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# Climate Change, Submergence and Rice Yield: Evidence from Coastal Barisal, Bangladesh

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# Climate Change, Submergence and Rice Yield: Evidence from Coastal Barisal, Bangladesh

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# Contents

# Abstract

In this paper, we investigate the effects of submergence due to heavy rainfall and river over-flow on rice production in the coastal Barisal region of Bangladesh. Our study uses plot level data to compare rice yields of cultivars in high and low submergence prone areas and to analyze variation in yield when high-yielding varieties (HYVs) versus local seeds are used. Results suggest that rice yields are, on average, some 10% lower in 'high submergence areas' relative to 'low submergence areas'. Both depth of submergence and duration have a negative effect on yield, with local varieties of rice seemingly better adapted to submergence. The widely grown Aman variety of rice faced an average of nine days of submergence in 2010, with 31% plots under 1-3 meters of water for 3-7 days. We forecast that an additional 13,564 hectares or 61% of total cropped Aman area in Barisal is likely to be inundated for 3-7 days in 2050 due to sea level rise and increased storm surge events. Correspondingly, given current levels of technology, we can expect a production loss of 10,856 tons of Aman in the future. The study recommends the introduction of submergence tolerant rice cultivars and low-cost water control technologies as adaptation options against climate change.



**Key words:** *Submergence, Rice yield, Climate change, Sea Level Rise (SLR), Storm surge, Aman yield, Barisal district, Bangladesh.*

# Climate Change, Submergence and Rice Yield: Evidence from Coastal Barisal, Bangladesh

## 1. Introduction

Bangladesh, in the basin of Padma, Meghna, and Jamuna rivers, is the largest deltaic country in the world. On the one hand, the river-hydrology based soil ecology and climatic conditions offer fertile land for agricultural production. On the other, this makes the land vulnerable to both traditional water related phenomenon such as submergence and new ones such as – sea level rise (SLR) and more intense storm surge events.

Bangladesh is gearing up for increased climatic changes. By the year 2030, estimates based on global climate models, suggest that annual mean temperature in Bangladesh will increase by 1°C, accompanied by a 5% increase in annual precipitation and a 14 cm rise in sea level. Alternate estimations from the PRECIS[1] models, suggest that mean annual temperature will rise by 0.3 to 1.18° C and precipitation will be 4 to 6% higher by 2030. The prediction for sea level rise is the same from both the models (MoEF, 2009). These climatic changes will likely affect more than 70 million people because of Bangladesh's geographic location, low elevation, high population density, poor infrastructure, high levels of poverty, absence of technological provisions and high dependency on natural resources (MoEF, 2009).

In this paper, we focus on the concerns climate change raises for coastal agricultural production in Bangladesh. Some 22% of Bangladesh's rice producing area is in the coastal region, which produces 18% of national rice output (BBS, 2009-10). Rice productivity in coastal Bangladesh is lower than the national average, partially because of the limited use of modern varieties of seed. Over the last decade, in an attempt to increase rice productivity, the Bangladesh Rice Research Institute (BRRI) has released several modern land races. However, there has been low acceptance of new rice varieties by coastal farmers. Apart from socio-economic factors, the two most significant reasons for low adoption of modern cultivars in these areas are risks related to submergence and soil salinity (Nasiruddin and Hassan 2009). In fact, among the different stresses affecting rice production, submergence is identified as the most important constraint to higher rice productivity.

Given the vulnerability of coastal farming to climatic changes, our study seeks to explore more deeply how water submergence influences crop productivity. This information will be useful as adaptation strategies are developed for the future when Bangladesh will likely face SLR and increased flooding. In this study, we first examine the impact of submergence on rice production by comparing yields of rice cultivars in 'high' and 'low submergence prone' areas. We then examine temporal and seasonal differences due to submergence. We also ask how different varieties of rice are affected by submergence. Finally, we forecast probable rice yield loss due to SLR coupled with storm surge in the monsoon season for the year 2050. Data for this study is from a comprehensive survey undertaken in 2011 of 120 farmers in the unions[2] of coastal Barisal district.

## 2. Submergence and Rice Yield: Understanding the Implications

With sea level rise, coastal areas in Bangladesh are expected to be inundated causing a reduction of crops and forage production and making the soil unsuitable for agricultural activities (CEGIS, 2006; McCarl et al., 2001). For instance, for a high emission A2 scenario, an IWM and CEGIS (2007) study predicts a 13% increase in inundated area by 2080 during the monsoon seasons due to an expected 62 cm sea level rise. A second study by CEGIS (2006) suggests that by 2100 the suitable area for T. Aman, a common rice variety grown in Bangladesh, will

[1] Providing Regional Climates for Impact Studies.
[2] A Union is the lowest level administrative unit in Bangladesh.

decrease by 18% and 76% respectively with 32 cm and 88 cm SLR. The situation is expected to get even worse with increased intensity of storm surge contributing to submergence of crops (Ali, 1996; Dasgupta et al., 2009).

In Bangladesh, complete and partial submergence can occur during the monsoon season for varying durations. Ismail et al., 2010 (p 158), for instance, report that more than one million hectare of rice fields in the coastal areas of Bangladesh suffer from prolonged partial flooding during the wet season. Submergence can occur due to a) heavy rainfall during the monsoon season, particularly from June to September/October, b) rain in the upper basin during the wet season, which raises water level in the rivers and their tributaries, and c) daily high tides when high density salt water pushes fresh water and raises water levels causing transient flooding (Ismail et al., 2010; p. 157).[3] Storm surge, experienced in early summer (April-May) or late rainy season (October-November), are other important sources of fresh water submergence.[4] Once storm surge is generated, the low lying coastal regions suffer fresh water inundation ranging from few days to several weeks due to 'back-water effects[5] from rivers and heavy rainfall ahead of cyclones.

Coastal agriculture in Bangladesh has three rice cropping seasons making it vulnerable to submergence throughout the year. Different seed varieties are grown in the different seasons – T. Aman rice is grown during the monsoons from July to January (also called the *Kharif II* season), irrigated Boro rice is grown from December to May (*Robi* season), and T. Aus is grown from April to August (*Kharif I* season). Our study investigates the effect of submergence, particularly inundation levels and duration, on the productivity of these different rice varieties.

Submergence has a complicated effect on rice yield. Rice can grow under submerged conditions. The reasons for this is being the ability of rice seeds to germinate without oxygen (Taylor, 1942) and accelerated stem extension of deep-water rice plants, which can keep apical parts above the slowly rising water (2-5 cm/day) (Catling et al., 1988, Jackson and Ram, 2003). However, there is also plenty of evidence to suggest that rice plants cannot survive when they face sudden and total inundation for multiple days (Ram et al., 2002, 1999; Mohanty et al., 2000; Sauter, 2000; Ito et al., 1999; Setter et al., 1995).

When submerged, cultivars face reduced oxygen supply limiting respiration, limited carbon-dioxide supply affecting photosynthesis, reduced ethylene diffusion away from the plant triggering chlorosis (a condition in which leaves produce insufficient chlorophyll) and excessive elongation of leaves (Jackson et al., 1987; Ella et al., 2003). Plants survival at this time depends on the submerged water environment, that is, the depth of inundation and physio-chemical characteristics (oxygen and carbon-dioxide concentration, pH, turbidity, temperature etc.) of the water. Survival also depends on plant characteristics such as the ability to maintain high, non-structural carbohydrate content before and following submergence, continued under water shoot extension, the extent of alcohol fermentation, and whether they have an efficient system to retain chlorophyll etc. (Ismail et al., 2010; p. 158). The effect of submergence on productivity also depends on the timing of submergence relative to the growth stage i.e. whether the rice plant is at the germination, seedling or growing stage. Local factors such as light availability, submerging water conditions (particularly turbidity and turbulence) and prevailing water temperature at the time of submergence can also influence the growth of rice plants (Sarkar et al. 2006). Thus, there is a complicated relationship between water submergence and rice yield.

Our study builds on several studies that provide evidence of the effect of flooding and submergence on rice production. Paul and Rashid (1993), for instance, investigating damage to rice crops, found that, on average, four percent of total rice production was lost due to riverine floods. A recent study by Banerjee (2010) investigated the long-term impacts of floods on agricultural performance. She distinguished between 'extreme' and 'normal' floods along with 'more' flood-prone districts and 'less' flooded districts of Bangladesh. Her study found that yield rates declined when floods assume 'extreme' proportions, but productivity increased during 'normal' floods and in the post-flood months. This work reinforces results from an earlier study by Sen et al. (2002), who report significant positive effects of early inundation on rice yield in the central plains of Thailand.

[3] Our study focuses only on fresh water submergence and does not consider daily tidal changes.
[4] A storm surge is the rise in water level caused primarily by strong wind generated due to variation in atmospheric pressure.
[5] 'Back-water effect' refers to the phenomenon where heavy saline water prohibits discharge of fresh water of rivers and their tributaries into the sea.

## 3. Data Collection in Barisal District

Our study area is Barisal district, located in the south-central part of Bangladesh (see Figure 1).[6] The district, which is about 136 km away from the national capital Dhaka, is crisscrossed by many rivers and faces submergence due to heavy monsoon rains, high tides and cyclonic storm surges. Almost 54% inhabitants of Barisal district earn their living from agriculture (Banglapedia, 2006) and rice cultivation occupies around 80% of the district's cropped area (BBS[7]). This explains the often used proverb in these areas, '*dhan-nodi-khal, ei tine Barisal*' (rice, river and canal are the part and parcel of Barisal).

Barisal division contains the least (13%) salt affected areas among Bangladesh's five coastal regions (Nasiruddin and Hassan, 2009). So, unlike other coastal regions, rice yield in Barisal district is least affected by soil salinity. During our field survey, storm surge, high tide and rainfall were reported to be the main reason for submergence of rice fields by around 49%, 37% and 14% farmers respectively.

