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Management of Water for the Prevention of Environmental Hazards

The paper points out that the HKH is inherently vulnerable to environmental hazards that often lead to disastrous consequences. Despite the fact that climate and hydrology are the principal causes of, as well as contributing factors to, natural hazards, research and data sharing in these fields have been limited. The paper concludes that management of environmental hazards essentially depends on management of water and calls for regional cooperation towards this end.

Background

Extending about 3,500km from Afghanistan in the west to Myanmar in the east, the Hindu Kush-Himalayas (HKH) are home to nearly 120 million people and influence the life of more than three times as many living in the downstream basins and plains. As the largest storehouse of fresh water in the lower latitudes, these tallest mountains and the Tibetan plateau are important water towers for nearly 500 million people on this earth and are the sources of such mighty rivers as the Indus, the Ganga, the Yarlung-Tsangpo, the Brahmaputra, the Nu-Salween, and the Mekong.

The combination of inherently weak geology and intense precipitation that characterise these mountains make them extremely vulnerable to hazards even in normal climatic conditions.

The HKH, as the youngest mountains on earth, are also tectonically very active and hence inherently vulnerable to hazards. In addition, these mountains are exposed annually to intense, seasonal precipitation during the four months (June-September) of summer monsoon, particularly in the eastern parts. This acts as a trigger for various types of natural hazards in different elevation zones. If snow avalanches and glacial lake outburst floods predominate at very high elevations (>3500m), then landslides, debris flows, and flash floods are common in the middle mountains (500-3500m). Floods are the principal hazards in the lower valleys and plains. During extreme weather events, the consequences are disastrous. Hundreds of lives and billions of dollars worth of property and investments in high-cost infrastructure are lost in the region every year due to landslides, debris flows, and floods, along with the destruction of scarce agricultural lands. In China, for example, landslides alone are estimated to cost US $ 15 billion and 150 deaths annually (Li 1996) and, in Nepal, landslides and flood hazards cause destruction of important infrastructures worth US $ 2.5 million and about 400 deaths annually (Khanal 1996).

It is seen that with the existing and available data and evidence, it is difficult to quantify the relative contributions of Man and Nature in the environmental degradation of the HKH and much of the 'uncertainty' and 'dilemma' originate due to the absence of long-term and reliable data that could be used to understand the governing processes on macro/micro/meso-scales (Ives and Messerli 1989).

Despite the fact that climate and hydrology are the principal causes of, as well as contributing factors to, natural hazards in the HKH, scientific research in these has not received enough attention. This is primarily because the establishment of reliable monitoring systems to collect data on climate and hydrology is not easy and involves very high costs in these high mountains where accessibility is difficult. In addition to these physical difficulties and the huge costs, which are not easily affordable by the countries of the region, hydrometeorological services and research in the HKH mountains have a short history in many countries of the region. (Afghanistan is an extreme case

