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Flood Research in Bangladesh in Retrospect and Prospect: a Review

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Abstract: The purpose of this paper is to present main findings of flood research conducted so far in Bangladesh. The paper emphasizes unconventional findings and points out how some of these findings differ from the popular perceptions regarding some important aspects of flooding. The available studies clearly suggests that research into the impact of flooding on human settlement and other relevant aspects is much less developed in Bangladesh than the body of literature focusing on human adjustment to flood hazard. The paper identifies flood research gaps in the context of Bangladesh and suggests a new arena for future research. © 1997 Elsevier Science Ltd

Key words: flooding, Bangladesh, natural hazard, human adjustment, flood loss, Flood Action Plan (FAP)

Introduction

Flooding is an annual event in Bangladesh. At least one-third of the country is vulnerable to flooding, but the nature and extent varies both spatially and temporally. Bangladesh has experienced 28 major floods during the past 42 years (1954–1996), of which 11 were classified as 'devastating' and five as 'most devastating' (Khondker, 1992, p. 2; Alam, 1994, p. 2; Smith, 1996, p. 12). Despite its recurrent nature, the research on flooding in Bangladesh has been very limited. However, since the most devastating floods of 1987 and 1988, significant interest has been stimulated in the country regarding research on floods (Alam, 1990a, p. 2). The purpose of this paper is to provide an overview of the major findings of flood hazard research conducted so far in Bangladesh. In light of the existing studies, this paper also outlines potential areas of future flood research in Bangladesh.

This study differs from most traditional review papers on one important way: it emphasizes unconventional findings and points out how these findings differ from the popular perceptions regarding some important aspects of flooding, such as flood-induced damage to crops. It is suggested that a large number of projects that are currently being undertaken to mitigate flood are generally based on certain popular myths. These myths not only obstruct but also create many unanticipated problems in the implementation of flood mitigation measures (Alam, 1991). The present review of flood research will help both individuals and government revise their misconceptions regarding some aspects of flooding in Bangladesh. This may, in turn, facilitate measures to better respond to the country's chronic flood problem.

The following section considers the development of flood hazard research in Bangladesh. A historic lineage is provided, key persons are identified, and important contributions noted. Major findings of the existing flood studies are then reviewed. Later in the paper, gaps in flood hazard research in the context of Bangladesh are identified and suggestions for new arenas for future research put forward.

Flood research in Bangladesh: background

Geographic research on human adjustment to natural hazards was first started with the pioneer work on flood hazards by White (1945). Joined by Burton and Kates in the early 1960s, and later by their students, the White–Burton–Kates School of natural hazards emerged from a line of thought (human ecology) opposed to the environmental determinism of Huntington and Semple in the late nineteenth and early twentieth centuries (Emel and Peet, 1989, p. 63). In the course of time, the study methods of the White–Burton–Kates School have grown in sophistication and have led to the development of a 'human ecological' model of hazard (Mitchell, 1989, p. 411), descending from Barrow's notion of geography as human ecology (Barrows, 1923).

Human ecological research on natural hazards was initiated in Bangladesh by Islam (1974), a participant in White–Burton–Kates' comparative research effort. He investigated the perception of, and adjustment to, coastal cyclones in Bangladesh. Using the same approach and theoretical premises, he later examined agricultural adjustments to flooding (Islam, 1980). Other notable studies came out in Bangladesh on flood include the works of Paul (1984, 1995), Rasid and Paul (1987), Alam (1990b), Haque (1993), Haque and Zaman (1993, 1994), Paul and Rasid (1993), Rasid (1993), Zaman (1993), and Rasid and Mallik (1995, 1996).

