Managing socio-economic and hydrological risks in northeast India

U. C. SHARMA[1] & VIKAS SHARMA[2]

1 *Centre for Natural Resources Management, VPO Tarore, District Jammu 181133, Jammu and Kashmir, India*
ucsharma2@rediffmail.com

2 *SK University of Agricultural Sciences & Technology, Chatha, Jammu 180009, Jammu and Kashmir, India*

Abstract Northeast India is vulnerable to hydrological risks such as flood-drought-flood syndrome, eutrophication of water bodies, huge runoff from hill slopes resulting in soil erosion, settling of contaminants in different sinks, contamination of surface water and groundwater because of its fragile geo-environmental setting and economic underdevelopment. The region paradoxically suffers from both water excess as well as water shortage. Three factors control flood hazard and vulnerability in the region; changes in climate, terrestrial and socio-economic systems, whose relative order of importance is site specific. The socio-economic risks are shifting cultivation as major agriculture land use, unique land tenure system, free range grazing, inaccessible terrain, population growth, economic and financial risks, and proper infrastructure to deal with the risks. Climate change will increase existing risks of species extinction and biodiversity loss. A multidisciplinary study was undertaken to evolve eco-friendly and viable land-use systems to replace shifting cultivation, a major risk factor.

Key words socio-economic and hydrological risks; risk management; northeast India

INTRODUCTION

Risk management is the term used here for the systematic approach and practice of managing uncertainty and potential losses, involving risk assessment and analysis and the development of strategies and specific actions to control and reduce risks and losses. The northeastern region of India, having an area of 255 090 km^2, is predominantly hilly. It presents a distinctive geophysical unit set in the pristine Eastern Himalayan Region with a unique physiographic framework having a monsoon dominated climate and a dynamic hydro-geomorphic regime. The region is endowed with rich water resources but their indiscriminate use has rendered them in a fragile state (Sharma, 2001). Northeast India is vulnerable to water-induced disasters because of its location in the eastern Himalayan periphery, fragile geo-environmental setting, and economic underdevelopment (Sharma, 1999). Having two major river basins, namely Brahmaputra and Barak, the region possesses about 30% of the total water resources potential, and about 41% of the total hydropower potential of the country. A high degree of vulnerability to the water and climate-induced disasters will increasingly make the region environmentally insecure in the future, unless pragmatic interventions are made immediately. Flood risk and vulnerability have been growing over many decades and are projected to grow in the future. Climate change is likely to have major implications for wetland ecosystems, which will include altered water level regimes due to modifications in local and catchment hydrology. The socio-economic factors in the region are mainly responsible for the decline of water resources. The hydrological and socio-economic risks are intimately interconnected. One of the most important constraints in water resources management is the incomplete knowledge of water resource systems, both as to their current dynamics and their future evolution. Climate change will increase existing risks of species extinction and biodiversity loss. The focus of the study is on risk assessment, as well as on measures to reduce risk within the framework of water resources management and integrate risks across various sectors. The hydrological changes are expected to be so large that they have to be considered explicitly in long-term integrated river basin management.

SITE OF STUDY

The site of study is the northeastern region of India, having 255 090 km^2 area and comprising seven states of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland and Tripura

(Fig. 1). To manage water resources effectively, a long-term multidisciplinary study is in progress since 1983, with seven land-use systems with watershed approach, to monitor their comparative efficacy with regard to *in situ* retention of rainwater, water yield as runoff, loss of soil from different watersheds, as well as to evolve eco-friendly, viable and sustainable land-use systems for higher productivity to ensure food security, resource conservation to manage hydrological and social risks. Besides the above, ecological aspects and economy of different land-use systems is also under investigation. The watersheds have slopes varying from 32% to 53%. The soil conservation measures followed were bench terracing, half-moon terraces, trenching and grassed water-ways. The land-use systems are livestock based (grasses and fodder crops), forestry, agro-forestry, agricultural crops, horticulture, agri-horticultural crops and shifting cultivation as control. The soil and nutrient losses were monitored through monitoring gauges fixed at the exit point of each watershed.

