Title: **Can Failure Effects of 'Autonomous Adaptation' to Extreme Flood Events in South Asia Cope With Future Climate Change? - A Case of Bangladesh**

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Abstract: 'Adaptation to climate change' and 'development' are reciprocal; adaptation and development issues are currently being emphasized; and adaptation efforts particularly in developing countries should be accelerated. IPCC's forthcoming chapter 17: *Assessment of Adaptation Practices, Options, Constraints and Capacity*, finalizes the adaptation issue. The concept of autonomous adaptation, a step in the Vulnerability & Adaptation guidelines given by IPCC, UNEP and USCSP (United Sates Country Study Program) in response to extreme flood events in Ganges-Brahmaputra-Meghna (GBM) River basins in South Asia, is a crucial issue. Bangladesh, as a reference of GBM River basins, faces extreme flood events which might have strong links with climate change. Current literature on climate change associated with flood management in South Asia support this argument.

This study has used multi method techniques: current literature review, a random questionnaire survey of over 140 households in seven Unions, two Participatory Rapid Appraisals (PRA) including focus group discussion and professional judgment.

The study investigates the issue through two objectives: firstly it examines farmers' crop adaptation processes in response to different types of extreme flood events (multi peak with longer duration flood, single peak with shorter duration flood and single peak at the period of harvesting) in the case study area over time, and describes how farmers have been adapting with the extreme floods; secondly it assesses the economic consequences of failure effects of autonomous adaptation in response to extreme flood events. The study found that Bangladeshi farmers are highly resilient to the extreme flood events, and the economic consequences (costs of seedlings: either local or HYV, watering, land preparation, laboring etc) of failure effects of autonomous crop adaptation on marginal farmers are huge. The study concludes that urgent action is needed to improve the sustainable crop adaptation capacity in the foreseeable future under climate change conditions.

Key Words: Autonomous Crop Adaptation (ACA), Extreme Flood Events (EFEs), Failure Effects of ACA, IPCC Fourth Assessment, *Bigha*, *Aman*, *kharif*,

Introduction

'Autonomous Adaptation' in relation to extreme flood events over mega-deltas (e.g. GBM River basins) (Figure 1) in South Asia, particularly in Bangladesh, is a process which is commonly practised by marginal farmers. Therefore the practices of 'autonomous crop adaptation' (ACA) and its success are very crucial to economic development in this region. The failure effects of ACA due to extreme flood events (EFEs) are huge not only in relation to the past EFEs as the paper suggests, but would also be accelerated with future EFEs under climate change conditions. As the Fourth Assessment of Working Group 2 of the United

Nations Intergovernmental Panel on Climate Change (UN IPCC) argued in the Asia section: "Coastal areas, especially heavily-populated mega-delta regions in South, East and Southeast Asia, will be at greatest risk due to increased flooding from the sea, in some mega-deltas, flooding from the rivers'' (Adger et al., April, 2007:8). UN IPCC in its Third Assessment Report concludes that extreme events would be increased in temperate Asia, including floods. Bangladesh would be at risk of increasing flood disasters in the wet season. The intensity of extreme events may be higher in a warmer climate (IPCC, 2001; Huq et al., 2003: 14). These predictions do ensure that the failure effects of ACAs would have enormous impact on South Asia including Bangladesh's economic development. Therefore it is essential to strengthen the capacity of ACA processes in order to ensure the sustainable development in future in South Asia.

Autonomous Crop Adaptations in Response to Flooding

The crop adaptation process in Bangladesh is autonomous – farmers adapt with the floods automatically. There are no mechanical adaptations in the farming system. The adaptive capacity is low and climate-sensitive. Farmers build their ACA capacity in response to flooding. Timing, depth, duration, multiple peak and single peak of floods are the determinants which virtually regulate the ACA process. The nature of the flood controls the autonomous crop adaptation process. ACA depends on the vulnerable farmers' decision making process; it comes about in accordance with the nature of the floods. If the flood comes in the late period of the cropping season then farmers decide to plant the local variety *aman* crop (paddy) instead of planting HYV *aman* because the local variety of *aman* takes a shorter period for maturation, which means farmers harvest the local variety crops within a reasonable shorter time period. Normally farmers plant the HYV *aman* which usually grows within tolerable flood waters, and it usually takes a longer time period for maturation. Farmers finally make the decision, considering the nature of flooding, as to whether they go for HYV variety *aman* crop or the local variety *aman* for the *kharif* 2 (one of major cropping season in monsoon in Bangladesh) cropping season. The ACAs are also divided by in-built, routine and tactical adjustments.

The failure effect of autonomous crop adaptation comprises total crop damage in *Taka* (*Tk*) plus total cost of crop production multiplied by the number of flood strikes on agricultural land. Total crop production cost is defined by cost of seedling, land preparation, agriculture input (fertilizer cost, pesticides costs) and watering. Therefore the failure effect of autonomous crop adaptation is large in an economic sense. If ACA fails then marginal farmers in South Asia's mega-delta region (e.g. GBM River basins) face severe food shortages and the region's food security would be threatened.

Bangladesh has been identified as the 'most disaster-prone' of all countries (Stern Report, 2006: 433). South Asia including Bangladesh is a multi hazardous area enduring simultaneous normal floods, riverine floods, extreme floods, flash floods and coastal floods, drought, cyclones and storms are common phenomena. It is notable that Bangladesh has suffered 170 large-scale disasters between 1970 and 1998. In particular, the extreme flood events in 1988, 1995 and 1998 were severe; the 1988 and 1998 floods devastated and submerged 57-60 percent of the country (Rashid and Pramanik, 1993: 189). The flood in 1998 was one of the most destructive flood events farmers in Bangladesh could recall for 50 or more years (Younus, 2005a, 2005b, 2007; Ahmed and Mirza, 1998). Different simultaneous hazardous events affected the same communities and areas in same year, and as a consequence, the severity of hazards was acute especially in rural households. The results were low income, lack of income generating sources, high dependence of family members in each household, loss of life and property, reduced growth and damage to living standards. The primary economic activity is farming, which is the main income source of the head of households where average monthly income is only 3000 to 5000 *Taka* (AUD 58-97). Very little of the fragmented lands is owned, there is severe landlessness (most households in the rural area do not have their own lands). Within the vastly agrarian economy, there are few other opportunities to earn wage income, food availability falls short of meeting basic requirements (scarcely 2000 kilocalories per person per day); some areas of the country still face the risk of famine, while others have frequent floods and often are devastated by cyclones and storm surges (Lal et al., 2001); more than 60% of rural households are functionally landless and there are limited opportunities for income diversification (Miamura and Harasawa, 2000); 37 % of the population were undernourished in 1997, which means 44 millions of people were undernourished (Lal et al., 2001: PP 560), primary occupation loss (cultivation) during the extreme flooding is common and the average loss of each household is 3000-3500 taka in 1998 and 1995, and 20000-25000 taka in 1988 flooding. These are typical statistics for rural households in Bangladesh, and the above characteristics are largely similar in other mega-delta regions in South Asia (Prasad et al., 2004; Ahmad, et al., 2004; Poudel and Sharma, 2004; Aggarwal et al., 2004). Within the above criteria the rural household's failure effect of ACAs in Bangladesh is very important and its distribution patterns indicate that it is a question of survival for farmers of this region, as they have already been experiencing these kinds of frequent shocks with the past extreme flood events.

