10.2478/v10060-008-0079-1

Annals of Warsaw University of Life Sciences – SGGW
Land Reclamation No 42 (1), 2010: 209–217
(Ann. Warsaw Univ. of Life Sci. – SGGW, Land Reclam. 42 (1), 2010)

Socio-economic aspects and impact of land use change on sediment production dynamics in the northeastern region of India

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Abstract: *Socio-economic aspects and impact of land use change on sediment dynamics in the northeastern region of India.* The northeastern region of India, with an area of 255 090 km^2, is predominantly hilly. Major socio-economic factors affecting sediment production in the region are; shifting cultivation, land tenure system, fast growing population, small land-holdings, deforestation and free range grazing. A multi-disciplinary long--term study showed that 92.9 to 99.1% of rainwater can be retained *in-situ,* compared to 66.3% in shifting cultivation. Mean annual soil loss varied from 11.2 to 97.2 t km^{-2} in new land use systems as against 3621.3 t km^{-2} in shifting cultivation. The sediment load per litre of runoff from watersheds varied from 1250–20,300 mg suspended sediment, 5.4 to 23.6 mg $NO_3 - N$, 2.3 to 6.5 mg $P–PO_4$, 17.2 to 35.8 mg K_2O, 0.4 to 1.8 mg Zn, 0.9 to 2.7 mg Mn, 6.5 to 12.0 mg Mg, 7.1 to 18.4 mg Fe and 4.0 to 7.2 mg SO_4. The sediment transport from the catchments showed spatial and temporal variations.

Key words: socio-economic aspects, land use change, sediment production, shifting cultivation.

INTRODUCTION

Though endowed with abundant natural resources, the north-eastern region of India has remained economically backward due to their indiscriminate use and mismanagement. Socio-economic constraints viz. shifting cultivation, land tenure system, small size of land holdings, unabated deforestation, free range grazing and undulating terrain have affected the sediment yield and, quantity and quality of available water (Sharma 1998, 2003). Shifting cultivation is an uneconomical socio-economic issue and the farmers are socio-culturally attached with the practice, because most of the festivals and rituals are associated with it. In most of the states of the region, the farmers have only usufructuary rights over land as the land belongs either to village chief or community. The fast growing population has pressurized the food production base and to satisfy their needs, the people have misused the natural resources (Sharma 2003).

The region receives about 510 km^3 of rain water, annually at an annual average of 2450 mm. Judicious management of water resources will not only reduce the heavy loss of soil and nutrients but also reduce the flood events in the region. Shifting cultivation is practised in 3869 km^2 area, annually in north eastern region of India; however the total affected area is 14 660 km^2. It has resulted in huge soil erosion in the hills and silting of river beds and floods in the plains.

Land clearance, land use change and other facets of catchment disturbance, soil conservation and sediment control programmes and dam construction are shown to have resulted in significant recent changes in the sediment loads of many world rivers (Walling 2000, 2008). Deforestation in shifting cultivation has depleted the biodiversity of the region. The important issue is to promote the conservation and sustainable use of natural resources which allow long term economic growth and enhancement of productive capacity, along with being equitable and environmentally acceptable (El Bassam 1997).

The region, though having sufficient water in aggregate, cannot boast of adequate quantities of water at all the places and during all the times. 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, land and environment degradation in the hills and silting of river beds and frequent floods in the plains (Sharma 1998). The problem has been aggravated by the prevalence of shifting cultivation in 3869 km^2, annually. There is annual loss of 83.3 million tones of soil and 10.65, 0.37 and 6.05 thousand tones of available N, P_2O_5 and K_2O, respectively due to shifting cultivation alone (Sharma and Prasad 1995). The major problems of facing the harmonious development and management of water resources system in the region are socio-economic constraints, paucity of reliable data and lack of human and institutional capacity necessary for confronting the complex interactions of the hydrological cycle with societal needs, socio-economic constraints and the environment. A long--term-multidisciplinary study was, therefore, undertaken to assess the soil and nutrient losses from the hill slopes, in-situ retention of rainwater as affected by vegetation and, water and soil conservation measures to reduce runoff as well as its impact on the environment.