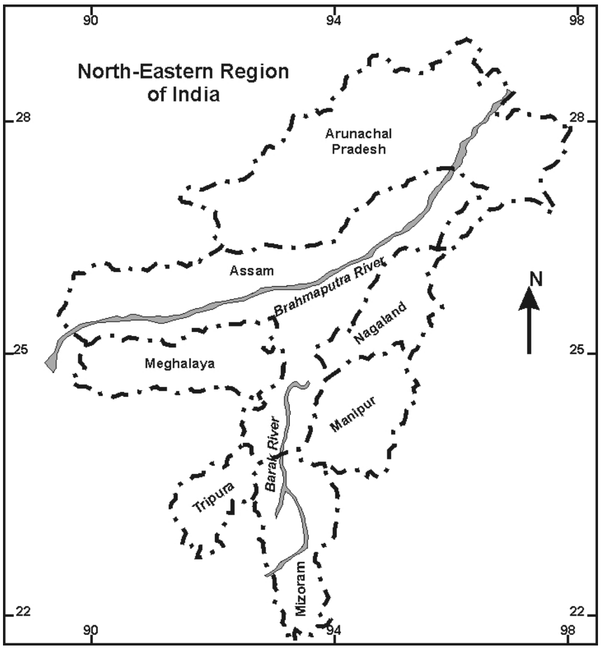

Fig. 1 Northeastern region of India.

RESULTS AND DISCUSSION

With an economy closely associated with its natural-resource-base and climate-sensitive sectors such as agriculture, water and forestry, the region faces a major threat because of changes in climate. The majority of the vulnerable population is poorly equipped to cope effectively with the adversities of climate change due to low capabilities, weak institutional mechanisms, and lack of access to sufficient resources. With a large population dependent on it, agriculture has always been vital to development policies of the region. Northeast India is vulnerable to hydrological risks such as the flood–drought–flood syndrome, eutrophication of water bodies, soil erosion, settling and contamination of surface water and groundwater. The socio-economic risks are shifting cultivation as major agriculture land use, land tenure system, free-range grazing, population growth, economic and financial risks, and proper infrastructure to deal with the risks. In northeastern India, the social sanctions and belief system maintained a balance between resource potential and their utilization for a long time, but due to the increase in the demographic pressure and indiscriminate use of natural resources, imbalance has been created. The fast growing population in the region has pressurized the food production base and to satisfy their needs, the people have mismanaged and misused water resources (Sharma, 2003). The region receives about 510 km^3 of water as rainfall, at an annual average of 2474 mm. However, gross misuse and mismanagement of rainwater has resulted in soil erosion, and land and environment degradation in the hills, and silting of river beds and frequent floods in the plains (Sharma, 1998). It has been estimated that total annual loss of soil and nutrients through erosion from the region is 601.2 and 1.434 million tonnes, respectively (Table 1). The annual rate of individual annual contribution towards soil loss from shifting cultivation, cultivated and non-cultivated areas is estimated to be 60.2, 25.5 and 20.2 t ha^{-2}, respectively (Sharma & Prasad, 1995). The huge sediment load settles in different sinks, including river beds, thus making them more prone to overflow their banks, leading to floods. This shows that faulty agricultural practices are, by far, the most responsible factor for creating a risky situation in the region.

Table 1 Loss of soil and nutrients from the northeast region of India.

State	Shifting cultivation	Soil loss (10^6 tonnes) Other cultivated areas	Non-cultivated areas	Total	Nutrient loss (10^3 tonnes)
Arunachal	14.5	2.9	160.7	178.1	454.0
Assam	12.3	67.7	98.3	178.4	438.7
Manipur	20.4	2.9	40.8	64.0	156.4
Meghalaya	14.2	3.8	39.7	57.7	126.8
Mizoram	13.0	2.2	39.4	53.6	116.1
Nagaland	8.0	4.8	28.9	41.7	91.2
Tripura	5.9	6.4	15.4	27.7	51.4
Total	88.3	90.7	422.2	601.2	1434.4

