# An analysis of changing land use pattern and its effect on Umtrew Basin, Northeast India

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## Abstract

Land use change is accelerating throughout Northeast India and is the cause of many environmental problems. The Umtrew is a major river that originates on the Meghalaya Plateau, flows down to the Assam Valley, and is one of the tributaries of the Brahmaputra (Roy, P.S. and Tomar, S. 2001).

The Umtrew Basin covers an area of 1253.1 sq km, mostly in the foothills of the Meghalaya Plateau. Remote sensing and GIS techniques are used to explore the changing pattern of land use/land cover. The study employs satellite data from Landsat-MSS and IRS-1C LISS III for the years 1977, 1999, 2004 and 2007. Its aim is to formulate a plan/strategy for maintaining environmental quality.

**Keywords:** land use, basin, remote sensing, GIS, GPS

## Introduction

Managing land use/land cover change in the river basin ecosystems of Northeast India is an extremely complex problem. However, success depends on having appropriate information on land use/land cover in the form of maps and statistical data. Although primarily a hydrological unit, a drainage basin also represents a natural unit for physical, economic, industrial and social planning and development (Iyer, K.G. and Roy, U.N. 2005; Reddy, Y.V.R. *et al.* 2008).

Changes in any of the components of the basin may change the overall environment of the basin. Today, anthropogenic impacts on land cover are rec-

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ognized as critical factors influencing global environmental change (Lambin, E.F. and Geist, H.J. 2006; Nagendra, H. *et al.* 2004).

Northeast India is rich in flora and fauna. It falls in one of the world's 25 biodiversity hotspots. Its physiography, climate and soils provide suitable conditions for luxuriant forest growth. However, unchecked economic activities and population growth have left their scars on the landscapes, particularly in the last few decades.

Over the last thirty years, the forest cover has changed significantly due to relocation of the people to the riverside, extensive deforestation, farm and grazing abandonments, intensification of agriculture and industrial activities.

Symptomatic of the environmental problems in the region are:

*a)* Dwindling rainfall, as recorded in the world's wettest part, the Cherrapunjee–Mousinram area.

*b)* Increasing floods and soil erosion in the major river basins, particularly the Brahmaputra and the Barak.

*c)* Habitat destruction the consequence of which is increasing human–animal conflict.

*d)* More frequent landslide activity and consequent disruption of transport and communication networks as well as river valley aggradation.

The Umtrew Basin is similar to that of many rivers in Northeast India and is taken for a case study of changing land cover and land use impacts.

This paper also seeks an appropriate methodology for other studies in this region using remote sensing integrated with GIS as a tool (Rhoades, R.E. 1998). Since many parts of Northeast India are difficult to access for precise field study, remote sensing and GIS techniques are the most adequate methods of analyzing land use and land cover change.

## Study area

The Umtrew River Basin of Northeast India lies in between 25˚ 35' 15″ N to 26˚ 14' 18″ N latitudes and 91˚ 35'17″ E to 92˚ 00' 15″ E longitudes *(Figure 1).* The river has its source in the East Khasi Hills of the Meghalaya Plateau and then it flows down from the south-western corner of the hills northward.

After crossing the national highway № 37 near Sonapur it ultimately receives the Kolong River near Kajalimukh of Chandrapur area. The upper reaches of the river course lie in Ri-Bhoi District of Meghalaya where it is called Umtrew whereas the lower course is found in Kamrup district of Assam where it is named as Digaru.

The total area of the basin is 1253.1 sq. km of which the upper and lower Umtrew basins cover 1035.6 sq. km and 217.5 sq. km respectively *(Figure 2).*

