What are the impacts of deforestation in the Himalayas on flooding in the lowlands?
Rethinking an old paradigm

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Abstract

Every year during the monsoon season the whole Himalayan region appears in the world’s headlines because of disastrous flooding in the plains of the Ganges and the Brahmaputra. It is often stated that the peasants of the Himalayas are to blame, as it is deforestation in these mountains that leads to devastating floods, particularly in Bangladesh. The validity of this paradigm has been increasingly questioned, mainly in the scientific community. This paper presents new evidences resulting from research activities carried out over the last two decades in the whole Himalayan region. In particular, the paper discusses a project that studied floods in Bangladesh in the context of highland-lowland interactions. A methodology is presented which allows to estimate the potential hydrological contribution from 13 defined sub-catchments in the Ganges-Brahmaputra-Meghna basin and the relevance of it for the hydrological processes in Bangladesh.

The hydrological impacts of mountain deforestation are a question of scale. Man-induced ecological changes in the Himalayas can be proven in specific examples at the small-scale level. However, at the large scale of the Ganges-Brahmaputra-Meghna system it has not been possible to find a significant correlation between human activities in the Himalayas and floods in Bangladesh. Precipitation and runoff in the Himalayas do not seem to contribute significantly to the floods in Bangladesh. The Meghalaya Hills, however, seem to be decisive because of their location close to the floodplains of Bangladesh and their high rainfall.

The habit of blaming mountain dwellers and their land-use practices for the flood catastrophes in the plains far downstream must be abandoned. However, the protection
and the sustainable management of mountain forests are essential for mountain communities and their environment. Afforestation programmes in the mountains should therefore be regarded in this context, and not as a means of preventing flooding in the lowlands.

Key words: Deforestation, floods, hydrology, highland-lowland linkages, Himalayas, Bangladesh

1.) The old paradigm

Every year during the monsoon season the whole Himalayan region appears in the world’s headlines because of disastrous flooding in the plains of the Ganges and the Brahmaputra. For example, the Bangladesh Observer in 1990 stated: “Bangladesh in grave danger: deforestation in the Himalayas aggravating floods”. This headline is noteworthy as it:

- states that there is a direct link between the hydro-meteorological processes in the Himalayas and the floods in the lowlands;
- assumes that it is the rapid forest removal in the mountains that is responsible for the intensification of the hydrological processes in the plains;
- assumes that flooding in Bangladesh has increased; and
- accuses mountain people and other users of mountain forests of being responsible for the presumably increasing flood frequency in the lowlands.

The question as to what extent these large-scale processes are natural or influenced by human activities has resulted in impassioned debate among politicians, journalists and scientists. The arguments are based usually on the following - rather convincing - chain of assumed mechanisms: population growth in the mountains → increasing demand for fuelwood, 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 and siltation in the densely populated and cultivated plains. This supposedly scientific sequence of events has been used by politicians in times of flood-related crises to apportion the blame on the rural people of remote mountain areas. And the mountain populations themselves shave accepted the blame because bad science has been presented to them as fact, and also because development agencies have funded reforestation programmes.
There is no doubt that the Himalayas and their forelands have undergone a dynamic change in land use in recent decades due to rapid population growth. However, the validity of the “old paradigm” has been increasingly questioned over the last two decades, mainly in the scientific community, as being too simplistic and misleading (see e.g. Ives, 1987). This paper presents some new evidences resulting from research activities carried out over more than twenty years at different geographical scales in the whole Himalayan region. The author of this paper has been actively involved in many of these activities.

2.) The project and research context

In 1979, Prof. Bruno Messerli (University of Berne) and Prof. Jack Ives (University of Boulder), together with many other institutions and individuals worldwide, initiated intensive scientific investigations of the ecological interactions between the Himalayas and the adjacent lowlands of the Ganges and Brahmaputra, as well as of the impact of human activities on these linkages. Most of the work, which from 1979 to 1991 focused primarily on the highlands, was carried out under the “Highland-Lowland Interactive Systems Project”, later renamed “Mountain Ecology and Sustainable Development”, of the United Nations University (UNU). The research addressed issues such as erosion processes in relation to land use, discharge characteristics of Himalayan rivers, forest cover change and forest history. The results, which were published in Ives and Messerli (1989) and Messerli et al. (1993) as well as in a number of articles (Hofer, 1993; Messerli and Hofer, 1995), confirmed that the highland-lowland interactions are much more complex and that the traditional understanding of these linkages needed to be revised.