The hydrological risks

The various extreme hydrological events, which have devastated many parts of the world, are a reminder of the dramatic consequences of extreme climatic events on people and society (Prudhomme *et al.*, 2002). There is a growing concern regarding these events as they are now more frequent and severe than has been observed earlier in the region. Because uncertainties are associated with such extreme events, the mitigation, as well as adaptation issues, have become more complex. The quantification and understanding of hydrological variability is of considerable importance for the estimation of flood risk. At present, traditional methods are largely empirical in that annual maximum floods are assumed to be independently and identically distributed (Franks & Kuczera, 2002). Flood risk is a key hydrological variable in terms of social and economic importance. Problems related to high streamflows are complex and are affected by natural, i.e. climatic, hydrogeologic, morphologic, etc., and anthropogenic, i.e. urbanization, irrigation, water works, socio-economic factors and human interference through deforestation and land use. The physical processes giving rise to floods of a given probability of occurrence are controlled by range of variables, including rainfall regime, snowmelt, state of the catchment and catchment characteristics. Because of this complexity, analysing and estimating of flood probabilities is usually based on fitting a statistical distribution to a sample of observed flood peaks or regionalized flood information (Merz & Bloschl, 2003). The quantification and understanding of hydrological variability is of considerable importance for the estimation of flood risk (Kiem & Franks, 2003). It appears that most of the studies have focused on one or a few out of many possible indicators of inferring the causative mechanisms of floods.

The climate of the northeastern region undoubtedly plays a major role in causing the floods, and precipitation is by far the single major factor. The huge runoff from high-gradient hill slopes carry very high content of sediment load, which results in siltation of river beds, thereby reducing their intake capacity year after year. The flood control measures in the tectonic alluvial plains almost invariably rely on structural measures such as embankments (Musiake, 2003). However, the embankments further complicate the problems by causing siltation of the river channel and lowering of its intake capacity. The gentle gradients in the valley areas make the flow of the Brahmaputra River in a highly braided channel with numerous sand bars and islands, bifurcating the river course at several places en route. Judicious management of rainwater by introducing eco-friendly land uses in the region would be a positive solution to reduce the flood risks.

Socio-economic risks

Prevalence of shifting cultivation in 3869 km^2, annually and affecting about 14 660 km^2 area, is the major factor associated with many risks in the region. There is annual loss of 83.3 million tonnes of soil and 10.65, 0.37 and 6.05 thousand tonnes of available N, P_2O_5 and K_2O, respectively due to shifting cultivation alone (Sharma & Prasad, 1995). The forecasts indicate that by 2021, an additional 20 million people will be part of the population of the region, thereby increasing the competition from various sectors of the society for more quantity of water and thus, exerting more pressure on the resource base (Sharma, 2003). There are three categories of land ownership in the northeastern region: land belonging to village chief, land belonging to the village community as a whole and land in individual names. In the first two categories, the people have only usufructuary rights over the land and, therefore, they have no interest in undertaking conservation measures because the land can be taken back from them at any moment. The land holdings are small and fragmented. More than 78% of the land holdings are less than 2 ha. On the hill slope, the land may belong to a number of farmers who have conflicting opinions about integrated resource management.

The annual compound growth rate in population of the region between 1951 and 2001 has been 2.64% in the northeastern region (Table 2), compared to 2.06% in the country as a whole. Increase in demographic pressure has led to degradation of the very resource base in the region due to misuse and abuse of natural resources. The food-grain deficit has increased steadily and continuously in the region. With a population of about 54 million by 2021, the region's capacity to produce sufficient food will be further severely tested. Most of the opportunities for opening new agricultural land to cultivation have already been exploited by encroaching onto forest land, and now are almost exhausted. To meet the projected demands, the productivity has to be increased. Without proper awareness, the encroachment on marginal and fragile land is increasing and threatening the health of the terrestrial ecosystem, thus putting it at risks of a severe nature.

Table 2 Population (million) and, food-grain requirement, production and deficit (million tonnes) in Brahmaputra basin.

Year	Population	Requirement	Food-grain: Production	Deficit
1951	9.07	1.81	1.26	0.55
1961	12.31	2.46	1.70	0.76
1971	16.62	3.32	2.47	0.85
1981	20.77	4.14	3.09	1.05
1991	26.26	5.25	4.04	1.21
2001	33.45	6.68	4.91	1.77
2021 (expected)	54.07	10.81	7.80	3.01

Risk management

Risk arising from climatic hazards can be addressed by preventative measures, such as avoiding settlement in flood plains and building strong buildings; and monitoring, with early warning and response measures to manage extreme events. Weather and climate-sensitive sectors such as water supply, agriculture, food security, energy, transportation, environmental management and public health need special attention. Special efforts are needed to bridge the gaps between sectoral organizations, in order to share relevant information concerning risks and their management as well as achieve efficiencies and synergies. This should include the systematic consideration of risk and risk reduction strategies in national integrated strategies and plans.

