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Implications of nutrient and soil transfer with runoff in the northeastern region of India

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Abstract The northeastern region of India is predominantly hilly with an average annual precipitation of 2500 mm. The Brahmaputra River and the Barak River are two major rivers in the region with an annual runoff of 537.2 km^3 and 59.8 km^3, respectively. Prevalence of shifting cultivation over an area of 14 660 km^2 is responsible for an annual transfer of 88.3 × 10^6 t soil and 10.65, 0.337 and 6.05 × 10^3 t available N, P_2O_5 and K_2O, respectively. Soil and nutrient transfer depends on the amount and intensity of rainfall, slope, vegetation cover, soil texture and human interference. The major sinks for sediment and nutrients are the sea, responsible for an intake of 51.4% of the total transferred quantity, followed by river systems (14.4%), and seasonal streams (11.0%). A major sink for the forest litter and humus transferred from the hill slopes is valley land adjacent to the hills, which retain about 50–65% of them, making the soil highly fertile.

Key words implications; India; nutrient and soil transfer; rain water; sinks

INTRODUCTION

The northeastern region of India, covering an area of 255 090 km^2, lies between latitudes 21°57′ and 29°28′ N and longitudes 89°40′ and 97°25′E (Fig. 1). The region is endowed with natural resources of soil, water and vegetation, but their indiscriminate use has rendered these resources in a fragile state (Sharma, 2003). About 600 × 10^6 t soil is lost every year through erosion, and land degradation occurs via other means (Borthakur, 1992). This huge quantity of soil, along with runoff, takes away large amounts of absorbed and dissolved crop nutrients to different sinks. Besides other factors, mismanagement of water resources has been the major cause of low productivity in the region. There is an annual loss of 88.3 × 10^6 t soil and 10.06, 0.37 and 6.05 × 10^3 t of available N, P_2O_5 and K_2O, respectively from shifting cultivation in the region due to soil erosion during the rainy season (Sharma & Prasad, 1995). The people are attached socio-culturally to the practice of shifting cultivation involving deforestation and burning of the biomass before land preparation. With the present rate of increase in population of the region (2.47%), the situation may become alarming if the use of existing water resources is not suitably planned, developed and conserved (Sharma, 1997). Though it is a gigantic task to estimate the amounts of soil and nutrients deposited through erosion and other means in the various sinks, an attempt has been made to delineate the possible sinks for eroded soil and other constituents for the northeastern region of India. Further studies are suggested to refine the estimated values of the transported fluvial load deposited en-route and at its final destination, the sea.

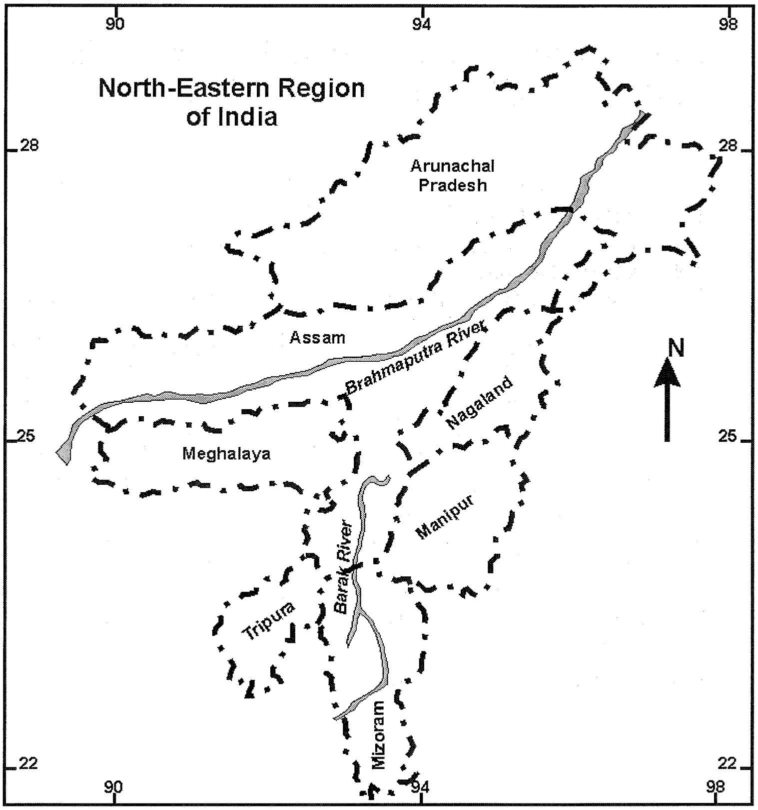

Fig. 1 Study area location.

