FLOODS IN BANGLADESH IN THE FRAMEWORK OF HIGHLAND-LOWLAND INTERACTIONS : SIX YEARS AFTER 'THE HIMALAYAN DILEMMA

Thomas Hofer, Rolf Weingartner

1. Background: The theory of Himalayan degradation

Every year during the monsoon season catastrophic flooding in the plains of the Ganges and Brahmaputra rivers is reported as being the result of human activities in the Himalayan region. The chain of mechanisms seems to be very clear: population growth in the mountains; increasing demand for fuel wood, fodder and timber; uncontrolled and increasing forest removal in more and more marginal areas; intensified erosion and higher peak flows in the rivers, severe flooding in the densely populated and cultivated plains of the Ganges and the Brahmaputra. These conclusions sound convincing and have been subscribed to carelessly by some scientists and adopted by many politicians in order to point a finger at the culprit. They are laden with sensation and potential for conflict, but they are not based on scientific fundamentals.

In 1979 the UNU Highland-Lowland Interactive Systems Programme, later renamed Mountain Ecology and Sustainable Development, was initiated with the aim of promoting a more serious scientific analysis of these crucial problems. The project was co-ordinated by Bruno Messerli and Jack Ives. This project marked the beginning of a long tradition of research on the Indian subcontinent at the Department of Geography of the University of Berne. From 1979 to 1991 numerous studies were carried out in the framework of this programme, focusing mainly on processes in the Himalayas. These investigations concentrated on erosion processes in relation to land use, on discharge characteristics of Himalayan rivers, on forest history, etc. An attempt was always made to relate the findings to flood processes in the plains. The conclusions of all these activities are documented in *The Himalayan Dilemma* (Ives and Messerli, 1989). A similar compilation of results, supplemented with some more recent findings, can be found in the volume *Himalayan Environment: Pressure-Problems-Processes; 12 Years of Research* (Messerli et al., 1993). The following key points summarise the state of knowledge after 12 years of research in the Himalayas:

- Human-induced ecological changes can be proven in some specific examples at the local level. The findings are not transferable to the scale of the Ganges-Brahmaputra basin.
- It has not yet been possible to find significant correlation between human activities in the mountains (e.g., forest removal) and catastrophes in the plains (e.g., floods). Thus the well-known theory which links forest cutting in the mountains with increased flooding in the plains has to be revised and differentiated.

- Due to restrictions in access to data, there is a serious lack of basic research, which is an absolute necessity for long-term, effective planning to enhance sustainable development in the overall Himalayan region.

2. *Floods in Bangladesh, processes and impacts: A project brief*

The project "Floods in Bangladesh - Processes and Impacts", which has been carried out since 1992, is a follow-up on research previously done by the Department of Geography at the University of Berne in the Himalaya-Ganges-Brahmaputra region. The focus of research activities has shifted from the highlands to the lowlands, with the primary aim of verifying the findings published in *The Himalayan Dilemma*. The project is financed by the Swiss Development Co-operation as well as by the United Nations University. It is being carried out in close collaboration with institutions in Bangladesh, mainly universities.

The project concentrates on the following basic questions:

- **Highland-lowland interactions**: Are the monsoon floods mainly produced by heavy rainfall over the flooded area itself, or do the precipitation events outside the flood plains or even in the highlands have a more significant impact on flood processes?
- **Complexity:** Is each flood event an individual combination of factors, or is it possible to identify certain repeating configurations?
- **Frequency:** Have the frequency and dimensions of severe flooding really increased, as it is usually assumed, or has the sensitivity of the population to flooding and flood damage increased due to extension of settlement and cultivation into flood-prone areas?
- **People's perception and experiences:** How do affected people perceive floods, and what are their strategies for managing floods? What has been learned from experience with existing flood protection embankments?

These basic topics are approached in seven specific studies:

a) Floods in Bengal before 1950 - case studies and analysis of long-term data series.

b) Frequency and processes of floods in Bangladesh in the framework of highland lowland interactions: Case studies, 1950-1990.

c) Cloud patterns and cloud movements before and during flood events in Bangladesh - an interpretation of NOAA imageries.

d) Landscape, land use, settlement dynamics and flooding - a study carried out in the test areas of Bhuanpur, Sirajgonj and Nagarbari, Bangladesh.

e) Soil fertility of river sediments.