Flood prevention and management

The root cause of the risk problems in the region is the prevalence of shifting cultivation and exponential increase in populations due to which more and more people live on marginal lands where there is a greater risk of floods. In order to reduce the economic impact of water-related natural disasters, it is important to impose the risk on a broader economic basis through insurance programmes. The prevalence of shifting cultivation in the region also results in heavy soil erosion, deforestation and water resources degradation (Sharma & Sharma, 2004). Rapid population growth, urbanization, uncontrolled developmental works, encroachments and land use in the region have significantly contributed to flood events and risk enhancement. The combined effect of prolonged and intense rainfall, steep slopes, well-developed drainage network and the fragile geology of the mountains make land inundation an annual event (Kattlemann, 1990). The knowledge of flood generation processes is crucial for evaluating the vulnerability of a region to floods. Management of emergencies arising due to floods can be conceptualized as consisting of four key elements namely; prevention, preparedness, response and recovery. Prevention can be affected by changes in land use, building regulations, levees, insurance incentives / disincentives etc.; preparedness is how resources at hand can efficiently be mobilized to cope with the floods; response means mobilization of resources, warning system implementation, flood rescue, medical assistance, etc. and recovery means the coordinated process of supporting affected communities in reconstruction of the physical infrastructure and restoration of social, economic and physical well being.

Replacing shifting cultivation

A multidisciplinary long-term study with various land-use systems was undertaken to evaluate their performance with regard to runoff, soil and nutrient loss, *in situ* rainwater retention, crop productivity and its impact on ecology and socio-economic conditions of the people of the basin (Table 3). The results showed that, on average, 0.11–1.97 tonnes ha^{-2} of soil loss and more than 90% of rainwater was retained *in situ* in new land-use systems compared to 36.2 tonnes of soil and 66.3% rainwater retention in shifting cultivation. Due to more infiltration of rainwater in the soil, the runoff has considerably reduced, which would result in low flows to river channel and reduced incidence of floods. The higher productivity in new land uses is likely to ensure livelihood security in the region and improve the quality of life and the environment, as well as reduce various kinds of risks. There is an urgent need to develop catchment-based methods that can be used to assess the impact on flood generation and flood risk of the impact of changes in land use and management.

Table 3 Effect of land use on the water-related parameters, crop yield and benefit/cost ratio (mean of 8 years).

Land use	Water yield from water-sheds (mm)	*In-situ* rainwater retention (%)	Soil loss (t ha^{-2})	Yield (rice equivalent) (kg ha^{-2})	Benefit/cost ratio
Fodder crops	14.0	99.4	0.16	2512	2.1
Forestry	433.3	82.3	1.97	1274	1.2
Agro-forestry	237.6	90.4	1.90	1832	1.5
Agriculture	20.9	99.1	0.11	2386	1.8
Agri-hort-silvi-pastoral	77.6	96.9	0.82	2433	1.9
Horticulture	212.0	89.3	1.82	1904	1.6
Shifting cultivation	835.3	65.9	36.21	726	0.6

CONCLUSIONS

For flood risk mitigation, a comprehensive watershed management approach provides the best solution. This approach has hydrological and social as two main components. The hydrological approach needs to be complemented by a social goal which aims to reduce the vulnerability of humans to floods in the region. With the population increase and changing climate in the region, changes are likely in the natural environment, causing stresses in natural and social habitats. The main approach is to increase the resilience of the population to various risks by strengthening the system for risk reduction at various levels. The key outputs should include the building capacity, including human resource development, strategies and tools, and knowledge and skills development. There is a need to provide the necessary equipment, legislative frameworks, and capacity building for integration of risk issues into development planning in the region.

