Impact of population growth and climate change on the quantity and quality of water resources in the northeast of India

U. C. SHARMA
CNRM, VPO Tarore, Bari Brahmnan – 181133, Jammu & Kashmir, India
ucsharma2@rediffmail.com

Abstract The northeastern region of India is extremely rich in water resources but a continuous increase in human interference and mismanagement has rendered these resources in a fragile state. The region receives about 510 km^3 of water as annual rainfall. It has two major river basins, the Brahmaputra and Barak, which drain 194 413 and 78 150 km^2, with an annual runoff of 537.0 and 59.8 km^3, respectively. The prevalence of shifting cultivation has resulted in deforestation and soil loss, causing silting of riverbeds and frequent occurrence of floods. Due to population pressure, more and more forest area is being cultivated, putting the whole ecology in peril. The declining trend in rainfall and frequent temperature fluctuations are a signal of climate change. The demand for water for domestic use has suddenly increased due to the rapid population growth and a change in the life style of the people. Water demand is high and the supply is not commensurate with it. Due to mismanagement of rainwater, about 3.586×10^6 ha of land has become prone to flooding. Further, water quality has also deteriorated due to its pollution by nitrates, chlorides and sulphates, and increased use of fertilizers and pesticides in an effort to increase crop productivity in the region. If the rate of population increase remains unabated, the water resources are likely to dwindle further and the quality of water is likely to deteriorate as well.

Key words climate change; India; quantity and quality of water; population growth

INTRODUCTION

The northeastern region of India, comprising seven states, lies between 21°57′N and 29°28′N latitude and 89°40′E and 97°25′E longitude (Fig. 1). The region, with an area of 255 090 km^2, is predominantly hilly. Though endowed well with water resources, their indiscriminate use and mismanagement have caused resource degradation to the extent that the quality and quantity of available water has been affected. Shortage of water is experienced during winter months (November to March) and when we expect good quality water. The fast growing population has pressurized the food production base and to satisfy their need the people have misused the water resources. The region, though having sufficient water in aggregate, cannot boast of adequate quantities of water for its people at all places and during all the seasons. Deforestation, burning of timber and forest vegetation in shifting cultivation has caused water, land and environmental degradation and in many cases irreversible damage to water resources. The social sanctions and belief system maintained a balance between resource potential and their utilization for a long time, but with the increase in population and indiscriminate use of water resources, imbalance has been created. The important issue is to promote conservation and sustainable use of resources which allow long-term economic growth

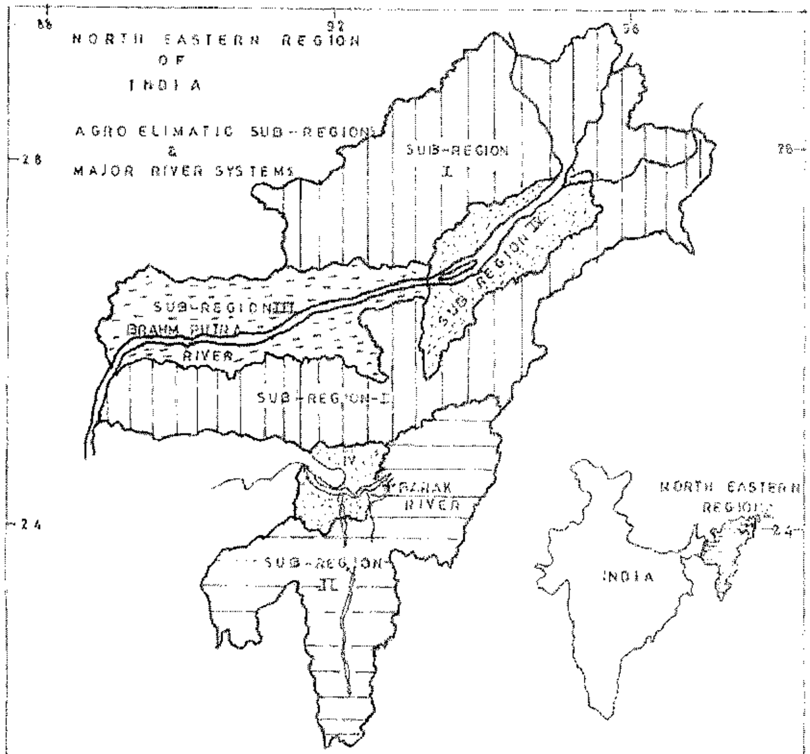

Fig. 1 Agroclimatic subregions and major river systems of the northeast region.