In 1992, a project on the processes and history of floods in Bangladesh was initiated and thus the research focus was shifted from the Himalayan highlands to the lowlands of the Ganges, Brahmaputra and Meghna rivers. The project was jointly implemented by the University of Berne, the Swiss Agency for Development and Cooperation, the United Nations University and a number of institutions in Bangladesh. A first project synthesis was published in 1997 (Hofer and Messerli, 1997). Further data analysis continued through the end of 2000. The final project report will shortly be published by the United Nations University Press (Hofer and Messerli, 2003).

3.) Floods in Bangladesh in the context of highland-lowland interactions
The question as to whether deforestation in the Himalayas is responsible for the frequency and magnitude of the floods in Bangladesh was one of the main topics of the project outlined above and will form the core of the following discussions. The history of flooding in Bangladesh, a second focus of project activities, is discussed in Box 1.

3.1. The data situation
The water resources of the Ganges-Brahmaputra-Meghna basin are shared by Bhutan, Bangladesh, China, India and Nepal (see Map 1). Water is a very sensitive issue in the area and hydrological information is often classified. Climatological information is less restricted. The density of both hydrological and meteorological measuring sites is rather low, especially in the Himalayas. All these factors are a real challenge for hydro-meteorological research in the Ganges-Brahmaputra-Meghna basin.

3.2. Methodology
In order to approach the question as to whether deforestation in the Himalayas is responsible for the floods in Bangladesh and considering the very difficult data situation, a methodology was developed to estimate the potential hydrological contribution from different areas of the Ganges-Brahmaputra-Meghna basin to the river system and to estimate the relevance of this contribution to the hydrological processes in Bangladesh. Two variables, the potential runoff R(pot) and a relevance factor R(relev), were introduced based on the following premises:

- Each of the 13 sub-catchments of the Ganges-Brahmaputra-Meghna Basin which were defined for the project, potentially contributes a specific amount of runoff to the hydrological system per any time period during a year. This potential runoff R(pot) is mainly a function of precipitation, the size of the respective sub-catchment, and of a discharge factor (percentage of the precipitation which is actually discharged). In the project R(pot) was calculated individually for the four monsoon months June to September for each year.
- The relevance of the potential runoff R(relev) of a specific sub-catchment for hydrological characteristics at a reference point in Bangladesh decreases as the distance of the respective sub-catchment from the reference point increases. Accordingly, R(relev) results from the multiplication of R(pot) with a reciprocal and weighted distance factor.

For each of the 13 sub-catchments, R(pot) and R(relev) were calculated for the four monsoon months over a time period of approximately 90 years. Subsequently, 11 case studies of flood situations in Bangladesh were carried out covering the time period 1906-1998. In the analysis, R(pot) and R(relev) proved to be valuable indicators, with which
the different sub-catchments in the Ganges-Brahmaputra-Meghna basin can be compared, in terms of their hydrological characteristics, their contribution to the hydrological system and their relevance for the hydrological processes in Bangladesh, on average as well as in specific years. For more details about this methodology, see Hofer and Messerli (2003).

3.3. The key results

The hydro-climatological processes in the Himalayas do not seem to be important for the floods in Bangladesh. Compared to other parts of the study area, the calculation of the relevance factor R(relev) for the Himalayan areas usually results in rather low values. Furthermore, the anomalies (variations from the average situation) of the potential runoff R(pot) calculated for the Himalayan areas and its foothills during a specific monsoon season are in most cases not related to the magnitude of flooding in Bangladesh. In particular, the potential runoff from the Himalayan areas tends to be below average in years of major flooding in Bangladesh. Finally, flood peaks originating in the highlands are leveled on their way downstream through the plains (see the example of 1993 presented in Box 2). In view of these findings, there is no reason to assume that deforestation or other land-use changes in the Himalayas will have any significant impacts on the flooding patterns in Bangladesh.