The Stern Report (2006: 7) warned that '*Developing countries – and especially the low-income countries in tropical and sub-tropical regions – are expected to suffer most, and soonest, from climate change. They are especially vulnerable to the effects of climate change, because of their existing exposure to an already fragile environment and their economic and social sensitivity to climate change. And their poverty reduces their capacity to adapt'*. It is indeed tropical and subtropical regions especially in South Asia, including the mega-delta of the GBM River basins, which are expected to be the most vulnerable due to climate change; and particularly due to extreme flood events. This region is already experiencing multiple hazards including extreme flood events. Its environment is fragile and also its economic and social activities are climate sensitive. For example, the farming system in Bangladesh is highly dependent on rain fed waters and flood waters; the *aman* crop needs a specific depth of flood water in order to grow reasonably. Farmers in India's Orissa state, where 10.34 % area is flood prone, usually cultivate Champeswar (local variety of paddy), which is very tolerant to water stagnation, to reduce agricultural output loss (Stern, 2006: 431; Prashad et al., 2004). Farmers in Assam, where 50.14 % area is flood prone, and West Bengal of India, where 37.42% area is flood prone, cultivate a quicker maturing variety of *Aus* paddy which can be harvested before the flood season (Prashad et al., 2004:123, 196).

Cultivation is usually the farmers' only occupation. Crop laborers are also dependent on the nature of flooding particularly in timing of flooding. Within the flood period they do not have any other income generating sources and most of the time they are unemployed. Farming laborers are usually very busy cultivating in the pre flood and post flood periods and can earn a reasonable amount of money which helps them survive for the rest of the lean season. During the flood period farmers including the daily land-less laborers usually look for alternative economic activities such as pulling rickshaws, boating and fishing. These are the common economic activities in Bangladeshi rural areas and these are mostly climate sensitive.

Poverty reduces farmers' ACA ability to cope with flooding. When the multiple peaks and longer duration floods impact on more than one time planted *aman* paddy crops at the *kharif* 2 cropping season then farmers lose their ability to buy the local variety seedling from the outside market. In that case the local agriculture department including other governmental agencies do not assist them any further such as providing bank loans or seedlings. UN IPCC predicted *'poor countries are especially vulnerable, in particular those concentrated in high-risk areas. They tend to have more limited adaptive capacities, and are more dependent on climate-sensitive resources such as local water and food supplies* (Adger et al., 2007:7). Bangladesh falls in the high risk category and farmers have limited adaptive capacity as they have very low income: in general two thirds of the household incomes fall between 3,001 and 9,000 Tk per annum (Younus, 2001). IPCC (2007) also predicted that the most vulnerable societies are generally those in river flood plains, those whose economies are closely linked with climate-sensitive resources, and those in areas prone to extreme weather events. In Bangladesh most of the lands fall in flood prone regions. It is argued, as PRA concludes, that farmers in Bangladesh are experiencing extreme floods more frequently during the 1988 to 2005 time period than in the previous decades. The intensity and severity is much stronger than the previous decades' extreme flood events. The numbers of flood peaks are more frequent and the depth and duration of each extreme flood event are greater (Younus, 2001, 2005). As a consequence the economic and social costs have increased severely. IPCC (2007) also predicted the same facts: extreme weather events would become more intense and / or more frequent and as a consequence economic and social costs of those events will increase. This is indeed what this paper argued. The question is to what extent the failure effects of ACAs in response to extreme floods in the period of 1988 to 1998 have impacted on marginal farmers' households? What would be the household distribution pattern of the failure effects of ACAs in response to EFEs during the period 1988 to 1998? Are these effects alarming for survival? If these kinds of extreme flood events do occur more frequently in future under probable climate change conditions then what would be the impact on the marginal farmers' economy? Are they causing severe impacts on the future development planning process? Would managing these impacts be beyond the capacity of farmers? Do these effects call for immediate emphasis in the plans?

Objectives and Aims

In order to address these research questions, the paper investigates two objectives; firstly it will focus on farmers' crop adaptation processes in response to different types of extreme flood events (multi peak with longer duration flood, single peak with shorter duration flood and single peak at the period of harvesting) in the case study area over time, and it will describe how farmers have been adapting to the extreme floods. Secondly it will assess the economic consequences of failure effects of autonomous adaptation in response to EFEs.

Methods

The methodology of this research is multi method which contains a number of research techniques: a structured questionnaire survey in 1998 and 2006, Participatory Rapid Appraisals (PRAs) in 2006, focus group discussions in 1998, in-depth case study in 1998 and professional judgment based on the field visits during 1998 and 2006. The questionnaire survey was applied to over 140 households in 2006 which are randomly distributed in seven Unions: Islampur, Chinaduli, Kulkandi, Belgacha, Sapdhari, Noapara and Patharsi in Islampur Thana (Figure 2) (located in North Central Bangladesh); 20 households were selected for participation from each union. In 1998 seventy questionnaires were surveyed over the above Unions in order to understand farmers' socio-economic, demographic and physical factors. PRA technique, used in 2006, is a technique which helps us assess the vulnerable farmers' perception and experiences regarding the flood severity and flood crop adjustments as well as the economic consequences of the failure effects of autonomous adjustments on agriculture base level data. It emphasizes local knowledge, and enables local people to make their own appraisal, analysis, and plans. The PRA technique uses group animation and facilitates information sharing with the stakeholders. Different stratified people: farmers, teachers, elected local public representatives, politicians, and students – were involved as participants in this interviewing session.