MATERIAL AND METHODS

The northeastern region of India (Fig. 1), comprising seven states viz. Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland Tripura, is predominantly hilly. Due to anthropogenic and natural factors, the region is subjected to heavy soil erosion and sediment deposits in the river channels, causing floods. To study the socio-economic aspects, old records were scanned as well as benchmark survey was conducted in selected areas. For the impact of land use on sediment yield, a long-term multidisciplinary study was undertaken with seven and land use systems to monitor their comparative efficacy with regard to *in-situ* retention of rain water, water yield, surface and subsurface flows and sediment yield from different watersheds as well as to evolve eco-friendly, viable and sustainable land use systems to replace shifting cultivation. The watersheds have slopes varying from 32% to 53%, at an altitudes varying from 920 m to 980 m above mean sea level. The soil conservation measures followed were bench terracing, contour bunds, half-moon terraces, trenching and grassed water-ways. The scientists from the disciplines of soil and water conservation, soil science, plant protection and social sciences are engaged in the project to study their relevant fields. The soil and

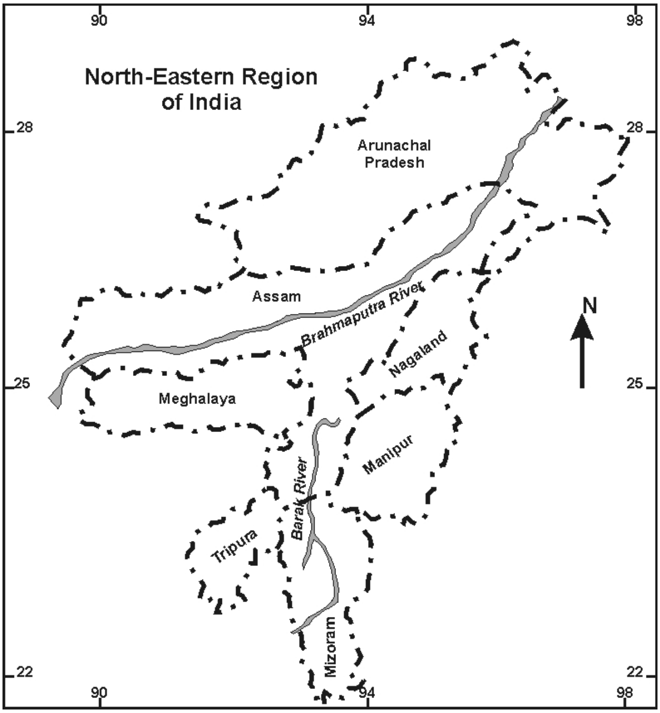

FIGURE 1. Northeastern region of India

TABLE 1. Vegetation cover in different land use systems

Land use	Slope [%]	Crops/trees	Livestock	Soil and water conservation measure
Livestock (grasses and fodders)	32.0	Maize, rice-bean, oats, pea, guinea grass, tapioca, broom grass	Cows, pigs, rabbits	Contour bunds, grassed water-ways, trenches
Forestry	38.0	*Alder nepalensis*, *Albziia lebbeck*, *Acacia auriculiformis*	None	None
Agro-forestry	32.2	*Ficus hookerii,* Eucalyptus, guava, pine, pineapple, french bean, pulse crops	Goats, rabbits	Contour bunds
Agriculture	32.4	Beans, radish, maize, paddy, ginger, turmeric, ground-nut, oats, grasses on risers	Cows	Bench terraces, contour bunds, grassed water-ways
Agri-horti--silvi-pastoral	41.8	Beans, vegetables, guava, citrus, ginger, *Alder nepalensis*, *Ficus hookeri, grasses*	Pigs, goats	Bench terraces, contour bunds, grassed water-ways
Horticulture	53.2	Peach, pear, citrus, guava, lemon, vegetables	None	Same as above

nutrient losses were monitored through monitoring gauges fixed at the exit point of each watershed. The meteorological data were collected in the observatory located near the project site. The crops grown in different land use systems, soil conservation measures followed and animals kept as per farmer's requirement are given in Table 1. The chemical analysis of soil and water samples was done as per procedures outlined by Jackson (1973).

