CHAPTER III
Northeast India: An Environmental Appraisal

3.1. Introduction

The Northeastern Region of India, hereafter referred to as NER, is a distinctive geophysical unit set in the Eastern Himalayan region with a unique physiographic framework and a vigorous monsoon dominated climatic regime. Situated between latitudes 22° N – 29°5' N and longitudes 89°3' E – 97°30' E (Figure 3.1), the region has an area of 255,083 km² comprising seven states viz. Arunachal Pradesh, Assam, Meghalaya, Tripura, Nagaland, Mizoram and Manipur (Table 3.1). It represents 7.76% of India’s total geographical area and 3.7% of the country’s total population.

Table 3.1 Basic information on the states of the Northeastern Region (NER)

<table>
<thead>
<tr>
<th>States</th>
<th>Geographical Extent</th>
<th>TGA (Km²)</th>
<th>Population* (Persons)</th>
<th>Population Density (Persons/km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arunachal Pradesh</td>
<td>26°28'-29°30' 91°30'-97°30'</td>
<td>83,743</td>
<td>10,91,117</td>
<td>13</td>
</tr>
<tr>
<td>Assam</td>
<td>24°8'-27°9' 89°42'-96°10'</td>
<td>78,438</td>
<td>2,66,38,407</td>
<td>340</td>
</tr>
<tr>
<td>Manipur</td>
<td>23°50'-25°41' 92°59'-94°47'</td>
<td>22,327</td>
<td>23,88,634</td>
<td>107</td>
</tr>
<tr>
<td>Meghalaya</td>
<td>25°00'-26°10' 89°45'-92°45'</td>
<td>22,429</td>
<td>23,06,069</td>
<td>103</td>
</tr>
<tr>
<td>Mizoram</td>
<td>21°58'-24°35' 92°16'-93°29'</td>
<td>22,081</td>
<td>8,91,058</td>
<td>40</td>
</tr>
<tr>
<td>Nagaland</td>
<td>25°05'-27°10' 93°28'-95°05'</td>
<td>16,579</td>
<td>19,88,636</td>
<td>120</td>
</tr>
<tr>
<td>Tripura</td>
<td>22°56'-24°32' 91°10'-92°21'</td>
<td>10,486</td>
<td>31,91,168</td>
<td>304</td>
</tr>
<tr>
<td>NER total</td>
<td></td>
<td>255,083</td>
<td>3,84,95,089</td>
<td>151</td>
</tr>
<tr>
<td>All India</td>
<td></td>
<td>3,287,263</td>
<td>102,70,15,247</td>
<td>312</td>
</tr>
</tbody>
</table>

Note: * Provisional population totals of Census of India 2001, Government of India
TGA: Total Geographical Area
Source: NEC (2002)

3.2. Physiography

The NER exhibits all forms of physiographic features ranging from high Himalayan mountains to low foothills, from elevated plateaus to extremely flat lowland basins and floodplains. Physiographic features such as relief and terrain configuration
Figure 3.1 Satellite mosaic map showing location of the study area (derived from IRS 1D Wifs image). Northeast India comprises of seven states viz. Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland and Tripura.
Physiography is also the prime factor determining meso-scale distribution and variability of rainfall of this land of hills and vales. The region can be broadly classified into five major physiographic zones as shown in Figure 3.2 (AAU, 1989; Taher and Ahmed, 2001). These are:

3.2.1. The Greater and Lesser Himalayas in Arunachal Pradesh

This region, comprising Greater and Lesser Himalayan ranges, extend from the Orkhala range along Bhutan-Arunachal border to Siang-Dihang rivers and covers most of Arunachal Pradesh with altitudes ranging from 800 m to 7000 m above mean sea level (msl). The Lesser Himalayan zone rises from a mere 300 m along the margin of the Brahmaputra valley to about 5000 m through a confused labyrinth of hills and ranges intervened by deep gorges. This precipitous zone has a thick vegetation cover and hardly any open valley. The northern parts show increasingly peri-glacial features made of fluvio-glacial deposits with thick layers of transported boulders, rocks and soils.

Beyond the transitional peri-glacial region to the north of the Lesser Himalayas with increasing altitude, there appears the Great Himalayan region devoid of significant vegetal cover and exhibiting roundish topographic features. Rocky surface, alpine vegetation and snow-capped high peaks dominate the physical landscape of this zone. The Great Himalayan range running along the Indo-China border has an average height of 6500 m in Tawang, West Kameng and Lower Subansiri districts. But its altitude decreases northeastward in Upper Subansiri and West Siang districts to an average of 5200 m. The range regains altitude only on entering Tibet and culminates in Namcha Barwa (7755 m), the highest peak in the range. In Arunachal, the highest Himalayan peak is Kangto (7089 m). These ranges show predominance of glacial topography with rounded outline and thick layers of unassorted fuvio-glacial transported deposits. The cold and wind swept surfaces hardly have any tall vegetation.
Figure 3.2  Physiographic zones of Northeast India delineated on a satellite mosaic map developed from IRS 1D Wifs image.
3.2.2. The Eastern Hill Ranges

