# Investing in Crop Agriculture in Bangladesh for Higher Growth and Productivity, and Adaptation to Climate Change

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# INVESTING IN CROP AGRICULTURE IN BANGLADESH FOR HIGHER GROWTH AND PRODUCTIVITY, AND ADAPTATION TO CLIMATE CHANGE

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# EXECUTIVE SUMMARY

Bangladesh faces formidable challenges to feed its population in the future from an increasingly vanishing and degraded natural resource base for agriculture. Crop agriculture is heavily dominated by the cultivation of rice. In the past three decades, Bangladesh has experienced significant growth in food production mainly due to increasing reliance on irrigated dry period high-yield variety (HYV) boro rice. The output of the other major rice—aman—has also progressed but rather slowly, due in part to its susceptibility to both flood and drought at different times during its life cycle. A third type of rice—rainfed aus—has been increasingly abandoned in Bangladesh.

Crop agriculture has to face many challenges. Within the millions of marginal and small farms scattered across Bangladesh, crop diversification is still limited and natural disasters regularly damage part of output. In many places, there are also serious problems with soil degradation and poor seed quality. The technology generation and dissemination systems are limited by institutional weaknesses, lack of resources, and unavailability of requisite skills. *Boro* rice cultivation depends heavily on groundwater irrigation, which has severe limitations. Some further expansion of *boro* is possible, but mainly in localized pockets of the country. In addition, water-use efficiency is low, and the climatic variability already exacts a heavy toll on outputs. The future projected climate change will further magnify these effects.

Against this backdrop, the government wishes to expand *boro* in areas where surface water is more abundant; there is a general agreement to utilize surface water as far as possible to lower costs of production while maximizing the use of available resources. On the other hand, because *boro* has reached its limit in general, getting as much as possible from *aman* should be a major objective in raising domestic output of rice. But this will necessitate revamping not only the technology generation system but also the technology dissemination system and the marketing system.

For the future, it has been proposed that investments must be focused on first developing an overall integrated water resource management plan, with a River Basin Development Approach at its core (with a Coastal Tidal Basin Development Approach for the coastal areas). This will ensure an integrated use of surface and groundwater for agricultural and other purposes. The River Basin Development Approach will subsume the government's present emphasis on rejuvenation of river flows and will necessitate regional and bilateral cooperation for water resource development.

The agricultural research system of the country will have to play a key role by developing varieties which are both resistant to submergence and drought tolerant (or low water using), as well as resistant to salinity and arsenic uptake, suitable for deep water areas, and of shorter maturity. Already some varieties have been developed. While these need to be popularized, more research will be needed for ecology-specific development of cultivars. Other priorities are cropping system development along with identifying suitable crops for problem soils.

To implement these major strategies, including supporting activities, Bangladesh needs to invest in the following areas:

- Integrated water resource management, through a River Basin Development Approach
- Technology generation system, including emphasis on biotechnology
- Technology dissemination or extension system
- Agricultural marketing services
- Soil health maintenance
- Climate change adaptation
- Provision of agricultural financial services
- Modernization of agricultural education system

An immediate and very sizeable scaling up of resources for technology generation is absolutely necessary. Substantial resources will also have to be provided for adaptation to climate change, including for research in several areas. Such investments have paid off handsomely in the past and may do so again in the future.

# INTRODUCTION

Bangladesh faces formidable challenges to feed its population in the future from a rapidly vanishing land base for agriculture. The population is expected to increase from 153 million in 2005 to 185 million people by 2020—and 222 million by 2050 (United Nations 2008). At the same time, over the last two decades the man-land ratio on cropland has increased from 4.9 to just about 7 persons, that is, by 42–43 percent. Against this backdrop, the worldwide sharp increases of food prices in 2007–2008, along with rising price of energy as well as fertilizer, have dramatized to policy makers, researchers and the general public, in this country as elsewhere, the thin razor's edge upon which the food security of nations rests. The experience has once again induced the government to revive the policy of self-sufficiency in food production as a target. The country thus needs new thinking regarding food security, related policies, and interventions (particularly investments) for both the short and the long term.

Key challenges to agricultural growth in the country include (on the supply side) water resource and land area constraints, soil degradation and climate change, coupled with (on the demand side) a rapidly growing, increasingly urbanized, and more affluent population with changing tastes. To address these challenges will require new thinking on how domestic food security goals can be met while sustaining an increasingly fragile environment and a large population dependent on agriculture for their livelihoods.

Food security in general has three basic elements: availability, access, and utilization. The dominant source of food in Bangladesh is domestic production. This paper will examine the availability of food from domestic production in crop agriculture. A companion paper examines issues related to fisheries and livestock development.

In this paper we first provide a brief history of growth in crop agriculture and its characteristics. This is followed by a discussion of the challenges that Bangladesh agriculture will face in future (including climate change) and the key issues that need resolution in order to face these challenges.

The resolution of these challenges will require interventions mediated by the government and involving the private sector,[1] including both policy actions and the necessary investments in relevant areas. These investment needs are elaborated as far as possible in this paper, along with an initial prioritization. We make no attempt to indicate how such investment needs may be realized, their sequence, or how to mobilize them. These are matters for future discussion.

[1] Agriculture is the largest private sector, and without its whole-hearted support, the government's efforts may have only limited impact.

# A BRIEF OVERVIEW OF THE CROP SECTOR

## Importance of agriculture

Agriculture's share in gross domestic product (GDP) has fallen over time—during the last decade, from one-quarter to one-fifth. Nevertheless, agriculture remains extremely important, as it provides the bulk of employment (just about 50 percent) as well as national food security.

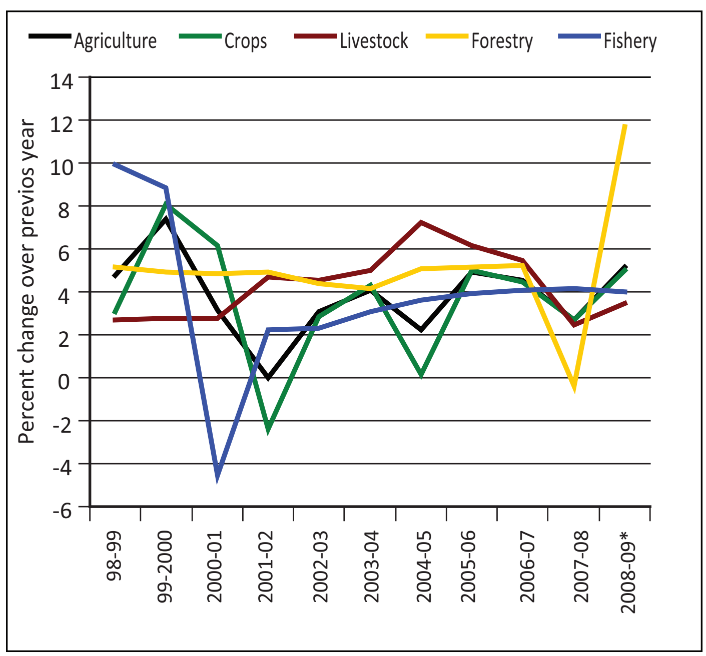
## Recent growth in agriculture

In recent years, particularly over the last decade or so, the GDP of the country has grown at the exponential rate of 5.5 percent, especially toward the end of that period. Since 2003/04, growth has hovered around or above 6 percent per year (Ministry of Finance 2010). During the same period, agricultural GDP (crop cultivation, fisheries, livestock, poultry, and forestry) has grown at a moderate rate of only 3.4 percent (Asaduzzaman 2009). Agricultural value added has thus grown from *taka* (TK) 448 billion in 1997/98 to TK 676 billion by 2008/09, that is, by around 44 percent.

The overall growth rate of agriculture has largely paralleled that of crop agriculture, which grew at an average annual rate of 3.1 percent over the decade 1997/98–2007/08. During the same period, livestock, fisheries, and forestry GDP rose at annual rates of 4.6, 3.0 and 4.7 percent respectively. These average rates mask year-to-year fluctuations, as shown in Figure 1.

