

In broad sense marketing functions include all activities that start from production of maize to its consumption by end users. Different types of marketing functions, such as harvesting, shelling, drying, packaging, storing, selling, financing, transportation, and milling/processing are prevailed in maize marketing in Bangladesh. The salient features of these activities are discussed below.

Harvesting and shelling of maize: Both family and hired labourers are involved in harvesting and shelling of maize. Female labourers are mostly involved in maize harvesting and shelling. Rob (2010) found in Char areas that maize farmers pay hired women labour 2 kg of maize for separating one mound (40 kg) of maize. About 25 shelling machines have been provided for shelling services in the Char areas, but due to huge demand for this service and long waiting time including high rental fee (Tk 20-25 or USD 0.26-USD 0.32 per mound), many farmers shell maize by hand. The female labourers of Ghoraghat and Nawbabgonj *Upazila* under Dinajpur district harvest maize from field at the rate of Tk 40-60 (USD 0.51-USD 0.77) per jute sac (Fig 5.15 & 5.16). Both the farmers of Dinajpur and Chuadanga districts shell their entire maize through shallow machine operated maize sheller (Fig 5.18) at the rate of Tk 250 to Tk 300 (USD 3.21 to USD 3.85) per *Bigha* (33 decimal or 0.134 ha) (FGD 2013).

Fig 5.15 Cleaning harvested maize cobs, Ghoraghat, Dinajpur

Fig 5.16 Bagging cleaned maize cobs, Ghoraghat, Dinajpur

Fig 5.17 Hand maize sheller, Joydebpur, Gazipur

Fig 5.18 Shallow machine operated maize sheller Joydebpur, Gazipur

Drying of maize: Farmers have no concrete *Chatal* (drying floor/ground) in their homestead. After harvesting, farmers sundry maize in their courtyard for 2-3 days and store it under the shed until they can sell it. Sometimes higher loss occurs due to rain or damp weather. It greatly affects the quality of maize and results in low price and less profit from maize farming.

Most big traders including wholesalers, *Arathdars,* millers and processors have cemented *Chatal* (drying floor) for drying maize. After procurement, they sundry maize in their *Chatal* for 2-3 days and store it under the shed until they can sell or use it. Before milling, maize kernels must be dried for decreasing the moisture content between 10 and 12 per cent. Generally, hired women labourers are involved in drying maize (Fig 5.19).

Fig 5.19 Women cleaning and drying cob and winnowing maize grain on Chatal
Source: http//news.priyo.com/files/photo (Photo left) and Katalyst 2011 (Photo right)

Packaging**:** Transportation of maize needs good packaging. *Farias* usually package their maize with plastic sack. But wholesalers, retailers, and NGOs (i.e., GKF, BRAC, CP Bangladesh) use jute sacks for packaging maize.

Storage of maize: Quality storage creates time utility. Therefore, it is very much important to make seasonal goods available throughout the year. Storage facilities for maize are not at all satisfactory in Bangladesh. There is limited storage facility at government level, especially at BADC. Some traders, processors, and NGOs have also limited storage facility. Wholesalers, stockiest, *Arathdars*, and NGOs store their maize according to their needs.

The farmers in general neither have good storage facilities nor the means to store their product for a longer time and sell it when the price rises. Besides, they cannot dry maize up to required level (10-12% moisture content) for storage. But sometimes, due to weather or communication problems they have to hold it for a while (Fig. 5.20). Nevertheless, they store little amount of maize for consumption and seed (traditional varieties) purpose and sometimes for better price. They generally use earthen pot, tin pot, jute bag, and drum to store maize grain. Recent FGD (2013) reveals that many well-off farmers of Chuadanga district store maize grain for 2-3 months in order to get higher price. Dinajpur farmers normally store their husked maize cob for 1-2 weeks.

The problems of maize grain storage are pest attack, infestation by fungus, lack of drying floor, and lack of moisture measuring machine.

Fig 5.20 Short time storage of maize, Ghoraghat, Dinajpur

Selling of maize: Maize farmers sell their produce generally at the farm gate and in the nearest primary or secondary markets. In the past, maize was mainly sold in the form of green cob. Elias et al. (1988) found that, on an average, 72 per cent farmers sold their maize in the form of cob and the rest 28 per cent in the form of grain at primary market. In that time, 100 per cent maize growers in Jessore district sold their maize in the form of green cob at primary market. This scenario has changed over time. Matin et al. (2007) found that the lion's share (76%) of maize was sold at the nearest primary and secondary markets. Only 24 per cent farmers sold their maize at farm gate. The farmers of Ghoraghat and Nawbabgonj *Upazila* under Dinajpur district sell 75-80 per cent maize at home or farm yard and the rest 20-25 per cent sold at market. The farmers of Chuadanga district generally sell their maize to middlemen trader at home (FGD 2013).

When the maize is harvested, the price goes down due to oversupply. Farmers cannot hold the maize in stock for getting prime price. As a result, poor farmers are compelled to sell their maize at a lower price to meet their family expenses, pay debts, and taxes or to meet the cost of cultivation of their next crop. The price rises when the crop leaves the hands of the farmers and then the main profit is accrued by the middlemen.

In most cases, the influence of buyers in maize price determination is much higher than that of farmers since farmers have no or little bargaining power due to lack of collective voice. Matin et al. (2007) found that 79 per cent of maize farmers sold their produce at the price which was determined by traders and only 21 per cent sold at the price which was determined through bargaining. On the other side, majority of the farmers sold their produces in cash (74%) and only 18 per cent sold it in credit (Table 5.5).

Table 5.5 Percent responses on price determination and nature of payment

Area	**Price determined by-**			**Nature of payment**		
	Farmer	Buyer	Through bargaining	In cash	In credit	Cash & credit
Bogra	--	66	34	95	5	--
Chuadanga	--	75	25	60	35	5
Dinajpur	--	80	20	66	21	13
Thakurgaon	--	95	5	75	10	15
Average	--	79	21	74	18	8

Source: Matin et al. 2007

Financing: Most small and marginal farmers do not have enough working capital for buying quality seed, fertilizer, and insecticides. They usually depend on input sellers and local moneylenders. Farmers sell their maize just after harvesting to repay the cost of inputs and other loans. In this context, Bangladesh Bank has directed all public and private banks to provide financial service to these poor farmers to meet up their production needs. But in practice, most maize farmers have little or no access to bank loan due to various socio-economic reasons (FGD 2013). Some NGOs have credit schemes and provide seasonal loan to meet the requirements of the poor farmers.

Small traders like *Farias* and *Beparis* run their business mostly by their own capital. But big traders, such as *Arathdars*, millers, processors, and poultry farmers have good access to institutional credit. The share of institutional credit to their business capital is much higher than that of own capital.

Transportation: Efficient transportation is the lifeblood of modern marketing systems. It creates place utility to the producer. The mode of transportations varies from area to area. In Bangladesh, the local markets are not well connected with the villages. Matin et al. (2007) found that farmers used shoulder, rickshaw, rickshaw van, trolley push cart, and head load to carry maize into the markets. The lion's share (91%) of the respondent farmers used rickshaw van (Fig 5.21) to carry maize from field to home or market premises (Table 5.6).

Fig 5. 21 Maize transportation by rickshaw van, Ghoraghat, Dinajpur

In the hilly areas, farmers usually use jeep (locally called *Chander Gari*) to carry maize into the markets. Boat is the main means of transporting maize from char area to market. During dry season, farmers bring their maize to boat landing site with the help of bicycle pullers who claim Tk 20 (USD 0.26) per mound of maize (Rob 2010).

Table 5.6 Percent responses on mode of transportation used by maize farmers

Area	**Mode of transportations used (%)**			
	Head-load or shoulder load	Rickshaw	Rickshaw van	Trolley push cart
Bogra	-	10	78	12
Chuadanga	2	-	98	-
Dinajpur	3	10	87	-
Thakurgaon	-	-	100	-
Average	1	5	91	3

Source: Matin et al. 2007

Milling/processing: Industrial maize milling in Bangladesh uses dry milling to converts maize into poultry, fish or cattle feed, and maize flour. Rob (2010) mentioned that almost 95 per cent of maize milled for animal feed and only 5 per cent are used as maize flour. Some people fry and then grind the maize and rice to make *Chatu* (maize powder). Maize flour is also mixed with wheat flour and used in bread, *Chanachur* to reduce cost of ingredient used in these products. Sometimes, small-scale poultry feed sellers who locally produce and sell poultry feed to small-scale farmers. They play an important role in the absence of large feed mills. FGD (2013) revealed that farmers in Dinajpur areas usually crush poor quality maize and paddy together (ratio of 50:50) for cattle feed.

5.4 Domestic Maize Trade in Bangladesh

This section discusses main marketing channels, important production and consumption centres, analysis of value chain, and impact of policy intervention on agricultural incentives.

5.4.1 Maize marketing systems and channels

Before 2000, maize marketing in Bangladesh was found mostly to be a seasonal system. The local production and marketing systems were not so developed. The organized marketing system to some extent has been developed since the demand and production of maize gradually increased over time. The maize growers are still not aware of the commercial end users and demand of their produces (Matin et al. 2007).

There are not many studies on maize marketing available in case of Bangladesh. Matin et al. (2007) conducted a study on maize marketing covering four maize growing districts, namely Bogra, Dinajpur, Chuadanga, and Thakurgaon and identified different marketing channels of maize. Rob (2010) studied the maize marketing system prevailed at Char areas of Gaibandha district. Ali et al. (2010) identified maize marketing channels for Chittagong Hill Tracts regions (i.e., Khagrachari, Rangamati, and Bandarban district). Therefore, most of the discussion in this section is based on the information delineated in those reports.

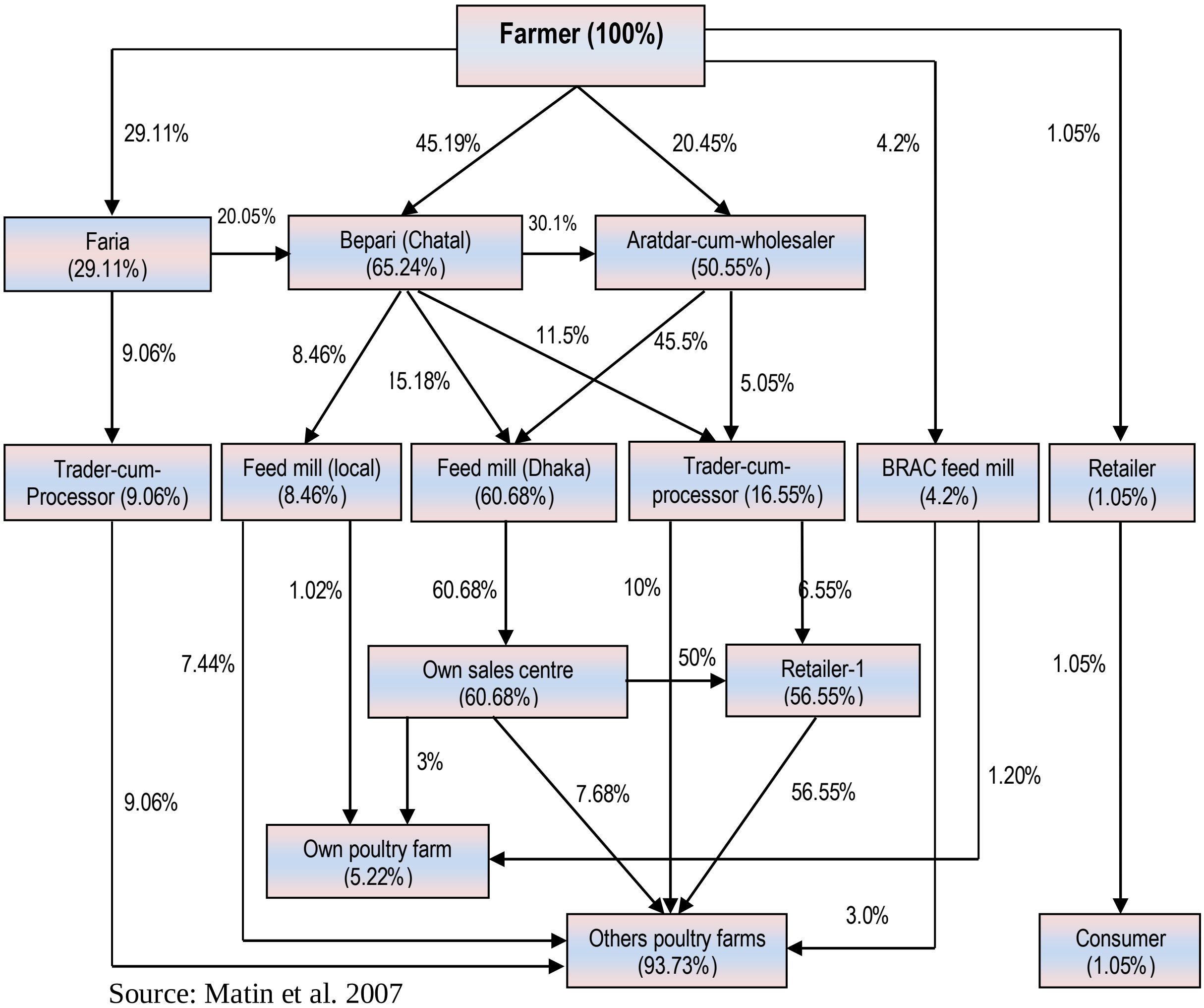
Marketing channel refers to the sequential arrangement of various marketing intermediaries involved in the movement of product from growers to ultimate consumers. In maize marketing, the product moves from producers-sellers to ultimate consumers through a number of market intermediaries. Grain maize or green cob marketing includes all the business activities involved in moving maize from producer to consumers through time (storage), space (transport), form (processing), and transferring ownership at various stages in the marketing chain. A number of marketing chains are prevailed in maize growing areas, but all the chains are not equally important. Some chains handle only a negligible portion of surplus of the area.

The marketing channels identified by Matin et al. (2007) are shown in a flow chart (Figure 5.22). They calculated marketing margin, marketing cost, and profit considering five major marketing channels. The other maize marketing channels identified by Rob (2010) and Ali et al. (2010) are shown in Figures 5.23 and 5.24, respectively.

The following marketing channels have been sorted from the above flow chart (Fig 5.22) for Bogra, Dinajpur, Chuadanga, and Thakurgaon district (Matin et al. 2007).

1. Farmer>Faria>Bepari>Arathdar-cum-wholesaler>Feed mill>Retailer>Poultry farm
2. Farmer >Faria >Bepari >Arathdar-cum-wholesaler >Feed mill >Poultry farm
3. Farmer >Faria >Arathdar-cum-wholesaler >Feed mill >Retailer >Poultry farm
4. Farmer >Faria >Arathdar-cum-wholesaler >Feed mill >Poultry farm
5. Farmer >Faria >Feed mill/feed processor >Retailer >Poultry farm
6. Farmer >Faria >Feed mill/feed processor >Poultry farm
7. Farmer >Bepari >Arathdar-cum-wholesaler >Feed mill >Retailer >Poultry farm
8. Farmer >Bepari >Arathdar-cum-wholesaler >Feed mill >Poultry farm
9. Farmer >Bepari >Feed mill/feed processor >Retailer >Poultry farm
10. Farmer >Bepari >Feed mill/feed processor >Poultry farm

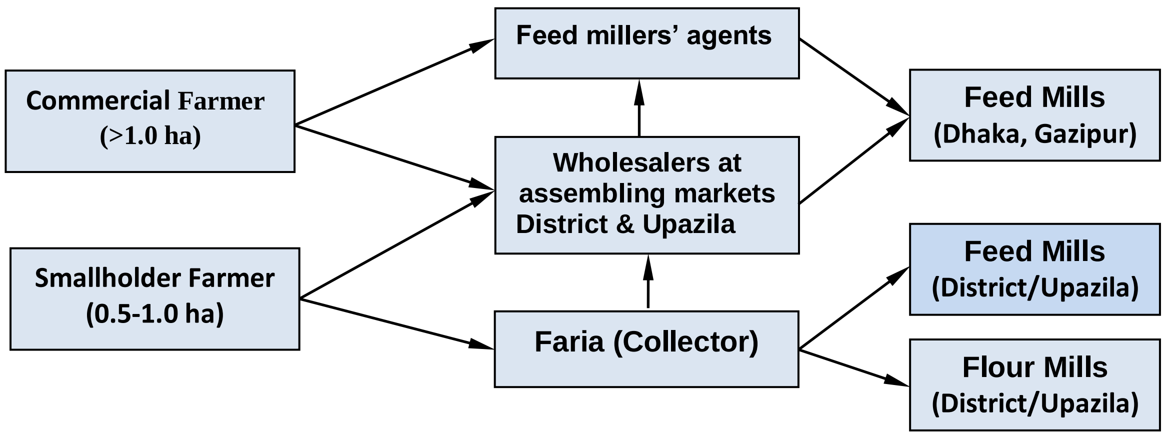
Fig 5.22 Maize marketing channels at major maize growing districts



Source: Matin et al. 2007

Marketing channels in *Char* areas: There are numerous *Char* areas in different parts of the country. These *Char* areas are highly potential for maize production. The simplified marketing channels in *Char* ares are given below (Rob 2010).

Fig 5.23 Marketing channels in *Char* areas of Gaibandha district



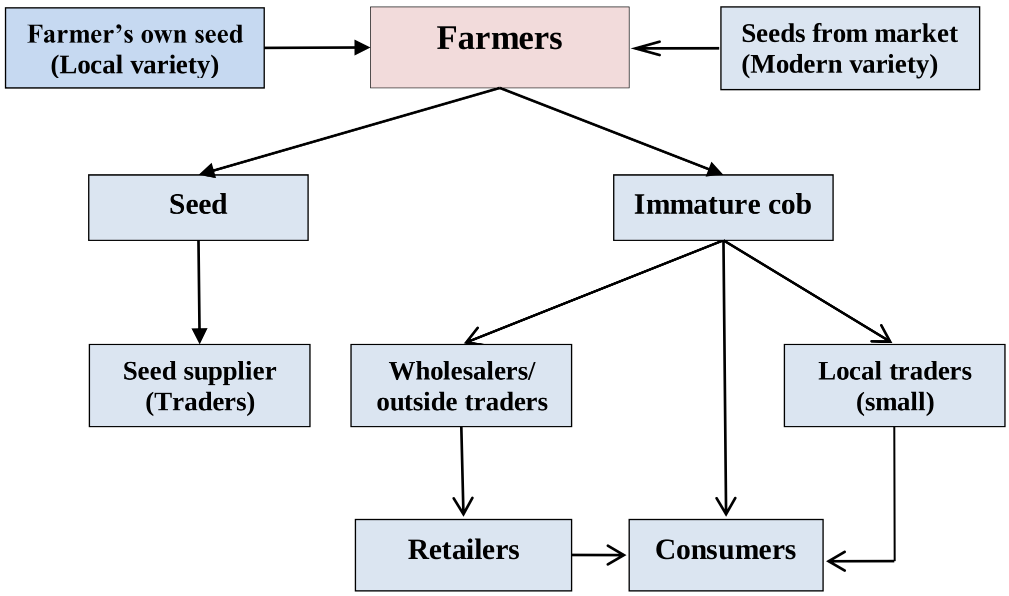
The following marketing channels have been sorted from the above flow chart (Fig 5.23) for Char areas.

1. Farmer (commercial) >Wholesaler >Feed mill agent >Feed mills
2. Farmer (commercial) >Feed mill agent >Feed mills
3. Farmer (commercial) >Wholesaler >Feed mills
4. Farmer (Smallholder) >Faria >Wholesaler >Feed mills
5. Farmer (Smallholder) >Faria >Feed mills
6. Farmer (Smallholder) >Faria >Flour mills
7. Farmer (Smallholder) >Wholesaler >Feed mills

The following channels for green cob marketing have been sorted from the below flow chart (Fig 5.24) for hill tract regions (Ali et al. 2010).

1. Farmer >Wholesaler/outside trader >Retailer >Consumer
2. Farmer >Local trader >Consumer
3. Farmer >Consumer

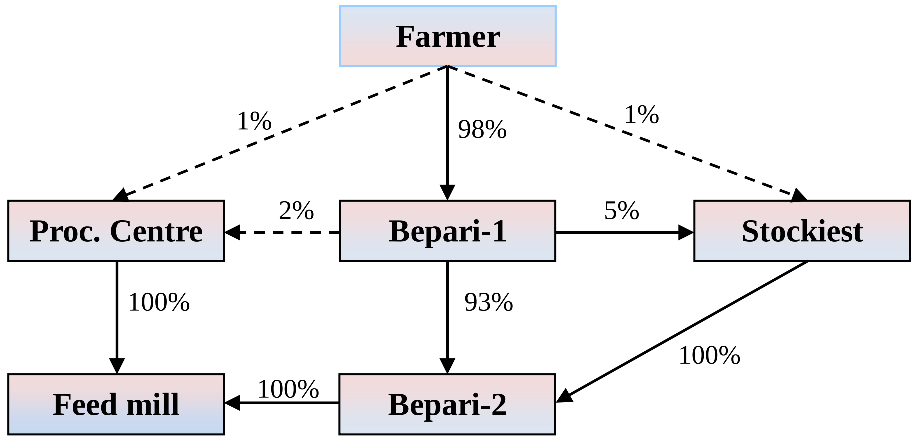
Fig 5.24 Marketing channels of maize in Chittagong Hill Tract Region



The following marketing channels (Fig 5.25) were identified during conducting FGDs (2013) with maize farmers and local maize traders.