For our study, the ten Upazilas[8] of Barisal district were first sub-divided into two categories -'high submergence prone' region and 'low submergence prone' region, with the help of three Upazila Agricultural Officers (UAOs).[9] Next, ten Unions from five Upazilas (2 per each upazila) were selected for further examination. Six unions from 'high submergence prone' regions and four unions from 'low submergence prone' regions were purposefully selected to collect plot level data (see additional details in Annexure II, Table A II.1). In selecting the Unions two issues were taken into consideration: a) interest and commitment for timely support by the Sub Assistant Agricultural Officers (SAAOs) to conduct the survey in the Unions under their jurisdiction and, b) accessibility of the Unions during the survey period.[10]

A comprehensive farm survey was carried out during January, 2011 in the selected Unions. To identify farmers for the survey, we first obtained base maps for each Union and sub-divided these into 250 m x 250 m grids. 12 grids with agricultural land use specifically devoted for rice production were then randomly selected from the Union maps. This gave us a total sample of 120 grids for ten Unions. Finally one plot from every single grid was randomly selected for detailed investigation. In total, 120 farmers who were owners or tenants of the plot (but not agricultural labourers) were surveyed. The survey questionnaire (see Annexure I) included questions on land holdings, cropping practices, crop production, losses and profits over the years, their agricultural knowledge etc.. We tried to obtain recall data from the farmers for the period 2006-2010.

Data were collected on 120 plot samples in the proportion of 3:2 for 'high' and 'low' submergence prone Unions.[11] In the final analysis, we were able to use data only from113 plots. Also, in the final data set, the ratio of samples from two groups of Unions was 71:42 due to exclusion of some outliers in yield data.[12]

### 3.1 Farmers and crop submergence in coastal Barisal

Table 1 presents summary statistics about the surveyed farmers. The data shows that almost 15% of the surveyed farmers are functionally landless. Small, medium and large farm holders are 48%, 36% and 1% respectively. This statistic is quite similar to national figures (BBS[13]). The average household size is six. On average two members are wage earners, with one of them being the cultivator. Some seventy seven percent of the sample farmers have at

[6] Barisal has an area of 2,790.51 sq. km. (Banglapedia, 2006) with a population density of 844.28 per sq. km (calculated from BBS).

[7] URL: http://www.bbs.gov.bd/WebTestApplication/userfiles/Image/AgricultureCensus/ZillaSeries/barisal.pdf accessed on September 22, 2011.

[8] In Bangladesh, districts are divided into Upazilas, which are further divided into Unions for administrative purposes.

[9] The former consists of six upazilas namely Bakerganj, Barisal Sadar, Hizla, Muladi, Mehendiganj and Banaripara. These upazilas are highly exposed to storm surge and high tide. The other four upazilas namely, Wazirpur, Gournadi, Agaljhara and Babuganj usually experience submergence while flash flood occurs at the upper basin.

[10] This is because multiple modes of transport, including rickshaw/van, trawler, motorbike etc. were required to access several remotely placed Unions and in some cases the frequency of trawler service was only twice a day.

[11] The remoteness of the Unions (Table II.1 depicts the one-way travel time from Barisal city to each Union), made accessing more samples difficult.

[12] The data set suffers from missing values in a number observations related to seasonal yield data of different rice cultivars in conjunction with submergence factors. These missing data may be due to two reasons. First, farmers may have found it difficult to recall seasonal production figures of different rice cultivars for the last five years in relation to depth of submergence water and duration of inundation (unless there was really huge problem). Second, the limited cases reporting Aus cultivation in *Kharif I* season is more likely explained, as per Banerjee (2010), by the diminishing popularity of these crops in Bangladesh.

[13] URL: http://www.bbs.gov.bd/WebTestApplication/userfiles/Image/AgricultureCensus/ZillaSeries/barisal.pdf accessed on September 22, 2011.

least started primary education. The average homestead size and average owned cultivable land are 34 and 156 decimal[14] per household respectively. Fifty seven percent of farmers indicated a preference for local Aman/T. Aman variety of rice during the wet season.

Farmers suggest that a major constraint to agricultural growth in the region is water related stress - almost 46% farmers report this as a major concern. Farm households identify lack of cash money as one of the main impediments to agricultural practice. Farmers are extremely dependent on the Sub Assistant Agriculture Officers, and take their advice on selection of crops and tackling of submergence problems.

Plot wise descriptive statistics on agricultural yield and submergence factors for the year 2010 are also summarized in Table 1. Our data shows that the average productivity of rice crop in *Kharif I*, *Kharif II* and *Robi* seasons was 7, 9 and 17 kg/decimal respectively. Almost 50% of surveyed fields faced an average of 3-7 days long inundation during 2010, while around 37% plots were submerged for more than one week. Some 57 % plots were under 1-3 meters of water and 26% were under 0.5-1 meter of water for at least some part of the time in 2010.

## 4. Methods

We try to answer several questions related to the effect of water submergence on rice yield. First, we ask whether there is a difference in rice productivity in high and low submergence areas. We then examine the temporal (2006-2010) impact of submergence by comparing average yield over time and across rice varieties. We use panel data comprising both cross-sectional and recall data at plot levels from 2006-2010 for the above analyses.

We also use regression analyses to estimate the effect of different submergence factors on Aman rice yield (*Kharif II* rice crop, i.e. during the monsoon season between July and January month), the widely grown crop in coastal Barisal. Table 2 shows the summary statistics of all the variables considered in the regression analysis. We focus on data from 2010 for this detailed analysis of the impacts of water depth and duration of submergence on rice yield.

A final aspect of our study is a projection of yield losses due to submergence in 2050. We use a model proposed by IWM and CEGIS (2007) to first estimate the area in Barisal district that is likely to be submerged in 2050 as a result of sea level rise and storm surge. This over-arching model combines hydrological models (eg. river flow model, flooding pattern model, inundation models etc.) and relative sea level rise models along the Bay of Bengal coast to predict levels of water inundation.[15] In this exercise, we build on the 3rd IPCC predictions of sea level rise of 27 cm for a high (A2) emission scenarios in the year 2050. Increased cyclone peak intensity (increase of maximum wind speed according to IPCC) along with sea level rise (27cm) contributes to corresponding water surges. We generate water and storm surge levels for 2050 from the modeling exercise and overlay this information on a digital elevation map of Barisal district using GIS (Geographic Information System) to calculate the submerged land area. Affected rice fields were determined both for the base year (2005) and projected year (2050). Based on our field-data based understanding of submergence impacts on yields, we estimate yield losses for 2050. Figure 2a and 2b show the results of the mathematical modeling for Aman cultivars.

## 5. Results

### 5.1 Difference in rice yield in high and low submergence areas

Figure 3 and Table 3 show the variation in average yield rates for rice in the Unions in high and low submergence areas. Figure 3 demonstrates that the annual average rice yield exhibited a slow but steady growth over 2006-2010, with a productivity decline during cyclone Sidr[16] in 2007. As expected, yield in 'low submergence prone' regions are higher (by 10% on an average) than those in 'high submergence prone' region. Notably differences in rice productivity between high and low submergence areas are statistically significant and seem to be increasing – there

[14] One decimal equals 0.004048583 hectare. 1 hectare equals 247 decimal.
[15] 2005 is selected as the baseline hydrological year to generate river flows, inundation levels etc.
[16] Cyclone Sidr, formed in the central Bay of Bengal, hit Bangladesh coast on November 15, 2007. Patuakhali, Barguna and Jhalokathi districts of Barisal Division were the hardest hit. Barisal district was also affected by heavy rainfall during the cyclone.

is an 8% difference in 2006 while there is a 19% difference in 2010.[17] This indicates that rice production may be at greater risk in 'high submergence prone' regions.

The annual average productivity figures however conceal differences in yields across different rice varieties. Some varieties are more susceptible to submergence relative to others. As Table 3 shows during 2006-2010, average annual rice yield (all varieties) is higher by almost 10% in 'low submergence prone' areas relative to 'high submergence prone' areas. Yield for HYV is always higher in low submergence areas relative to high submergence areas. In contrast, local paddy (T. Aus, T. Aman and Boro) yield is higher in 'high submergence areas' (relative to low submergence areas) by approximately 40% relative to 'low submergence areas'. These deviations between mean yields are statistically significant. Further, in high submergence areas, in most cases, there is no major difference in average yield between local paddy and high-yielding varieties. This seems to suggest that local low yielding variety paddy is more suitable than high yielding varieties in areas that are more prone to submergence.

## 5.2 Seasonal effects

Table 4 reveals that throughout the year (when all cropping seasons are considered together) rice productivity decreases significantly when inundation level increases. The productivity of rice cultivars facing less than 0.5 meter submergence[18] is almost three times higher than that of cultivars exposed to more than 3 meter of submergence.

However, there are significant seasonal differences. *Robi* crops are highly sensitive to water level in the field. The average *Robi* yield decreases almost by 49% with increasing water depth from 0.5 meter to 1.0 meter. The reduction of average yield with increasing level of water in *Kharif II* season is also of concern because the majority of rice is grown in this season. Average yield rates in the *Kharif I* season decrease by 26% with a half meter increase in submergence.

## 5.3 Variation in yield with changes in depth and duration of submergence

The effect of two important submergence variables (i.e. depth and duration of submergence water) on yields of different rice cultivars is summarized in Figures 4 and 5. Table 5 focuses more specifically on differences in HYV Aman and local Aman/T. Aman.

