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Rice Research, Technological Progress, and Impacts on the Poor: The Bangladesh Case (Summary Report)

Mahabub Hossain, David Lewis, Manik L. Bose, and Alamgir Chowdhury

Environment and Production Technology Division

International Food Policy Research Institute
2033 K Street, N.W.
Washington, D.C. 20006 U.S.A.

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ABSTRACT

This case study builds on an ongoing large-scale quantitative research project undertaken by BIDS/IRRI since 1987 originally in 64 unions from 57 districts of the country. It adds a qualitative research component to examine the impact of modern rice varieties (MVs) on livelihoods in a structured sample of eight of these villages across a range of favorable and unfavorable contexts. This component was structured using the sustainable livelihoods framework and employed focus groups stratified by poverty ranking and gender.

Rice is grown over almost 75 percent of the land area and is the country's most important crop. Two-thirds of this land area is now covered by MV technology after a rapid expansion over the past 15 years. The adoption process has been driven by the subsistence demands of households rather than by systematic agricultural extension efforts. Smaller farmers have adopted MVs more readily than larger ones. The privatization of shallow tubewell (STW) irrigation helped to make widescale MV adoption possible, as has the provision of improved infrastructure such as rural roads, bridges, and rural electrification. As a result, the general issue of MV adoption is no longer a current one for most farmers, except for households in flood-prone and coastal areas where adoption has so far proved difficult.

The quantitative research shows that for households with access to land there have been *direct* adoption impacts in the form of increased yields and higher profits. However, since rice now only represents around 20 percent of most households' overall income, nonagricultural income is found to have gained dramatically in importance for rural households. While the profitability has declined over time, rice contributes to improved

food security and provides a "springboard" for both rich and poor farm households moving into nonfarm income generation and employment.

In terms of impact on the poor, MV adoption has no significant direct impact except for a small fraction who have been able to access land from the expanding tenancy market. But *indirect* impacts in the form of employment and price changes are found to have been largely positive for the poor in reducing vulnerability. The qualitative research component generally confirmed these general findings, highlighting other factors such as the improved status associated with fixed-rent tenancy and "contract" labor arrangements.

The qualitative research also shows negative adoption impacts such as shrinking common property resources (wild fish, vegetables, etc., and declining soil fertility, both of which may increase the long-term vulnerability of the poor. It also throws light on the processes of technology dissemination. After initial release and dissemination of MVs by BRRI and the Department of Agricultural Extension, adoption has taken place primarily though informal farmer-to-farmer learning. The focus group discussions revealed low levels of confidence in the largely inactive public sector agricultural extension service and highlighted the highly variable performance of both local and national NGOs engaged in providing credit. It was found that the linking of qualitative and quantitative research methodologies was useful in (a) generating complementary data of different kinds on similar issues and (b) generating new data missed within a purely quantitative approach.

The sustainable livelihoods framework was a useful, flexible tool for structuring the qualitative data collection and analysis. However, the research study as a whole was limited by the fact that the qualitative component was "bolted onto" a quantitative study already underway. Therefore the framework, and the various data collection methodologies, were not systematically integrated across both components of the study. In conclusion, future agricultural research on rice may need to further address the question of MV adoption potential on risk-prone lands, the relevance of existing technology dissemination systems, the relationship between MV adoption and crop diversification, and the challenges of more sustainable crop management techniques.

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Mahabub Hossain[1], David Lewis[2], Manik L. Bose[1], and Alamgir Chowdhury[3]

1. INTRODUCTION

CONTEXT

Through large-scale adoption of modern rices, Bangladesh has made notable progress in sustaining a respectable growth in rice production over the last three decades. This growth occurred despite the declining availability of arable land and the predomination of small farmers and landless agricultural laborers. The coverage of irrigation has expanded to over 50 percent of cultivated land and adoption of MVs to 63 percent of the rice area. Rice production has increased from 17.6 million tons of paddy in 1975–76 to 37.6 million tons in 2000–01. Bangladesh faced a famine situation in 1974–75. Since then, it has been able to avert severe food insecurity in spite of several natural disasters including devastating floods in 1987, 1988, and 1998.

Economic growth has accelerated since the mid-1980s, and was quite impressive in the 1990s. The national income grew at 5.1 percent per year and per capita income at 3.6 percent.[4] Recent studies have shown moderate improvements in poverty for both rural and urban population despite trends toward income inequality, but questions have been raised about the validity of the methodology used for assessing the changes (Muqtada

[1] International Rice Research Institute, Philippines.
[2] Department of Social Policy, London School of Economics.
[3] Socioconsult, Bangladesh.
[4] This data suggests that concerns raised in several in-depth rural studies in the 1970s and 1980s (e.g., Van Schendel 1976, Januzzi and Peach 1980, Boyce 1987) that the agrarian structure would constrain the development of productive forces in Bangladesh were perhaps overstated.

1986, Rahman and Haque 1988, Khan 1990, Osmani 1990, Hossain and Sen 1992, Rahman and Hossain 1995, Ravallian and Sen 1996, Hossain et al. 2000, Khan and Sen 2001).

This study was undertaken to understand the pathways of the impact of technological progress in rice cultivation on the livelihood of the rural households, particularly of the poor. The literature on the adoption of modern rice varieties for Bangladesh is quite rich, (Asaduzzaman 1979; Mandal 1980; Hossain 1977, 1988; Hossain et al. 1994; Magor 1996). Contrary to the general perception that small farmers and tenants would have an inherent disadvantage in adopting the input-intensive MVs (Griffin 1974, Pears 1980, Lipton 1989) these studies did not find any significant association of adoption with agrarian structure. The disincentives to adopt varieties that require substantial investment in irrigation and chemical fertilizers under the widely prevalent sharecropping system, noted by Jannuzi and Peach (1980) and Boyce (1988), were ameliorated by institutional changes, such as renting of land under fixed-rent arrangements for MVs, but continuation of sharecropping for the cultivation of traditional varieties (TVs), and sharing of the cost of certain inputs by landowners.

The perception that withdrawal of agricultural subsidies and privatization in the marketing of key agricultural inputs would adversely affect the adoption by small and marginal farmers (Osmani and Quasem 1990) was proved unfounded by subsequent empirical studies. Private investment in irrigation spread rapidly, and small and marginal farmers got access to irrigation and chemical fertilizers through expanding and competitive markets for water and fertilizers (Hossain 1996). The technological progress was found to have a significant positive effect on efficiency in input use, employment of

hired labor, and household incomes, although it accentuated the inequality in the distribution of rural incomes (Sidhu and Banante 1984, Alauddin and Tisdell 1986, Hossain 1988).

Magor (1996) found a small fraction of rural households as vulnerable in spite of being in a land-scarce environment, and a significant group of small and marginal farm families not only had maintained their landholding, but also actually increased it over the present generation. Diversification of income sources and access to infrastructure were the major factors contributing to resilience against the shocks created by natural disasters (Ahmed and Hossain 1990, Magor 1996). Recent empirical studies demonstrated that the landless and marginal farm families did benefit from the green revolution technology and provided a critique of the hypothesis of polarization and social conflict put forward by eminent social scientists from studies in 1970s and 1980s (Jahangir 1979, van Schendel 1981, Boyce 1987, Jansen 1987).

A point of departure in the present study is the use of the sustainable livelihoods approach (SL) developed by the Department for International Development (Chambers and Conway 1992, Bebbington 1996). The framework considers livelihoods in terms of access to five types of capital or assets; it also incorporates an analysis of the economic, social, and political relationships that create poverty and wealth. Household-level quantitative and qualitative data are used to analyze the asset-base of poor and nonpoor households and its relationship to the adoption of improved rice varieties. We have analyzed the effect of adoption on productivity, profitability, rice farming, and rural household incomes of low-income people. We measure how they have gained or lost from changes in the livelihood strategies and outcomes induced by the productivity

growth in rice cultivation, especially as mediated by key institutions such as land, labor, credit, and water markets. The latter includes the spillover benefits accruing to landless and marginal landowning households arising from new employment opportunities in the rural nonfarm sector and from higher wages and less costly food.

Methodology

The study builds on an ongoing large-scale quantitative research project undertaken by the Bangladesh Institute of Development Studies (BIDS) and the International Rice Research Institute (IRRI) in 62 villages covering 57 districts.

The benchmark data are drawn from a sample survey conducted in 1987–88 using a multistage random sampling method for the project "Differential Impact of Modern Rice Technology in Favorable and Unfavorable Rice Growing Environments," sponsored by the International Rice Research Institute (IRRI) (David and Otsuka 1994). In the *first stage*, 64 unions (to cover one union each from the 64 districts in Bangladesh) were selected from the list of all the unions in the country, using a random number table. In the *second stage*, data on landholdings, total population and literacy rates were obtained for all villages in selected Unions from the district reports of the 1981 population census. Two villages were selected purposively for each union, such that the population pressure and the literacy rate for the selected villages were close to those for the selected unions. A census of all households in the first-choice village was undertaken to collect information on the ownership and tenure of land, adoption of modern rice varieties, and the major source of household incomes. Where the first-choice village was uncooperative, the second choice was included in the sample. Two sites were dropped at this stage because of logistics problems.

The census of the selected villages enumerated 9,874 households or 159 households per village. The census was used as the sample frame for the final draw of the sample for the generation of quantitative data on the operation of the household economy. The households were classified into four land ownership groups: (1) functionally landless (up to 0.2 ha of land); (2) small landowner (0.2–1.0 ha); (3) medium landowner (1.0–2.0); and (4) large owner (over 2.0 ha). Each group was further classified into two subgroups according to whether the household engaged in tenancy cultivation. Twenty households were then selected using the proportionate random sampling method so that each of the eight (4x2) strata was represented according to its weight. For a few villages, the sample size was 21 households because of a rounding error. The total sample for the 1987 survey was 1,245 households.

The selected households were interviewed with a structured questionnaire for generating data on the demographic characteristics of all household members, the use of all parcels of land owned and operated by the household, costs and returns on the cultivation of major crops, purchase of inputs and the marketing of products, ownership of nonland assets, employment of working members and earnings from nonfarm activities, and the perception of changes in household economic conditions. The findings were published in Hossain, et al. in 1994.

All the villages originally surveyed in 1988 were revisited again in 2001 generating data for the 2000 agriculture calendar (*boro*, *aus*, and *aman* harvests) to generate two-point panel data for the study. The sample was drawn using the classification of households by the wealth ranking method of the participatory rural appraisal (PRA) technique. The households in the village were classified into four

groups: (1) rich, (2) solvent, (3) poor, and (4) very poor. To ensure that all the 1987 sample households and their offshoots were covered in the present survey, a sample of 30 households was drawn from the four groups proportional to their weights, using the stratified random sampling method. New samples were drawn for the cells that were under represented by the old sample. The total sample size consists of 1,888 households.

For this study we used the data from 60 villages. Two villages were dropped (only a few farms grew rice and there were abnormally high incomes from remittances and trade and business).

The qualitative component of the research used focus group interviews, stratified by poverty ranking based on categories adapted from the Bangladesh Participatory Poverty Assessment (PPA) to complement longitudinal survey data collected by the quantitative study. The focus group methodology was judged to be a cost effective means of building on an existing large-scale quantitative study while still maintaining a relatively large coverage and sample size that would be attractive to researchers more used to quantitative approaches.