1. Farmer >Bepari-1 (small trader)>Bepari-2 (big trader)>Feed mill
2. Farmer >Bepari-1>Procurement centre>Feed mill
3. Farmer >Procurement centre>Feed mill
4. Farmer >Stockiest>Bepari-2>Feed mill

Fig 5.25 Marketing channels of maize in Dinajpur and Chuadanga districts



5.4.2 Seasonality of maize marketing

Farmers cultivate maize both in *Kharif-1* (16 March-15 July) and *Rabi* (16 October-15 March) seasons in Bangladesh. The area coverage of maize during *Rabi* season is much higher than that of *Kharif-1* season. Poultry industry usually starts buying maize from March and continues up to the arrival of next crop. The maximum procurement is made during fourth quarter of the year (January to March). The quantity procured declined after the first quarter and becomes lowest in the second quarter (July to September) of the year. Matin et al. (2007) found that trader-cum processors and feed mills procured 27.16 per cent and 25.90 per cent of their total procurement in the fourth quarter. Farmers generally sell maize in the primary or secondary markets during February to May.

5.4.3 Production and consumption centres of maize

Maize is grown in almost all the areas of Bangladesh. However, it has some pocket areas where the lion's share of maize is produced every year. Among maize growing districts, about 75.3 per cent of the total maize is grown at Dinajpur, Rangpur, and Kushtia district. The other important districts are Bogra, Dhaka, Jessore, and Rajshahi (Table 5.7).

Table 5.7 Important production and consumption centres of maize in Bangladesh

Important growing area		Important consumption area	
District	**% of production**	**District**	**No. of feed mills**
1. Dinajpur	30.31	1. Gazipur	16
2. Rangpur	25.74	2. Mymensingh	8
3. Kushtia	19.20	3. Chittagong	7
4. Bogra/ Joypurhat	5.05	4. Comilla	5
5. Dhaka/ Manikgonj	4.95	5. Bogra & Joypurhat	9
6. Jessore	4.66	6. Satkhira & Khulna	4
7. Rajshahi	3.89	7. Naogaon	3
8. Comilla	3.03	8. Narayanganj	3
9. Pabna	1.70	9. Jessore & Chuadanga	5
10. Jamalpur	0.40	10. Kishoregonj	2
11. Other districts	1.06	11. Other districts	8
Total	**100**	**Total**	**70**

Source: BBS 2011 for maize growing area; FGDs 2013 with MAB and FIAB

There are also some important maize consumption areas of Bangladesh. These consumption centres are important poultry and fish feed hubs. There are three starch manufacturing units in Bangladesh which are now very irregular in production due to inexperienced entrepreneurs, lack of efficiency, and poor quality machinery (FGD 2013). A total of 70 feed mills and many large and small-scale poultry farms are located in these areas. The feed produced from 70 feed mills is generally distributed to different parts of the country. The highest maize consumption area is Gazipur. A huge amount of maize is consumed by the 16 feed mills in this area. The other important consumption centres can be found in Table 5.7.

Feed millers collect their bulk amount of maize from important producing centres through middlemen traders (e.g., *Bepari*, *Arathdar*, Stockiest, etc.) during the month from March to July. Feed millers fill their shortage through importation from India (FGD 2013).

5.4.4 Value chain analysis of maize

Matin et al. (2007) studied details of maize marketing in Bangladesh. Hence, three marketing channels (stated in Fig 5.17) were taken into consideration for estimating marketing cost and margins for each intermediary and presented in Table 5.8, 5.9, and 5.10. Table 5.8 reveals that the highest net margins [Tk 29.69 (USD 0.38) per quintal] and return on investment (3.34%) was received by feed millers followed by *Arathdar*-cum-wholesalers in Channel-I. Again, the highest net marketing margin (Tk 109.34 (USD 1.40) per quintal) and return on investment (13.86%) was received by feed processors in Channel III followed by *Farias* because they sold little amount of maize at higher price (Table 5.10). However, the highest net margin was observed in Channel-III and the lowest in Channel-I. The lowest net margin was attributed to the involvement of a large number of intermediaries in the channel.

Table 5.8 Marketing margins, costs and profits (Tk/quintal) of maize in channel-I

Type of intermediaries	Faria	Bepari	Arathdar-cum-wholesaler	Feed miller	Total
1. Purchase price	722.01	741.07	781.10	852.12	--
2. Sale price	741.07	781.10	852.12	918.18	--
3. Gross margin (2-1)	19.06	40.03	71.02	66.06	196.17
4. Marketing cost (4)	16.91	26.73	47.67	36.37	127.68
5. Net margin (3-4)	2.15	13.30	23.35	29.69	68.49
6. Invested business capital	738.92	767.80	828.77	888.49	--
7. Returns to business capital (%)	0.29	1.73	2.81	3.34	--

Channel-I: Farmer-Faria>Bepari>Arathdar-cum-wholesaler>Feed miller>Poultry farm
Source: Adopted from Matin et al. 2007; Conversion rate 1 USD = 78.0 BDT

Table 5.9 Marketing margins, costs and profits (Tk/quintal) of maize in channel-II

Type of intermediaries	Faria	Bepari	Arathdar-cum-wholesaler	Feed processor	Total
1. Purchase price	710.59	733.62	776.81	844.11	--
2. Sale price	733.62	776.81	844.11	908.16	--
3. Gross margin (2-1)	23.03	43.19	67.30	64.05	197.57
4. Marketing cost (4)	16.91	26.73	47.67	44.33	135.64
5. Net margin (3-4)	6.12	16.46	19.63	19.72	61.93
6. Invested business capital	727.50	760.35	824.48	888.44	--
7. Returns to business capital (%)	0.84	2.16	2.34	2.21	--

Note: Conversion rate 1 USD = 78.0 BDT
Channel-1I: Farmer-Faria>Bepari>Arathdar-cum-wholesaler>Feed processor>Poultry farm
Source: Adopted from Matin et al. 2007

Table 5.10 Marketing margins costs and profits of maize in channel-III

(Tk/quintal)

Type of intermediaries	Faria	Feed processor	Total
1. Purchase price	719.81	744.51	--
2. Sale price	744.51	898.18	--
3. Gross margin (2-1)	24.70	153.33	178.03
4. Marketing cost (4)	15.81	44.33	60.14
5. Net margin (3-4)	8.89	109.34	118.23
6. Invested business capital	735.62	788.84	--
7. Returns to business capital (%)	1.21	13.86	--

Source: Adopted from Matin et al. 2007; *Channel-III: Farmer-Faria-Feed processor-Poultry farm;*
Conversion rate 1 USD = 78.0 BDT

Table 5.11 shows the price spread and producers' share in the consumers' price in three marketing channels. Farmers' gross shares were estimated at 78.6 per cent, 78.2 per cent, and 80.1 per cent for Channel I, II, and III, respectively that were paid by the consumers as retail price. Again, farmers' net shares for the above mentioned three channels were 76.8 per cent, 76.4 per cent, and 78.33 per cent, respectively which were computed from the ratio of farmers' net price and retail price. However, the highest producer's net share was received from Channel-III followed by that of Channel-I and II. The highest share in Channel III as compared to Channel I indicates that producers' shares increased with the decrease in number of intermediaries in the marketing channel.

Table 5.11 Price spreads in different channels of maize marketing

Particulars	Channel-I		Channel-II		Channel-III	
	Tk/Quintal	%	Tk/Quintal	%	Tk/Quintal	%
A. Gross price received by the producer	**722.01**	**78.64**	**710.59**	**78.24**	**719.81**	**80.16**
i. Marketing cost	16.86	1.84	16.31	1.80	16.72	1.87
ii. Net price received	705.15	76.80	694.28	76.44	703.09	78.29
B. Gross margin (GM) of Faria	**19.06**	**2.08**	**23.03**	**2.54**	**24.70**	**2.75**
i. Marketing cost	16.91	1.84	16.91	1.87	15.81	1.76
ii. Net amount received	2.15	0.33	6.12	0.67	8.89	0.99
C. GM of Bepari	**40.03**	**4.36**	**43.19**	**4.75**	**--**	**--**
i. Marketing cost	26.73	2.91	26.73	2.94	--	--
ii. Net amount received	13.30	1.45	16.46	1.81	--	--
D. GM of Arathdar	**71.02**	**7.73**	**67.30**	**7.41**	**--**	**--**
i. Marketing cost	47.67	5.19	47.67	5.25	--	--
ii. Net amount received	23.35	2.54	19.63	2.16	--	--
E. GM of feed miller	**66.06**	**7.19**	**--**	**--**	**--**	**--**
i. Marketing cost	36.37	3.96	--	--	--	--
ii. Net amount received	29.69	3.23	--	--	--	--
F. GM of feed processor	**--**	**--**	**64.05**	**7.06**	**153.33**	**17.09**
i. Marketing cost	--	--	44.33	4.88	44.33	4.95
ii. Net amount received	--	--	19.72	2.18	109.00	12.14
G. Price paid by the consumer	**918.18**	**100**	**908.16**	**100**	**897.84**	**100**

Note: Conversion rate 1 USD = 78.0 BDT
Channel-I: Farmer-Faria>Bepari>Arathdar-cum-wholesaler>Feed miller>Poultry farm
Channel-1I: Farmer-Faria>Bepari>Arathdar-cum-wholesaler>Feed processor>Poultry farm
Channel-V: Farmer-Faria-Feed processor-Poultry farm
Source: Adopted from Matin et al. 2007

Rob (2010) found in the *Char* areas that both farmer and trader get very encouraging revenue from maize cultivation and trade, respectively. Among different traders processors received the highest profit followed by *Beparis, Farias,* and wholesalers (Table 5.12).

Table 5.12 Gross profit sharing ratio of the maize value chains

Actors	Cost (Tk/MT)	Revenue (Tk/MT)	Net profit (Tk/MT)
Input sellers	1,900	2,100	200
Farmers	5,000	10,000	5,000
Farias	10,000	10,500	500
Beparis	11,000	12,000	1,000
Wholesalers	12,000	12,500	500
Processors	13,000	16,000	3,000

Source: Rob 2010; Conversion rate 1 USD = 78.0 BDT

5.5 International Maize Trade in Bangladesh

This section mainly discusses the maize import and export scenarios and the debate on maize exports.

5.5.1 Maize imports in Bangladesh

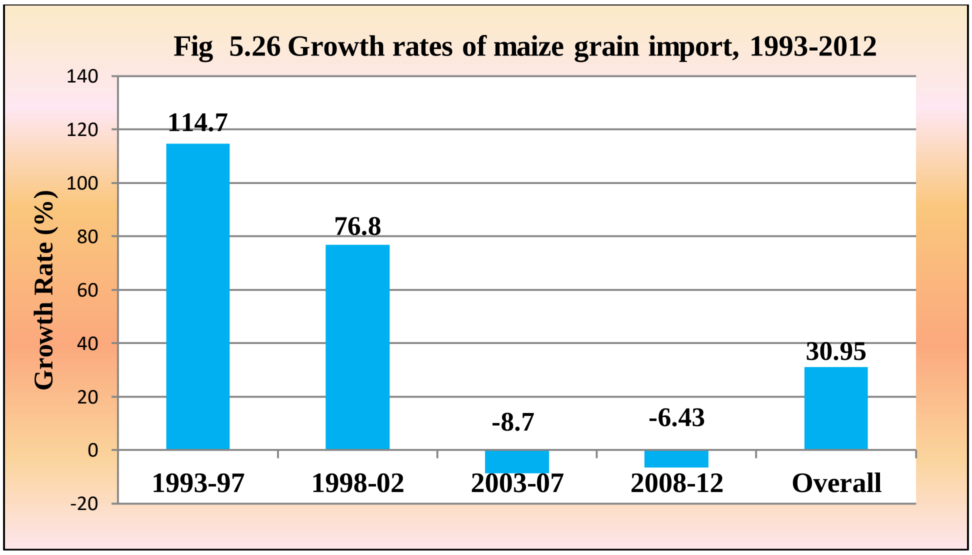
Bangladesh is a net importer of most of the commodities including maize. Although the growth rates of area, production, and yield of maize are excellent in Bangladesh, the country is still deficit in maize production and has to import a huge quantity of maize every year in order to fulfill demand. Table 5.13 reveals a fluctuating import scenario over the period of 1993-2012. The quantity of import decreased sharply from 2003 and continued up to 2005

Table 5.13 Quantity and value of imported maize grain and maize oil during 1991-2010

	Quantity (tons)		Value ('000' USD)	
Year	Maize oil	Maize grain	Maize oil	Maize grain
1993	26	112	21	27
1994	0	648	0	91
1995	0	15,000	54	1,554
1996	51	4,357	28	588
1997	58	13,344	120	1,464
1998	25	6,348	50	993
1999	0	125,000	0	13,000
2000	20	270,000	18	26,296
2001	120	230,000	95	29,000
2002	92	217,713	102	26,045
2003	315	331,728	161	46,316
2004	124	246,347	113	37,744
2005	82	115,983	96	19,254
2006	77	228,034	90	31,523
2007	106	223,145	132	36,601
2008	66	111,786	132	27,994
2009	84	597,039	168	134,173
2010	318	701,356	281	176,157
*2011	--	229,400	--	58,641
*2012	--	130,739	--	33,513

Source: FAOStat; *Bangladesh Bank, 2013 due to higher domestic production and less demand from poultry farms. Again, the quantity of import increased sharply in 2009 which might be due to the increased demand for feed from poultry and fish farms. In 2010, Bangladesh imported about 701,356 tons of maize valuing USD 176.16 million from different countries, especially from India (Table 5.13). The Maize Association of Bangladesh (MAB) mentioned that due to lower cost, Bangladesh imported maize totally from India in the last couple of years. The FIAB opined that the amount of import has decreased in the last year due to increase in domestic supply (FGD 2013).

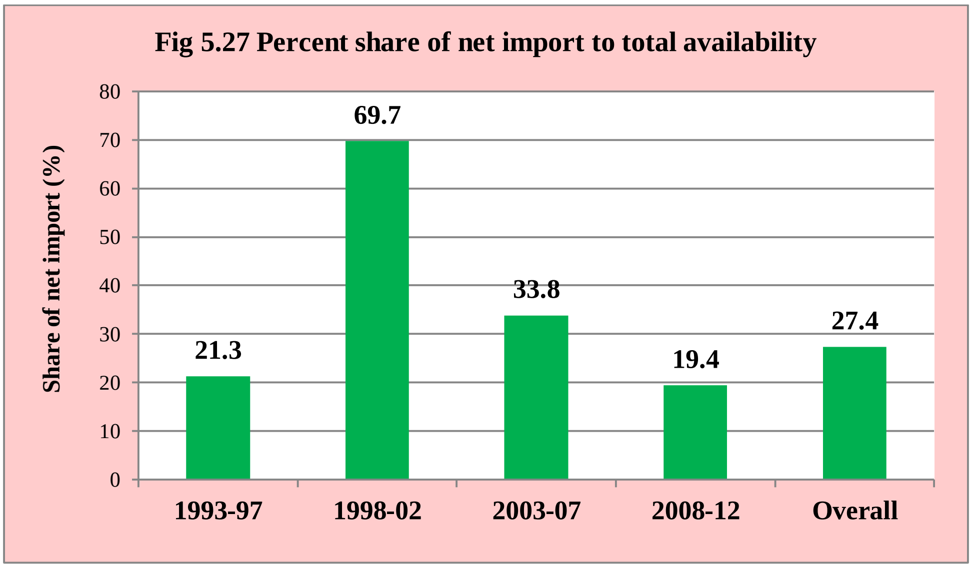
Figure 5.26 shows that the importation of maize in Bangladesh registered a high and significant growth rate during the period from 1993 to 2012. Growth rates calculated in different periods further reveal that higher growth rates were found in 1993-1997 and 1998-2002 periods, but these growth rates were not significant at all. But there were negative declining rates in import during 2003-2007 and 2008-2012 periods which were due to higher domestic prodction. In these periods, maize imports declined with the rate of 8.7 per cent and 6.4 per cent, respectively. The overall growth rate of maize import during 1993-2012 is about 31 per cent.



Source: Calculated using data from FAOStat & Bangladesh Bank

5.5.2 Share of net import to total availability

The average overall share of net import of maize to its total availability was 27.4 per cent (calculated using equations 10) during 1993-2012. The data presented in Figure 5.27 also confirm that the percentage share of net import decreased over the period from 1998 to 2012 which was due to higher domestic production of maize in Bangladesh.



Source: FAOStat; DAE 2013; Bangladesh Bank 2013

5.5.3 Trade matrix

Maize is imported from many countries including Australia, China, India, Myanmar, Thailand, and Vietnam. Currently, the total amount of import decreased to 130.74 thousand tons in year 2012 from 331.73 thousand tons in year 2003. The imports from India and Myanmar increased in the period 1998-2007 and it decreased from Thailand. A change has been observed over time in import share from different countries and in amount of total import also. FAO statistics presented in Table 5.14 shows that Bangladesh imported huge amount of maize from three countries sharing 44 per cent from India, 22 per cent from Myanmar, and 33 per cent from Thailand during 1998. But in 2005, the lion's share (78.6%) of maize was imported from Thailand followed by India. In the later period the import shares changed dramatically because of lower price and less import cost. Therefore, the shares of total imported maize from India became highest that ranged from 83 to 90.4 per cent during the period from 2006 to 2007.

Table 5.14 Change of maize importing trade matrix in the period 1998-2007

Country	1998		2005		2006		2007	
	Quantity ('000'ton)	Share (%)	Quantity ('000'ton)	Share (%)	Quantity ('000'ton)	Share (%)	Quantity ('000'ton)	Share (%)
India	2.813	44.3	24.168	20.8	189.282	83.0	201.786	90.4
Myanmar	1.407	22.2	91.190	78.6	36.974	16.2	21.027	9.4
Thailand	2.100	33.1	0.465	0.4	0.211	0.1	0.292	0.1
China		--	0.152	0.1	1.520	0.7	--	--
Australia	0.017	0.3	--	--	0.003	--	0.001	--
USA	--	--	0.007	--	0.005	--	0.011	--
Philippines	--	--	--	--	0.040	--	--	--
Vietnam	--	--	--	--	--	--	0.028	--
Singapore	0.009	0.1	--	--	--	--	--	--
Mexico	0.001	--	--	--	--	--	--	--
Korea	0.001	--	--	--	--	--	--	--
Total	**6.348**	**100**	**115.982**	**100**	**228.035**	**100**	**223.145**	**100**

Source: FAOStat

5.5.4 Export of maize from Bangladesh

There is a high potential for maize from Bangaldesh to be exported to other countries. The pressure from MAB government has taken conditional decision for exporting maize from Bangladesh for FY 2012-2013. The first condition is the minimum export price of maize has to be USD 325 per metric ton. Export data furnished in Table 5.15 reveal that the quantity of export has decreased over time and prices remained unchanged and lower than the government minimum export price. It implies that Bangladesh could not receive the minimum export price of maize in one hand and unfavorable government's rule constraints to higher export on the other.

Table 5.15 Exports of maize in Bangladesh

Year	Export destination	Quantity exported (Ton)	Price (USD/Ton)
2010	Malaysia & Saudi Arabia	200,000	280
2011	Malaysia, Indonesia, Saudi Arabia, Nepal	50,000	280
2012	Malaysia, Indonesia, Saudi Arabia, Nepal	10,000	280

Source: FGD 2013 with MAB

5.5.5 Debate on maize export in Bangladesh

Bangladesh is participating in international trade as maize exporter. Currently, the country is facing a debate and dilemma whether changing the law for further strengthening the export protection or for relaxing export protection rules and encourageing export. It is important to state that the Government of Bangladesh previously fixed the minimum export price of maize at USD 600 (during September 2008) in order to discourage maize export. The MAB is in favor of maize export on the one hand and the Poultry Feed Association of Bangladesh (PFAB) wants protection to maize export on the other.

No country was interested to import maize from Bangladesh at higher price of USD 600 per ton. Therefore, two exporters, namely *M/S Refad Enterprise* and *M/S Think to Supply* applied for reducing the minimum export price. Based on their applications, Bangladesh government has given permission to export maize on a conditional basis during July 2012. The condition is that an exporter can export maize when they get minimum price of USD 325 and above per ton. The Feed Industry Association of Bangladesh (FIAB) claims that some exporters exported maize to Nepal and some other countries at lower price that ranged from USD 184 to USD 190 per ton which would be a clear violation of the government rules. The FIAB argued that the exports of locally produced maize may increase the price of poultry feed which will ultimately increase the cost of production of chicken, egg, and poultry products. Higher prices of poultry and poultry products decrease its demand as well. The PFAB claims that as maize is one of the major ingredients of poultry feed, the increase of maize price will obviously increase the price of poultry feed as well as poultry products. They also claimed that exporting maize has already created a price hike in the poultry feed market (80-100%) in 2012.

On the other side, MAB dose not agree with the statement of PFAB regarding price hike due to maize export. They argud that Bangaldesh is still importing much more maize then it imports, therefore, the feed prices should be more likely to be affected by the price of the maize imported. Small-scale maize export dose not affect feed price significantly in the country. Therefore, MAB is expressing their willingness to export maize from Bangladesh. Current statistics show that poultry industry has used one-fourth of 12 million tons of maize in 2011. The demand for maize in poultry industry has decreased by 2.0 million tons due to decrease in demand for poultry feed in 2012 (FGD 2013). This decrease in feed demand was mostly due to the reduction of a number of poultry firms when there was a wide spread of avian influenza or bird flu virus. According to DAE, the production of maize in the year 2013 increased and reached at 1.96 million tons. On the other hand, due to outbreak of bird flu disease, 47 per cent of poultry farm were closed down. According to *Bangladesh Poultry Khamar Rakkha Jatiya Parishad* (Bangladesh National Poultry Farm Protection Association), the number of poultry farms came down to 60,824 from 114,763 in last one and half years. The reduction of poultry industry leads to a decrease in maize demand for poultry feed. Decline of maize demand hampers farmers to get a fair maize price. Due to reduction of demand, maize sale price became Tk 11/kg (USD 0.14), whereas farmers production cost was Tk 13 or USD 0.17 (FGD 2013).