It is not so surprising that overall agricultural growth (and its fluctuations) closely follows growth in crop cultivation,

**Figure 1—Year-on-year rates of growth in sub-sectors of agriculture (%)**




Source: Computed by authors based on information in Ministry of Finance (2010).

which accounts for a steady share of 56–57 percent of the value added in agriculture over the past decade (at constant prices of 1995/96). In crop agriculture, we see three peaks following three troughs (in years of flood or other major natural disaster, as in 1998/99 and 2007/08). Thus the performance of Bangladesh crop agriculture, and consequently agriculture as a whole, is still heavily influenced by weather and related events.

## Dominance of rice

Crop agriculture is dominated heavily by rice cultivation, and crop diversification is still rather limited. In fact, according to official statistics, the predominance of rice as a share of cropped area increased in most recent years. Over 2003/04, 2004/05, and 2005/06, rice area accounted for 75–76 percent of total cropped area. In later years this may have shot up above 80 percent, to as much as 84 percent by 2008/09. In terms of value added, however, the shares are somewhat less. The changes in shares in value added for rice and other selected crops are shown in Table 1.

**Table 1—Percentage shares of crops in value added in crop agriculture**

| Crops | 2002/03 | 2003/04 | 2004/05 | 2005/06 | 2006/07 | 2007/08 |
|---|---|---|---|---|---|---|
| Paddy | 68.2 | 67.8 | 63.4 | 64.1 | 62.8 | 62.6 |
| Wheat | 2.6 | 2.1 | 1.6 | 1.2 | 1.1 | 1.2 |
| Beverages | 2.7 | 2.8 | 2.8 | 2.9 | 2.8 | 2.4 |
| Jute | 2.8 | 2.7 | 2.4 | 2.7 | 2.7 | 2.5 |
| Pulses | 2.2 | 2.1 | 1.9 | 1.7 | 1.6 | 1.5 |
| Oilseeds | 1.7 | 1.7 | 1.8 | 1.8 | 1.9 | 1.8 |
| Sugarcane | 2.4 | 2.2 | 2.1 | 1.7 | 1.8 | 1.7 |
| Potato | 3.8 | 4.3 | 5.3 | 4.6 | 5.5 | 7.7 |
| Other veg. | 5.10 | 5.3 | 6.1 | 6.1 | 5.9 | 5.3 |
| Fruits | 3.7 | 3.9 | 5.5 | 5.9 | 6.2 | 5.4 |

Source: BBS 2009.

The table indicates that the shares in value added for paddy has somewhat fallen and those of the so called minor crops, potato, other vegetables and fruits have increased.[2] Several other crops have lost share, including sugarcane and pulses, while others have remained static. Such figures lead to two kinds of implications.

First, despite efforts over the years, crop diversification has not progressed well. As Deb (2008) observes, the index of diversification has moved only slightly, from 0.54 in the 1980s to 0.6 in recent times.[3] The diversification indices (constructed on value share basis) for the years 2002/03 to 2007/08 have generally remained within the range 0.52 to 0.57. Even after much effort, the diversification that has occurred is of little significance.

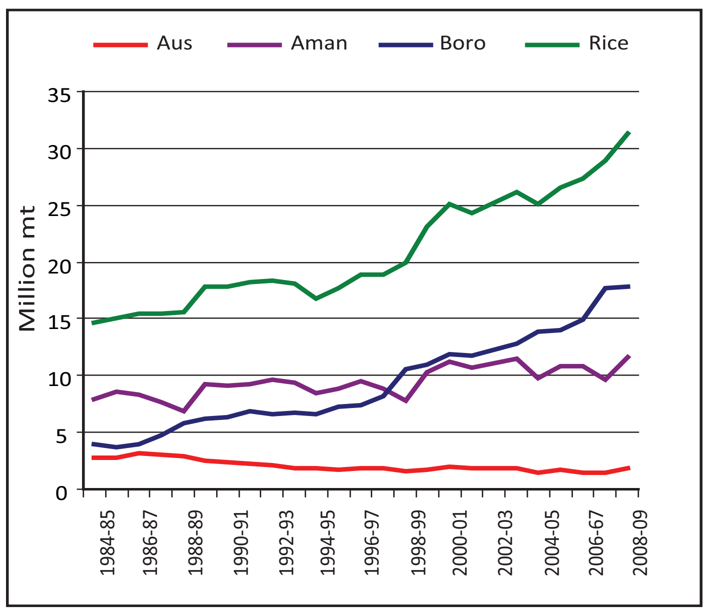
A second important point is that some crops that reduced contribution to added agricultural value are important for nutritional status, for example, in the case of pulses, which constitute a major source of protein in the country. The story is similar for sugarcane, the raw material for sugar production.

## Rice cultivation and its characteristics[4]

To understand the peculiarities of crop agriculture, one has to understand the intricate intertwining of rice culture with climate, land level, and moisture availability (from rainfall or irrigation). Rice is grown in three seasons. *Aman,* grown during July/August to December/January, is part rain-fed (during early part of growth) and part dry season crop (during flowering and harvest time). This is followed by *boro,* grown at present under irrigated conditions during the largely dry period from February/March to April/May. *Aus* is grown in rain-fed conditions; it falls in between *boro* and *aman* season but may overlap with both. This means that the longer-duration varieties of rice do not allow for more than two rice crops per season on the same land, although other crops may be grown, depending on duration of the crop and other agronomic factors.

The growth in rice output over the last quarter of a century has been characterized by increasing reliance on irrigated *boro* cultivation, using fertilizer-intensive high-yielding varieties (HYVs). *Boro* rice now accounts for the bulk of rice grown in the country (Figure 2). The area expansion under *boro* has come increasingly at the expense of *aus*, and, more recently, of *aman* as well, although *aman* acreage has generally remained static. Within *aman*, too, there has been a switch to HYVs. Yet the output growth in *aman* has been rather modest, reflecting not only loss of area but also slower

**Figure 2—Rice output trend**




Source: Authors' calculations based on various official statistics.

[2] While statistics do not capture this trend, there are now non-conventional vegetables (such as *bathua shak*) and fruits (such as *lotkon*) cultivated for the market.

[3] Diversity has been measured here by Simpson's Index, which is defined as: SID = 1- $\sum (pi)^2$ where the sum is over all *i.* SID means Simpson's index and pi is the proportion of the area or value of $i^{th}$ crop or activity. SID varies from 0 to 1, the higher value signifying higher level of diversification. See Deb 2008.

[4] This section draws heavily upon Asaduzzaman 2008.

*Note: All references to taka (TK), the currency of Bangladesh, are based on the official exchange rate as of May 20, 2010: TK 69.35 per US$1.

rate of yield increase compared to *boro* (see Table 2). A possible contributing factor is damage caused by weather-related hazards, such as floods, drought, and cyclonic storms along the coast.

**Table 2—Components of change (%) in rice output (1992-2007)**

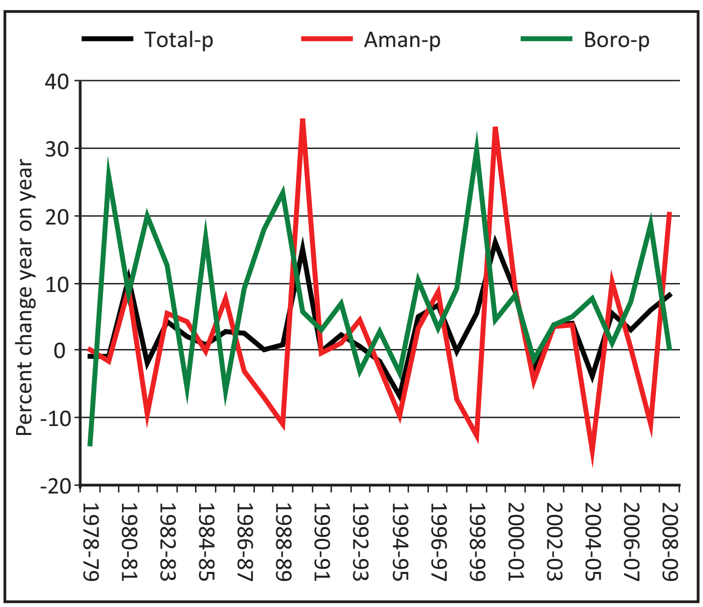
| Season | Output change | Area change | Yield change |
|---|---|---|---|
| *Aman* | 1.65 | -0.42 | 2.07 |
| *Boro* | 6.60 | 4.04 | 2.56 |
| *Aus* | -1.08 | -4.30 | 3.22 |
| **All** | **3.67** | **0.52** | **3.14** |

Source: Asaduzzaman 2009.