Socio-economic, Demographic and Physical Characteristics of Case Study Area

The average income of the head of the household in the case study area is less than one dollar per day. Two thirds of the household incomes fell between 3,001 and 9,000 Tk (AUD 58-175) per annum. Respondents who are in the Unions of Chinaduli and Kulkandi have the smallest annual incomes. The respondents of Belgacha and Sapdhari Unions have somewhat higher annual incomes than those in other Unions. Only half of the households have an income from secondary sources and only two have three sources of income. Most of those with a secondary source obtain small amounts ranging from 1-3,000 Tk. The Unions of Islampur and Pathorsi have a higher number of respondents who have income from secondary sources as the inhabitants of these Unions have access to work in the Thana HQ (Islampur). The Unions where there is the lowest incidence of secondary income are Belgacha, Noapara, Sapdhari and Kulkandi. These unions are located by the Jamuna river. Most of the study *char* lands are in these Unions.

There is considerable variability in household incomes within the low end of the range, i.e., 1,000-12,000 Tk per annum. Few farmers indicated that their annual income exceeded 15,000 Tk. When these incomes are put alongside the quite high family sizes, it is apparent that most households have limited ability to fund replanting of flood damaged crops. If crops are destroyed by floods, then income has to be used to purchase food, especially if there is little grain in store for the next planting. Low incomes thus contribute to the sense of vulnerability for riverine farmers in the face of very severe floods such as the one that occurred in 1988.

In terms of family size, I categorized the number of family members as follows: *small size:* up to 3 members; *medium size:* 4-5 members; *large family:* 6-8 members; and *very large family:* 9-15 members. Of the 70 respondents interviewed in 1998, 38 percent had large families, 34 percent medium sized families, 9 percent very large families and only 9 percent were in the small family category of 2-3 members. Most of the respondents' family sizes therefore fell between the medium and very large. Farmers with such families are, therefore, vulnerable to shortages of food to feed their families if flooding severely affects their crops. Within the 70 surveyed households, 47 percent have between 5 and 11 dependent members. The Union of Chinaduli has the highest number of dependent family members per household and this is the Union that is most vulnerable to flooding. Almost all of the heads of household are economically active. Just over half the households have only one economically active family member; 21 percent have two members who are economically active. The Unions of Belgacha, Chinaduli and Noapara tend to have households with larger numbers of economically active family members, i.e., 4-5 who are economically active. The sources of income for households in these Unions are more diverse than in other parts of Islampur. The largest numbers of households with only one economically active member were found in Islampur and Kulkandi Unions.

The major economic activity in 68 of the 70 households is farming. There is a number of secondary economic activities which respondents are engaged in: 7 were labourers, 8 were drivers, and 3 were teachers. Only two respondents had a third economic activity. One was a commissioner and the other a labourer.

Small farmers who have up to 299 *shotok* (one *shotok* means .0104 acres; one *bigha* (local unit) = .33 of an acre). 63 percent of informants fell into the category of small farmers. Medium farmers who have lands totaling 300 to 699 *shotok.* 17 percent of informants fell into this category. Large farmers who have lands above 700 *shotok.* 14 percent of informants fell into this category.

The distribution pattern of current total household farming lands over 140 households in 2006 is shown in figure 3 and 4. Most of the household total lands are distributed in between 0 to 5 *bighas* (1.65 acre). Households in Shapdhari, Kulkandi and Noapara own the lowest amount of lands; mostly fall below 5 *bighas*. Only 8 out of 140 households fall between 15 to 30 Bighas.

Superficially the agricultural lands of Islampur look like a flat surface. However, the lands can be divided into four categories: very low land (VLL), low land (LL), medium low land (MLL) and medium high land (MHL). This is the FAO's (1988) classification which gives the following characteristics of the different lands: VLL-flooded up to 300 cms in the monsoon, LL-flooded up to 180 cms, MLL-flooded up to 90-180 cms, MHL-flooded up to 90 cms. The 70 households interviewed have a total of 24,830 *shotok* of land. The largest percentage of this land (33 percent or 8,289 *shotok)* is in the category of medium high land. The other three categories are distributed as follows: medium low land 31 percent (7,907 *shotok),* low land 23 percent (5,383 *shotok),* and very low land 13 percent (3,251 *shotok).*

Autonomous Crop Adaptations and Extreme Flood Events in Bangladesh

1998 CASE

The flood in 1998 appeared approximately at the period of harvesting in *kharif* 1 and it remained with different flood peaks up to the middle of the period of crop maturation in the *kharif* 2 season. This is a flood period lasting from approximately June 11 to September 30. In reality farmers had only 45 days (end of September to mid-November) of the *kharif* 2 cropping season in hand by the time the flood waters receded. This was very much a competitive situation with regard to getting crop production from the replanted seedlings. This is because farmers had lost the optimal length of the cropping season required for seedling maturation. The crop season was effectively wiped out by floods. Within this period farmers experienced three flood peaks with high depths of flood waters. This was a multi-peak flood. When adjusting to the receding flood waters between each peak farmers attempted to plant seedlings at least three times, but every time those seedlings were wiped out by a new peak. Within this period farmers had lost so much of the cropping season, even on the medium low and medium high lands, that their autonomous adjustment strategies were not able to guarantee successful production of either HYV or local varieties of rice. The resilience of autonomous adjustment strategies had been exceeded by this flood. Even though farmers knew that there was not enough time left in *kharif* 2 to guarantee production, many still planted seedlings for a fourth time in the hope of getting some return during the period of transition between *kharif* 2 and *rabi* 2.

Mr Hossian, a farmer of about 45 years of age living in the village of Panchabahala, stated: "This was an unexpected flood and I had not seen this kind of devastating flood *(gojobi ban)* ever before in my entire life. The flood came three times and washed out the planted crops three times twice high yielding varieties and once the local one. You look at the last crop *gainja*, a local crop variety. Nothing will be returned from it." These statements suggest the following points relating to the 1998 flood: the flood caused damage three times during the period of flooding; farmers planted the HYV *aman* twice, the first time at the beginning of June, which is in the pre-flood period; the second time HYV *aman* was planted was at the beginning of August when the flood waters came down sufficiently so that farmers were able to replant; the third planting was of local varieties of *aman* during the last week of August; a fourth attempt was made in some areas at planting local varieties of *aman* in mid- September. The local variety of transplanted *aman* was again replanted when the flood water had receded. At this time it was already late in the season, even for local varieties of *aman*, but farmers took the chance in the hope of getting some rice. During my field visit in November 1998 informants noted that the replanted *gainja*, which was one and a half months old, would not be able to grow properly as the growing season had been severely shortened by flooding.