MAB argues to ensure better price for the farmers and generate a complete utilization of maize through an effective maize export. MAB also identified some countries like Malaysia, Indonesia, Saudi Arabia and United Arab Emirates (UAE) to which maize exports might be possible. Poultry feed industry on the other hand argues to ban maize export for an interim period to stabilize the poultry feed price as well as the prices of eggs and meat and also to provide farmers a satisfactory and profitable price and to inspire them to produce maize instead of tobacco (FGD 2013).

Chapter VI

MAIZE OUTLOOK

6.1 Introduction

This chapter discusses the future outlook (10 years) for maize. It also highlights future scenarios of maize production and consumption based on recent trends and projections. Future outlook of maize is discussed considering various factors, such as population growth, economic growth, future climate change impact, technology change and its impacts, and future policy changes. Outlook of the investment in maize research and development is also discussed in this section.

6.2 Outlook of Maize Production

6.2.1 Forecast of area, production and yield at national level

An attempt was made to forecast the area, production, and yield of maize for 10 years' period using 25 years time series data[6] with the aid of ARIMA model. The concerned scientists, extension personnel, and different seed companies are unanimous on the point that the quantity of maize area and production published by BBS are far behind the reality and much lower compared to the data recorded by DAE. Therefore, forecasting at national level was done using DAE data (1989-2013). This model provides the lowest Akaike Information Criterion (AIC) values for 1st difference of data. Data relating to the area, production, and yield of maize in 2013 were considered base in this study for providing guideline to the policy makers and farmers that what percentage in area, production, and yield would increase in future. The forecasting on area, production, and yield of maize for different divisions was not done due to unavailable division level data.

"Almost 100 per cent of the maize area in Bangladesh is planted with hybrid maize seed each year, mainly with single cross and double cross hybrids" (Ali et al. 2008). It has already been earlier that intensive agricultural extension efforts through the Integrated Maize Promotion Project of the Ministry of Agriculture have made a significant contribution to such a rapid rate of increase. Maize productivity is increasing due to favorable growing conditions (no serious constraints) during the main maize growing season (October-March) and the use of hybrid seeds. Maize productivity (6.2 t/ha) is the highest in Asia.

The forecasts of area, production, and yield of maize using available data from 1989-2013 are presented in Table 6.1 and Fig 6.1. The predicted area, production, and yield of maize show an increasing trend. Considering the base year, area under maize cultivation will be increased by 4.5 per cent to 41.6 per cent and the production will be increased from 8.2 per cent to 48.4 per cent in the next 10 years. As year to year area and production will increase, so per unit yield of maize will also be increased and in the next 10 years, the range of this increase will be confined between 4.0 per cent and 36.7 per cent. In this case, year to year rate of increase in yield is slightly less than the rate of increase in area and production.

On the average, 378.3 thousand hectares of area, 3,128.8 thousand tons of production, and 8.27 t/ha productivity are expected in maize in Bangladesh during 2018, and 4,223.3 thousand tons of production from 442.7 thousand hectares of area under plough with a

[6] ARIMA model needs 25 years time series data for successful prediction/forecasting.

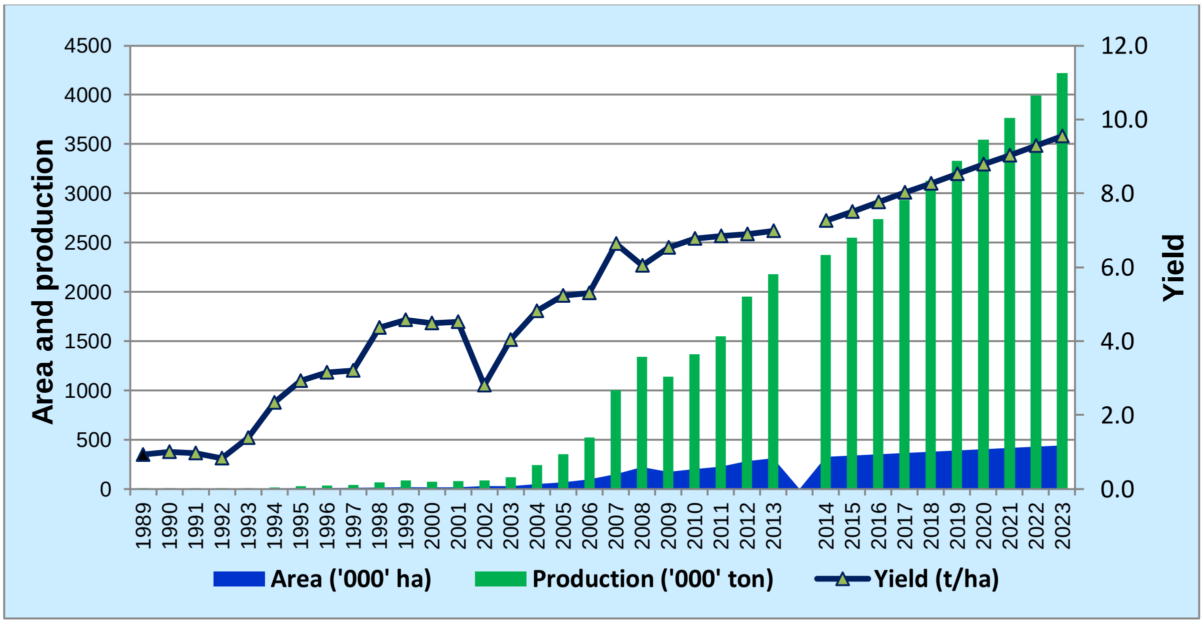
productivity of more than 9.54 tons per hectare by 2023. The predicted maize area in 2018 and in 2023 would be 21.0 per cent and 41.6 per cent higher than its base year 2013. Similarly, the predicted amounts of production in 2018 and in 2023 would be 21.0 per cent and 41.6 per cent higher, respectively than that of production in 2013. In 2018 and 2023, the predicted yields would be 8.27 t/ha and 9.54 t/ha, respectively which are 18.5 per cent and 36.7 per cent higher than that of yield in 2013. The forcasted area, production, and yield of maize are close to the reality of Bangladesh as opined by the concerned scientists of BARI and the representatives of different seed companies (FGD 2013). However, the predicted area, production, and yield show upward pattern and the interval between lower and upper price limit was very close to the forecasted values and also the forecasting error was too small (Appendix A-19).

Table 6.1 Forecast of area, production and yield of maize in Bangladesh

Year	Area		Production		Yield	
	'000' ha	% increase from 2013	'000' ton	% increase from 2013	t/ha	% increase from 2013
2014	326.7	4.5	2,371.8	8.2	7.26	4.0
2015	339.7	8.7	2,551.1	14.6	7.51	7.5
2016	352.6	12.8	2,736.0	20.4	7.76	11.2
2017	365.5	16.9	2,930.9	25.7	8.02	14.8
2018	378.3	21.0	3,128.8	30.4	8.27	18.5
2019	391.2	25.2	3,333.0	34.7	8.52	22.1
2020	404.1	29.3	3,547.8	38.6	8.78	25.8
2021	416.9	33.4	3,765.0	42.2	9.03	29.4
2022	429.8	37.5	3,993.0	45.5	9.29	33.0
2023	442.7	41.6	4,223.32	48.4	9.54	36.7

Source: Using data from DAE and http://www.moa.gov.bd/statistics/bag.htm

Fig 6.1 Forecast of area, production and yield of maize in Bangladesh



Source: Using data from DAE and http://www.moa.gov.bd/statistics/bag.htm

6.2.2 Impact of climate change on maize production

Future climate change effect on agricultural crop production may be significant to a great extent since it is a critical parameter for crop yield (Rosenzweig and Parry 1994). Most of the crops, especially wheat, maize, and barley in the world will face a decline of yield due to an increase in the global temperatures (Lobell and Field 2007). The scientists of BARI opined that future climate change especially temperature rise will not much be detrimental to maize production for most of the areas of Bangladesh since maize is a C_4 crop which can tolerate temperature up to 35^0C. But, the day time temperature at flowering stage sometime exceeds 35^0C in some locations, such as Chuadunga, Jessore, Rajshahi, and Iswardi, which is a threat to maize cultivation for those areas. This temperature may increase in future and therefore will become serious issue for further research. Again the soil and weather of Bangladesh are very friendly for maize cultivation. The major climate change related problems of concern to Bangladesh are related to salinity, drought, unstable season, sudden flood (Fig. 6.2), water logging (Fig. 6.3), etc.

Fig 6.2 Water-logging in maize due to sudden flood

Source: PBD, BARI, Gazipur

Fig 6.3 Water-logging stress in maize cultivation

Source: PBD, BARI, Gazipur

Although BARI scientists don't consider climate change as a major challenge for maize production, at present the country is facing heat, drought, salinity, and water logging problems. However, maize fits well in Bangladesh's climate, soils, and intensive farming systems. The decreased yield potential of maize due to aforesaid problems can be mitigated through screening and by adopting new maize varieties more resistant to heat, drought, salinity, and water logging.

6.2.3 Impact of varietal change on maize production

Although some of the BARI varieties achieved similar or higher levels of yield than varieties originating from aboroad, the level of adoption of most BARI varieties is very low. On the other side, the involvement of private seed, fertilizer, and pesticide companies is increasing day by day. They are working on seed production, seed import, seed distribution, variety development, plant protection, processing, and marketing of their produces. Therefore, they are capable to cope with any changing situation in future in order to supply required level of inputs for sustainable maize production.

The role of the DAE is crucial in promoting BARI maize varieties at farm level since it has establishments throughout the country with strong root level linkages with farmers. The farm level adoption of a maize variety depends to some extent on the initiatives of DAE, varietal quality, its availability and price, and type of production technology along with other socio-economic characteristics of the farmers and environmental factors. If the variety is found to be attractive to the farmers then they will look for the technology for cultivation.

BARI is continuing its efforts towards developing new varieties including saline tolerant, drought tolerant, excess moisture tolerant, and heat tolerant maize varieties in order to mitigate current and future climate change impacts. In this respect, the development of new varieties and technologies suitable for cultivation under stress conditions and their adoption will expand the area under maize cultivation through inclusion of saline areas in coastal regions; drought and heat stress areas at Chuadung, Jessore, Rajshahi, and Pabna districts; waterlogged areas at Comilla and *Hoar* areas; and the char areas of Bangladesh. Again, the seed importers are more conscious about the demand of maize farmers. Therefore, it can be expected that the seed importers will import saline, heat, and drought tolerant varieties based on farmers' demand which will obviously help increasing the area and production of maize in the near future.

It is opined from scientists level that the lack of sticky and protein rich maize varieties is one of the important constraints to its higher level of use as food in Bangladesh (FGD 2013). The technological development towards these varieties in future will increase the production and consumption of maize throughout the country.

6.2.4 Impact of policy change on maize production

Policies regarding maize in Bangladesh will largely depend on maize demand from poultry, dairy, and fish farms, and the type of human consumption. Being a dynamic issue, the future policy on maize development will also change based on emerging problems or risks, technology options for rice-maize systems, and future research and development needs in this sector. Currently, maize has gained popularity as human food in different forms side by side with the poultry feed. Maize became the third major cereal after rice and wheat, contributing to food security and human nutrition, and improving the livelihoods of resource-poor farmers. Therefore, maize can be an important policy concern to the government of Bangladesh in the near future.

Bangladeshi people are mostly mono rice based cereal consumers. So, the production system is dominated by a single crop (i.e., rice) which is neither scientific nor justified from the economic point of view. It is also a threat to ensure food security of the country since future climate change effects might hamper rice production. Therefore, future policy planning must be focused on diversified consumption of non-rice based cereals. Wheat and maize alone or together can play a vital role in cereal consumption diversification. The time has come to go for a significant cereal consumption diversification policy initiative.

Therefore, future policy with regard to food production, food processing, and food marketing should be focused towards variety development; maize area and production increase ; establishment of maize based different backward and forward linkages; government initiative for purchasing maize to encourage farmers; identification of diversified use of maize; and the establishment of maize based food industries. The initiatives that have already been outlined in Bangladesh are scientist's efforts toward variety development to cope with future climate change impacts; BARI in association with DAE provides whole family training to the farmers of areas where maize is currently grown to a lower extent, such as Barisal, Chittagong, and Comilla to encourage maize production; BRAC is establishing a starch factory in Sylhet district; and CIMMYT is organizing food fairs to popularise maize based food in Bangladesh.

6.3 Outlook of Cereal Prices

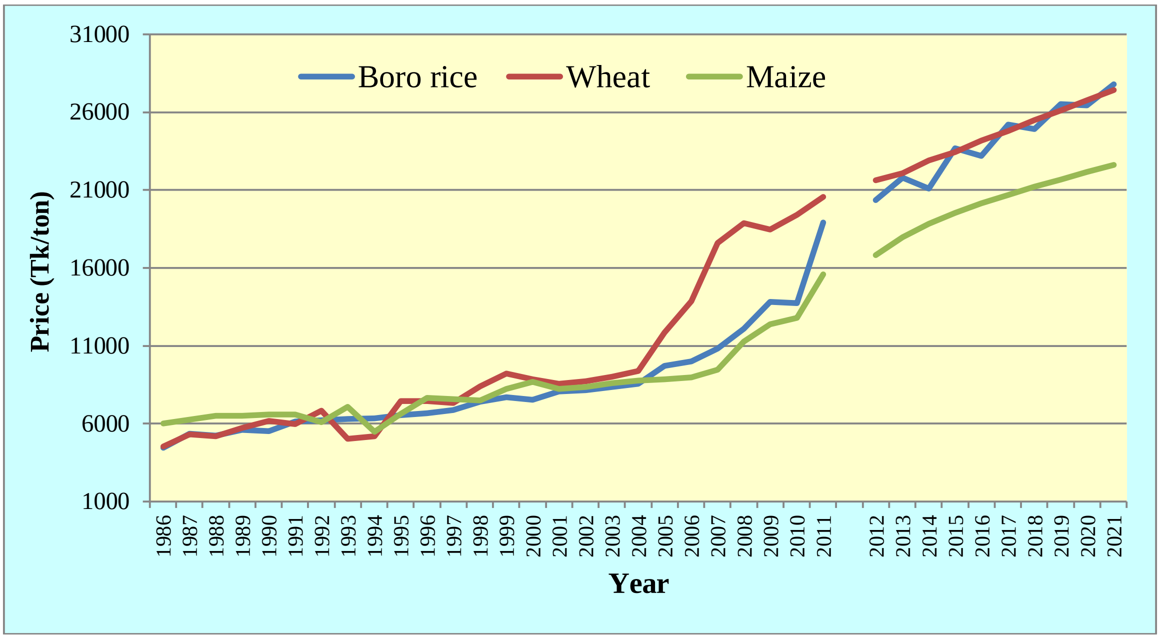
The prices of major cereals, namely rice, wheat, and maize remained static during the period from 1986 to 1992. After that cereal prices increased. Interestingly, the price of wheat remained below the price of rice and maize during 1986-1994, but after this period, the wheat price increased at a faster rate compared to maize and rice. Again, the price of maize remained higher than the price of rice up to the year 2004. But after that period, rice price increased faster than the price of maize (Fig 6.4).

Table 6.2 Predicted prices of major cereals in Bangladesh

Year	Boro price		Wheat price		Maize price	
	Tk/ton	% increase over 2011	Tk/ton	% increase over 2011	Tk/ton	% increase over 2011
2012	20,355	8	21,624	5	16,826	8
2013	21,788	15	22,091	7	17,985	15
2014	21,107	11	22,907	11	18,824	21
2015	23,701	25	23,442	14	19,537	25
2016	23,190	23	24,187	18	20,146	29
2017	25,197	33	24,773	21	20,695	33
2018	24,901	32	25,480	24	21,203	36
2019	26,524	40	26,095	27	21,687	39
2020	26,428	40	26,779	30	22,154	42
2021	27,788	47	27,411	33	22,611	45

Note: Figures in the parentheses indicate percent increase over the base year 2011
Conversion rate 1 USD = 78.0 BDT
Source: Using data from BBS

Figure 6.4 Trend and forecast of prices of major cereals in Bangladesh



Source: Using data from BBS 2011 (Appendix A-21)

Currently, to some extent mixing of maize and wheat is a phenomenon in Bangladesh which is mainly due to the higher price of wheat.

Forecasts on cereal prices are shown in Table 6.7. It reveals that the prices of rice, wheat, and maize will gradually increase till 2021. The percent increase of maize price is found to be much higher than the increase found in the price of wheat. Until 2021, the maize price might increase by 45 per cent and the wheat price by 33 per cent from its base year 2011 if other factors remain constant.

6.4 Outlook of Maize Value Chains and Consumption

The current consumption and existing value chains of maize may be changed to a great extent due to various factors in the near future. This section describes the outlook of maize consumption and maize value chains due to future population growth and economic growth of Bangladesh.

6.4.1 Outlook of maize consumption

The human consumption of maize is closely related to the consumption of wheat since maize is generally mixed with wheat flower. The use of maize for human consumption is increasing year after year (FGD 2013). The major divers of this increase are population and economic growth. Bangladesh population is growing at the rate of 1.58 per cent annually. Again, in real terms, Bangladesh's economy has grown 5.8 per cent per year since 1996 (www.indexmundi .com /Bangladesh/economy_overview.html).

The major demand rises from poultry, fish, and livestock farms. Small demand also rises from starch industries and flour mills. Therefore, future demand for maize will mostly depend on many factors, such as number of livestock and poultry farms, the pattern of human consumption, intensity of industrial use, price of wheat, etc. National statistics show that responding to demand from expanding poultry and fish feed markets, maize area in Bangladesh rose from 3,570 ha in the 1989-2090 to 286,870 ha in 2012-2013 (DAE 2013).

A detailed demand estimation for poultry feed was done by Islam (2003; 2001). He projected poultry population and total requirement of maize for poultry feed preparation up to the year of 2020. The projected populations of scavenging birds[7], layers, and broilers were 175.88 million, 47.54 million, and 10.16 million, respectively for the year 2020 (Table 6.3).

Table 6.3 Projections of poultry population by scavenging and commercial type in Bangladesh (Trend Approach)

Poultry type	Base year 2000	Projection of poultry population for selected years (Million birds)			
		2005	2010	2015	2020
Domestic chicken	128.04	138.62	150.07	162.47	175.88
Layer	34.61	37.48	40.57	43.92	47.54
Broiler	7.40	8.02	8.67	9.39	10.16
Total	170.05	184.10	199.31	215.78	233.59

Source: Islam 2001; Islam 2003

Based on these figures, Islam (2003; 2001) estimated the future requirement of maize applying both a demand approach (AIDS model) and a trend approach. The projected requirements of maize based on the demand approach are estimated to be 642,430 tons and 698,490 tons for the years 2015 and 2020, respectively (Table 6.4). The estimated requirements of maize based on trend approach for the same year are much less (Table 6.5).

[7] Domestic chickens and ducks mostly depend on outside feed and left overs of household's foods.

Table 6.4 Projected requirements of grains as poultry feed in Bangladesh (Demand Approach)

Grain by poultry type	Base year 2000	Requirement of poultry feed ('000' tons)			
		2005	2010	2015	2020
1. Scavenging bird					
Wheat	--	100.99	113.36	125.47	136.42
2. Layer					
Wheat	--	38.09	42.75	47.31	51.44
Maize	--	500.59	561.87	621.85	676.11
3. Broiler					
Wheat	--	8.63	9.69	10.72	11.66
Maize	--	16.56	18.59	20.58	22.38
4. All birds					
Wheat	140.56	147.71	165.80	183.50	199.52
Maize	490.51	517.15	580.46	642.43	698.49
Total grain	631.07	664.86	746.26	825.93	898.01

Source: Adopted from Islam 2001 and Islam 2003

Islam (2003) also did sensitivity analysis in estimating the future requirements of wheat and maize grain under four scenarios. In the demand approach (4th scenario), highest demand projected for maize for poultry feed is 700,550 tons and 756,870 tons in the year of 2015 and 2020, respectively (Table 6.6). Using the trend approach, the 4th scenario projected the highest demand for maize as poultry feed estimated to be 1,050,410 tons in 2015 and 1,435,290 tons in 2020 (Table 6.7).

Table 6.5 Projected requirements of grains as poultry feed in Bangladesh (Trend Approach[8])

Grain by poultry type	Base year 2000	Requirement of poultry feeds ('000' tons)			
		2005	2010	2015	2020
1. Scavenging bird					
Wheat	79.70	86.28	93.41	101.13	109.48
2. Layer					
Wheat	34.02	36.83	39.87	43.16	46.73
Maize	438.98	475.24	514.49	556.99	602.99
3. Broiler					
Wheat	26.85	29.06	31.46	34.06	36.88
Maize	51.53	55.79	60.40	65.39	70.79
4. All birds					
Wheat	140.56	152.17	164.74	178.35	193.08
Maize	490.51	531.03	574.89	622.38	673.78
Total grain	631.07	683.20	739.63	800.73	866.86

Source: Islam 2001; Islam 2003

[8] The trend growth rate of both poultry population and commercial farms is taken as equal to the current population growth rate (1.6%). A 10% mortality rate is assumed. For both layers and broilers, consumptions are adjusted for annual level. For layers, feed consumption (per week) level applies for the life cycle of 78 weeks, from which that for 52 weeks is estimated. For broilers, average feed consumption (per week) applies for the life cycle of 6 weeks. 6 batches of broilers in a year are considered. This means feed demand for 36 weeks is considered in a year. As estimated from field survey, the wheat consumption by scavenging birds is equivalent to 10% of the average quantity consumed by layers and broilers. No maize consumption is considered for scavenging birds. Half of scavenging birds are estimated to lay eggs in the whole year.