and enhancement of production capacity, along with being equitable and environmentally acceptable (Bassam, 1997). There is increasing competition by various sectors of society in the region for not only water quantity, but also water quality. Forecasts indicate that by 2021, an additional 20 million people will be added to the population, demanding 50% more water for survival. Virtually all developing countries, even those with adequate water in the aggregate, suffer from debilitating regional and seasonal shortages of water (IFPRI, 1995). Drinking water, though representing the lowest percentage of the total demand in the region, would dominate as the survival issue. A multidisciplinary study, running since 1983, is developing new farming and rainwater harvesting systems for judicious management of water, monitoring water yield and sediment load, to replace shifting cultivation. The major objective of the study is to highlight the problems and make the people aware of the issues related to population growth and climate change vis-à-vis its impact on water resources and suggest strategies.

DISCUSSION

Agro-climatic zones

Based on topography, climate, soil type, cropping systems and geographical continuity, the northeastern region can conveniently be divided into four zones (Fig. 1). For the sake of expediency, the areas which have two or three similar, if not identical, parameters have been grouped into a broad homogeneous zone. Zone I comprises the Arunachal Pradesh, Meghalaya and Nagaland states and the hills of Assam state. The states of Manipur, Mizoram and Tripura are in zone II. The valley areas of Assam state (plains) have been included in zone III and IV. Zone III includes the central and lower Brahmaputra valley comprising the Nagaon, Darrang, Kamrup and Goalpara districts of Assam while zone IV comprises Lakhimpur, Dibrugarh, Sibsagar and the Barak valley of Assam (Borthakur *et al.*, 1991). The Brahmaputra valley is an extension of the Indo-Gangetic plains where water logging and floods are a common feature.

Population growth

The population of the northeastern region is increasing at an annual compound growth rate (ACGR) of 2.43% as against 1.69% for the whole country (Table 1). The likely ACGR between 2001 and 2021 is expected to be 2.10% in the region; the decrease is expected due to general awareness and Government efforts. The population in the region increased almost four fold between 1951 and 2001. The sudden spurt in population growth has put tremendous pressure on land and water resources, while development has not kept pace to accommodate this increased growth rate. The increase in population density means management for more people per unit of natural resources. The pressure on the freshwater system continues to grow for domestic use, agriculture, industry, energy and disposal of effluents, not only due to the population increase but also due to a change in lifestyle of the people (Table 2). The present annual demand for freshwater is 27.4 km^3 and will grow by 35% in the next 20 years. Since food productivity is highly dependent on spatial and seasonal changes in water availability, the future needs for water will have to be met from resources similar to those existing at present.

Table 1 Population trends in the northeastern region and the whole country.

Year	Population (millions)		Annual compound growth rate (%)		Density (persons per km^2)	
	NE Region	India	NE Region	India	NE Region	India
1951	10.5	361.1	–	–	41	116
1961	14.5	439.2	3.28	1.97	57	133
1971	19.6	548.1	3.06	2.24	77	166
1981	24.7	683.3	2.34	2.23	96	208
1991	31.5	846.3	2.46	2.16	123	257
2001	40.2	1001.1	2.43	1.69	157	304
2021–expected	60.9	1348.3	2.10	1.50	238	410

Table 2 Approximate water needs of the northeastern region (km^3).

Purpose	2001	2021
Domestic use	2.90	4.30
Agriculture	20.00	25.20
Energy	1.50	2.50
Industry	1.50	2.50
Others uses	1.50	2.50
Total	27.40	37.00

Shifting cultivation

Shifting cultivation is prevalent over about 3869 km^2 of the region on hill slopes. The practice involves cutting of forest and burning of material, which affects the overall environment in the region. Rainfall is also showing a declining trend (Table 3). The practice was sustainable when the shifting cycle was 25 to 30 years but with an increase in population, the cycle length has reduced to 2 to 10 years and the land does not get enough time for rejuvenation, thereby loosing soil sustainability. The practice of shifting cultivation has affected the water resources, both quantitatively and qualitatively. The forest cover has considerably reduced due to this age old practice with an annual loss of 316.5 km^2 due to shifting cultivation and other reasons (Table 4). A maximum net loss of 218 km^2 between 1991 and 1993 has been estimated in sub-region I. Resource degradation, low productivity, a tendency for encouraging large family sizes and little or practically no scope for the application of improved technology are some of the major features of shifting cultivation.