The qualitative component collected and analyzed data from eight villages selected to represent different agro-ecological conditions (such as elevated or flood-prone land) and levels of infrastructure (such as access to tubewell irrigation and proximity to road communications). Within the villages, separate focus groups were held representing three socioeconomic categories (nonpoor, poor, and very poor) divided by gender (separate male and female group for each category), giving a total of 48 focus groups. The investigators selected a key informant from the village and visited every household for familiarization and explaining the purpose of their visit. They invited a male and

female member to join PRA sessions mentioning the time and venue. The classification of households into groups with regard to wellbeing was done in a general meeting with those household members who accepted the invitation. The time and venue of focus group meetings for the three socioeconomic groups separately with the male and female members were decided in the general meeting. The participation in the focus group was voluntary. Attendance in focus group meetings varied from seven to 10 individuals, with some members leaving before the end of the meeting. A few male relatives came to observe the meetings of the women, but facilitators used gatekeeping techniques to prevent the men from influencing the discussions. Members who participated in the focus group meetings had no systematic relationship with the sample households selected for the quantitative study. The focus group discussion questions were drawn from the SLF and were supplemented by selected PRA techniques such as ranking exercises.

Research Questions

Following a discussion of SLF in Dhaka with the research team at the inception workshop in November 2000, the following main research questions were developed by mapping the original research issues of the IRRI-BIDS study onto the SLF:

- How do we understand the overall trend in household economy and vulnerability context, and what is their relationship with the adoption of MVs?
- What is the relationship between access to assets, technology adoption, and livelihood strategies? What are the asset constraints to adoption?
- What are the transforming effects of the intervening organizations and institutions? How do the approaches of the public sector agencies and NGOs affect livelihood strategies?
- How does adoption of MVs affect paddy yields, farm incomes, and household incomes?

- What outcomes can be detected in terms of direct and indirect effects of MV adoption on livelihoods and welfare of the poor and nonpoor households?

2. RICE RESEARCH AND TECHNOLOGICAL PROGRESS

DEVELOPMENT OF RICE RESEARCH CAPACITY

Formal rice research in the geographical area that now constitutes Bangladesh dates back to 1935, when a research station was set up at Habiganj, Sylhet to conduct research on deepwater rice. Research was mainly concentrated on yield improvements through pure line selection of TVs. Today, the Bangladesh Rice Research Institute (BRRI) is the main organization responsible for rice research. In developing its capacity for rice research and training, BRRI has received substantial support from the International Rice Research Institute (IRRI).

PRODUCTION OF IMPROVED VARIETIES

The major achievement of rice research in Bangladesh, as in other Asian countries, has been the development of high yielding modern varieties (MVs). To date BRRI has released 41 rice varieties for different agro-ecological conditions, while BINA and BAU have released six. The varieties have, however, been developed and released following a top-down breeding and evaluation process. Farmers' involvement in the identification of research issues and evaluation of improved germplasm has been lacking. Only in recent years have breeders used farmer participatory variety selection methodology to select advanced lines for unfavorable rice growing environments. Many of the varieties are direct releases of advanced lines developed at IRRI, and most of the crosses made for developing the varieties contained IRRI breeding materials distributed through IRRI's International Network for Genetic Evaluation of rice (Evenson and Golin

1997). Almost 70 percent of the varieties released in Bangladesh have IRRI blood (Hossain et al. 2003).

Only a few improved varieties have however remained popular with the farmers. In the 1970s the most popular varieties in the dry season (*boro*) were IR8, Purbachi (released before the introduction of IRRI varieties under the FAO program), BR1 and BR3 which were replaced in 1980s by BR8, BR14 and BR16. Since late 1990s BRRI Dhan 28 and BRRI Dhan 29 released in 1994 has spread fast because of higher yield potential compared to the varieties released in the 1970s and 1980s . For the wet season (aman), the most popular varieties in the 1970s were Paijam (Mashuri) and IR20 (IRRI Shail), which have been gradually replaced by BR11 since the early 1980s. BR11 still remains the most popular variety, although many varieties have been released since then for the wet season.

The 2000 household-level survey conducted for the study found the most popular varieties grown in the wet season as BR11 (introduced in 1980), Paijam (1960s), and BRRI dhan 30 (1994); and in the dry season BR14 (1983), BRRI dhan 28 (1994), and BRRI dhan 29 (1994).

DIFFUSION OF IMPROVED VARIETIES

BRRI has used several mechanisms to transfer rice technology to farmers (BRRI 1989, Hossain et al. 2002). It has developed a network of multilocation trials with district-level extension officers of the Department of Agricultural Extension (DAE). BRRI also organizes a training course on rice production for the extension officers of public sector development agencies and NGOs, which play a key role in disseminating new knowledge and technologies for rice production.

The direct contact of farmers with agricultural extension has, however, remained weak. The household-level surveys conducted for this study found that only 12 percent of the farmers in 2000 got information on MVs from the public sector extension officials; the number was estimated at 11 percent by the 1987 survey. Furthermore, the qualitative component of the present study revealed low levels of trust and confidence in public sector services, including agricultural extension (see below). Only three percent of the farmers got information from the input traders or NGO workers. The data presented in this report supports the argument that it has been primarily through informal farmer- to farmer exchange and learning, rather than through official extension efforts, that the increase in MV adoption has been achieved.

A major constraint to the diffusion of MVs is the production of high quality seeds (Hossain et al. 2001). BRRI provides breeders' seed of newly released varieties to the Bangladesh Agricultural Development Corporation (BADC) that has mandate for multiplication of foundation seeds, and production of certified seeds through contract growers. The capacity utilization has however remained limited due to price control by the government and lack of incentives. The seed supplied by the BADC now accounts for only 4.2 percent of the seed requirement of MVs. The seed replacement rate has remained at a low level. Nearly 90 percent of the seed planted is obtained from the farmers' own harvest or exchanged with neighbors.

TECHNOLOGICAL PROGRESS

Farmers started cultivating MVs in 1967 when the Bangladesh Academy of Rural Development imported IR8 seeds from IRRI and introduced them to farmers in the dry

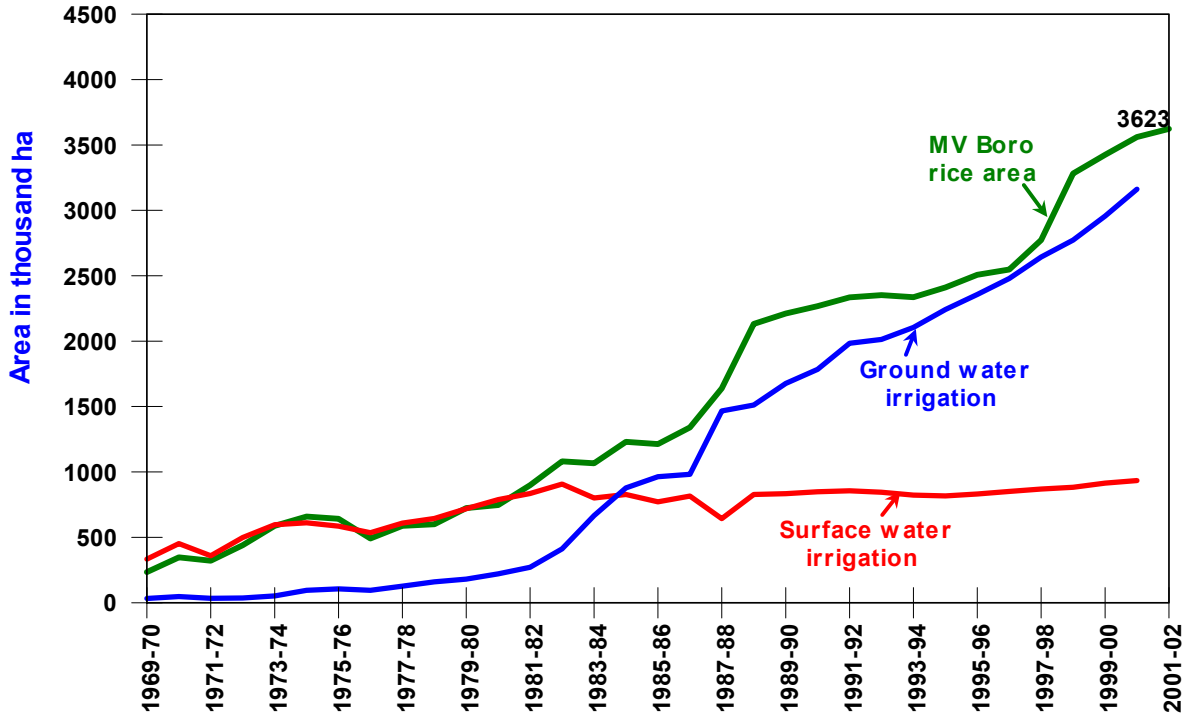
(*boro*) season. For the wet season (*aman*), IR20 was the first MV; it was introduced in 1970 and became known as IRRI Shail. Two other improved varieties of non-IRRI origin were introduced in the 1960s: Purbachi (Taiwan) and Paijam (known as Mashuri in India and Nepal, of Malaysian origin).

The spread of MVs was relatively slow during the 1970s. By 1980, coverage had expanded to 16 percent of the rice area in the wet season (aman), and 28 percent for the dry season (*boro* plus *aus*). Diffusion in the dry season has been rapid since the mid-1980s, which coincided with changes in government policies in favor of privatization in the procurement and distribution of small-scale irrigation equipment and chemical fertilizers, liberalization of trade, and reduction in tariff for imported agricultural equipment (Hossain 1996). Another spurt in the expansion of MVs took place in the late 1990s with improved linkages between agricultural extension and research, and collaboration between the public sector and the NGOs for the production of certified seeds of newly released varieties. By the 2000–01 crop year, the coverage of MVs had expanded to 63 percent of the rice-cropped area, 95 percent for the irrigated dry season crop (*boro*), 35 percent for the pre-monsoon drought-prone crop (aus), and 49 percent for the rainfed monsoon rice crop (aman).

A dominant factor facilitating the diffusion of MVs is the private investment in small-scale irrigation equipment such as shallow tubewells and power pumps. At the inception of modern irrigation in the late 1950s, the government placed exclusive emphasis on large-scale surface water development projects. The projects, however, had long gestation periods, suffered from management and maintenance problems, and were unpopular with farmers because the distribution canals took up scarce land. Over time,

the government shifted emphasis to small-scale projects: fielding power pumps to lift surface water and deep tubewells for extraction of groundwater. Since the early 1980s, the government has privatized the procurement and distribution of minor irrigation equipment, reduced import duties, and removed the restriction on the standardization of irrigation equipment (Mandal 1989, Hossain 1996). As a result, farmers have made substantial investment in shallow tubewells and power pumps that contributed to rapid expansion of irrigation facilities since the mid-1980s (Figure 1). The area irrigated by tubewells expanded from 53,000 ha in 1973 to 982,000 ha in 1987; it then expanded exponentially to reach 3.3 million ha by 2000. Shallow tubewells and power pumps owned by the farmers accounted for 71 percent of total irrigated area in 2000. The diffusion of MV *boro* rice is strongly related with the expansion of groundwater irrigation.