From the perspective of management, there are several questions that need to be addressed in order to mitigate the risk of potential flood events in a most efficient manner, such as frequency and severity of the event, vulnerabilities and expected losses and mitigation efforts. The logical outcome of this process is the identification of measures that will provide an "acceptable" risk to society for the specific flood event at the lowest cost. Altering land use and agricultural practices in the region would ensure enduring food security. Proper policy frameworks for planning, management and development of water resources under such situations can be devised, taking advantage of the indigenous knowledge of some tribes of the region in water systems management. There is urgent need for replacement of shifting cultivation with alternate eco-friendly and sustainable land-use systems, enacting suitable land ownership laws and preventing free-range grazing in the region.

REFERENCES

Franks, S. W. & Kuczera, G. (2002) Flood frequency analysis: evidence and implications of Secular climate variability, New South Wales. *Water Resour. Res.* **38**, doi:10.1029/ 2001 WR000232.

Kiem, A. S. & Franks, S. W. (2003) The impact of climatic variability on flood risk. In: *Water Resources Systems – Hydrological Risks, Management and Development* (ed. by G. Bloschl, S. Franks, M. Kumagai, K. Musiake & D. Rosberg), 11–17. IAHS Publ. 281. IAHS Press, Wallingford, UK.

Kattelmann, R. (1990) Conflicts and cooperation over floods in the Himalaya Ganges Region. *Water International* **15**, 189–194.

Merz, R & Bloschl, G. (2003) Regional flood risk-what are the driving processes, In: *Water Resources Systems– Hydrological Risks, Management and Development* (ed. by G. Bloschl, S. Franks, M. Kumagai, K. Musiake & D. Rosberg), 49–58. IAHS Publ. 281. IAHS Press, Wallingford, UK.

Musiake, K. (2003). Regional Characteristics of hydrology and water resources in monsoon Asia. In: *Proc. First International Conference on Hydrology and Water Resources in the Asia Pacific Region,* vol. I, 1–8. APHW, Kyoto, Japan.

Prasad, R. N. & Sharma, U. C. (1994) *Potential Indigenous Farming Systems of Northeastern Region.* Indian Council of Agricultural Research Complex for Northeastern Hills Region, Barapani, Meghalaya, India.

Prudhomme, C., Jacob, D. & Svensson, C. (2002). Impact of climate change on flooding in the UK: a methodology for estimating uncertainty. In: *Friend 2002 – Regional Hydrology: Bridging the Gap Between Research and Practice* (ed. by H. A. Van Lanen & S. Demuth), 109–116. IAHS Publ. 274. IAHS Press, Wallingford, UK.

Sharma, U. C. (1998) Water management by the tribes of northeastern region: the traditional wisdom and future strategies. *Fert. News*. **43**, 43–49.

Sharma, U. C. (1999) Food security in the northeast: new paradigms. In: *Perspective for Planning and Development in Northeastern India* (ed. by R. C. Sundariyal, U. Shankar & T. C. Upreti), 197–212. GB Pant Institute of Himalyan Environment and Development, Almorah, India.

Sharma, U. C. (2001) Effect of farming systems type on *in-situ* ground water recharge and quality in northeast India. In: *Impact of Human Activity on Groundwater Dynamic* (ed. by H. Gehrels, N. E. Peters, E. Hoehn, K. Jensen, C. Leibundgut, J. Griffioen, B. Webb & W. J. Zaadnoordijk), 167–169. IAHS Publ. 269. IAHS Press, Wallingford, UK.

Sharma, U. C. (2003) Impact of population growth and climate change on the quantity and quality of water resources in the northeast of India. In: *Water Resources Systems – Hydrological Risks, Management and Development* (ed. by G. Bloschl, S. Franks, M. Kumagai, K. Musiake & D. Rosbjerg), 240–247. IAHS Publ. 281. IAHS Press, Wallingford, UK.

Sharma, U. C. & Prasad, R. N. (1995) Socio-economic aspects of acid soil management and alternate land use systems for northeastern states of India. In: *Plant-Soil Interactions at Low pH* (ed. by R. A. Date, N. J. Grundon, G. E. Rayment & M. E. Probert), 689–696. Kluwer Academic Press, The Netherlands.

Sharma, U. C. & Sharma, V. (2004) Implications of nutrient and soil transfer with runoff in the northeastern region of India. In: *Sediment Transfer Through the Fluvial System* (ed. by V. Golosov, V. Belyaev & D. E. Walling), 488–493. IAHS Publ. 288. IAHS Press, Wallingford, UK.