Water resources

The region has a surface and groundwater potential of 1064.8 km^3 and 16.6 km^3, respectively (Table 5). Sub region I has the highest surface water potential and sub-region III, the highest ground water potential. Out of an irrigation potential of 36 810 km^2, only 5720 km^2 or 15.3% of the potential has been exploited (Table 5). The north-eastern region has about 46% of the surface water resources of the country. Annual renewable freshwater available in the region is about 40% of that of the country (Table 6). The per capita availability of annual renewable freshwater in the India was 5856 m^3 and 2083 m^3 in 1951 and 2001, respectively; it was 79 066 m^3 and 20 651 m^3 in the northeastern region during the corresponding years. The problem is not the quantity of water but the quality of water in the region. Misuse and mismanagement have resulted in shortage of water at many places. The region receives about 510 km^3 of water as annual rainfall, i.e. 2468 mm. The highest rainfall receiving place, Cherrapunji, lies in this region, getting about 11 500 mm rainfall annually. Yet, it is not debarred from the drought and drinking water problem.

However, two major river systems, the Brahmaputra and the Barak, drain the region. The catchment area of the Brahmaputra is 0.58×10^6 km^2, which is 2.3 times the total area of the northeastern region. Of this catchment area, 0.194×10^6 km^2 is in the region, while the rest is in China. The average annual runoff of the river is $537\,240 \times 10^6$ m^3 and it drains about 76% of the area of the region. The Brahmaputra valley has a width of 80 to 90 km of which the river covers 6 to 10 km at some places. More than 660 m^3 km^{-2} silt load is brought by the northern tributaries and about 100 m^3 km^{-2} silt by the southern tributaries of the Brahmaputra River. With more silt load entering from the northern tributaries, the Brahmaputra has a tendency to drift towards the south. Due to the high silt load, heavy flood discharges and frequent bed changes, the Brahmaputra is causing more harm than benefit. The Barak River drains 78 150 km^2 with an average annual runoff of $59\,800 \times 10^6$ m^3. Most of the surface water in the region is confined to river systems which are in a highly dynamic state due to the high gradient and thus retain a very small quantity of freshwater for human use.

Table 3 Rainfall in the northeastern region of India (Barapani, Meghalaya State).

Years	Rainfall (mm, average per annum)
1986–88	2780
1989–91	2460
1992–94	2384
1995–97	2251

Table 4 Change in forest cover in the northeastern region (km^2).

Sub-region	Total area: 1991	1993	Loss due to shifting cultivation and other	Gain due to regeneration and new planting	Net loss
I	94 977	94 759	326	108	–218
II	49 282	49 065	357	140	–217
III	10 891	10 782	156	47	–109
IV	10 627	10 536	144	53	–91
Total	165 777	165 142	983	348	–635

Table 5 Water resources and utilization in the northeastern region (km^3).

Sub-region	Surface water (km^3)	Groundwater (km^3)	Irrigation potential (km^2)	Irrigation utilization	Irrigation use as % net sown area
I	466.1	2.28	5 260	1160	19.1
II	58.7	0.64	5 350	800	16.8
III	282.4	7.52	13 280	1820	13.2
IV	257.6	6.18	12 920	1940	15.3
Total	1064.8	16.62	36 810	5720	15.3

Table 6 Annual renewable freshwater available in the northeastern region.

Region/Country	Annual renewable freshwater (km^3)	Per capita availability (m^3): 1951	2001	2025
India	2085.0	5 856	2 083	1 496
NE Region	830.2	79 066	20 651	13 389

Table 7 Area affected by floods in the northeastern region of India (km^2).

Sub–region	Area prone to floods	Annual flood affected area	Flood prone area as % of geographical area	Annual flood affected area as % of cultivated area
I	290	12	0.21	0.19
II	4 100	151	7.60	3.18
III	22 450	1721	64.79	12.52
IV	9 000	1876	31.43	14.79
Total	35 840	3760	14.05	10.10

Floods

Floods have severely affected the plains of the northeastern region. The scale as well as 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 because of erosion. Heavy rain fall in the catchment area, deforestation, denudation of hillslopes and low water retention capacity all contribute to the flooding. About 35 810 km^2 of the region is prone to floods out of which 3760 km^2 is affected annually (Table 7). A maximum of 64.79% in sub-region III and 31.43% in sub-region IV of the area is prone to flooding. These sub-regions are confined to the Brahmaputra valley. About 10% of the cultivated area is seriously affected by floods in each year.