Figure 1--Trend in MV *boro* rice area and irrigation coverage, 1969–70 to 2001–02

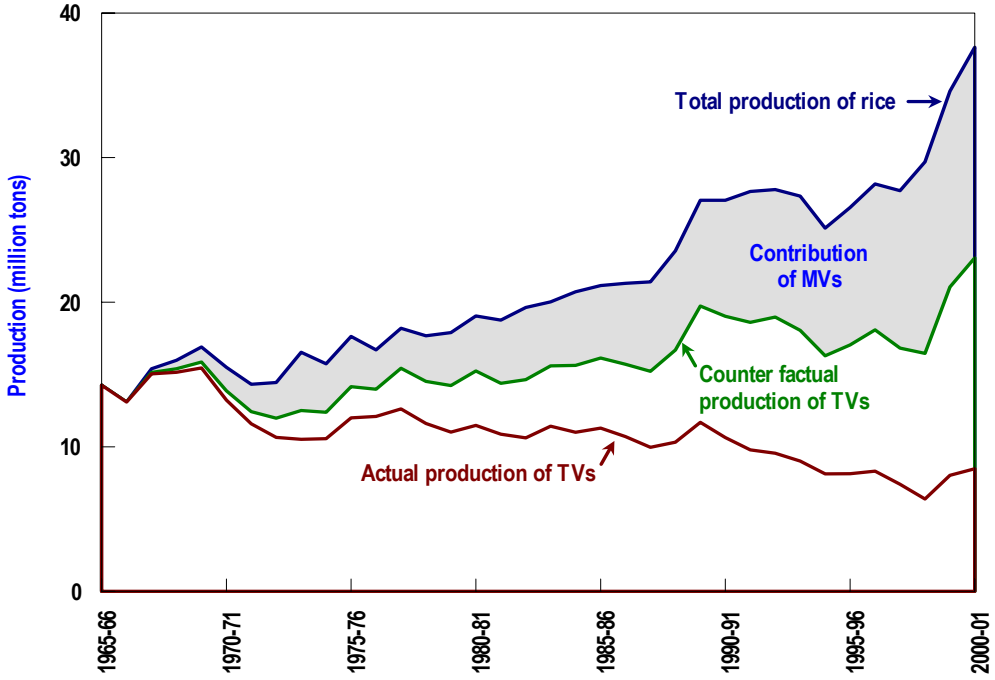


The average rice yield increased from 1.52 t/ha in 1965 to 3.48 t/ha by 2000–01, a 2.4 percent per year growth rate. Although rice-cropped area remained almost stagnant at about 10 million ha, the growth in yield has enabled Bangladesh to maintain a favorable food-population balance. While the population doubled during the 1965–2000 period, rice production grew 164 percent, from 14.3 mt in 1965 to 37.6 mt in 2000.

What would have happened to rice production if the modern rice varieties had not been developed and adopted is hard to establish. The yield of TVs has also increased from 1.52 t/ha in 1965 to 2.14 t/ha by 2000, a growth rate of 0.9 percent per year. Major factors behind the increase in yield of TVs are the increase in the use of chemical

fertilizers, a reduction in the share of rice grown in lowest yielding season (aus), and an increase in cultivation of *boro* rice with higher yields. We assume that, if rice area had remained unchanged, total rice production could have increased at the rate at which the TV yield grew. Figure 2 shows the estimate of the trend in counterfactual rice production based on this assumption, and compares it to actual production. The net contribution of MVs (actual production minus the counterfactual) has grown to 5.8 mt by 1985 and to 13.1 mt in 2000, which can feed about 59 million people (46 percent of the population in 2000). Without this impressive increase in production, Bangladesh would have faced a growing demand-supply gap, which could have been difficult to meet with imports, given the country's precarious foreign exchange position. The market would have distributed the scarce supplies in favor of the upper income groups who could afford to pay higher prices, which would have worsened food-insecurity and poverty.

Figure 2--Long-term trend in rice production and the contribution of MVs



LIVELIHOOD SYSTEMS

Vulnerability context

The poor in Bangladesh face many sources of vulnerability, including trends in resource availability and depletion, seasonality in employment and health, and shocks such as floods or human or animal diseases. The specific research questions for our study that followed were

(a) What are the changes in household economy for different household categories between 1987 and 2000 in each group of villages?

(b) What are the vulnerability-related factors that contribute to adoption or nonadoption of MVs at household and village level?

(c) What are the main types of shocks and crises that affect livelihood strategies of adopters and nonadopters?

The IRRI research already had the means to provide quantitative data on a range of vulnerability context issues. It provided data on the wider patterns of technological change across the country and plotted changes in prices and employment. The use of agro-ecological variables in site selection allows comparison of villages with and without irrigation facilities, and those with and without electricity. It is also possible to compare more or less flood-prone villages. By evaluating the adoption of MVs by socially differentiated groups, it becomes possible to examine the determinants of adoption, including agro-ecological factors and unfavorable environments.

Qualitative data adds to this picture in providing more information on how different categories of households cope with crises and on the effects of shocks on livelihood strategies. For example, focus groups were asked whether food security had improved as a result of changing prices and changing employment opportunities. They were also asked whether access to credit services from NGOs or other sources had affected their overall vulnerability to shocks. Moving away from direct references to technology adoption, there were also discussions about whether wider social changes—such as the growth of dowry or deteriorating law and order conditions in the locality—had made a difference to household vulnerability. The focus groups attempted to better understand people's changing perceptions of vulnerability and how these perceptions may have influenced livelihood strategies.

Landlessness, land holding, and tenancy

The household-level endowment of land is very low in Bangladesh because of extreme population pressure. Three-fourths of the population live in rural areas. In 2001, Bangladesh supported a population of 129 million with an arable land of 8.1 million ha (BBS 2002). The rate of population growth has declined from about 2.4 percent per year

in the 1980s to 1.5 percent in the 1990s, and the rural population is still growing despite rapid rural urban migration. According to agricultural census reports (GOB 1998), the average size farm holding declined from 1.7 ha in 1960 to 0.91 ha in 1983–84 and 0.68 ha in 1996. The latest census enumerated 17.8 million rural households in 1996 of which 5.8 million (29 percent) did not own any cultivated land, and 9.4 million (53 percent) operated less than 0.2 ha, which cannot generate significant income. At the other end, only 0.1 percent owned more than 10 ha and 2.1 percent owned more than 3 ha.

The survey showed that households owning up to 0.2 ha of land (functionally landless) made up 47 percent of households in 1987; this increased to 50 percent in 2000 (Table 1).

Table 1--Changes in the distribution of landownership, 1987 and 2000

Landownership (ha)	1987		2000	
	% of household	% share of land	% of household	% share of land
Up to 0.20	46.5	3.9	49.9	4.7
0.21 to 0.40	11.9	5.6	15.0	8.2
0.41 to 1.00	21.9	22.8	19.5	23.4
1.01 to 2.00	11.4	26.0	10.4	27.1
2.01 and above	8.3	41.7	5.2	36.6
Total	100.0	100.0	100.0	100.0
Average size of land ownership (ha)	0.61		0.53	

Source: IRRI-BIDS sample household survey.

The proportion of households owning more than 2.0 ha declined from 8.3 to 5.2 percent. The average size of land owned per rural household has declined from 0.61 to 0.53 ha over the period 1987–2000. The proportion of nonfarm households has increased from 33

to 40 percent. For farm households, the number of those who operate holdings of up to 0.4 ha (marginal farms) has increased from 35 to 46 percent, while the number of farms with holdings of over 2.0 ha has declined from 10.6 to 4.4 percent. The marginal and small farms dominate the agrarian structure of Bangladesh although they control a small share of land. The picture is of a trend toward pauperization rather than differentiation.

Substantial land transactions occur through the operation of the tenancy market. The information obtained from the surveys shows that tenancy cultivation is widespread and has increased over the 1987–2000 period. The proportion of tenant farmers has increased from 44 to 54 percent, and the area under tenancy cultivation has grown from 23 to 34 percent. The majority of the tenants own some land and rent more to increase the capacity utilization of the farm establishment. It is more socially prestigious to self-employ family labor on rented holdings than to work as wage laborers on another's farm. The number of pure tenant farmers who do not own any cultivated land has grown from14 to 23 percent and their share of land from 7 to 15 percent. Thus, some landless households are getting access to land through the operation of the tenancy market.

Since land is extremely scarce, households look for options to increase income through more intensive use of land and through the adoption of improved technologies. Investment in irrigation has been the most important means of increasing cropping intensity and land productivity. The coverage of irrigation has expanded fast, from 24 to 60 percent of cultivated land during 1987–2000 (Table 2). This situation is in many ways comparable to Geertz's (1963) analysis of "agricultural involution" in Indonesian wet rice cultivation systems where, like Bangladesh, there are small, fragmented land plots.

Table 2--Coverage of irrigation and adoption of modern rice varieties by farm size and tenure groups

Socioeconomic group	% of cultivated land irrigated		% of rice area under MVs	
	1987	2000	1987	2000
Farm size (ha):				
Up to 0.4	32.5	73.0	52.7	81.2
0.41 to 1.0	24.9	62.2	37.8	72.6
1.0 to 2.0	23.0	60.6	30.7	67.8
2.01 & above	22.4	48.2	27.5	62.2
Land tenure:				
Owner	25.6	62.9	32.6	72.0
Owner-tenant	20.8	57.6	32.1	68.3
Pure-tenant	27.0	58.4	43.4	70.1
All farms	24.0	60.1	33.1	70.3

Source: IRRI-BIDS sample household survey.

However, our data points to a less pessimistic view of the structural obstacles to technological change (Jannuzi and Peach 1980, Boyce 1987).

Endowment of other capital

Labor is the most abundant resource in Bangladesh. The number of members per household was very high at six in 1987, but has declined to 5.53 by 2000 due to the recent progress in fertility control. The child-woman ratio, an indicator of current fertility declined from 84 children (up to age 5) per 100 women of reproductive age (16–49) in 1987 to 58 per 100 in 2000. The proportion of children up to 15 years declined from 47 to

38 per 100 women over this period. The effect of reduced population growth has, however, not been felt on the working age population. The average number of earning members per household has declined from 1.82 to 1.68, but this was mainly due to reduction in the proportion of child labor and increased participation of young adults in colleges. But the number of agricultural workers has declined substantially, giving way to an increase in the number of nonagricultural workers. The difference in the number of earning members was, however, relatively less in the poor than nonpoor households.

The level of education of the earning members has increased by 50 percent, but still remains low, indicating poor quality of human capital (Table 3).

Table 3--Changes in asset base 1987 and 2000

Asset base	Land-poor households[a]		All households	
	1987	2000	1987	2000
Natural capital indicators:				
Land owned (ha)	0.33	0.20	0.61	0.53
Cultivated holding (ha)	0.56	0.41	0.87	0.67
Farm households (%)	36	52	67	60
Tenant farmers (%)	48	62	44	54
Area under tenancy (%)	35	51	23	34
Irrigated land (%)	20	51	24	59
Human capital indicators:				
Household size	5.98	5.47	6.00	5.53
No. of workers	1.69	1.49	1.82	1.68
No. of nonagricultural workers	0.54	0.56	0.66	0.83
Education of head (year of schooling)	2.54	2.10	3.12	3.79
Education of workers (years)	2.21	2.85	2.99	4.65
Physical and financial capital indicators:				
Nonland fixed assets (US$)	142	135	304	441
Nonagricultural fixed asset (US$)	91	44	151	290
Borrower households (%)	36	41	36	37
Household borrowing from insts. (%)	12	28	12	27
Credit from institutional sources (US$)	11	31	16	58
Total credit (US$)	34	44	49	82

Note: [a] Land-poor households defined as those owning up to 0.2 hectares.

Source: IRRI-BIDS sample household survey.

The average years of schooling was only three in 1987, but increased to 4.7 by 2000. There is substantial potential for improving the quality of labor through higher participation in secondary and tertiary schools. For land-poor households, the level of schooling is substantially lower, and the improvement over the 1987–2000 period much less pronounced, indicating unequal access to an educated labor force. The improvement in educational attainment of the labor force, although small, has facilitated occupational mobility from lower-productive agriculture to higher-productive nonagricultural activities (see below).