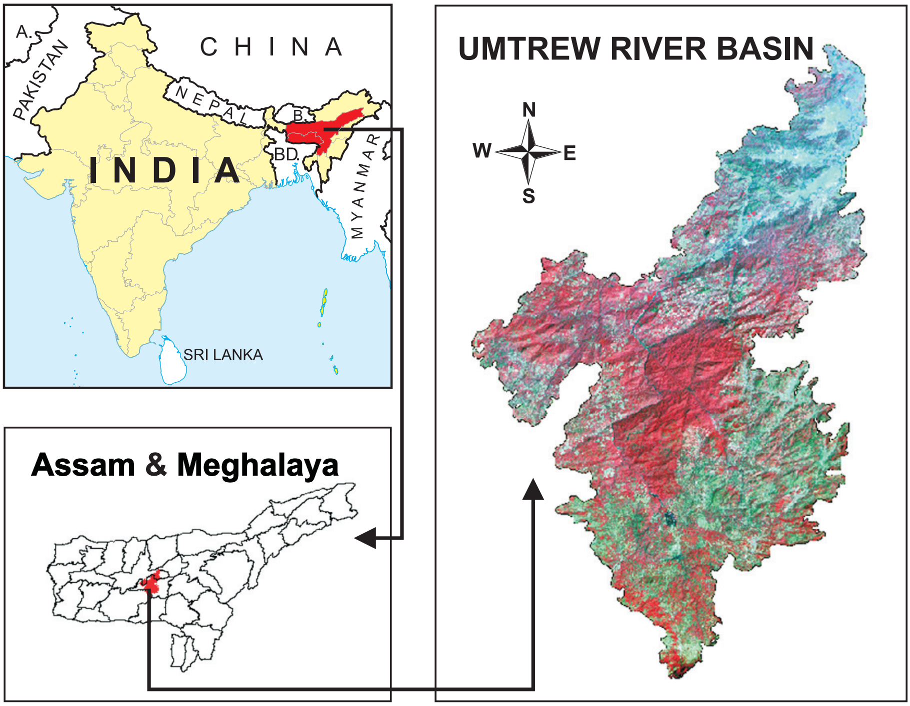


*Fig. 1.* Location map of the study area

## Aims and objectives

The study focuses on the geo-environmental issues of the Umtrew Basin with special emphasis on land use/land cover changes.

The specific objectives of the study were the following:

*a)* Assessment of changing pattern of land use/land cover, particularly in the last three decades using remote sensing data.

*b)* Assessment of the cause and effect relations of such changes responsible for the alteration of the geo-environmental condition of the region.

*c)* Finding a strategy for maintaining environmental quality mainly through identification of potential areas for afforestation.

## Dataset used

To analyze the land use/land cover change dynamics in Umtrew River Basin, multi-temporal satellite imageries were used. Additionally, the Survey of India