This region comprises the Dibang-Lohit-Patkai-Naga-Manipur Mizoram ranges most of it belonging to the eastern and southern Patkai Purvachal hills covering the eastern parts of Arunachal Pradesh and almost all the hilly areas of Manipur, Nagaland, Mizoram, Tripura and North Cachar district of Assam. This is a relatively low hilly range with altitudes varying between 1000 m near the Brahmaputra valley to 5000 m near the Indo-China border. It starts from the Dibang-Lohit mountain knot between the Siang and the Burhidihing and then branching out to the east and southeast (NIH, 1992). The Patkai reaches its zenith at Saramati Peak (3826 m) in Nagaland. To the west of Patkai, the lofty Barail range stretches from Tuensang to the southwest to the North Cachar hills district across Nagaland. The Barails rise on the average to a height of 2000 m in Nagaland to reach its highest point at the Mount Japvo (3016 m). In the southeastern part there is an inter-montane hill tract with an average elevation of 1400 m between the Patkai and the Barail ranges making up a part of Tuensang and Phek districts of Nagaland. While its eastern part belongs to the catchment of the Chindwin, the western part is washed by the head-stream of the Barak. This physiographic sub-region presents an impression of a series of rounded hills and flat-bottomed valleys. The Patkai and the Barail ranges continue westward from Nagaland to cover the North Cachar Hills district in Assam. The Barails retain an average altitude of 1600 m and rise to the highest elevation near the eastern part of Mahadeo peak to the east of Haflong. The part of North Cachar Hills north of the Barails contribute to the Brahmaputra catchment while the southern part falls in the Barak catchment. The hills of North Cachar rises from about 500 m from the south of the Karbi plateau to the central Barail range and fall in height southward to the Barak valley. The chain of the eastern hill ranges extend from Nagaland to cover Manipur, Mizoram, Tripura and even beyond India’s NE region as far as to the Chittagong Hills tract in Bangladesh.
3.2.3. The Plateau Region

The plateau region, 32,829 km² in area covering 12 percent of the NER geographical area, consists of the Meghalaya and the Karbi plateaus having average elevations ranging from 200 m to 1357 m and 80 m to 1400 m above mean sea level respectively. The plateaus, although denuded, still retain a hilly character unlike the Deccan and can be compared rather to the eastern or western Ghat than the central Deccan plateau (NIH, 1992). The Meghalaya plateau rises abruptly for about 1000 m above the Sylhet plain (in Bangladesh) due to an upthrust and retains an uniform outline towards south except in places where it is dissected by south flowing streams through gorges and water falls. From this margin the plateau rises slowly northward to the central part where there are distinct ranges of east-west alignment like the Tura-Kylas range and Shillong range. In Garo hills, the Tura-Kylas range attains a maximum height of 1412 m at Nokrek Peak while in the east Khasi hills, the Shillong range reaches up to 1961 m at Shillong Peak. The Meghalaya plateau then begins to loose height, but through successive ranges thrown out in all directions, still retaining a hilly character which is particularly prominent to the north of the middle part i.e. the Khasi hills. The western and eastern ends, i.e. the Garo and Jaintia hills are more dissected and denuded and merge with the Brahmaputra plain through gentle gradients and isolated hills and hillocks.

The Karbi hills, projected northward up to the bank of the Brahmaputra causing constriction to the valley, lies to the east of the Meghalaya plateau. It is almost separated from the Meghalaya plateau by the degradation of the river Kopili and its headstreams like Diyung, Lumding, Lankajan etc. On the southeastern side it is separated from the Nagaland hills by the Dhansiri river and its head streams. It is denuded by the Jamuna on its southern part. It is only in the heartland that this plateau rises high up to 1959 m at Chenghehision Peak and 1361 m at Dambukso.
3.2.4. The Plains

There are four major plains areas in Northeast India formed mainly by valleys of rivers viz. the Brahmaputra plains, the Barak plains the Manipur plains, and the Tripura plains.

3.2.4.1. The Brahmaputra Plains

The Brahmaputra plain (valley) having an area of 56480 km² with altitude varying from 34 m to 130 m comprises mainly the vast alluvial floodplains of the Brahmaputra valley in Assam. It is a narrow and elongated plain with a length of about 660 km and average width of about 70 km. From its widest part with a width of about 90 km in the upper part, the valley becomes narrow as the river flows to the west because of the constriction imposed by the Karbi plateau in its central part to attain a width of about 50 km. The plain widens to the west and narrows down again near Guwahati because of the Meghalaya plateau overlooking the bank of the river. The plain opens up and becomes wide again as the Meghalaya plateau recedes to the south. In contrast to the northern margin of the valley its southern fringe is fairly irregular being combed by the plain embayments created by the larger tributaries entering into the plateau and hills.

3.2.4.2. The Intermontane and Piedmont Plains

The Barak, Manipur and Tripura plains belong to the inter-montane piedmont plains surrounded by the eastern hill ranges that have developed into important urban centers of respective states.

3.2.4.2.1. The Barak Plain

The Barak plain (valley) in the state of Assam is situated between 24°10' N-25°10' N latitudes and 92°15' E-93°15' E longitudes in the southern part of the state. The Barak plain, 6922 km² in area and 75 m in average altitude, is the head-ward...
piedmont part of the Barak-Surma-Kushiara plain that lies largely in Bangladesh. The plain slopes down gently to the west with its middle part being the lowest through which flows the river Barak sluggishly in an extremely meandering course leaving a series of ox-bow lakes and swamps.