Table 6.6 Projected use of grain for poultry feeds in Bangladesh under various scenarios (Demand Approach)

Scenario	Grain	Base year 2000	Projected use of grain for poultry feed ('000' tons) Demand Approach			
			2005	2010	2015	2020
I	Wheat	140.56	147.71	165.80	183.50	199.52
	Maize	490.51	517.15	580.46	642.43	698.49
	Total Grain	631.07	664.86	746.26	825.93	898.01
II	Wheat	140.56	145.04	162.80	173.16	188.27
	Maize	490.51	506.75	568.78	604.70	657.47
	Total Grain	631.07	651.79	731.58	777.86	845.74
III	Wheat	140.56	157.12	175.35	185.45	200.62
	Maize	490.51	559.54	623.65	658.45	711.45
	Total Grain	631.07	716.66	799.00	843.90	912.07
IV	Wheat	140.56	160.21	178.79	196.79	212.86
	Maize	490.51	571.84	637.30	700.55	756.87
	Total Grain	631.07	732.05	816.09	897.34	969.73

Note: **Scenario-1**: Using rural consumption from FMRSP and urban consumption from HIES 2000 and fixed income elasticities for egg 2.00 (during 2000-2020) and meat 1.23 (during 2000-2020).

Scenario-2: Using rural consumption from FMRSP and urban consumption from HIES 2000 and declining income elasticities for egg 1.67 (during 2000-2010) and 1.30 (during 2010-2020); for meat 1.14 (during 2000-2010) and 0.83 (during 2010-2020).

Scenario-3: Using both rural and urban consumption data from HIES 2000 and declining income elasticities as above.

Scenario-4: Using both rural and urban consumption from HIES 2000 and fixed income elasticities for egg 2.00 (during 2000-2020) and meat 1.23 (during 2000-2020).

Source: Islam 2001; Islam 2003

Table 6.7 Projected use of grain for poultry feeds in Bangladesh under various scenarios (Trend Approach)

Scenario	Grain	Base year 2000	Projected use of grain for poultry feed ('000' tons) Trend Approach			
			2005	2010	2015	2020
I	Wheat	140.56	152.17	164.74	178.35	193.08
	Maize	490.51	531.03	574.89	622.38	673.78
	Total Grain	631.07	683.20	739.63	800.73	866.87
II	Wheat	140.56	149.20	158.37	168.10	178.43
	Maize	490.51	520.66	552.65	586.62	622.67
	Total Grain	631.07	669.85	711.02	754.72	801.10
III	Wheat	140.56	159.51	181.03	205.45	233.17
	Maize	490.51	561.77	643.38	736.85	843.90
	Total Grain	631.07	721.29	824.40	942.30	1,077.07
IV	Wheat	140.56	179.19	229.85	295.96	382.06
	Maize	490.51	615.18	792.35	1,050.41	1,435.29
	Total Grain	631.07	794.37	1,022.20	1,346.37	1,817.35

Note: **Scenario-1**: Trend growth rate of both poultry population and commercial farms taken as equal to current population growth rate (1.6%).

Scenario-2: Trend growth rate of both poultry population and commercial farms taken as equal to future population growth rate (1.2%).

Scenario-3: Half of past trend growth rate of poultry population (2.5%) & half of that of commercial farms (2.75%).

Scenario-4: Past trend growth rate of poultry population (5%) and past trend growth rate of commercial farms (5.5%).

Source: Islam 2001; Islam 2003

6.4.2 Outlook of maize value chains

Future value chains of maize will be dynamic and changing due to the increasing demand created by its diversified use and the increasing number of poultry, livestock, and fish farms and food processing industries in the country. The increased demand may create higher prices for the farmers which would encourage them to grow more maize. Increased maize production will involve different technologies in the process of maize cultivation, harvesting, shelling, drying, and processing. More involvement of new technology will reduce the cost and time for production, processing, and marketing of maize due to lower labour cost, higher yield, reduction in harvest time and pos-harvest losess, and value addition. 'Appropriate use of mechanization increases productivity along the entire value chain, improving yields and reducing on-farm and post-harvest loss, all critical elements in the sustainable intensification of agriculture' (Zeigler 2013).

6.5 Outlook of Maize Inputs, R&D, and Policy

Efficient use of maize inputs and adequate government policies for increasing farmers' capacity are very much important for maize production. The outlook on maize inputs, R&D, and policy is discussed in the following sections.

6.5.1 Outlook on maize inputs and policy

Different studies emphasized on improving the capability of farmers to use inputs judiciously in maize production. Mohiuddin et al. (2007) found that farmers showed their higher efficiency in using the resources in maize production since the average technical efficiency of the farmers was 98 per cent. Hasan (2008) estimated average technical efficiency of maize farmers as being 0.84 for Dinajpur and 0.80 for Panchagarh district. He argued that there are ample scopes at both regions to increase maize productivity through judicious and increased use of resources. Therefore, future policy may be focused on farmers' capacity building through human resource development and strengthening extension services for using inputs efficiently and obtaining and sustaining the higher yield of maize.

6.5.2 Outlook on maize R&D and policy

It has already been shown that the cultivation of maize at farm level is much more remunerative than that of wheat and many other crops.

The investment on research and development (R&D) of maize was found to be encouraging in Bangladesh. Hossain et al. (2002) evaluated the past investment on maize R&D in Bangladesh through *Economic Surplus Model* using time series data from 1980-1981 to 2000-2001. The study estimated the internal rate of return (IRR) to investment to be 23 per cent. Under various assumptions on R&D expenditures, the IRR ranged from 17 to 28 per cent and BCR from 9 to 19. The yield advantage of composite varieties over local varieties ranged from 40 to 65 per cent, and that of hybrids ranged from 73 to 79 per cent. Hossain et al. (2002) also calculated the amount of foreign exchange savings due to R&D of maize (e.g., higher production and less importation) for the period from 1992/93 to 2000/01, and the amount of total foreign exchange savings was Tk 276.06 (USD 3.539) billion. Therefore, both government and donor agencies should come forward to invest in maize R&D in Bangladesh.

Chapter VII

MAIZE INVESTMENT OPPORTUNITIES

7.1 Introduction

The main focus of this chapter is on the investment opportunities for Research and Development (R&D) in both public and private sectors in Bangladesh, and policy recommendations including technological, economic, social, and environmental considerations.

7.2 Constraints and Opportunities in Maize Sub-sector

A strengths, weaknesses, opportunities, and threats (SWOT) analysis has been conducted and is presente in this section to explore the constraints and opportunities with respect to research and development of maize in Bangladesh.

7.2.1 Strengths

Research capability: BARI as well as two agricultural universities have the sufficient staff and ediquate technical capacity to develop hybrid maize varieties that can compete with many other imported varieties, and can be grown under various biotic and abitic stresses conditions.

Availability of inputs: Recently, the Government of Bangladesh has taken a number of steps to increase the supply of different inputs, especially fertilizer and electricity (for irrigation) at farm level. It also formulates farmer's friendly agricultural credit policy, provides 100 hours free supplementary irrigation, supports for accelerated mechanization of agriculture, and facilitates surface water irrigation for the farmers (Ahmed 2010).

Availability of good varieties: BARI has so far developed 19 composite and hybrid varieties of maize which are available to some extent for cultivation. The scientists of BARI reported that BARI maize varieties are available to some extent at Kushtia, Jamalpur, Lalmonirhat, Dinajpur, Rangpur, and Manikgonj district (FGD 2013). In addition, private seed companies also import a huge amount of hybrid maize seed every year. The availability of BARI varieties at local markets (14.2% of the total seed requirement) is playing an important role in the expansion of maize cultivation in Bangladesh.

Productivity of maize: Productivity is one of the major strengths of maize in Bangladesh. The yield potentials of hybrid maize varieties ranged from 10.73 to 15.53 t/ha (Apendix Table 3). During the period 1994-2006, the yield of hybrid maize increased by 18.65 per cent compared to the period 1971-1993 (Rahman 2011).

Higher profitability: Different studies showed that the profitability of maize is higher than that of competing crops like wheat, mustard, pulses, jute, etc. BCR is found to be 1.63 and 1.61 for *Kharif* and *Rabi* maize, respectively (Rahman 2011). Due to its higher profitability and existing/ assured markets farmers are very much interested to cultivate this crop in future.

Availability of extension facilities: Bangladesh Government has a strong agricultural extension network (DAE) throughout the country for disbursing agricultural inputs to the farmers. A total of 63 Multi Location Test (MLT) sites under the On-Farm Research Division

(OFRD) of BARI are available which can play a crucial role in diffusing HYV varieties and production technologies of maize at farm level.

International collaboration for maize research: The scientists of BARI continue their efforts in evolving with new varieties, maize-based cropping patterns, crop and soil management technologies, and in providing whole family training with the support of international institutes, especially from CIMMYT. The BARI scientists are trying to develop saline and drought tolerant varieties and they are going to release a water logging maize variety very soon. This variety has the capacity to live under water at vegetative growth stage for 5-7 days. The Agronomy Division of BARI also started conducting research on dual purpose maize for both grain and fodder use (FGD 2013).

7.2.2 Weaknesses

The weaknesses involved in maize cultivation are related to input, production, post-harvest management, market access, and enabling environment. Al these issues are briefly discussed below.

Lack of awareness: Farmers generally buy maize seed from input dealers at the local or nearby markets. They have to trust input dealers regarding seed quality which sometimes lead them buy poor quality seed. Such lacking of awareness regarding identification and usage of quality seeds leads them to purchase lower quality seeds and as a result, the productivity declines.

Poor quality and higher price of seed: Good quality seed is a pre-requisite for higher yield. Farmers generally identify good quality seed through observation, past experience, and trust on seed dealers. In many cases, they are being cheated by seed dealers and experienced with low seed germination (75-80%), early flowering, and immature cob formation resulting in a decline of production (FGD 2013). This happens because the government has no control over maize seed importation and quality assurance. The price of hybrid seed is opined to be very high, ranging from Tk 300 toTk 450 (USD 3.85-USD 5.77). The price of BADC seed (BARI variety) is Tk 90 (USD 1.15), but the supply of BADC seed is very low.

Adulteration in fertilizers: It is currently a common problem of Bangladesh. Maize farmers mentioned that they could not get good response of the application of balanced fertilizer dose because of adulteration. This problem increase production cost and decreases yield (FGD 2013).

The Soil Resource Development Institute (SRDI) carried out thorough laboratory tests on 17 different brands of fertilizers in its laboratories across the country in 2011. Of these, 14 brands were found to be highly adulterated. The percentages of fertilizers which were adulterated were urea 2 per cent; TSP 25 per cent; DAP 21 per cent; SSP 33 per cent; MoP 11 per cent; mixed fertilizer (NPKS) 80 per cent; zinc sulphate 80 per cent; SoP 30 per cent; boron 40 per cent; magnesium sulphate 14 per cent; gypsum 21 per cent; organic 47 per cent; and other fertilizers 29 per cent. It was also found that most of the imported fertilizers are adulterated (Khan 2012).

Lack of irrigation/High price of irrigation: Insufficient supply of irrigation is a common problem of Char areas in Bangladesh. The areas with adequate irrigation facilities during maize cultivation are suffering from high prices of irrigation. The load shedding of electricity, the high price of diesel, high labour prices, low water aquifers, low discharge of water, etc. make irrigation cost very high to the farmers.

Lack of access to financial institutions: Most of the farmers of our country are poor. They do not have enough access to state owned financial institutions due to lots of rules and regulations. Maize farmers need agricultural credit at lower cost since maize cultivation requires higher amount of cash. Therefore, lack of access to finance leads to inferior input purchase and improper post-harvest management resulting in low income. Sometimes they borrow money from informal sources at very high interest rates. They have to sell maize quickly after harvest at lower price to repay the loan.

Lack of adoption of BARI varieties: BARI has developed a good number of HYV and hybrid maize varieties, but unfortunately very few of them are currently available in the farmers' fields. Most of the farmers used hybrid varieties of maize mostly imported by different private companies. BARI scientists have no information about the adoption rate and total area coverage of BARI maize varieties. Due to the tallness of the BARI maize varieties, farmers face top dressing and intercultural operation problems. The germination and viability of BARI maize seed are opined to be very low which is due to poor management of BADC (FGD 2013).

Lack of availability of BARI varieties: There is, to some extent, a demand for seed of BARI maize varieties in some pocket areas of maize. But the unavailability of BARI maize seed compels farmers to buy seeds of other varieties.

Lack of HYVs of maize for hilly regions: The hill regions of Bangladesh are rich in maize cultivation since a long time. The indigenous people of this region generally cultivate local varieties of maize in different types which are very low yielders but tasty. Till to date, no agency could provide them any high performance variety or hybrid suitable to the local taste in the hill areas.

Lack of stress tolerant varieties: Many areas of Bangladesh are prone to various biotic and abiotic stresses. The prominent abiotic stresses are heat, drought, water logging, and excess moisture. The water logging problem is mainly associated with *Kharif-1* maize production. The farmers who have low lying land normally face loss due to damages of water logged maize plants. In many parts of the country, temperature exceeds 35ºC, which is harmful to maize production. But, Bangladesh does not own suitable stress tolerant maize varieties.

Lack of proper technical knowledge: Although technical knowledge in terms of planting time, seed rate, plant spacing, fertilization, irrigation, etc. plays a significant role in getting higher yield, many farmers still are not aware of the improved methods of maize production leading to lower production. The lack in maize related technical knowledge dissemination to maize farmers is also a problem.

Post-harvest management

Poor post-harvest activities: Most of the maize growers are poor and small-scale producers. They use only traditional methods of harvesting and processing. A good quantity of maize is lost due to poor post-harvest activities and lack of adequate knowledge on post-harvest processing and storage. A FAO funded study estimated the total post harvest loss of maize as 4.07 per cent in which storage loss was 2.50 per cent, drying loss 0.62 per cent, threshing loss 0.55 per cent, transport loss 0.12 per cent, and harvesting loss 0.33 per cent (Bala et al. 2010, P. 51).

Lack of drying facility: After harvesting the crop it needs adequate space to dry for storage. Due to the lack of adequate drying facilities in farmyards, most of the farmers sell their product with a too high level of moisture, achieving only a low price. Therefore, the unavailability of proper drying facility results in low quality of maize leading to low income.

Lack of storage facilities: This is one of the major reasons for quality deterioration. Small-scale producers do not have enough storage space to store bulky harvests of maize on their farms. Most of them are exposed to bad weather and other destructive forces. On the other side, there are no warehousing facilities in the producing areas where they can store their produces for the time being. Therefore, lack of storage facility bounds farmers to sell maize just after harvesting and results a low chance for farmers to benefit from higher prices at later points in time.

Due to lack of drying floor and enough space for storing maize grain for longer period, most of the farmers of Dinajpur district store cleaned maize cob in their homestead just for a week. Therefore, they get a low price for their produce due to distressed sale. However, many Chuadanga farmers have drying floor and space for storing maize grain. They can store maize grain for at least 2-3 months and get higher prices (FGDs 2013).

High transaction cost: Most of the maize producers of Bangladesh are small-holders with small market surplus. Their cultivated lands are small in size and scattered. Assembling village markets are also not so close to their residences. Therefore, the transaction cost is high due to small and scattered lot of marketed surplus and higher transport cost. Due to lack of highway and transport facilities, most of the farmers face high marketing cost to bring the crop to urban markets.

Low product price and poor access to high price market: Maize growers of Bangladesh often face the problem of low price of their product due to various reasons. The causes of low price are lack of bargaining power of the farmer, poor product quality, lack of storage facility, sometimes less demand from poultry industry, and unrestricted imports from India.

Most maize farmers are small-scale producers and are not linked with industrial buyers. Industrial buyers generally procure quality maize for producing feed and starch. Without access to such knowledge, they do not attempt to produce the expected quality demanded by such buyers. Most farmers sell maize to local traders at lower price. These middlemen traders supply quality maize to industrial buyers at higher price after proper sorting and grading. This chain inherently impedes opportunities for farmers to get fair prices for their produce.

Lack of floor price: Bangladesh government procures rice and wheat directly from farmers and traders at the prices fixed early in every year in order to accumulate a big stock for meeting country's emergencies and to control the price. Government has no such policy for maize procurement.

Lack of organized market: There are no organized markets or a single place for bulk procurement of maize. It has to be procured from individual farmers or through middlemen which may hamper the regular availability or may cause price fluctuations.

Scarcity of labour: Currently the non-farm sector is well developed in Bangladesh. A significant portion of wage labourers has been shifted to non-farm sector resulting in scarcity of wage labourers in agriculture. Cultivation of maize requires a high amount of labour. But sometimes it creates problems for the farmers as they cannot hire labour due to its scarcity and high price.

Lack of cultivable land for small holders: Most of the farmers of Bangladesh are small holders. They cannot expand their maize production, even if they have the investment capacity and opportunity only because of the lack of enough cultivable land. The land and property rights are also not in favour of small farmers.

Unrestricted import from India: Bangladesh Government has no control over maize imports. The government usually allows importers to import maize from neighbouring countries at the time of our maize harvest. Such a policy is very much harmful to the maize producers in getting a lower price for their produces.

Lack of *Char* friendly transportation system: There are no well-constructed road networks available in the *Char* areas of Bangladesh. Boats are the only viable means of transport for the majority of the farmers to transport products from the *Char* to markets. Carrying maize in a large volume is totally dependent on human labour and it is costly. A very few horse carts or other animal driven carts are available in *Char* areas, and almost none in the core lands (Oxfam 2013).

Lack of broadcasting maize related information: Timely and accurate information regarding production inputs, their availability, input prices, product demand, and product price play a vital role in achieving higher profit for the growers. In Bangladesh, different mass media, such as radio, television, and newspapers are not usually used for broadcasting maize related information.

7.2.3 Opportunities

Maize is one of the cash crops of Bangladesh which have the potential to pull farmers out of poverty. Its demand and supply are increasing year after year. Bangladesh has ample opportunities to increase both area and productivity of maize cultivation significantly since it has suitable soil conditions, topography, and climate. Alsoat the production and post-harvest processing levels, there is some potential for mechanical interventions that might add value to current maize production processes, and allow poor farmers to earn more from maize.

Land suitability: Suitable land for growing a variety of crops including maize is a gift of nature of Bangladesh. The area on which maize can potentially be grown is 2.8 million hectares in Bangladesh which is very high (Javed 2001). Maize can also be grown in fallow and *Char* land where the cultivation of maize is found to be more profitable than the cultivation of other crops.

Growing season: Maize being a photo intensive crop can be grown throughout the year both in *Kharif-1 (Aus)* and *Rabi (Boro)* seasons either as sole crop or in association with a range of other crops under inter-, mixed and relay cropping (see crop calendar in Appendix A-9). Maize can play a vital role in narrowing the gap between demand and supply of food in our country due to the wide range of growing seasons and the high productivity.

Availability of maize based cropping patterns: Bangladesh Agricultural Research Institute (BARI) has developed some maize based cropping patterns which ensure higher yield and financial return compared to traditional cropping pattern. Besides, it has also developed some maize based intercropping and relay cropping practices which are found to be more profitable. The Agronomy Division of BARI has developed maize intercropping systems e.g., with spinach, chickpea, and bush bean.

Improved production technology: Technology related to maize cultivation has been changed in the last 10 years due to the efforts of BARI scientists. The PBD along with other relevant divisions of BARI has already developed suitable production technologies for maize which is very much useful to increase the production of maize. Soil scientists have recommended 2.0 ton of boron and lime per hectare for successful grain formation and to minimize soil pH (FGD 2013).

Private sector involvement: Currently, different private organizations are involved in import and distribution of hybrid maize varieties at farm level which influences the growth of maize production in Bangladesh. Besides, higher demand for feed is being created by the expansion of manufacturing capacities of the private feed mills. The scientists of BARI opined that many industries are involved in manufacturing maize shellers and dryers in the country due to higher demand for those at farmers' level. Maize shellers, especially electric shellers play a significant role in increasing the area of maize in some maize growing districts (FGD 2013).

Employment generation: The cultivation of maize would help generating employment in the rural areas due to its higher human labourer employment capacity compared to other crops like wheat, potato, transplanted *Aus* rice, and pulses. Moreover, distressed women labours are also involved in post-harvest activities (i.e., shelling, dehusking) of maize. In 2009-2010, around 375,000 farmers and 93,000 labourers were involved in the production of approximately one million tons of maize in Bangladesh (www.katalyst.com.bd/ op_maize.php).

Demand of maize as poultry feed: Seventy private sector feed mills have been established accross the country. These mills generally use maize to the extent of 45-55 per cent as a source of carbohydrate feeds (Quasem 1999). Some feed mills use 55-60 per cent maize as one of the feed ingredients (FGD 2013). Poultry feed with maize produce eggs with yellow yolks and harder shells. However, it is expected that more demand will be created for maize in future because more poultry farms will be established across the country to meet up the demand forpoultry of the increasing population of Banladesh.