The endowment of physical capital (the value of nonland fixed assets such as draft animal and agricultural and nonagricultural machinery equipments) remained low in 2000, at US$441 for all households and US$135 for poor households (Table 3), indicating unequal access. There has been some accumulation of physical capital in agriculture, with increased investment in irrigation equipment and power tillers. In 1987, 3 percent of a sample of households owned shallow tubewells; this increased to 9 percent by 2000. Only 1 percent owned a power tiller in 1987 compared to 19 percent in 2000. But there was an absolute reduction in the number of cattle that are used as draft power, due to spread of mechanization in land preparation and the increased cost of maintaining cattle. On balance, the value of agricultural capital did not increase. However, rural capital accumulation has been very impressive in nonfarm activities such as transport operations and trade and business. Ownership of rickshaws and rickshaw vans increased from 2 percent of households in 1987 to 5.7 percent in 2000. The value of nonland fixed assets increased by 45 percent, almost entirely on account of nonagricultural fixed assets and accumulation of working capital in trade and business.

Bangladesh has always had a substantial credit market largely managed by professional moneylenders, rich peasants, and traders. Many analysts see the informal credit market as a source of exploitation that perpetuates semifeudal relationships (Bhaduri 1973). But in an imperfect financial market where the landless households and small farmers had difficulty gaining access to banks and credit societies, moneylenders perform a socially useful function of financial mediation. The relationship between lenders and borrowers in the informal market constitutes an important component of social capital and the relationship between landowners and tenants in the tenancy market (Woolcock 1998, Bebbington and Perreault 1999). The expansion of supply of microcredit by a number of large nongovernmental organizations (NGOs) in Bangladesh has reduced the importance of informal credit markets in Bangladesh. Households taking credit from NGOs increased from 4 percent in 1987 to 20 percent in 2000, and the share of NGOs in total credit supply increased from 7 to 30 percent. As a result, households borrowing from informal credit markets declined from 31 to 13 percent during the period. Greater access to NGO credit was an important source of capital accumulation of land-poor households.

One of the issues discussed in the focus groups was the general perception of the kinds of assets deemed important for survival. The perceptions of the respondents on the relative importance of different assets for the poor and nonpoor households are shown in Box 1. The “very poor” reported good health, trust of the employer, and social network as the most important assets needed, while the nonpoor households reported land, house, and education as the most important assets. Women in poor households reported goat and poultry raising, homestead trees, and NGO membership as important assets, while

women in nonpoor households mentioned raising livestock and savings in jewelry as important assets. The data shows quite clearly that people within poorer households are likely to value security enhancing assets over opportunity enhancing assets. It also shows that for the very poor the human body is the most important tangible asset and the household becomes vulnerable if the working member becomes sick. Therefore, the government's health and nutrition programs are of highest priority for this group.

Box 1--Perceptions of people on the importance of different assets

Nonpoor	*Poor*	*Very poor*
Owned land	Rented land	Good health
House	House	Trust of the employer
Education	Good health	Social network
Social network	Social network	Goats and poultry (women)
Political affiliation	Homestead trees	NGO membership (women)
Agricultural machinery	Goats and poultry (women)	Cottage industry skills
Livestock (women)	Education	Fishing nets
Nonagricultural machinery	Agricultural implements	Agricultural implements
Jewelry (women)	Membership in NGO (women)	
Cash savings in banks	Transport equipment	

Livelihood strategy

The information obtained from the survey on occupations of rural households is reported in Table 4.

Table 4--Distribution of workers by primary occupation, 1987 and 2000

Primary occupation	% households reporting it as primary occupation		% households reporting some income from the occupation	
	1987	2000	1987	2000
Farming	44.6	36.7	64.0	69.9
Agricultural labor	22.4	11.8	51.6	28.2
Other agriculture	1.2	0.9	78.0	86.2
Trade and business	8.3	12.2	31.9	32.3
Services	14.7	21.7	21.9	28.0
Nonagricultural labor	8.7	16.8	29.2	23.7
Total	100.0	100.0	–	–

Source: IRRI-BIDS sample household survey.

In 2000, only half of the households earned a livelihood from agriculture; others were dependent on various nonfarm activities—salaried and personal services, petty trade, shopkeeping, and business; and in providing labor in agro-processing activities, transport operations, and road and house construction. Very few workers reported fishing or livestock and poultry raising as a principal occupation, but the proportion getting some income from agriculture increased, perhaps because there were increased opportunities for landless laborers to gain access to land through tenancy.

Very few households reported women engaged in income earning activities. An analysis of the time budget for the last four days preceding the date of the survey shows that in 2000 about 36 percent of the workers engaged in expenditure-saving or income earning activities were women. The number was 40 percent in 1987. Women engaged in income earning activities outside the homestead declined from 7.7 percent (of all female

workers) in 1987 to 5.7 percent in 2000. The decline was mostly on account of nonpoor households. For very poor households, the incidence of women working outside home was higher: 11.2 percent in 1987 and 10.2 percent in 2000. The data shows that women's participation in income earning activities outside home is poverty induced.

Many households are engaged in multiple occupations. For example, a landless household may be simultaneously engaged in agricultural wage labor, tenancy cultivation, goat and poultry raising, petty trade, and transport operations. Even an individual worker may be engaged in two or three occupations. This is indicated by a much larger proportion of households reporting earning some income from the source, than the proportion of workers indicating it as the principal occupation (Table 4). Nearly 83 percent of the households reported some income from livestock and poultry raising in 2000, but few reported these as the principal or second occupation. Similarly, 28 percent of households reported some income from agricultural wage labor, but only 12 percent reported it as the principal occupation. The incidence of multiple occupations was less for households engaged in nonfarm activities. It has declined over the period, indicating a trend toward specialization and relatively full-time employment in a particular occupation.

The data show that agriculture has been releasing labor for the expansion of the rural nonfarm activities. The dependence on agriculture for livelihoods has waned substantially during 1987–2000, with the proportion of primary cultivators declining from 45 percent to 37 percent of all rural workers and the proportion of agricultural wage laborers from 22 percent to 12 percent. The mobility in rural occupations has been most pronounced for land-poor households whose members were initially employed as

agricultural wage laborers. They have been increasingly seeking employment in rural transport operations such as rickshaw pulling, and at the lower end of the productivity scale of service and trading activities. The mobility of the labor force from agriculture to rural nonfarm activities was facilitated by the improvement in rural roads and the increase in the level of schooling. It was also stimulated by technological progress in rice cultivation that created additional employment in trade and transport operations related to the marketing of agricultural inputs and the disposal of marketable surplus.

The perception of the people on the importance of different livelihood strategies obtained from the focus group discussions are reported in Box 2. Agricultural labor is the most important source of livelihood for the very poor followed by nonagricultural labor, goat and poultry raising, and cottage industries. Cultivation is not at all an important source of livelihood for this group. The moderately poor mentioned tenancy cultivation as the most important source of livelihood followed by nonagricultural labor, agricultural labor, and informal trade and business. The nonpoor households mentioned services, business, livestock raising, and rental of agricultural machinery as important means of livelihood besides cultivation of land.

Box 2--Perceptions of the people on the importance of different livelihood strategies.

Nonpoor	**Poor**	**Very poor**
Farming/farm supervision	Tenancy cultivation	Agricultural labor
Services	Farming own land	Nonagricultural labor
Business enterprises	Transport operation	Goat & poultry raising
Livestock raising	Agricultural labor	Cottage industry
Rental of machinery	Informal trade	Construction labor
Contractor with local government	Livestock raising	Open water fisheries
	Cottage industry	

Transforming structures

The qualitative data obtained from the focus group discussions helped us understand a range of intervening structures and processes that bear on the livelihood strategies of rural people. The focus is on wider issues that may have relevance to farm households engaged in the adoption of MVs.

A striking finding is the generally weak relationship and the absence of trust between rural people and public-sector agricultural service providers, contrary to the evidence of synergy between government involvement and private corporate efforts provided by Evans (1996). In many places, people reported the Department of Agricultural Extension as the least effective among a range of governmental and nongovernmental service providers. All categories of farmers report the importance of informal farmer-to-farmer learning in the acquisition of knowledge and skills for MV cultivation. In one site the very poor mentioned that they learned about cultivation of MVs from the experience of working as laborers on the land of rich farmers. Some groups cited broadcast on agricultural issues in TV and radio as an important source of information.

There are similarly negative perceptions of wider public services and local governance. Very few people have anything positive to say about the Union Parishad (the lowest unit of local government): a male poor group member said “The political leaders only come to the village at election time and give out packets of *bidi* [local cigarettes] asking for votes.” They are simply remote and irrelevant to the people. There is also a feeling that otherwise reliable people quickly become corrupted by the system if they

enter local politics and achieve office. The government veterinary services were also generally poor and inaccessible.

Women in all categories and some men tend to be very positive about the Health and Family Planning Department. Female groups in one site were also very enthusiastic about the government's mass literacy program.

NGOs generally fare much better than public service providers in the ranking given to them, particularly by the poor groups. They are seen mainly as providers of credit and agricultural inputs. However, the very poor and some of the moderate poor are fearful of taking loans, even from NGOs, because they are worried about the pressure of having to repay the loan regularly and feel that this might increase their overall vulnerability. There is also a high degree of variation in the perceptions of different NGOs, which suggests that NGOs vary in the quality of services they deliver.

It was believed that there is a decline in the law and order situation and access to governance. One of the very poor group members said "There is no justice. Those who have money give money and the case against them is dismissed. But we are always punished." This view is most acute among the very poor, who are particularly vulnerable. There is a hostile attitude toward the police: "When there is a conflict, they come and take money from both sides." A link is occasionally made between greater prosperity and deterioration in the law and order situation.

The formal banking sector is generally seen unfavorably. Even the nonpoor groups report that it is difficult to get a bank loan without paying a bribe, normally 10 percent of the loan.

Livelihood outcomes

Table 5 reports the findings of the survey on household income and its composition. The concept of income used here is comprehensive, including income received in kind and cash.

Table 5--Growth and structure of rural incomes, 1987 and 2000

Source of income	Income (US$/household)		Share of total income		% annual rate of growth, 1987–2000
	1987	2000	1987	2000	
Agriculture	541	560	60.9	48.7	0.3
Rice farming	266	252	29.9	21.9	–0.4
Other crops	79	134	8.9	11.6	4.3
Noncrop agriculture	94	122	10.6	10.6	2.1
Agricultural wage	102	52	11.5	4.5	–5.5
Nonagriculture	348	591	39.1	51.3	4.3
Trade and business	112	229	12.6	19.9	5.9
Services	126	144	14.2	12.5	1.1
Remittances	42	136	4.7	11.8	9.8
Nonagricultural labor	68	82	7.6	7.1	1.5
Total household income	889	1151	100.0	100.0	2.1
Household size (persons)	6.00	5.53	–	–	–0.6
Per capita income	148	208	–	–	2.7

Source: IRRI-BIDS sample household survey.

A money value was imputed to production and receipts in kind at average prices for the entire sample. Household consumption of self-produced crops, livestock, forestry, and fisheries products is treated as income. For international comparison, and comparison over time, the income has been estimated in U.S. dollars using the exchange rate prevailing during the reference periods of the survey. The exchange rate increased by 68 percent over the period, compared to a 72 percent increase in the wholesale price index. Thus, the growth rate estimated from the dollar-denominated income should approximate growth in real incomes.

The average household income increased from US$889 in 1987 to US$1151 in 2000, indicating a rate of growth of 2.1 percent per year. Per capita income has increased faster, at 2.7 percent, because of the reduction in household size. The per capita rural income was estimated at US$208 in 2000. The growth in rural incomes over 1987–2000 was almost entirely on account of nonfarm activities. The share of nonagriculture in total household incomes has grown from 42 percent in 1987 to 54 percent in 2000. From a sample survey of 16 villages, Hossain (1988) estimated the share at 36 percent for 1982. Thus the income from rural nonfarm activities has been increasing at a faster rate than that from agriculture since the early 1980s. These findings support the general observation that the rural nonfarm economy accounts for an increasing proportion of rural employment and incomes with the development of the overall economy (Chuta and Liedholm 1979, Shand 1986, Ranis and Stewart 1993, Rosegrant and Hazel 2000, Reardon et al. 2001).