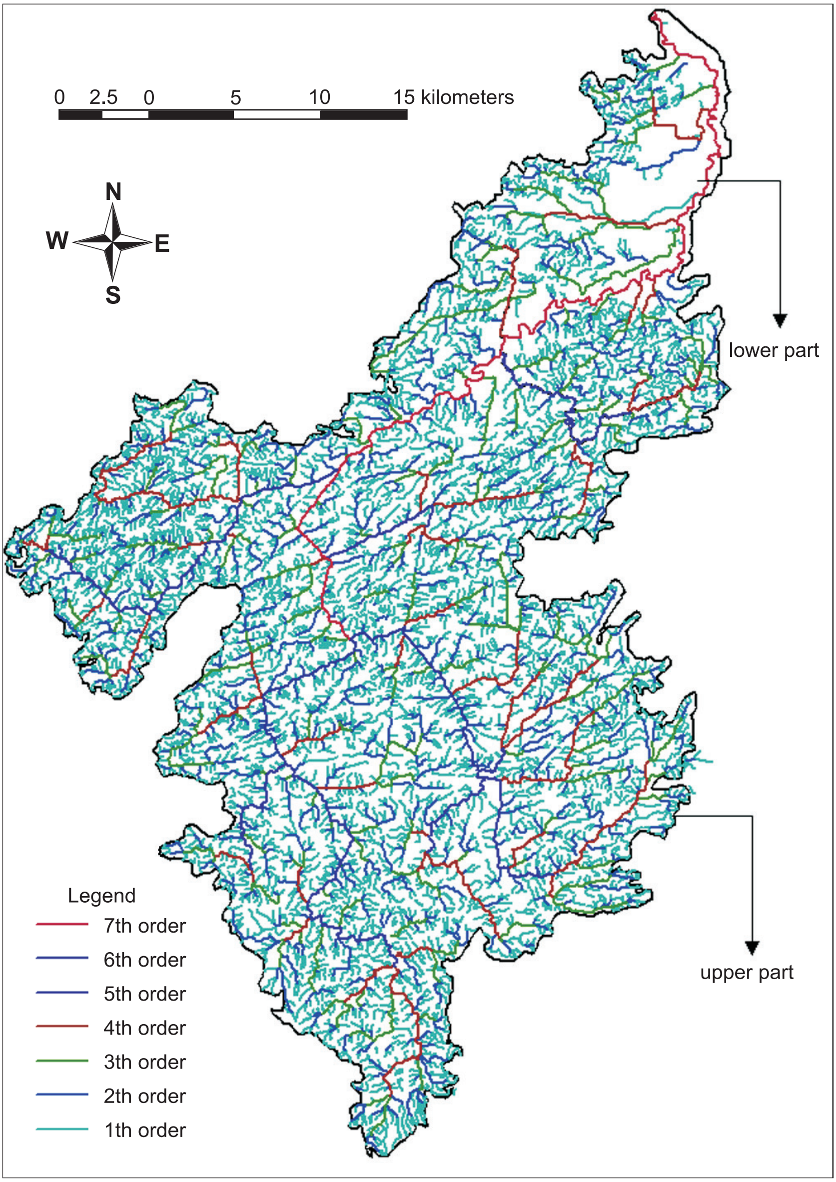


*Fig. 2.* Drainage map of the study area

topographic map sheets № 78 N/16, 78 O/9, 78 O/13 and 78 O/14 at a scale of 1:50,000 were used to delineate basin boundary and to generate baseline information of the study area *(Table 1)*.

*Table 1. Sources and types of data used*

| Data Type | Path/Row | Date of Acquisition |
|---|---|---|
| Landsat MSS | 146/42 | 22.02.1977 |
| IRS LISS III | 110/53 | 15.03.1999 |
| IRS LISS III | 110/53 | 7.03.2004 |
| IRS LISS III | 110/53 | 25.03.2007 |
| SoI Toposheet | No- 78 N/16, 78 O/9, 78 O/13 and 78 O/14 | 1974 |

## Methodology

The methodology adopted here for detecting land cover changes was based on the comparison between the satellite imageries of different years. Satellite imageries of Landsat MSS for the year 1977 and IRS 1C LISS III for 1999, 2004 and 2007 were used to assess the land use/land cover change dynamics in the study area. The Landsat MSS of 1977 was downloaded from the NASA's Global Land Cover Facilitator's (GLCF) website and satellite imageries of other years were procured from National Remote Sensing Centre, Hyderabad, India. The downloaded imagery was geometrically corrected using the UTM/WGS 84 projection system. Other imageries were geometrically corrected by taking the Landsat image and the topographic sheets as the reference. As the spatial resolution of the Landsat MSS imagery was only 80 meter compared to other images with the resolution 23.5 meter used in this study, it has been taken only as a base for assessing the changes in land use pattern. Sub pixel image to image registration accuracy was obtained through repeated attempts. Subset operation of satellite imageries of all the years was carried out by creating an area of interest (AoI) layer from the vector layer of the basin boundary, which was digitized from the Survey of India topographical sheets at 1:50,000 scale.

After generating the subset of all the imageries, supervised classification using parametric rule and maximum likelihood operation was used to assess the land use/land cover change dynamics in the Umtrew River Basin. This is a type of automatic multi-spectral image interpretation in which the user supervises feature classification by setting up prototypes (collections of sample points) for each feature, class, or land cover to be mapped. It is the procedure most often used for quantitative analysis of remotely sensed data. It rests upon using suitable algorithms to label the pixels in an image as representing particular ground cover type, or classes. The pre and post field visit has been done with an eTrex vista GPS receiver and using a set of questionnaire designed for the purpose. Just 50 GPS points were selected for ground truth validation and verification of location (latitude and longitude) and elevation. Then the four satellite imageries of different dates mentioned above were superimposed to identify the changes in land use over a period of around thirty years. For various GIS and remote sensing operations the image processing software ERDAS 9.1 and GIS software ARC GIS 9.1 have been used.

## Analysis and findings

Quantitative analysis of the nature and trend of land use and land cover change provides the basic picture of probable environmental degradation. Since LISS III data were not available during the 1980s, Landsat MSS imagery was used as the base-line database. All subsequent land use and land cover estimations were made using IRS LISS III data *(Figure 3a).* From previous field knowledge, the study area was classified into seven land use/land cover types. Comparative analysis of the land use pattern of 1977, 1999, 2004, and 2007 clearly shows changes: the categories of fallow land, barren land and mixed built up area have shown an increasing trend in all the years, while all forest categories show a decreasing trend *(Figure 3b).* The only increase of forest cover between 1977 to 1999 have taken place because of an extensive afforestation programme taken up by the government of Meghalaya during the 1980s and the presence of an extensive reserve forest, Nangkhylleum in the central part of the upper basin. This area is inaccessible to some extent, hence human interference was comparatively less, and an increasing trend of forest cover was recorded during that period. By contrast, forest cover in the lower part of the basin, which lies in the territory of Assam, suffered most degradation because it is, by and large, a plain area and provides easy access to all kinds of human activities.