Figure 4 indicates that average rice yield (all varieties considered together) significantly[19] decreases when the plant faces rising level of submergence water. Plants facing more than 3 meter inundation, show almost a 66% decline in their yield relative to those exposed to less than 0.5 meter submergence level. Figure 5 shows that average yield decreases as the cultivar becomes submerged for longer duration (less than 3 days to 7 days or more) - the difference in average yield across four different durations of submergence is statistically significant.[20] [21]

Table 5 shows the decline in yield in both HYV and local Aman when they experience rising levels of submergence for longer time horizons. HYVs do reasonably well if the water level in the field is below one meter. If water height exceeds this range, however, local Aman has higher yields relative to HYV.

Duration of water seems to have a stronger negative effect on HYV rice relative to the local Aman rice. As Table 5 shows, at low water depths (i.e. 0.5 to 1 meter) the production of HYV Aman is around 13 kg/decimal when faced with 3-7 days of submergence and 7 kg/decimal with more than 15 days of continuous inundation (during the harvesting period). This represents a yield decline of some 45% with increased duration of inundation; in contrast local Aman yield declines by only 24% under the same scenario. These numbers reinforce earlier results (see

[17] The null hypothesis, in this context, is Ho: $\overline{X_{HSR}} = \overline{X_{LSR}}$, where $\overline{X_{HSR}}$ and $\overline{X_{LSR}}$ are respectively the average annual yield rate of rice in 'high' and 'low' submergence prone regions. We reject the null hypothesis at 10% significance level.

[18] Partial submergence of around 0.5 meter for agricultural field for almost all the year round is a very common phenomenon in the coastal areas of South-East Asia including Bangladesh (Ismail et al., 2010; p. 157).

[19] The null hypothesis concerning equality of the average yield rates of rice varieties for 2010 at four distinct level of submergence water is rejected at 0.5% significance level.

[20] The null hypothesis concerning equality of the average yield rates of rice varieties for four different categories of submergence duration is rejected at 0.5% significance level.

[21] It should be mentioned that the effect of *daily* inundation due to high and low tide is not considered because this regular phenomenon has no distinguishable impact in the study context.

Table 3) suggesting that local varieties of rice are more resistant to submergence factors and explain why farmers feel comfortable growing low yielding local cultivars in coastal areas. Such findings are strengthened by other contemporary studies (e.g. Ismail et al., 2010; Nasiruddin and Hassan, 2009).

To further understanding the effect of depth and duration of submergence on yield, we regressed *Kharif II* season's Aman (includes both HYV and local variety) rice crop yield on a number of independent variables, including depth and duration. Table 6 (and Table A II.2) presents the estimated ordinary least square (OLS) regression results with Aman yield as the dependent variable (while in Table A II.2 we report estimations with natural logarithm of Aman yield as the dependent variable). Alternative models are estimated to assess the robustness of our estimates to changes in submergence variables. Models 1 and 2 regress yield on depth and other variables, while in Models 3 and 4 we regress yield on duration and other independent variables. In models 2 and 4, we interact rice variety with depth or duration to identify if the local variety stands out relative to HYV in the presence of water logging. Depth and duration are correlated; so, we estimate the effects of these submergence factors on yield in separate models.

Models 1 and 2 in Table 6 both depict significant negative effects of inundation depth on yield. Other factors being constant, Model 1 and 2 estimate around 2.8 kg/decimal and 4.8 kg/decimal yield loss due to more than 0.75 m water in the field respectively. As shown in Model 2, other things being constant, yield is lower with local varieties relative to HYV seeds.

An interesting result - though statistically insignificant in three models, but significant in Model 1- is that yield is higher in high submergence areas. This simply suggests that once we control for depth and crop variety, yields may be higher in high submergence areas. Another interesting result in Model 2 is that the coefficient of the interaction between crop type and depth is positive and significant. This suggests that when local varieties are used and depth is greater than 0.75 meters, yield is higher relative to scenarios where this is not the case. This reinforces our understanding of why farmers choose to use local varieties when they expect higher submergence.

Model 3 and 4 show the results of duration of inundation on yield. Model 3 estimates around 2.6 kg/decimal decrease in Aman harvest because of seven days or longer submergence. Overall, Table 6 suggests that depth of submergence water has a stronger negative effect than duration of submergence on Aman yield.

## 5.4 Estimated Aman yield loss in 2050

Our model is able to predict the different areas of Barisal that are likely to face different depths of water submergence in 2050 as a result of sea level rise and storms. The additional area of Aman that is likely to be submerged in 2050 is shown in Table 7 – additional area that is expected to be under less than one meter, 1-3 meters, and more than 3 meters of water in 2050 are 1,877,276 decimal (7,600 ha), 399,795 decimal (1,619 ha) and 1,073,309 decimal (4,345 ha) respectively. In total, we expect 5,964 ha of Aman producing land to face over one meter of inundation in 2050.[22]

Given the different levels of water inundation, in order to estimate losses, we need to make some assumptions about the duration of inundation. Our model is not able to predict the average duration of inundation in 2050. Thus, conservatively, our analysis assumes that there is no more than 3-7 days of submergence in 2050. From Table 1, we note that around 50% of plots in 2010 suffered from submergence of this duration and 37% faced more than seven days of submergence. However, for our 2050 analyses, we assume that all plots that face different levels of inundation are inundated on average for only 3-7 days.

Our field data provides us estimates of the average yield in 2010 for different levels of submergence for 3-7 days. These are identified under column 5 in Table 7. The Table shows that the average yield of Aman (includes both HYV and local varieties) rice in 2010 was around 13 kg/decimal under un-inundated conditions, i.e., below one meter level of water. However, the yield decreases by 32% (becomes about 9 kg/decimal) when crops face submergence of one to three meters. We assume that productivity goes to zero at above three meters inundation level. We assume that productivity does not change in 2050 relative to 2010 due to any other technological and geo-physical

[22] We calculate these figures based on additional submergence in 2050 relative to 2005 (and not 2010) because our base model for this analysis is 2005. However, we assume the conditions between 2005 and 2010 are not too different.

reasons. Thus, we are able to use the 2010 yield information to project rice production losses in 2050. Column 6 in Table 7 shows the lower average yield with increased level of submergence. Column 7 estimates total average yield losses in 2050 based on the total area expected to be inundated. Thus, we estimate that there will be a net loss of 10,856 tons (ranging from 3,661 ton to 18,052 ton) of Aman rice in 2050 because of submergence. This number amounts to about 5% of total Aman production in Barisal district in 2009-2010.[23]

Note, however, that we do not bring into consideration in this study, the growth stage of rice plants during submergence. The effect of continuous inundation at different growing stage of crops reduces its yield differently and this may affect farmers in different ways.

## 6. Conclusions and Policy Implications

This study investigates temporal and seasonal variation in rice productions in coastal Barisal because of different levels of water submergence. We aim to understand the consequences of future climate change and SLR by examining how productivity is currently affected by water inundation into paddy fields.

We find that rice cultivation in Barisal district is at risk due to continuous submergence with high levels of water for considerable time period during the cropping seasons. On average, farmers faced a maximum of nine days of submergence of the main rice crop (Aman crop in the *Kharif II* season) in 2010. Eighteen percent of total Aman fields in our study area were under 0.5-1 meter of water for 3-7 days, while 31% were under 1-3 meters of water for the same number of days. Some plots suffer even more water for longer duration.

Our study results emphasize that high yielding rice cultivars are more vulnerable in this region to water stress relative to local low yielding varieties. In areas where there is 1-3 meters of inundation for 3-7 days, HYV Aman production is, on average, 20% lower relative to local paddy production. It is therefore, not surprising that some 41% of the farmers use local Aman during the main *Kharif II* season in high submergence areas relative to 17% of farmers in low submergence areas. 57% farmers in our sample survey indicated a preference for local Aman during the monsoon season. This may also be due to cash constraints and/or flood related un-certainties in the region or even in some occasion because of poor drainage within embankment protected areas. Our study has not been able to distinguish among these reasons and this is an area for future research.

In 2050, we expect an additional 13,564 hectares of Aman fields in Barisal district, or 61% of agricultural land, to face three to seven days of submergence from water of varying heights because of SLR and increased storm surge events. Unless there are technological and productivity changes, this means that there will be a 5% reduction in total Aman (HYV and local Aman) production in 2050 relative to 2010.

Sustainable harvesting in Barisal may be possible with the use of modern submergence tolerant rice varieties accompanied by proper agricultural management practices. In 2010, the Bangladesh Rice Research Institute developed two submergence tolerant rice varieties, Dhan51 and Dhan52, for flash flood prone areas (Bari and Baltazar, 2010). Whether these crops will be adopted will depend on the field productivity of these two varieties and farmers' perceptions. Development and introduction of low cost water control technologies such as rain water harvest and water conservation may also increase the possibility of modern varieties adoption (Fuwa et al., 2007). In order to address cash restraints, the possibility of micro-credit loans and other options and their use for buying new rice seeds will need to be further evaluated.

[23] URL: http://www.bbs.gov.bd/WebTestApplication/userfiles/Image/AgricultureCensus/ZillaSeries/barisal.pdf accessed on September 22, 2011.