Several aspects are noteworthy with respect to changes in the structure of household incomes over the 1987–2000 period. First, landownership is no longer the

predominant source of household income in rural Bangladesh. This may be judged by the fact that income originating from agriculture has declined from 61 percent to 49 percent, and from rice farming from 30 to 22 percent. Land is the dominant factor of production in these activities. Second, business, services, and remittances accounted for 43 percent of rural incomes, a substantial increase from 31 percent in 1987. The most dramatic increase has been in the share of remittance income from relatives who have migrated to cities and abroad. The number of households receiving remittances increased from 8 to 19 percent over the period, and the income from remittances increased from 4.7 to 11.8 percent. These numbers suggests that education (human capital) and the accumulation of physical capital have become important sources of livelihoods. Third the role of the labor market in income generation is no longer of high importance. Hiring out of labor services in crop production, processing and construction activities, and generation of self-employment in manual labor-based activities (cottage industries and transport operations) accounted for only 12 percent of rural incomes in 2000, a sharp drop from 19 percent in 1987. For poor households who supply bulk of the wage labor, the income from agricultural and nonfarm labor accounted for a third of the household income in 2000.

The absolute decline in the income from rice farming is surprising in view of the impressive increase in rice yield and production in the 1990s. An important factor is the decline in the size of landholding due to demographic pressure. But more important is an adverse movement in the terms of trade for the rice farmers. The wholesale price index has increased by 5.3 percent per year over 1987–2000, while the paddy price increased by only 3.1 percent. The prices of major agricultural inputs also increased at a faster rate than paddy prices: the wage rate at 5.6 percent per year and the chemical fertilizers at 3.8

percent. Had the paddy price increased at par with inflation, the erosion in income from rice cultivation would have been much slower.

3. DETERMINANTS OF TECHNOLOGY ADOPTION

ADOPTION BY SOCIOECONOMIC GROUPS

A crucial factor affecting the distribution of gains from technological progress is the extent and intensity of adoption among different groups of farmers. The literature is full of studies that analyze adoption behavior of farmers to test the hypothesis that the gains from the introduction of new technology have been unequally distributed (Griffin 1974; Pearse 1980; Feder, Just, and Zilberman 1985; Lipton 1989). It is argued that the new technology may entail fixed costs in the form of access to information and sources of supply of new inputs and arrangements for finance and marketing, which tend to discourage adoption by small farmers and tenants. On the other hand, Knox, Meinzen-Dick, and Hazell's (1998) review of adoption studies suggests that land tenure is not likely to constrain adoption of new crop varieties, because the returns are relatively short term (unlike, for example, planting trees), and the technology itself is not "lumpy," but can be adopted on any size area.

This section reports the findings of the household-level survey on the adoption of improved rice varieties and analyzes what assets are needed for adoption. The requirement of working physical and financial capital in cultivating a given amount of land is higher for modern than for TVs (see below). Farmers who grow MVs need to invest in irrigation equipment, such as tubewells and pumps, or pay water charges to owners of the equipment for the purchase of the services. Unless the government bears

the cost of irrigation development, access to capital in the form of accumulated savings or low-cost credit from financial institutions may become an important factor determining the extent of MV adoption. Because small landowners and tenants have little physical capital and limited access to institutional credit, a priori they would adopt modern rice varieties less heavily than large landowner cultivators.

Table 2 reports the findings of the survey regarding the use of irrigation and adoption of MVs by various farm size and land tenure groups. Contrary to the a priori hypothesis, the coverage of irrigation is found larger in smaller farms during 1987, when about 24 percent of the land area was covered by irrigation. The coverage of irrigation has increased substantially since then, reaching about 60 percent of the cultivated land in 2000. The inverse relationship between farm size and the coverage of irrigation still persisted. No consistent relationship between the tenure status of the farm and the coverage of irrigation was found. The pure owners and pure tenant farms had higher coverage of irrigation than the mixed tenant farms, which tend to be large in size of holding.

How can one explain the above observations? In the early years, irrigation facilities were developed by the government, largely through externally funded projects that benefited cultivators irrespective of farm size. Even with the private ownership of shallow tubewells and power pumps that have expanded greatly since mid 1980s, the small- and medium-sized farms have a higher probability of having some parcels located within the command area of these equipment compared to the large farmers with greater number of parcels, because of the random location of scattered holdings. The subsistence

pressure of producing more rice to meet family needs may also induce the small and tenant farmers to take advantage of the irrigation facilities more than the larger farmers.

The coverage of MVs in the villages covered by the survey has expanded from 33 percent of rice cropped area in 1967 to 70 percent in 2000. The intensity of adoption of MVs is inversely related to the size of farm and is not systematically related with land tenure status, contrary to findings reported in the early green revolution literature. The inverse relationship with farm size was observed in 1987 as well as in 2000 (see also Hossain 1977, Asaduzzaman 1979, Mandal 1980, Hossain 1988, Hossain et al. 1994).

DETERMINANTS OF ADOPTION: A MULTIVARIATE ANALYSIS

To analyze the relationship between the asset base of the farm households and the intensity of adoption of MVs, a multivariate regression model was estimated with household-level data (Table 6). The explanatory variables include both socioeconomic characteristics of the household and the biophysical characteristics of the farm. The dependent variable is measured as the area under modern rice varieties as percentage of cultivated area.

Table 6. MV adoption function: estimates of TOBIT model.

Factors	Wet Season[a/] 1987	Wet Season[a/] 2000	Dry Season[a/] 1987	Dry Season[a/] 2000
Intercept	–17.01*	–24.96*	–21.78*	–16.10*
	(–2.33)	(–3.26)	(–3.97)	(–2.92)
Size of farm	–7.10	–1.76	–0.41	–4.06
	(–1.27)	(–0.35)	(–0.10)	(–1.18)
Tenancy ratio	–10.56	3.44	2.93	8.92*
	(–1.47)	(0.66)	(0.56)	(2.41)
Education of workers	0.98	0.66	0.52	0.44
	(1.39)	(1.16)	(1.01)	(1.06)
Extension contact	21.08*	21.20*	3.05	3.32
	(3.88)	(4.69)	(0.74)	(1.04)
Land per agricultural worker	6.02	–0.23	–2.92	–0.43
	(1.01)	(–0.04)	(–0.68)	(–0.11)
Land per nonagricultural worker	–1.07	–1.89	0.12	4.48
	(–0.22)	(–0.39)	(0.03)	(1.41)
Nonland fixed assets per unit of land	–1.61	–0.23	2.81	0.86
	(–0.35)	(–0.15)	(0.96)	(0.84)
Institutional loan per unit of land	–7.61	–1.11	24.2*	–2.12
	(–0.47)	(–0.71)	(2.36)	(–1.59)
Irrigation coverage (% of land holding)	0.41*	0.54*	0.97*	0.85
	(5.86)	(10.24)	(18.56)	(22.10)*
High land[b/] (% of holding)	0.22*	0.29*	0.05	–0.05
	(3.05)	(5.44)	(0.79)	(–1.28)
Low land[b/] (% of holding)	–0.46*	–0.49*	–0.05	5.43
	(–4.62)	(–5.82)	(–0.71)	(0.94)
Very low land[b/] (% of holding)	–0.73	–1.05	0.23*	0.15*
	(–5.01)	(–10.94)	(2.93)	(2.94)
Sigma	59.84	59.54	45.45	46.20
	(22.92)	(30.43)	(26.67)	(37.71)
Number of cases	801	1090		

Note: **a/** The dependent variable is measured at the area under modern rice variety during the season as percent of cultivated land.
b/ The variables are measured at land under different elevation as percent of the total holding. Highlands are those not flooded during the peak of the monsoon season, lowlands flooded at a depth of 50cm to 100cm, and very lowland at a depth of more than 100cm. The medium highland flooded at a depth of up to 50cm is used as control and not included in the model.

Figures within parenthesis are asymptotic "*t*" values.
* Denotes that the coefficient is statistically significant at 5 percent probability level.

Source: IRRI-BIDS sample household survey.

The equation was estimated separately for two seasons. For the overlapping *aus* and *boro* seasons (dry season), irrigation is a prerequisite for growing MVs because the rainfall is scanty and the puddling of soil for transplantation of seedlings cannot be done without irrigation. For *aman* rice (wet season), rainfall is plentiful (although farmers' face occasional droughts), so MVs can be grown under rainfed conditions. But physical control is imposed by land elevation, since lowlands remain deeply flooded throughout the monsoon season and are thus unsuitable for growing dwarf MVs. The model includes land elevation and irrigation variables in the adoption function to capture the effects of these technical factors. Since the observed value of the dependent variable has a limited range, the function was estimated by the TOBIT method using the LIMDEP software.

The estimated parameters of the functions are reported in Table 6. As expected, irrigation is found to be the most significant variable in determining the rate of adoption. The asymptotic t-value of the regression coefficient is the highest for irrigation compared to other variables included in the model. The findings also show that irrigation is a more important factor determining adoption for the dry season than for the wet season.

The other technical factors such as the land elevation variable are also important determinants of adoption, particularly for the wet season. The findings show that MVs are adopted less in the low- and very low-lying lands compared to the medium-level land (used as control in the equation) in the wet season. For the dry season, MVs are adopted more in the very low land. Such lands become favorable for growing dwarf MVs during the dry season, because of the low cost of irrigation due to higher recharge of the groundwater available in upper aquifers in such types of land, and plentiful surface water in nearby creeks and canals. Such land is also regularly silted by floods, contributing to

the higher nutrient-supplying capacity of the soil, thus requiring lower use of inorganic fertilizers.

It may be noted that the level of education of the farmers, the endowment of labor and physical capital in relation to land, and the size of holding are not significant determinants of the intensity of adoption of MVs. The coefficient of the tenancy variable was found positive in the equation for 2000, indicating higher rate of adoption on tenant farms, contrary to a priori hypothesis. The coefficient is however statistically significant only in the equation for the dry season. These findings are contrary to the observations made in the earlier literature on the constraints to adoption of new technologies.

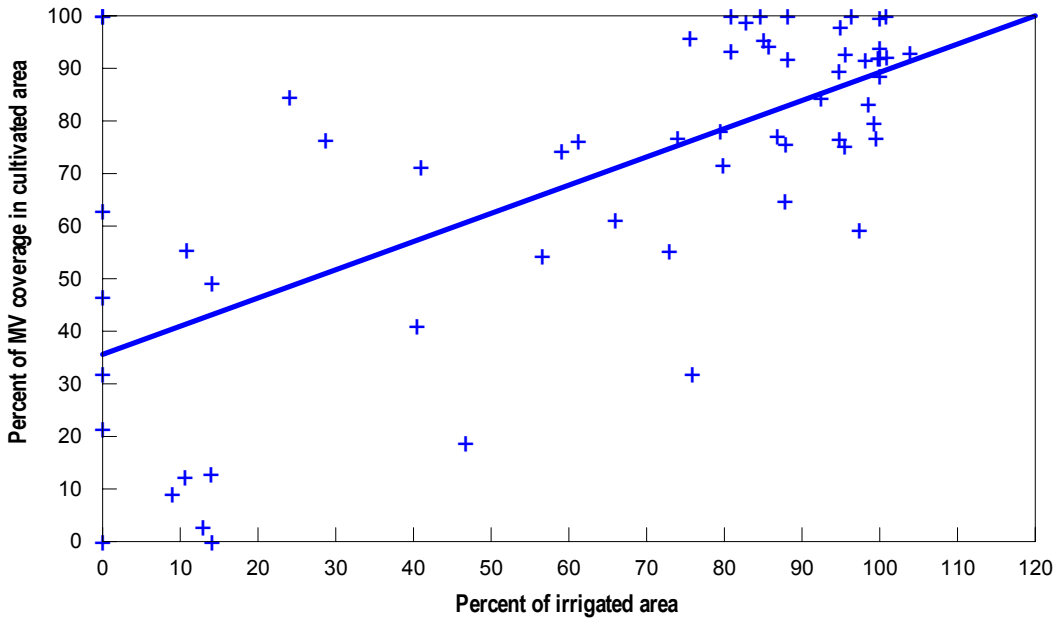
Among other institutional variables only the farm's contact with extension officials was found significantly associated with adoption of MVs in 1987. But with large scale adoption of the MVs, the extension contact was no longer a critical factor in affecting the adoption of MVs in 2000.[5] The availability of institutional loans was found significant only in the equation for the dry season in 1987, but not in 2000.