RESULTS AND DISCUSSION

Socio-economic aspects

The homo-sapiens were under awe of natural objects such as mountain, oceans, rivers, forests etc., from the pre-historic age. The people were small in number, primitive in technology and their needs were extremely limited. Slowly, their number increased and needs multiplied. The northeastern region is inhabited by various tribes and their economy can conveniently be divided into hunting, nomadism, pastrolism, shifting cultivation and now, settled cultivation up to some extent. The rural economy of the region is mainly dependent on shifting cultivation. In the past, when the land was in abundance and population sparse, the rotational cycle of shifting cultivation in the region used to be 25 to 30 years, the land getting enough time for rejuvenation of vegetation. The soil fertility was maintained with *in-situ* burning of vegetation of forests and the production was enough to feed the limited population. However, with increase in population, the rotational cycle has come down to 2 to 10 years and the land does not get enough time for rejuvenation. The sediment yield from shifting cultivation areas has increased tremendously (Tab. 2). The annual area under shifting cultivation in the region is 3869 km^2, whereas total area affected is 14 660 km^2 and about 443.3 thousand families are involved in the practice (Anonymous 2000). Shifting cultivation is not only a set of agricultural practices but implies the whole nexus of people's religious beliefs, attitudes, self image and tribal identity. This kind of inter-connections between different elements and domains of social life restricts the cultivators to leave shifting cultivation. As high as 70.6 and 130.2 t ha^{-1} of annual soil loss has been reported during first and second year of shifting cultivation on a hill having a slope of 70% (Singh and Singh 1978). Annual soil loss from the region is 88.3 million tonnes from shifting cultivation land, 90.7 million tonnes from other agricultural land and 422.7 million tonnes from non-agricultural land. It was estimated that annual loss of N, P, K, Mn, Zn, Ca and Mg is 686.0, 100.2, 511.0, 22.7, 14.0, 57.3 and 43.4 thousand tonnes, respectively (Sharma and Sharma, 2004). The soil fertility is on decline as there is limited material to burn and add to the soil (Tab. 3). The results showed that at least 20 years time is necessary for rejuvenation of enough vegetation to get optimum available major nutrients for crop support. In 20 years cycle, the available N, P_2O_5 and K_2O increased by 55.1%, 22.8% and 128.4%, respectively over their initial status. The low increase in available P_2O_5 compared to other nutrients was due to the reason that soil was strongly acidic in reaction, most of the phosphorus got fixed as aluminium and iron compounds.

TABLE 2. Shifting cultivation and soil and nutrient loss in the region

State	Shifting cultivation			Total soil loss [million tonnes]	Nutrient loss [000' t]		
	Annual area [km^2]	Fallow period [years]	Soil loss [million tonnes]		N	P	K
Arunachal pradesh	700	3–10	14.5	178.1	217	36.6	153
Assam	696	2–10	12.3	178.4	201	33.4	155
Manipur	900	4–7	20.4	64.0	76	7.4	63
Meghalaya	530	5–7	14.2	57.7	62	7.0	48
Mizoram	630	3–4	13.0	39.4	60	6.9	40
Nagaland	190	5–8	8.0	41.7	44	5.2	34
Tripura	223	4–9	5.9	15.4	26	2.7	18
Total	3869	2–10	88.3	601.2	686	99.2	511

TABLE 3. Available soil nutrients per ha by burning of rejuvenated vegetation

Available nutrients [kg·ha^{-1}]	Period after abandoning shifting cultivation [years]					
	Initial	5	10	15	20	25
N	176	182	204	244	273	275
P_2O_5	5.7	5.9	6.2	6.9	7.0	7.2
K_2O	123	130	162	248	281	276

