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Impact of Recent Severe Floods on Rice Production in Bangladesh

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Abstract: The long-term variations of rice production in Bangladesh are examined in the latter half of the 20th century and the impact of recent severe floods is discussed. Unprecedented severe floods, which submerged nearly two thirds of the country, occurred recently in Bangladesh in 1988 and 1998, and the effects of these severe floods to rice cropping are revealed. In these severe flood years, the rainy season crop *aman* drastically declined in production due to the decrease of the cultivated area and yield. On the other hand, the dry season crop *boro*, which is planted after the flood withdrawal, increased its production much higher than that of the previous year, mainly because of utilization of the residual flood water. In terms of total annual rice production, it turns out that severe floods have even a positive effect on rice production in Bangladesh. Furthermore, rice production after these severe flood years is higher than that of the previous years, suggesting that severe floods may act as a trigger for increasing rice production level through the change of the hydrological environment and farmers' reaction to it.

Key words: Bangladesh, rice production, floods, irrigation

Introduction

Bangladesh is one of the major rice producing countries in the world (the 4th country in production in 2004, FAO 2005), and its rice production has played an important role in food problems of the world in recent years. It is expected that food supply in the world will be scarce in the middle of this century as a result of population explosion. The rice production in Asia is, however, still unstable and fluctuates year by year (Yoshino 1998). In this sense, it is necessary to research rice production variations in this country and to seek a way to increase its production.

Most of the rice producing countries in the world are located within the Asian monsoon region and rice cultivation is largely influenced by monsoon climate. For instance, Parthasarathy et al. (1992) showed the foodgrain production in India is highly influenced by the summer monsoon rainfall and there is a good positive correlation between them; high production in abundant rainfall years and low production in scarce rainfall years. Mowla (1976) researched the relationship between rice production and annual rainfall in Bangladesh and showed that the fluctuation in rice production and yield is mostly related to annual rainfall variations. However, the hydrological environment of rice cultivation in Bangladesh is very different from that in India.

In Bangladesh, rice is grown in the low-lying delta land formed by three major rivers; the Ganges, Brahmaputra, and Meghna (Figure 1). The catchment basins of these rivers are located in one of the highest rainfall regions of the world, and huge water discharges flow into the small country, which cause floods there almost every year. As long as the extent is moderate, floods are not a devastating disaster. However, severe floods occur once every several years and they cause people to suffer and cause damage to their property. In 1974, 1987, 1988, and 1998, large-scale severe floods occurred in Bangladesh, and among them, the flood in 1998 was the worst when approximately 1,000 people were killed and approximately 70% of the country was inundated.

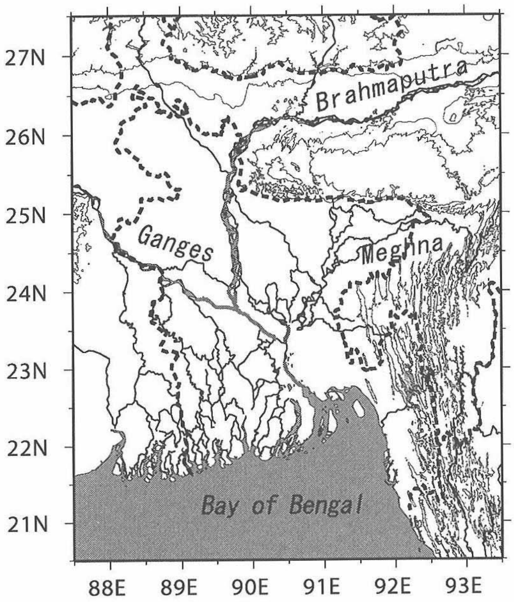

Figure 1. The study area and Ganges–Brahmaputra–Meghna rivers. Contours are 100, 500 and 3,000 m.

The Bangladesh government has tried to handle severe floods in cooperation with the help of foreign aid, but the damage is still serious despite efforts put forth over a long period of time. In the 1960s and 70s, the flood master plan was carried out after the floods in the mid-1950s. The Flood Action Plan (FAP) was initiated in 1989 to investigate the damages that occurred in 1987/88 and to seek out a solution to mitigate flood damage. A lot of cases were considered by engineers and scientists from many countries during the FAP, but heavy floods occurred again in 1998.