The coefficient of the size of land holding is negative in all four equations, indicating higher rate of adoption in smaller farms. But the values of the coefficients were not statistically significant.

There are villages in both ends of the adoption scale, and the relationship with irrigation is very strong.. The villages with low levels of adoption are mostly located in the coastal areas or in the depression basins with a majority of land deeply flooded during the wet season.

[5] Low levels of contact with public extension agencies reported within the qualitative data suggests that informal farmer-to-farmer learning has become dominant, perhaps associated with improved communications, levels of education and the proliferation of NGOs.

Fig.3--Relationship between MV adoption and irrigation coverage, village level, 2000



The findings indicate that technical factors, the availability of irrigation facilities, and the elevation of the parcel of land are more important determinants of adoption than the socioeconomic factors such as endowment of other assets and access to finance. It is also subsistence pressure that pushes small farms to adopt the new technology. As noted earlier MVs have already spread to 70 percent of the rice land. The coverage has remained low in the flood- and salinity-prone areas for which appropriate MVs have not yet been developed.

4. IMPACT OF ADOPTION

This section assesses the impact of the adoption of MVs by estimating (a) the direct effect on farm incomes through changes in the input-output relationships and (b) the indirect benefits accruing to the poor through the operation of different markets and agricultural growth-induced expansion of rural nonfarm activities.

EFFECT ON PRODUCTIVITY, UNIT COST, AND PROFITABILITY

The level of input use, yield, and costs and returns for the traditional and MVs estimated by the survey are shown in Table 7.

Table 7--Costs and returns in the cultivation of traditional and modern rice varieties

[US$/ha]

Items	TVs		MVs		All varieties	
	1987	2000	1987	2000	1987	2000
Gross value of production [a/]	325	312	638	625	429	509
Paid-out costs	106	115	296	251	469	202
Household income	219	197	342	374	260	307
Total cost [b/]	251	177	467	327	322	272
Yield (t/ha)	1.67	1.98	3.58	4.19	2.30	3.37
Unit cost (US$/ton)	150	89	130	78	140	81
Output price (US$/ton)	174	145	167	141	171	142
Profit (US$/ton)	24	56	37	63	31	61
Labor use (days/ha)	142	110	206	133	163	125
Labor productivity (US$/day)	2.29	2.84	3.10	4.70	2.63	4.07

Note: **a/** Includes the value of byproducts.
b/ Includes imputed costs of family supplied inputs and interest charges on working capital but excludes the land rent. For 2000, the rent paid by tenants is estimated at US$136/ha for TVs, US$192 for MVs.

Source: IRRI-BIDS sample household survey.

For ease of comparison, the values are expressed in U.S. dollars at the prevailing exchanges rates of Bangladesh Taka in 1987 and 2000. The "paid-out costs" include the cost on account of seed, fertilizer, manure, irrigation, pesticides, hired labor, animal power, and rental of agricultural machinery. Total cost includes the imputed value of family and animal labor and the interest charges on working capital. The family labor was imputed at the wage rate paid to the hired labor.

The costs and returns data shows that farmers use many times more chemical fertilizers and pesticides in the cultivation of MVs than for TVs. This is a major environmental problem. Pesticides, however, account for less than 2 percent of the total cost of production.

The cash cost of production per unit of land was three times higher for cultivation of MVs than traditional ones in 1987, and 120 percent higher in 2000. The total cost of production per ha was about 86 percent higher in 1987 and 2000. The numbers clearly show that the MVs are substantially more input-intensive and hence may not favor low-income farmers with limited access to working capital. But the increase in production from the adoption of MVs is much higher than the increase in cost, so the cost per unit of output goes down with the adoption of MVs. The unit cost was 13 percent lower in the cultivation of MVs compared to TVs in 1987, and 12 percent lower in 2000. Thus, technological progress contributed to reduction in the unit cost of production, which has helped maintain rice prices at a low level, a major factor behind the improvement in food entitlement of the low-income households.

The rice price in nominal U.S. dollars declined by 17 percent over 1987–2000 (higher than the reduction in unit cost), dampening the income effect from the adoption

of MVs. The increase in the gross value of production from the shift from traditional and MVs was US$313/ha in both periods. Farmers, however, have reduced the cost by introducing mechanization, reducing use of animal and human labor, and making more economical use of chemical fertilizers. The labor use in the cultivation of MVs was reduced from 206 days/ha in 1987 to 133 days/ha in 2000, and the use of chemical fertilizers from 380 kg (materials) in 1987 to 291 kg in 2000. Farm income (gross value of production minus cash cost) per ha was lower in 2000 than in 1987 for TVs but increased marginally for MVs. The net gains from the shift of land from traditional to MVs in fact increased from US$123/ha in 1987 to US$177/ha in 2000.

Impact on household income

How important are the gains from adoption of MVs in relation to household incomes? The average size of farm in 2000 was estimated at 0.67 ha, and the average household income at US$1,151. With two MV rice crops per year, the net gains from adoption for an average household would have been US$237, or 21 percent of total household income.

The adoption of MVs could also have substantial indirect effects on household incomes. The positive indirect benefit may arise from agricultural growth linkage effects (Mellor 1976, Hazell et al. 1983, Hazell and Ramasamy 1991). The negative indirect benefit may occur due to diversion of labor and capital for the cultivation of MVs, which could have higher returns in other activities. For capturing these indirect effects, we estimated an income function with the household-level data for a rigorous estimation of the impact of MVs. The household income is related to the endowment of different assets—land, worker, physical capital, and education—as well as some location-specific

variables such as access of the village to infrastructure (measured by the availability of electricity). For estimating the effect of MVs, the land under MVs was introduced as an additional explanatory variable. We note in Table 6 that the adoption of MVs is strongly influenced by the coverage of irrigation and the elevation of the parcel of land that determined the depth of flooding. These factors would affect household incomes through the adoption of MVs. Since the area under MV is an endogenous variable, the predicted values of the area under MVs was used in the regression model. The area under irrigation was used as the instrumental variable for predicting the area under MVs (absolute area, not percentage of area under MVs) for the dry season, and the area under different elevation of land was used for predicting the area under MVs for the wet season. A village-level dummy variable representing adopter and nonadopter villages was used to estimate the indirect effect of MV adoption for the nonfarm households. For 2000, two dummy variables were used: the early adopter village representing villages that had more than 50 percent of the area under MVs before 1987; and a late adopter village where the coverage of MVs expanded to more that 50 percent of the cultivated land during 1987–2000. The villages where MV adoption was less than 50 percent even in 2000 were used as control. Another dummy variable was used to estimate the effect of infrastructure development. We found that access to electricity was highly correlated with the development of road network. We used a dummy variable for the villages with access to irrigation to represent the state of development of infrastructure. An interaction variable with farm size and MV coverage were used to assess the impact of the adoption of MVs on smaller farms.

The results of the income function are reported in Table 8. The results show that the most important factors affecting household incomes are the amount of land owned, the number of nonagricultural workers, and the physical capital employed in nonagricultural activities.

Table 8--Determinants of household incomes, 1987 and 2000

Factor	All households		Farm households		Nonfarm households	
	1987	2000	1987	2000	1987	2000
Age of the household head (year)	–0.02ns	–2.17ns	0.27ns	0.81ns	–1.49ns	–4.58
	(–0.01)	(–1.22)	(0.15)	(0.28)	(–0.90)	(–2.53)
Dependency ratio (person/worker)	–0.74ns	23.34ns	–10.47ns	–1.13ns	17.40ns	55.75
	(–0.07)	(1.53)	(–0.72)	(–0.05)	(1.34)	(3.27)
Land owned (ha)	351.13	445.32	439.81	445.79	–15.52ns	486.76
	(11.74)	(12.41)	(11.80)	(9.14)	(–0.32)	(9.31)
Land rented (ha)	171.96	168.53	224.68	178.14	–	–
	(2.97)	(2.03)	(3.42)	(1.82)	–	–
Predicted area under MV (ha)	246.77	519.39	239.80	508.49	–	–
	(2.42)	(6.97)	(1.84)	(5.47)	–	–
Agricultural worker (unit)	52.73	154.20	–1.22ns	116.74	225.82	187.53
	(1.89)	(4.30)	(–0.04)	(2.30)	(5.55)	(3.52)
Nonagricultural worker (unit)	164.97	402.42	137.46	373.26	263.93	417.94
	(4.30)	(9.04)	(2.51)	(4.90)	(5.95)	(8.46)
Agricultural fixed assets (US$)	0.33	0.45	0.31	0.44	0.37ns	0.66
	(4.54)	(3.47)	(3.71)	(2.82)	(1.31)	(2.11)
Nonagricultural fixed assets (US$)	0.51	0.36	0.53	0.37	0.52	0.36
	(18.61)	(23.19)	(12.67)	(18.34)	(19.16)	(13.43)
Education level (year/worker)	–8.21ns	8.51ns	–6.88ns	4.93ns	–4.32ns	17.28
	(–1.27)	(1.12)	(–0.85)	(0.45)	(–0.43)	(1.72)
Education level*nonagri worker	40.49	18.18	44.93	26.03	37.13	8.59ns
	(6.76)	(3.09)	(5.45)	(2.59)	(4.29)	(1.22)
Ownland*predicted MV area	49.92	–6.83ns	24.27ns	–6.28ns	–	–
	(2.43)	(–0.76)	(0.93)	(–0.57)	–	–
Bus stand*predicted MV area	10.45ns	–57.10	13.69ns	–55.82	–	–
	(0.75)	(–6.29)	(0.88)	(–5.30)	–	–
Early MV adopter village (dummy)	78.64	23.72ns	106.06	56.97ns	–	–
	(1.94)	(0.41)	(1.95)	(0.64)	–	–
Late MV adopter village (dummy)	–	–5.47ns	–	63.24ns	–	–
	–	(–0.10)	–	(0.77)	–	–
Villages with electricity (dummy)	71.46	149.65	99.97	143.47	3.07ns	140.54
	(1.79)	(3.39)	(1.86)	(2.17)	(0.07)	(2.78)
Gender dummy (Female=1)	–168.03	–272.18	–256.33	–382.09	–120.52ns	–216.94
	(–2.25)	(–2.88)	(–2.31)	(–2.18)	(–1.56)	(–2.33)
Religion dummy (Nonmuslim=1)	–124.78	–207.95	–119.66ns	–292.71	–111.52	–
	(–2.00)	(–2.71)	(–1.34)	(–2.56)	(–1.68)	89.87ns
Constant term	214.61	–2.58ns	223.67	–	104.35ns	(–0.99)
	(2.76)	(–0.02)	(2.01)	26.63ns	(1.18)	–
				(–0.14)		48.19ns
						(–0.36)
R^2	0.657	0.613	0.653	0.596	0.665	0.631
Number of cases	1199	1828	801	1090	398	738

Note: The dependent variable is total household income measured in US dollars at the exchange rate for the year of survey. The figures within parenthesis are estimated "***t***" values.
ns denotes that the coefficient is not statistically significant at 10 percent probability error.