1988 CASE

Farmers had experienced a devastating flood in 1988 which was characterized by the high volume of water but the lands were flooded for a very short period. In this regard farmers said that agricultural lands were flooded within 6-12 hours and homesteads were flooded within one night and day. Farmers also mentioned that the flood came suddenly and receded quickly. This suggests that the 1988 flood was a high volume single peak flood. In summary, there were a number of indicators that had influenced the nature of adjustments to the flood. These are: the flood appeared during the period when the plants had begun maturing; flood duration exceeded the normal level of crop tolerance of floods; flood depth also exceeded the normal level of crop tolerance of floods; heavy local downpours had an influence on the large quantity of river run-off and, as a consequence, the flood was a high volume one causing significant damage; it was a single peak high volume flood.

In 1988 farmers had at least 60 days of the growing season in hand after the flood waters receded. The majority of respondents said that they planted the local variety of *aman*. Some planted HYV *aman*, particularly on medium high lands where the flood waters receded relatively quickly. In that case, farmers got more days for maturing. This made them more confident when planting *aman* seedlings, whether these were HYV or local varieties. As noted, the 1988 flood had a single peak; flooding did not return to wipe out the replanted seedlings.

Taking into account the above characteristics of the 1988 flood event, farmers adopted autonomous adjustment strategies that were different from those they would have adopted during a normal flood early in *kharif* 2. In 1988 the farmers had already lost a substantial number of weeks of the growing season by the time the flood occurred. As a consequence, they did not execute their normal adjustment practices. Instead of replanting seedlings of HYV *aman* most of them planted local varieties. Farmers who had medium high land had more opportunity to plant HYV *aman* because the flood waters receded from these lands relatively faster than from the very low lands or low lands. In 1988 farmers were close to a critical threshold for rice maturation during *kharif* 2 when the resilience of autonomous adjustment was being tested.

1995 CASE

According to the farmers, the flood event of 1995 appeared during phase l or the seedling phase in *kharif* 2 . It is estimated that the length of flood period in 1995 was approximately from June 29 to July 20. In some places it extended up to August 3. Farmers had already planted *aman* seedlings (either HYV or local). The beginning of the flood overlapped with the end of harvesting of crops in *kharif* 1 and the establishing of seedling beds in *kharif* 2.

On the basis of the farmers' responses the following points can be noted about the 1995 flood: the flood waters appeared when the seedlings were getting established; there were lower flood depths than in 1988 and 1998; flood depths exceeded the danger level for crops for a smaller number of days according to information from the farmers; by comparison with the flood events in 1988 and 1998, the 1995 event was a relatively moderate flood.

Because the flood lasted until mid July-early August farmers did lose a substantial number of weeks from the cropping season of *kharif* 2. However, farmers theoretically still had 90 days (from the end of August to the middle of November) for crop cultivation in *kharif* 2 and this is still viable for *aman*'*s* normal growth. Farmers were thus able to replant their *aman* seedlings a second time with a reasonable expectation of a successful harvest. Most of the informants opted for the HYV variety of seedling instead of the local variety in 1995. They took a calculated risk about getting production from their crop but their response in the case of the 1995 flood was very much routine autonomous adjustment.

Autonomous adjustments and their effects on cropping

The major objective of this research has been to explore the resilience of adjustments under devastating flood conditions. In 1995 the flood damaged the HYV *aman* on most categories of land in Islampur but the farmers were able to cope with this event using a mix of routine and tactical adjustments. They tended to plant the HYV *aman* on the higher land (a routine adjustment) and the local varieties on lower land (a tactical adjustment). In 1998 the greater depth of flood water caused much more extensive damage to crops and tested the resilience of autonomous adjustment strategies more severely than was the case in 1995. Again, a mix of routine and tactical adjustments ensured that farmers managed to get production of some HYV *aman* as well as local varieties of *aman* off their lands.

The 1998 flood, on the other hand, with its multiple peaks and long duration, meant that farmers were unsuccessful in their several attempts to get a crop of rice from either HYV or local varieties of seeds and seedlings. Their routine and tactical adjustments all failed in this case. Notwithstanding this failure, farmers persisted in their attempts to get some return from crops even though the conditions favouring plant maturation were clearly sub-optimal. In-built mechanisms for adjustment to flooding are thus deeply ingrained in the Bangladeshi farming system, reflecting a long history of people having to rely on their own resources in the event of natural disaster. These adjustments are attempted even if the financial costs of a further replanting of seedlings clearly outweigh the probable returns, in economic terms anyway, from the resultant production. In a situation where survival rather than economic returns is uppermost in the farmers' minds, it is hardly surprising they persist with their autonomous adjustment strategies.

The 1998 flood had a particularly devastating impact on crop production. Plantings of both transplant and broadcast *aman* (HYV and local) were destroyed at least twice as were crops of jute, sugarcane, *kaun* (one kind of fine grain) mixed *aus* (a variety of paddy) and *aman.* In addition, farmers also lost most of the *boro* (late variety) (a variety of paddy) crop on the very low lands and low lands. Not only this but crops in the transition period (the period in-between *kharif* 2 and *rabi* (cropping season)) (oil seeds and chilli) failed in general to mature in most of the studied *mauzas.* There were two reasons for this. Firstly, there was continuous rainfall throughout much of the transition period. Secondly, the normal length of the transition period was shorter because of intrusion of *kharif* 2 crops into the transition. In summary, this flood had affected cropping patterns either directly or indirectly over all phases of *kharif* 2 as well as into the transition period.