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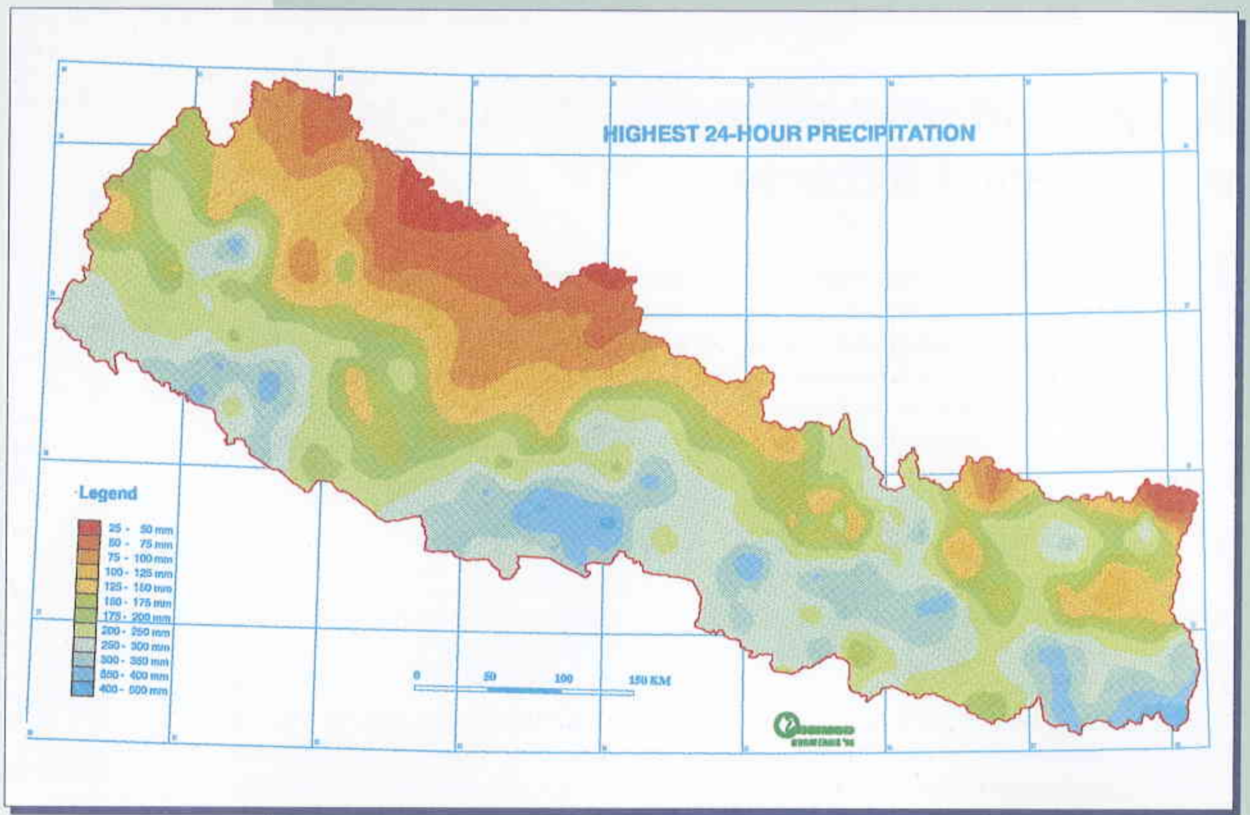


***Source**: Climatic and Hydrological Atlas of Nepal, ICIMOD, 1997*

Water-induced disasters of varying intensity and magnitude regularly affect various parts of Nepal. The principal triggering factor is the monsoon rainfall which is mostly confined between June and September each year. Although local geology, land-use, and steepness of slopes are also important contributing factors to such disasters, the intensity, amount, and spatial distribution of rainfall are the key elements that determine the extent and magnitude of damage caused by such disasters. Rainfall data are, therefore, extremely important. Some analysis of available rainfall data for Nepal, carried out at ICIMOD, indicates that rainfall maps could be useful for primary identification of water-induced, disaster-prone areas, despite the limitation of data availability (Chalise, Shrestha and Nayaju 1995).

where the civil war has destroyed the hydrological and meteorological stations.) Although hydrological and climatic data for operational and forecasting purposes are regularly collected in many countries, the sharing of such data for research is virtually non-existent.

Despite uncertainties, potential impacts of global warming which could affect the HKH region include increased monsoon rainfall, increased precipitation, and shrinking of areas under snow and permafrost (Chalise 1994)

Hazards and Uncertainties

Much of the discussion regarding environmental degradation in the HKH which started in the mid-70s (Eckholm 1975 and 1976) focussed primarily on ecological concerns, particularly on deforestation caused by the fast growing human and animal population and its impact on local and regional ecology and economics, particularly erosion and sedimentation. Since then the bulk of the research work, whether field-based or based on available data, has primarily focussed on ascertaining in quantifiable terms the relative roles, impacts, and contributions of human and natural processes in causing environmental degradation in the region. A recent study has shown that human processes are more important for micro-basins whereas natural processes predominate in macro-basins, and, without a fuller understanding of the processes occurring on the meso-scale and the linkages between these processes on different scales, it is not possible to be certain of the roles of Man and Nature (Grosjean et al. 1995).