3.2.4.2.2. The Manipur Plain

The Manipur plain (basin), 1843 km² in area and 700 m in mean altitude, is said to be of lacustrine origin. It features gravel patches occurring in small strips by the side of some streams rising occasionally to about 30 m above the surrounding plains and many a isolated hills aligned north-south even in the bosom of the Lake Loktak standing as islands.

3.2.4.2.3. The Tripura Plain

The Tripura Plain, 3500 km² in area and 20 m in average altitude, represents a part of the margin of the Bangladesh plain. It contains both erosional and depositional features with worn down hillocks, piedmont terraces and thick alluvial deposits covering the structural synclines (NIH, 1992).

3.3. Geology

Northeast India and its adjoining territories represent a tectonically distinct geological domain occurring in intimate spatial association (Nandy, 2001). Rocks representing the entire span, from Archean to Recent, occur in this relatively small region. Eocene (Disang) sediments of trench facies occur in juxtaposition with those of platform facies (Jaintia) of stable self condition. Neogene Siwalik foredeep molasses in front of the Himalaya and Tipam molasses of Upper Assam basin in front of the Indo-Myanmar mobile belt occur in close proximity and are separated by the Brahmaputra Alluvium.
3.4. Hazard Scenario

The NE Region is an extremely hazard prone area due to its location in the Himalayan and Sub-Himalayan belt with a fragile geologic base and a powerful monsoon driven hydrologic regime. Among natural disasters floods, earthquakes and landslides are the three main sources of hazards while hydrometeorological disasters like cyclones and rainstorms are, in general, limited in actual impact and damage except in their significant contribution to enhance the river-runoff leading to intensification of floods. Heavy rainstorms and cloudbursts in the hilly uplands of the basins of the flashy tributaries of the Brahmaputra often result in flow-deluge in the rivers sweeping the downstream plains in flash floods.

3.4.1. Earthquake Hazard

Being located in the most active seismic zone of the world (Nandy, 2001), Northeast India and adjoining areas are highly vulnerable to earthquake hazards. Out of the five great earthquakes (with magnitude > 8 in the Richter scale), that have rocked the planet so far, three occurred in this region. These are the Great Assam earthquake of 1897 and the Assam earthquake of 1950, having magnitudes 8.7 and 8.6 in the Richter scale respectively that caused catastrophic damage to life and property. Besides, there were nine incidences of large (> 7 Richter magnitude) earthquakes during the period 1897 to 1947. Out of these nine, four events occurred in the Indo-Myanmar tectogene, three in the Meghalaya plateau-Karbi hills domain, one in the Eastern Himalaya and one occurred in the northeast corner of the Bengal Basin. The area between 88°E and 98°E longitudes and 20°N and 31°N latitudes in this region experienced 974 earthquake events of magnitude > 4 during the period from 1964 to 1993 (Nandy, 2001). Major earthquake episodes of Assam appear to be separated by a period of seismic quiescence.
3.4.2. Impact of Earthquakes on the Hydrologic Regime

The Brahmaputra basin in Northeast India constitutes an extremely unstable seismic region of the world. Tectonic activity has had very significant impact on the hydrologic and geomorphic regime of the region, especially that of the Brahmaputra river system including its host of tributaries and water bodies (wetlands) strewn over the flood plains, leading to intensification of flood hazards in the aftermath of the two great earthquakes of 1897 and 1950 (Goswami and Das, 2002). These earthquakes caused extensive landslips and rock-falls on hillslopes, subsidence and fissuring of ground in the valley, and changes in the course and configuration of the rivers. So far as the hydrologic regime of the region is concerned, these earthquakes have resulted in (i) landslides on the hillslopes including blockage of river courses (ii) flash floods due to sudden bursting of landslide-induced temporary dams (iii) raising of river beds due to heavy siltation, fissuring and sand venting (iv) subsidence/elevation of existing river and lake bottoms and margins and creation of new water bodies and waterfalls due to faulting. Tectonics and denudation of the Himalayas and alluviation of the Brahmaputra valley in Assam are concomitant phenomena (Goswami, 1985). There appears to be phases of rapid aggradation of the Brahmaputra channel associated with earthquakes followed by relatively slower removal of accumulated debris over longer time periods.

3.4.3. Flood Hazard

The Brahmaputra and the Barak basin, particularly in Assam, have earned notoriety for the awesome hazards of annual flood and erosion that create mayhem every year, bringing misery to the people and shattering the fragile agro-economic base of the region. The valleys of the Brahmaputra and the Barak, which together account for 24.9% of the surface area of NER and 80.8% of Assam, are two of the worst flood ravaged regions of India receiving on the average 3-4 waves of flood every year from the Brahmaputra and the Barak rivers and their dense networks of tributaries. These floods cause extensive damage to agriculture, environment, human life and property.
and thereby to the overall economy of the state. With 40% of its land surface (3.2 million ha) susceptible to flood damage which is 9.4% of the country’s total flood prone area (33.5 million ha), Assam’s Brahmaputra valley represents one of the most acutely hazard-prone regions in the country.