The Failure Effects of Autonomous Crop Adaptation (ACAs)

This paper assesses the failure effects of autonomous crop adaptation in response to extreme flood events. The failure effects of ACAs are defined as total crop loss (might have been produced) plus total agriculture cost multiplied by number of flood strikes on the studied area. Total agriculture cost includes cost of seedlings, fertilizer, pesticides, land preparation, total labouring, and watering.

$$FEACAs = TECL + N\,(SC+ FC+PC+ LPC+LC+WC)$$

FEACAs- Failure Effects of Autonomous Crop Adaptations (ACAs)

TECL- Total Expected Crop Loss

N-Number of Floods Strike

SC-Seedling Cost

FC-Fertilizer Cost

PC- Pesticides Cost

LPC- Land Preparation Cost

LC- Labouring Cost

WC- Watering Cost

The failure effects of ACAs in each extreme flood year are huge in relation to the households’ low annual income, higher number of dependant family members, small amount of farming lands, less opportunities of earning sources, and higher total occupational loss in each extreme flood year. The failure effects of ACAs are distributed over 140 households in seven Unions. First able farmers have been asked for the crop losses of each flood event at the *kharif* 2 cropping season. Generally in 1988 the crop losses per *bigha* are higher than the losses in 1998 and 1995 extreme flood events. For example, 760 kg per *bigha* losses in 1988, which is equivalent to 5000 *Tk*; the same farmer responded in 1998 that 684 kg per *bigha* crop losses which is equivalent to 5400 *Tk* and in 1995 the crop loss was 685 kg which is equivalent to 5400 *Tk*. The actual price of rice in 1998 is higher than in 1988 and 1995 – this illustrates the variation in the price of rice over time. The main point is that the crop losses in 1988 are higher than the losses of 1998 and 1995 because farmers in 1988 held relatively higher amount of lands than they owned in 1998 and 1995. The time of appearing of the flood is the other significant reason for the crop loss recorded.

Farmers lose crops several times with the extreme flood events. Particularly in 1998, single flood strikes were uncommon, and in the majority of cases the number was three times; total cost of seedlings, fertilizer, pesticides, land preparations (together called 'agriculture cost') was therefore multiplied by three. As a consequence the distribution pattern of all these costs in 1998 appears higher in relation to the costs of agriculture in 1988 and 1995. One respondent's first time total agriculture cost was 2326 *Tk* per *bigha*; the second time it was 2450 *Tk* and third time 1950 *Tk*; all together it was 6725 *Tk* (AUD 131) per *bihga* (0.33 acre). This is a huge loss in the light of the surveyed farmers' social-economic, demographic and bio-physical settings

The distribution pattern of failure effects of autonomous crop adaptations is shown in figure 5. These effects are enormous. Households' effects have been assessed in the monetary sense in *Tk*. The majority of effects are distributed within 0-50,000 *Tk* (AUD 0-976). The total losses are also largely distributed in the category 50,000-100,000 *Tk* (AUD 976-1953); other relatively lower numbers of households' total losses were *Tk* 100,000-200,000 (AUD 1953-3906); and only a few households' total losses fall between 200.000-450,000 *Tk* (AUD 3906-8789). The pattern of total households' crop losses in 1998 is higher than the losses in 1988 and 1995; the majority of households' crop losses in 1998 fall between 0-150,000 *Tk* and only 5 households out of 140 crop losses in 1998 were between 150,000-300,000 *Tk*. The damaging pattern in 1988 was severe: the majority of households' crop related losses were 0-150,000 *Tk* and only 9 households out of 140 households' crop related losses fell between 150, 000 to 450, 000 *Tk*. The household damaging pattern of crop related losses in 1995 was mostly concentrated in between 0 to 100,000 *Tk*.

These are the household distribution scenarios of failure effects of autonomous crop adaptations in 1998, 88 and 1995. The total crop related loss due to failure effects of autonomous crop adaptations over 140 households in 1998 is *Tk* 6183167, in 1988 is *Tk* 7217559 and in 1995 is *Tk* 464954. These indicate that on an average each household's crop related loss is *Tk* 44,165 in 1998, in 1988 is *Tk* 51, 553 and in 1995 is *Tk* 3321. The total number of households in Islampur is 40,876 (BBS, 1986). Therefore, in 1998 the total crop related loss due to extreme flooding in Islampur is 1805288540 *Tk* (A$35.26 Million); in 1988 is 2107280428 *Tk* (A$ 41.20 Million) and in 1995 is 135749196 *Tk* (A$ 2.7 Million).

This is the case for one Thana Islampur in Bangladesh. As Bangladesh occupies 60-70 per cent lands which are flood prone (total flood plain area is 80 per cent), and 314 *Thanas* were affected by 1998 flood (Ahmad et al., 2005, 2000; Brammer, 1997). The failure effects of ACAs that means, if autonomous crop adjustments fail in response to the extreme flooding then crop related loss due to extreme flooding in 1998 in Bangladesh is A$ $1.107149587 \times 10^{10}$, in 1988 is A$$1.292355575 \times 10^{10}$, and in 1995 is A$ 8325,24214. This is an assumption as there are lots of uncertainties in the flood severity and its impact on the affected 314 *Thanas*, in different flood depths over different land types (very low land, low land, medium low land and medium high land), in hydrological cycles, in local heavy rainfall, in total number of households in each *Thana*, etc.

Consequences of the failure effects of autonomous crop adjustments

The failure effects of ACAs in each household are 44,165 *Tk* in 1998, in 1988 is 51, 553 *Tk* and in 1995 is 3321 *Tk*. Typical households hold a minimum amount of cropping lands, have a high number of dependent family members and a low level of annual income. They experience a higher number of frequent extreme flood events with multiple peaks and longer duration floods which come in a short period/time, and their primary economic activity is farming only. The failure effects are very important in the perspective of the above socio-economic, demographic and bio-physical factors. These amounts control the expenses of a high number of household members, as well as the cost of seedlings, agricultural inputs, watering and land preparation for next following cropping season. If each household loses this amount of money from the major cropping season *Kharif* 2, then the head of the household would be unable to pay for food and ancillary costs (clothing, education, medical, etc) that will be incurred up to next cropping season. As a consequence there was often acute food shortage and local food security was threatened. In this event, some heads of households tried to obtain a loan from the local banks or the money lenders, with high interest. Alternatively, some head of households became daily laborers involved with land preparation activities in rich farmers' or large farmers' cropping lands. That is, the head of household tried to survive up to at least the next cropping season by changing occupation. Others migrated to the city in order to survive and they were usually occupied in rickshaw pulling and other odd jobs (for example garment workers), which are very poorly paid.