Bringing potential areas under cultivation: Huge potential lies in locations, such as the *Chars* and saline areas of Bangladesh where most of the residents are marginal and small farmers. A report showed that the landless and marginal farmers of northern districts achieved bumper production of various crops, such as pumpkin, maize, vegetables, groundnut, china, kawn, pulses, sesame, mustard, wheat, and watermelon on the *Char* and dried-up riverbeds (Financial Express 2012). Currently, the crops which potentially compete with maize in *Char* lands are groundnut, sesame, watermelon, mustard, and some vegetables like brinjal, bean, and cucumber. Another study showed that Bangladesh has accessible land of 0.82, 0.85, and 1.20 million hectares in *Char*, saline, and drought prone area, respectively for maize cultivation (Banik et al. 2011). If these potential areas can be brought under maize cultivation, the country can fulfill its growing demand through producing huge amount of maize.

Establishment of starch plants: Maize is on the fringe of the Bangladeshi diet. However, maize as a feedstock for starch for the garments industry is a more practical and likely major market in the near future. Corn starch is also identified as one of the ingredients for manufacture of biodegradable plastic. Establishment of such a plant needs 140,000 MT of maize (Gibson 2006) which will help increase the demand for maize.

Development of water logging and saline tolerant varieties: Water logging is one of the problems in summer maize cultivation, while intrusion of saline water due to climate change also creates problems in maize cultivation, especially in southern part of the country. There is an opportunity of more research to develop water logging and saline tolerant varieties in Bangladesh.

Development of quality protein maize: The scientists of BARI with the help of CIMMYT developed a variety (BARI Hybrid-5) of quality protein maize (QPM) which has no stickiness. They are also trying to develop more QPM varieties for human consumption and attaining food security. Therefore, ample opportunity exists at BARI to make efforts on developing QPM varieties with sticky quality.

Promoting maize-based cropping patterns: BARI has developed lots of maize based cropping patterns and inter-cropping practices, but these patterns are not fully adopted by the farmers. These practices increase soil quality and fertility. Therfore, the promotion of maize-based cropping patterns in the potential areas may increase the area under maize cultivation.

Introduction of mechanized planter and bed system planting: There is an ample scope of introducing mechanized planter and raised bed technology in maize production to increase the yield. The turnaround period between T. Aman rice and maize is very short. After ploughing the land, farmers can use mechanized planter for sowing maize seed quickly. Bed planting system is relatively new in Bangladesh and is very much helpful for summer maize cultivation under wet conditions.

Promoting contract farming: Cultivation of maize requires a higher amount of cash compared to many other crops. There is an opportunity for the state authorities to promote contract farming systems. This will enable farmers to link with traders who can provide them with technical knowledge regarding maize production, access to larger buyers, and credit to buy inputs. The contract farming system was very much prominent just a couple of years ago, but due to huge production this system is opine to be very less in Bangladesh. Some local NGOs in the northern districts are producing maize under contract farming system (FGD 2013).

Provision of technical knowledge: Many farmers still are not aware of the improved production technologies of maize. Training can play an important role in this regards. Studies showed that trained farmers can receive more than 1.0 t/ha of additional maize yield compared to non trained farmers (CIMMYT 2006). Hence, there is an opportunity to disseminate technical knowledge to the farmers through short-term training programmes, especially in the intensive maize growing areas for better performance.

Dissemination of best production practices: BARI has developed complete production technologies for maize production at farm level that can be demonstrated through DAE both at public and private sector for comparison (FGD 2013). This initiative obviously makes farmers enthusiastic toward higher maize production.

Improve post-harvest management practices: Farmers of Bangladesh generally complete the post-harvest work manually. Maize shelling and drying are the crucial steps in post-harvest operations. Growing maize during the summer seriously faces the problem of drying due to coincide with the rainy season. Mechanical shellers and low-cost dryers (i.e., STR dryer) can play an important role in this aspect as they result in less time and space required to complete post-harvest practices.

Establish better linkage between extension agent and farmers: Farmers should be provided with the up-to-date information regarding maize cultivation. Agricultural extension agent can play a crucial role in this regard. Extension contact between farmers and extension agent is not up to the mark; therefore proper steps need to be taken to improve the situation. The state authority may take some departmental initiatives for giving right time promotion to the devoted extension workers, providing reward and additional yearly increment to dutiful personnel, and ensuring punishment through demotion and held-up yearly increment for inefficient workers.

Value addition and capturing: There are ample opportunities to create value addition through promoting speciality corns (e.g., baby corn, sweet corn, pop corn, etc.) in case of assured markets. Promotion of the production and consumption of fortified maize-based products can also create value addition at producer and national levels. For instance, India has already promoted fortified maize-based flour/products at higher price.

7.2.4 Threats

Fall of ground water level: "Experts warn rapid depletion of Bangladesh's underground water table could jeopardize food and water security for millions throughout the country" (www.irinnews.org/report/94454/bangladesh-invisible-hazard-of-groundwater-depletion). In many parts of Bangladesh, the water table can fall below the reach of traditional shallow tube wells during the period of February to May. In the changing climate scenario, maize cultivation like other crops may be threatened to a large extent in future.

Deteriorate soil health: "During the years 1967-1995, the highest depletion of organic matter occurred in soils of Meghna River Floodplain (35%) followed by Madhupur Tract (29%), Brahmaputra Floodplain (21%), Old Himalayan Piedmont Plains (18%), and Gangetic Floodplain (15%)" (Jahiruddin and Satter 2010 as cited in Ali et al. 1997). Maize is comparatively an exhaustive crop. It is also treated as a fertilizer loving crop. Cultivation of this crop repeatedly in a same piece of land may create serious threats to soil productivity.

Heavy and continuous rainfall: Summer maize (*Kharif-1*) is harvested during monsoon season. Often it rains heavily and continuously during that time. It was reported that during *Kharif-1* season (March-July), the rainfall recorded in 2011 ranged from 714 to 1133 mm in the major maize growing districts (Table 3.21).Thus, heavy and continous rainfall sometimes create serious threat to the maize growers because they can't harvest maize from the field and can't dry maize grain.

Heavy dependency on poultry and fish feed sector: Future demand for maize will largely be an outcome of the growth of poultry and fish farms. Again, bird flu is one of the devastating diseases of farm poultry occurring frequently in Bangladesh. It causes significant damage to poultry industries, which reduces the demand for feed. Consequently, the demand of maize can be trimmed down.

Climate variability: Climate change could have a significant impact on maize production. Due to the greenhouse effect, the temperature of our country is increasing and rainfall is decreasing over time. Although maize is quite adaptive to harsh conditions, warmer temperatures, and lower levels of rainfall could have detrimental effects on the yields of maize. Past studies showed that a 10 per cent reduction in mean precipitation reduces the mean maize yield by approximately 4 per cent. Similarly, as the mean temperature increases from 21.4 to 21.6 ºC, the average maize yield increases by 0.4 per cent. But after that, the gain in maize yields prompted by increased temperature begins to diminish as temperature increases further (Akpalu et al. 2009). Besides, Bangladesh is also facing a problem of salinity due to climate change which also hinders maize area expansion.

High dependency on imports of hybrid seed: In the recent past, both the public (i.e., BADC, DAE) and private (i.e. seed companies, NGOs) sector were involved in producing hybrid maize seed across the country. Due to the rapid expansion of the animal feed industry as well as maize growing areas, the amount of seed imported increased over the years. Currently, Bangladesh heavily relies on the imports of hybrid maize seed since domestic production could meet only 14.2 per cent (Table 4.1) of the total requirement (FGD 2013). Another study showed that almost 90 per cent of the demand of hybrid maize seed is fulfilled by private sector (Anonymous 2006) and the private sector imported this seed from foreign countries. Disfavour of any trade negotiation with foreign countries may hamper the maize production throughout the country.

High competition with other crops: Most of the farmers in Bangladesh are poor and the main cereal food items for them are rice and wheat. They are always interested mainly to grow rice in their field. Therefore, most of them grow *Boro* rice in winter season. Nevertheless, a variety of high value crops are also grown in the winter season. As a result, maize has to face serious competition with these high value crops in terms of crop choice by the farmers.

Adulterate maize seed: Good quality seed plays an important role in higher production. Most of the farmers in Bangladesh are illiterate and they usually purchase seeds from local markets. Keeping this in view, a few fraudulent businessmen of the locality sell adulterated seed to the farmers. By planting this seeds, farmers do not get desired yield and return from maize.

7.3 R&D Priorities in Maize Sub-sector

Bangladesh is a densely populated country and its cultivable land is shrinking but food demand is increasing every year. Therefore, we need to produce more food from a unit area of land. Maize has the highest potential of producing more food from a unit area of land as compared to other cereal crops (FGD 2013). Bangladesh has a unique opportunity to increase maize production. Area, production, and yield steadily increased since the introduction of hybrid maize in 1993 by the private sector. This is due to favourable growing conditions, use of hybrid seeds, and modern cultivation practices.

Different private and public organizations have been conducting research to generate suitable technologies for the farmers not only to sustain maize production, but also to enhance maize productivity by minimizing the yield gap at farm level. At present, the national average yield is 5.30 t/ha, while the demonstration average yield is 10.0 t/ha. Therefore, national average yield could be raised to 7.5-8.5 t/ha quite easily by adopting the appropriate technologies by the farmers (www.badc.gov.bd/). Considering the above scenario, the research thrust should be given in the following priority areas within each discipline (Table 7.1).

Besides, research on farm economics and post-harvest management is also needed. We know that adoption of any crop variety depends on many factors, but profitability is considered as the prime factor of adoption. The cultivation of maize is profitable compared to other crops like wheat or *Boro* rice. But the indicators of profitability can be changed quite sharply. If the price of different inputs increases or if the price of wheat/rice increases what will happen to maize cultivation? So, profitability of maize needs to be analyzed in different situations and areas on a continuous basis. In Bangladesh, summer maize is generally harvested in rainy season. Farmers do not get enough sunlight for drying. As a result, they receive lower price. Hence, an easy and cheap technology package for drying needs to be developed.

Table 7.1 Priority researchable areas/issues for maize

Thematic areas	Researchable areas/issues	Priority ranking	Research duration
1. Maize production (Varietal improvement)	1.1. Development of disease resistant hybrids (QPM)	High	Long
	1.2. Development of abiotic stress tolerant hybrids	Medium	Long
	1.3. Development of short-stature maize to withstand lodging due to high wind	High	Long
	1.4. Development of Mg, B, Mo, Zn efficient inbred and hybrids	Medium	Long
	1.5. Development of pop corn and sweet corn hybrids	Medium	Long
	1.6. Hybrid seed production & preservation	Medium	Short
	1.7. Molecular characterization of varieties and inbred	Medium	Long
2. Maize production (Management practices)	2.1. Develop maize based cropping pattern to sustain and improve soil fertility	High	Medium
	2.2. Introduction of maize after T. Aman rice in new areas, especially in the southern Bangladesh	High	Medium
	2.3. Develop and refine improved management packages for high yield goal on regional basis	High	Medium
	2.4. Determination of optimum planting time for maximum seed setting of inbreeds and F1s	High	Medium
	2.5. Seed quality research, seed health, vigour, seed abnormality etc. in storage.	High	Medium
3. Maize protection (Disease & insect-pests)	3.1. Surveillance of diseases and insect pests and new races of disease pathogens	High	Long
	3.2. Cultural, chemical and integrated control of major disease and insect pests, if any	High	Short-Medium
	3.3. Molecular characterization of disease pathogens	Medium	Long
	3.4. Screening for QPM with high carotene and minerals for human consumption	Medium	--
4. Biotechnology	4.1 Molecular characterization (finger printing) of varieties and inbred lines	High	Long-Medium
	4.2 Marker Assisted Selection to identify and tag molecular markers for taints of interest.	High	Long-Medium
	4.3 Gene mapping and sequencing for desirable, agronomic traits and biotic and abiotic resistant gene	High	Long-Medium
	4.4 Haploid breeding for development of homozygous inbred lines	Medium	Long-Medium
5. Farm machinery	5.1 Small scale farm machinery should be improved, weeder, furrower	High	Short-Long-Medium
	5.2 New entrepreneur should develop to enhance fabrication of machinery	High	Long-Medium
	5.3 Development of drier for maize, especially for kharif season.	High	Medium
6. Seed technology & food processing	6.1 Seed quality research (seed viability on storage, seed health, seedling vigour associated with seed vigour, seedling abnormality etc	--	Long-Medium
	6.2 Strengthening Hybrid seed production	--	Short, Long & Medium
	6.3 Blended food and bakery product development	High	Short-Medium
	6.4 Screening for QPM with high carotene and minerals for human consumption.	High	Short-Long-Medium

Source: *www.barc.gov.bd/documents/Research_Priorities_Bangladesh_Agriculture.pdf*
www.barc.gov.bd/documents/Final-Prof.Jahir.pdf

7.3.1 Relative role of private and public sector in R&D of maize

In Bangladesh, different research institutes, public universities, and development organizations including NGOs are carrying out agricultural research. Bangladesh has ten public research institutes under the National Agricultural Research System (NARS). The NARS system is linked to the Ministry of Agriculture, Fisheries and Livestock, Environment and Forests, and Commerce. All institutes except Bangladesh, Forest Research Institute now operate under Acts/Ordinances that give them limited autonomy. These institutes highly concentrate on technical research, such as plant breeding, soil analysis, seed production, etc. (Quasem and Yasmin 2010).

The introduction of agricultural technology by private companies is increasingly important for the development of agriculture. Bangladesh has been gradually easing the regulations that are not conducive to involve the private sectorin agricultural research, development and innovation. The USAID supported Agro-based and Technology Development Projects I and II during 1996-2005 may be the pioneer attempt to expand private agricultural innovation. The World Bank supported the Krishi Gobeshona Foundation (KGF) to fund private and public agricultural research. A survey of 51 private organizations in Bangladesh, which was carried out by Rashid et al. (2012), showed that private agricultural R&D has been expanding rapidly. Importation and marketing of some items, such as seeds of rice, wheat, potatoes, jute, and sugarcane are regulated by the government. For non-notified crops like maize, private companies have introduced hundreds of cultivars, but there is no centralized record of what has been introduced. A survey of seed stores throughout Bangladesh found 70 maize hybrids, mostly coming from China, India, and Thailand, only 1 or 2 were introduced through local breeding (Rashid et al. 2012).

Rashid et al. (2012) also stated the following:

> Shortly after the government of Bangladesh removed controls on the introduction of new cultivars for all but five crops (GoB 1993), private companies and NGOs began to introduce maize hybrids from Thailand and other countries, later supplemented with some in-country breeding. Some of the larger private seed research programmes not only assessed imported cultivars, but also breed new hybrids and varieties from both imported and local genetic material. BRAC has developed a popular maize hybrid from imported lines. With private hybrids, maize yields increased from an average of less than 1.0 ton per hectare for several decades through 1992 to more than 6.0 tons per hectare in 2010. Maize yields in Bangladesh exceed yields in China and Japan (Bødker and Thorp 2006). Maize production spread onto land that had been used for wheat. The increase in net income from private hybrids can be estimated by assuming that farmers replace wheat with maize. With this assumption, farmers planting maize on 202,000 hectares in 2010 realized an estimated USD 125 million in additional net income.

Government based agricultural research in Bangladesh is coordinated by BARC. Government agencies and donors have multiple points of contact with private organizations through which they can influence private innovation and R&D. Agricultural research has been mainly depended on donor financing, particularly in terms of World Bank loans, which facilitated considerable investments in infrastructure and equipment. Private organizations look to public agencies not only for money, but also for technical assistance. Science-based companies look to the government to provide scientists. Companies not only recruit entry-level technical staff from public universities, but also engage public-sector scientists as consultants, and often hire them away midcareer, or recruit them after retirement. Although in recent time, Bangladesh’s agricultural research capacity has deteriorated in terms of researcher numbers as a result of the brain drain of the qualified and experienced researchers. The private sector has minimal input into agricultural R&D in Bangladesh. Only BRAC is increasing investment in research and development over time. The government has established programmes to assist private R&D, but there is room for improvement. Currently, BARI assists different private seed companies and NGOs, such as Supreem Seed, Monsanto, ACI, and BRAC in the areas of human resource development and imported germplasm evaluation. This collaboration among private organizations and BARI may be strengthened to foster the development of improved maize germplasm.

Chapter VIII

CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

Agriculture is the backbone of the economy of Bangladesh. But agricultural land is the scarcest means of production in Bangladesh. To overcome this situation, agricultural lands should be utilized more efficiently through cultivating high yielding crops like maize. Maize is playing an important role in the agrarian economy of Bangladesh. The area under maize cultivation is increasing day by day due to high demand. Besides, the genetic yield potential of maize is also very high. There is an ample scope of increasing the current yield and production in the country. Maize can be used as food for ensuring food security presently as well as in future increasing population of the country.

During the last decade, highly impressive growth rates with low instability were registered in maize area and production due to the expansion of poultry and fish farming across the country. More than 80 per cent of the maize is grown in the winter season of Bangladesh although area under summer maize increased to 9.8 per cent in 2013. Maize is relatively more profitable compared to other cereal crops. Therefore, maize growers are currently fitting maize with a widening range of other traditional crops, such as potato, jute, and various vegetables which augment the chance to increase maize production and ensure food security for the population of the country.

Both the public and private sectors are involved in supplying maize seeds to the farmers. Maize growing areas are now mostly covered by a wide range of exotic hybrid varieties of non-QPM type. Only 14.2 per cent of total seed requirement was produced locally in 2012-13. BADC along with private traders are responsible for purchase and import of different chemical fertilizers which improved the availability and wider adoption of chemical fertilizers at farm level. Along with public organizations many actors in the private sector have entered into agricultural R&D. The PBD of BARI is now leading the maize research in Bangladesh. More research and collaboration between private and public sector need to be established to ensure the availability of quality hybrid maize seed and reduce the import of hybrid varieties.

Maize is used as different types of foods for human consumption, feed for poultry and fish, fodder for livestock, and starch for industrial use. Currently most of the maize is used as poultry and fish feed. Maize use increased at the rate of 9.17 per cent per year. A different scenario is found in hill tracts of Bangladesh where 45 per cent of the growers produce maize only for own consumption. Different maize based food items need to be demonstrated through mass media to increase awareness and to popularize maize based human food items. Farmers' net shares to the consumers' price ranged from Tk 76.4 to Tk 78.3 (USD 0.98- USD 1.00) per quintal in different marketing channels. The study shows that the period March-July is the peak period of domestic maize trade in Bangladesh. Government may need to introduce procurement plan for maize during the peak period to ensure a fair price of maize.

The future prediction shows that maize cultivation in 2023 might be 41.8 per cent, 45.1 per cent, and 37.1 per cent higher in terms of area, production, and yield, respectively compared to 2013. Future climate change, especially temperature rise may be detrimental to maize production to some extent although maize can tolerate temperature up to 35^0C. Future policy planning must be focused on diversified consumption of non-rice based cereal. Wheat and maize alone or together can play a vital role in cereal consumption diversification. Both government and donor agencies should come forward to invest in maize R&D activities for Bangladesh.

SWOT analysis was used to explore the constraints and investment opportunities put behind the R&D of maize in Bangladesh. The analysis identified different strengths and opportunities in maize cultivation like land availability, wide range of growing seasons, availability of improved production technology, bring potential areas under cultivation, establishment of starch plants, development of water logging and saline tolerant varieties, development of quality protein maize varieties, etc. In addition, there are also some weaknesses and threats in maize cultivation like poor quality and higher price of seed, adulteration in fertilizers, heavy dependency on poultry and fish industries, climate variability, high dependency on importation of hybrid seeds, etc. Overall findings of the SWOT analysis suggested that the strength and opportunities of maize cultivation in Bangladesh outweigh the weaknesses and threats in maize cultivation. Based on the findings, different steps and measures discussed in the recommendation section should be taken into consideration to enhance maize production in the country.

8.2 Recommendations

The following recommendations can be drawn to improve the performance of the maize sector in Bangladesh.

8.2.1 Initiatives for higher production

To increase the maize production the following measures can be taken.

***Quality seed production*:** Seed is the major input which has a significant effect on yield. At present (2012-2013), only 17.5 per cent of the hybrid maize seed requirement is met up locally and rest of the requirement is fulfilled by import which requires huge amount of foreign exchange. Among different government organizations, only BADC produces hybrid seed of BARI developed varieties. Among different NGOs ACI, BRAC, and Supreme Seed also produce some hybrid maize seed in the country. However, more care is needed by BADC to improve seed quality.

Government should encourage and support different private organizations to produce hybrid maize seeds. The supports may be tax reduction for importing maize breeder seed and provision of incentives for maize seed production. This initiative can increase the availability of locally produced seed and reduce the price of hybrid seed. Resumption

***Proper use of fertilizers*:** Hybrid maize needs adequate fertilizer for higher production. To encourage the use of balanced fertilizers, chemical fertilizers must be integrated with organic manures and subsidy benefits for non-urea fertilizers should continue. Timely supply of fertilizers should receive top priority to ensure higher production of maize.

***Bring suitable land under maize cultivation*:** SWOT analysis shows that Bangladesh has a huge amount of accessible land in *Char* and saline areas which can be brought under maize cultivation. Currently, farmers are growing maize successfully in the *Char* areas, but due to lack of saline tolerant varieties, they face problem to grow maize successfully and exploit its full potential in saline areas. Concerned authorities (e.g., BARI, BINA, Agricultural Universities, etc.) need to develop suitable varieties for these areas.

***Credit for input*:** Farmers do not have enough access to formal sources of credit. Government must take some actions so that the farmers have an access to the credit of the institution without any collateral requirement. In this case, government can follow the strategies followed by Grameen Bank or any other similar NGOs working in Bangladesh. The credit should be disbursed before planting time and realized at the end of the cropping season or after the harvest of the crops.