Floods in NER are caused by a combination of natural and anthropogenic factors. The unique geo-environmental setting of the region vis-à-vis the eastern Himalayas, the highly potent monsoon regime, weak geological formation, active seismicity, accelerated erosion, rapid channel aggradation, massive deforestation, intense landuse pressure and high population growth, especially in the floodplain belt, and ad hoc type temporary flood control measures are some of the dominant factors that cause and/or intensify floods in the Brahmaputra and the Barak basins (Goswami, 1998). The scenario is further exacerbated by a myriad of social, environmental and economic factors that make populations increasingly vulnerable.

Assam, the most flood prone and flood ravaged state of the region, has experienced major floods in the years 1954, 1962, 1966, 1972, 1977, 1984, 1986, 1988, 1998 and 2000 in both the Brahmaputra and the Barak valleys. In the aftermath of the Great Earthquake of 1950, the damage due to and intensity and frequency of floods increased progressively. The floods of 1988 and 1998 were the worst in recent history. The 1988 floods broke all previous records of flood damage, affecting 3.820 million ha. of land, nearly 12 million people, 5 lakh households and 1.43 million ha. of cropland, besides claiming 226 human lives and innumerable cattle and wildlife. The total damage was estimated at Rs. 1,512 crores. Similarly, the 1998 floods were unprecedented in terms of inundation and persistence. Record high flood levels were created at many gauge stations. The total loss was estimated at Rs.1000 crores. In 2002, when almost the entire Brahmaputra valley was submerged, the loss was estimated at Rs. 2000 crores (Goswami and Das, 2003a).

Breaching of embankments has been a major cause of intensification of the flood hazards in recent times. The undesirable consequences of embankments, especially in aiding channel aggradation and overbank flooding is clearly visible in
Assam. Structural measures, mainly embankments, have been used so far as the sole answer to tackling floods. Out of a total of 15,675 km. of embankments built in the entire country, Assam alone has as much as 5,027 km., about 32% of the country’s total.

3.4.4. Landslide Hazard

The hilly terrain of Northeast India, a part of an active Himalayan mountain belt, is characterized by steep slopes, high relative relief, young weathered jointed and folded rocks and therefore this geologically unstable region is highly prone to landslides and related phenomena (Tiwari et al., 1998). All over the hilly terrain of NER, landslides are seen to occur more frequently during and immediately after the monsoons and major landslides are found to have been preceded by heavy rain spells of several hours to several days while some of the catastrophic landslides have been triggered by high cumulative rainfall of previous days to months (Saikia, 2002; Sikdar et al., 2002). High intensity and prolonged rainspells are a major factor inducing landslides in the region. Other natural and anthropogenic factors responsible for frequent landslides are young geology, tectonic activity, high slope and relief and improper landuse practices, denudation of forest cover, soil erosion, building up of hillslopes, earth cutting, blasting, quarrying etc.

3.5. Weather and Climate Regime

The weather and climatic regime of the region belongs to the sub (extra) tropical monsoon type dominated by the southwest monsoon system. According to Pant and Rupa Kumar (1997) the NER has a dominant humid/per humid climate and the Mesothermal type of thermal regime. But at the same time, the region’s weather/climate patterns are endowed with a strong regional character by virtue of its subtropical location, extremely varied forms of physiography and local climatic controls viz. alternating pressure cells of the Bay of Bengal and north west India, local
depressions and their periodic oscillations, western disturbances, local mountain and valley winds and the vast extent of water bodies etc. The pattern is so distinctive that the climate of the region is recognized as a class by itself incomparable to other regions in western part of India lying on the same latitudes (Barthakur, 1986). Especially in respect of the Brahmaputra and the Barak valleys, the local climatic conditions exhibit an individuality that mark it different from the Koppen’s ‘Cwg’ i.e. *humid mesothermal gangetic* type with which the valley areas of the region are normally identified.

Because of these local climate controls, the different physiographic divisions and subdivisions have acquired certain individual characteristics within the larger framework of monsoonal climate domain. Consequently remarkable spatio-temporal variability is observed in the climatic elements such as rainfall, temperature, pressure and wind patterns, humidity etc. over the region. Based on variations of these climatic elements the NER can be divided into the following climatic sub-zones (Taher and Ahmed, 2001).

(i) *Cold, Humid, High Altitude Climate*: Central and northern Arunachal Pradesh and the eastern hills region above 2000 m of altitude have this climate type where temperature extremes range between 0°C to 20°C and precipitation averages at about 1500 mm with occasional snow-fall.

(ii) *Humid Subtropical Monsoon Climate*: Arunachal foothills bordering the Brahmaputra valley, Nagaland, eastern part of North Cachar Hills, Manipur and Mizoram belong to this climate type. Here average annual temperature varies between 10°C and 20°C, summer is hot (18°C-25°C), and humid and winter is longer and drier than in the plains.

(iii) *Hot, Humid Monsoon Climate*: This type of climate prevails in the valleys of the Brahmaputra and the Barak, the plains of Manipur and Tripura and northern foothills of Meghalaya. Summer maximum and winter minimum temperatures range between 36°C and 10°C in this region with hot climate and high rainfall, average annual rainfall varying between 1500 mm to 3000 mm. Humidity remains above 60% for nine months of the year.
(iv) **Rainy, Cool, Monsoon Climate**: Found in the southern parts of Meghalaya and Karbi plateaus, the hallmark of this climate type is relatively low temperature throughout the year with average summer temperature remaining below 20°C and winter temperature coming down to 0°C. This highly precipitous zone experiences average rainfall of 2500 mm for almost eight months of the year. Cherrapunjee and Mawsynram, two rainiest places on the earth, belong to this region.