The Meghalaya Hills, which are located immediately adjacent to the Bangladesh floodplains (see Map 1), tell a different story: precipitation in this area is usually very high, rainfall in Cherrapunji often reaches world record values. Accordingly, the relevance factor R(relev) of this area for the hydrological processes in Bangladesh turned out to be very high. Furthermore, the anomalies of the potential runoff R(pot) in the Meghalaya Hills are usually well-correlated to the dimension of flooding in Bangladesh (see also box 3).

The large-scale investigations, based on the calculations of R(pot) and R(relev), were complemented with more detailed analysis of the flood process within Bangladesh. Resulting from these investigations and in addition to the regional differentiation presented above, the following factors, particularly in their combination, seem to be important for the floods in Bangladesh: temporal coincidence of the highest flow of the main rivers; rainfall and short-term discharge peaks within Bangladesh; high groundwater level; and back-water effects caused by spring tides.

There is not sufficient room in this paper to present the research results in more detail. For indepth reading we refer to Hofer (1998) as well as Hofer and Messerli (2003).
4. Deforestation in the mountains and its local effects

The following thoughts about the roles of mountain forests at the scale of small watersheds in mountain areas aim to complement the large-scale discussion in the previous section. A substantial amount of work has been carried out on this issue, many projects have been implemented and much literature is available. It is widely accepted that in small watersheds (up to approx. 5000 km$^2$), forests contribute to the regulation of river flows. Due to high infiltration capacity of forest soils and vegetation water use (evapotranspiration), good quality forests can store and temporally retain precipitation and reduce runoff rates. It can therefore be stated that, in general, deforestation (if not followed by well-maintained agricultural use) or afforestation in small mountainous watersheds can have a direct effect, in a negative or positive way, on the discharge characteristics and the sediment concentration of the water courses in the respective watersheds. However, according to Hamilton (1987), a mountain forest does not guarantee soil and water conservation per se. A forest without any canopy layers or litter cover may be much worse in terms of erosion than well-maintained sloping agricultural terraces or grazing lands. Big raindrops formed in the crowns of the trees might cause significant splash erosion on the unprotected soil. It is not the forest cover as such, but the vertical structure of the forest and the hydrologic properties of the forest soils that are decisive for the protective role of a mountain forest. There is yet another dimension to this: forest cover in a mountainous watershed only provides flood protection to near downstream dwellers in the case of normal rainfall events. In extreme events, floods and deep-rooted landslides will occur in any case, independently of the availability or absence of forest cover in the respective watershed.

5. Conclusions

The impacts of mountain deforestation on hydrological systems seem to be a question of scale (see also Ives and Messerli, 1989):

- Man-induced ecological changes in the Himalayas are documented in some specific examples at the local, small-scale level. Forest clearance in highland watershed, if not replaced by well-maintained agricultural terraces or other adapted and well-managed land-use systems, can lead to increased runoff and accelerated soil erosion in these local watersheds.
- At the large scale of the Ganges-Brahmaputra-Meghna system it has not been possible to find a significant correlation between human activities in the
mountains (e.g. forest removal) and catastrophes in the plains (e.g. floods), and the human influences seem to be concealed by the overwhelming dimensions of natural processes. There is no statistical evidence that the frequency or the volume of flooding in Bangladesh has increased over the last 120 years. Furthermore, precipitation and runoff in the Himalaya do not seem to contribute significantly to the floods in Bangladesh. Because the Himalayas are so far from the Bangladeshi floodplains, the flood flows and peaks of Himalayan tributaries are integrated and “leveled” into the base flow of the bigger rivers as they move downstream. The Meghalaya Hills, however, have a greater potential to contribute to downstream flooding because of their close location to the floodplains of Bangladesh and their high rainfall.

If these findings are accepted it gets obvious that it is not admissible to extrapolate results from a small watershed in the Himalayas to the entire Ganges-Brahmaputra basin. It also becomes clear that the habit of blaming mountain dwellers and their land-use practices for the flood catastrophes in the plains far downstream must be abandoned. However, this does not relieve the mountain people of their responsibility to use their environment in a sustainable manner. Mountain forests are crucial for the ecology of the entire Himalayas and the people who depend on them, and afforestation programmes should therefore be regarded in this context, and not as a means of preventing flooding in the lowlands.