***Strong extension linkage*:** Extension contact plays a significant role in achieving higher production. Through regular extension contact, farmers can receive information regarding production technology, new varieties, etc. So far, BARI has developed improved production technologies for maize cultivation. But the adoption of these technologies is low in Bangladesh. At present, the government has an extension network throughout the country for the diffusion process. Now local level authority should take administrative (right time promotion, reward for good deeds, demotion for negligencies in duties, etc.) measures so that the present extension system of the country provides technological information more effectively and efficiently at farm level.

***Training for the farmers*:** Massive and relevant training programmes should be undertaken for maize growers to increase/ raise their awareness and understanding of the use of different production technologies. Different government and non-government organizations should be involved in conducting different trainings on maize production. Arranging more *whole families* training programmes can be useful in this regard.

Promotion of intercropping and relay cropping: Intercropping and relay cropping of maize are very much profitable and acceptable to the resource poor farmers. Therefore, such diversified and highly profitable systems should be promoted throughout the country.

8.2.2 Development of marketing and processing system

The following measures may be taken to ensure effective and efficient maize marketing.

Development of marketing infrastructure: A strong network of physical market is required for the efficient flow of information of market demand position and price discovery. Physical assembling market, especially for food grains (i.e., rice, wheat, and maize) can be established in each *Upazila* and the market can be operated twice a week. It will help farmers selling their products with fair price.

***Construction of concrete roads*:** Most of the rural areas of Bangladesh are generally lacking of concrete roads and good transportation facilities. Due to these reasons, most of the farmers face higher transportation cost to bring the crop to the urban markets and receive lower profits. In this context, government should construct concrete roads in the rural areas and connect those to the urban markets for reducing transportation problems to a certain levels.

Provide storage and credit facilities: Maize needs to be stored from one harvest to the next in order to maintain its constant supply all year round and to preserve its quality until required for use. Successful farm storage enables farmers to sell maize when prices are most attractive.

Currently, the differences of seasonal price of maize are high due to a lack of adequate storage facilities. Government can provide improved storage facilities at *Upazila* level, and provide credit to small, medium, and marginal farmers against their stored gains. The Directorate of Agricultural Marketing (DAM) launched a special crop marketing programme (Shogorip) for small and marginal farmers in some selected areas of Bangladesh. This programme has been largely successful in providing storage and credit facilities to the poor growers. This programme needs to be intensified in maize growing areas to ensure the stability of prices and sustainability of maize production at the farm level.

Supply of inputs at subsidized rate: Quality seed, fertilizers, irrigation, and pesticides are the important inputs of maize. Farmers of Bangladesh almost all the time face the problem of capital. As a result these inputs need to be supplied at subsidized rate to increase the acreage under maize cultivation.

Introduction of public sector procurement: The production of maize has shown prospective results in the last two years. Maize has also gained popularity as human food to some extent side by side with the poultry feed. Public sector procurement of maize should be introduced like rice and wheat in order to ensure fair price of maize for the farmers. Appropriate procurement policy will help stabilizing maize price and farmers' interest toward maize production that will increase the area and production of maize throughout the country.

Involvement of mass media**:** Timely and accurate information regarding product availability, demand, and price plays a vital role in achieving higher profit for the growers. Using radio and different local television channels may be more beneficial to disseminate information like commodity stock, prevailing market price, etc. to ensure a fair price of maize.

Establishment of maize based industries for human consumption**:** Now-a-days, maize is grown in most of the areas of Bangladesh. But most of these maize is used for poultry feed. Concerned authorities should take necessary action to popularize maize as human food. In this context, existing flour mills in the country may be oriented to the production of mixed flour with wheat and maize. In order to encourage increased human consumption of maize flour, special motivational programme (e.g., drama, short film, advertisement, etc.) may be initiated in the state media like television and radio. Government should encourage the private sector to build up maize based industries for the production of starch, flakes, corn oil, etc. Credit and exemption of taxes on equipment and machinery for these industries should be introduced by the government.

Improvement in post-harvest operation management**:** Most of maize growers of our country use traditional methods for drying and shelling maize. Thus a huge quantity of maize is lost in the traditional post-harvest activities. Mechanical shellers and low-cost driers can play an important role in this aspect. Concerned authorities (i.e., BARI, DAE) should ensure the availability of these machineries at farm level so that the growers can use this technology to improve their post-harvest operation management.

Initiative for value addition and capturing: A substantial value addition at producer and national level is possible through promoting speciality corns in the assured market. Again, promotion of the production and consumption of fortified maize-based products can also create value addition. Therefore, market should be developed for specialty corn in rural areas and organised food festival with micro-nutrient fortified maize-based products through government or any other agencies in Bangladesh.

8.2.3 Creating favourable environment for maize export

Bangladesh Government currently provides limited support on maize export because Government has to balance the interests of maize farmers, local feed producers, poultry farmers, and the consumers of maize and maize related products. The Secretary General of MAB opined that government should facilitate friendly environment for maize export so that maize growers, traders, feed producers, and poultry farmers get benefit simultaneously.

Although Bangladesh is a net importer of maize, the following steps may be taken into consideration for creating favourable environment for maize export.

Friendly government policy: Bangladesh Government has given permission to export maize at the minimum prices of USD 325 and above per ton. With this price, exporters can't export maize because the world price is lower than this fixed price. In 2012, most exporters exported maize to Malaysia, Indonesia, Nepal, and Saudi Arabia at lower prices that ranged from USD 280 to USD 300 per ton, which is a clear violation of the government rules. So, government should formulate appropriate and practical policy for maize export.

Pre-assessment of production and export quantity: Excess export of maize may be harmful to local feed producers and poultry farmers. In this context, government may estimate total local demand and supply of maize before its harvesting on a regular basis. Based on this estimation, Government can fix and declare total amount of maize being allowed for export. The quantity of export may be monitored jointly by MAB and Government authorized agencies.

Ensure product quality: Ensuring product quality is a pre-requisite for sustainable maize exports. Cheating buyers in terms of product quality makes export business difficult which in turn is also detrimental to the economy of a country. Therefore, Government in association with MAB can take appropriate measures in order to protect those exporters who malpractice in exporting maize.

8.2.4 Strengthening maize research

Since investment in agricultural research is highly rewarding and beneficial, the Government should raise the investment in agriculture to at least 2 per cent of GDP as recommended by World Bank and FAO. Different private and public organizations have been conducting research to generate suitable technologies to sustain maize production and increase maize productivity at farm level. The concerned BARI scientists have given emphasis on the following research areas.

- The Government should support BARI, private companies, and NGOs to develop their own hybrid variety programmes of maize within the country.
- Development of short-duration, dwarf, water logging, drought, and saline tolerant maize varieties with high grain yield potential should be given priority in Bangladesh. Water logging tolerant varieties would create great opportunity to cultivate *Kharif* maize in different areas, while drought tolerant variety will help enhance the area under winter maize cultivation. Saline tolerant varieties will expand maize cultivation in the saline regions.
- More QPM, fortified, micro-nutrient enriched, and sticky maize varieties should be released to ensure the supply of higher quality protein for human consumption as well as for poultry industries.
- More research should be taken to develop low-cost driers for *Kharif* maize.
- Post-harvest research should be strengthened for developing quality maize food and diversifying maize consumption.

8.2.5 Strengthening international collaboration

Collaboration with international research institutes and donor agencies is very much important for maize research and development in Bangladesh. Therefore, current collaboration with CYMMIT and other organizations may be strengthened in the following areas.

- Maize germplasm exchange with foreign agencies, like CYMMIT.
- Increase investment in the research and development of maize. It will certainly encourage scientists to develop suitable maize technologies.
- Human resource development

8.2.6 Policy interventions

The main task of maize technology generation in Bangladesh should be shouldered by BARI in association with international organizations like CIMMYT. Besides, some existing polices need to be reconsidered by the Government for better results.

Clarity of public and private sector roles: Although the seed sector in Bangladesh achieved remarkable growth rate over time, a large part of the seed market still lies in the informal sector. The informal system of seed trade falls outside any legal or quality-monitoring system. Although the seed sector has opened the avenue for the private sector, there is not much clarity in the legislations about the overall strategy for the seed sector and the balance of function between the public and private sectors. Therefore, public and private sector roles should be clearly defined and a stable policy needs to be formulated to attract the national private sector to the seed industry.

Establishment of testing laboratories: The fertilizer sector in Bangladesh faces several challenges like sales of fake fertilizers, price hike of fertilizers, etc. With the advancement of private fertilizer marketing, the availability of quality fertilizers has always been an issue of concern. Despite attempts to regulate fertilizer quality through district committees, high rates of fertilizer adulteration continue to be a fact. To overcome this problem, Government may establish simple laboratories at major entry points to test fertilizers imported into the country and make it mandatory for every consignment to go through the test.

Improvement of research and extension linkage: With the adoption of the New Agricultural Extension Policy (NAEP), Bangladesh underwent a major shift in its extension policy. But still the link between research and extension is very weak. Therefore, Government needs to take some steps to improve this linkage. In this perspective, researchers may be involved from the early stage in extension planning. Government may advise different NGOs and BARI along with DAE to start their own extension programme to inform the farmers about their own hybrid maize varieties and modern production technologies.

Encouraging farmers' cooperatives: Since agricultural production is very expensive and risky, often it is not possible for the farmers to grow crops profitably at the individual level due to the shortage of required labour and capital. Therefore, the government should encourage the formation of self-motivated cooperatives for producing and marketing agricultural commodities which should ideally succeed in mobilizing adequate resources (including labour and capital) for more production, income, and equity.

8.2.7 Areas of future studies

Besides varietal improvement research of maize, the following socio-economic studies related to maize production, consumption, and marketing need to be implemented.

1. An in-depth economic study on maize production in Bangladesh.
2. Assessment of demand and supply of maize in Bangladesh.
3. In-depth value chain analysis of maize in Bangladesh.
4. Study on the impacts of hybrid maize cultivation on the livelihood development of the poor farmers in Bangladesh.
5. Economic analysis of hybrid maize seed production for small and medium enterprises.
6. Study on the implications of adoption of hybrid maize production for women's and children's labour in the field, post-harvest, and processing levels.

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Appendix

A-1: Snapshots on Focused Group Discussion

FGD$_1$. Discussion with BARI scientists of different disciplines

FGD$_2$. Discussion with the representatives of different seed companies

FGD$_3$. Discussion with Secretary, MAB

FGD$_4$. Discussion with President, FIAB

FGD$_5$. Discussion with extension personnel, farmers, traders, millers, sheller operator, input seller at Ghoraghat, Dinajpur district

FGD$_6$. Discussion with extension personnel, farmers, traders, millers, sheller operator, input seller at Nawbabgonj, Dinajpur district

FGD$_7$. Discussion with extension personnel, farmers, traders, millers, sheller operator, input seller at Sadar *Upazila*, Chuadanga dist.

FGD$_8$. Discussion with extension personnel, farmers, traders, millers, sheller operator, input seller at Damurhuda, Chuadanga district

A-2. Current price (year 2013) of inputs and output of maize for different districts

Input/output	Study area								All area
	Bogr a	Chuad -anga	Dinaj -pur	Lalmo- nirhat	Kishor egonj	Dhaka	Rangpur	Kustia	
Inputs									
H. labour (Tk/m-d)	250	250	300	200	200	200	200	250	227
Tillage cost (Tk/ha)	5,239	4,692	5,614	5,988	4,491	4,117	4,892	7,485	5,315
Seed (Tk/kg)	300	310	260	260	250	174	300	320	267
Cowdung (Tk/ton)	500	500	500	500	500	0	500	500	471
Urea (Tk/kg)	20	20	20	20	20	20	20	20	20
TSP (Tk/kg)	25	25	25	25	25	25	25	25	25
MoP (Tk/kg)	16	16	16	16	16	16	16	16	16
Gypsum (Tk/kg)	8	8	8	9	0	8	0	0	8
Zinc sulphate (Tk/kg)	120	120	120	120	0	0	120	120	128
Borax (Tk/kg)	160	160	160	160	0	0	160	0	149
Pesticides (Tk/ha)	1,497	898	1,310	1,123	0	524	1,123	1,871	1,043
Irrigation (Tk/ha)	3,742	5,239	6,785	2,994	2,620	2,994	4,117	5,614	4,263
Output price									
Price (Tk/kg)	14.5	13.75	13.25	14.8	16.15	17.25	14.15	14.25	14.76

Source: Collected from SAAO and farmers over telephone during 2013
Conversion rate 1 USD = 78.0 BDT

A-3: Area, production and yield of maize in Bangladesh

Year	Area (ha)	Producton (ton)	Yield (t/ha)
1988-89	3,567	3,359	0.94
1989-90	3,300	3,300	1.00
1990-91	3,110	3,000	0.96
1991-92	3,600	3,000	0.83
1992-93	5,060	7,000	1.38
1993-94	6,400	15,000	2.34
1994-95	9,940	29,100	2.93
1995-96	10,130	32,000	3.16
1996-97	12,670	40,700	3.21
1997-98	14,930	65,300	4.37
1998-99	18,490	84,500	4.57
1999-00	16,710	74,900	4.48
2000-01	17,600	79,700	4.53
2001-02	30,050	64,300	2.14
2002-03	29,060	117,300	4.04
2003-04	50,050	241,400	4.82
2004-05	68,040	356,200	5.24
2005-06	98,440	522,800	5.31
2006-07	150,899	1,002,150	6.64
2007-08	222,336	1,343,436	6.04
2008-09	174,000	1,137,000	6.53
2009-10	202,000	1,370,000	6.78
2010-11	227,060	1,552,267	6.84
2011-12	286,874	1,956,501	6.82
2012-13	312,566	2,183,183	6.98

Sources: DAE, http://www.moa.gov.bd/statistics/bag.htm, and FAOStat (only data of 1988-89)
Note: Due to inconsistancies, area and production for the years 1999/00 and 00/01 have been generated through 2-year moving average.

A-4: Test of stationarity or non-stationarity for the original and the first difference data of area production and yield of maize

Item	Method used	Condition used	Intercept	Coefficient of P_{t-1}	Coefficient of ΔP_{t-1}	Coefficient of trend (t)	d-value	Decision
			β_1	δ	α_1	β_2		
AREA	**Original of area**							Non-stationary
	DF	With constant & trend	-14893.1	-0.060 (-0.589)		2363.814	2.555	
	ADF	1 lagged difference with trend	-17864.1	-0.048 (-0.406)	-0.145	2613.412	2.043	
	1st difference of area							Stationary
	DF	With constant & trend	-14051.0	-1.183 (-5.382)		2125.386	2.053	
	ADF	1 lagged difference with trend	-17704.3	-1.352 (-3.716)	0.140	2477.436	2.102	
PRODUCTION	**Original of production**							Non-stationary
	DF	With constant & trend	-84329.3	0.003 (0.032)		12892.198	1.981	
	ADF	1 lagged difference with trend	-104476	-0.013 (-0.132)	0.020	14516.469	2.007	
	1st difference of production							Stationary
	DF	With constant & trend	-97600	-993 (-4.468)		13701.559	2.009	
	ADF	1 lagged difference with trend	-133513	-1.247 (-3.813)	0.246	17242.163	2.095	
YIELD	**Original of yield**							Non-stationary
	DF	With constant & trend	0.457	-0.645 (-3.130)		0.176	1.928	
	ADF	1 lagged difference with trend	0.474	-0.697 (-2.637)	0.083	0.189	2.022	
	1st difference of yield							Stationary
	DF	With constant & trend	0.425	-1.269 (-5.908)		-0.007	2.073	
	ADF	1 lagged difference with trend	0.575	-1.445 (-3.911)	0.132	-0.013	2.058	

Note: Figure within brackets show t-values of the regression coefficients, n=25
Dickey-Fuller Critical values at 1% and 5% are: Without a constant: -2.66 and -1.95, respectively; with a constant: -3.75 and -3.00, respectively; with a constant and trend: -4.38 and -3.60, respectively (Gujarati 2004, p.975).

A-5. Auto generation of *p*, *d* and *q* values for predicting area, production and yield of maize

Models	Akaike Information Criterion (AIC)	Schwarz Criterion (SC)	Durbin-Watson Statistic (DW)	Number of Iterations
AREA				
P=0, D=1, Q=1	22.9959	23.2608	1.9622	9
P=1, D=1, Q=0	**22.0223**	**22.2949**	**2.0298**	**10**
P=2, D=1, Q=0	23.0431	23.4646	1.9962	11
PRODUCTION				
P=0, D=1, Q=1	26.5864	26.8512	1.9267	8
P=1, D=1, Q=0	**25.4425**	**25.7152**	**2.0325**	**7**
P=2, D=1, Q=0	26.6330	27.0545	2.0175	9
YIELD				
P=1, D=1, Q=0	**2.1719**	**2.4445**	**2.0690**	**7**
P=0, D=1, Q=1	2.1987	2.4635	1.8090	6
P=2, D=1, Q=0	2.2873	2.7088	2.0438	10

A-6: Relevant information for analyzing ARIMA for 10 years prediction of area , production and yield of maize

	Area (1,1,0)		**Production (1,1,0)**		**Yield (1,1,0)**	
Regression Results						
	Intercept	AR(1)	Intercept	AR(1)	Intercept	AR(1)
Coefficients	12194.1064	0.1017	65035.4228	0.3502	0.3283	-0.2663
Standard Error	5912.2616	0.2170	36076.0134	0.2067	0.1729	0.2101
t-Statistic	2.0625	0.4685	1.8027	1.6944	1.8989	-1.2674
p-Value	0.0517	0.6443	0.0858	0.1050	0.0714	0.2189
				Area	**Production**	**Yield**
Regression Statistics						
Akaike Information Criterion (AIC)				22.0223	25.4425	2.1719
Schwarz Criterion (SC)				22.2949	25.7152	2.4445
Log Likelihood				-253.26	-292.59	-24.98
Durbin-Watson (DW) Statistic				2.0298	2.0325	2.0690
Adjusted R-Squared				-0.0368	0.0784	0.0268
F-Statistic				0.22	2.87	1.61
RMSE				24165.93	144432.99	0.7530

A-7: Test of Stationary/Non-stationary through Auto Correlation Function (ACF) and Partial Auto Correlation Function (PACF)