The theoretical premises of some of the above studies are rooted in the basic conceptual proposition of the White–Burton–Kates School of natural hazard research, while others (e.g. Haque, 1993; Haque and Zaman, 1993) have adopted a social-historical and political economy approach. Zaman (1989, p. 198) and Rahman (1991, p. 171) criticized the works that exclusively used the natural hazard tradition of White–Burton–Kates for not paying enough attention to social and cultural factors of adjustment. In his study of riverbank erosion, Zaman (1989) treated individual responses in broad socio-political and historical context (also see Rahman, 1991, pp. 171–172). He maintains that "behavioral and decision-making models must take into account historical structural features of the society in the analysis of human responses to natural hazards" (Zaman, 1989, p. 198). He also proposed that the social structural perspective may be extended even further to include variables such as the structure of local landholdings and the nature of land tenure systems (Zaman, 1989).

In the early and mid 1980s, most studies (e.g. Paul, 1984; Rasid and Paul, 1987) on flood in Bangladesh were conducted by geographers. These studies provide significant insight into human response toward hazard issues, and report strategies used to mitigate hazard loss. After the floods of 1987 and 1988, researchers from other disciplines such as anthropology, sociology, and economics joined with geographers to study various aspects of flood in Bangladesh. As a result, flood research in Bangladesh has advanced beyond the confines of the 'human ecological' model, even though geographers still dominate flood research in the country (Alam, 1990a, p. 6).

Research topics became more diversified once scholars from other disciplines became involved in flood hazard research. This, in turn, led a shift in emphasis from a response-based analytical perspective, which focuses on the range of adjustments people adopt to compensate for flooding, to other aspects of flood hazards such as the spatial and temporal patterns of damage to crops resulting from flooding (e.g. Paul and Rasid, 1993), various aspects of flood-induced riverbank erosion (e.g. Haque and Zaman, 1989; Zaman, 1989; Haque, 1991), physical and other causes of flooding (e.g. Haque and Zaman, 1993; Rasid, 1993), socio-economic impacts of floods (Thompson and Sultana, 1996), and issues related to structural and non-structural measures of flood control (e.g. Boyce, 1990; Brammer, 1990a, b; Islam, 1990; Adnan, 1991; Rasid and Mallik, 1993, 1995, 1996). Many research areas remain unexplored. Some of these areas are identified and briefly discussed later in this paper.

Major findings

The major findings of the flood studies so far conducted in Bangladesh are presented under four headings: flood perception, flood adjustments, flood loss/coping with uncertainty, and Flood Action Plan (FAP).

Flood perception

In the Western world, 'flood' is uniformly viewed negatively and considered a natural hazard (Kates, 1962; White, 1974). But the people of Bangladesh

perceive flood as both a resource and a hazard (Paul, 1984, p. 9; Rasid and Paul, 1987, p. 68; Alam, 1990b, p. 355; Cobb, 1993). A normal flood (*barsha*) resulting from usual monsoon rainfall is considered a resource by farmers in Bangladesh. It is beneficial in the sense that it makes the land productive by providing necessary moisture and fresh silt to the soil (Brammer, 1990b, p. 64). Two of the three rice varieties (*aus* and *aman*) cannot thrive without flood-water. Moreover, fish caught during flood season constitute the main source of protein for many. Additionally, millions of Bangladeshis depend on fisheries in the floodplains for their livelihood and the life-cycle of some key fish species depends on the ability to migrate between the rivers and the seasonal floodplains.

Abnormal flood (*bonna*), which occurs once every few years and results from excessive rainfall, is regarded by farmers as an undesirable and damaging phenomenon (see Paul, 1984, pp. 10–13; Rasid, 1993, p. 40). It causes widespread damage to standing crops and properties and sometimes costs animal and human lives. Although the people of Bangladesh have evolved numerous adaptive strategies to benefit from normal flooding, an abnormal one surpasses their ability to adjust.

Floods are beneficial only within certain limits of timing, duration, and magnitude (Paul, 1984, p. 9; Rasid and Paul, 1987, p. 168). If flooding occurs either earlier or later than the normal time (June–July), if it stays for a longer period than usual duration (not more than 4 months and not beyond the month of October), or if flood water rises higher than the usual height (not more than 2.4 m above the broadcast *aman* fields), it is perceived as abnormal. Thus, there are four types of abnormal floods: early, late, prolonged, and high magnitude floods (Rasid and Mallik, 1995, p. 5).