More than 65% of the workers in the region are engaged in agriculture or allied sectors and the rest are marginal or non-workers (Tab. 4). The land tenure system in the north-eastern region is unique. The land belongs either to (1) village chief, (2) community or (3) individuals. In the first two categories, the farmers have usufructuary rights over land and therefore have little interest in its development and protection from soil erosion. The prevalence of free range grazing by animals during winter season (December to February) by community order, discourages the cultivators from going for winter crops. Free range grazing is responsible for huge sediment yield from hill slopes as well as valley lands. Fast urbanization and change in life style of the people has also affected natural resources management. With proper vegetative cover, maximum rainwater could be retained *in-situ* and the soil can retain sufficient moisture for growing winter crops (Sharma 2001). This would also help to reduce runoff and soil loss and consequently better ecological conditions could be assured. Fast increase in population (Tab. 5) and in an effort to enhance crop productivity to sustain this has put extreme pressure on land resources, resulting in heavy sediment loads in run-off and choking of fluvial system. Virtually all developing countries, even those with adequate water in the aggregate, suffer from debilitating regional and seasonal shortages (IFPRI 1995). Since food productivity is highly dependent on the spatial and seasonal changes in water availability,

TABLE 4. Economic classification of population in northeastern region [per cent]

State	Cultivators	Agricultural labourers	Household industry, processing, etc.	Marginal workers/ /non-workers
Arunachal pradesh	60.4	5.1	0.2	34.3
Assam	50.9	12.1	0.9	36.1
Manipur	61.8	6.7	5.8	25.7
Meghalaya	55.3	12.5	0.4	31.8
Mizoram	61.3	3.3	1.0	34.4
Nagaland	72.6	1.4	0.4	25.6
Tripura	38.1	23.9	1.4	36.6

TABLE 5. Population and food grains situation in the northeastern region of India

Year	Population [millions]	Foodgrains [million tonnes]		
		production	requirement	deficit
1951	10.5	2.10	1.79	0.31
1961	14.5	2.90	2.08	0.82
1971	19.6	3.92	3.01	0.91
1981	24.7	4.94	3.84	1.10
1991	31.5	6.30	4.93	1.37
2001	40.2	8.04	5.96	2.08
2021	60.9	12.18	9.02	3.16

the food security cannot be ensured for all times unless suitable measures are undertaken to minimize the effect of runoff on soil erosion. The region has a food grains deficit of about 2.5 million tonnes and the deficit gap is widening year after year (Sharma 1999).

The sediment load per litre of runoff from watersheds varied from 1250––20 300 mg soil, 5.4 to 23.6 mg NO_3 – N, 2.3 to 6.5 mg P–PO_4, 17.2 to 35.8 mg K_2O, 0.4 to 1.8 mg Zn, 0.9 to 2.7 mg Mn, 6.5 to 12.0 mg Mg, 7.1 to 18.4 mg Fe and 4.0 to 7.2 mg SO_4. The sediment transport from the catchments showed spatial and temporal variations. Intensification of agriculture has potentially harmful impact on already fragile hydrological system.

Effect of land use and rainfall on soil loss

The average sediment yield was only 0.44%, 2.68%, 1.47%, 0.31%, 0.73% and 2.27% in fodder, forestry, agro-forestry, agriculture, agri-horti-silvi-pastoral and horticulture land use systems of that of shifting cultivation (Tab. 6). The average sediment yield varied between 11.2 t km^{-2} in agriculture land use and 3621.3 t km^{-2} in the shifting cultivation. Highest average sediment yield in new land use systems was 71.7 t km^{-2} when the annual rainfall was 2770 mm and minimum 28.1 t km^{-2} when the annual rainfall was 1992 mm as against 4499.7 km^{-2} and 2669.4 km^{-2} in shifting cultivation, respectively. More than 90% of rainwater was retained *in-*

TABLE 6. Effect of land use and precipitation on the sediment yield through runoff [t km^{-2}]