*Boro* rice is now the lifeline for Bangladesh. The scope for its further expansion, however, appears to be limited except for specific pockets. Thus, the focus for *Boro* rice has to be on increasing the efficiency of inputs—both water and fertilizers. Moreover, the cost of production of *boro* high-yield variety (HYV) rice is rather high because of intensively used, costly inputs such as irrigation and fertilizer. Further increase in rice output over the long run is therefore likely to come from *aman*. In the near future, however, such an increase is not likely because of the uncertainties that surround *aman* harvest in any given year.

*Aman* output is highly volatile due to its susceptibility to natural hazards. As Figure 3 shows, both *aman* and *boro* outputs are in fact volatile. But whereas *aman* has just two major peaks above the zero line (representing no change), it shows several troughs signifying fall in output. The nature of volatility of *boro* output is just the opposite, with changes mostly on the positive side. In fact, the positive *boro* output change often counterbalances the negative output changes in *aman*, as indicated by the line for total production. Relying more on *aman* for future rice output growth and lessening the dependence on *boro*, however desirable, will be difficult though not impossible, as discussed below.

**Figure 3—Year-to-year fluctuation in rice output**




One way of achieving higher output is to focus on regions where crop agriculture has comparatively lagged behind, particularly in southwest Bangladesh (SWB). It has been observed that all districts showing low yield of rice are in the southwestern region, particularly along the coast; while those showing more than 1 metric ton of yield per acre are, at present, the highly irrigated districts of the northwest: the northern part of Jessore, Kushtia, Chittagong, Comilla, Dhaka, and Mymensingh. There are three types of problems in raising crops in the coastal districts of SWB: salinity, particularly during the dry period; water-logging and drainage congestion in many areas; and the storm surges during cyclones which make agriculture riskier.

In 2008/09, just above 6.0 million hectares (ha) were irrigated, all with mechanized means. Of this total area, 70 percent depends on groundwater, using shallow and deep tubewells. Low-lift pumps dependent on surface water account for 20 percent of the area irrigated. Groundwater is costly, however, for both the environment and, due to high farmer subsidies, the government. For example, groundwater mining has resulted in the lowering of water tables in parts of the country. Moreover, groundwater dependence has increased the risk of arsenic in food production.

Two important research questions arise. First, how can water-use efficiency be increased to reduce the cost of production of crops, particularly boro rice declines? A higher water-use efficiency would also reduce energy consumption and lower greenhouse gas emissions, for example, through the adoption of the alternative wetting and drying method. Development of new varieties that consume less water can also help reduce boro water needs. Second, how far can surface water be substituted for groundwater, particularly in areas where surface water is more abundant, for example, in the southwest?

## Other issues in agriculture

### *Organization of agricultural production*

Several other issues should be noted that apply to rice cultivation and also generally to crop agriculture. Foremost is the organization of production. Agricultural and particularly crop cultivation takes place in millions of tiny-to-small farms, operating no more than 2.5 acres of land. Such smallholders account for 88 percent of farms and 60 percent of all operated land. Large farmers, with operational holdings 7.5 acres or above, accounted for 1.2 percent of farms and 10 percent of area.

With access to land so limited, there is fierce competition for land. There is an active market for sharing in and out as well as renting land in and out. In general, however, most farmers operate what they own, or rent from others to supplement their own land.

Several past attempts at redistributive land reforms ended in failure. Other attempts, such as distribution of *khas* (government owned) land, apparently had only limited success, since most such lands are under the control of influential local people (predictable in a country with huge population and limited land area).[5] Nevertheless, any investment in agriculture must help the smallholders, or all efforts to raise production will be in vain.

### *Capitalization of agriculture*

There have been two types of change in technology of production. One was the cultivation of fertiliser-intensive HYVs under a controlled water management regime, which generally meant irrigation through mechanized means. This technological change was basically land-augmenting and labor-intensive. Apart from irrigation, the other type of capitalization was a rapid spread of mechanized tillage using power tillers and tractors.

Irrigated agriculture, in generating large demand for labor, also helped ensure food security for labor households. Mechanization of tillage may or may not have such a positive impact on labor use. Mandal and Asaduzzaman (2002) found that mechanization of tillage helps in raising cropping intensity by breaking the time constraint, and thus is likely to be labor-friendly. The main time constraint is between the harvest of *aman* and the beginning of *boro*. If power tillers and tractors allow more *boro* rice to be cultivated, it certainly will help in raising labor employment, as *boro* is almost wholly HYVs. However, if land is instead released from *boro* cultivation to other crops during the *rabi* season (winter months), as part of a drive for crop diversification, the beneficial impact of mechanization on labor absorption will depend on the particular crop cultivated: for example, potato is labor-intensive to harvest.

### *Problem of seed*

Agricultural growth is dependent on very wide-scale switch to HYV seed, but seed quality in general remains a major problem. Bangladesh Agricultural Development Corporation (BADC), which has the mandate to supply quality seeds, can supply only a miniscule part of the total demand. For example, there is a need for 600,000 tons of potato seeds, but BADC's capacity is only 18 thousand tons. Various related investments are needed to enhance provision of quality seeds in adequate quantities. Some of the non-government organizations and the private sector have started to enter the seed sector with positive impacts on availability, although quality still remains a vexing issue in some cases. Further private-public partnerships for seed, marketing, and extension need to be explored.

### *Post-harvest losses*

Post-harvest losses are conventionally thought to be high in Bangladesh. According to Bangladesh Agricultural Research Institute (BARI), the losses may be 12–15 percent for rice and around one-fourth of non-rice crops. Recent information, however, casts doubt on the loss figure for rice, which is now estimated to be about 7–8 percent of production. On that basis, the return to investment for post-harvest loss reductions may not seem high, unlike the case of non-rice crops, particularly high-value and highly perishable crops like fruits and vegetables.

Note, however, that while the rice post-harvest losses may not be as high as once thought, losses may be higher for particular groups, such as marginal and small farmers, or in areas where insect damage or weather-related factors (high humidity, for example) cause spoilage in storage. In such cases, targeted investments to minimize post-harvest losses may be effective in raising availability of food.

### *Soil degradation*

Soil degradation is common place in Bangladesh, whether manmade (for example, through unbalanced use of fertilizers) or due to natural factors (salinity ingress in coastal areas, or landslides on hilly terrain). Estimates by BARC (2000) indicate that problem soils may be major constraint to agricultural growth. Organic matter depletion is observed in 7.5 million ha of land. Declining soil fertility, soil erosion, and salinization affect respectively 5.6–8.7 million ha, 5.3 million ha, and 3.05 million ha of land. It is estimated that some 2 million metric tons of nutrients are removed from Bangladesh soils annually. Unless compensated through balanced application of nutrients every year, the fertility of land is expected to decline and so will its productivity. One estimate puts the cost of land degradation as 3 percent of crop output or 1 percent of crop GDP every year (BIDS 2004).