Farmers lost their *aman* crops entirely in the 1998 flood and many had no additional funds or resources to cultivate the IRRI *boro* for the next cropping season: *rabi* period. If they lost their entire crops due to the devastating floods had little food and lost their ability to plant the seedlings at the following next season. Although somehow farmers do try to recover their losses and continue their cultivation process, the normal floods as well as extreme floods again destroy the autonomous adaptation capacity, leading to a vicious cycle of poverty. Every extreme flood therefore reduces the farmers' coping ability to manage normal flooding for the next year. The autonomous crop adaptation capacity has already been threatened due to frequent extreme flooding over the past couple of decades as the distribution pattern of failure effects of autonomous crop adaptations in 1988, 98 and 1995 over the studied area indicates.

Since the number of dependent members of each household is large and the head of household's annual income is minimum, the household faces severe money shortages up to next cropping season. The head of the household also needs to spend at least the average seedling cost of 500 *Tk* per *bigha*, average fertilizer cost of 667 *Tk*, pesticides cost of 300 *Tk* per *bigha*, land preparation cost for cultivation of 667 *Tk* per *bigha*, watering cost 333 *Tk*, a total of 2467 *Tk* per *bigha* (1988 assessment).

As the head of the household's income only comes from farming, they have no other alternative sources to cover foods and agriculture related costs up to next cropping season. Their other expenses for clothing, medicine, crop land taxing, children's education, cattle feed, house repair and maintenance, transportation costs, electricity / kerosene costs, and livelihood and ancillary costs. Some farmers, who have rented lands, have to pay the money to land owners; other farmers have to pay mortgage money in order to recover their own cropping lands. After experiencing each extreme flood some farmers give their equity in their lands as mortgage in order to get some money for surviving for the rest of the year. This leaves many landless as they are not able to pay the money back.

With each extreme flood crisis the marginal farmers suffer severe food crisis and the region is at risk of food insecurity. As a whole the question can be raised about the overall human security situation of the studied area as household members do not have ability to generate alternative economic resources in order to survive, they do not have any access to available foods, no fixed assets which ensure survival up to next cropping season, they cannot meet family expenses (education, health care, clothing, cattle fodder, utility expenses, domestic energy) and they do not have any access to adequate institutional arrangements (government or NGO support). If these factors persist for a longer period and if the extreme floods frequently occur then food security vis a vis human security would be rapidly threatened. The question can be asked whether global climate change is a security issue? The study suggests the argument that increasing extreme flood events, which might have a strong link with global climate change, accelerate food insecurity and ultimately human insecurity.

Bangladesh, one of the least developed countries, is one of the most vulnerable to the effects of climate change and has the least capacity to adapt to these changes; it lacks the socio-economic, demographic, bio-physical and institutional capacity to cope with climate change impacts; overall poverty reduces the capacity to adapt to climatic shocks such as extreme floods. Bangladesh tends to have more limited adaptive capacity and also will suffer from a possible increase in extreme floods (Huq, et al., 2003: 6; Stern, 2006: 430; Adger et al., 2007: 7). Floods are a recurrent phenomenon in Bangladesh and it is apprehended that they will become more intense and more frequent on account of global warming and the consequent climate change. This paper has argued that a critical aspect of Bangladesh agriculture, the capacity for autonomous adjustments by vulnerable farmers, will cease with increased frequency of extreme flood events associated with climate change, leading to food insecurity and human insecurity risk.

The GBM River basins are spread over five countries – China (Ganges: occupied 4 %, B'putra: 50%), India (Ganges: 79%, B'putra: 34%, Meghna: 54%), Nepal (Ganges: 13%), Bangladesh (Ganges: 4%, B'putra: 8%, Meghna: 46%) and Bhutan in South Asia (Ahmad and Rahseed, 1998). The socio-economic, demographic and bio-physical settings of South Asia particularly over GBM River basins (mega-delta) have many similarities with the studied area. The autonomous crop adaptation processes among the various agro-ecological zones have many dissimilarities also but the farming processes are mostly autonomous and reliant on the traditional knowledge and adaptive capacity of the farmer: mechanical cultivation processes are not strong in much of the region. The farming systems are also entirely climate sensitive. The case study leads us to a view, as through a window, of these GBM River basins. As IPCC has predicted that the mega -deltas such as GBM River basins will experience extreme flood events in future, this window shows that the adaptation capacity and food security vis a vis human security is at risk. The study suggests that the failure effects of autonomous crop adaptations of each household in the case study area are huge in the economic sense and have already affected the capacity of autonomous crop adaptation processes. These effects would be accelerated with extreme flood events in the foreseeable near future. Therefore the issue of autonomous crop adaptations should be incorporated into future development planning in this region.

Conclusion

Conclusion

The paper has drawn a detailed bottom-up case study of autonomous crop adaptations in response to extreme flood events in Bangladesh which reveals some important facts about the failure effects of autonomous crop adaptations (FEACAs). The case study deals with the facts as a reference case of the mega-delta of GBM River basins of South Asia. The paper suggests: a) the intensity and frequency of extreme flood events have increased in this region over time; b) farmers are very resilient in their responses to the extreme flood events but multi-peak and longer duration floods terminate their capacity for autonomous crop adaptations; c) the failure effects of ACAs are huge in the perspective of the socio-economic, demographic and bio-physical settings of the studied farmers; d) the longer the persistence of FEACAs the worse the autonomous crop adaptation capacity, meaning that farmers lose the ability to cope with extreme flood events (the autonomous crop adaptation capacity is become weaker due to the longer persistence of FEACAs); e) extreme flood events, which might have a strong link with global climate change, accelerate food insecurity and ultimately human insecurity.

Adjustments to the 1998 flood were compared with those farmers recalled for the previous two severe floods in 1995 and 1988. An important finding was that the success of autonomous adjustment strategies is very much influenced by the nature of the flood event in terms of timing of the onset of flooding, the depth of the flood waters, the duration of time flood waters stayed on the crop lands, and the occurrence of peak flows. A general conclusion was that through the autonomous adjustments employed, Bangladeshi farmers when faced with floods are very resilient, and can cope with a wide range of flood events. However, the multi-peak 1998 flood exceeded the capacity for these adjustments to ensure that farmers could achieve some crop production during the main season for growing and harvesting wet rice. If this type of flood event becomes much more common in Bangladesh as a result of climate change then the highly resilient farming system that characterizes much of the riverine environment in the country, and which is well-adjusted to a wide range of flood events, is going to be exposed to severe stress.