Land use	Annual rainfall [mm]						
	2195	2705	2770	2599	2388	1992	Mean
Fodders/grasses	14.2	16.3	28.8	18.6	10.6	9.0	16.2
Forestry (trees)	60.1	115.4	141.1	131.7	69.9	65.3	97.2
Agro-forestry	35.4	70.2	75.6	74.3	37.6	27.8	53.4
Agriculture	3.9	9.8	24.3	22.7	3.7	3.1	11.2
Agri-horti-silvi-pastoral	20.1	37.4	36.0	36.5	18.2	11.6	26.6
Horticulture	65.0	101.4	124.8	80.2	70.5	51.7	82.2
Shifting cultivation	2950.0	4580.0	4499.7	3610.0	3419.1	2669.4	3621.3

-*situ* in new land use systems compared to below 60% in the shifting cultivation. More *in-situ* retention of rainwater helped in the availability of adequate moisture from the soil to the succeeding crops when the rainy season receded. The sediment yield varied according to the rainfall received during a particular year and the nature of vegetation in a particular land use.

It was interesting to note that while in shifting cultivation 34.1% of rain water escaped as runoff, it varied from 0.9% to 7.1% in the new land use systems. Maximum of 99.1% of rain water was retained in livestock based land use system, followed by agriculture (99.1%). It was reported earlier also that more than 95% of rain-water can be retained *in-situ* by following these land use systems (Anonymous 2000). There was significant reduction as well as delay in runoff generation from newly introduced land use systems compared to shifting cultivation. As such there was considerable reduction in the sediment yield. One of the characteristic values in rainfall-runoff modelling is the retention of the system or lag time, which is defined as the time elapsed between the centroids of effective rainfall and the direct runoff hydrograph (Banasik et al. 2005; Banasik et al. 2008). They analyzed the data from small agricultural watersheds to investigate the relationship between instaneous unit hydrograph and instaneous unit sedimentgraph. Annual soil loss due to erosion was considerably higher than the permissible limit (1000 t km^{-2}) in the shifting cultivation whereas it was significantly low in the new land use systems. The soil loss was very low in newly tried land use systems due to reduced runoff because of proper vegetation cover and water and soil conservation measures undertaken. These land use systems could be adopted to replace shifting cultivation in the region depending on topography, slope and nearness to the market. The livestock based land use system can be adopted where there is demand for milk or if there is a market for disposal of the animal produce. Similar is the case with the agri-horti-silvi-pastoral land use system which has horticultural crops as its component.

With new sustainable and eco-friendly land use systems in place, the farmers have an alternative to leave shifting cultivation and go for settled cultivation. This would also help in reducing runoff and soil loss and, improved environmental conditions could be assured. In the present study, the runoff water from the land use systems is collected in a pond down the slope and used for irrigation during winter as well as for rearing of fish.

CONCLUSIONS

The results of the study undertaken showed that the introduction of new land use systems, with suitable water and soil conservation measures, significantly reduced runoff from the watersheds on hill slopes and helped in more *in-situ* retention of rainwater, thereby reducing the soil and nutrient erosion and silting of river channels, consequently reducing the flood events in the region as well as improving the environment quality. Different land use systems also improved the soil quality with continuous recommended cropping patterns and other measures. The practice of shifting cultivation in northeastern region of India has become uneconomical with increase in demographic pressure and reduction in the shifting cycle period. The practice needs to be replaced with sustainable, socially acceptable and eco-friendly land use systems. Proper policy framework for planning, development and management of land and water resources in the region can be devised, taking advantage of the advances made in water science and technology as well as from positive and negative experiences of the developed countries.

REFERENCES

ANONYMOUS, 2000: *Basic Statistics of the Northeastern Region*. North Eastern Council, Shillong, Meghalaya, India.

BANASIK K., MADEYSKI M., MITCHEL J.K., MORI K., 2005: An investigation of lag times for rainfall-runoff-sediment yield events in small river basin. Hydrologic Science Journal, 50(5), 857–866.