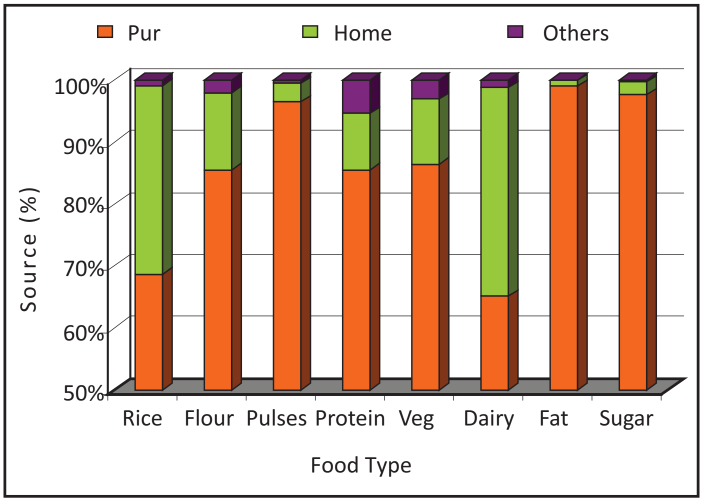
Apart from the natural factors, a major reason is unbalanced use of fertilizer—a reflection of the historical legacy of low relative price of urea compared to non-urea fertilizers. Pricing policy, as along with investments in awareness-raising for balanced fertilizer application and popularization of more efficient fertilizer application techniques, can help preserve soil quality, raise output, lower costs of production, and save the government budget huge amounts of money.

### *Marketing*

In Bangladesh, production is now largely for the market, as substantial parts of consumption is now purchased (see Figure 4). Even for rice, nearly 70 percent of what is consumed is bought from the market. Apart from dairy products, the percentage for all other types of food is much higher, possibly nearly 100 percent. Quite a few of these products, including meat and dairy as well as wheat and sugar, are highly income-responsive. Both such income response as well as market behavior of households indicate the need for improved marketing services, generally considered quite underdeveloped.

[5] Anecdotal evidence and newspaper reports suggest that a similar pattern of control affects such resources as bodies of water, parts of rivers, vacant government land, forest, and even the sea front.

**Figure 4—Source of procurement of food**




Source: Based on unit records of HIES 2005 (BBS 2006a).

## *Technology generation and dissemination systems*

The National Agricultural Research System (NARS) consists of an apex organization, the Bangladesh Agricultural Research Council (BARC), together with nine other research organizations, including those specializing in rice, various non-rice crops, sugarcane, jute, tea, and soil management. The NARS has a poor public image despite the fact it has developed varieties that are resistant to flood submergence, drought, and salinity, as well as of shorter maturity. The system is characterized by scarcity of resources (discussed below), shortage of trained manpower, and lack of incentives due to a poor compensation system. Moreover, the system is still largely dependent on conventional breeding research with a long gestation period. Shortening the gestation period through biotechnology research has not yet been attempted, whether due to inertia or lack of awareness at the scientist or policy levels.

Will the investments in agricultural research pay off? Asaduzzaman (2009) and current research by the International Food Policy Research Institute (IFPRI) indicate they will. Asaduzzaman indicates that the past rate of growth in factor productivity of 1 percent per year due to technological change will require the crop sector output to grow at 3.7 percent, to achieve overall economic growth of 8 percent by 2015. But if factor productivity grows by 1.5 percent per year due to a more efficient technology generation system, the required rate of growth of output of crop agriculture is only 2.7 percent per annum. Similarly, IFPRI research shows that if there is substantial investment in the agricultural research system, yield of rice will grow by 7 percent by 2025 and by nearly 17 percent by 2050.

The supply of personnel trained in tertiary level agricultural disciplines is extremely critical for sustaining capacity for technology generation. While the country has agricultural universities and several agricultural colleges, a question hardly addressed is whether these are capable of supplying sufficient trained personnel of the type and category needed. We believe that education in agricultural sciences and disciplines must be considered an integral part of the investment in agriculture as a whole, and most importantly for technology generation and dissemination.

Technology dissemination is as important as technology generation. In general the link between the two is not well established or defined. The extension system has its own weaknesses, and the so-called community-based extension approach is probably neither understood nor practiced properly. The training and education system for extension personnel is rather weak, dependent as it is on private training schools.

## *Agricultural finance and credit*

In 2005, nearly a third of farmers had taken some loan (BBS 2006b). The proportion did not vary much by farm size, but the amount of borrowing did. While marginal and small farmers borrowed TK 15,000–16,000 per farm, medium farmers borrowed TK 25,000 and large farmers borrowed TK 51,000.

We do not know whether the non-borrowers did not need credit because they had self-financed their activities, or if they did not have any activity to finance. Nor is it clear who provides the credit. While many banks in the formal sector provide credit, how much is provided by informal sources is not known with any certainty. Hence the total credit availability for recent years is unknown.

## *Climate change impacts*

Climate change impacts on Bangladesh agriculture have been discussed by various authors, including the government of Bangladesh (2009). It has been observed that in general climate change will probably have familiar kinds of effects: first round physical impacts would include temperature and rainfall increases; and second round physical impacts would entail floods, cyclonic storms, sea level rise, salinity rise, and so forth. There appears to be more uncertainty regarding precipitation changes than temperature rise. However, the frequency and severity of such problems may increase very substantially, and extreme events may become more common than at present. The uncertainty and associated risks in agricultural production will almost certainly be exacerbated. These will have severe consequences for agriculture and will pose challenges to food security, as discussed below.

For modelling the physical impacts, the business-as-usual scenario (with present climatic variability) has been compared with the projected climate change scenario. Similarly for economic impacts, first the effects due to present climatic variability are introduced and in the second round those due to future climate change have been simulated.

The present climatic variability already imposes a cost. While *aus* and *aman* rice are little affected on the whole, the potential decline for *boro* rice production is 3 percent by the 2030s and 5 percent by the 2050s. Compared to an "optimal" climate simulation—in which highest simulated yields are used, and sector productivity and factor supplies increase smoothly at average long-term growth rates with no inter-annual variations—current climate variability is estimated to reduce long-term rice production by an average 7.4 percent each year, over the 2005–50 simulation period.

Regions vary in their exposure to the potential losses. Production in the southern sub-regions is most vulnerable to climate change. For instance, average losses in the Khulna region have been projected as follows, by the 2050s: -10 percent for *aus*, *aman*, and wheat; and -18 percent for *boro*, due in large part to rising sea levels. These production impacts ignore economic responses to these shocks (such as land and labor reallocation and price effects), which may limit or exacerbate some of the effects.

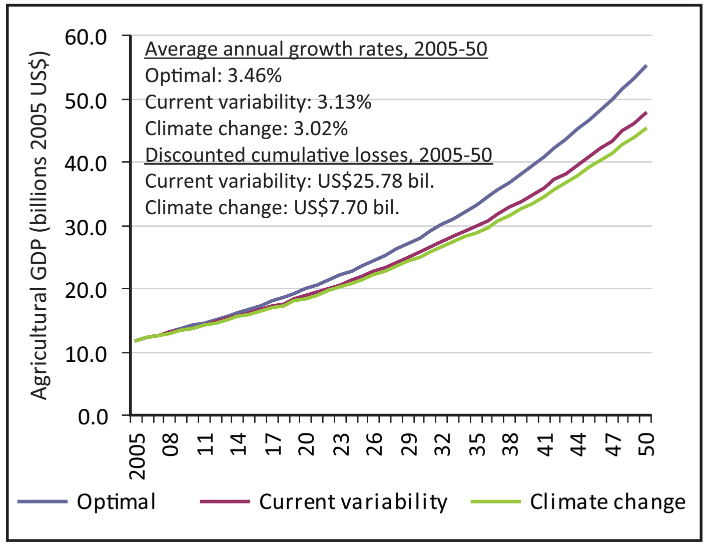
Model results indicate that climate change will exacerbate the negative impacts of existing climate variability by further reducing rice production by a projected cumulative total of 80 million tons over 2005–50 (about 3.9 percent each year, ranging between 3.6 percent and 4.3 percent), driven primarily by reduced *boro* crop production. Climate change has particularly adverse implications for *boro* rice production and will limit its ability to compensate for lost *aus* and *aman* rice production during extreme climate events. Rice production in the southern regions of Patuakhali and Khulna is particularly vulnerable.