These preoccupations with the roles of Man and Nature have somewhat overshadowed the fact that the HKH environment is not only inherently (geologically) fragile but also subjected to two powerful triggering factors - earthquakes and climate. Of these, climate affects the environment regularly and more intensely during the extreme weather events that occur more frequently. Therefore, the long-term average annual loss of life and property due to floods and landslides associated with normal as well as abnormal weather conditions becomes significantly high compared to the loss from earthquakes. Although extreme weather events could be associated within the normal fluctuations of climate, it is important to ascertain whether or not the increasing frequency of extreme weather events is within these normal fluctuations. The implications are therefore of an increase in hazardous events, particularly in hydrological aspects, since both accumulation and ablation of snow occur in the summer in most parts of the HKH. In any case, it is obvious that both the inherent and triggering factors contribute towards the hazardous nature of the HKH environment, and the incidences of natural disasters are likely to increase rather than decrease.

Hydrology and Sustainable Development in the HKH

There is yet another important aspect of water management in the HKH that needs to be emphasised. Water is not only a principal contributing factor to environmental hazards. It is also a critical resource not only because of its rapidly growing demand due to rural, urban, and industrial development in the HKH, but also because it is the single-most important resource which, if harnessed properly, could generate enormous power, control floods, irrigate millions of hectares of land, and radically transform the economy of the region to ensure prosperity for all (Verghese 1990).

Although water has also been a contentious issue in the region in the past, more recently there have been important and encouraging agreements between countries in the region concerning the sharing and development of water resources for mutual benefit. The theoretical power potential of the region exceeds 310,000MW, and even smaller countries such as Bhutan and Nepal are considered to possess hydropower potential of 20,000MW and 83,000MW respectively (Chalise et al. 1994). These estimates would be much greater if all the potential sites for mini-and micro-hydro stations could be assessed. Hence, high expectations from water are not unfounded.

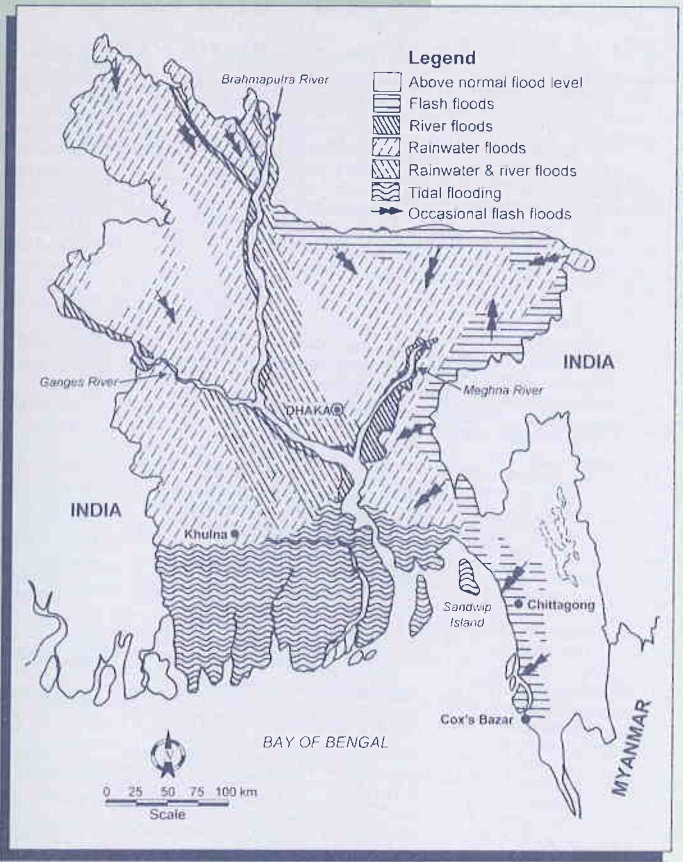
Although reliable rainfall data, even for the past 50 years, are generally not available for many areas of the HKH region, it is seen that smaller watersheds or subwatersheds (<50km^2) are more affected than the bigger ones by disasters caused by flash floods and debris flows triggered by intense rainfall associated with extreme weather events, as was seen in Central Nepal during July 1993 & 1996, and August 1996 (Dhital et al. 1993, ICIMOD 1996 and DPTC 1996). It has also been seen that new settlements, which are often located on old landslide deposits or on the debris fan in such small watersheds, close to recently constructed roads, are the worst affected by flash floods and debris flows. Again, hydrological monitoring and measurements in such watersheds are difficult, particularly because big boulders often roll down the rivers and streams and can damage or destroy hydrological monitoring and measuring stations during the monsoon. In addition, the river beds are normally unstable due to very high volumes of sediment discharged from upstream mountain slopes. These problems demand innovative and intensive hydrological monitoring systems in the HKH mountains. Smaller watersheds are also often inhabited by poor and marginalised farmers who have to live with the local environmental hazards.