Source: IRRI-BIDS sample household survey.

This supports the findings reported earlier on changes in the structure of household income. The values of the regression coefficient for the MV area at the household level in the equation for all rural households suggest the additional incremental income from the adoption of MVs was US$247/ha in 1987 and $519 for 2000. For farm households the estimates are US$240 and US$508 respectively for the two periods.

The regression coefficient for the dummy variables representing the stage of development of MVs at the village level is positive but not statistically significant. This indicates relatively weak indirect spillover effect of the technological progress on landless households. The coefficient of the interaction variable of MV adoption with own land was positive in 1987, but not statistically significant in 2000. This indicates positive effect of MV adoption on smaller farms only in 1987, but a neutral effect in 2000. The effect of infrastructure on household income is positive for both periods, but the effect was higher in 2000 compared to 1987. Higher education seems to have a positive impact on household income through promotion of occupational mobility from agriculture to nonfarm occupations. Other household characteristics such as the age of the household head and the dependency ratio do not seem to affect household income significantly.

Benefits to the poor

In Bangladesh poverty is concentrated mostly in households with no access to natural, physical, or financial capitals. It was noted from the findings of the focus group discussions that health (for providing manual labor), trust with employers, and social networks (human and social capitals) are the only assets the poor have. The wealth ranking exercise conducted for this study can shed some light on the profile of the poor. These numbers are based on the perceptions of the people themselves regarding their status, and takes into account economic and noneconomic factors and the

multidimensional concept of ill-being (Narayan et al. 2000). Twelve percent of rural households considered themselves very poor. Most own less than 0.2 ha of land and provide wage labor on others' land. Another 31 percent of households considered themselves as moderately poor; 90 percent of them own up to 0.4 ha. The incidence of poverty was 80 percent among households with no cultivated land, 60 percent for those holding up to 0.2 ha, and almost none for households with more than 1.0 ha. Households that were unable to provide three meals a day were reported at 40 percent for households with no cultivated land, 26 percent for those with up to 0.2 ha, and very little among households owning over 0.4 ha. Since rice production requires land, and MVs aim to increase the productivity of land, a pertinent question is how MVs can improve the livelihood of the bottom 50 percent of households that do not own land and constitute the vast majority of the poor.

It is estimated from the 2000 survey that a poor household operated 0.41 ha of land. At prevailing land productivity, this size holding would generate only US$217 per household or US$38 per capita per year. This is only about a quarter of poverty-level income. In that sense, broad-based rural development rather than a narrowly focused agricultural development is essential for poverty reduction in Bangladesh.

Poor households may however gain indirectly from technological progress, particularly through the operation of different rural markets (Otsuka et al. 1992, David and Otsuka 1994, Hossain et al. 2002). The most important is obviously the labor market. As landowning households hire labor for conducting farm operations, and MVs require

more labor than TVs, the agricultural labor households could gain from additional employment generated from the adoption of MVs.

But, since the proportion of medium and large farmers is very small, the agricultural labor market can generate employment for only a small fraction of the vast number of landless and marginal landowning households. It was noted earlier that only 22 percent of rural workers had agricultural wage labor as a primary occupation in 1987, and the number declined to 12 percent by 2000. When the MVs were first introduced, the demand for hired labor increased substantially. But recently, labor use per ha has declined with the spread of agricultural mechanization in land preparation, irrigation, and postharvest processing. Even full employment in agricultural labor market cannot provide a poverty-escaping income at the prevailing agricultural wage rate of US$1/day. The estimate of the structure of household income from the survey shows that agricultural wage income accounted for 11 percent of the rural household incomes in 1987–88, but declined to 4 percent in 2000.

The availability of work for wage-labor dependent households used to fluctuate highly during the year due to seasonal peaks and slacks in the demand for agricultural labor. The photo-period insensitivity of most MVs and the availability of nonagricultural jobs have changed the crop calendars and helped smooth out such seasonal fluctuations in the demand for labor. Also the rapid expansion of area under *boro* rice (which now accounts for half of total rice production) has generated additional employment during the February–May period that was usually a slack season of agricultural activity. In focus group discussions, the poor households mentioned the year-round availability of employment as a substantial positive impact of the adoption of MVs. The results of the

analysis of the qualitative data on the seasonal pattern of employment and income in the favorable and unfavorable villages with regard to the adoption of MVs are reported in Figures 5 and 6. The figures demonstrate the positive impact of MVs on reduction in the seasonal instability on employment and incomes for the poor and very poor households.

The quantitative survey noted substantial change in the labor hiring contracts over the 1987–2000 period away from attached workers (*bandha majur*) and daily wage contract (*din major* or *kamla*) to piece rate contracts (*chukti* or *thika majur*) (see Hossain et al. 2002). Contract workers are hired to complete a specific operation for a piece-rated wage, depending on the size of the parcel of land on which the work has to be done. The piece-rated workers can increase earnings by working more intensively, at any time of convenience to the work team. The estimated wage rate per day was about one-third higher for the piece-rated contract than for the daily-wage contracts. The piece-rated hiring of labor was almost nonexistent in 1987. In 2000, three-fourths of the labor hired for land preparation was under a piece-rated contract, and 35 percent for transplanting operations. The changes in the contractual arrangements have benefited the land-poor households, the dominant suppliers of labor in the market.

The change in the contractual arrangement was mainly in response to the reduction in the availability of agricultural labor and the high cost of supervision of workers under daily wage contracts. However, the incidence of piece-rated hiring of labor was found more prevalent in villages with higher proportion of area under MVs. Thus, the diffusion of MVs has contributed to an increase in the earnings of the laboring class.

Fig. 5--Seasonal crisis of very poor households in favorable and unfavorable villages

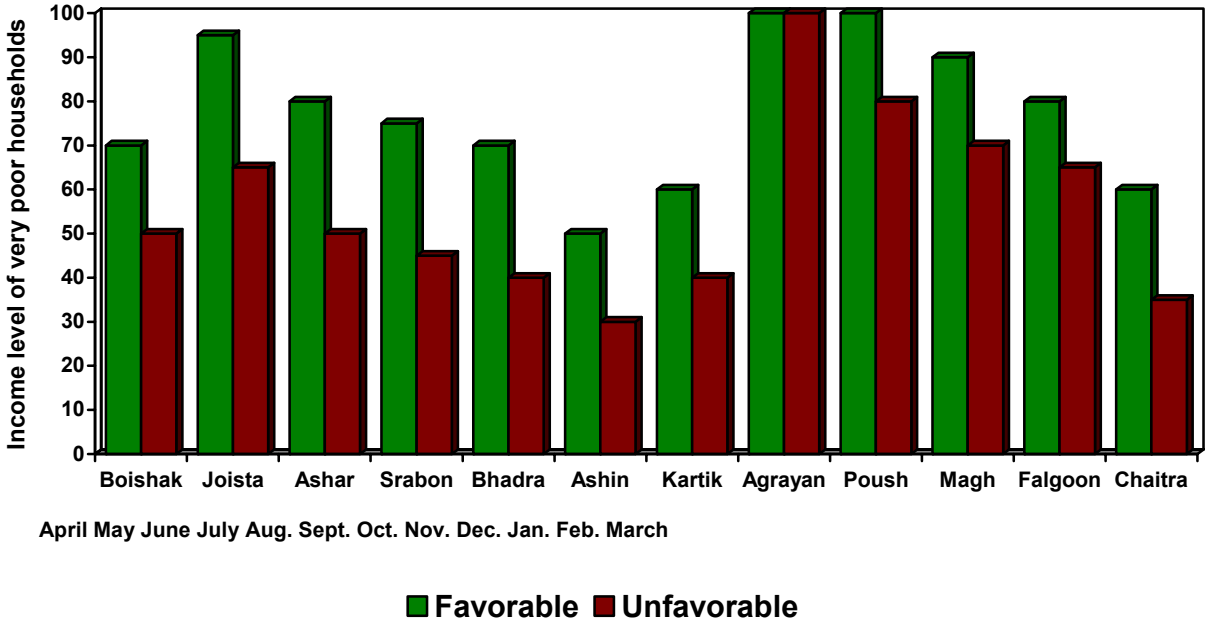
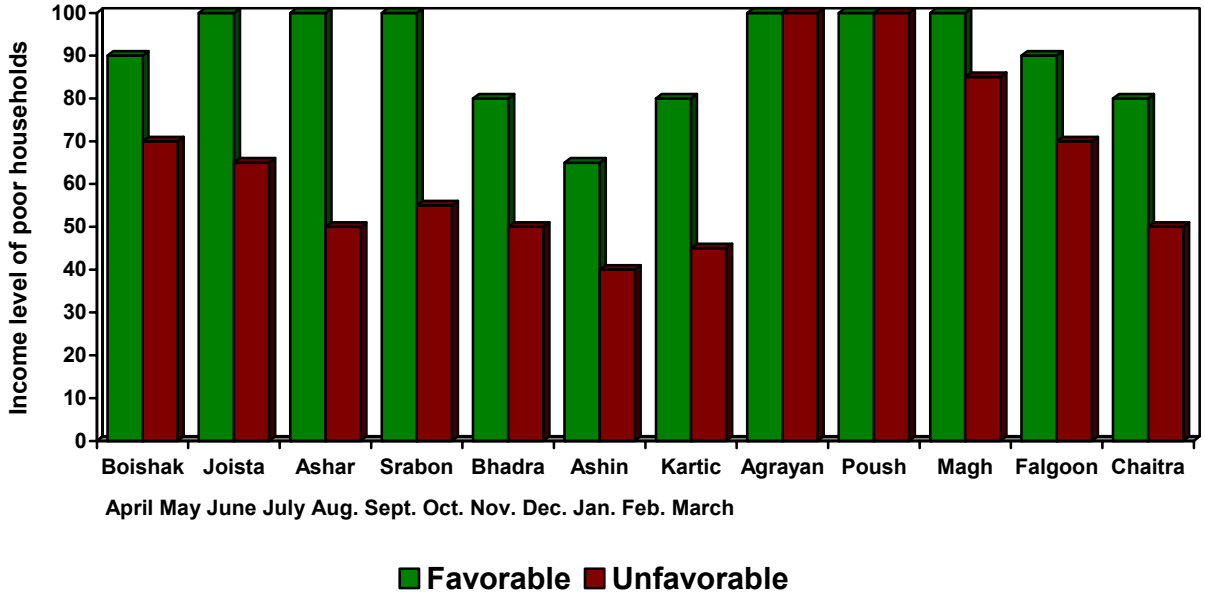


Fig.6--Seasonal crisis of poor households in favorable and unfavorable villages.



Marginal landowning households have also gained to some extent from substantial land transactions that occur through the operation of the tenancy markets. The rate of tenancy increased by almost 50 percent over 1987–2000 period, for two major reasons. First, with rapid rural-urban migration taking place, many urban settlers became absentee landowners, getting the land cultivated by their resident relatives. Second, as higher-productive employment opportunities in the rural nonfarm sector come up with agricultural growth linkage effects (Mellor 1976, Hazell and Roel 1983, Haggblade et al. 1989) and developed infrastructure (Ahmed and Hossain 1990), the better-educated and capital-rich households find it more economical to rent out land and engage in rural nonfarm occupations. So, the rising supply of land in the tenancy market and falling demand provide greater access to land to the land-poor households. The increase in the area under tenancy was found higher in villages with larger coverage of MVs. The sharecropping system, under which the harvest and certain input costs are shared between the landowner and the tenants, was the predominant tenancy arrangement in Bangladesh (Hossain 1977). Fixed-rent tenancy both in kind and in cash-rental payments is gaining prominence with the spread of cultivation of MVs. The area under shared tenancy declined from 72 percent of the rented area in 1987 to 64 percent in 2000. The effective rent paid to the landowner was 31 percent of the gross produce under the fixed-rent tenancy, compared to 50 percent for sharecropping. The change in the terms and conditions in the tenancy market has thus gone in favor of the tenant. The greater availability of rental land and the increased incidence of fixed-rent tenancy with the spread of MVs have facilitated the distribution of some benefits from the spread of MVs to land-poor households.