Existing climate variability can have pronounced detrimental economy-wide impacts. Future climate change will exacerbate these negative effects. As shown in Figure 5, the simulated variability is projected to cost the agriculture sector (in discounted terms) US$26 billion[6] in lost agricultural GDP during the 2005–50 period (the gap between "optimal" and "climate variability" scenarios). Through the linkage effects within the economy, existing climate variability is estimated to cost Bangladesh $121 billion in lost national GDP during this period ($3 billion per year). This is 5 percent below what could be achieved if the climate were "optimal." As Figure 5 shows, the projected climate change will further exacerbate these negative impacts.

Overall, agricultural GDP is projected to be 3.1 percent lower each year as a result of climate change ($7.7 billion in lost value-added). Climate change also has broader economy-wide implications. This is estimated to cost Bangladesh $26 billion in total GDP over the 45-year period 2005–50, equivalent to $570 million overall lost each year due to climate change —an average annual 1.15 percent reduction in total GDP. Average loss in agricultural GDP due to climate change is projected to be a third of the agricultural GDP losses associated with existing climate variability. Uncertainty surrounding global climate models (GCMs) and emission scenarios means that costs may be as high as $1 billion per year in 2005–50, under less optimistic scenarios. Moreover, these economic losses are projected to rise in later years, thus underlining the need to address climate-change related losses in the near term.

[6] All dollar figures refer to U.S. dollars.

**Figure 5—Losses in agricultural GDP due to current climate variability and future climate change**




Source: IFPRI computable general equilibrium (CGE) model results reported in Yu et al. 2010.

These climate risks will also have severe implications for household welfare. For both the climate variability and climate change simulations, around 80 percent of total losses fall directly on household consumption. Much of the economic losses occur outside of agriculture, particularly in the downstream agriculture processing sectors. This means that both rural and urban households are adversely affected, and per capita consumption is projected to fall for both farm and non-farm households.

The southern and northwest regions are the most vulnerable. These areas are expected to experience the largest decline in rice production due to climate change, for three reasons. First, these regions already experience significant declines in *aus* and *aman* rice production due to climate variability, which is expected to worsen under climate change. Second, *boro* yields are severely affected by changes in mean rainfall and temperature, and by mean shifts in the flood hydrographs. Consequent reductions in *boro* production limit the ability for these regions to compensate for lost *aus* and *aman* rice production during extreme events. The south is also most affected by rising sea levels, which permanently reduce cultivable land. The largest percentage declines in per capita consumption are projected in these regions. Finally, the northwest is also vulnerable, as the lost consumption represents a large fraction of current household consumption. Adaptation measures should therefore focus on these areas.

## *Feminization of agriculture*

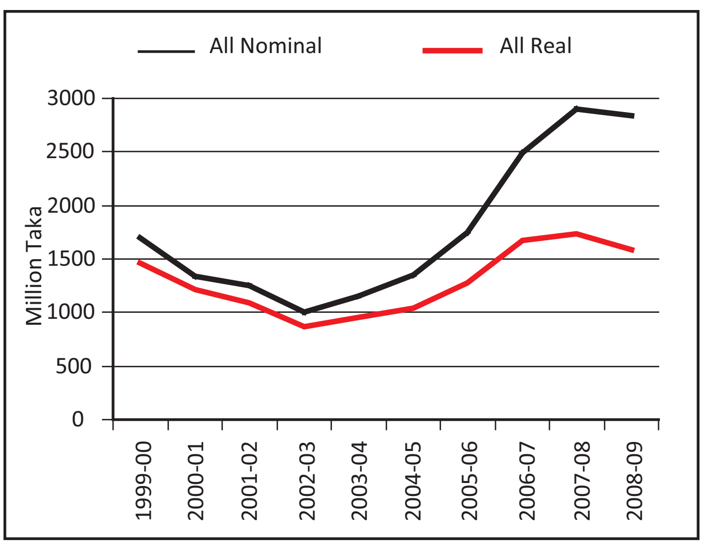
One particular issue of importance for future agriculture may be the recent trend toward feminization. (A separate paper looks at gender issues in food security.) While the proportion and absolute numbers of male agricultural workers has fallen over 1999/00 and 2005/06, the absolute number of female workers has increased from 3.8 to 7.7 million—that is, by more than 100 percent. In fact, the proportion of female labor in total employed agricultural labor has increased from 20 percent to more than a third of the total. Such a feminization, apart from social implications, may raise questions regarding the future organization of agricultural production as well as the nature of support required, as discussed below.

### *Public investment in agriculture*

In general, the allocations of development expenditures to agriculture and to the Ministry of Agriculture, as shares of total public development expenditures, appear highly inadequate. In most years since 1999/2000, the proportion of development budget allocation for agriculture has been around 20 percent. The Ministry of Agriculture's share in ADP allocation has been mostly 2–3 percent, and has not gone above 15 percent in the last few years. The absolute allocation in most years has been below TK 5 billion. Agriculture has been accorded minimal support in terms of resource allocation, despite its critical role in keeping the nation fed and providing employment to the majority.

Investment has been wholly inadequate in three critical areas of public intervention in agriculture: research and technology generation, marketing, and extension. Figure 6 shows the total expenditures by research organizations for research and development, and Figure 7 shows total expenditures by the Department of Agricultural Extension (DAE) for extension and by the Department for Agricultural Marketing (DAM) for marketing services. (For all these organizations, the normal activities are development activities, and hence revenue and development expenditures are not distinguished.)

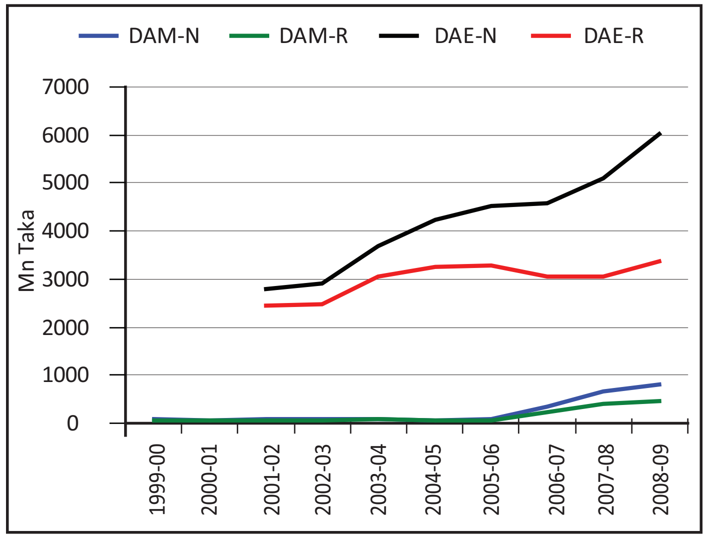
**Figure 6—Nominal and real expenditures for R&D in Agriculture**




Source: Based on information provided by Ministry of Agriculture.
Notes: Research organizations include BARC, BARI, Bangladesh Rice Research Institute (BRRI), Bangladesh Jute Research Institute (BJRI), Bangladesh Sugarcane Research Institute (BSRI), Bangladesh Institute of Nuclear Agriculture (BINA), and Soil Research Development Institute (SRDI). The nominal figures have been adjusted for inflation using crop sector deflators (BBS 2009). Figures include both development and revenue expenditure.

Research and development show a fall in nominal (and real) expenditures over the first few years of the past decade. Expenditures revived beginning in 2002/2003, but real expenditures (as Figure 6 shows) barely exceeded their initial 1999 level, as inflation chipped away much of the value of nominal expenditures.

**Figure 7—Nominal and Real Expenditures for DAE and DAM**




Source: Ministry of Agriculture.
Notes: The nominal figures have been adjusted for inflation using crop sector deflators (BBS 2009). Figures include both development and revenue expenditure.

For extension, data are available only since 2001/2002. Figure 7 shows, for the years for which data were available, a sharp increase in nominal expenditures for extension; real expenditures, however, show hardly any improvement.

But the worst situation is in marketing services, which has received only a pittance of public funding. Only beginning in 2005/2006 were there signs of improvement, and the government has since constituted a Committee of Experts to suggest a reorganization of the DAM.