Along with studies of water control, there are also some studies focusing on the damage of floods to rice production (Murshid 1989; Brammer 1990; Paul and Rasid 1993). However, these studies analyze crop damage data, which only reveals the negative aspect of floods on agriculture. It is important to note that floods are not necessarily disasters for farmers, and they sometimes have positive implications as they bring water and fertile soil (Nakao 1996). Furthermore, it is expected that both the incidence, areal extent and depth of floods may be enhanced with global warming (Asian Development Bank 1994), thus the research of the impact of severe floods on rice production is very important.

This paper aims to examine the trend of rice production in Bangladesh for the latter half of the last century and to reveal the relationship between recent severe floods and rice production.

The Rice Cropping System in Bangladesh

Rice is grown under an environment of fertile soil and abundant water. Most portions of Bangladesh excluding northwest and southeast hilly areas, are comprised of low alluvial plains and vast deltas, and the altitude is less than 10 m. Although it is a rather flat country, the small relief of topography and associated water environment stipulate the local cropping pattern.

In general, there are three varieties of rice crops in Bangladesh; *aus, aman*, and *boro* (Figure 2). The growing period of each variety corresponds well with the climatic season. Climate in Bangladesh is characterized by a cool dry season, a hot summer season and a rainy monsoon season. The dry season prevails from mid-October through February and less than 5% of the annual rainfall occurs during this season. From March to May is the hot pre-monsoon season, which accounts for 15–20% of the annual rainfall. The rainy season starts from early June and ends in mid-October, and 75–80% of the annual rainfall occurs during this season.

Aus is normally planted in April and harvested in July or August. In the pre-monsoon season (March–May), the precipitation is not abundant, but the rainfall in that season has a close relationship with the preparation of land for *aus* planting (Ahmed and Karmakar 1993). *Aus* is harvested before annual floods reach the peak stage. After that, *aman* is planted in August to correspond with the drop of flood water, and is usually harvested in November or December. These two varieties are grown in the rainy season. On the other hand, *boro* is the dry season variety. It is normally planted in December and harvested in April or May. During this season, precipitation is scarce and there might occasionally be droughts, but *boro* is

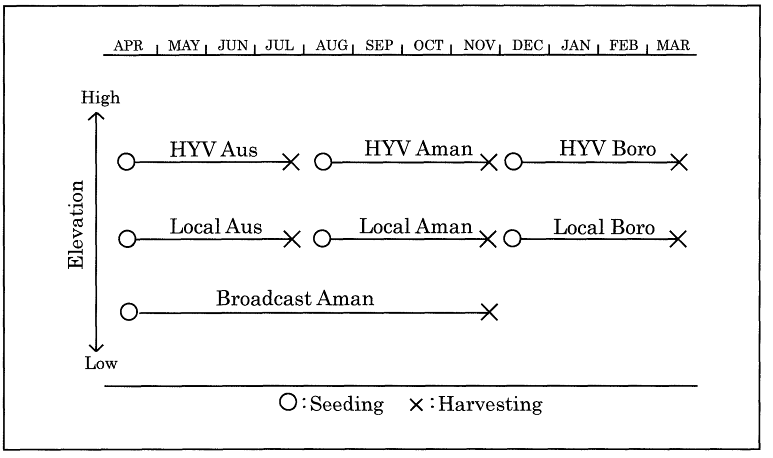

Figure 2. Rice cropping pattern and land elevation. The seeding and harvesting period of high yielding variety (HYV), local variety and broadcast variety are shown.

grown under abundant sunshine and moderate temperature conditions. Planting and harvesting months vary in different areas within the country, which depends on the local topography and hydrological conditions.

It is useful to describe the differences between the local variety and the high yield variety (HYV) amongst these three varieties. The local variety is the rice crop which has been grown in Bangladesh since early times. This variety is suitable for the natural environment in this country, but the yield is relatively low. The HYV was invented after breed improvement and was introduced in the late 1960s after the Green Revolution (Islam and Taniguchi 2000). As the name implies, the characteristics of the HYV is that the yield is much higher than the local varieties. However, it requires adequate water supply, fertilizer and sufficient care, as it is vulnerable to drought or harmful insects. This variety costs more than local variety, but its benefits are much higher (Islam et al. 2001).

Generally, the local variety is planted in the lower fields where the flood water reaches 1 to 2 meters high. HYV needs to be grown in the shallower water heights, and is planted in the middle or higher fields where the flood water is less than 50 cm (Ito 1989).