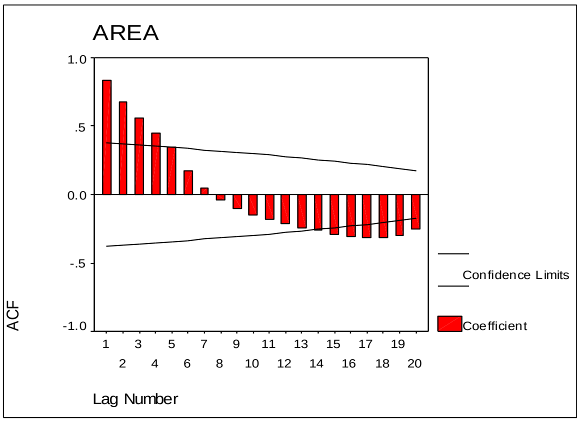


Fig 1: ACF of area-original

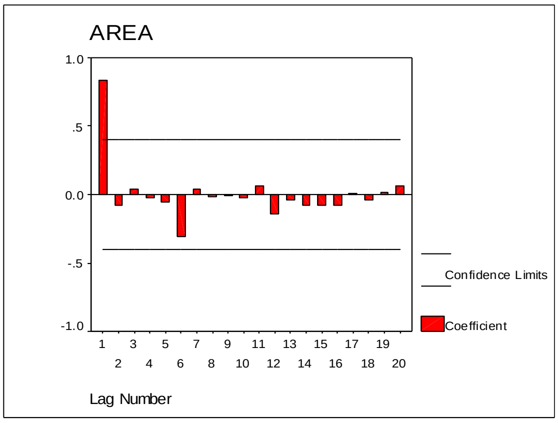


Fig 2: PACF of area-original

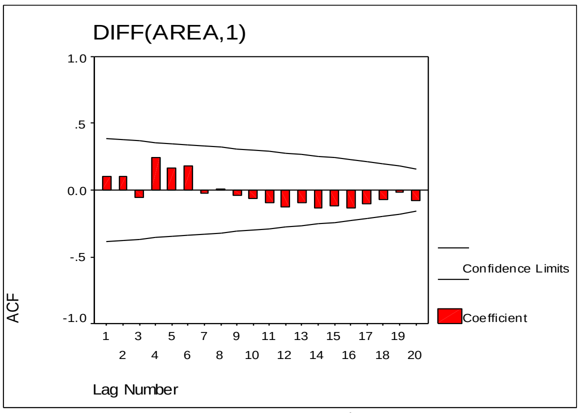


Fig 3: ACF of area-1st difference

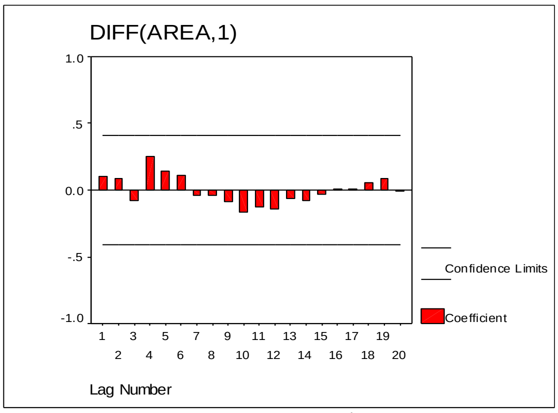


Fig 4: PACF of area-1st difference

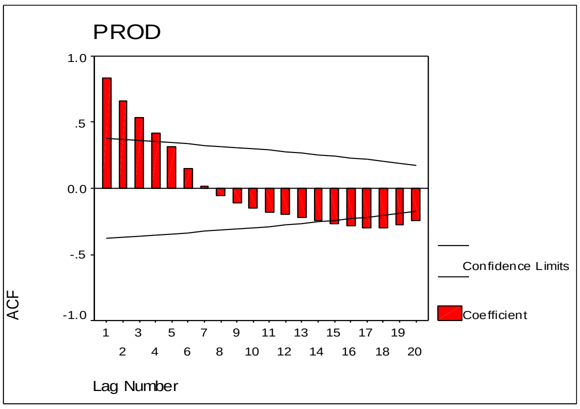


Fig 5: ACF of production-original

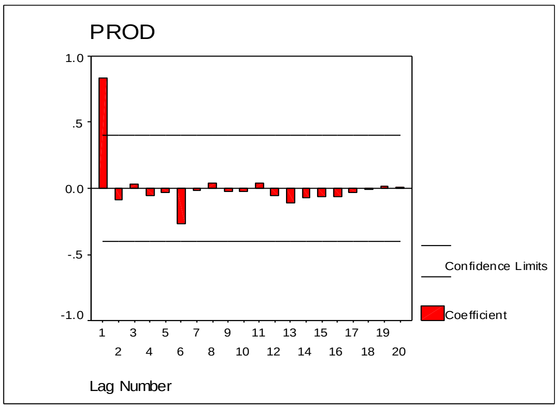


Fig 6: PACF of production-original

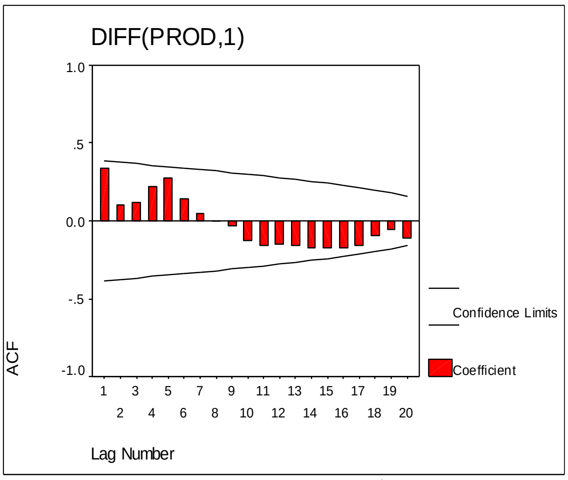


Fig 7: ACF of production-1st difference

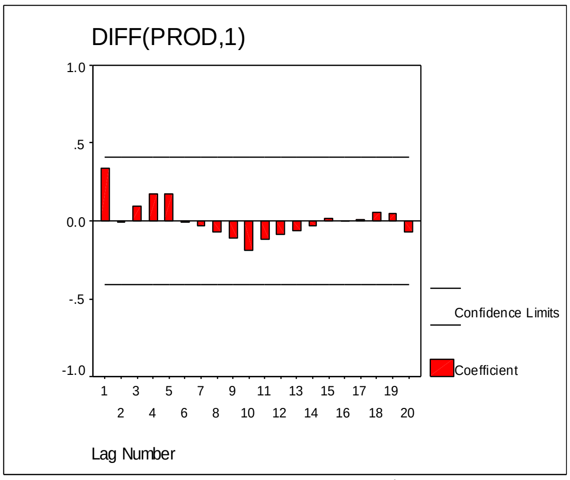


Fig 8: PACF of production-1st difference

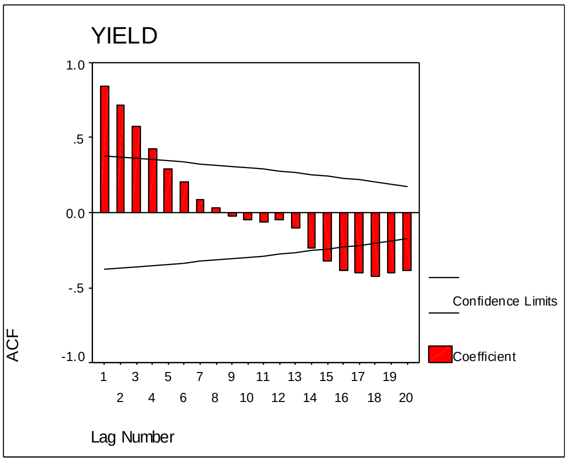


Fig 9: ACF of yield-original

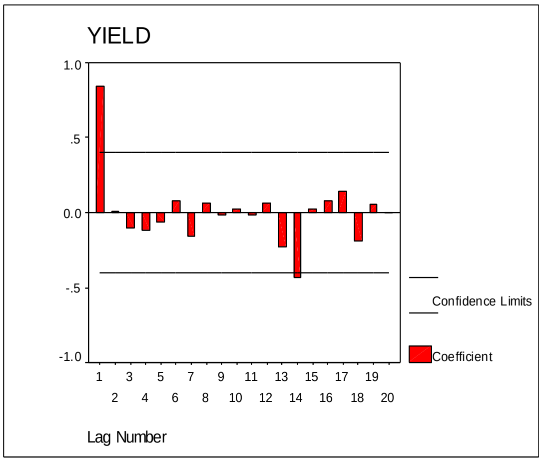


Fig 10: PACF of yield-original

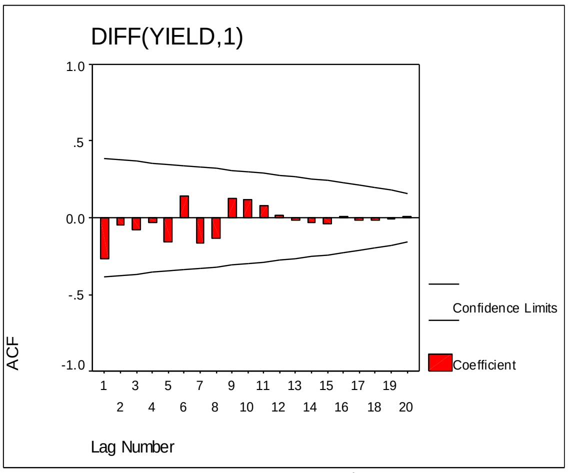


Fig 11: ACF of yield-1st difference

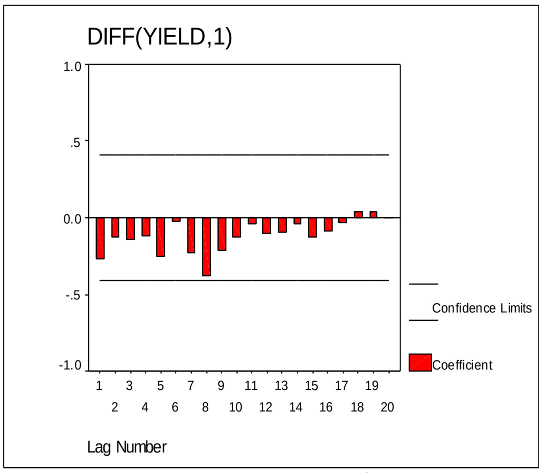
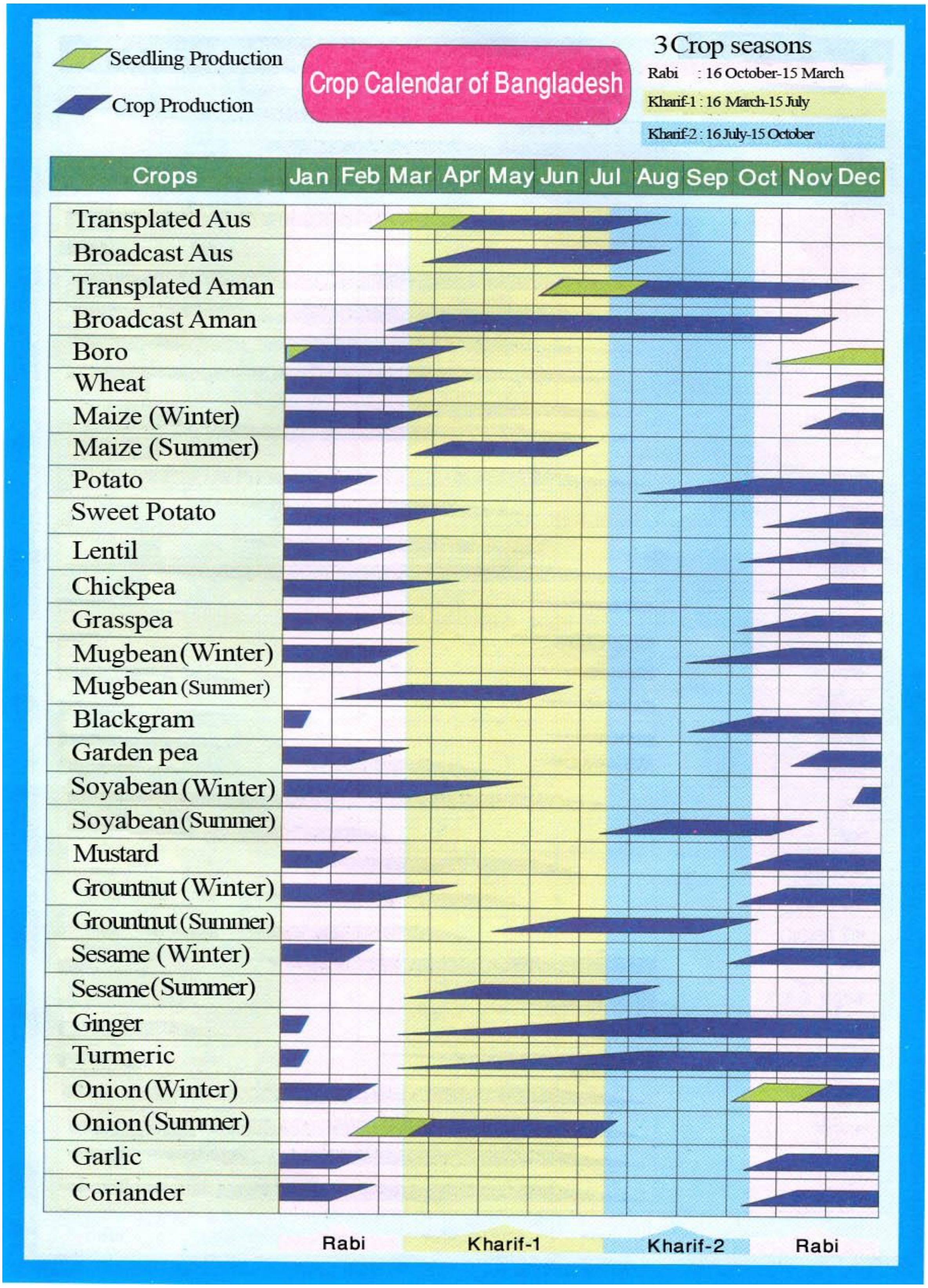


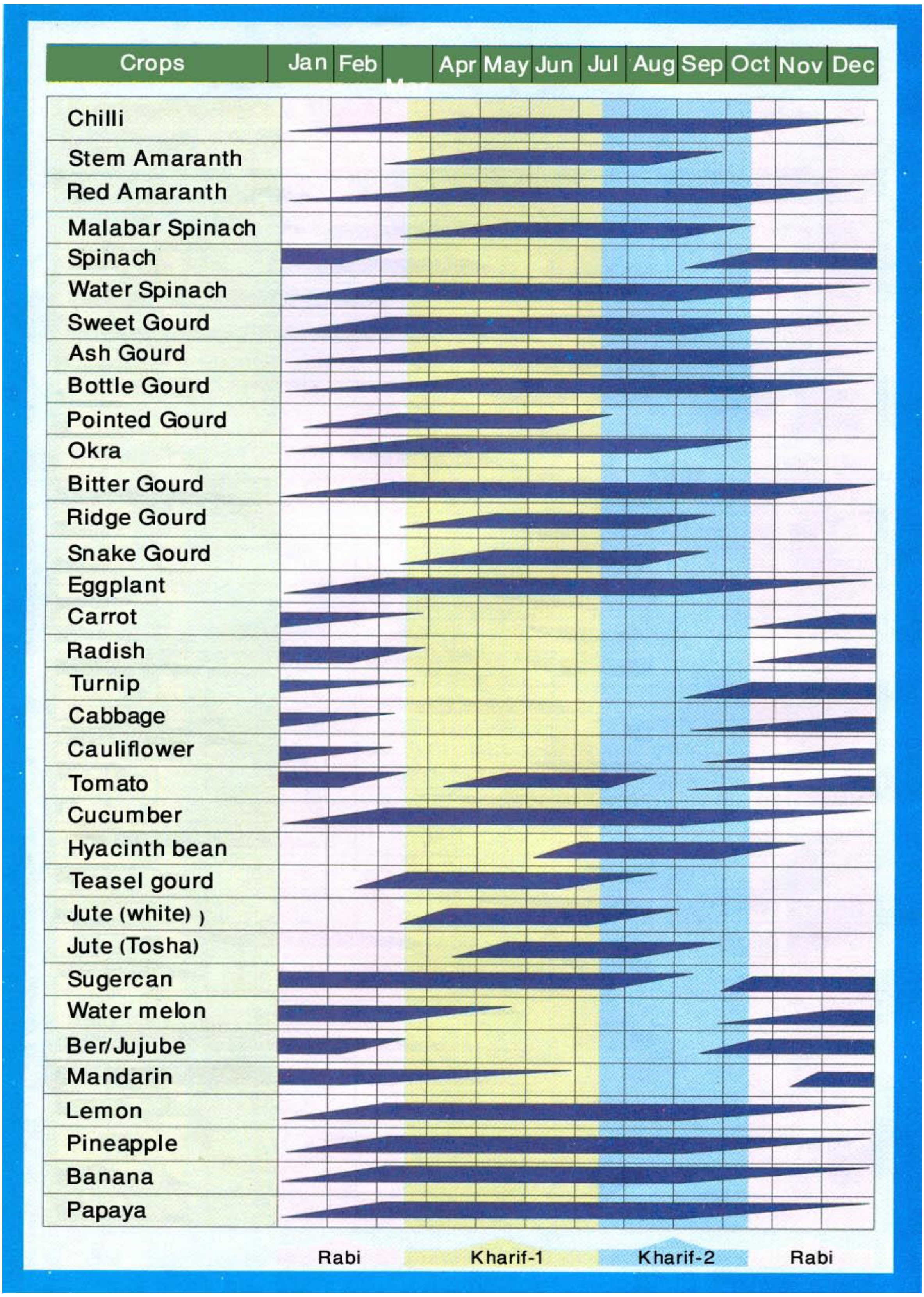
Fig 12: PACF of yield-1st difference

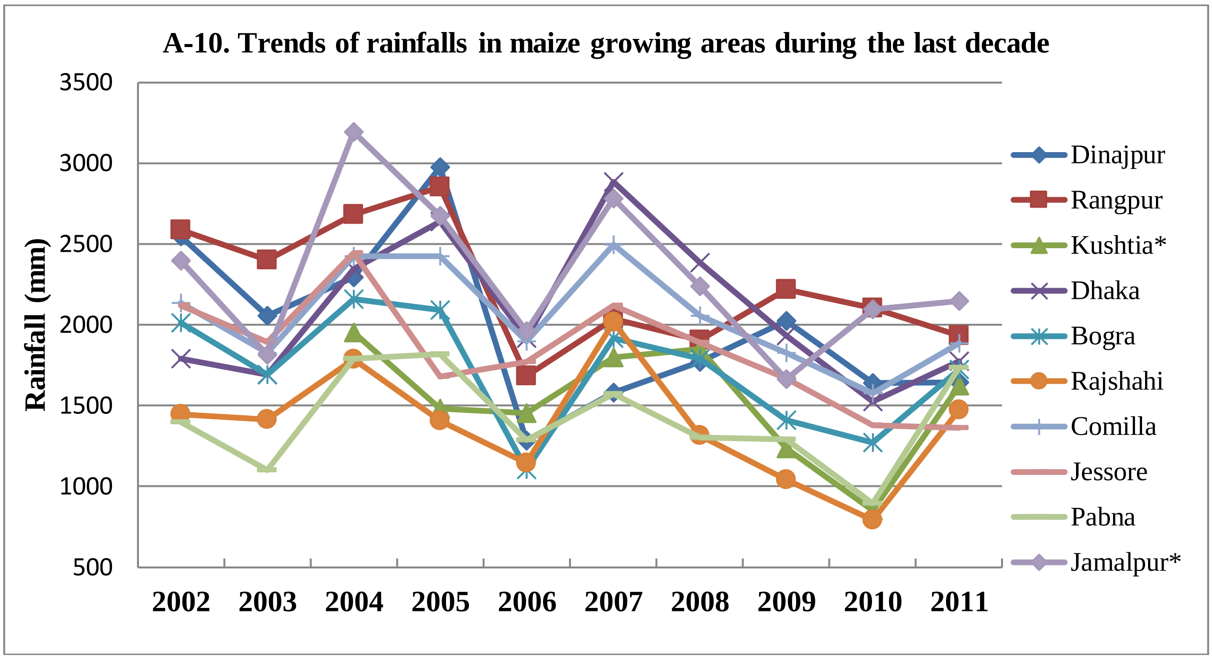
A-8. Growth and instability of maize area, production and yield at division level of Bangladesh, 1990-2011

Division	Area (ha)		Production (tone)		Yield (t/ha)	
	Growth (%)	Instability (%)	Growth (%)	Instability (%)	Growth (%)	Instability (%)
	Period I (1990-1999)					
Dhaka	-11.8	45.88	-8.5	40.13	3.30	5.62
Chittagong	-4.50	15.56	-4.4	15.52	0.10	3.54
Rajshahi	-11.1	20.71	-7.9	27.56	3.30	8.14
Rangpur	15.9	12.12	18.3	20.08	3.00	12.11
Khulna	11.2	34.85	10.80	37.86	-0.40	7.38
Barisal	--	--	--	--	--	--
Sylhet	--	--	--	--	--	--
Bangladesh	-3.7	13.04	-2.6	13.28	1.00	3.10
	Period II (2000-2011)					
Dhaka	26.00	7.35	31.96	8.84	5.96	4.39
Chittagong	13.49	2.26	28.61	4.29	15.12	3.78
Rajshahi	36.04	20.90	48.76	24.61	12.72	13.98
Rangpur	49.00	6.39	58.98	7.63	9.98	5.57
Khulna	41.74	16.91	18.46	50.02	8.27	6.37
Barisal	37.37	9.06	47.51	11.40	10.14	16.46
Sylhet	-40.60	128.59	-55.00	60.30	11.40	67.13
Bangladesh	35.4	7.81	46.7	9.93	11.30	5.49

A-9. Crop calendar of Bangladesh




Crops
Jan
Feb
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Chilli
Stem Amaranth
Red Amaranth
Malabar Spinach
Spinach
Water Spinach
Sweet Gourd
Ash Gourd
Bottle Gourd
Pointed Gourd
Okra
Bitter Gourd
Ridge Gourd
Snake Gourd
Eggplant
Carrot
Radish
Turnip
Cabbage
Cauliflower
Tomato
Cucumber
Hyacinth bean
Teasel gourd
Jute (white))
Jute (Tosha)
Sugercan
Water melon
Ber/Jujube
Mandarin
Lemon
Pineapple
Banana
Papaya
Rabi
Kharif-1
Kharif-2
Rabi



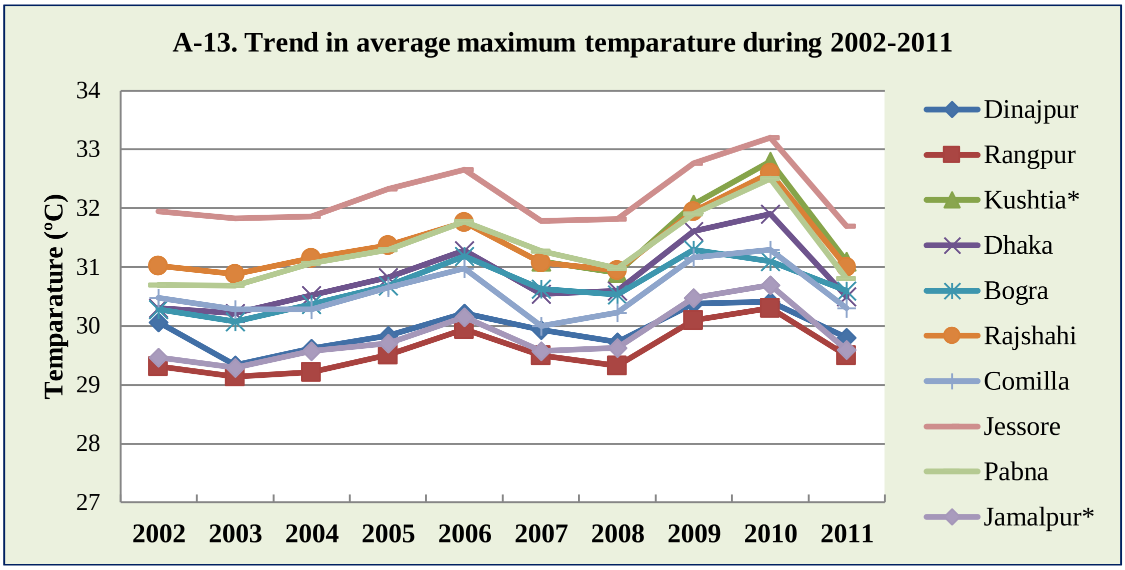
A-11. Standard deviation, coefficient of variation and growth rate of rainfall in different districts during 1991-2011