In the ongoing project, highland-lowland interactions are still a key issue. Within this overall framework, an attempt is being made to gain an understanding of the process of flooding in Bangladesh, from various perspectives at different geographical scales (whole basin and test area studies), and of the combination of physical and cultural aspects of flooding. Basic research (the main interest of the university) and applied research (main interest of Swiss Development Co-operation) are being combined in this approach.

3. *Floods in Bangladesh: A highland lowland interaction?*

For this project report, study b) has been selected for more detailed comments. This study concentrates on the period 1950 to 1990, and is particularly focused on highland-lowland interactions. The study, which is based on the investigation of monthly rainfall and monthly discharge data, addresses the following questions:

- Which years from 1950 to 1990, and which time periods, show particularly important anomalies in rainfall and discharge characteristics in the Ganges-Brahmaputra-Meghna basin?
- If we consider specific "flood years", "average years" and "dry years" in Bangladesh and India, in which part of the basin did the main positive or negative climatological anomalies occur?
- What is the hydrological contribution from different sub-catchments into the system, and what is the relevance of this contribution for flood processes in Bangladesh?
- What conclusions can we draw about our understanding of the hydrological processes in Bangladesh in the framework of highland-lowland interactions?

Methodology

To answer the above questions, a specific methodology had to be developed which is based on two premises:

1. Each sub-catchment of the Ganges-Brahmaputra-Meghna basin contributes a specific amount of potential runoff to the hydrological system per month, or per any other time period during a year. This potential runoff is a function of precipitation, of the sub-catchment area, and of a discharge factor (evaporation, infiltration, etc.).
2. The relevance of the potential runoff of a specific sub-catchment for the hydrological characteristics at a reference point in Bangladesh decreases as the distance of the respective sub-catchment from the reference point increases.

The methodology was developed in the following steps:

- 13 sub-catchments were delineated in the Ganges-Brahmaputra-Meghna catchment (figure 1), taking into account the catchment boundaries of the three main rivers, the political boundaries, the transition between highlands and lowlands, and the average patterns of precipitation. The eastern upper Meghna catchment (Tripura, Manipur, Mizoram), Arunachal Himalaya, and the whole Tibetan part of the Brahmaputra catchment had to be excluded due to a lack of climatic stations.
- 33 climatological stations were selected, for which a sufficiently long data record was available. These stations are more or less regularly spread over the 13 sub-catchments.
- Each year was sub-divided into 6 time periods: January-March (winter), April-May (pre-monsoon period), June, July, August, September (monsoon months). October, November and December were excluded from the analysis. For each time period and year the area rainfall per sub-catchment was calculated (average of the precipitation at the available stations).
- The potential runoff for a specific sub-catchment, time period and year was calculated with the formula:

$$PR = P * S * a$$

PR: Potential Runoff
P: Average precipitation of a sub-catchment
S: Surface of the sub-catchment
a: Discharge factor

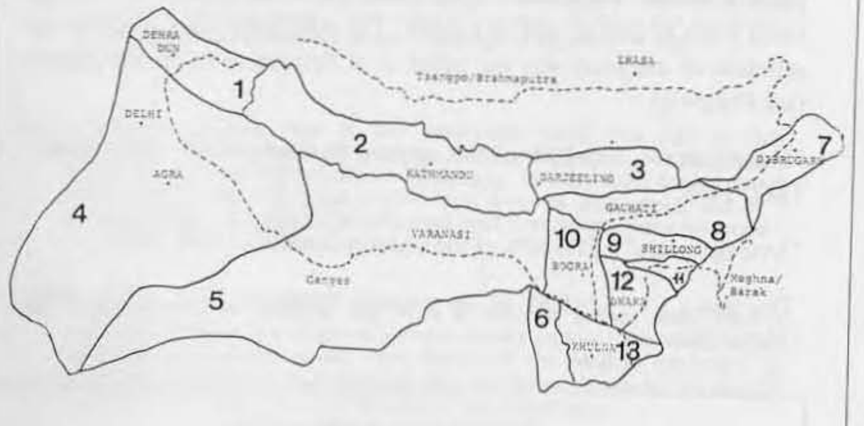
The discharge factors range from 0.1 to 0.9. They were assessed for each sub-catchment on the basis of the location of the respective sub-catchment (highland or lowland; east or west in the basin) and they were differentiated for specific time periods within the year. For the sub-catchments in the Ganges system, the discharge factors were tested with the discharge data for the Ganges at Farakka.