(v) **Alpine Climate**: The Greater Himalayan ranges in northern Arunachal belong to this cold climate domain with temperature remaining below freezing point during the winter. Precipitation occurs mostly in the form of snow-fall in winter and occasionally as rainfall in the summer. Cold mountain winds and blizzards is a general feature of this climate region.

### 3.6. Hydrological Regime

The Brahmaputra in the northern part and the Barak flowing through the southern margins along with their numerous tributaries are the two main river systems that have created a very dynamic and powerful hydrological regime in the region (Figure 2.3). A third river, the Irrawaddy, flowing through Myanmar at the easternmost flanks of the region also drains a part of it mainly through some of its tributaries like the Chindwin. Individually the basins of the Brahmaputra, the Barak and the Irrawaddy occupy 68.42% (174528 km²), 16.36% (41723 km²) and 7.27% (18539 km²) of the region and together they account for 92.04% (234790 km²) of the region's geographical area. But the Brahmaputra and the Barak, the catchments of which jointly claim 84.78% (216251 km²) of NER, remain the most dominant hydrological systems having the greatest impact on the environment and lives of the people. The surface water resources available in the region amounts 652.8 billion cubic meters (BCM) that gives it the highest (34%) share in the country's total surface water resources potential. Out of the total of 84,044 MW of the country's total hydropower potential the NER carries
a potential of 31,857 MW (37% of the country) of which about 3% has so far been tapped for human use (Brahmaputra Board, 2000). The per capita and per hectare availability of water in this region is the highest in the country.

Figure 3.3 Drainage network of Northeast India (after Brahmaputra Board, 1985). The Brahmaputra and the Barak having nearly 30 and 10 major tributaries in NE India respectively are the two major river system of the region draining 68% and 16% of the region's total area respectively. The Irrawaddy that drains only 7% of the total area of the region is not shown in the map.
3.6.1. The Brahmaputra River and its Basin

The Brahmaputra is one of the world’s largest rivers, with a drainage area of 580,000 km², (50.5% in China, 33.6% in India, 8.1% in Bangladesh and 7.8% in Bhutan). In India, its basin is shared by Arunachal Pradesh (41.9%), Assam (36.3%), Meghalaya (6.1%), Nagaland (5.6%), Sikkim (3.8%) and West Bengal (6.3%). Originating from the great glacier mass of Chema-Yung-Dung in south east of the Mansorovar lake in the Kailash range of the Himalayas of southern Tibet at an elevation of 5300 m, it traverses 1,625 km in China and 918 km in India, before passing 337 km through Bangladesh and emptying into the Bay of Bengal through a joint channel with the Ganga. A unique river, it drains such diverse environments as the cold dry plateau of Tibet, the rain-drenched Himalayan slopes, the landlocked alluvial plains of Assam and the vast deltaic lowlands of Bangladesh (Goswami, 1985).

Flowing eastward for 1,625 km over the Tibetan plateau, the Brahmaputra, known there as the Tsangpo, enters a deep narrow gorge at Pe (3,500 m) and continues southwards across the east-west trending ranges of the Himalayas viz. the Greater Himalayas, Middle-Himalayas and sub-Himalayas before debouching onto the Assam plain near Pasighat. These different geo-ecological zones have a distinctive assemblage of topographical, geological, climatological and floral characteristics. The gradient of the Brahmaputra river is as steep as 4.3 to 16.8 m/km in the gorge section upstream of Pasighat, but near Guwahati it is as flat as 0.1 m/km. The dramatic reduction in slope exhibited by the Brahmaputra as it cascades through one of the world’s deepest gorges in the Himalayas before debouching on to the Assam plain explains the sudden dissipation of immense energy locked in it and the resulting unloading of large amounts of sediments in the valley downstream. Two rivers, the Dibang and the Lohit, join the upper course of the Brahmaputra, known as the Dihang (or Siang) river, a little south of Pasighat and the combined flow, hereafter called the Brahmaputra, traverses westward through Assam for about 640 km. until near Dhubri, where it abruptly turns south and enters Bangladesh.
In the plains of Assam and Bangladesh, the Brahmaputra flows in a highly braided channel marked by the presence of numerous mid-channel and lateral bars and islands. An extremely dominant monsoon domain interacting with a unique physiographic setting, fragile geological base and active seismo-tectonic instability together with anthropogenic factors have molded the Brahmaputra into one of the world’s most intriguing gigantic fluvial system (Goswami, 1985; Ives and Messerli, 1989).

In the course of its 2,880 km. journey, the Brahmaputra receives as many as 22 major tributaries in Tibet, 33 in India (in the northeastern part, 20 of these coming from the north and another 13 from the south bank) and 3 in Bangladesh. The northern and southern tributaries differ considerably in their hydro-geomorphological behaviour owing to different geological and climatic conditions. The north bank tributaries generally flow in shallow braided channels, have steep slopes, carry a heavy silt charge and are flashy in character, whereas the south bank tributaries have a flatter gradient, deep meandering channels with beds and banks composed of fine alluvial soils, marked by a relatively low sediment load. Many of the north bank tributaries are of Himalayan origin fed by glaciers in their upper reaches viz. the Subansiri, the Jia Bharali and the Manas. The Debang and the Lohit are two large tributaries emerging from the extreme eastern flanks of the of the Himalayas, while the Jiadhal, the Ranganadi, the Puthimari, the Pagladiya etc. are major rivers having their sources in the sub-Himalayas, the later two in Bhutan. Among the south-bank tributaries, Burhidihing originates at the Nagaland-Myanmar border; the Dhansiri and the Dikhow originate in the Naga hills; the Kapili in the Karbi plateau, while the Kulsi and the Krishnai flow from the Meghalaya hills.