METHODOLOGY

The methodology for estimating the possible deposition of eroded soil and associated nutrients from the northeastern region of India is primarily based on determining the loss of soil and its deposition at different places by quantifying the soil/sediment and nutrient load in runoff. Soil loss from erosion was estimated through representative gauges from shifting cultivation and other cultivated areas as well as from non-agricultural land. It may be difficult to justify the exact soil and nutrient loss from an area of 255 090 km^2 of northeastern region of India. However, total soil loss was estimated as a product of soil loss from the representative areas of the watersheds studied under different situations, extrapolated to the total area of the region, taking into consideration slope, vegetation, rainfall and soil texture. Deposition of eroded soil in the sediment sinks was estimated by analysing the water samples for dissolved elements. Total amount of elements was determined by multiplying with quantity of water collected in different sinks. The sediment load carried to the sea was estimated by subtracting the sediment load in different sinks (except sea) from the total sediments lost from the northeastern region. Eight to ten samples were taken from each sink from around the region for estimation. Nutrient content of the soil was determined by standard procedures as outlined by Jackson (1967).

Table 1 Water availability in major rivers of northeastern region of India.

River	Drainage (km^2)	Average annual runoff (Mm^3)
Brahmputra	194 413	537 240
Barak	78 150	59 800

Table 2 Aquatic resources of northeastern region of India.

Type	Area
River length (km)	19 548
Reservoirs (ha)	51 697
Lakes (ha)	91 265
Tanks (ha)	40 706

DISCUSSION

Sources of water

The northeastern region has two major river basins viz. Brahmaputra and Barak, draining 194 413 km^2 and 78 150 km^2 respectively, with an annual runoff of 537.2 and 59.8 km^3, respectively (Table 1). Total river length in the region is 19 548 km (Table 2). The region also has a number of other streams and tributaries. Due to a high silt load entering from the catchments and northern tributaries, the Brahmputra River has a tendency to change its course, resulting in bank cutting and thereby causing additional loss of land and generating further particulate and nutrient load. Most of the surface water in the region is confined to rivers, which are in a highly dynamic state due to the high gradient, and they transfer a high load of soil and nutrients to various sinks. The region receives 510 km^3 of water annually as rainfall. Most of the rains are received from May to October, which is also the period during which maximum soil and nutrient displacement takes place. Reservoirs, lakes and tanks account for about 183 668 ha of the area.

Floods

It is important to mention the floods in the north-eastern region of India where their occurrence is a common feature every year during the rainy season. The scale, as well as the frequency, of the floods has been increasing year after year (Borthakur, 1992). The main cause of floods in the Brahmaputra basin is the heavy silt load brought from hill slopes due to erosion because of heavy rainfall in the catchment area and deforestation, which continues unabated. About 35 840 km^2 area of the region is prone to floods while an area of about 3760 km^2 is affected every year (Table 3). On average, the flood water contains 2250 mg l^{-1} of sediment (Table 4) (Fig.1). It also contains 10.6, 3.2, 13.5 and 23.6 mg l^{-1} of NO_3-N, P-PO_4, K_2O and other nutrients, respectively (Table 4).

Sinks for soil and nutrients

The possible sinks for the soil and nutrients displaced from various parts of the region are the major riverbeds, streams, flood affected areas, valleys, areas of temporary water storage after

Table 3 Area affected by floods in northeastern region of India (km^2).

Sub-region	Area prone to floods	Annual flood affected area
I	290	12
II	4100	151
III	22450	1721
IV	9000	1876
Total	35840	3760

Table 4 Sediment and nutrient concentration range in flood water (dissolved phase).