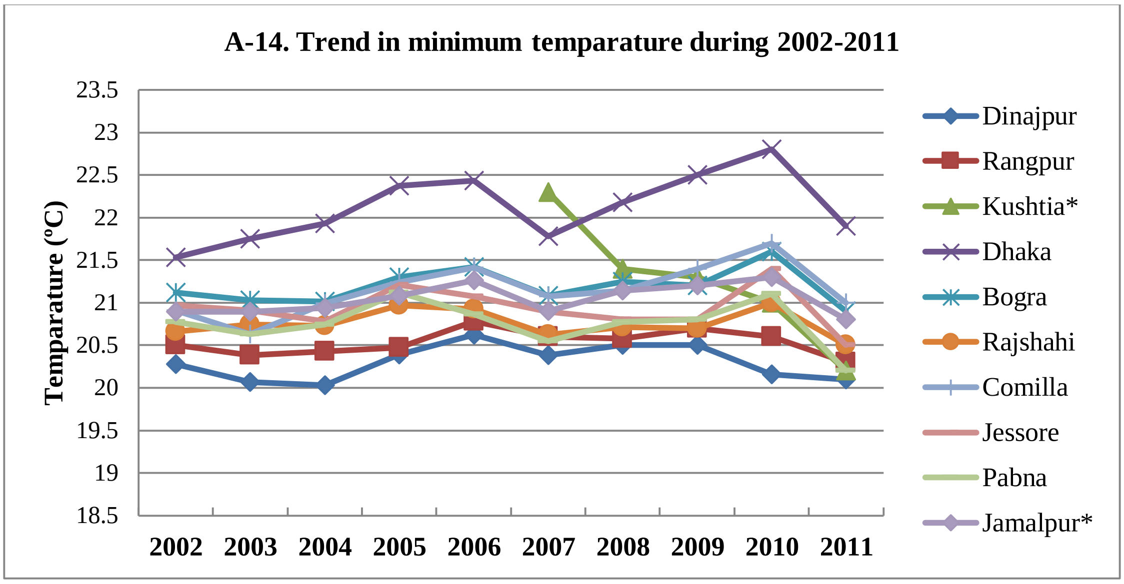
District	Mean rainfall (mm)	Standard deviation (mm)	Coefficient of variation (%)	Growth rate (%)
Dinajpur	1,974.38	476.53	24.14	-0.21
Rangpur	2,233.52	418.64	18.74	-0.14
Kushtia	1,530.13	361.69	23.64	-5.30
Dhaka	2,070.52	471.94	22.79	0.13
Bogra	1,762.05	396.27	22.49	-0.79
Rajshahi	1,434.48	337.82	23.55	-0.44
Comilla	2,098.43	417.33	19.89	-0.33
Jessore	1,708.10	308.24	18.05	0.43
Pabna	1,470.14	291.43	19.82	-0.25
Jamalpur	2,258.05	496.19	21.97	-0.08

A-12. Standard deviation, coefficient of variation and growth rate of average minimum and maximum temperature in different maize growing districts during 1991-2011

District	Mean temperature (°C)		Standard deviation		Coefficient of variation (%)		Growth rate (%)	
	Min	Max	Min	Max	Min	Max	Min	Max
Dinajpur	20.11	30.08	0.38	0.37	1.89	1.24	0.20***	-0.03
Rangpur	20.31	29.64	0.34	0.35	1.70	1.18	0.10***	0.01
Kushtia	21.24	31.59	0.76	0.81	3.56	2.58	-2.1***	0.59
Dhaka	21.86	30.81	0.44	0.56	2.00	1.80	0.20***	0.05
Bogra	21.08	30.71	0.33	0.35	1.55	1.15	0.10***	0.00
Rajshahi	20.61	31.29	0.37	0.46	1.82	1.48	0.16***	0.05
Comilla	20.96	30.42	0.38	0.40	1.81	1.31	0.18***	0.09**
Jessore	20.92	31.92	0.26	0.49	1.23	1.53	0.02	0.01***
Pabna	20.64	31.15	0.34	0.49	1.67	1.59	0.12**	0.08
Jamalpur	20.86	29.89	0.50	0.44	2.42	1.47	0.21***	0.01

Note: *** and ** indicates significance at 1% and 5% level, respectively.
Growth rates are estimated fitting semi-log function





A-15. Recommended doses (kg/ha) of fertilizers for maize cultivation in Bangladesh

Items	Composite variety		Hybrid
	Rabi season	Kharif season	Rabi season
Seed rate	25-30	25-30	25-30
Cowdung (ton)	4-6	4-6	4-6
Fertilizers			
Urea	172-312	216-264	500-550
TSP	168-216	132-216	240-260
MoP	96-144	72-120	180-220
Gypsum	144-168	96-144	240-260
Zinc sulphate	10-15	7-12	10-15
Boric acid	5-7	5-7	5-7

Source: KPH 2011

A-16. Mean yield and potential yield of different hybrid maize varieties cultivated in Bangladesh

Name of hybrid variety	Experiment district for potential yield	Year of experiment for potential yield	Potential yield (t/ha)	Overall mean yield (t/ha)*
7001k	Rahmatpur	2010-11	12.35	10.63
827k	Rangpur	2010-11	12.48	10.83
717k	Rahmatpur	2010-11	12.96	11.14
7074	Rahmatpur	2010-11	11.10	9.81
962	Jessore	2010-11	12.76	11.70
981	Rahmatpur	2011-12	14.18	12.89
900Mgold	Gazipur	2010-11	14.05	12.54
900M	Rangpur	2011-12	12.87	10.74
Pinacle	Jessore	2011-12	14.43	13.13
Raza777	Hathazari	2010-11	11.55	10.82
Chakra Makra	Rangpur	2010-11	11.96	11.18
NK 40	Jessore	2010-11	11.95	11.69
Pioneer	Rahmatpur	2010-11	12.98	11.80
P984	Rahmarpur	2010-11	15.53	11.65
Uttaran 2	Rangpur	2010-11	13.57	12.34
BHM 5	Hathazari	2010-11	10.73	9.46
BHM 7	Rangpur	2010-11	13.13	10.75
BHM 11	Rahmatpur	2010-11	10.97	9.47
KONOK	Rangpur	2010-11	13.45	11.53
BHM 9	Rahmatpur	2011-12	11.85	9.99
Pac 740	Jessore	2011-12	11.03	9.37
Pac 296	Rahmatpur	2011-12	13.18	10.84
Pac 339	Rahmatpur	2011-12	13.10	11.02
980	Rangpur	2011-12	11.17	10.41
C 6485	Rahmatpur	2011-12	11.33	10.32
C 1837	Rahmatpur	2011-12	12.47	10.29
Prince	Rahmatpur	2011-12	13.02	11.38
C 1921	Gazipur	2011-12	11.83	9.42
Pacific 60	Rahmatpur	2011-12	13.65	11.20
Average			**12.61**	**10.98**

* Mean yield for different varieties has been calculated for the year 2010-11 and 2011-12 in different on-farm experimental locations.

A-17. Calculation of domestic resource cost (DRC) for maize in Bangladesh

Items	Year		
	2010	2011	2012
A. Traded inputs (Tk/ton)	3,760	1,508	1,847
B. Non-traded inputs and domestic resources (Tk/ton)	4,216	7,541	11,177
Human labour	1,368	3,226	5,767
Animal labour	359	567	695
Seed	391	555	1,140
Manure	184	368	413
Irrigation	452	773	794
Pesticides	87	128	122
Shelling cost	139	195	225
Land rent	1,099	1,562	1,829
Interest on operating capital	137	166	192
C. Price of output (Tk/ton)	16,159	18,104	20,314
D. Value added (tradable) (C-A) (Tk/ton)	12,399	16,600	18,467
E. **DRC (B÷D)**	**0.340**	**0.454**	**0.605**

Source: Author's calculation using data from Karim et al. (2010), Ferdausi 2011 & Paul 2012
Conversion rate 1 USD = 78.0 BDT

A-18. Calculation of import parity border prices for maize in Bangladesh

Items	Year		
	2010	2011	2012
A. c.i.f price (Tk/ton) at port of entry, Chittagong	15,975	17,864	20,088
B. Marketing margin (Tk/ton) from the port of entry to the wholesale market	1,647	1,704	1,759
Import handling cost	479	536	603
Transportation cost	1,016	1,016	1,016
Domestic trading cost	152	152	140
C. Border price (Tk/ton) at wholesale level (A+B)	17,622	19,568	21,847
D. Components of the marketing spread (Tk/ton) between the wholesale market to the produce level	1,464	1,464	1,534
Cost from farm gate to wholesale market	1,144	1,144	1,144
Interest cost	320	320	390
E. Border price (Tk/ton) of farm produce at producer level (C-D)	**16,159**	**18,104**	**20,314**

Conversion rate 1 USD = 78.0 BDT

A-19: Actual vs predicted line of area, production and yield of maize for 10 years forecast

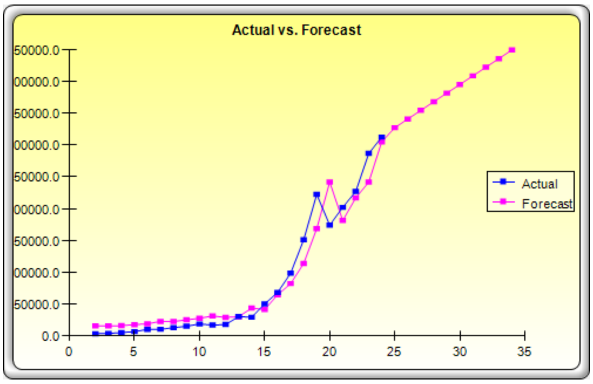


Fig 1: Actual vs predicted line of maize area

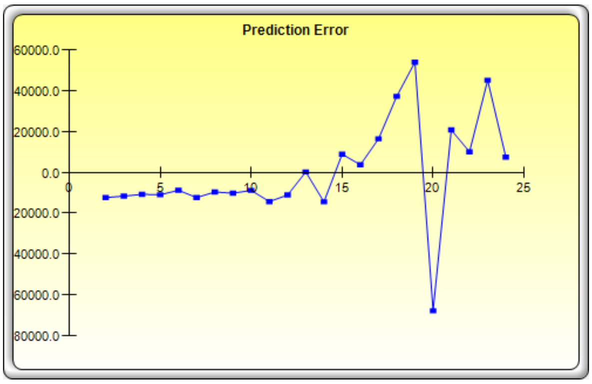


Fig 2: Prediction error of maize area

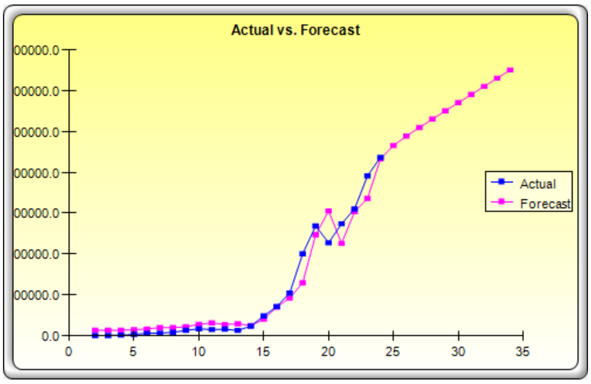


Fig 3: Actual vs predicted line of maize production

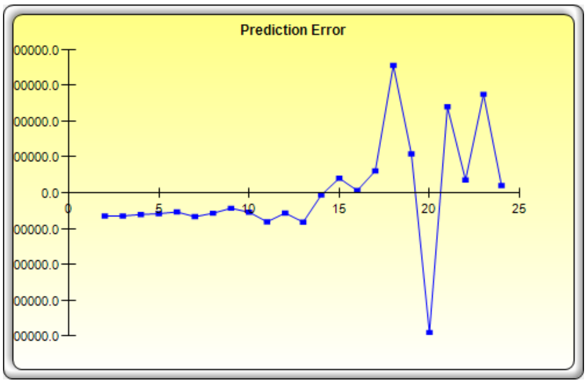


Fig 4: Prediction error of maize production

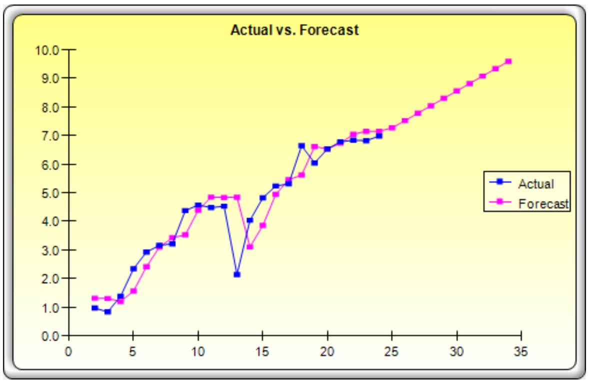


Fig 5: Actual vs predicted line of maize yield

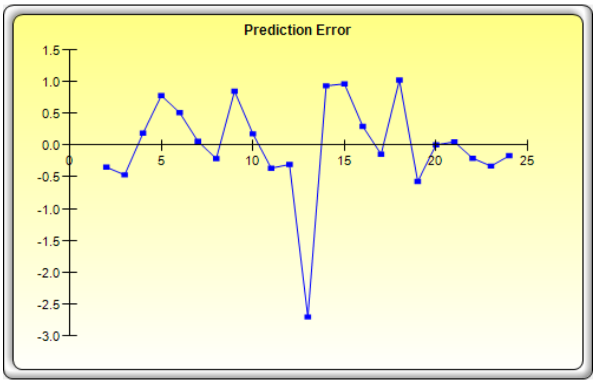


Fig 6: Prediction error of maize yield

A-20: AACF and PACF of prediction error from estimated ARIMA model: 10 years of forecast

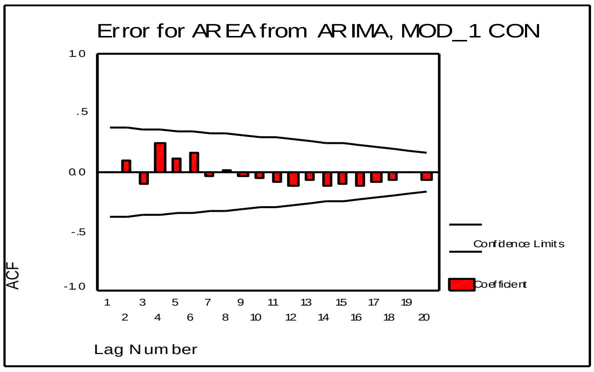


Fig 1: ACF of predicted error of area

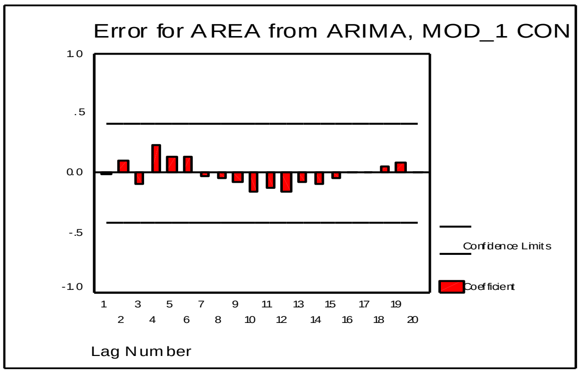


Fig 2: PACF of predicted error of area

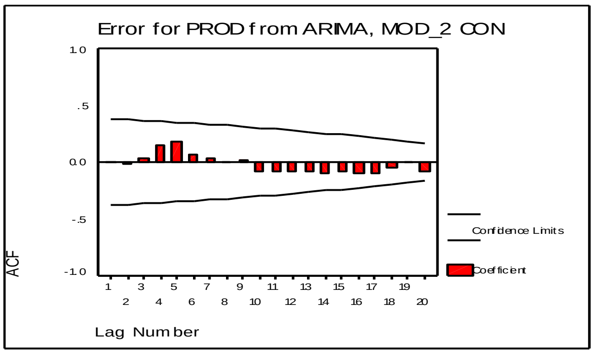


Fig 3: ACF of predicted error of production

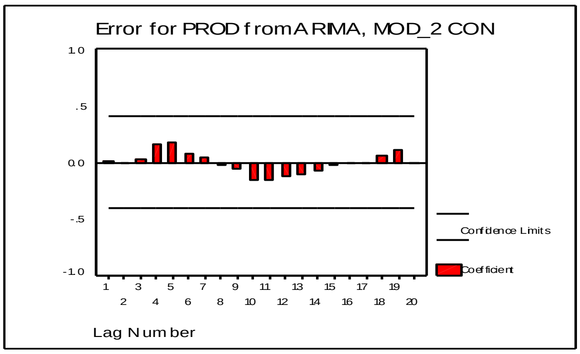


Fig 4: PACF of predicted error of production

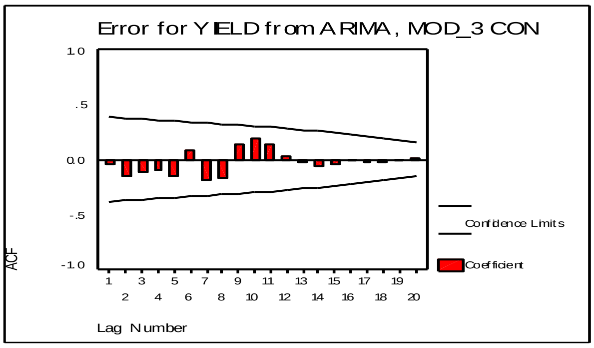


Fig 5: ACF of predicted error of yield

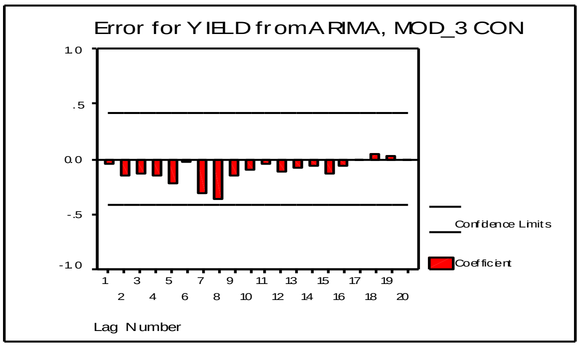


Fig 6: PACF of predicted error of yield

A-21. Farm gate price (Tk/ton) of major cereals (maize, wheat and boro rice) in Bangladesh

Year	Major cereals			Year	Major cereals		
	Maize	Wheat	Rice		Maize	Wheat	Rice
1986	6,000	4,552	4,457	1999	8,212	9,200	7,709
1987	6,250	5,302	5,340	2000	8,671	8,860	7,515
1988	6,500	5,201	5,244	2001	8,222	8,545	8,050
1989	6,500	5,708	5,608	2002	8,354	8,740	8,165
1990	6,600	6,160	5,512	2003	8,589	9,000	8,346
1991	6,600	5,969	6,155	2004	8,773	9,380	8,564
1992	6,100	6,844	6,225	2005	8,865	11,850	9,700
1993	7,079	5,009	6,280	2006	8,959	13,880	9,987
1994	5,488	5,186	6,358	2007	9,460	17,610	10,815
1995	6,610	7,444	6,541	2008	11,286	18,890	12,095
1996	7,651	7,463	6,664	2009	12,386	18,460	13,805
1997	7,569	7,309	6,890	2010	12,790	19,390	13,735
1998	7,487	8,391	7,414	2011	15,580	20,560	18,905

Source: BBS 2011; Conversion rate 1 USD = 78.0 BDT

A-22. Number of poultry in Bangladesh during 1990 to 2013 (in'000 heads)

Year	Chickens	Ducks	Total
1990	91,103	23,000	114,103
1991	94,656	24,000	118,656
1992	100,563	25,000	125,563
1993	109,244	26,000	135,244
1994	115,800	27,000	142,800
1995	123,000	28,000	151,000
1996	103,200	29,000	132,200
1997	109,900	30,000	139,900
1998	117,000	31,000	148,000
1999	124,600	32,000	156,600
2000	132,700	33,000	165,700
2001	142,680	33,830	176,510
2002	152,240	34,670	186,910
2003	162,440	35,540	197,980
2004	172,630	36,400	209,030
2005	183,450	37,280	220,730
2006	194,820	38,070	232,890
2007	206,900	39,080	245,980
2008	212,470	39,840	252,310
2009	221,394	41,234	262,628
2010	228,035	42,677	270,712
2011	234,686	44,120	278,806
2012	241,527	45,613	287,140
2013	248,568	47,156	295,723
Growth rates			
1990-2000	3.03***	3.60***	3.14***
2001-2013	4.62***	2.72***	4.29***
1990-2013	4.63***	2.95***	4.33***

Source: FAOStat 2011; Extrapolation for 2012 and 2013

A-23. List of maize varieties available in the market

1. Dekalb981	19. 900M	37. Uttaran	55. Kaveri 24
2. 717 K	20. Gold	38. Uttaran-2	56. K60
3. 700K	21. Super Gold	39. CP818	57. Kaveri 50
4. 827K	22. Fortune	40. CP808	58. Pac 11
5. 987K	23. 981	41. CP838	59. Pac 60
6. 900K	24. Sunshine	42. HP-100	60. Pac 296
7. 7001K	25. NK40	43. SP-100	61. Pac 740
8. Pinnacle	26. NK-6621	44. AP-100	62. Pac 339
9. Elite	27. 30V92	45. P-3637	63. Pac 999 Super
10. Miracle	28. 30B07	46. Badsha	64. Karnal
11. 962	29. 3396	47. NHM909	65. Heera 108
12. Denali	30. Super999	48. NHM777	66. Heera 109
13. Kiron	31. 984	49. Kanak740	67. C 1837
14. X-92	32. Pioneer	50. 740	68. C 1940
15. Jai Kisaan-101	33. X-81	51. C 6485	69. C 1921
16. 985	34. Raza 777	52. Moni Mukta	70. Ajanta
17. 999	35. HI Grade	53. Ps-2097	71. DKC9120
18. 900M	36. 224	54. Prince	

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Sources of cover page pictures:
Maize plant with cob: http://www.earthtimes.org/climate/hottest-hit-hardest-africa-maize-vunerable-warming-climate-463/
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