The hydrological regime of the Brahmaputra that responds to the seasonal rhythm of the monsoon and freeze-thaw cycle of the Himalayan snow, is characterized by an extremely large and variable flow, enormous rates of sediment discharge, rapid channel aggradations, accelerated rates of basin denudation and unique patterns of river morphology. With an average annual discharge of 19,830 m$^3$s$^{-1}$ (cubic metre per second
or cumec) at its mouth, the Brahmaputra ranks fourth among the large rivers of the world. In terms of water yield per unit discharge area, the Brahmaputra leads other major rivers, the rate for the catchment upstream of Pandu being 0.0306 m$^3$s$^{-1}$km$^{-2}$. Water yields of some of the tributaries of the Brahmaputra like the Subansiri, Jia Bhoroli and Manas rivers are as high as 0.076, 0.086 and 0.023 m$^3$s$^{-1}$km$^{-2}$ respectively, surpassing many of the world’s major rivers (Goswami 1998). High monsoon rainfall in the upper catchments and steep gradients are considered to be the major factors responsible for the high rates of unit discharge which in turn help generate the high sediment yield from the basin and contribute significantly towards causing drainage congestion in the valley.

The Brahmaputra is characterised by marked seasonality and high variability of daily flow. The highest recorded daily discharge in the Brahmaputra at Pandu was 72,726 cumecs in August 1962 while the lowest was 1,757 cumecs in February 1968. The discharge in the river between summer high flows and winter low flows fluctuates, on an average, by 12 times although in certain years it has been as high as 20 times (Goswami and Das, 2003b). The mean annual flood of the river, 48,200 cumecs, has a recurrence interval of 2.2 years, while the maximum recorded flood of 72,726 cumecs is likely to be repeated once in about every 133 years. The enormously large variations in the river’s daily discharge over different seasons are a remarkable feature of its flow regime. Since the time lags and peaking characteristics of flood flows are different in different rivers draining into the Brahmaputra due to variations in catchment physiography and monsoon precipitation, the tributary inflows generate large and variable perturbations on the Brahmaputra’s discharge hydrograph.

3.6.2. The Barak River and its Basin

The river Barak with its tributaries is the second largest river system in Northeast India. The river Barak rises in the Manipur hills south of 'Mao' bordering Nagaland and Manipur, south east of mount Japvo. From its origin the river flows in a southwesterly direction through a narrow valley up to Jirighat where it takes a
westward turn. After traversing through Manipur hills, Mizoram and Assam-Manipur border it emerges from the hills and debouches into the plains, known as the Barak valley, near Lakhipur. It traverses the valley in a westerly direction up to Karimganj where it bifurcates into two branches known as the Surma and the Kusiyara which reunite near Bhairab Bazar in Bangladesh, the joint stream being called the Meghna which later meets with the Brahmaputra, known locally as the Padma and merges with the Bay of Bengal. The Barak has a total length of 902 km from its origin to its outfall with the Meghna in Bangladesh out of which the Indian reach is 564 km long. Out of the total basin area of 42,455 km², 26,193 km² lies within India (NE India). The principal tributaries of Barak in Assam are Jiri, Chiri, Madhura, Jatinga in the north and Sonai, Rukni, Dhaleswari, Katakhali, Singla and Longai in the south. While average rainfall in the Barak basin is 2640 mm (Mirza et al., 2001), during the monsoon the intensity of rainfall may be as high as 350 mm per day. Average discharge in the Barak river at Badarpur is 694 cumec which can rise to 7764 cumec during floods. Mean annual runoff of the Barak at Badarpurghat is 41,000 million cubic metre (Kothyari and Garde, 1991).

3.7. Landuse/Landcover

The landuse/landcover pattern of the NE Region and its states are shown in Figure 3.4 and Table 3.2 respectively. All the states have more than the mandatory forest cover of 33% of their respective geographical areas except Assam which has 22% forest cover. Arunachal Pradesh, with 69,350.87 km² of forested area remains the greenest state of the region. The NER as a whole has 59% forest cover, the highest in the country.
Table 3.2  Land Use/Land Cover statistics of NER (Area in km²).