Abnormal floods are perceived primarily in terms of the height of the floodwater. They are essentially deep floods that exceed certain threshold values of depth. Field works (e.g. Paul, 1984, p. 10; Rasid and Mallik, 1995, p. 5) conducted in different floodplains of Bangladesh suggest that most farmers described abnormal floods to be those in which the flood water rises higher than 2.4 m above the broadcast *aman* fields and overtops the homestead land. In Bangladesh, *aus* is cultivated on upper middle lands, transplanted *aman* is planted on poorly drained upper middle lands, and broadcast *aman* is grown in lowlands (Rasid and Paul, 1987, p. 168).

Flood adjustments

Flood control measures so far drawn up by the Bangladesh government seem to have a bias toward structural-engineering solutions. But the bulk of the current literature has concentrated on the adjustment strategies farmers use to lessen the severe impact of flood (Haque and Zaman, 1993, p. 100). The literature shows that most responses are non-structural and include adaptive actions taken by communities and farmers either individually or collectively before, during, and after floods (Haque and Zaman, 1994, p. 74). Selling land, livestock, and belongings, borrowing from friends and relatives, or spending of previous savings are some of the non-structural adjustments farmers generally practice to mitigate loss caused by flooding.

The people of Bangladesh have long been familiar with flooding and they have adopted numerous adjustments to cope with abnormal flood utilizing available indigenous technological, and material and societal resources. Most of the adjustments are of a corrective type, which are practiced to minimize the damage caused by flood. Some of the corrective type of adjustments are related to social organizations and relationships; others are associated with material responses at an individual level (Haque and Zaman, 1993, p. 101; Haque and Zaman, 1994, p. 74).

Based on data collected from a rural area of central Bangladesh in 1988, Haque and Zaman (1994, pp. 74–75) reported that more than 71% of the respondents attempted to reduce their loss caused by floods by selling land, livestock, or other belongings. Some moved housing structures, livestock, and family members to safer areas. They further claim that most of the villagers received some assistance following a disastrous flood from a variety of sources: relatives (79%), other community members (33%), local government sources (7%), national government sources (4%), and relief agencies and other institutions (18%). The items of assistance received consisted of moral support, temporary shelter and accommodation, free help with moving family or livestock, and loans of cash or food. Besides, non-government organizations (NGOs) provided much support to the flood victims. More than 50% of the sample received food and clothing, housing materials, seeds, and loans from the NGOs. This assistance minimized the hardships of the victims and helped them to regain their pre-disaster status.

More than 50% of respondents considered it important to remain within or to maintain closer ties with their traditional *samaj* organization in coping with flood loss. The *samaj* is an informal but very common social grouping based on kinship and the social and religious interests of its members. It is the primary forum within which members interact on a regular basis and are involved in networks of social and ceremonial links and interdependence (Haque and Zaman, 1989). *Samaj* participants are obliged to help with difficult situations confronting other members. Another study (Hossain *et al.*, 1987, p. 24) found that during the flood period people try to remain in or near their homes as long as possible. Flood victims also face disasters by taking help from the relatively more affluent *gushti* (lineage) members (see Alam, 1991).

Haque and Zaman (1994, p. 75) further reported that households who had members in the institutionalized groups performed better compared to their counterpart non-members, both in terms of flood preparedness and ability to cope with flood losses. The institutionalized groups were defined as the registered target groups of governmental and NGOs such as credit unions and agricultural cooperatives. This observation supports the hypothesis that the development of social and institutional networks can effectively lessen hazard impact.