- The multiplication of the potential runoff and a distance factor resulted in the relevance of this particular potential runoff for the hydrological processes at a reference point in Bangladesh. The reference point was located at the confluence of the Meghna with the combined Ganges-Jamuna (Brahmaputra) flow. The distance factor (d) of a specific sub-catchment was calculated with the formula

$$d = \frac{1/di^2}{\sum_{i=1}^{11}(1/di^2)}$$

di: Distance from a specific sub-catchment i to the reference point in Bangladesh.

In the analysis and interpretation of the case studies, for which this methodology was applied, the anomaly of potential runoff as well as of relevance, i.e. variation from the average situation, was a key issue. The main advantage of the methodology is that a large-scale analysis is possible, looking at almost the entire area of the Ganges-Brahmaputra-Meghna basin. The disadvantages of this approach are the low spatial coverage of the rainfall stations, and the fact that the investigation is almost purely based on one main parameter-monthly rainfall.



Sub-catchment 1: Northwestern Himalaya
Sub-catchment 2: Nepal
Sub-catchment 3: Darjeeling Himalayas
Sub-catchment 4: Upper Indian Ganges Plain
Sub-catchment 5: Lower Indian Ganges Plain
Sub-catchment 6: Southern West Bengal
Sub-catchment 7: Upper Assam
Sub-catchment 8: Lower Assam
Sub-catchment 9: Meghalaya Hills
Sub-catchment 10: Northwestern Bangladesh
Sub-catchment 11: Sylhet basin
Sub-catchment 12: Central & eastern Bangladesh
Sub-catchment 13: Southern Bangladesh

Figure 1: Sub-catchments of the Ganges-Brahmaputra-Meghna basin

The methodology explained above was applied to the investigation of 12 specific years over the period 1950 to 1990. In order to identify the particular conditions of potential runoff and of relevance in outstanding flood years for Bangladesh, these years were contrasted with average flood years as well as with dry years. The main parameter used for the selection of the years was the statistics of flooded areas in Bangladesh (see Figure 2):

"Flood years" (>30% of the country flooded): 1955, 1974, 1984[1], 1987, 1988.

"Average years" (10-30% of the country flooded): 1960, 1971.

"Dry years" (<10% of the country flooded): 1977, 1978, 1982, 1986, 1990.

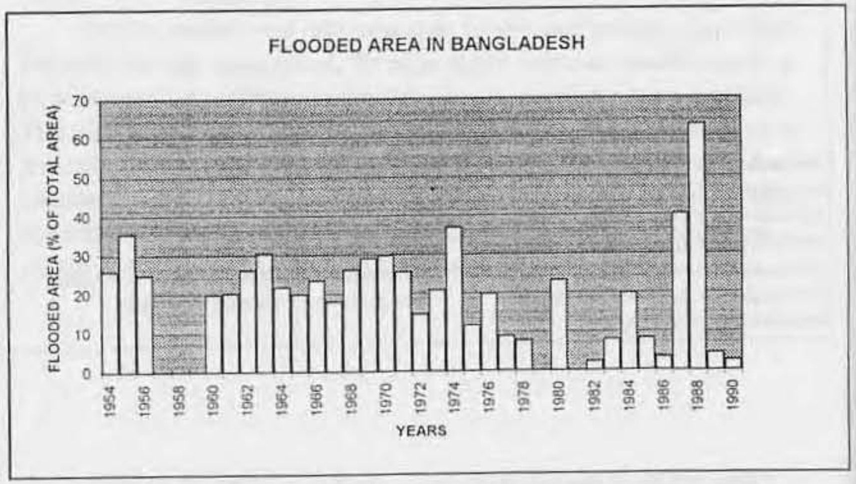


Figure 2: Flooded areas in Bangladesh, 1954 to 1990 (as % of the total area of the country; data were missing for 1957, 1958, 1959, 1979, and 1981). Source: BWDB, 1991.

[1]1984 is not a "flood year" with regard to the inundated area, but with regard to the flood intensity and damage in certain areas of Bangladesh.

The analysis highlighted the following key issues for the 12 years:

"FLOOD YEARS

1955: The flood most probably took place in the period end of July-mid August. The flood was strongly influenced by temporally and regionally widespread positive variations in potential runoff. The external influence on the flood was significant, as Bangladesh recorded above-average hydrological input only in July.