Quantity and quality of water

Impact of population growth With the fast increase in population growth and the dwindling of water resources, per capita availability of water has decreased and the pressure on existing water resources has increased tremendously in the region (Table 8). The demand for water for drinking, agriculture, energy, industry and other uses, which presently is 27.4 km^3, will increase by about 37.9% by 2021, while the water resources will remain similar to today (Table 8). It is quite likely that the water resources may dwindle further in the future with more interference by the additional 20 million people. The data presented in Table 8 show the per capita availability of water and land resources during 1951, 2001 and 2021. There has been an almost four-times reduction in the availability of water and land resources per person in the region over a period of 50 years, and this reduction is likely to grow to six times in the next 20 years compared to the 1951 status. With the present rate of population increase, the situation may become alarming if the use of existing water resources is not suitably planned, developed and conserved (Sharma, 1997). With an increase in population and overall development, pollution by sewage and other domestic products, poisonous industrial effluents, agricultural chemicals, etc., has been steadily increasing. Human activities and mismanagement have altered the chemical and biological status of the water resources. Eutrophication of water bodies by domestic sewage and agricultural runoff has caused drastic changes in the biomass. Water pollution has been caused by increases in the concentration of chlorides, sulfates, nitrate and aluminium, possibly because of higher aluminium content in the soils, and use of agricultural chemicals in an efforts to increase productivity (Table 9). Drinking water from shallow depths is also threatened with pollution. Nitrate, aluminium and manganese concentrations have exceeded the critical limits at some places and the water is not suitable for drinking. With an increase in population, particularly in rural areas, the people have no access to sanitary latrines. There is practically no system of garbage collection and disposal. This results in malaria and waterborne diseases like diarrhoea, dysentery, typhoid, cholera, jaundice, etc. The seasonal rainfall flushes the catchments charged with pollutants causing bacterial pollution of water sources (Warr, 1991). The authorities could not cope with the increasing demand for water of good quality, possibly due to lack of funds, unplanned urbanization, mismanagement of water resources and absence of awareness about health and good quality water. People have to spend considerable amounts of money on medical treatment when they fall sick after drinking polluted water.

Impact of climate change Continuous deforestation has resulted in soil erosion, loss of soil fertility, and land and environmental degradation in the hills and silting of river beds and floods in the plains (Table 7). While it is difficult to measure the effect

Table 8 Effect of population growth on the water resources.

Source	Average annual runoff (Mm^3)	Per capita availability (m^3 per person) 1951	2001	2021
Brahmaputra River	537 240	51 165	13 366	8 850
Barak River	59 800	5 695	1 487	985
Reservoirs, lakes/ponds	5 506	540	137	90

Table 9 Nutrient content in surface and groundwater (mg l^{-1}) (mean of 10 samples)

Nutrients	Surface water	Groundwater
$NO_3 - N$	35.2	45.8
$P - PO_4$	7.4	5.3
Chlorides	68.0	104.3
Sulphates	20.5	26.1
Aluminium	0.3	0.4
Manganese	1.2	1.3
Copper	0.2	0.2

of pollution on resources, and of burning in shifting cultivation on temperature in the region, a declining trend in rainfall has been observed (Table 3). However, a rise of temperature has been experienced. About 25 years back, water in thin layers used to freeze when kept in the open during winter months but this phenomenon has almost ceased now. There is an overall increase in temperature in the region. An increase of temperature by 3°C accompanied by a decrease in rainfall, would increase irrigation needs by 26% (Postal, 1989), because of increased evapotranspiration.

Deforestation and denudation of basins has resulted in water scarcity because the natural water cycle has been upset. The runoff water goes untapped from denuded hill slopes instead of infiltrating to recharge aquifers. This has left even high rainfall areas without water during the dry season. Artificial lakes, reservoirs, ponds and tanks, generally have not filled with water for many years due to climate change, causing water shortage during winter. The forests which control environmental stability, may also affect water resources by enhancing rainfall through higher evapotranspiration rates, although the actual extent of this effect at the regional scale is not clear. About 60% of the land is under forest cover in the region but the high rate of destruction is alarming, jeopardizing the water resources base. Deforestation has to be checked and the most appropriate measure would be to stop shifting cultivation by introducing new sustainable, economically viable and eco-friendly farming systems.