Sustainable harnessing of such enormous potential requires adequate scientific understanding of the hydrology of the region which, in turn, can help develop regional cooperation in the management and optimal utilisation of water resources for multifarious benefits on scientifically sound and objectively realistic terms.

From the foregoing discussion, it is obvious that management of environmental hazards essentially depends on management of water. Similarly, management of water is also critical for using the huge potential of water for power, irrigation, and rural/urban and industrial supplies for sustainable economic development of the region.

Bangladesh Flood Types

Floods are found to be frequent disaster events in Bangladesh and their occurrence has increased several-fold. Almost every year flood damages human settlements, crops and properties; kills humans and livestock; disrupts transportation and communication networks; damages roads, railways and other development infrastructures; causes scarcity of food, water, and other basic necessities; spreads water-borne disease sometimes resulting in epidemics; brings untold miseries and suffering to the people; and seriously slows down the development process and economic growth in the country. A country cannot sustain such a recurrent loss. Suitable measures are deemed essential for mitigation of flood hazards (Shamsul Hoque 1995).



Features and Triggering Factors of Major Landslides in Pakistan

Features	Jalial	Kohala	Lowargali Muzaffarabad	Jaglot KKH	Riala Village, Ayubia	Simbal motorway (M1) Lahore
Slide material	Clay and sandstone	Clay, silt sand and broken rock	Schists and slates	Glacial till	Shale marl and limestone	Overburden of shale and limestone fragments
Slip surface	Circular in clay and fractured rock	Circular in clay, fractured rock Failure in old landslide	a. Planar failure b. Wedge failure c. Creep	a. Flow b. Wedge failure c. Creep	Circular (mainly), toppling and rockfall in limestone only	Circular
Rate of movement	Generally slow	Generally slow but becomes rapid after rainfall	Mostly slow Rapid in some places	a. Slow generally b. Rapid at times	Rapid in May 1988, slow in 1991, 1993, and 1994	Slow in 1993, rapid in Aug. 1994
Behaviour of mass movement (volume displaced)	Mixture of disintegrated mass	Mixture of disintegrated mass with large blocks (70,000m^3)	Small blocks and splintery material (volume varies)	Mixture of soil and rock blocks	Mixture of soil and fractured limestone	Mixture of boulders, cobbles, and clay/shale
Triggering factors	Rainfall	Rainfall (mainly) Earthquake 1992	Loading at head, rainfall and mass wasting	Snowmelt vibration and earthquake	Rainfall, pore pressures, fracturing of limestone	Rainfall

Malik and Farooq, 1994

Introduction of Heisha River Debris Flow and Its Integrated Control, Sichuan Province, China (from the Case Study Report on Debris Flow in the People's Republic of China by Li Tianchi in Training Manual Module III: Capacity Building in Landslide Management and Control, ICIMOD 1996)

Heisha River in Xichang area, south-west Sichuan, China, was famous for debris flow hazard. The bare mountains, broken rock strata, and many landslides caused high-frequent debris flows. During the 1950s and 1960s, five villages were destroyed one after another, 3,000 *mu*[1] of cultivated land became wasteland. The Chengdu-Kunming Railway, the Sichuan-Yunnan Western Road, and three main canals of Xichang city were seriously disturbed. Twelve villages, one power plant, and more than 6,000 *mu* of cultivated land were endangered by debris flow.

