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Land-use options for the flood plains of the northeastern region of India

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Abstract Large flood plains are a characteristic feature of the northeastern region of India and combined, have an area of 54 015 km^2. There are three prominent flood plain valleys in the region: the Brahmaputra, Barak and Manipur. These flood plains contain a multitude of morphological features including; depressions, swamps and temporary water storages that are subject to regular inundation. The total flood-prone area is 35 860 km^2 with an average area experiencing annual inundation of approximately 3761 km^2. The intensity of flooding results in crop and property damage along with the loss of human and animal life. However, floods also result in an increase in the nutrient status of the flood plain soils and temporary water storage areas. This has a significant influence on the productivity of crops in the region. In this study, changes in the nutrient content of flood plain soils and the temporary water storages are reported. Annual floods deposit 88.3 Mt of soil along with 10.61, 0.37 and 6.05 thousand tonnes of nitrogen, phosphorus and potassium respectively on these flood plains. Suitable cropping patterns are required for these flood plains in order to benefit from this addition of natural resources thereby improving food security.

Key words flood plain fertility; flood plain land-use options

INTRODUCTION

Large flood plains are a feature of the river valleys in the northeastern region of India. Combined, the flood plains of the Brahmaputra, Barak and Manipur rivers in the region, have an area in excess of 71 000 km^2, all of which are extensively used for agriculture. The agricultural productivity on these flood plains is partly influenced by the supply of nutrients and minerals during periods of inundation. The physical and chemical properties of the flood plain soils and the temporary water storages located on the flood plains change as a result of floods and this influences crop growth. Although the discharge of sediments and nutrients in these river systems has been studied by Morii *et al.* (1993) the influence of flooding on the overall nutrient status of these flood plains and hence agricultural production is not well understood. The fertility of flood plains is important to the long-term agricultural sustainability of the region.

This paper presents the results of a preliminary study on the physical and chemical status of flood waters, flood plain soils and temporary water storages on the flood plains of the Brahmaputra, Barak and Manipur rivers. Based on this information, an understanding of the influence of inundation to flood plain fertility is recommended in order to increase overall crop production on these flood plains.

STUDY AREA AND METHODS

The Brahmaputra, Barak and Manipur rivers are fed by water from the Himalayas. The flood plains of the northeastern region of India receive heavy rainfall during the monsoon season which averages 2252 mm. The northeastern region of India is prone to flooding, with flood plain inundation being experienced once a year, on average. Four agroclimatic zones have been identified in the region, of which two are considered to have a high probability of flooding (Fig. 1). Details of the individual agroclimatic zones are given in Table 1. The study area lies mainly within agroclimatic zones III and IV where temporary water storages are common because off the high frequency of flooding.

The region can be divided into two areas: (a) those which are prone to floods and (b) active floods plains (Fig. 1). The Brahmaputra River has a catchment area of 194 400 km^2 (Table 2) and an average runoff of 537 240 mm year^{-1}. The main Brahmaputra Valley is about 660 km long and 70 km wide. This valley has a gentle gradient of 13 cm km^{-1} and dips towards the west and southwest (Borthakur *et al.*, 1989). The gentle gradient promotes temporary water storages where water stays for long periods following flooding and this influences the sediment and nutrients status of the area. In the southern sections of the Brahmaputra Valley there are also active flood plains with many swamps and temporary storage areas. By comparison the Barak River drains 78 100 km^2 of the Himalayas and has an annual runoff of 59 820 mm. The Barak Valley has an area of 6962 km^2 and the middle sections of the valley contain an extensive lowlying flood plain with numerous swamps and temporary and permanent storages. These active flood plains with marshy tracts are subject to annual inundation. The Manipur Valley is smaller than the Brahmaputra and Barak with an area of 1853 km^2

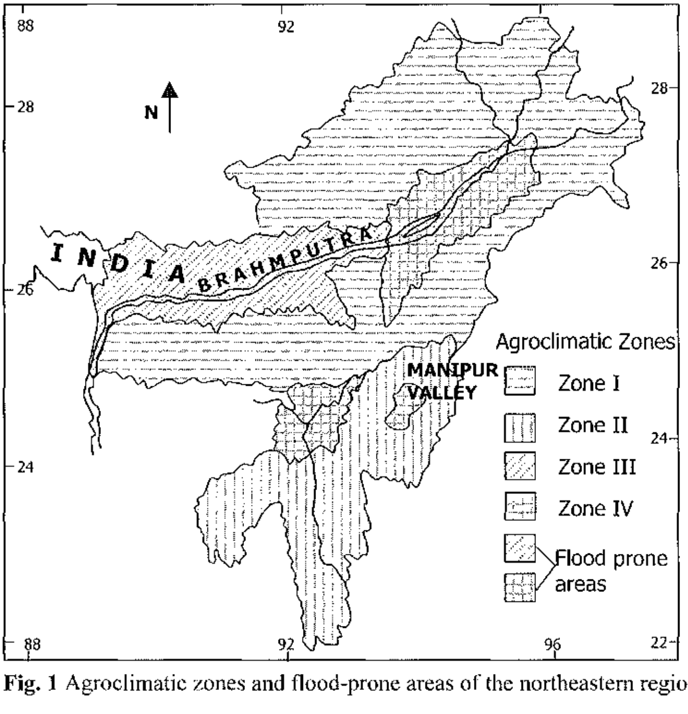

Fig. 1 Agroclimatic zones and flood-prone areas of the northeastern region of India.

and with a maximum width of 32 km. The valley has a number of depressions, marshes and lakes (Anonymous, 1994).