Government investment in seed multiplication and delivery (by BADC) remained at the level of TK 1.1–1.2 billion, up to 2003/04. In 2004/05, expenditures fell to only TK 161.3 million (about $2.3 million). The next year saw a very high expenditure, of TK 3.64 billion—only to fall again to one-fourth of that level by 2008/09. The seed business of BADC needs a clearer strategic thinking as well as appropriate investments for the future.

## FUTURE CHALLENGES AND KEY ISSUES

### Challenges

Crop agriculture in Bangladesh faces the basic challenge of continuing to ensure supply of food from domestic production to the utmost extent possible to serve the needs of the rising population, while producing enough high-value non-staple and high-nutrition food crops. This will help provide direct income generation and processing for value addition and thus ultimately ensure better economic access to food. Note that crop agriculture is also the largest employer, and that agricultural wage labor are among the poorest. Hence another challenge for agriculture is to ensure that marginal farmers and labor do not lose out in the race for agricultural growth. There trend toward feminization of agriculture also makes the employment issue more complex.

There are, however, major constraints to expanding agriculture and ensuring food security arising from several natural and man-made adverse factors. Without their resolution, agricultural growth will be slow and limited, affecting everybody adversely.

The soil is heavily degraded in many parts of the country; water availability is not ensured or costly, and its use is often inefficient or wasteful, as discussed above. The issue of climate change threatens extensive negative impacts on agricultural production potential and productivity. Part of the challenge reflects over-dependence on rice, to the extent that it is grown even in areas that are not suitable for its cultivation.

Several key issues need resolution to meet these challenges. First, we must plan for water resource management, including both ground and surface water, to:

- balance, in the long run, between irrigated *boro* and part rain-fed *aman*, particularly as *boro* is likely to be most affected by climate change;
- minimize, wherever irrigation is needed, the use of costlier groundwater irrigation and substitute with cheaper surface water-based irrigation;
- lower dependence on heavily cultivated areas and provide opportunities for further growth in agriculture in less developed regions, such as the southwest and others that have abundant water but need major water-related infrastructure; and
- minimize the consumption of water, particularly in case of irrigated cultivation which in turn consumes energy (diesel and electricity).

Second is the issue of maintaining soil health. What types of policies are needed, including pricing and subsidy policies for fertilizer and irrigation support? How can crop diversification be encouraged along with crop specialization, both to maintain soil health and to raise incomes of farmers?

Third, we need to prepare for adjustments and adaptation both to present climatic variability and to future climate changes, which are expected to make Bangladesh highly food insecure particularly through adverse impacts on *boro* rice production. What adaptation options should Bangladesh choose so that agricultural growth can continue unimpeded?

Fortunately, the processes of adapting to climate change and stimulating the agriculture sector to further growth align well. Both will require the following measures:

- Diversify household income sources.
- Improve crop productivity.
- Support greater agricultural research and development.
- Promote education and skills development.
- Increase access to financial services.
- Enhance irrigation efficiency and overall water and land productivity.
- Strengthen climate risk management.
- Develop protective infrastructure.

Moreover, the current large gap between actual and potential yields suggests substantial on-farm opportunities for growth and poverty reduction. Expanded availability of modern rice varieties, irrigation facilities, fertilizer use and labor could increase average yields at rates that could more than offset the climate change impacts. Significant additional planning and investment are still needed, but the government has begun to address many of these issues.

### Population issues

Bangladesh is extremely heavily populated. The growth of population must be further curbed through judicious policies and investment, including in awareness-raising. While many instruments have to be explored and applied, one that must be uppermost in the minds of policymakers, given world-wide experience, is raising the status of women through education (at least up to secondary level) and through employment in out-of-home economic activities.[7] This may not be enough; women must also be in control of what they earn. Investments in women's education and positive discrimination in favor of women in the job market are therefore absolutely necessary for any food security measure to succeed in the long run.

## FACING THE CHALLENGE: STRATEGY AND INVESTMENT

These issues and problems must be resolved in an integrated framework. No piecemeal, ad hoc or short-term solution will suffice. The stakes are too high: the lives and livelihood of a huge part of humanity, estimated at 200–250 million (including the future generation). This campaign must be well planned and integrated, and its various elements must have synergy with each other.

[7] For a detailed discussion of the issues as well as references see Zaman (2002).

## Integrated water resource management and river basin development

An integrated water resource management, with river basin development as its integral element, may be the core planning framework for long-term, sustained food security in Bangladesh. While the groundwater development strategy has served us well so far, it appears to have reached its limits, and surface water development has been neglected for too long. An integrated ground and surface water development is needed.

The history of development of water management structures, their costs and benefits, and the problems of a technocratic approach are well documented.[8] The present woes of people affected by first Sidr and then Aila in the coastal region have also been well reported. A properly balanced "River Basin Development Approach," including both structural and non-structural measures, would integrate the present concerns of the government related to rejuvenation of the river system. This will also facilitate expansion of the surface water irrigation system in a coordinated manner, thus aiding *boro* production and reducing its costs.

Bangladesh also needs a Coastal Tidal basin Development Strategy to address the more complex water resource management issues along the coast. Such a development approach also necessitates moves toward regional and bilateral cooperation across basins in neighboring countries. Such activities are already envisioned in the government's water resources cooperation process, but they may need to be re-examined from a fresh angle.

## Develop an integrated crop production strategy

An integrated crop sector development strategy is needed to achieve several objectives at the same time. The strategy has to begin from the premise that Bangladesh needs to raise and stabilize productivity of both *boro* and *aman*, keeping in mind the present climatic variability and future projected climate change impacts. This will necessitate a range of activities.

### *Development of new crop varieties*

A two-pronged approach will be needed. First, *aman* cultivation will have to be protected as far as possible from drought (during the flowering/fruiting period) and from floods or excessive rains (during the early growth period). Drought protection may be addressed in two ways, and both may be necessary. First, develop shorter maturity varieties that can be harvested several weeks earlier than the normal harvest period, thus escaping the drier period. Varieties with such characteristics have been developed already, but more are needed to fit various ecological niches. Secondly, varieties which are drought-tolerant in various degrees have to be developed.

[8] See the Flood Action Plan reports, including those on FAP-12 on Agricultural Study and FAP-13 on Operation and Maintenance. For a summary view, see Asaduzzaman (1994).

For protection from flood or drainage congestion, there are also two approaches. First, develop varieties which are submergence tolerant. Already varieties have been developed which are tolerant to about two weeks of submergence, but more needs to be done. The second method is to invest in appropriate water management structures for protection from flood. This will be part of the integrated water management under the River Basin Development Approach discussed above.

### *Coastal area agriculture*

In the coastal areas, an expansion of *boro* or *aman* will necessitate huge investments in flood control and water-logging removal, as well as structures for controlling salinity intrusion. Managing salinity intrusion may conflict, however, at least in the southwest, with shrimp cultivation, possibly requiring land zoning. But note that this will require an efficient and effective regulatory system for water and land use in a complex ecological setting, which is so far nonexistent in the country.

Controlling salinity intrusion is particularly essential for encouraging *boro* rice cultivation in the southwest. Earlier attempts (for instance, through the Barisal Irrigation project and the Bhola Irrigation Project) have had limited success, as farmers did not switch to *boro* but continued with damage-prone *aman*. Better analysis of the outcomes of these irrigation projects would be valuable. In any case, higher salinity during rabi period is bound to discourage farmers from cultivating HYVs (Hossain, Bose, and Mustafi 2002).

An alternative solution is to develop salinity-tolerant varieties. Bangladesh scientists have developed such varieties, but they have not been adopted by farmers, either due to extension limitations or because the varieties are not high-yielding enough. There is still a lot to do in developing such varieties, graded by level of salinity suitability.

### *Adaptation to climate change impacts on agriculture*

The government has already given approval at the highest level to the Bangladesh Climate Change Strategy and Action Plan (2009). This Action Plan has explicit provisions regarding adaptation needs in agriculture and associated investment areas, in general conformity with earlier discussions. These investment needs have been prioritized for the Sixth Plan; they can be viewed as part of the overall investment needs for adaptation of crop agriculture to climate change.