Along with the local variety and HYV, 'broadcast' is the other major variety in *aman*. Broadcast *aman* is sown in very low land before floods (in April or May), and it increases its height with the rise of water level. It reaches a height of 5–7 m long and is harvested after the flood (in November). This variety is generally called 'floating rice,' and is well-suited to the hydrological conditions in Bangladesh.

Data Used in This Study

The agricultural data used in this study is taken from Hamid (1991) over the periods of 1947 to 1967, and from the Yearbook of Agricultural Statistics of Bangladesh published in the Bangladesh Bureau of Statistics (BBS) from 1968 to 2000.[1] These books contain information about rice production (in metric tons) and cultivated area (in hectares) of *aus, aman*, and *boro*. In each variety, the data of local and HYV are classified, and beside them, broadcast is shown in the case of *aman*. Districtwise data of the three varieties are available throughout the period. The district is the second largest administrative unit in Bangladesh.[2] The data of the local variety and HYV are available from 1968 to 2000.

The irrigated area data (in hectares) can also be obtained from the same yearbook. This data is available for each of the three varieties. On the other hand, the period of data is only from 1969 to 2000 in each district.

The only source providing year-wise flood affected area data is the Bangladesh Water De-

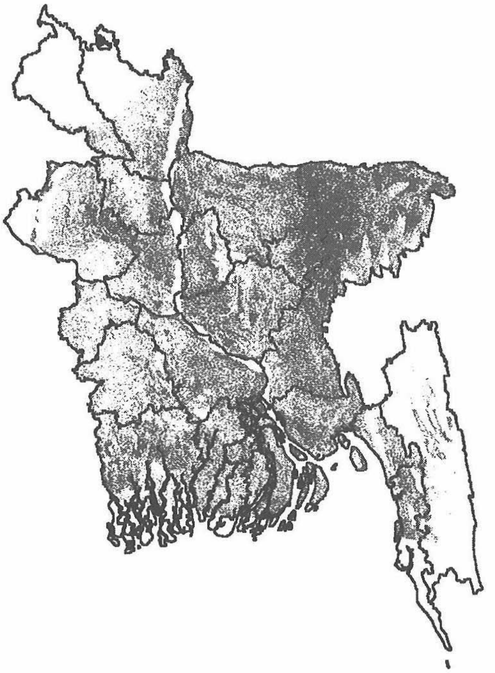

Figure 3. RADARSAT image on 26 August 1998. The gray dots denote the water-logged points. The thick line represents the district border.

velopment Board (BWDB). Flood affected area includes an area once flooded during the monsoon season (FFWC 2004), and is represented in percentile figures of total country area. This data is available from 1954 to 2000, however, it is lacking in 1957–1959, 1979, 1981, and 1997.[3]

The floods in 1988 and 1998, both inundating over 60 per cent of the country, would be similarly categorized and would be assigned a return period of about 100 years (Ahmad and Ahmed 2003). In this study, which considers 1988 and 1998 as the severe flood years, the variations of rice production in the severe flood years are analyzed.

In the case of the severest flood in 1998, the satellite images from the Centre for Environmental and Geographical Information Services (CEGIS) are analyzed (Figure 3). Three RADARSAT images were acquired on 26 August, 14 September, and 25 September in 1998 to map and monitor flood extent (EGIS 2002).

All data used in this study is shown in Table 1.

Table 1. Data used in this study.

Data	Period	Source
Area and Production	1947–1967	Hamid (1991)
of Rice	1968–2000	BBS
Irrigated Area of Rice	1969–2000	BBS
Flood Affected Area	1954–2000	BWDB
RADARSAT Images	1998	CEGIS

The Inter-annual Variations of the Rice Production

The total rice production increased constantly through the whole investigated period and has more than tripled for the last half-century from 7 million tons in 1947 to 25 million tons in 2000 (Figure 4). Among the three varieties, *boro* shows remarkable advance, especially after the 1980s, and it affected the increase of the total rice production.

The increasing rate of the annual total production is higher especially after the severe floods in 1988 and 1998. It seems that these production variations during flood years are closely related with the variation of *boro*. The production of *boro* increases rapidly during these severe flood years and in the following year. Throughout the whole period, the rate of increase of *boro* is higher than that of *aman*, and the production of *boro* exceeded that of *aman* in 1998 and afterwards. *Boro* is now the main rice variety in rice production in Bangladesh.