1974: Flooding took place more or less permanently from early July to early September. The anomalies of potential runoff concentrated on the Meghna catchment, and more specifically on Meghalaya. In July, these driving forces were supported by widespread surplus input from the other areas, and by a potentially high soil saturation in the coastal areas from the pre-monsoon period.

1984: Different types of flooding took place in different periods from May to September, producing a pattern of isolated affected regions. The main positive anomalies of potential runoff were located in the Meghna catchment, in Meghalaya in particular, in Bangladesh and, to a lesser extent, in Assam. The base flow of the main rivers into Bangladesh was rather high.

1987: Different types of flooding took place in different periods from June to September. North-western, western and south-western Bangladesh were the most seriously affected areas in terms of duration. The floods were triggered primarily in Bangladesh, more specifically in the north-western part of the country. The base flow of the main rivers into Bangladesh was rather high. It is possible that there was a connection between the floods in Assam, Bihar, West Bengal and Bangladesh in August.

1988: The "flood of the century" took place from the second part of August to early September and was preceded by a Meghna flood in July. Apart from parameters mentioned in the literature (synchronisation of peak discharges, tides, back-water effects etc.), the floods were strongly influenced by above-average potential runoff in Bangladesh, Meghalaya and Assam over a long period of time. The base flow, mainly of the Brahmaputra and the Meghna, into Bangladesh was high. There was a connection between the floods in Assam and Bangladesh at the end of August.

"AVERAGE YEARS"

1960: The widespread above-average potential runoff in July was similar to 1974. The external input from July to September was high. Widespread dry conditions from winter to June, and the alternation of humid July and September with dry June and August in the Meghna catchment and north-western Bangladesh, moderated the dimension of flooding.

1971: In the three states of the Indian Ganges Plain, the dimensions of flooding were great. In Assam, inundation was below average. In Bangladesh, a new combination of factors produced the specific flood conditions in the delta.

"DRY YEARS"

1977: Widespread humid pre-monsoon and early monsoon conditions, and high external input during the monsoon season, mainly from Assam, are not sufficient to create large-scale flooding in Bangladesh if no triggering factors are present in Bangladesh during the main monsoon months. The lower Meghna catchment seemed to have played a key role in moderating floods.

1978: In the Indian Ganges plain considerable flooding was recorded from July to September. The downstream effect on Bangladesh of large floods in the Ganges Plain is almost nil if no corresponding triggering factors are present in Bangladesh. In Bangladesh we find a new combination of factors producing the specific flood conditions in the delta. In this new combination the patterns in Bangladesh itself and Meghalya, supported by Assam, dominate. The potential runoff in the Himalayas would have provided favourable conditions for large-scale downstream flooding

1982: Below-average input of potential runoff dominated in Bangladesh and Assam. The very high hydrological input in the Ganges catchment during certain periods did not have any significant effect on the hydrology in Bangladesh.

1986: The conditions outside Bangladesh, especially in Assam and Meghalaya, were drier than inside the country. The potential flood triggers in Bangladesh were moderated by the low external input. In Bangladesh humid July and September were preceded by dry June and August.

1990: Our investigation and the literature question the reduced dimensions of flooding as recorded in the flood statistics for 1990. The conditions in winter and spring were humid. The external input during the monsoon months was rather high. In Bangladesh humid July and September were preceded by dry June and August.

Floods in Bangladesh: Five theses

These theses result from comparisons of the 12 years analysed. An attempt was made to identify basic patterns which provide insight

into the flood processes in the framework of highland-lowland interactive systems:

a. The rainfall patterns in the Ganges-Brahmaputra-Meghna basin must be differentiated for each monsoon season.

This statement is based on analysis of long-term data series. Dry years in the west may be humid years in the east and vice versa. The climatological conditions in the Himalayas do not necessarily correlate with those in the Ganges or Brahmaputra plains. Therefore, the floods in Bangladesh are produced by a combination of regionally differentiated characteristics, for which the patterns in the east seem to be more important than those in the west.

b. The rainfall in the Meghalaya Hills and Bangladesh itself has the highest relevance for the flood processes.

During spring and June in the Meghalaya Hills, an average of 20-25% of the total potential runoff for the 13 sub-catchments was recorded, although this area represents barely 2% of the surface! Moreover, the positive and negative anomalies of potential runoff for specific years in Meghalaya and Bangladesh showed the greatest correlation with the dimensions of flooding.

c. A combination of a high external "base flow" with short-term, "home-made" discharge peaks is important in Bangladesh.