## Raise water-use efficiency

A major strategy for lowering cost of production is to raise water use efficiency. This may be accomplished by developing drought-resistant varieties, by shifting to locally appropriate lower water-use crops (which will have to be remunerative enough to give up rice cultivation), and adopting more appropriate agronomic practices such as the Alternative Wetting and Drying method, particularly in the case of rice. Here the role of the extension department is extremely important. More fuel-efficient pumps and new governance structures for groundwater users, including informal groundwater markets, can also be useful in conserving important water resources and in increasing equity in water access.

## Revamp the technology generation system

Growth in crop agriculture and productivity depends finally on what the technology generation system in the country can deliver. The NARS will have to evolve varieties of crops (particularly rice) with the following characteristics:

- shorter maturity,
- drought-resistance or low water consumption,
- resistance to moderate flood levels,
- salinity resistance—both moderate and high,
- resistance to arsenic uptake,
- resistance to lodging in moderate storms, and
- suitability for cultivation in deep water areas.

In each case, disease and pest resistance also have to be built in and proper agronomic practices developed for the optimal results.

The conventional research method needs to be improved, and biotechnology research has to be encouraged for faster breeding and genetic improvement. Of course, there will have to be a proper regulatory system in such cases for risk assessment.

## Ensure supply of quality seed, fertilizer, and pesticides

A key element of production for any crop is a reliable supply of inputs. This may require substantial expansion of capacity for seed multiplication as well as the establishment of a new system of seed collection, preservation, multiplication, certification, and regulation— not only for seeds developed in the conventional manner but also for genetically modified Information and Communication technologies and biotechnologically developed seeds. Quality seeds of various kinds of food crops and non-food crops should be preserved, multiplied, certified, and made available through large-scale dealership, in a public-private partnership system.

As with seeds, there is a long-standing need for strong regulatory and certification mechanisms for ensuring quality of fertilizer and pesticides. Here there is a role for a strong farmer-level organization to work with a centralized regulatory authority.

## Maintain soil health

Maintenance of soil health will have to be a major strategy. Where soil and land degradation is due mainly to natural factors, the strategy should be to develop relevant cropping systems or varieties. Where the degradation is mainly the result of particular policies, policy revisions will be necessary. This is especially important in the case of fertilizer subsidy, including indirect support in the form of gas supply subsidy given to fertilizer factories.

## Overhaul the extension system

In addition to the substantial expansion of the extension system, the quality of extension needs major improvement. While continuing with conventional extension, the quality, skills, and knowledge of extension personnel need to be upgraded through training, including redesigning the syllabus of training schools. Extension must increasingly use information and communication technologies (ICT) and related technologies, including an information bank for use by the general public and farmers in particular. The burgeoning telecenters in Bangladesh should be used as a vehicle for public-private partnership in this process.

## Crop diversification and crop specialization

Diversification and specialization of crop cultivation will reflect specific opportunities available to farmers: land availability, quality seed, extension services, and information and marketing services. If *aman* yields become stable and improve over time, and if *boro* yields also rise, farmers will release part of the land under *boro* and put it under other rabi crops, comprising most of the high value food and non-food cash crops. In some cases, farmers will need to be assured of stable rice prices if crop specialization is to be ensured. Non-rice crop specialization, particularly in problem soils, may not only ensure better use of land but may also mean higher income for farmers. In this case, awareness-raising may be important, as farmers may not completely withdraw from rice due to subsistence considerations. Credit may also be an issue. A necessary safeguard may be a weather-indexed insurance scheme, in case of crop failure. While crop diversification and specialization may be useful strategies, they may not require completely new types of investments.

## Upgrade marketing services and reduce post-harvest losses

Bangladesh has little by way of a modern marketing service. In addition to construction of physical facilities and marketplace improvements, various other business advisory services need to be made available to farmers. Market intelligence is a major issue which may be improved and made faster with the adoption of ICT and mobile technology.

A related important issue is limiting post-harvest losses. Rice may require a program targeted at specific groups of farmers or geographic areas. But for high-value, highly perishable crops, these losses must be reduced as fast as possible. Various kinds of off-the-shelf technology must be promoted and made available to farmers and marketing agents, including farmer-level storage, storage at market intermediary level, and prevention of transport loss through better packaging methods.

## Ensure agricultural financial services

Agricultural financial services, particularly credit, may be a major factor in the proper application of inputs such as irrigation and fertilizer, particularly at times of rising prices. Adequate credit for farmers will therefore be essential to reap the benefits of the public/private investments in creating various public and semi-public goods. Financing and refinancing schemes may be needed, but credit is only one type of needed financial service. Insurance, particularly weather-indexed insurance, may help in inducing farmers to either diversify their crops or specialize, to cover the risk of crop failure. The increased climatic variability that is currently experienced and projected for the future call for a much strengthened insurance system to cover farmers all over the country. This will in turn necessitate various kinds of financing and refinancing system to be put in place.

## Modernize the agricultural education and training system

As a specialized manpower-based education system, agricultural education must meet the demand for trained scientists in various agriculture-related disciplines. Appropriate secondary and tertiary level education will be necessary and has to be supported with resources, and restructuring if necessary.

The same approach applies to training extension agents. A strategic link is needed between the technology generation system and the technology dissemination system.

## Encourage farmers' organizations

Farmers cannot be merely passive recipients of advice or resources from the government or other agents, private or NGO. They must have a strong organization of their own to champion the general interests of farmers, regarding such issues as prevention of adulteration of fertilizer, pesticides, or seeds; dissemination of information on new techniques or rules; equitable access to government lands; and prevention of use of toxic chemicals for ripening or preservation of food crops.

## Investment opportunities

Investments have to be made in the following areas, as discussed in more detail in this section.

- Integrated water resource management
- Technology generation system
- Technology dissemination or extension system
- Agricultural marketing services
- Soil health maintenance
- Climate change adaptation
- Provision of agricultural financial services
- Modernization of agricultural education system

Prioritizing investment needs will depend on a host of factors and will require more in-depth information and analysis, as indicated at the end of this section.

### *Integrated water resource management, river basin development and tidal basin development*

Integrated water resource management will be one of the main keys to the realization of the goal of agricultural growth and enhanced productivity. One aspect is on-field water resource management for raising water use efficiency, part of the mandate of agricultural extension. The other aspect relates to the large-scale structural and non-structural management of water, inland or coastal. Integrated River Basin Development and Coastal Tidal Basin Development are two potential areas for investment.

### *Technology generation system*

The technology generation system has fared poorly in access to resources (as shown in Figure 6), limiting the capacity for essential research. The real level of funding for research has to be immediately restored to its earlier levels—and, indeed, increased several-fold. At the same time, the absorptive capacity of the system may have been eroded through lack of support. Both institutional and human resource capacity have to be built up as an urgent priority.

In the longer run, the link between the agricultural education system and the technology generation system has to be made explicit, by establishing a definite supply-demand relationship. Institutions such as Bangladesh Agricultural University (BAU) must tailor their courses to the longer term demand of the research organizations and others. At the same time, BAU and similar educational institutions will have to be supported with greatly increased resources, along with restructuring, to meet present and future demand for trained human resources.

Resources will have to be increased for biotechnology research, while continuing to pursue conventional programs. We need to expand the present gene bank and establish banks in several other areas (at least one or two in each division, depending on size) to adequately develop crop technology, identifying desirable traits and integrating them into new or modified crops.

To scale up research activities, each (existing) district should have a research station focusing on particular local crops. Research stations may also be established for broad agroecological regions to develop technology suited to particular ecological niches.

An integrated planning framework for technology generation should include raising the number and quality of human resources, by specific skill type and level, through a modernized and appropriate agricultural education system at secondary and tertiary levels. Such an investment in research capability may have dramatic returns, as suggested by results of modelling conducted at the International Food Policy Research Institute (IFPRI). The modelling included two kinds of benchmark: the level of yield and production in 2005; and another baseline incorporating the carbon fertilization effects of climate change. We reproduce here two of several research investment scenarios, including only the Bangladesh-specific results (see Table 3).