<table>
<thead>
<tr>
<th>State</th>
<th>TGA</th>
<th>Built-up Area</th>
<th>Agricultural Area</th>
<th>Forest Area</th>
<th>Water body</th>
<th>Wasteland</th>
<th>Others*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arunachal Pradesh</td>
<td>83,743</td>
<td>99.12 (0.12)</td>
<td>2063.80 (2.46)</td>
<td>69350.87 (82.81)</td>
<td>803.30 (0.96)</td>
<td>1147.32 (1.37)</td>
<td>10278.59 (12.27)</td>
</tr>
<tr>
<td>Assam</td>
<td>78,438</td>
<td>211.47 (0.27)</td>
<td>42486.38 (54.16)</td>
<td>17263.87 (22.00)</td>
<td>5571.80 (7.10)</td>
<td>5780.31 (7.37)</td>
<td>7124.17 (9.08)</td>
</tr>
<tr>
<td>Manipur</td>
<td>22,327</td>
<td>78.34 (0.35)</td>
<td>1692.12 (7.58)</td>
<td>14140.78 (63.33)</td>
<td>106.64 (0.48)</td>
<td>290.10 (1.30)</td>
<td>6019.02 (26.96)</td>
</tr>
<tr>
<td>Meghalaya</td>
<td>22,429</td>
<td>16.98 (0.08)</td>
<td>731.62 (3.26)</td>
<td>14249.83 (63.53)</td>
<td>101.53 (0.45)</td>
<td>25.50 (0.11)</td>
<td>7303.54 (32.56)</td>
</tr>
<tr>
<td>Mizoram</td>
<td>21,081</td>
<td>78.73 (0.37)</td>
<td>66.00 (0.31)</td>
<td>20079.56 (95.25)</td>
<td>0.63 (0.0029)</td>
<td>0 (0)</td>
<td>856.08 (4.06)</td>
</tr>
<tr>
<td>Nagaland</td>
<td>16,579</td>
<td>28.73 (0.17)</td>
<td>389.51 (2.35)</td>
<td>11421.84 (68.89)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>4738.92 (28.58)</td>
</tr>
<tr>
<td>Tripura</td>
<td>10,486</td>
<td>39.37 (0.38)</td>
<td>1548.07 (14.76)</td>
<td>3806.52 (36.30)</td>
<td>65.62 (0.63)</td>
<td>0 (0)</td>
<td>5026.42 (47.93)</td>
</tr>
<tr>
<td>NER total</td>
<td>255,083</td>
<td>552.74</td>
<td>48977.50</td>
<td>150313.27</td>
<td>6649.52</td>
<td>7243.23</td>
<td>41346.74</td>
</tr>
<tr>
<td>All India</td>
<td>3,287,263</td>
<td>139137.72</td>
<td>1652443.59</td>
<td>1657108.15</td>
<td>106108.20</td>
<td>443903.15</td>
<td>205268.19</td>
</tr>
</tbody>
</table>

*Others include areas under shifting cultivation, grassland/grazing land, snow covered area, mining/industrial waste and unclassified area.

TGA: Total Geographical Area. Figures in parentheses indicate percentages of corresponding TGA of respective states.

3.8. Forest, Vegetation and Biodiversity

The NER belongs to the Indo-Burma biodiversity hotspot, one of the 25 biodiversity hotspots recognized by the World Conservation Union (IUCN). It is the richest reservoir of floristic and faunal diversity in India owing to its unique physiographic and climatic characteristics. NE India encompasses a broad range of ecological habitats varying from grassy meadows to dense humid evergreen forests and disturbed secondary formations to almost virgin natural forests. The altitudinal and rainfall patterns of southwest and northeast monsoons play a significant role in the development of ecological niches in this region (IIRS, 2002).

The region supports all types of vegetation right from the cultivated plants to grasslands, meadows, marshes, swamps, scrub forests, mixed deciduous forests, humid evergreen forests, temperate and even alpine vegetation (Mao and Hynniewta, 2000). The major forest types of the region based on altitude (Rao, 1998) are - Alpine forests (4000-5500 m); Sub-alpine (3000-4000 m); Temperate forests (1800-3000 m); Subtropical forests (1000-1800 m) and Tropical forests (up to 1200 m). Arunachal Pradesh, the meeting region of temperate east Himalayan flora, palaeo-arctic flora of Tibetan highland and wet evergreen flora of south-east Asia and Yunnan, occupies a significant place as a crucible for the evolution of flora in NE India and for speciation. The Brahmaputra valley presents the convergence of temperate east Himalayan flora and the wet evergreen and wet deciduous floristic elements. The Khasi-Jaintia hills is the corridor through which the southeast Asia floristic elements have entered into the subcontinent through the Arakan arc.

Out of the total number of about 17,500 flowering plants species estimated to occur in India by the Botanical Survey of India (BSI), 8500 species, accounting for about half of the total, hail from this region. NE India has about 1808 endemic species out of 5725 found in India, the largest in this category. The varied forest types found in the region exhibit innumerable varieties and kinds of orchids, medicinal, horticultural plants, bamboos, canes, timbre, dye, fibre and resin yielding plants, wild relatives of cultivated plant species etc. Still many new species of plants are being discovered and
many more will become known in the future on further investigation in many forests and ecosystems that lie unexplored as yet. The region is one of the major centres of diversity of crop plants (Vavilov, 1951). More than 9650 species of rice, 15 species of maize, 14 species of banana, 17 species of citrus with 52 varieties, 15 species of sugarcane and their wild relatives and more than 60 species of bamboos are found here (Hore, 1998).

About 600 plant species from NE India are listed as rare, endangered or threatened. Further, over 800 species of orchids are reported from this region which are included in the Appendix-II of the CITES (Convention on International Trade in Endangered Species) and considered endangered. As many as 114 floral species from this region feature in the Red Data Book of Indian plants prepared by the BSI. The rich species diversity that characterize the flora of Northeast India is largely attributable to the diverse geographical area, varied topography, climate and soil variability, immigration and colonization of plant species from widely different territories coupled with the fact that it is the transitional zone between the Paleo-arctic, Indo-Malayan and Indo-Chinese biogeographical zones as well as the confluence of the Himalayan region with Peninsular India.