The potential for flooding can be assessed by the level of the "base flow", but the floods are triggered by the short-term discharge peaks due to local rainfall. Therefore, the external hydrological input into Bangladesh is important as a basic contribution to the floods, but most probably not as a flood trigger.

d. The rainfall patterns in the Himalayas have almost no impact on flood processes in Bangladesh due to their distance from the Bangladeshi floodplains.

A heavy rainfall event in the first Himalayan ranges and in the foothills may be the decisive factor for flooding in the adjacent plains, owing to a very sharp rise of the hydrographs of the rivers in the affected areas.

As the catchment areas of the rivers are comparably small, the system reacts very quickly to heavy rainfall events. As distance from the Himalayan foothills increases, the short-term discharge peaks are levelled, lose their flood triggering effect, and are transformed into "base flow", the flooding disappears.

The catchment area of the rivers in Bangladesh and the amounts of water involved in flood processes are huge. The basic conditions for large-scale flooding build up gradually due to the accumulation of water over a longer period of time. Consequently, the above-mentioned heavy rainfall event in the Himalayan foothills is not important; it is just one of many other contributing puzzle pieces responsible for the pattern of flooding in Bangladesh. Only local heavy rainfall events in Bangladesh itself are important as triggering factors, as they may result in an overflow of the rivers and the groundwater table.

e. Flooding in Bangladesh may have a connection to flooding in Assam, but not with flooding in the Indian Ganges Plain.

Large-scale flooding which originates upstream in the plains does not move downstream with increasing dimensions: In 1978, all three Indian states of the Ganges plain (UP, Bihar and West Bengal) faced severe flooding problems, but in different periods of the monsoon season. The flooding processes were therefore regionally limited phenomena, linked together by the high "base flow" of the Ganges, but triggered by local or regional rainfall events. The high "base flow" entering Bangladesh had no flooding effect, because heavy local rainfall was absent as a triggering factor. However, Assam seems to play a more important role.

Conclusion and outlook

The five theses presented in the previous section are based on an investigation of monthly rainfall, and partly on monthly discharge information. Monthly data is the only information available for more or less the whole basin; discharge data in general are highly restricted for political reasons. In the next steps of this particular study, the theses will be further verified by analysing daily discharge data for the main rivers in Bangladesh, daily rainfall data, and groundwater information within Bangladesh.

The research activities resulting in *The Himalayan Dilemma* focused on processes in the Himalayas and on their downstream effects. The findings raise serious questions about the theory of Himalayan degradation. Current activities focus on the processes in Bangladesh and on upstream contributing factors. The preliminary findings greatly support and differentiate the various theses formulated in *The Himalayan Dilemma*. The climatological and hydrological processes in the Himalayas are important for flooding in the foothills, and they may have some impact on flooding in the Indian Ganges plain or Assam, but they are unimportant, perhaps even negligible for flood processes in Bangladesh. Regarding rainfall, the patterns in Bangladesh itself or in its north-eastern neighbourhood, the Meghalaya Hills, or perhaps even Assam, decisively influence the dimensions of flooding in Bangladesh. The areas outside Bangladesh are important as contributors to "base flow", but the lood triggers are located in the flood plains of Bangladesh or in areas nearby. Backwater effects due to tidal movements, the synchronisation of peak discharge of the big rivers, the groundwater table in Bangladesh, etc. seem to be very important, but have not yet been investigated in the framework of our project. Based on all these statements, there is absolutely no reason to assign responsibility for the floods in Bangladesh to the people living in the Himalayas. Much more important for the flood processes are the anthropogenic interventions in the floodplains, such as the embanking of large rivers, and the drying out of swamps which are natural water storage areas, etc. This ongoing project again very clearly documents the need for an in-depth understanding of the processes of highland-lowland interactions to promote sustainable watershed management.

References

BWDB
1991, *Annual Flood Report 1991*. Directorate of Surface Hydrology-2, Bangladesh Water Development Board, Dhaka.
Ives, J.D., Messerli, B.
1989, *The Himalayan Dilemma. Reconciling Development and Conservation*, London, Routledge.

Messerli, B., Hofer, T., Wymann, S.
1993, *Himalayan Environment: Pressure-Problems-Processes,* Bern, Geographica Bernensia G38, Institute of Geography, University of Bern.