FUTURE STRATEGIES

As the freshwater supplies dwindle in northeastern India, alternative arrangements for available water use are a must. The following measures are suggested for efficient utilization of water in the region:

(1) Conservation of rainwater is important; as the rains are concentrated during the monsoon (May–September) and the rest of the period is almost dry, it is necessary

to implement soil and water conservation measures. Harvesting ponds can be constructed at the foot of hillslopes, at appropriate places, to harvest rainwater.

(2) Better use of rainwater during the rainy season can considerably increase the amount of available water. When rains are plenty, diversification of crops could be undertaken. Better crop management techniques could make better use of water. Only those crops which allow water infiltration and reduce soil erosion should be sown on hillslopes. By improving permeability, runoff can be reduced, resulting in more groundwater recharge.

(3) There is a need to abandon the practice of shifting cultivation. To this end, a long-term study developing new eco-friendly and sustainable farming systems to replace shifting cultivation, has been in progress since 1983. The new farming systems are based on agriculture, livestock, horticulture, silvi-pastoral cultivation (trees with pasture grasses) and pisciculture (fish rearing), which can be adopted depending on the slope and configuration of the land. Water harvesting is done at the base of the hills. This water is being used for irrigation and pisciculture. With suitable treatment, the water can also be used as drinking water. Now, the farmers are adopting these farming systems, though at a slow pace as they are attached to shifting cultivation, socially and culturally.

(4) Re-use of wastewater is important due to several factors such as a need for more water, water pollution control, etc.

(5) Irrigation scheduling of the time and amount of water to be applied is necessary.

(6) Measures for efficient use of water include better water delivery systems, which are flexible and reliable including stream flow controls. Canal seepage needs to be reduced by canal lining practices. Re-use of irrigation-drain water until it is no longer usable would contribute to water conservation.

(7) There is a need for sustainable planning of different cropping and farming systems in a drainage basin context. This will help in better conservation and management of water.

Sustainable solutions to water problems require a radical policy and institutional reforms centred around the establishment of the water regime (Saleth, 2000). Better pricing can help in the collection of funds to maintain the water structures properly. This would also eliminate wasteful and unreasonable use of water resources.

CONCLUSIONS

Northeastern India has plenty of water resources but their misuse and abuse has affected the quantity as well as quality of water. Rainwater harvesting and its efficient use can enhance and improve the water resource base, both quantitatively and qualitatively. The authorities must make concerted efforts to improve the quality of drinking water on which the health of the people depends. Suitable re-scheduling of irrigation and pricing of water is necessary to avoid wasteful use of water. There is also a need to replace shifting cultivation with productive, sustainable and eco-friendly farming systems, to discourage deforestation and encourage infiltration of precipitation. A general awareness programme should be launched to make the people conscious of the efficient use of available water.

REFERENCES

Borthakur, D. N. (1992) *Agriculture in the Northeastern Region*. Bee Cee Publishers, Guwahati, Assam, India.

Borthakur, H. P., Bora, C. K., Phukan, U., Bhathacharya, B. K., Bhowmic, B. C. & Khound, H. P. (1991) Agro-climatic regional planning, Eastern Himalayan region: profile and strategy. Assam Agricultural University, Jorhat 785013, Assam, India.

El Bassam, N. (1997) Fundamentals of sustainability in agricultural production systems and global food security. In: *Sustainable Agriculture for Food, Energy and Industry* vol. I (ed. by N. El Bassam, R. K. Behl & B. Prochnow), 3–11. James & James Publishers, London, UK.

IFPRI (1995) *A 2020 Vision for Food, Agriculture and the Environment: The Vision, Challenge and Recommended Action*. International Food Policy Research Institute, Washington DC, USA

Postal, S. (1989) *Water for Agriculture: Facing the Limits*. World Watch Paper 93. World Water Institute, Washington DC, USA.

Saleth, R. M. (2000) *Water Resources Management: Economic, Legal and Institutional Issues* (Extended summaries, International Conference on Managing Natural Resources). Indian Society of Soil science, New Delhi, India.

Sharma, U. C. (1997) Food security in the northeast. In: *Perspectives for Planning and Development in Northeastern India* (ed. by R. C. Sundryal, Uma Shankar & T. C. Upreti), 197–212. G. B. Pant Institute of Himalayan Environment and Development, Almorah, India.

Warr, V. K. (1991) *Urban Water Supply and Water Borne Diseases during Monsoon*. Water Resources Day Celebrations Souvenir, Shillong, Meghalaya, India.