Similarly, its unique bio-geographical composition has endowed NE India with an abundance of faunal wealth. The region is reported to have about 7233 animal species that include 195 mammalian, 607 bird, 115 reptile, 54 amphibian, 267 fish and 4953 insect species (Hattar, 2000). About 68 of these species (32 mammalian, 28 bird, 6 reptile and 1 amphibian) are considered endangered. The Brahmaputra and the Barak, the two principal rivers of the region along with a plethora of wetlands and water bodies, make this region extremely rich in fish-diversity. A combined length of 19,150 km of river stretch, 23,972 ha of reservoirs, 143,740 ha of lakes, 40809 ha of ponds and 2780 ha of rice-cum-fish culture area of the region harbour about 267 fish species. Assam alone has 185 species in its rivers with total length of nearly 4820 km and 1.2 lakh ha of flood plain wetlands and swamps (Das, 2000). Out of 818 species of avifauna found in NER, Assam has the highest- 689 species accounting for 53.49% of
avifauna found in the whole of India followed by Arunachal Pradesh with 646 species (50.19%), Manipur with 523 species (40.61%), Nagaland with 451 (35.01%), Meghalaya with 366 species (28.42%), Mizoram with 243 species (18.87%) and Tripura with 139 (10.79%).

The natural landscapes in this region have been extensively modified in the recent past due to pressure on land, decreasing cycle of shifting cultivation, commercial exploitation of forests for timbre and lack of scientific forest management. Shifting cultivation (Jhum), the age-old agricultural tradition of indigenous hill-tribes continues to thrive in the region, albeit, with cycles reduced from 20-30 years in earlier times to 5 years and even 3 years in many areas. Short-cycle Jhuming is considered to be a major cause of degradation of forests and land in the region and extensive changes in the region’s landscape (IIRS, 2002). Reduction in the Jhum cycle resulting from increase in pressure on land by a phenomenally exploding population has accelerated the process of eco-degradation leaving behind degraded secondary forests, bamboo thickets, weeds or simply barren, lands in the jhumscapes (Toky and Ramakrishnan, 1981).

The tropical vegetation of Northeast India, typically occurring at elevations up to 900 m with vegetation types such as evergreen, semi evergreen and moist deciduous forests, is facing maximum pressure at present due to human interventions. The evergreen (rain) forests found in the Assam valley, the foothills of the eastern Himalayas and the lower parts of the Naga hills, Meghalaya, Mizoram and Manipur where rainfall exceeds 2300 mm per annum have been fragmented extensively due to shifting cultivation and timbre logging setting off a retrogressive successional trend resulting in irreparable loss of bio-diversity. Very high levels of floristic richness and endemism (Chatterjee, 1939) and large-scale deforestation due to anthropogenic pressures (Khan et al., 1997) have made conservation of biodiversity most important in the NE region. A network of as many as 51 protected areas of which 13 are National Parks and 38 are Wildlife Sanctuaries created in the region over the years have served the cause of conservation of its delicate ecosystems and precious biodiversity.
3.9. Population and Settlement Pattern

Northeast India is peopled by a great variety of ethno-linguistic tribes, castes and communities thus demonstrating a diversity of cultures and ethnicity that is no less astounding than its fabulous biological and ecological diversities. With a total population of 3,84,95,089 the NER is home to 3.7% of India’s total population (Census of India, 2001). The rugged hilly terrain of the region and the dense forests have considerably influenced its settlement pattern and resulted in a low population density of 151 persons per sq. km in contrast to the country’s figure of 312 persons per sq. km. Growth rate of population during the last census decade (1991-2001) was 22.02% comparable to the country’s figure of 21.34%. Assam is the most populous state of the NER with 69.20% of the region’s population followed by Tripura (8.29%). Mizoram is the least populated state with 2.31% of the region’s total population (Table 3.1). The decadal variation in population of the seven states of the region over the period 1951-2001 are shown in Figure 3.5 (NEC, 2002). Projected Scenario (Brahmaputra Board, 2000) in the same graphical plot shows that the region will grow in population at a moderate rate to a figure of 70 million by the year 2050.

The settlement pattern of the region is highly influenced by its physiography and climate resulting in remarkably uneven distribution of population (Bhattacharyya, 1986). As much as 72 percent of the region is covered by mountains, hills and plateaus that are agriculturally less productive and hence have low and sparsely distributed population. The bulk of the region’s population is supported by the plains that cover 28 percent of its geographical area made up mainly of river valleys. About two-third of the NER’s population is concentrated in the valleys and plains of the Brahmaputra and the Barak rivers. Population is also sparse in flood plains of the rivers that are vulnerable to floods and erosion and in foothills where thick forests and unproductive soils restrict traditional agricultural practices (Taher and Ahmed, 2001).
Population of Northeastern states except Assam (Million)

- Arunachal Pradesh
- Manipur
- Meghalaya
- Mizoram
- Nagaland
- Assam
- Arunachal Pradesh
- Mizoram


Figure 3.5 Growth of population in NE India and its states during 1951-2001 and projected growth till 2050.