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# Tables

## Table 1: Summary statistics on sample farmers and plots

| Attributes | Variables | All cases |
|---|---|---|
| Socio-economic characteristics | • Distribution (percentages) according to farm size | |
| | – Small farm (operated area of 0.05 to 2.49 acres with a minimum of 0.05 acres cultivated area) | 47.8 |
| | – Medium Farm (operated area of 2.50 to 7.49 acres) | 35.8 |
| | – Large Farm (operated area is more than 7.50 acres) | 1.5 |
| | – Non Farm Holding (less than 0.05 acres of cultivated area) | 14.9 |
| | • Average household size | 6 |
| | • Average homestead size (decimal) per household | 34 |
| | • Average owned cultivable land (decimal) per household | 156 |
| | • Average number of wage earners in each household | 2 |
| | • Population (average) dependent on agriculture per household | 1 |
| | • Literacy rate[24] | 77% |
| Major crop | • Share of farmers produced major crops in 2010 *Kharif II* season- | |
| | – HYV Aman | 43% |
| | – Local aman/T. Aman | 57% |
| Perceptions of farmers* (in percentages) | • Constraints for rice production in Barisal district | |
| | – Lack of cash money | 16.3 |
| | – Production factors related constraints | 32.1 |
| | – Water related stresses | 45.8 |
| | – Soil salinity | 5.8 |
| | • Development of agricultural knowledge through | |
| | – Experience | 6.1 |
| | – Consultation with other farmer | 12.1 |
| | – Consultation with Agriculture Officers | 64.1 |
| | – Watching TV | 15.2 |
| | – Reading newspaper/magazine | 2.4 |
| | • Consultation options once faces submergence in rice production | |
| | – Consult with the elderly persons | 9.5 |
| | – Consult with other farmers | 12.9 |
| | – Consult with Agriculture Field Officer | 69.4 |
| | – Use past years' experiences | 8.2 |
| Plot level statistics, 2010 | • Average rice yield (kg/decimal) in | |
| | – *Kharif I* season | 7.20 |
| | – *Kharif II* season | 9.46 |
| | – *Robi* season | 16.70 |
| | • Distribution (percentage) of plots under different duration of submergence | |
| | – Less than 3 days | 13.6 |
| | – 3-7 days | 49.5 |
| | – 8-15 days | 13.6 |
| | – More than 15 days | 23.3 |
| | • Distribution of plots under different level of submergence | |
| | – Less than 0.5 meter | 14.8 |
| | – 0.5-1.0 meter | 26.2 |
| | – 1.0-3.0 meter | 56.6 |
| | – More than 3.0 meter | 2.5 |

[24] Percentage of people who has at least started primary level of education.

**Table 2: Summary statistics of the regression variables**

| Variable | Description | Min | Max | Mean |
|---|---|---|---|---|
| Yield_2010* | Yield (kg/decimal) of rice crop (including HYV and local variety) in *Kharif II* season, 2010 | 0.55 | 20.00 | 9.34 |
| LNyield_2010* | Natural logarithm of yield (kg/decimal) of rice crop (including HYV and local variety) in *Kharif II* season, 2010 | -0.60 | 3.00 | 2.08 |
| LN_ Input Cost | Natural logarithm of total cost of input (Tk./decimal) in *Kharif II* season, 2010 | 3.01 | 4.67 | 3.88 |
| Elevation | Dummy for land elevation; 1= high submergence prone region, 0= otherwise | 0 | 1 | 0.69 |
| Crop type | Dummy for crop type; 1= local variety, 0= HYV Aman | 0 | 1 | 0.55 |
| Depth | Dummy for average water depth (meter) during inundation in *Kharif II* season, 2010; 1=More than 0.75 m, 0=Otherwise | 0 | 1 | 0.66 |
| Duration | Dummy for maximum duration (days) of inundation in *Kharif II* season, 2010; 1= More than 7 days, 0=Otherwise | 0 | 1 | 0.36 |
| Crop typeX Depth | Interaction variable of Crop type and Depth | 0 | 1 | 0.39 |
| Crop typeX Duration | Interaction variable of Crop type and Duration | 0 | 1 | 0.28 |

*Dependent variable.

**Table 3: Average rice crop yield in 'high' and 'low' submergence prone regions, Barisal district, 2006-2010[a]**

| | Average yield rate (Kg/decimal) of rice varieties, 2006-2010 | | | | |
|---|---|---|---|---|---|
| | All varieties | HYV Aus | HYV Aman | HYV Boro | Local Paddy* |
| High submergence prone region | 10.77 (5.41) | 8.54 (4.73) | 10.13 (5.41) | 15.17 (8.42) | 10.49 (4.78) |
| Low submergence prone region | 12.12 (8.59) | 10.27 (3.21) | 11.76 (6.82) | 20.64 (11.45) | 6.31 (3.79) |

[a] Standard deviations in parentheses
* The null hypothesis, in this context, is Ho: $\overline{x_{HSR}} = \overline{x_{LSR}}$, where $\overline{x_{HSR}}$ and $\overline{x_{LSR}}$ are respectively the average annual yield rate of local paddy in 'high' and 'low' submergence prone regions. We reject the null hypothesis at 0.5% significance level.

**Table 4: Seasonal variation of rice productivity according to depth of submergence water, Barisal district, 2006-2010[a]**

| | Seasonal variation in average yield rate (Kg/decimal) | | | |
|---|---|---|---|---|
| | All seasons* | *Kharif I* | *Kharif II*** | *Robi* |
| below .5m | 16.53 (8.34) | 8.89 (4.19) | 15.03 (6.16) | 23.09 (11.36) |
| .5 m -1m | 10.38 (4.54) | 6.59 (5.77) | 10.63 (4.39) | 11.74 (3.89) |
| 1m - 3m | 8.56 (4.89) | 6.43 (3.70) | 8.57 (4.89) | - |
| above 3m | 4.91 (6.77) | - | 4.91 (6.77) | - |

[a] Standard deviations in parentheses
* The null hypothesis concerning equality of the seasonal variation in average yield rates of rice at four different level of submergence water is rejected at 0.5% significance level.
**The null hypothesis, in this context, is Ho: $X_1 = X_2, X_2 = X_3, X_3 = X_4$, where $X_1$, $X_2$, $X_3$ and $X_4$ are respectively the average annual yield rate of *Kharif II* season's rice crop at four different level of submergence water. We reject the first two null hypotheses at 5% significance level. However the last is not statistically rejected.

N.B. Missing values in the table are due to two reasons: (i) data on yield rates may lack corresponding value of water depth; (ii) there may be no harvest during the study period corresponding to the mentioned variables. However, the study acknowledges its limitation in distinguishing these two facts while describing missing values.

**Table 5: Average yield of Aman varieties by depth of submergence water and duration of inundation, Barisal district, 2010[a]**

| | Average yield rate (Kg/decimal) of rice varieties according to depth of submergence water and duration of inundation | | | |
|---|---|---|---|---|
| | .5m- 1m | | 1m- 3m | |
| | HYV Aman | Local Aman | HYV Aman | Local Aman |
| <3 days | 15.64 (0.94) | - | - | - |
| 3-7 days | 13.33 (4.71) | 10.98 (3.99) | 7.55 (5.24) | 9.71 (4.80) |
| 8-15 days | - | 6.69 (4.19) | 7.80 (2.54) | 9.10 (1.94) |
| 15 days > | 7.35 (2.47) | 8.40 (5.09) | - | 7.26 (2.49) |

[a] Standard deviations in parentheses

N.B. Missing values in the table are due to lack of data on yield rates and corresponding value of submergence factors.

**Table 6: Results of regression analysis (Dependent variable: Yield_2010; n=74)**

| | Model 1 | Model 2 | Model 3 | Model 4 |
|---|---|---|---|---|
| R2 | 0.133 | 0.177 | 0.106 | 0.108 |
| Constant | 5.536 (4.791) | 6.174 (4.715) | 9.914 (5.218)* | 9.690 (5.284)* |
| Crop type | -0.390 (1.036) | -2.975 (1.699)* | -0.265 (1.073) | -0.005 (1.281) |
| Depth | -2.802 (1.087)** | -4.770 (1.487)*** | | |
| Duration | | | -2.646 (1.263)** | -1.989 (2.157) |
| Crop typeX Depth | | 3.938 (2.073)* | | |
| Crop typeX Duration | | | | -0.906 (2.401) |
| Elevation | 2.048 (1.135)* | 1.648 (1.134) | 0.337 (1.216) | 0.432 (1.249) |
| LN_ Input Cost | 1.148 (1.226) | 1.362 (1.208) | 0.078 (1.277) | 0.086 (1.285) |

Standard errors in parentheses; ***, ** and * indicate significance at 1%, 5% and 10% level respectively.

**Table 7: Land inundation and yield loss of Aman rice in 2050**

| | Inundated Aman area (decimal) | | Newly inundated area (decimal) in 2050 | Average Aman yield (kg/decimal) with 3-7 days inundation in 2010 (and by assumption for 2050) a ** | Decline in average productivity (kg/ decimal) with increased level of inundation | Yield loss in 2050 (kg) |
|---|---|---|---|---|---|---|
| | Y 2005* | Y 2050* | | | | |
| 1 | 2 | 3 | 4=(3-2) | 5 | 6 | 7 = (6*4) |
| Uninundated | - | - | - | 12.60 (5.56) | | - |
| below 1m | 3,414,785 | 5,292,061 | 1,877,276 | 12.55 (4.51) | 12.60-12.55 = 0.05 | 93,864 |
| 1m - 3m | 14,560,368 | 14,960,163 | 399,795 | 8.53 (5.08) | 12.55-8.53 = 4.02 | 1,607,176 |
| above 3m | 9,191,364 | 10,264,673 | 1,073,309 | 0.00*** | 8.53-0 = 8.53 | 9,155,326 |
| Total | 27,166,517 | 30,516,897 | 3,350,380 | | | 10,856,366 |

*Calculated by CEGIS. Inundation is for 3-7 days by assumption.