Poor households have, however, gained substantially from expansion of the rural nonfarm activities, which can partly be traced to increased land productivity due to technological progress. An impressive development in the rural road network in the 1990s coupled with the increase in the marketed surplus of rice, vegetables, and fruits have created employment opportunities in transport operations and petty trading. The increase in the number of shallow tubewells, pumps, power tillers, rickshaw, and rickshaw vans has created jobs in the operation and maintenance of agricultural machinery and transport equipment. Agricultural growth stimulated jobs in agro-processing and other business enterprises in rural towns. Many marginal landowning households with some skills for utilizing capital have been able to generate self-employment in livestock and poultry raising, petty trading, and various personal services with the vast increase in microcredit supplied by the NGOs.

The most important way that technological progress has contributed to improving the livelihood of the poor is by keeping rice prices affordable for low-income households. The household income and expenditure survey conducted by the Bangladesh Bureau of Statistics in 2000 found that the bottom 40 percent of households in the per capita income scale spent 68 percent of their income on food—35 percent on rice alone—compared to 44 and 10 percent respectively for the top 10 percent in the income scale (GOB 2001). So a reduction in the price of food relative to the industrial products benefits the poor relatively more than the nonpoor households. The survey data show that the nominal wage rate for agricultural laborers increased from TK30 in 1987 to TK66 per day's labor in 2000, while the price of rice increased from TK10.91 to TK13.07/kg. The rice

equivalent wage thus has increased from 2.74 kg to 5.04 kg/day, a rate of growth of 4.8 percent per year.

The indirect benefits of improved rice varieties were also consistently reported by participants in the focus groups (reported in Box 3). Higher intensity of crop cultivation, and increased production and marketed surplus of rice were mentioned as important benefits only by the nonpoor households. They also mentioned that the increase in rice yield led to reduction in area under rice cultivation that helped diversification towards other crops. The surplus generated by the increase in rice productivity was used for capital accumulation in agriculture, setting up nonagricultural business and investment in children's education, that contributes to higher earnings from services and business.

Both the very and moderately poor mentioned year-round employment opportunities, diversified livelihood strategies, and increased wage rates as major impacts. The very poor mentioned increased food entitlement from low rice prices and reduced drudgery of women as other important benefits. Increased rice production from tenancy cultivation, and reduced obligation to provide services to employers at below-market prices were mentioned as other important benefits.[6] Both groups mentioned improved housing and increased enrollment of children in schools as important social benefits. At the same time, MVs have made it possible to free resources, especially land and labor, for other agricultural and nonagricultural uses.

In the focus group discussions, concerns were also raised on some negative effects of the expansion of cultivation of MVs. These were reduction in wetlands and

[6] The qualitative data was useful in illustrating these changes. For example, the female very poor group in Patardia said they now benefit from higher wages (which used to depend on the whim of the landowner): "In the past, the landowners sat there comfortably in their shoes, but would not pay us more than Tk20 a day; now we tell them we won't work for less than Tk50 and they have no alternative but to agree."

common property resources such as flood-plain fisheries, reduction in soil fertility, declining stock of cattle due to lack of grazing land, increase in income disparity between the rich and poor, and increased violence.

Box 3--Perceptions of people regarding impact of improved varieties

Nonpoor	Moderate poor	Very poor
Rice production increased	Year-round employment	Year-round employment
Cropping intensity increased	Diversified livelihood	Diversified livelihood
Marketed surplus expanded	Rice production increase from tenancy	Wage rate increased
More land available for nonrice crops	Wage rate increased	Affordable rice price increased food entitlement
Capital accumulation for nonfarm activities	Obligation for providing free services to employers reduced	Women's drudgery reduced
Housing conditions improved	Children attending schools	Higher school enrolment of children
More investment in education of children	Housing conditions improved	Higher earnings through migration

Impact on vulnerability

Technological progress in rice cultivation has contributed to farmers' resilience to natural disasters, floods, and droughts. The area under pre-monsoon *aus* crops that are highly susceptible to droughts has been reduced by nearly 2 million ha over the three decades: the area has been diverted partly to growing MV *boro* rice and partly to vegetables and fruits. So the loss from the late arrival of the monsoon is now much lower than in the 1970s. Similarly, the area under deepwater broadcast *aman* has declined from 2.2 million to only 0.7 million ha, reducing losses from floods. In the deeply flooded area, farmers now keep the land fallow during the monsoon season and grow high-

yielding *boro* rice during the dry season with irrigation. The *boro* area has expanded from 0.5 million to 3.8 million ha, which brings about 50 percent of total rice harvest during the May–June period. Thus, losses in *aman* crop from floods or droughts could be recovered within six months, while in 1970s farmers and consumers had to suffer until the next *aman* harvest in December. The loss of *aman* crop from droughts has also been reduced due to large-scale expansion of shallow tubewells for supplement irrigation. This is one reason why the apprehension of the severe impact of the disastrous floods in 1998 on food insecurity and famine proved wrong. The government still does not realize the effect of the increase in *boro* production on reduced vulnerability and chooses excessive imports and food aid in response to floods, thus depressing foodgrain prices in the postflood seasons.

Another dimension of vulnerability for the poor is the fragile environment in which low-income households are forced to live. The common property resources, such as floodplains, are an important source of income for the poor (Knox McCulloch et al. 1998). There is some evidence from qualitative data that the spread of MVs has contributed to a range of environmental problems such as reduction in fish habitat, contamination of water bodies with pesticides and chemical fertilizers, reduced biodiversity, and declining soil fertility. The loss of previously available wild leafy vegetables was also noted. These developments may impact negatively on the livelihood of the poor in the long run.

5. CONCLUDING REMARKS

SUMMARY OF FINDINGS

IRRI has played a major role in developing the rice research capacity in Bangladesh. The BRRI has produced large numbers of MVs, two-thirds of them with some IRRI blood. Farmers have adopted only a few of them, but some remained popular long after their release. MV coverage has now expanded to about 63 percent of the rice area. The technological progress has helped Bangladesh maintain the food-population balance without having to extend rice cultivation to new lands. The increased production due to MVs now feeds almost 45 percent of the population.

The dominance of small farmers and tenants in Bangladesh agrarian structure did not constrain the adoption of MVs. Indeed MVs are adopted more on smaller farms. It is technical factors—access to irrigation facilities and the elevation of the land parcel—that are the significant determinants of MV adoption. The privatization of minor irrigation equipment (shallow tubewells and power pumps) and reduction in import duties since late 1980s helped make widescale MV adoption possible in the 1990s, as has the provision of improved infrastructure such as rural roads and electrification. As a result the general issue of MV adoption is no longer a current one for most farmers, except for the flood- and salinity-prone coastal areas where adoption has so far proved difficult.

The quantitative research shows that for the upper 50 percent of households with access to land there has been direct positive impact from adoption of MVs in the form of increased yields, reduction in unit costs, and increased farm incomes. But productivity increases led to lower output prices: rice now accounts for 20 percent of the household income. Therefore, the effect of the MV adoption on overall household income remains

small. Nonagricultural income is found to have gained dramatically in importance for rural households. While not highly profitable, rice contributes to improved food security and provides a "springboard" for both rich and poor farm households to move into nonfarm income generation and employment. In terms of impact on the poor, MV adoption does not have a significant direct impact, except for some pure tenant households that were able to gain access land from the expanding tenancy market. But indirect impacts in the form of stable employment and reduced real price of rice have large benefits for the poor, improving food security and reducing vulnerability. The rice equivalent wage has increased at about 4.8 percent per year over 1987–2000. The poor households mention year-round employment, reduction in women's drudgery, improvement in housing, and increased school attendance of children as major impact of the expansion of MV cultivation.

The qualitative research highlighted other factors such as improved status of laborers associated with adoption of MVs, and changes in the new form of piece-rated contracts in the agricultural labor market. It also showed several negative adoption impacts such as shrinking common property resources, increased use of pesticides, and declining soil fertility, all of which may increase the long-term vulnerability of the poor. It also throws light on the processes involved in technology dissemination, which after initial release and demonstration on a small scale by BRRI and extension agents has taken place primarily through informal farmer-to-farmer learning. The focus group discussions revealed low levels of confidence in the public sector agencies and highlighted highly variable performance of NGOs engaged in providing credit.

Reflections on the methodology

The idea of linking quantitative and qualitative methodologies proved instructive in broadening the ability of the research project examine the relationship between technology adoption and poverty. While the quantitative survey data speaks to changes in household structure, landholding, employment, and income, the qualitative data provides insights on the nonincome dimensions of poverty, social and institutional processes, and on less visible aspects of seasonality with particular implications for the poor: the prioritization of assets; the importance of health, trust, and social networks; and the complexity of gender issues. The qualitative data showed how important human and social capital are to the very poor in negotiating their way through periods of distress.

What was less satisfactory was the approach taken in the study to "bolt-on" the qualitative component to ongoing quantitative research. While this was necessary to conserve resources, and the longitudinal quantitative data certainly added to the quality of the research, there were limitations brought out by the fact that the research was not designed to integrate both approaches. With both qualitative and quantitative research it can be difficult to separate the impact of one component of change (such as technological progress) from the overall development interventions on the changes in livelihood systems. New capacities will be needed among researchers of all persuasions to ensure that the synthesis of a large volume of diverse forms of data (e.g., statistics, opinions, and observations) can take place in a transparent way that builds meaning and avoids bias brought about by researcher loyalty to one research methodology or another.

Agricultural research and the future

The research confirms the relevance of this particular CGIAR technology to poverty reduction, but it raises a set of issues and questions about the future direction of

agriculture-related research. For mainstream technical research, the findings could point to the need for rice varieties that require less water use to reduce pressure on groundwater, particularly given the current crisis of arsenic contamination in many areas of Bangladesh. There may also be a need to "unpack" the complexity of vulnerability to develop specific technological solutions to suit less favorable or more unpredictable conditions such as in less flood-prone areas where the wait is longer between crops, or where previously adopting villages have lost control of irrigation water access and "unadopted" IRRI rice.

Another important concern is the gradual tradeoff over time as soil fertility declines and insects become resistant to chemicals. New varieties of rice may be needed in the medium term that are relevant to risk-prone lands, suit a diversified crop portfolio, and are amenable to sustainable crop management techniques.

The study also shows the need for agricultural researchers to recognize important changes in the economic landscape of rural Bangladesh. It has long been known that more than half the rural population of Bangladesh is functionally landless and is therefore dependent on a combination of various forms of agricultural tenancy, laboring, and nonagricultural livelihoods. But the growing importance of nonagricultural income among the better-off households now means that very few people are full-time farmers who rely on agriculture as the main source of income.

There are now limits to the indirect benefits available to the poor from this technology in the form of "trickle down" effects of higher employment and lower prices. Research and development may need to take into account the livelihood strategies of the poorest more directly—by connecting rice research with work on other crops such as

vegetables, which provide more opportunities for the poor (e.g, developing shorter duration varieties for accommodating nonrice crops in rice-based systems).

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