Paul (1984) studied agricultural adjustments to flood hazards in four adjacent villages of the Jamuna floodplain (also see Rasid and Paul, 1987, pp. 168–169). Rasid and Mallik (1995, p. 7) examined adjustments of rice cropping to the flood regimes of 1987. They observed that farmers have made a careful selection of the most adaptive varieties of rice (*aus*, *aman*, and *boro*) over the centuries, to enable them to face abnormal floods. For example, *aus* rice is generally cultivated in elevated areas since the rice variety cannot tolerate standing flood water. Because broadcast *aman* rice can grow with flood, it is cultivated in low-lying areas. The most widely practiced adjustment is the intercropping of broadcast *aman* and *aus*. Practicing such interculture protects farmers against flood, in the way that they are able to harvest at least one rice crop. If it is a year of drought and the floodwaters are below normal, the *aus* will survive and the *aman* will wither. If floods are greater than usual, the *aus* will be destroyed but the *aman* will survive. If it is a normal year, both crops can be harvested. Broadcast *aman* variety can grow by more than 15 cm in 24 hr to keep pace with rising flood levels and can attain heights of 4–5 m to keep their heads above water level.

At the time of abnormal flooding, farmers protect their rice crops by constructing floating bamboo fences that keep away water hyacinth and other aquatic weeds transported by flood water (see Paul, 1984, p. 15; Rasid and Mallik, 1995, p. 7). Farmers make considerable efforts to salvage damaged rice plants. Salvage activities include trimming silt-laden leaves from rice plants and recovery of live tillers for subsequent retransplanting. Farmers also make some small scale structural adjustments prior to floods. One of the most common is raising the bhiti (plinth) of houses by digging earth from local depressions (Rasid and Paul, 1987, p. 166). Annual maintenance of the bhiti is necessary to keep it above the normal flood level (Islam, 1980, p. 54). Farmers usually construct homesteads on relatively elevated natural levees. The rural nonmetalled roads, courtyards of local primary and high schools, and mosques are often raised to the level of abnormal floods, and used as flood shelters. As a flood shelter, villagers also build platforms or *machan* using bamboo, straw, and other materials to avoid abnormal floods (Paul, 1984, p. 16; Rasid, 1993, pp. 49–50).

Flood loss/coping with uncertainty

Because of the lack of systematic time series data on flood damage and loss in Bangladesh, a number of studies (Chowdhury, 1988; Montgomery, 1985) have provided micro and macro level accounts of damage caused by flood of a particular year. Although the recent floods are not physically different than those of the past (Rogers *et al.*, 1989), both economic losses and the vulnerability of the population have dramatically increased in recent years. This increase is partly attributed to the trend toward perpetual poverty and marginalization of the majority of the population (Haque, 1993, p. 370), and to the increasing siting of tangible resources such as crops, roads, railways, buildings, factories, and electric transmission networks in riverine floodplain areas that are more prone to hazard impact.

Based on secondary data, Table 1 presents information on the magnitude of damage caused by abnormal riverine floods that have occurred since 1971. The data suggest that the magnitude of loss of human lives and livestock is directly associated with the severity of flooding. As many as 2379 people died and 172,000

Table 1. Damage due to abnormal floods, 1971–1988

Year	Loss of human lives	Loss of livestock (in '000)	Houses totally/partially damaged (in '000)
1971	120	2	229
1974*	1987	46	1165
1975	15	—	19
1976	54	—	89
1984*	553	76	—
1987*	1657	65	2536
1988*	2379	172	7179

*More catastrophic flood years.
Sources: Mirza (1984); International Red Cross (1988); Brammer (1990b).

livestock were lost during the 1988 flood, which is considered by many analysts as the most disastrous in the recorded history of Bangladesh. More than 40 million persons were displaced and nearly 7.2 million houses were destroyed or damaged by this flood. The material damage caused exceeded US $2 billion (UNDP, 1989).

Physical infrastructure was also severely damaged by the 1988 flood; about 900 bridges and culverts were destroyed and more than 15,000 km of rural and trunk roads were affected. However, it is important to note that the most devastating flood of Bangladesh caused much less damage than the 1993 destructive flood in the Midwest of the United States. That flood affected over 56,295 dwellings and forced the evacution of over 74,000 residents. But it caused over $16 billion in property damage. About half of this damage occurred in agricultural areas (Meyers and White, 1993). Federal, state, and local flood control programs, however, prevented nearly $20 billion in potential damage (IFMRC, 1994).