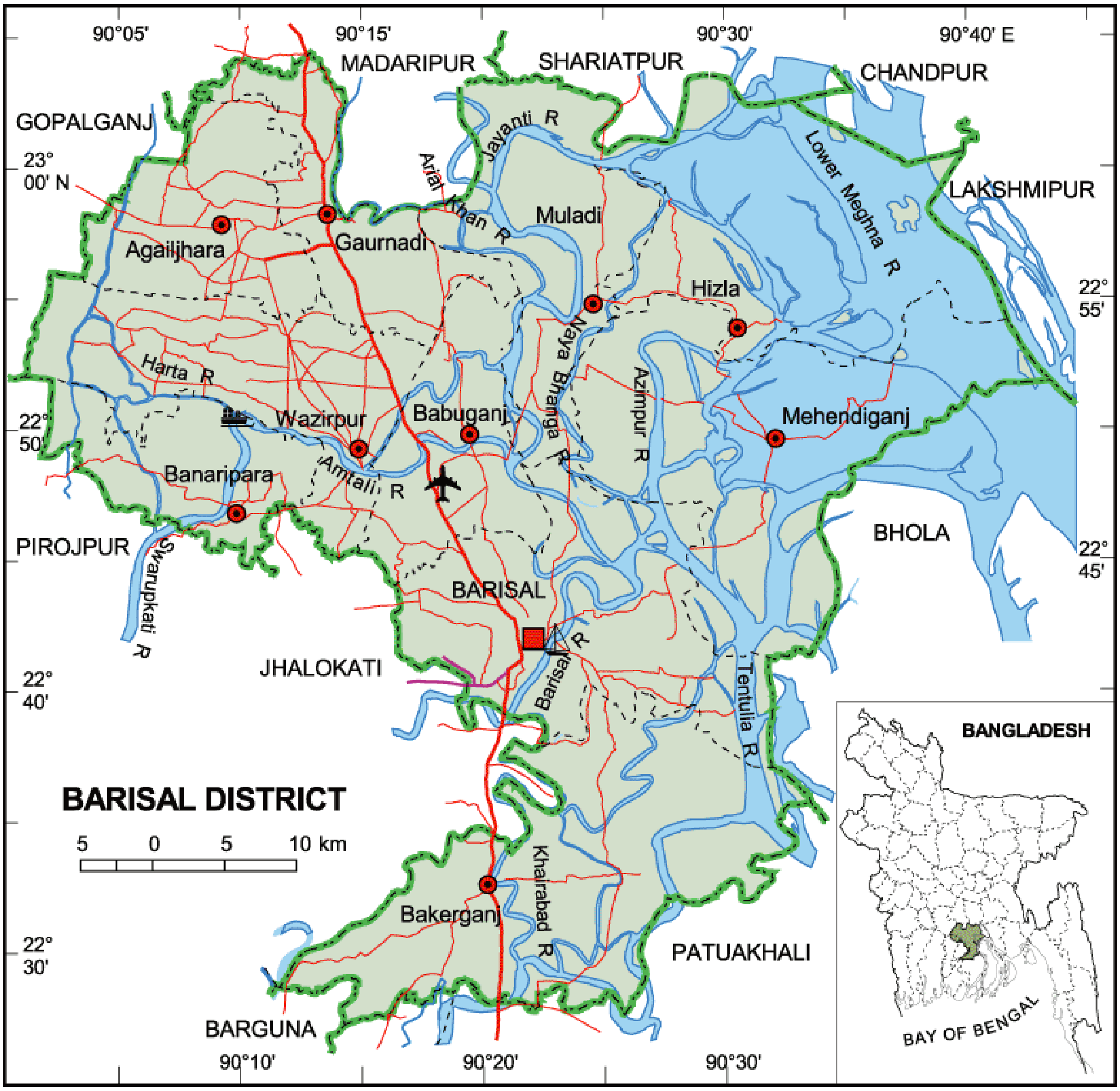
**Based on field survey, 2011.

***The figure is assumed in the absence of field level data.

[a] Standard deviations in parentheses.

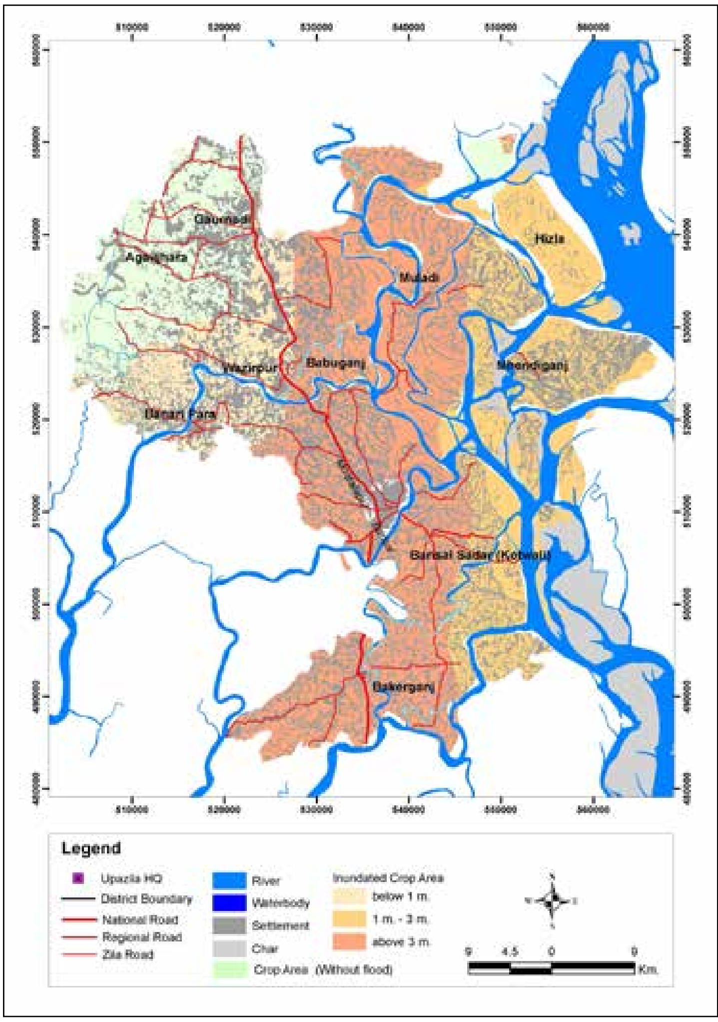
## Figures

**Figure 1:. Map of the Barisal District**



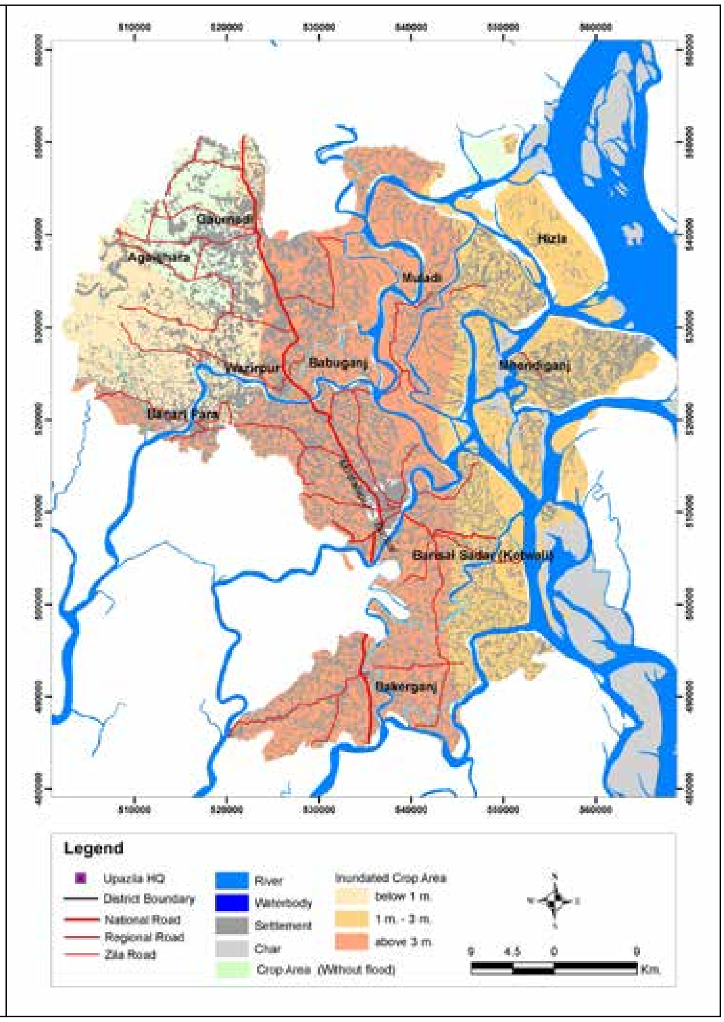

Source: Banglapedia, 2006.