On the other hand, during the severe flood years the production of *aman* goes downwards but in the following years, the production returns to the previous level or higher. The decrease of *aman* production during the flood years is complemented by the increase of *boro* production planted after the floods and as a result, the annual rice production is almost at the normal level. The production of *aus* does not seem to be related much to the floods. The production of *aus* remained at the same level until the mid 1980s and then it gradually decreased. *Aus* accounted for about 30% of the total rice production in 1970, but it accounted for only less than 10% in 2000, while *boro* accounted for 20% in 1970 and 50% in 2000.

As a result of the variations of the three

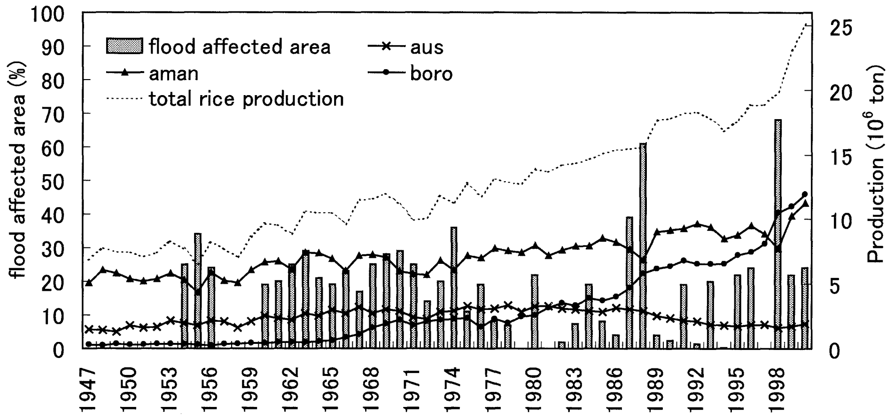

Figure 4. The inter-annual variation of the rice production and flood affected area from 1947 to 2000.

varieties, the annual total production remains almost constant during the severe flood years and it rapidly rises the following year. Over a short time scale, severe floods are a devastating disaster for the local people due to the damage of *aman* production. On the other hand, they act as a trigger for the rise of rice production levels, and thus from a broader perspective over several years, it also shows benefit for the rice cropping in Bangladesh. In the following section, the variations of the cultivated area and the yield are examined in order to reveal the factors of rice production variations as described above.

Variations of the Cultivated Area

The total cultivated area gradually increased up until the 1970s, but it has not changed very much since the 1980s (Figure 5(a)), which demonstrates that there is little prospect for expanding the physical land area for rice cultivation. The shortage of arable land is considered to be the major bottleneck in agricultural development in Bangladesh, and excess foodgrain can only be produced by increasing either the yield or the cropping intensity (Siddiqui and Suzuki 1990).

According to Figure 5(a), all three rice variations in severe flood years show similar variations to those that appear in Figure 4. That means, the main cause of the rice production variation in severe flood years is attributed to the expansion or reduction of the cultivated area.

The cultivated area of *aus*

The cultivated area of *aus* does not seem to be affected by severe floods as *aus* is planted a few months before the flood season (Figure 5(b)). It constantly decreases in sharp contrast to the constant increase of *boro*. The problem is that farmers plant *aus* before floods occur and they can not anticipate during the planting season whether floods will occur a few months later or not.

Before the Green Revolution in the mid-1960s, farmers could grow rice crops only during the rainy season in this country, and dry season cultivation was only peripheral. However, the progression of technology which includes the introduction of irrigation and the modern variety in the dry season has enabled them to plant rice crops throughout the year. Enough production can be obtained by *aman* and *boro* without *aus*. Therefore, the recent trend is to avoid planting unstable *aus* which may later be affected by flood in the harvest season.

The cultivated area of *aman*

The cultivated area of *aman* shows apparent decreases during the severe flood years (Figure 5(a)), but it remains on the same level during the non-flood years and during the flood years in which the submerged area is less than 30% of the total acreage. Among *aman* varieties, the cultivated area of the local *aman* and the broadcast *aman* decreases constantly and the in-