For floods other than the abnormal ones, flood damage is primarily restricted to crop damage. Of all crop losses, it is rice and jute, the two most important crops of Bangladesh, which are affected most seriously. Rice alone accounts for more than 80% of the annual loss of agricultural production (Rasid and Paul, 1987, p. 161). But the annual flood-induced loss of rice production, in both absolute and relative terms, is not as high as popular perceptions suggest. The flood loss is comparable to the annual loss of foodgrain production caused by drought. From 1973 to 1987, the average loss of foodgrain production due to drought was 0.15 million metric tons. For the same period, the average annual flood damage was 0.16 million metric tons (Ahmed and Bernard, 1989; Hossain, 1990, p. 37). Even postharvest loss of rice production seems higher than the loss resulting from floods. From 1978 to 1980, the postharvest loss accounted for seven percent of the total rice production (Greeley, 1987, pp. 120–121). Paul and Rasid (1993) report that during the period 1962–1988, almost 4% of the total rice production was lost due to flooding.

Media emphasis on reporting flood-induced crop damage reflects the prevailing perception. Usually the media tend to focus on areas severely affected by flood. This often magnifies people's perception of flood-induced damage at the countrywide scale. However, the annual loss of rice production from flooding has not been very severe for several reasons. First, farmers, as noted earlier, have tried to compensate rice loss by adopting several traditional adjustment techniques. Second, floods rarely affect the entire country in a given year. Although severe flooding may cause substantial losses of rice production in one region, others experience normal flooding and bumper crops. In both 1987 and 1988, bumper harvests of transplanted *aman* were reported in regions beyond the flood-affected areas except in those parts affected by the November 1988 cyclone. Similarly, farmers growing broadcast *aman* recognize that yields are often higher in severe flood years, except when such floods come late (as they did in 1987 and 1988) (Brammer, 1990a, p. 21). The shortfall in production in affected regions is, to a large extent, compensated by above-normal output in non-affected areas during the same season.

Even regions that are severely affected by flood may experience bumper crops during the subsequent dry season. Hurdus (1988) and Brammer (1990a) reported that during the abnormal flood years, the spread of flood water over extensive areas plays a compensatory role in crop damage. The damage to the wet season

paddies (*aus* and *aman*) is largely compensated by better soil moisture conditions, especially for *boro* production in the dry season.

The regional relationship also holds true at the local level. Because *aus* does not tolerate excessive amounts of standing water, farmers cultivate this rice type on high ground. Broadcast *aman* thrives best on low land that is subject to deep flooding. Transplanted *aman*, though requiring floodwaters, does not grow in deep flood areas. Farmers generally select land with intermediate local relief for cultivation of this rice variety. At the local level, a severe flood rarely causes equal amounts of damage to all three rice varieties. A severe flood for transplanted *aman* may be a normal one for *aus* rice. When one variety suffers from severe flooding, another flourishes and minimizes the loss of total rice production from flooding.

Similar to the regional situation, if *boro* is cultivated in areas earlier devoted to transplanted and broadcast *aman*, it is more likely that the former crop will thrive well because of increased soil fertility due to siltation by flood. Also, the yield of broadcast and transplanted *aman* of the following year will be higher than the previous year's harvest, provided no abnormal flood occurs in the latter year. In essence, cultivation of *boro* during the post-flood season allows farmers to recover crop losses from floods (Brammer, 1990a, p. 15). The extra moisture and fertility provided by abnormal floods benefit the following *rabi* (dry) season crops, notably *boro* rice. Moreover, the abrupt rise of rice prices in the dry season after a severe flood is an incentive for farmers to bring more land under *boro* rice (Brammer, 1990a, p. 21). Empirical evidence suggests that impressive expansion of foodgrain production has been realized in flood-affected regions (Hossain, 1990, p. 51).

Flood Action Plan

Bangladesh has recently adopted a multimillion dollar FAP funded by the World Bank. This sets forth an agenda of flood control activities, including the proposal to build massive embankments along all the major river course. It is viewed as the first step in the implementation of a comprehensive long-term programme for flood control in Bangladesh (World Bank, 1990, p. 1).