**Figure 2a: Inundated Aman cropped area in Barisal District, 2005**




Source: Prepared by CEGIS

**Figure 2b: Inundated Aman cropped area in Barisal District, 2050**




Source: Prepared by CEGIS

**Figure 3: Temporal variation of rice productivity in 'high' and 'low' submergence prone regions, Barisal district, 2006-2010.**

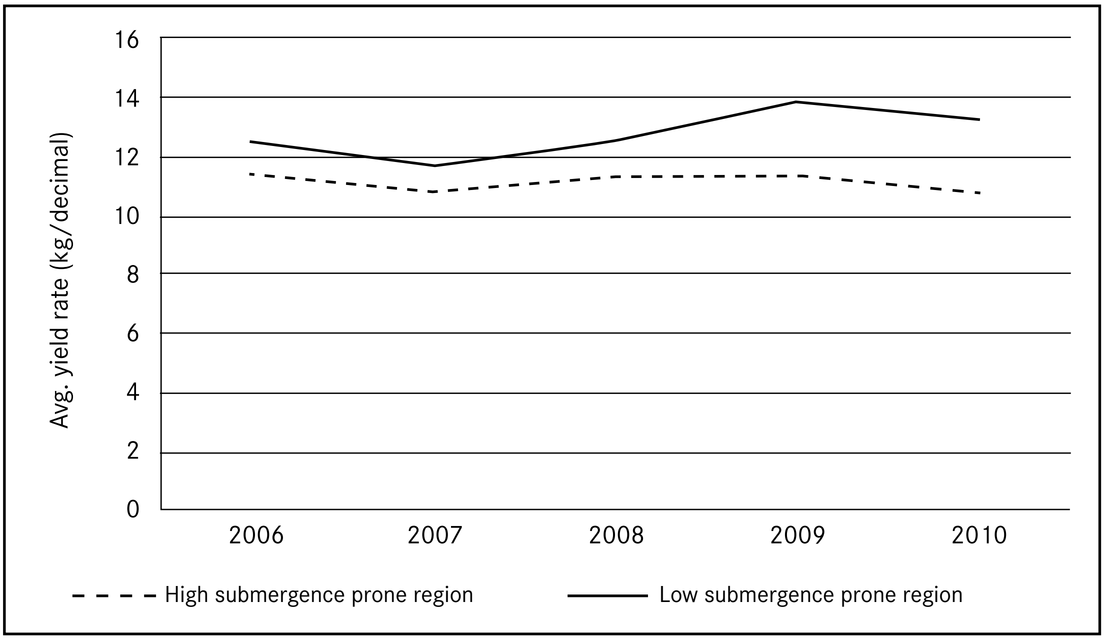


**Figure 4: Average rice yield by depth of submergence water, Barisal district, 2010**

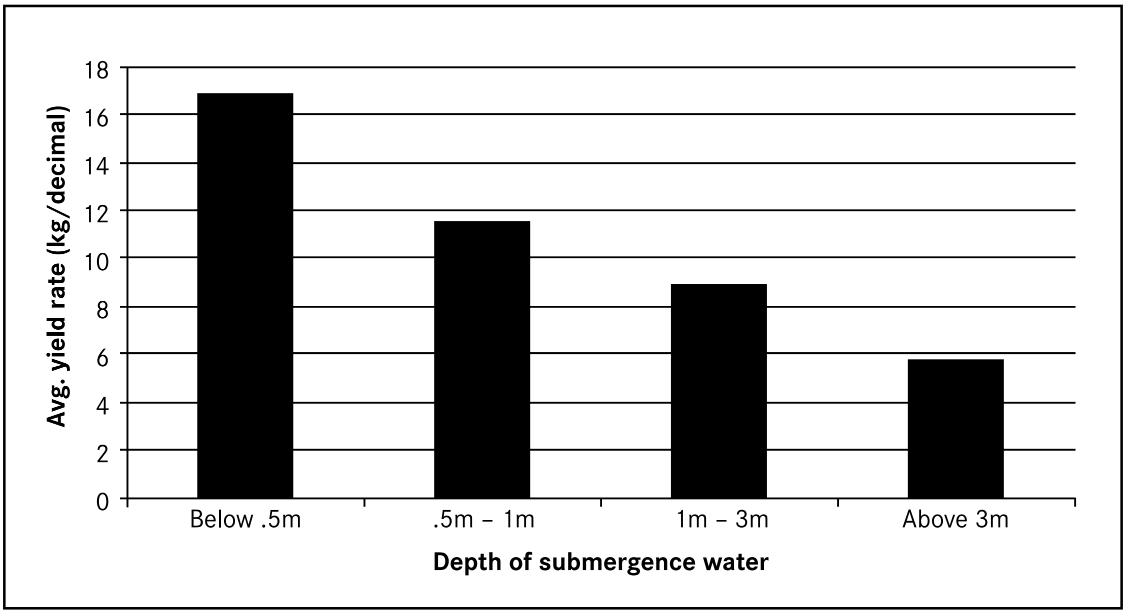
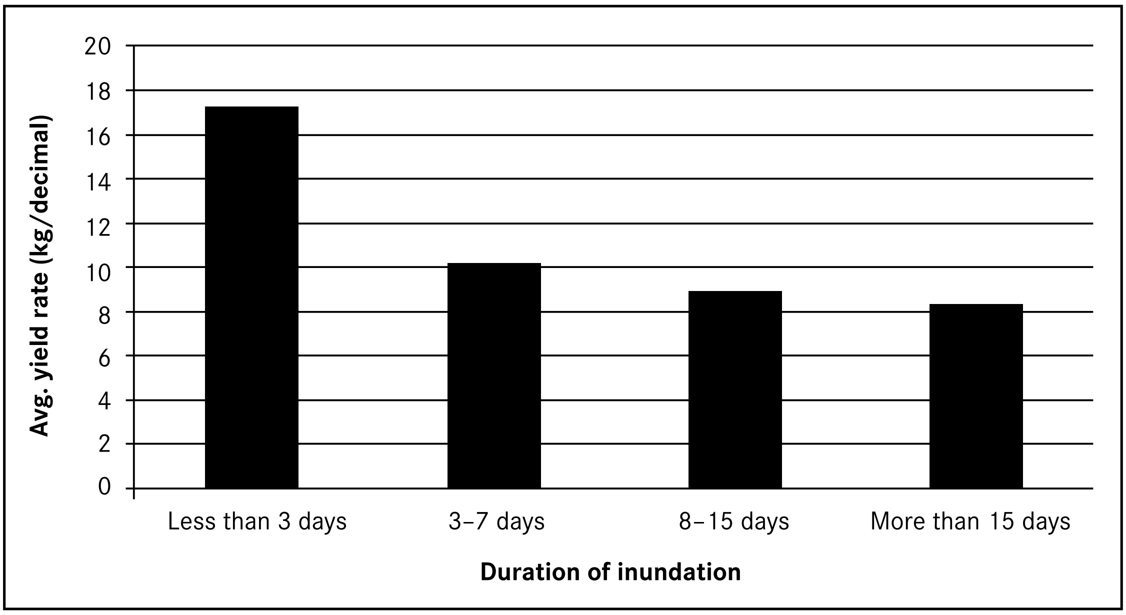



**Figure 5: Average rice yield by duration of inundation, Barisal district, 2010**



# Annex 1: Questionnaire on Agricultural Survey in Barisal

## Bangladesh University of Engineering and Technology

## Agricultural Survey

Greetings! We are conducting a research on “Impact of Climate Change in Bangladesh: A Multi-Sector Analysis”. This research is supported by SANDEE and aims at finding the impact of Sea Level Rise associated with storm surge on the agriculture sector of coastal regions of Bangladesh. It requires conducting interview of the farmers (owner or tenant of the farm land) to have insights on the agriculture practices and impact of water logging/inundation in this region (Barisal). This research is designed solely for academic purpose and all your responses will remain confidential. We shall try our best to share the results of our research with you once completed. We shall be extremely grateful if you agree to cooperate with us and give some of your time to answer a set of questions we have. We thank you in advance for your kind cooperation.

For any further query, please feel free to contact Dr. Afsana Haque, Assistant Professor, Department of Urban and Regional Planning, Bangladesh University of Engineering and Technology (BUET), Dhaka-1000; Phone: 880-2-8360534; Email: e_haque2@ yahoo.com

Would you like to participate in the interview? (Circle) Yes No

| Thana Code | | | Union Code | | | Village Code | | | Plot Code | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | |

### A. General Information

A1. a) Plot ID.: ………………………….. b) Village name: …………………………………….
c) Union name (use code): …………. d) Thana name (use code): ………………………….
e) Latitude: ………………………….. f) Longitude: ……………………………………….

Code for A1 (c). 1: Durgapasha 2: Darial 3: Vashanchar 4: Jangalia 5: Chandramohan 6: Chormonai 7: Ghutia 8: Harta 9: Chandpasha 10: Kedarpur

Code for A1 (d). 1: Bakerganj 2: Mehendiganj 3: Barisal Sadar 4: Wazirpur 5: Babuganj

A2. Name of the respondent: …………………………………………

Plot at a Glance

| A3. Ownership pattern (Use code) | A4. Operational status (Use code) | A5. Plot area in decimal | A6. Current land price (Tk./decimal) |
|---|---|---|---|
| | | | |

Code for A3. 1: State land 2: Inherited land 3: Purchased land 4: Other (please specify)

Code for A4. 1: Owner (Individual/family who owns the land, may or may not lease out some land but operate his own land)
2: Tenant_*Bargha* (Individual/family who does not own the land but operate it taken from others on share cropping basis)
3: Tenant_Other (Individual/family, who does not own the land but operate it taken from others on any basis other than *Bargha* such as lease, usufractuary mortgage etc.)