Agroclimatic zones III and IV have 22 450 and 9005 km^2 respectively of flood-prone areas of which 1720 and 1880 km^2 are flooded annually. Flooding results in temporary water storages over large areas of the flood plain and this requires suitable crop planning and forward warning systems to save the people from huge losses as well as enhancing productivity in the flood plains. Flooding in the region occurs as a result of: (a) shifting cultivation in the hills, which loosens the soil on steep hillslopes hence making it easy to be washed downslope by heavy rainfall; (b) river aggradation because of large-scale sediment deposition—the loss of river channel capacity has increased overbank flows; (c) high intensity rainfall during monsoon season; (d) inappropriate flood control measures; (e) steep gradients in catchment areas; and, (f) low flood absorbing capacity of eroded land surfaces.

There are two main flood plain soil types in the region; new alluvium (entisols) and old alluvium (alfisols and ultisols) (Anonymous, 1994). New alluvium soils predominate both banks of the Brahmaputra River. Most of the soils are acidic, more so near the hills (pH 4.5–5.0), whereas others are weakly acidic (pH 5.0–6.0). The soils of the flood plains are very low in phosphorus with medium levels of nitrogen and potassium. Predominant soil sub-groups in the flood-prone areas are aquic ustifluvent and aquic udifluvent in zone I and II and typic fluvaquent, aeric fluvaquent, typic udifluvent, aeric haplaquent, aquic udipsamment and typic haplaquent in zones III and IV.

In this study flood water and soil samples were collected from temporary storages for physical and chemical analysis before and after the floods. Water samples were collected in half-litre polythene bottles and soil samples (up to 20 cm depth) were taken in cloth bags. The soil samples were dried in the shade, pulverized and passed through a 2-mm sieve. These samples were analysed for different constituents using the methods described by Jackson (1967) and Lindsay & Norvel (1978). These data were combined with those collected in an earlier preliminary study of temporary storages in the region and were used to recommend cropping systems in order to achieve higher crop productivity.

Table 1 Agro-climatic zones of the northeastern region of India.

Zone	State/areas	Area (km^2)	Maximum elevation (m)
I	Arunachal, Meghalaya, Nagaland and Assam hills	137 900	7089
II	Manipur (except valley area), Tripura and Mizoram	53 900	2994
III	Central and lower Brahmaputra Valley in Assam	34 700	106
IV	Upper Brahmaputra Manipur Valley and Barak Valley in Assam	28 800	600

Table 2 Water availability in major rivers of the northeastern region.

River basin	Drainage area (km^2)	Average annual runoff (mm^3)	Average annual runoff per capita (m^3)	Average runoff per km^2 (m^3)
Brahmaputra	194 400	537 200	17 330	276 300
Barak	78 100	59 800	6 040	765 600

RESULTS AND DISCUSSION

Suspended sediment concentrations and the chemical composition of flood waters, taken at different river stages in the Brahmaputra, Barak and Manipur rivers are given in Table 3. The majority of these values are relatively high compared to other Indian rivers (Morii *et al.*, 1993). Sediment and nutrient loads have increased in the region because of changing land use and shifting cultivation on adjacent hillslopes. Annual loads of sediment, nitrogen, phosphorous and potassium in the region are estimated to be 83.3 m, 10.6 m and 6050 t respectively (Sharma & Prasad, 1995). These materials are mainly transported during periods of high runoff and are deposited in lowlying flood plain areas and temporary water storages in the main valleys of the region. A webbed network of tributaries of the Brahmaputra and Barak rivers characterizes the flood-prone areas of the northeastern region of India and although they can cause much havoc as a result of flood damage, floods increase soil fertility.

The nutrient content of flood plain soils taken before and after flooding in temporary storages is given in Table 4. In all cases increases in soil nutrient concentrations were recorded. For example, concentrations of nitrogen, phosphorous and potassium in the soil samples following flooding increased by 148.8%, 233.2% and 151.1% respectively. Substantial increases in DTPA extractable Zn and Mn were

Table 3 Sediment load in flood waters.

Soil/nutrient	Range (mg l^{-1})
Soil	1500–30000
NO_3-N	6.4–25.8
P-PO_4	2.3–8.5
K_2O	15.4–33.8
Zn	0.3–1.6
Mn	0.8–2.4
Cu	0.1–0.3
Fe	6.3–18.4
Ca	2.5–6.4
Mg	6.5–14.
SO_4	5.0–8.5

Table 4 Nutrient status of temporary water storages before and after floods.