There is, however, strong opposition within the country to the proposed 'structural solution' to its flood problem (e.g. Custers, 1992, p. 242; Haque and Zaman, 1993, p. 95; Wescoat and Jacobs, 1993, pp. 35–40). Many responsible and environmentally conscious citizens, NGOs, and international experts have raised serious questions about the viability of an expensive 'technological fix' strategy. They have criticized the FAP for its structural emphasis, use of scarce land for embankments, and potential ecological stresses. It is feared that the FAP will transform Bangladesh into 'a land without water' or from 'a wet land into a dry land' (Alam, 1991).

The finding of Stewart's study in southern coastal Bangladesh supports the view of concerned Bangladeshis and others (Stewart, 1988). Stewart found that the average material damage was worse inside the embankment than in areas outside it. An independent Bangladesh Agricultural Research Council (BARC) report (BARC, 1989) presented time series data to show that the area flooded in fact may have increased when more rivers are embanked to control flood. The above findings run against the proponents of the 'structural' approach to flood mitigation in Bangladesh.

The finding of Stewart's (1988) study (Stewart, 1988) is consistent with a similar observation by Thompson and Sultana (1996, p. 12), who reported that the existing flood protection projects had failed to reduce damage and vulnerability. In fact flood losses were higher in some protected areas compared to unprotected areas. As part of the FAP, Thompson and Sultana examined the distributional and social impacts of 17 completed FCD projects. They claim that flood protection has disadvantaged some groups, notably fishermen and boatmen, and has generally had a limited impact on agriculture (Thompson and Sultana, 1996, p. 12). Other studies (Boyce, 1990; Thompson, 1990) found loss of open-water fisheries in many of the existing flood control projects.

Contrary to these concerns, a recent study (Paul, 1995, p. 178) reported that 96% of all sample farmers supported the embankment projects of the FAP. A similar finding is also reported by Rasid and Mallik (1993, p. 70). They studied the responses of the 380 residents living within a small flood structure, the Dhaka–Narayanganj–Demra (DND) Project area, regarding the effectiveness of the structure in controlling floods. A systematic sampling procedure was adopted in which every alternate household was sampled. A door-to-door interview was conducted by

a team of five field assistants under the supervision of the first author. The survey showed that an overwhelming 90% of respondents prefer the security of their monsoon season crops through regulated flood levels rather than living with the status quo of no regulation at all. This finding is also consistent with their later study, which was based on responses of 484 farmers of five floodplains (Rasid and Mallik, 1995, pp. 12–13).

Paul (1995) collected data from two rural areas: one located near the confluence of the Jamuna and Padma rivers, the other away from any major river. A structured questionnaire was administered among a sample of households from the selected villages in order to obtain information concerning the construction of embankment along the major rivers of Bangladesh. A total of 164 heads of the households were interviewed from two study sites. The author and the five field investigators collected the relevant information from the study villages.

Since the magnitude and frequency of floods would be expected to decrease with the increase of distance from a major river, it was anticipated that the responses of the farmers would differ. But no difference was found between the farmers of the two study sites regarding their responses to the construction of the proposed embankment projects. Similarly, no variation was observed in the responses to the projects among farmers of different socio-economic groups. This latter finding does not support the contention of researchers who use social-historical and political-economic perspectives in studying environmental hazards.

Although Paul's (1995) and Rasid and Mallick's (1993 and 1995) studies provide somewhat surprising findings, these are the only studies that provide the point of view of the sufferers regarding the construction of massive flood-control embankments along the major rivers of Bangladesh. They are not only the actual sufferers of floods but also are supposed to be the primary beneficiaries of the proposed flood control programme. It is worthwhile to mention that issues related to structural and non-structural measures of flood control have been the topics of several recent flood studies (e.g. Adnan, 1991; Boyce, 1990; Brammer, 1990b; Islam, 1990).