Socio-Demographic Characteristics Of The Respondent

| A7. Gender (Use code) | A8. Age (Use code) | A9. Relationship with H/H head (Use code) | A10. Permanent resident (Use code) | A11. Education level (Use code) | A12. Primary occupation (Use code) | A13. Secondary occupation (Use code) | A14. Family size | A15. No. of wage earners in the family | A16. No. of wage earners in the family from agriculture |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

Code for A7. 1: Male 2: Female

Code for A8. 1: Below 20 yrs 2: 20-40 yrs 3: 40-60 yrs 4: Above 60 yrs

Code for A9. 1: H/H head 2: Wife/Husband 3: Son/Daughter 4: Father/Mother 5: Sister/Brother 6: Others

Code for A10. 1: In the village 2: In the same union but from other village 3: In the same upazila but from other union
4: In the same district but from other upazilas 5: From ……………………………….district

Code for A11. 1: Illiterate 2: Can sign only 3: Primary (Class I-V) 4: Secondary (Class VI-X), Higher secondary (HSC)
5: Degree 6: Above degree

Code for A12/A13 1: Agriculture 2: Business 3: Service 4: Farm labour 5: Non-farm labour 6: Student
7: Unemployed 8: Other profession (Specify)

Land Holdings of the Respondent

| Owned land | Area (decimal) | | Cultivable land | Area (decimal) |
|---|---|---|---|---|
| A17. Homestead area | | | A21. Rented in for *Bargha* | |
| A18. Cultivable land (own) | | | A22. Rented in for lease etc. | |
| A19. Fallow land (own) | | | A23. Rented out for *Bargha* | |
| A20. Total owned land | | | A24. Rented out for lease etc. | |
| A25. Total operated land (A18+A21+A22-A23-A24) ………………………………….decimal | | | | |

Farming Assets of the Respondent

| Serial no. | Assets | A26. No. of the asset own by the respondent | A27. Usage of the asset for farming activity, 1: Yes 2: No |
|---|---|---|---|
| a. | Cows | | |
| b. | Buffalo | | |
| c. | Tractor | | |
| d. | Water pump | | |
| e. | Husking machine | | |
| f. | Wooden plough | | |
| g. | Trolley | | |
| h. | Generator | | |
| i. | Others (specify) | | |
| j. | Others (specify) | | |
| | | | |
| | | | |

## B. Cropping Details At Plot Level

| Table 1: Seasonal Distribution of crops and agricultural practices | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | B1. Plot area in decimal | B2. Season (Circle) | B3. Name of the crop | B4. Broader type of the crop (Use code) | B5. Yield from this plot (Quintals) | B6. Crop cultivation month (Use code) | B7. Crop harvesting month (Use code) | B8. Mode of irrigation (Use code) | B9. Is the plot protected by any physical infrastructure like polder/embankment? (Use code) |
| 2010 | | S1 | | | | | | | |
| | | S2 | | | | | | | |
| | | S3 | | | | | | | |
| | | | | | | | | | |
| 2009 | | S1 | | | | | | | |
| | | S2 | | | | | | | |
| | | S3 | | | | | | | |
| | | | | | | | | | |
| 2008 | | S1 | | | | | | | |
| | | S2 | | | | | | | |
| | | S3 | | | | | | | |
| | | | | | | | | | |
| 2007 | | S1 | | | | | | | |
| | | S2 | | | | | | | |
| | | S3 | | | | | | | |
| | | | | | | | | | |
| 2006 | | S1 | | | | | | | |
| | | S2 | | | | | | | |
| | | S3 | | | | | | | |

Code for B2. S1: *Kharif I* (March 16 – June 15) S2: *Kharif II* (June 16 – October 15) S3: *Robi* (October 16 – March 15)

Code for B4. 1: HYV Aus 2: HYV Aman 3: HYV Boro 4: Local paddy 5: Others (specify)

Code for B6/B7. 1: January 2: February 3: March 4: April 5: May 6: June
7: July 8: August 9: September 10: October 11: November 12: December

Code for B8. 1: Not irrigated 2: Tube well 3: Canal 4: Pond/Tank 5: Others (specify)

Code for B9. 1: Yes (protected by polder) 2: Yes (protected by embankment) 3: Yes (protected by other option (please specify))
4: Not protected 5: No need for protection, high land

**Table 2: Seasonal distribution of crops and inundation status (continuation of Table 1)**

| Year | Plot area in decimal | Season (Circle) | Name of the crop | Broader type of the crop (Use code) | B10. Inundation status (Use code) | B11. Duration of inundation (Use code) | B12. Water depth (highest) during inundation (Use code) | B13. Causes of inundation (Use code) | B14. State of the crop during inundation (Use code) |
|---|---|---|---|---|---|---|---|---|---|
| 2010 | | S1 | | | | | | | |
| | | S2 | | | | | | | |
| | | S3 | | | | | | | |
| | | | | | | | | | |
| 2009 | | S1 | | | | | | | |
| | | S2 | | | | | | | |
| | | S3 | | | | | | | |
| | | | | | | | | | |
| 2008 | | S1 | | | | | | | |
| | | S2 | | | | | | | |
| | | S3 | | | | | | | |
| | | | | | | | | | |
| 2007 | | S1 | | | | | | | |
| | | S2 | | | | | | | |
| | | S3 | | | | | | | |
| | | | | | | | | | |
| 2006 | | S1 | | | | | | | |
| | | S2 | | | | | | | |
| | | S3 | | | | | | | |

Code for crops. 1: HYV Aus 2: HYV Aman 3: HYV Boro 4: Local paddy 5: Others (specify)

Code for B10. 1: Yes 2: No

Code for B11. 1: Less than 3 days 2: 3-7 days 3:8-15 days 4: 15-30 days 5: More than a month 6: Periodical inundation daily

Code for B12. 1: Less than 0.5 m 2: 0.5-1.0 m 3: 1-3 m 4: Above 3 m

Code for B13. 1: Rainfall 2: Storm surge 3: High tide 4: Others (specify)

Code for B14. 1: Land preparation 2: Sowing/transplanting 3: Weeding/fertilizing 4: Watching/guarding 5: Harvesting and carrying

**Table 3: Seasonal variation of costs in agricultural production**

| Year | Season (Circle) | Costs involved in agricultural production | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | B15. Land preparation (Tk/ decimal) | Seed/seedling | | Fertilizer | | Irrigation | | Labour | | B24. Other Costs eg. pesticides etc. (Tk.) | B25. *Marketing cost for total output (Tk.) |
| | | | B16. Quantity (Kg) | B17. Tk./ unit | B18. Quantity (Kg) | B19. Tk./ unit | B20. Area (decimal) | B21. Tk./ unit | B22. Male (At a rate of ...Tk./day) | B23. Female (At a rate of ... Tk./day) | | |
| 2010 | S1 | | | | | | | | | | | |
| | S2 | | | | | | | | | | | |
| | S3 | | | | | | | | | | | |
| | | | | | | | | | | | | |
| 2009 | S1 | | | | | | | | | | | |
| | S2 | | | | | | | | | | | |
| | S3 | | | | | | | | | | | |
| | | | | | | | | | | | | |
| 2008 | S1 | | | | | | | | | | | |
| | S2 | | | | | | | | | | | |
| | S3 | | | | | | | | | | | |
| | | | | | | | | | | | | |
| 2007 | S1 | | | | | | | | | | | |
| | S2 | | | | | | | | | | | |
| | S3 | | | | | | | | | | | |
| | | | | | | | | | | | | |
| 2006 | S1 | | | | | | | | | | | |
| | S2 | | | | | | | | | | | |
| | S3 | | | | | | | | | | | |

* Marketing cost = (Cost of transportation + Market toll+ Personal expenses due to sale)

## Table 4: Seasonal variation of yields of different crops and their usage

| Year | Season (Circle) | Plot area (decimal) | Crop type (Use code) | Usage of the yield: B26. Total yield (Quintal) | B27. Consumption for HH use (Kg) | B28. Use as seed (Kg) | B29. Sale (Kg) | B30. Sold to whom? (Use code) | B31. Place of sale (Use code) | B32. Price of the output (Tk./Kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2010 | S1 | | | | | | | | | |
| | S2 | | | | | | | | | |
| | S3 | | | | | | | | | |
| | | | | | | | | | | |
| 2009 | S1 | | | | | | | | | |
| | S2 | | | | | | | | | |
| | S3 | | | | | | | | | |
| | | | | | | | | | | |
| 2008 | S1 | | | | | | | | | |
| | S2 | | | | | | | | | |
| | S3 | | | | | | | | | |
| | | | | | | | | | | |
| 2007 | S1 | | | | | | | | | |
| | S2 | | | | | | | | | |
| | S3 | | | | | | | | | |
| | | | | | | | | | | |
| 2006 | S1 | | | | | | | | | |
| | S2 | | | | | | | | | |
| | S3 | | | | | | | | | |

Code for crop type. 1: HYV Aus 2: HYV Aman 3: HYV Boro 4: Local paddy 5: Others (specify)

Code for B30. 1: General consumer (farm yard) 2: General consumer (in market) 3: Bepari (farm yard) 4: Bepari (in market) 5: Arathdar (in market)

Code for B31. 1: Local market 2: Urban market

## Table 5: Plot facing changes in cropping pattern in the last 5 years

| Season* | Is there any noticeable seasonal change observed in the last 5 years — Crop type: B33. Changes observed (Use code) | B34. Broad category of the new crop (Use code) | B35. Reasons for such change (Use code) | Usual crop calendar: B36. Changes observed (Use code) | B37. New calendar | B38. Reasons for such change (Use code) | Crop yield: B39. Changes observed © (Use code) | B40. Gross yield of the new varieties of crop (Quintal/acre) | B41. Crop yield of the traditional varieties is .............. (Use code) | B42. Reasons for such change (Use code) |
|---|---|---|---|---|---|---|---|---|---|---|
| S1 | | | | | | | | | | |
| S2 | | | | | | | | | | |
| S3 | | | | | | | | | | |

S1: *Kharif I* (March 16 – June 15) S2: *Kharif II* (June 16 – October 15) S3: *Robi* (October 16 – March 15)

© If answer is 'yes' with new crop then go to B40. And if answer is 'yes' with traditional crop then go to B41.