Nutrient	Before floods	After floods
Average N (kg ha^{-1})	170	253
Average P_2O_5 (kg ha^{-1})	6	14
Average K_2O (kg ha^{-1})	135	204
Average Zn (mg kg^{-1})	2.7	3.8
Average Mn (mg kg^{-1})	6.8	9.1
Average Cu (mg kg^{-1})	0.5	0.5
Average Fe (mg kg^{-1}	4.6	3.9
Cation exchange capacity [cmol(p+) kg^{-1})]	6.7	11.5
Organic matter (%)	0.8	2.2

also observed after the floods. However, there was no significant change in the Cu and Fe content of the flood plain soil. Cation exchange capacities increased significantly as did the organic matter content. These changes in the chemical composition of the soil after a flood are considered to be advantageous to subsequent crop production. Conveyance loss of sediment and nutrient to the flood plain during overbank flows plus the recycling of soil and nutrients has an important influence on the chemical properties of the temporary storage as well as on the physical status.

Frequent changes in the physical and chemical composition of the soil require changes in cropping patterns to match prevailing conditions. Although more than 75% of the population in the northeastern region is engaged in agriculture, the region is still deficient in food grains. Suitable cropping patterns are required for different agroclimatic zones.

Flood plains are one area where food production can be increased tremendously provided judicious agricultural practices are followed. The potential in agricultural production from the flood plain ecosystem must be tapped to supply the future demand for food grains in the northeastern region. The flood plain ecosystems are constrained by a number of biotic and abiotic stresses that limit crop yields. The prevalent socio-economic structure and its strong association with the people determines the type of technology required by the farmers. There is a need for judicious use and management of inputs, product diversification and farm consolidation in lowland areas.

Rice is the most important crop of the flood plains as it is grown in about 70% of the cultivated area and more than 90% of the area used for food grains. The improvement in rice production and the inclusion of other suitable crops in the system can ensure enduring food security in the region. Brahmaputra and Barak valleys are more suitable for autumn rice production whilst the lower flood plains are more suitable for summer rice production. Winter rice can be grown successfully in either area. Besides rice, many other crops, such as mustard, pulses, groundnut, potato, wheat and vegetables, can be cultivated in flood-prone areas by using suitable cropping patterns (Sharma, 2000), but the productivity of these crops is quite low (Table 5).

Suitable and profitable cropping patterns for the flood-prone plains would be any system having rice as its major crop. Suitable cropping systems recommended for flood plains are given in Table 6. The flood-prone areas in zones I and II have relatively steep gradients compared with zones III and IV and so the flood waters recede in a very short period. Vegetables like cabbage, radish, peas and potatoes can be grown in these zones. High humidity during most of the year and adequate temperatures mean that spices such as ginger and turmeric can also be grown successfully. These crops should be included in cropping systems along with rice in zones I and II. While the temperature remains adequate for rice production in zones III and IV, two or three crops of rice should be grown during the year where, at present, generally only one crop is cultivated. Due to sandy loam soils in the river basins, groundnuts and potatoes can be grown with ease. The major crops which can be cultivated before or after rice are mustard, pea, groundnut, potato, ginger, turmeric, soybean, pulse crops, wheat and cowpea. Different vegetables can also be grown where the market exists. Very little of zone III and IV is under cultivation during winter. Mustard, potato, wheat and cabbage could be successfully grown in those areas that are presently kept fallow. If the proper cropping systems, as suggested in Table 6,

Table 5 Area, production and yield of major crops in flood-prone areas of northeastern India.

Crop	Area (ha)	Production (t)	Yield (kg ha^{-1})
Rice	2 285 000	3 079 000	1347
Maize	7 500	4 100	547
Wheat	82 900	100 200	1208
Pulses	110 100	50 500	459
Food grains	2 518 000	3 268 000	1298
Oilseeds	308 400	154 000	499
Potato	78 800	610 000	7736

Table 6 Cropping pattern for flood plains.

Zone	Cropping pattern
I	Rice–potato, Rice vegetables
II	Rice–vegetables, Millets–vegetables, Ginger/ Turmeric–pulses
III	Rice–groundnut, Rice–rice–cowpea, Rice–rice, Rice–potato–jute, Rice–mustard/pea, Rice– pulses, Soybean–pulse
IV	Rice–rice, Rice–potato, Rice–potato, Rice–wheat, Jute–rice–rice, Jute–rice–rice, Jute–wheat/pulses oilseeds, Rice–groundnut, Autumn rice–pea

are followed, the production and productivity of various crops can be increased thereby ensuring food security.

CONCLUSIONS

The lowland flood plain areas, including temporary water storages, in northeastern India play an important role in the cycling of sediment and nutrients. The economy of the region is dependent on these flood plains. Frequent changes in soil fertility and sediment deposition require special management practices and suitable cropping patterns to ensure the optimum productivity of various crops. Detailed and systematic studies should be undertaken to monitor the physical and chemical behaviour of temporary storages within the flood plains to derive maximum benefits from diversifying the use of these temporary storages.

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