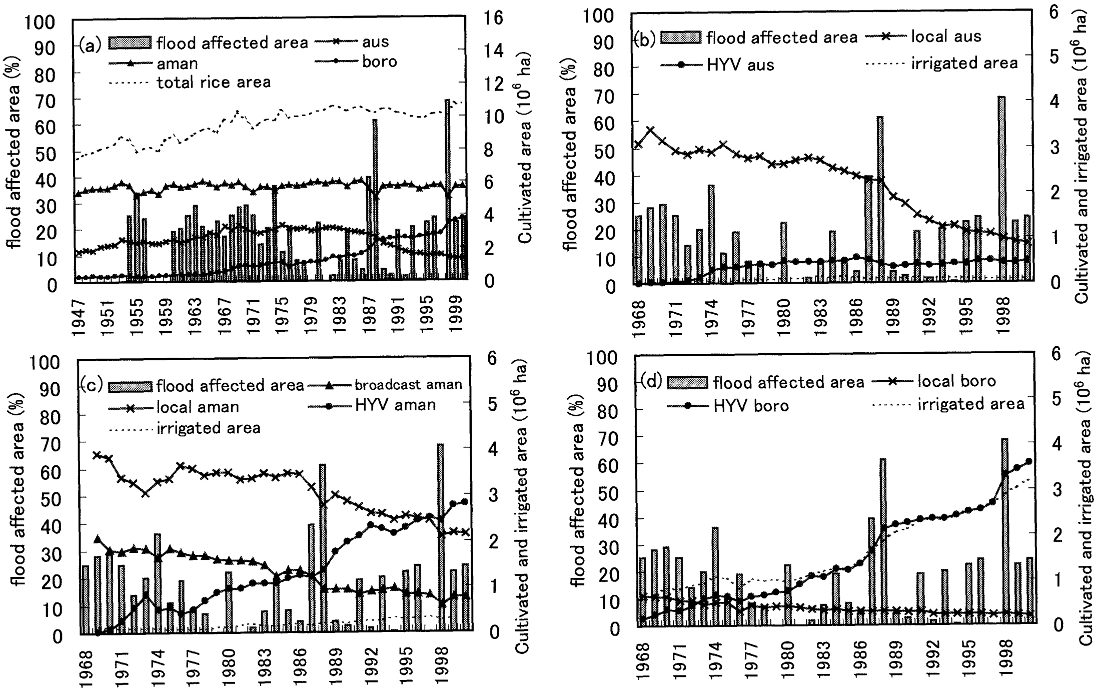

Figure 5. The inter-annual variation of the cultivated area and flood affected area. Also shown is the irrigation area for each variety. (a) total (b) *aus* (c) *aman* (d) *boro*.

crease of HYV *aman* is notable (Figure 5(c)). The HYV *aman* is planted in the relatively high land while the local *aman* is planted in the middle high land and the broadcast *aman* is planted in the lowest land (Johnson 1982). During severe flood years, the decrease of the cultivated area of the local *aman* and the broadcast *aman* is especially large. The cultivated area of the HYV *aman* does not show rapid change during the flood years, but after severe floods it increases rapidly and became the largest among the three *aman* varieties in 1999.

Aman is planted in July or August when the flood stage reaches a peak. If a large flood occurs, the middle and low lands are submerged by the floodwater and local *aman* and broadcast *aman* cannot be planted there. However, the cultivated area of the HYV *aman* is not affected by the flood, since the floodwater does not reach the high lands and the HYV *aman* can be transplanted after the flood stage goes down. Thus, the farmers tend to decrease the cultivated area of the local *aman* and the broadcast *aman* and increase that of the HYV *aman* alternatively when severe floods occur. It is noteworthy that the severe floods in 1988 and 1998 induced the rapid replacement of the cultivated area of *aman* varieties.

The cultivated area of *boro*

The cultivated area of *boro* rapidly increases in 1988 and 1998 and remains at a similar level after these severe floods (Figure 5(a)). From a long-term perspective, the area of *boro* expands constantly and recently it has played a more important role in overall rice production in this country. *Boro* is grown during the dry season, and a constant water supply is necessary for its growing stage. It is noticeable that the variation of the cultivated area of the HYV *boro* roughly corresponds to the growth of the irrigated area (Figure 5(d)).