Codes for B33/B36/B39. 1: Yes 2: No

Codes for B34. 1: HYV Aus 2: HYV Aman 3: HYV Boro 4: Local paddy 5: Others (specify)

Codes for B35. 1: Heard of new profitable crop 2: Soil salinity 3: Water logging 4: Cyclone 5: Increase of water height during high tide 6: Other (specify)

Codes for B38. 1: Fluctuations in rainfall 2: Availability of new crop varieties 3: Permanent water logging 4: For irrigation facilities 5: Other (specify)

Codes for B41. 1: Rapidly increasing 2: Increasing 3: Decreasing 4: Rapidly decreasing

Codes for B42. 1: Use of chemical fertilizer 2: Soil salinity 3: Water logging 4: Cyclone 5: Absence/presence of skilled/trained labour 6: Increase of water height during high tide 7: Other (specify)

**TABLE 6: Plot facing changes in cropping pattern in the last 20 years**

| | Is there any noticeable seasonal change observed in the last 20 years | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Crop type | | | Usual crop calendar | | | Crop yield | | | |
| Season* | B43. Changes observed (Use code) | B44. Broad category of the new crop (Use code) | B45. Reasons for such change (Use code) | B46. Changes observed (Use code) | B47. New calendar | B48. Reasons for such change (Use code) | B49. Changes observed © (Use code) | B50. Gross yield of the new varieties of crop (Quintal/ acre) | B51. Crop yield of the traditional varieties is ……………(Use code) | B52. Reasons for such change (Use code) |
| S1 | | | | | | | | | | |
| S2 | | | | | | | | | | |
| S3 | | | | | | | | | | |

S1: *Kharif I* (March 16 – June 15) S2: *Kharif II* (June 16 – October 15) S3: *Robi* (October 16 – March 15)

© If answer is 'yes' with new crop then go to B40. And if answer is 'yes' with traditional crop then go to B41.

Codes for B43/B46/B49. 1: Yes 2: No
Codes for B44. 1: HYV Aus 2: HYV Aman 3: HYV Boro 4: Local paddy 5: Others (specify)
Codes for B45. 1: Heard of new profitable crop 2: Soil salinity 3: Water logging 4: Cyclone 5: Increase of water height during high tide 6: Other (specify)
Codes for B48. 1: Fluctuations in rainfall 2: Availability of new crop varieties 3: Permanent water logging 4: For irrigation facilities 5: Other (specify)
Codes for B51. 1: Rapidly increasing 2: Increasing 3: Decreasing 4: Rapidly decreasing
Codes for B52. 1: Use of chemical fertilizer 2: Soil salinity 3: Water logging 4: Cyclone 5: Absence/presence of skilled/trained labour 6: Increase of water height during high tide 7: Other (specify)

## C. Agricultural Knowledge Of The Respondent

C1. How do you decide which varieties of crop to grow in your plot? (Circle only one answer)
1: See last year's price 2: See last year's yield 3: Consult with Neighbour
4: Consult with Agriculture Field Officer 5: Use past years' experiences 6: Others (Specify)

C2. What do you usually do when you face sudden inundation or any other natural calamity destroying your crop? Please answer the question using the following table and code.

| | Cleaning and burning | Sowing/transplanting | Weeding/fertilizing | Watching/guarding crop | Harvesting and carrying |
|---|---|---|---|---|---|
| S1 | | | | | |
| S2 | | | | | |
| S3 | | | | | |
| | | | | | |

Codes for C2. 1: Wait for next cropping season of the same crop 2: Wait for next cropping season of different crop
3: Immediately go for alternate crop option 4: Go for other option like fishery 5: Others (specify)

C3. How do you take decision once the plot faces inundation or other natural calamity? (Circle)
1: Consult with the elderly persons 2: Consult with other farmers 3: Consult with Agriculture Field Officer
4: Use past years' experiences 5: Others (Specify)

C4. How do you develop your agricultural knowledge? (Circle)
1: Through experience 2: Consultation with other farmers 3: Consultation with Agriculture Field Officer
4: Watching TV 5: Reading newspaper/magazine 6: From cooperative society 7: Others (specify)

C5. Rank the following variables according to your own understanding:

| | | | | | | |
|---|---|---|---|---|---|---|
| a. | Cyclone/storm surge forecasts | 1: Not at all responsive | 2: Responsive at a low scale | 3: Neutral | 4: Often Responsive | 5: Always Responsive |
| b. | Flood forecasts | 1: Not at all responsive | 2: Responsive at a low scale | 3: Neutral | 4: Often Responsive | 5: Always Responsive |
| c. | Awareness about soil salinity | 1: Completely unaware | 2: Heard of but could not understand | 3: Understand | 4: Understand and know what to do | 5: Practicing Accordingly |
| d. | Adaptation to rainfall cycle | 1: Completely unpredictable, no chance of adaptation | | | 2: Trying to be adaptive | |
| e. | Awareness about the consequences of sea level rise* (increase of water level during high tide) | 1: Completely unaware | 2: Heard of but could not understand | 3: Understand | 4: Understand and know what to do | 5: Practicing Accordingly |
| If answer is 2/3/4/5, then where did you hear of? | | | | | | |

## D. Information On Credit Received For Farming Last Year (2010)

| | D1. Source of credit | D2. Loan amount (Tk.) | D3. Interest rate | D4. Usage of the credit |
|---|---|---|---|---|
| a. | Bank | | | |
| b. | NGO | | | |
| c. | Money lender | | | |
| d. | Relatives | | | |
| e. | Cooperative society | | | |

## E. Miscellaneous Issues

E1. Are you a member of a cooperative society? (Circle) 1: Yes (Go to E2) 2: No (Go to E3)

E2. Briefly describe the role of the society to your farming practices.

| |
|---|
| |

E3. Have you attended any training program related to agriculture in last one year? 1: Yes (Go to E4) 2: No (Go to E5)

E4. Write the name of the attended training program.

| |
|---|
| |

E5. Rank the following according to frequency:

| | 1: Always | 2: Frequently | 3: Sometimes | 4: Rarely | 5: Never |
|---|---|---|---|---|---|
| Taking agricultural credit from banks | | | | | |
| Taking agricultural credit from NGOs | | | | | |
| Taking loan from middle man | | | | | |
| Use of modern technology | | | | | |
| Selling products directly to the market | | | | | |
| | | | | | |

E6. What are the major constraints in this area for crop production? (Multiple answers are acceptable).

1: Lack of cash money
2: Scarcity of labour
3: Insect and pests infestation
4: Lack of HYV seed
5: Heavy rainfall
6: Water logging
7: Soil salinity
8: Cyclone/storm surge
9: Water level during high tide
10: Scarcity of insecticides
11: Absence of modern technology
12: Other (specify)

## F. This Section Is To Be Filled In By The Interviewer After Finishing The Interview.

F1. Completed (Circle): (a) Yes (b) No
F2. Time of Meeting (a) Start time: ........................ (b) Finish Time: ...................
F3. Date of Interview (day/month/year): ___ ___ /___ ___ /___ ___ ___ ___

F4. Name of the Interviewer: ........................................................
F5. Signature of Interviewer: ........................................................

Thank You Very Much For Your Kind Cooperation

# ANNEXURE II

### Table A II.1: Key information about the selected unions

| Region | Upazila | Union | Popun* in 2001 | Time distance from Barisal city** (one-way) (hr) | Total cropped area*** (ha) | Area under HYV Aus*** (ha) | Area under HYV T. Aman*** (ha) | Area under HYV Boro*** (ha) | Area under local paddy*** (ha) |
|---|---|---|---|---|---|---|---|---|---|
| High submergence prone areas | Bakerganj | Darial | 29,519 | 2 | 3532.91 | 222.58 | 83.77 | 17.00 | 2306.30 |
| | | Durgapasha | 15,489 | 2 | 1469.01 | 2.83 | 20.64 | 0.00 | 1004.43 |
| | Barisal Sadar | Chandramohan | 13,846 | 0.5 | 1433.40 | 0.81 | 24.69 | 3.64 | 1021.83 |
| | | Chormonai | 33,824 | 0.5 | 2920.62 | 26.30 | 232.29 | 57.47 | 1858.32 |
| | Mehendiganj | Jangalia | 19,987 | 3 | 2411.52 | 8.50 | 68.80 | 316.87 | 1570.58 |
| | | Vashanchar | 15,026 | 3 | 1949.37 | 4.86 | 60.30 | 135.57 | 1114.91 |
| Low submergence prone areas | Babuganj | Chandpasha | 27,795 | 1.5 | 2221.32 | 12.14 | 551.99 | 16.59 | 669.35 |
| | | Kedarpur | 20,734 | 1.5 | 2371.46 | 28.73 | 369.88 | 119.38 | 884.24 |
| | Wazirpur | Ghutia | 27,145 | 2 | 2054.18 | 25.09 | 58.27 | 104.00 | 1175.61 |
| | | Harta | 22,511 | 2.5 | 1735.29 | 10.12 | 42.90 | 1428.95 | 146.50 |

Source: *BBS. **Based on field visit in January, 2011. ***BBS, 2000.

### Table A II.2: Regression results (Dependent variable: LNyield_2010; n=74)

| | Model 1 | Model 2 | Model 3 | Model 4 |
|---|---|---|---|---|
| R2 | 0.103 | 0.147 | 0.086 | 0.102 |
| Constant | 1.398 (0.711)* | 1.492 (0.701)** | 1.865 (0.771)** | 1.767 (0.774)** |
| Crop type | -0.048 (0.154) | -0.428 (0.252)* | -0.037 (0.158) | 0.076 (0.188) |
| Depth | -0.308 (0.161)* | -0.597 (0.221)*** | | |
| Duration | | | -0.281 (0.186) | 0.005 (0.316) |
| Crop typeX Depth | | 0.579 (0.308)* | | |
| Crop typeX Duration | | | | -0.394 (0.352) |
| Elevation | 0.293 (0.169)* | 0.234 (0.168) | 0.108 (0.180) | 0.150 (0.183) |
| LN_ Input Cost | 0.184 (0.182) | 0.215 (0.180) | 0.069 (0.189) | 0.072 (0.188) |

Standard errors in parentheses; ***, ** and * indicate significance at 1%, 5% and 10% level respectively.

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