An integrated plan for Heisha River debris flow control started in 1971 and was completed in 1978. Civil engineering works included one flood-regulating reservoir, seven sediment-trapped dams, four checkdams, seven division dams, a 5.8km long division dyke, and one flood-relief channel; bio-engineering works included planting water-source holding forests - 12,000*mu* (including air-seeding forests before), water and soil conservation forests - 6,000*mu*, seven lines of debris flow preventing forests, and 31 lines of windbreak forests; and improving farmland engineering works included building terraced fields of more than 3,200*mu*.

Since then, debris flow in the Heisha River has not reoccurred. The construction also endured a 50-year recurrence-period rainstorm. Observations indicated that the solid materials carried by floods to the ravine mouth section were 1/5 of those before control constructions, and peak flood discharge caused by a 10-year recurrence period rainstorm was 12-20% of that before control measurement, in which the discharge from the mainstream was only 1/20. Not only were the railway, roads, canals, factory, and villages and farmland safeguarded, but also cultivated land increased to 4,500 *mu* of crop fields with high stable yields. According to the data of 1980, the grain yields increased 50 to 100% more than the yields before control measurement. The silkworm nursery built on the former debris flow wasteland fan became a highlight of Liangshan Prefecture, with annual benefits of 10-15 million *Yuan*[2].

1. 15 *mu* is equal to 1 ha.
2. There are 8.5 *yuan* to the US dollar

Regional Cooperation on Hydrological Research

A hazardous combination of weak geology, intense monsoon precipitation, and high relief within short distances has also hindered the growth of knowledge and understanding of the hydrology of the region. Again, transfer of hydrological models and techniques of measurement developed in the temperate region for use in the HKH mountains is difficult and could also be inappropriate. Hence, development of adequate understanding of the hydrology of the HKH mountains depends very much on studies carried out in the region based on reliable and adequate data on hydrology, meteorology, and other relevant parameters. Thus, generation and sharing of such reliable data among the researchers of the region are of fundamental importance.

For various reasons outlined above, hydrological research in the region has either a weak base or is carried out in isolation and modern techniques and methods and instruments used for hydrological studies are also not within the reach of researchers in hydrology. Thus, development of human capability is a must and should be the first step in embarking on the challenging task of developing an adequate knowledge of hydrology to solve the problems of management of environmental hazards and optimal and sustainable development of the rich water resources. UNESCO and ICIMOD in collaboration with all the regional countries and the World Meteorological Organisation have been successful in launching a HKH Flow Regimes from International Experimental and Network Data (FRIEND) project in this region in order to develop a regional hydrological research programme for the HKH.

As HKH-FRIEND has evolved through a series of regional consultations within the framework of UNESCO's International Hydrological Programme since December 1989, it is based on the real needs of researchers in hydrology in the region. Its priorities have also evolved accordingly. It is therefore expected to provide an active forum and institutional base for intensifying hydrological research through exchange and sharing knowledge, experience, and data among researchers in the region. Considering the extreme vulnerability of small watersheds, it would be appropriate to focus research on watersheds in diverse climatic and altitudinal settings and develop a regional database on participating watersheds. Watersheds that are presently under study and have monitoring systems should be considered for this research work instead of new watersheds.

The challenges of preventing and managing environmental hazards and sustainable development and management of water resources in the HKH are enormous and complex, but a beginning has been made by launching the HKH-FRIEND.

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