However, the near unanimous support of the farmers toward embankment projects can be explained in several ways. One possible reason could be their recent experience with the catastrophic floods of 1987 and 1988. Generally, people's responses to environmental hazards are strongly influenced by the recency of the experience. Additionally, it has been found that the farmers are usually influenced by local officials and leaders, who often blindly support government development programmes. The embankment construction will provide scope for employment for villagers. The respondents, particularly those who live close to the confluence of the Padma and Jamuna rivers, might have thought that the construction of embankments would bring wage labour in the construction and maintenance of these embankments. Moreover, the field survey suggests that respondents usually have a high regard for Western technology. Thus, they have greater confidence in the technological solution to their chronic flood problem.

Additionally, the overwhelming support for the embankment projects is consistent with the widely prevalent myth that flooding of the floodplains can be controlled by building embankments (Alam, 1991). Since the early 1960s embankment building has remained the most common means of flood protection initiative in Bangladesh. Over the last three decades, more than 200 major Flood Control and Drainage (FCD) and Flood Control, Drainage, and Irrigation (FCDI) projects have been completed (Potten, 1994, p. 159).

Future research

Although a shift of emphasis from a response-based analytical perspective, which focuses on the range of adjustments people adopt to compensate for flooding, to other aspects of flood hazard is evident from the existing literature, no detailed study has yet been conducted on the most vulnerable social groups, such as the elderly, children, and women. Some of the existing studies (e.g. Adnan, 1991) occasionally mentioned these groups, but none of them became the subject of systematic study. Each of the social groups mentioned above face different problems with flooding. They may perceive and respond to the various aspects of flood hazard differently. Any comprehensive flood control plan for Bangladesh must seriously consider their viewpoints.

As a vulnerable group, women, for example, face many problems under conditions of flooding when

trying to fulfill their daily chores (see Thompson and Sultana, 1996, p. 7). Cooking places may be innundated. Collection of fire wood for cooking purposes may also be difficult. Women may also have to travel long distances in order to fetch drinking water during the flood season.

Because of poverty, husbands often desert their wives. Poverty usually intensifies in the severe flood years, which increases desertion (see Adnan, 1991, p. 65). Destitute women without employment sometimes are compelled to migrate elsewhere and face the most acute conditions of physical and social insecurity. Often an entire family is uprooted by floods and forced to migrate to urban areas. Many of the younger women refugees remain unmarried because their families are unable to provide the kind of dowry customarily needed for their marriage. Some of these, together with other destitute women, are lured away by professional gangs and pimps with promises of jobs elsewhere. Many are likely to be forced into prostitution, either in towns or even abroad. Older women, on the other hand, becomes helpless beggars and live on charity (Adnan, 1991, p. 65). The various impacts of abnormal flood on women should receive high priority in future flood research in Bangladesh.

The law and order situation in rural areas usually deteriorates during the flood season. Incidence of theft and robbery increases in flood affected areas, both during and after flood. Because of reduced food production, prices of foodgrains usually rise rapidly following a flood. Decreased food production, abnormal increase in foodgrain prices, and non-availability of jobs often force people to secure food by any means. In this stage public intervention is needed to provide necessary food, either free of cost or at nominal prices, to the affected people. Flood-affected area residents also suffer from water-borne and other diseases, both during and after the flood. Although an attempt has been made to compare the incidence of disease between areas located within and outside a flood embankment structure (Emch, 1995), no one has studied how the flood victims and the government respond to the law and order situation, or to the occurence of diseases during and after flood. These could be important topics of future flood research in Bangladesh.

Post-traumatic stress disorder or psychological aspects of flood hazard are other aspects that have not received much attention in Bangladesh. So far, only one study (Durkin *et al.*, 1993) is available in this area. The study examined the effects of flood on child behaviour. Using the relevant data collected both before and after a flood, this study tested the hypothesis that stressful events play a causal role in the development of behaviour disorder in children. A study of this nature may contribute in developing and evaluating interventions aimed at ameliorating the behavioural and psychological consequences of people's exposure to extreme and traumatic situations. Future studies could cover other areas, such as the impact of flooding on the physical and mental health of floodplain residents.