The research sought to make a contribution to the development of effective vulnerability and adaptation guidelines for farming in Bangladesh in the wider context of the debate about climate change. The sort of micro-scale research reported in the paper is increasingly seen as being critically important for understanding the capacities of societies to cope with changing patterns of climatic variability. This is especially the case in situations where there is a range of proven methods for coping with environmental adversity that are woven into the social fabric of a long-established farming system, such as the one studied in Islampur.

Recent research on climate change makes it clear that successful adaptation to changed conditions of climatic variability will depend heavily on how farmers manage their cropping regimes in the context of changed local conditions. Understanding processes of adjustment to climatic variability is likely to be more important than undue concentration on the extent to which global and regional models can predict the impacts of increasing gas concentrations on temperature and rainfall at the meso and macro scales. It is now recognised that there needs to be much more research at the community level on how people adjust to variability in climatic conditions. These adjustment processes, rather than more powerful forecasting models, hold the key to successful adaptation to new patterns of variability.

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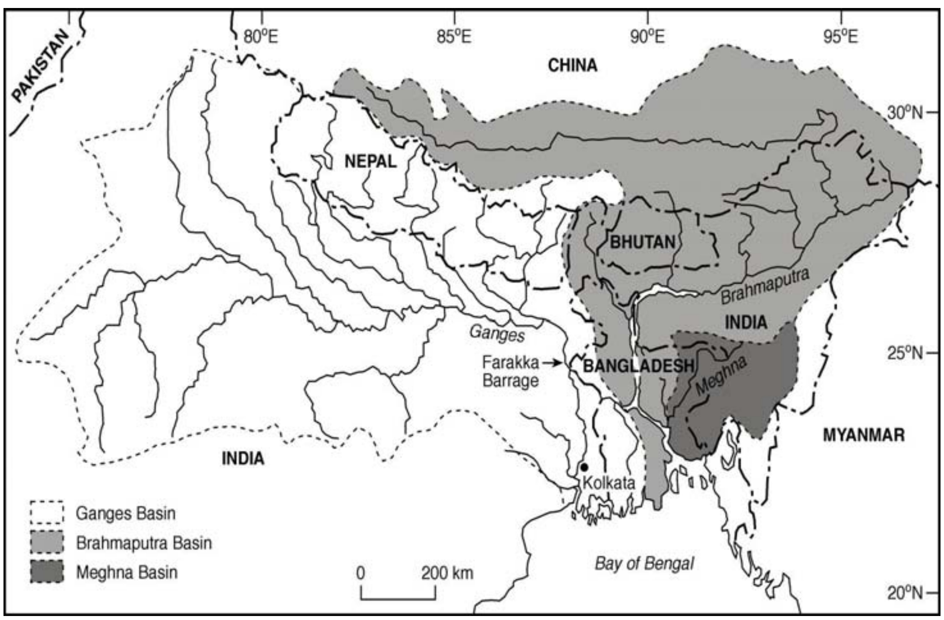

Figure 1: The Location of Ganges, Brahmaputra and Meghna River Basins.

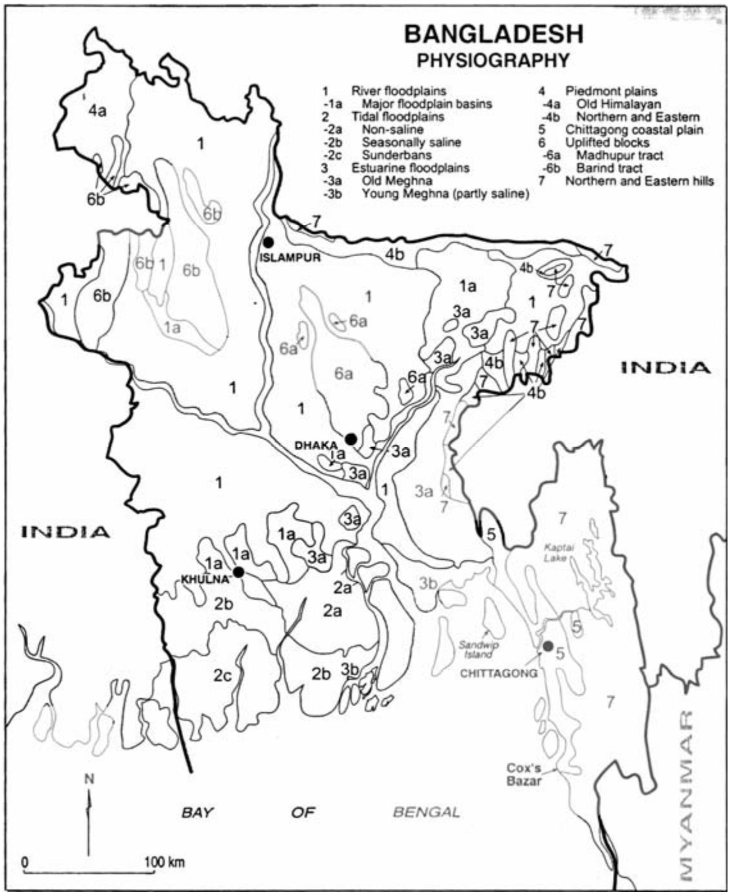

Figure 2: Bangladesh Physiography and the Location of Case Study Area (Islampur)
Source: Brammer et al. (1996)