The increase of the cultivated area of the HYV *boro* is especially high in recent severe flood years. The irrigated area also increases during these flood years, but the rate of increase of the HYV *boro* is higher than that of the irrigated area in 1988 and 1998. This suggests that during the years when severe floods occur, they can plant the HYV *boro* even on land

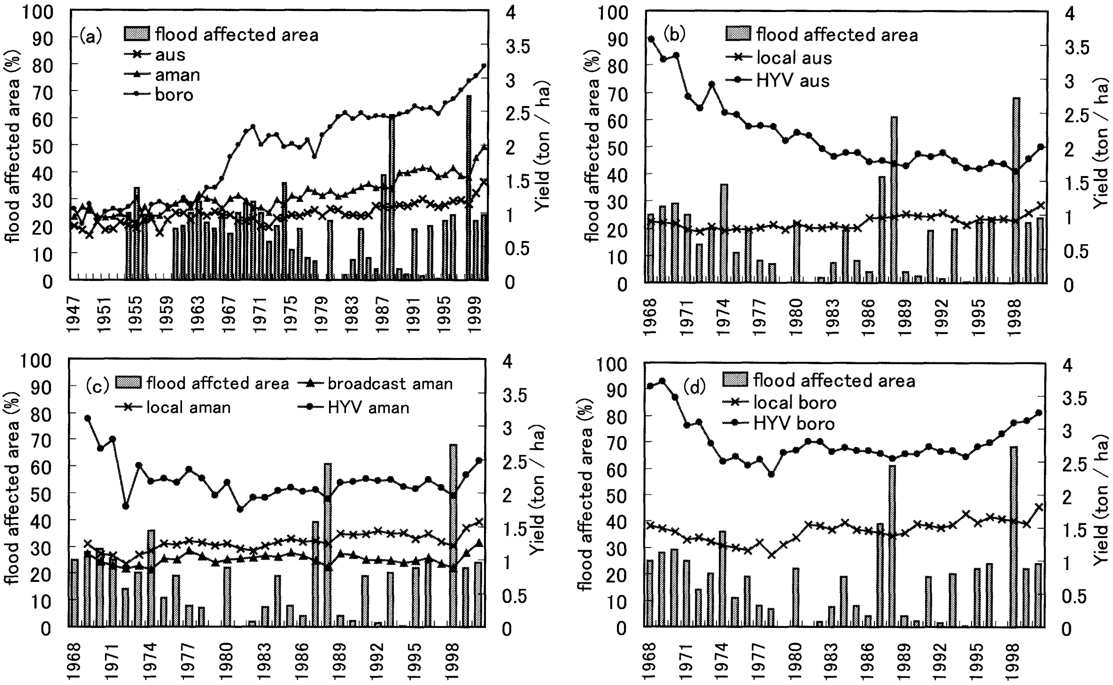

Figure 6. The inter-annual variation of the rice yield and flood affected area. (a) total (b) *aus* (c) *aman* (d) *boro*.

where an irrigation system (e.g. tube well and power pump) is not available. In contrast to artificial irrigation, natural water resources can be accessed since the floodwater stagnates for several months during the dry season after severe floods.

The cultivated area of the HYV *boro* rapidly expands during the severe flood years, and the expanded level of the cultivated area is kept high after the flood years. This is the most remarkable feature in the relationships between rice cultivation and severe floods. Severe floods not only had an effect on rice production in 1988 and 1998, but also enhanced the total rice production by shifting the rice cropping system.

Variations of Yield

The variations in production is expressed by both variations of the cultivated area and the yield, which is calculated by dividing the production by the cultivated area. Hence, the variations of yield of each variety are investigated.

The rice yields of the three varieties largely depend on the rate of the HYV. The yield of *boro* is the highest among the three varieties and the second highest is *aman*. The yield of *aus* is the lowest of the three (Figure 6(a)). Thus, the HYV *boro* accounts for the largest portion of the total *boro* produced in the cultivated area (more than 90%), and the rate of the HYV *aus* of the total *aus* is relatively smaller (about 30%) than that of *aman* and *boro*.

The yield of the HYV *aus*, HYV *aman*, and HYV *boro* is particularly high at more than 3 ton/ha but unstable when it was initially planted on experimental farms and grown in ideal conditions during the late 1960s (Figure 6(b)–(d)). Yield of all HYV then gradually decreased as the HYV planting became widespread throughout the country, and in the mid-1980s it became constant. Although the growth rate and yield of both the local variety and the HYV variety is slow, farmers increase the total rice yield by making a shift from local variety to HYV.

During the severe flood years, the yield of all *aman* varieties declined sharply, but the yield of *aus* and *boro* varieties seems to be hardly related to the severe floods. In the year following the severe floods, the yield of all local varieties and HYVs rises significantly, which implies soil fertilization by the severe floods in 1988 and 1998. Apart from the physical effect of severe floods, the total rice yield increases after flood years by raising the proportion of cultivated area of HYV drastically.