Table 3 shows that even if fertilization effects of carbon may raise both yield and output, additional resources put into research and development raises them further, by 7–8 percent for rice and 11–13 percent for wheat by 2025. (The range reflects the two scenarios, one showing increased expenditures on research and development alone (R&D), and the other showing R&D increases including spillover effects.) By 2050, the yield increases for rice are 17–43 percent. Correspondingly, the output increases for rice are 5–6 percent for 2025 and 11–26 percent for 2050. The changes for wheat are even more substantial.

**Table 3—Yield and output changes under R&D investment scenarios for rice and wheat**

| Crop/scenario | Yield (mt/ha) | | Output (mn mt) | |
|---|---|---|---|---|
| | 2025 | 2050 | 2025 | 2050 |
| **Rice** | | | | |
| 2005 | 2.5 | 2.5 | 25.9 | 25.9 |
| Carbon fertilization | 3.1 | 3.7 | 32.8 | 35.9 |
| R&D (% increase over baseline) | 7.0 | 16.6 | 5.0 | 10.8 |
| R&D with spillover (% increase over baseline) | 8.4 | 43.2 | 6.0 | 26.0 |
| **Wheat** | | | | |
| 2005 | 1.8 | 1.8 | 1.0 | 1.0 |
| Carbon fertilization | 2.1 | 2.8 | 1.0 | 1.0 |
| R&D (% increase over baseline) | 11.2 | 26.5 | 10.5 | 58.3 |
| R&D with spillover (% increase over baseline) | 13.4 | 76.9 | 9.1 | 53.1 |

Source: IFPRI IMPACT simulations.
Note: Yields are in metric tons per hectare; outputs are in million metric tons.

The price tags for even substantial increases in research and development are rather modest. Under the business-as-usual scenario, investments in public agricultural research, rural roads, and irrigation over the 2005–2050 period are estimated at $9 billion. Investment needs for the two agricultural research scenarios would increase expenditures by only $1.5 billion and $4.1 billion over the same period, or $0.3 billion annually, a rather small sum compared to the baseline. By lowering investment needs elsewhere, such as irrigation, its impact would be multiplied. Given the likelihood of adverse impacts of climate change beyond carbon fertilization, these resource needs may be much greater. But this exercise clearly points out that R&D must be a major instrument for encouraging future agricultural growth and ensuring food security.

## *Technology dissemination or extension system*

The extension system has to develop new skills, and training in new knowledge, techniques, and methods of dissemination are absolutely essential. There must be strategic link between the NARS and the DAE: scientists in NARS must be directly involved in field activities of the DAE to better understand the needs of the farmers.

More training schools for DAE personnel are needed, for both pre-job and on-the-job training. These may be set up by private firms or the government, and they must have adequate facilities, including laboratories for experimentation. DAE personnel should visit other parts of the country to observe problems in other areas and the approaches of DAE personnel in the field. They also need full access to internet to connect with each other and also with farmers. A huge knowledge base, grounded on practice, can be developed and used by all.

One important area of investment is the quality seed program. More extensive seed multiplication programs are needed for various crops, particularly some that have been cultivated for only a few years (such as strawberry). Seed storage facilities need to be expanded several-fold, and farmers should be trained to preserve farm-grown seed. In this program, women may be increasingly involved.

## *Agricultural marketing system*

The marketing service needs immediate improvement, including added personnel and facilities as well as access to ICT services. Investment may be needed to prevent spoilage and losses in marketing. The report of the newly commissioned expert group on marketing will undoubtedly identify other areas needing investment.

## *Adaptation to climate change*

Adaptation to climate change does not raise wholly new issues, apart from those specified in the discussion of technology generation. The Theme on Food Security includes two broad programs related to this challenge, focusing on research and extension respectively: "Institutional capacity for research on climate-resilient cultivars and their dissemination," and "Adaptation against drought, salinity, and heat in crop agriculture." Work must begin on a pilot basis to gather experience to be analyzed through research and the extension system, which will have to be sensitized to these needs.

The Action Plan also calls for several broadly relevant water management strategies: structures for protection from flood; repair and maintenance of coastal polders; and resuscitation of rivers. River restoration is part of the proposed "River Basin Development Approach," while the coastal polders may be included under "Coastal Tidal Basin Management." The specific tasks that may need to be undertaken are shown in Annex 1.

The basic overall strategy for agricultural growth has three major components. First, a key element is the shift away from overdependence on *boro* and toward output growth during *aman*, a shift that may depend on successful technological advances. Second, we emphasize water use efficiency on-field—and here, the role of the extension department becomes important. Third, we would emphasize the importance of long-range weather forecasting and flood warning, so that farmers have timely warning of potential damage and can take preventive measures to minimize losses. In this context, over the longer run, water sector management—both river basin and tidal basin management—becomes the major facilitating factor to be considered for major investment.

With these advances in place, other issues such as crop diversification will be resolved to a considerable extent, as long as the relevant marketing issues have been addressed. For the basic strategy, however, adequate investment in technology generation is key—as it is also for the challenges of adaptation to climate change.

Finally, of the increasing feminization of agriculture may call for adaptive approaches relating to technological change, extension services and marketing services, as women farmers become a significant part of the farming community. This will need not so much investment but rather an understanding of the changing socioeconomic framework within which agriculture may evolve.

## CONCLUSION

Assuring future growth in agriculture will be a difficult endeavor, though it is not impossible. It will require actions and investments on many fronts. The decline of funding for research in the past has had deleterious effects on its ability to generate and evolve new technology; this needs to be rectified urgently. Other spheres of publicly supported activity, like marketing and extension, have also suffered reductions, and increased attention should be given to these support services. Finally, for longer term growth, well-designed management of the water resources is absolutely essential, and will be particularly important for adaptation to climate change.

## ANNEX 1: ACTIVITIES FOR INVESTMENT IN ADAPTATION TO CLIMATE CHANGE

1. Collection and preservation of local varieties of robust cultivars and documentation of their characteristics.
2. Research to develop climate-resilient varieties of rice (for example, varieties tolerant to heat, drought, salinity, and submergence).
3. Research to develop climate-resilient cultivars of wheat and other food and non-food crops, including vegetables.
4. Field trials and dissemination to farmers of the local robust cultivars and the newly developed varieties, in partnership with the extension service and NGOs.
5. Strengthening the capacity of key research institutes and scientists to undertake the work.
6. Identify likely changes in agroeconomic zones and probable climatic parameters.
7. Develop climate-resilient cropping patterns suited to specific regions of the country.
8. Field level trials of climate-resilient cropping patterns and associated water management systems.
9. Develop seed supply and extension mechanisms.
10. Prepare GIS maps of areas vulnerable to drought.
11. Develop and test adaptive measures in drought-prone areas by combining appropriate cultivars, cropping patterns, and land and water management practices, including effective dissemination to farmers.
12. Assess the condition of all existing flood embankments and prepare GIS maps.
13. Immediate repair and rehabilitation of existing embankments and structures, taking future forecast flood levels into account.
14. Survey of the condition of coastal polders and preparation of GIS maps with present. coverage of areas protected by these polders
15. Plan, design, and cost immediate repairs of existing dikes, based on future projected sea level rises and storm surges.
16. Reconstruction and repair of polders/embankments to design height and section.
17. Hydrological modelling of the Brahmaputra-Ganges-Meghna Basin against future climate change scenarios, to estimate future flood levels and risks in Bangladesh.
18. Develop a flood vulnerability map based on future projected climatic parameters.
19. Plan, design, and construct flood management infrastructure (embankments and/or others as appropriate) in light of likely future flood levels.
20. Flood plain zoning corresponding to various levels of vulnerability.
21. Long-term improvement of flood forecasting and warning, including installation of a telemetric network and weather and hydrological RADARS, and development of Digital Elevation Models (DEM).
22. Plan and implement non-structural flood-proofing measures.

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