BANASIK K., MITCHELL J.K., 2008: Conceptual model of sedimentograph from flood events in a small agricultural watershed. Annals of Warsaw University of Life Sciences, Land Reclam. 39: 49–57.

EL BASSAM N., 1997: Fundamentals of sustainability in agricultural production systems and global food security. In: *Sustainable Agriculture for Food, Energy and Industry*, (ed. by N. El Bassam, R.K. Behl, B. Prochnow), 1–12, James and James (Publishers, London, U.K.

IFPRI, 1995: A 2020 vision for food, agriculture and the environment. The vision, Challenge and Recommended Action. International Food Policy Research Institute, pp. 50.

JACKSON M.L., 1973: *Soil Chemical Analysis*. Parentice Hall of India, New Delhi, India

SHARMA U.C., 1998: Water Management by the tribes of northeastern region: The traditional wisdom and future strategies. *Fertilizer News*: 43, 43–49.

SHARMA U.C., 1999: Food Security in the northeast: new paradigms. In: *Persrpective for Planning and Development in North Eastern India* (ed. by R.C. Sundariyal, Uma Shankar and T.C. Upreti), 197–212, G.B. Pant Institute of Himalayan Environmental and Development, Almorah, India.

SHARMA U.C., 2001: Effect of farming system type on *in-situ* ground water recharge and quality in northeast India. In: *Impact of human Activity on Groundwater Dynamics* (ed. by H. Gehrels, N.E. Peters, E. Hoehn, K. Jenson, C. Leibundgut, J. Griffioen, B. Webb & W.J. Zaadnoordijk), IAHS Publ. No 269, 167–169, IAHS Press, Wallingford, U.K.

SHARMA U.C., 2003: Impact of population growth and climate change on the quantity and quality of water resources in the northeast region of India. In: *Water Resources System – Hydrological Risks, Management and Development.* (ed. by G. Bloschl, S. Franks, M. Kumagia, K. Musiake and D. Rosbjerg), IAHS Publ. No 281, 349–357, IAHS Press, Wallingford, U.K.

SHARMA U.C., PRASAD R.N., 1995: Socio--economic aspects of acid sooil 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 and 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 reghion of India. In: *Sediment Transfer through the Fluvial System* (ed. by V. Golosov, V. Belyaev and D.E. Walling). IAHS Publ. No 288, 488–493, IAHS Press, Wallingford, U.K.

SINGH A., SINGH M.D., 1978: Effect of various stages of shifting cultivation on soil erosion from steep hill slopes. *Indian Forester, Vol.* 106: pp. 115–121.

WALLING D.E., 2000: Linking land use, erosion and sediment yields in river basins. Hydrobiol., 410, pp. 223–240.

WALLING D.E., 2008: The changing sediment loads of the world's rivers. Annals of Warsaw University of Life Sciences, Land Reclam. 39, 3–20.

Streszczenie: *Wpływ aspektów społeczno-ekonomicznych oraz zmian zagospodarowania terenu na dynamikę wytwarzania rumowiska w północno-wschodnim regionie Indii.* W pracy przedstawiono analizę czynników wpływających na wytwarzanie rumowiska w północno-wschodnim regionie Indii. Do głównych czynników naturalnych można zaliczyć wysokie opady deszczu (średniorocznie 2450 mm) oraz duże nachylenie terenu w zlewniach, dochodzące do 32–53%. Wśród czynników antropogenicznych jako istotne wskazuje się: duży udział gruntów ornych, duże rozdrobnienie i system własności gospodarstw rolnych, postępujące wylesianie oraz swobodny wypas bydła. Stwierdzono, że w wyniku przekształcenia gruntów ornych na inne użytki rolne wzrośnie retencyjność zlewni, a ilości odpływającego rumowiska zmniejszy się o ok. 90%. W tym celu konieczne są działania o charakterze prawnym, planistycznym, z zakresu gospodarki wodnej i zagospodarowania terenu.

MS. received April 2010

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