The Impact of the Severest Flood in 1998

The impact of the severest flood in 1998 on rice production was analyzed in order to investigate whether the above results are also applicable at the district level. The rate of change in each of the rice varieties compared to the former year 1997 is investigated with the inundated area as the indicator of the flood inten-

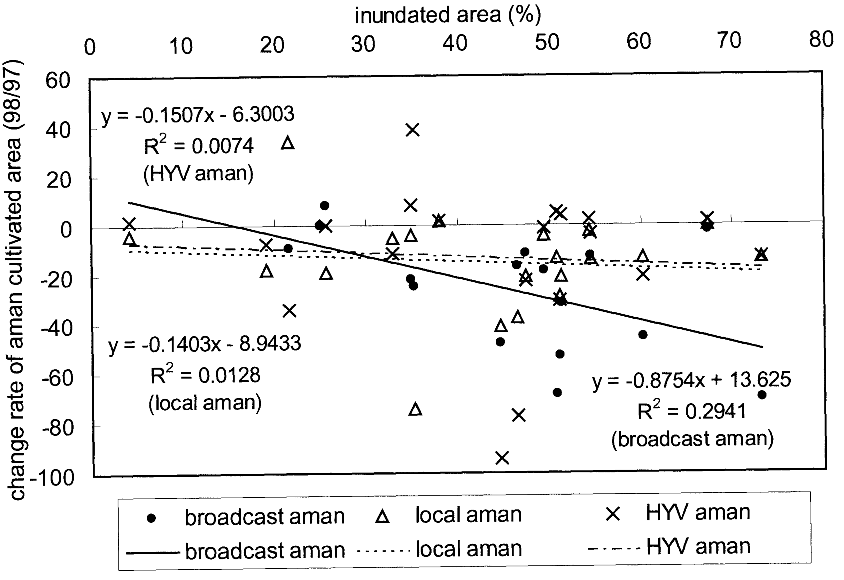

Figure 7. The change rate (%) of *aman* cultivated area (98/97) and inundated area in flood 1998.

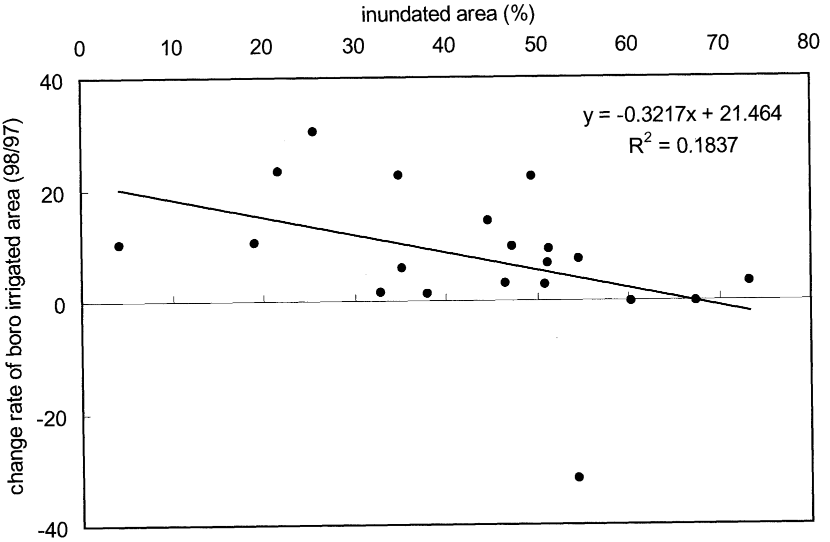

Figure 8. The change rate (%) of *boro* irrigated area (98/97) and inundated area in flood 1998.

sity. The percentage of inundated area of each district is calculated from RADARSAT images using software ArcView by ESRI.

The inundated area varies by district and extends from 20% to 80%. Roughly speaking, in the districts where the inundation rate is higher, the decrease of the cultivated area of the broadcast *aman* is higher (Figure 7). This trend is not seen in the local *aman* or in the HYV *aman*, which is planted in the higher land and is less affected by floods. The drastic decrease of the cultivated area of broadcast *aman* resulted in the large expansion of HYV *aman* in the following year, and these changes in the cropping system made the *aman* yield higher and more stable.