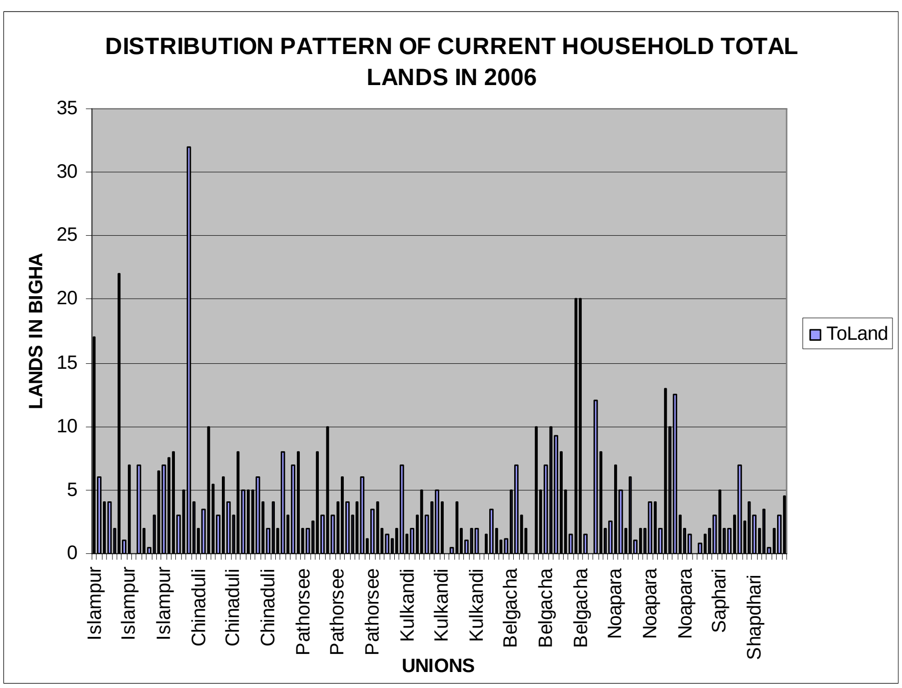

Figure 3

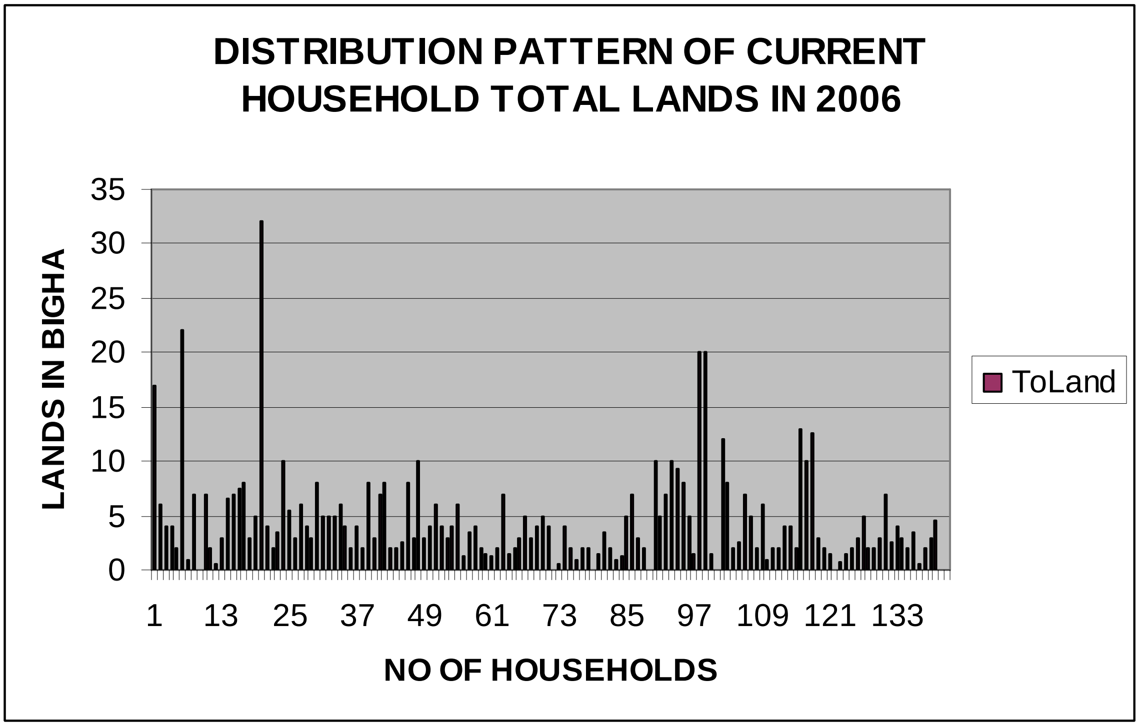

Figure 4

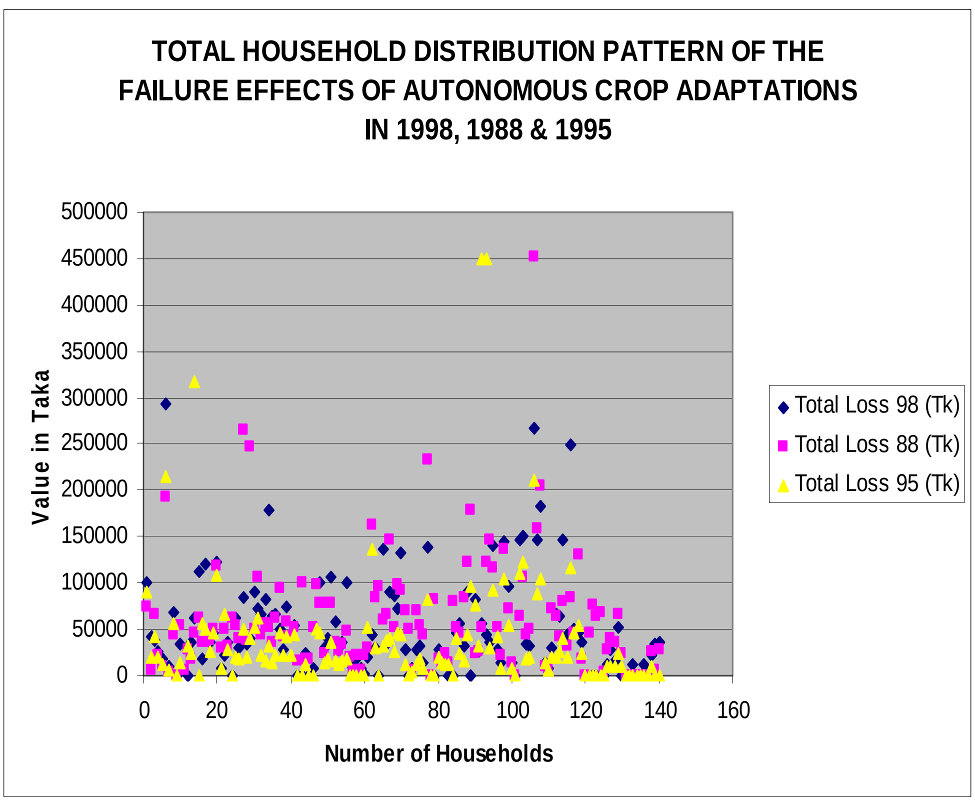

Figure 5