Attempts to investigate the role of social organizations and other societal forces in mitigating flood effects have been scanty. One important study (Khan, 1991) focused on the role of powerful elites in the actual location of flood shelters in four communities in northern Bangladesh. Because of the influence of elite groups none of the four centers are optimally located. The optimum location is judged primarily in relation to the location of the households at risk from flooding. The study rightly proposed a full appraisal before locating any infrastructure in rural areas. The planning process should allow sufficient time to permit negotiation with the power structure to determine the optimal location for construction (Khan, 1991, p. 353). Similar studies should be conducted in other parts of Bangladesh.

In the 'Western' world, geographers have contributed to the growth of hazard research, specifically in the areas of assessment, communication and management (Mitchell, 1989). Research in assessment involves mapping physical risks, the evolution of vulnerability, and other factors influencing human behaviour (e.g. Mitchell, 1984; Tobin, 1985). Communication studies explore the distribution process and level of comprehension regarding information about hazard and risk (Kasperson, 1986; Sims and Baumann, 1983). Research in management includes determination of physical flood hazard risks in the study area, monitoring the effect of different hazard management strategies, and modelling the success of flood control objectives. These areas of flood research are virtually untouched in Bangladesh.

It is also emphasized that careful evaluation of the performance (economic, social, and ecological) of the different FCD and FCDI projects that have already been built needs to be conducted. Hunting Technical

Services Ltd (HTS) of Britain has studied the impact of seventeen selected FCD projects in order to assess the impact of efforts to control and manage floods, in order to identify lessons that might be of use to those planning future interventions (Potten, 1994, p. 159). The study revealed that the impacts were mixed. Some of the projects were successful in achieving their goals but others had failed. Clearly other FCD and FCDI projects need to be evaluated in a similar way.

Another fruitful area of flood research in Bangladesh would be a longitudinal study to compare the changes and the process of change over time because of natural disasters. Flood adjustments, for example, may vary over time and from place to place. By studying the same areas for long periods can result in a better understanding of these adjustments. The role of NGOs in relief and rehabilitation programmes and a comparison of NGO activities with government activities would be other potential areas of flood research in Bangladesh.

Research on urban flooding has not received much attention in Bangladesh. In 1988 most parts of Dhaka city, the capital, were flooded. The government subsequently constructed a 30-km-long embankment along its western perimeter to protect the city from the threat of similar devastating floods. Rasid and Mallik (1996, p. 89) identified three environmental problems that could be related directly to the construction the embankment: growth of water hyacinth, foul ordors, and accululation of municipal sewage. Various environmental and social impacts of the Dhaka city embankment project have unrealized potential for future research.

With the adoption of the FAP, many consulting firms emerged in the late 1980s and early 1990s to conduct environmental impact studies of proposed embankment projects. Some of the major structural projects originally envisaged by the FAP have now either been dropped or at least scaled down substantially. The reduced emphasis on embankment projects as a measure to control flooding may affect the existence of these consulting firms.

Conclusion

Drawn from existing studies, this paper has presented several important findings about flood hazard in Bangladesh, and outlined future areas of flood research. A review of relevant literature suggests that the early research themes concerning flood in Bangladesh followed the human ecology tradition focusing upon interaction between the human use systems and the physical processes operating in floodplain environments. These studies examined adjustments, perception, and the choice processes that floodplain residents undergo in coping with flood. Early flood studies placed limited emphasis on topics that deal with the socio-economic impacts of floods and other related topics.

As noted earlier, the Bangladesh government has recently changed its strategy from a strictly structural approach to a combination of both structural and non-structural measures to solve the flood problem of the country. With this change, a new focus of study should be directed toward non-structural flood control measures, particularly on the efficiency of flood warning systems. Research along this line may aim at efficient dissemination of flood warnings and determination of appropriate public and institutional responses. Research directed toward policies that favour mitigation, preparedness, and prevention of flood hazards should prosper in the future.

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