Though *boro* is grown during the dry season after floodwater withdraws, the influence of the flood in 1998 on the *boro* cropping can be recognized (Figure 8). The increase in the rate of irrigation is higher in the districts affected less by floods and irrigation hardly increases in the districts where most of the land was submerged by the floods. This trend means that farmers do not have to introduce artificial irrigation facilities in the deeply inundated district because residual water is available either in the low wetland or under ground. Through the use of this abundant water, they can expand the cultivated area of *boro* (especially, the HYV *boro*) during the dry season.

It turns out that the hypothesis at a nationwide scale proposed in above sections is also true at the district level. There is a more complicated process behind the drastic change of rice cropping during severe flood years, therefore the farmers' response is investigated.

Farmers' Response in Severe Flood Years

According to Dorosh (2001), sharp rises in rice price and input supply efforts by government could be incentives for farmers to expand *boro* planting in the years of poor *aman* harvests.

During the severe flood years, due to the failure of *aman* production by floods, the rice price rose before the planting season of *boro*. The national average wholesale price of coarse HYV rice was 12.0 taka per kilogram (Tk/kg)[4] in June of 1998. As the floods began, it rose sharply in July and remained at the relatively high price of 14.1–14.8 Tk/kg until the *boro* harvest season in April 1999 (Ninno et al. 2003). The severe floods caused the reduction of income for farmers, and the high price of rice became incentives to earn more income by expanding the cultivated area of *boro* rice.

The agricultural rehabilitation program was implemented by the Bangladesh government soon after the onset of severe floods. To promote incentive in the cultivation of *boro*, the government implemented the deregulation of the import of the diesel engine for tube well, the reform of the fertilizer distribution market and the rationing of seeds and fertilizer, free of cost (Khuda and Nizamuddin 2000; Fujita 2001). The cultivation of HYV *boro* requires water supply and fertilizer input, and the residual flood water and governmental aid enabled farmers to expand *boro* cultivation rapidly during the severe flood years.

As the result of quick response of government and farmers, *boro* production after the severe floods yielded especially good harvests, and compensated for the loss of *aman* production.

Conclusions

This study investigated the long-term variations of rice production in Bangladesh and reveals the relationship between rice cultivation and the hydrological environment in Bangladesh, which is quite different from that of other Asian Monsoon regions.

From the inter-annual variations of the rice crop analyzed, some hypotheses about rice production in the recent severe flood years were proposed. During the severe flood years of 1988 and 1998, the influence of the severe floods on rice production is apparent. *Aman* production is highly damaged in both cultivated area and yield, but on the other hand, the *boro* crops increased the cultivated area drastically. This expansion of *boro* may be attributed to the utilization of the residual surface water of floods and farmers' response. The quick response of rice cultivation to the change of the hydrological environment is reported in a village survey

(Ando et al. 1990). It is also noticeable that introduction of the HYV is more active after the severe flood years, which leads to a rise in the yield. The rise of the yield also may be caused by the fertile soil brought with the flood water.

Although the amount of serious damage to rice cropping as well as human resources is not negligible (Brammer 1990; Paul and Rasid 1993; Ahmad and Rasheed 2000), the recent severe floods are not necessarily a devastating disaster from the viewpoint of rice production since they also have a positive effect, especially over long time-scales. The facts revealed in this study should be noted in the rice production after 1988 and 1998, which is much higher than that before these flood years. The severe floods in this country may work as a trigger which raises the production levels through the change of the hydrological environment and the farmers' reaction to it.

The results revealed in this study are derived from the analysis of statistical data, and they should be confirmed by a hearing survey in rural villages. It is also necessary to compare them with those in other regions like India, especially the flood prone Ganges and Brahmaputra basin of northeastern India, where the frequent occurrence of large floods is reported (Dhar and Nandargi 2001; Bora 2003). The flood impact on agriculture in this region needs to be investigated and compared with the situation in Bangladesh.

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Notes

1. The statistical year does not always agree with the actual crop year. In these data books, the annual rice production data is based on the seeding period of each variety. For instance, crop year 2000 means year 2000–01, and the production of *boro* in 2000 is that seeded and grown from November 2000 to April 2001. The annual rice production in 2000 includes the sum of the production of *aus* and *aman* harvested in 2000 and that of *boro* harvested in 2001.
2. Politically there are 64 districts in Bangladesh today, but only 23 districts are used in agricultural statistics. The average area is 6,079 km^2.
3. These lacking years correspond to the lesser flood years, and the influence on rice cultivation is negligible during the rainy season.
4. The exchange rate in 1998 was approximately 50 taka per USD.

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