Soil / nutrients	$mg\ l^{-1}$
Soil (sediment)	1500–3000
NO_3-N	6.4–25.8
P-PO_4	2.3–8.5
K_2O	15.4–33.8
Other nutrients	21.5–51.6

the floods recede, lakes and reservoirs including ponds, and the sea. The total displacement of soil, nitrogen, phosphorus, potassium, manganese, zinc, calcium and magnesium has been estimated at 601 million tonnes (soil) and 685.8, 99.8, 511.1, 22.6, 14.0, 57.1 and 43.0 thousand tonnes of nutrients and trace elements, respectively (Table 5). As sinks, the rivers, flood prone area, streams, valleys, temporary water storage areas after floods, lakes and reservoirs, and the sea account for about 4.6, 7.6, 11.0, 9.6, 5.0, 1.0 and 51.2% of the sediment load of soil as against 11.4, 7.1, 10.6, 8.5, 4.0, 1.1 and 57.3% of the nutrient load, respectively (Table 5).

Implications

The transfer of the soil and nutrient load, along with runoff from rainfall has many implications for the resource base and environment in the region. Due to heavy soil erosion because of rains, there has been large scale land and environment degradation. The prevalence of shifting cultivation over an annual area of 386.9 thousand ha has resulted in

Table 5 Sinks for the soil nutrients and trace elements transferred in northeastern region.

Sink	Soil (10^6 t)	Nutrient/elements (10^3 t) N	P	K	Mn	Zn	Ca	Mg
River	86	77.5	11.6	57.0	2.5	1.9	7.7	5.6
Flood area	46	48.7	7.5	36.5	1.6	0.9	3.6	2.6
Streams	66	72.0	10.3	53.1	2.3	1.8	7.0	5.5
Valleys	58	57.6	8.9	42.9	1.8	1.4	5.5	4.3
Temporary water storage	30	27.4	4.9	20.0	0.8	0.6	2.3	1.9
Lakes & Reservoir	6	7.5	1.2	5.4	0.2	0.2	0.7	0.6
Sea	309	395.1	55.4	296.2	13.4	7.2	30.3	22.5
Total	601	685.8	99.8	511.1	22.6	14.0	57.1	43.0

Table 6 Land degradation in northeastern region of India.

State of the region	Degraded land (10^3 ha)
Arunachal Pradesh	2854
Assam	2999
Manipur	734
Meghalaya	1102
Mizoram	610
Nagaland	482
Tripura	279
Total	8860

deforestation because the practice involves burning of the forest biomass. About 8.86×10^6 ha land has been degraded due to soil erosion and other degradation problems in the northeastern region of India (Borthakur, 1992) (Table 6) (Fig 1). Continuous degradation of land has affected the water resources, which may lead to crisis of enormous magnitude. Planning for management of land and water resources, therefore, assumes great significance. An increase in population putting more pressure on water and land resources has also contributed to environmental degradation. Pollution by sewage and other domestic products, poisonous industrial effluents, agricultural chemicals etc. has increased. Eutrophication of water bodies with agricultural runoff has caused drastic changes in the biomass. Water pollution has been caused by an increase in the concentration of chlorides, sulphates, nitrate and aluminium, possibly because of high aluminium content in the soil. High runoff during the rainy season from May to October has resulted in perpetual floods (Table 3). More than 95% of the soils in the region are acidic in nature, which is the result of leaching of salts due to heavy rainfall in the region that is 2450 mm per annum, on average. Soil degradation and mismanagement have had an impact on crop productivity, which is quite poor and the region is still in deficit in food grains.

Nevertheless, there has been a positive effect of runoff in the immediate vicinity of the hill slopes as a lot of forest litter and humus from the forests becomes deposited in the near valley areas. This has increased the soil fertility in the limited adjoining areas to the forests and crop productivity is higher in these areas even without the application of inorganic fertilizers.

CONCLUSIONS

Transport of large load of soil and sediment associated nutrients in the runoff and its deposition in various sinks is a matter of concern for the northeastern region of India. Deforestation and denudation of basins has resulted in water scarcity because the natural water cycle has been upset. The runoff during rains goes untapped from denuded hill slopes instead of infiltrating to recharge aquifers. There has been large scale land and environmental degradation in the region. There is an urgent need to conserve and manage the rain water judiciously to reduce runoff. Sustainable solutions to water problems and judicious use of water resources require a radical policy at the government level as well as relevant institutional reforms to create awareness among the people.

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