These statements represent results from work in progress. A lot of questions about the effects of forest removal in the highlands on flooding in the lowlands remain open and need to be further explored, provided the availability and accessibility of data improves in the future. The e-mail conference on land and water linkages in rural watersheds, conducted in 2000 by FAO, has significantly contributed to the further understanding of these processes. In addition, FAO is carrying out an exercise entitled “Preparing the Next Generation of Watershed Management Programmes” in which highland-lowland linkages are a key aspect. The International Year of Mountains 2002 has provided an excellent platform for the discussion of these issues and the forthcoming International Year of Freshwater 2003 promises to do the same.
Box 1: Have floods in Bangladesh increased as a result of deforestation or land use changes in the Himalayas?

The last 20 000 years: large depositions in the Bangladesh delta indicate that massive floods must have occurred regularly long before man’s impact on the large watersheds of the big rivers began.

18th and 19th centuries: a number of major floods were recorded. Fluctuations in flood frequency correspond to fluctuations of the monsoon rainfall. The catastrophic flood of 1787 was associated with an earthquake and resulted in major river course changes in the territory of modern Bangladesh.

1890 to the present: there is no evidence that the frequency of major floods in Bangladesh has increased. There is some indication, however, that the inter-annual variation of the flood dimension and the areal extent of big events have been increasing since 1950. These trends can be related to similar trends in rainfall and discharge patterns. The concentration of suspended sediments in the Ganges, Brahmaputra and Meghna is highly variable over time and is not well correlated to the amount of river flow. The investigation of the available time series did not indicate any trend towards increased sediment load.

Based on demographic statistics and land holding figures it is obvious that the impacts of flooding and the vulnerability of the Bangladeshi population to flooding must have increased.

Large-scale flooding has always occurred in Bangladesh. Based on these project findings there is no reason to assume that anthropogenic activities in the Himalayas have changed the frequency and dimension of flooding in Bangladesh.
Box 2: No connection between flooding in Nepal and flood processes in Bangladesh in 1993

Evidences from Nepal: between 19-20 July 1993, an extraordinary flood event took place in eastern and central Nepal with catastrophic effects: several districts were hit by floods and landslides, and many people died or became homeless. Widespread destruction of crops occurred in the wheat-growing zone in the Terai. Due to very high sedimentation the life-span of the Kulekhani-Reservoir was reduced by many years. This catastrophic flood is hardly documented in the water-level graph of the Ganges at Hardinge Bridge, located approximately 600 km downstream to the flood-affected areas in Nepal. The flood peaks of the Nepalese tributaries to the Ganges were leveled.

Evidences from Bangladesh: two flood periods were identified: 18-25 June and 10-26 July 1993. Both events were the result of heavy rainfall in Bangladesh and were concentrated on the Meghna and Brahmaputra systems. Western Bangladesh, which is the only part of the country which belongs to the Ganges system, was almost completely unaffected by flooding.
Box 3: Rainfall in the Meghalaya Hills is decisive for flood processes in Bangladesh

Rainfall in Cherrapunji: Cherrapunji, a small town located on the southern slopes of the Meghalaya Hills, receives very high rainfall. The average monsoon rainfall (May to September) amounts to 9,527 mm, in 1974 it reached as much as 19,728 mm. The rainfall at Cherrapunji in the monsoon months of 1974 and 1988, which were two major flood years in Bangladesh, was far above normal. Indeed, some of the anomalies were extraordinary. In 1978 and 1986, years of very low flood dimension in Bangladesh, the rainfall in Cherrapunji was below average.

Discussion: the Meghalaya Hills are located adjacent to the vast floodplains of northeastern Bangladesh. They form a first orographic barrier for the humid monsoon winds on their way from the Bay of Bengal to the Himalaya. The southern slopes of the Meghalaya Hills, in particular, receive very high rainfall during the monsoon months. In addition, the shallow soils produce high surface runoff. As a result, considerable quantities of water pour down the steep slopes of the Meghalaya Hills into the Meghna floodplains of Bangladesh.
References


Figure 1: Catchment area of the Ganga, Brahmaputra and Meghna rivers