### *Description of different land use/land cover classes*

*Forest Land***:** All categories of forest show a slow declining trend, particularly in case of open forest from 1977 to 2004 at an average rate of 1 sq. km per year. From 2004 to 2007, this trend increased massively attaining the average of 14 sq. km per annum. The land use maps show that all these changes occurred in the lower part of the basin and the area near National Highway № 40, which passes through the eastern side of the upper part of the basin. By contrast, the dense forest category shows an increasing trend from 1977 to 1999 due to the afforestation programme held in the upper part of the basin. From 1999 to 2007, it decreases at an average rate of 34 sq. km per year *(Figure 4, Table 2).*

*Scrub Land:* The **c**onversion of forest into scrub land is a general trend across Northeast India. Extensive tree felling leads to the development of dense scrub as the first stage of degradation, which in course of time degrades

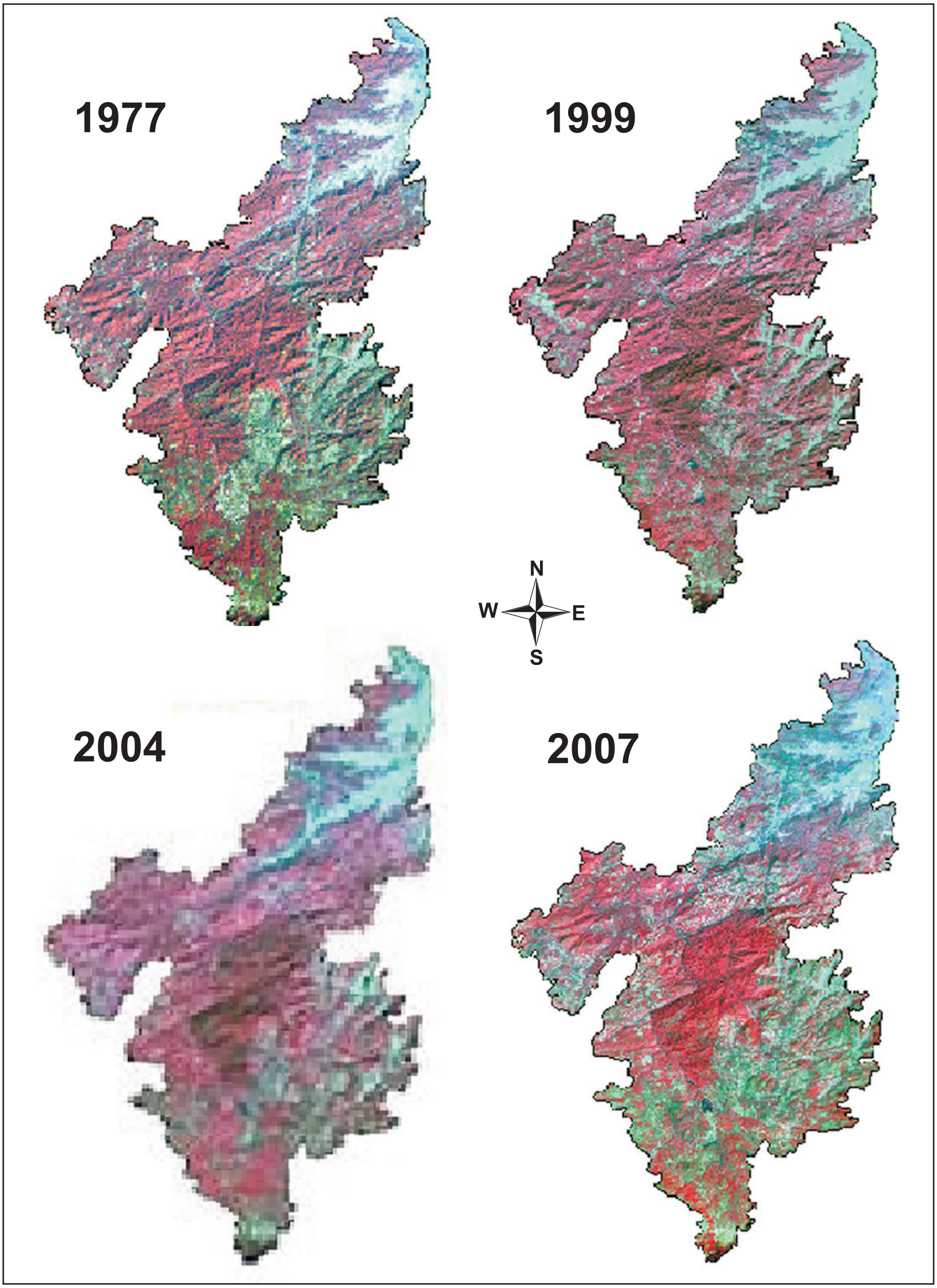


*Fig. 3a.* Satellite imagery of different years and land use map showing pattern of change during 1977–2007

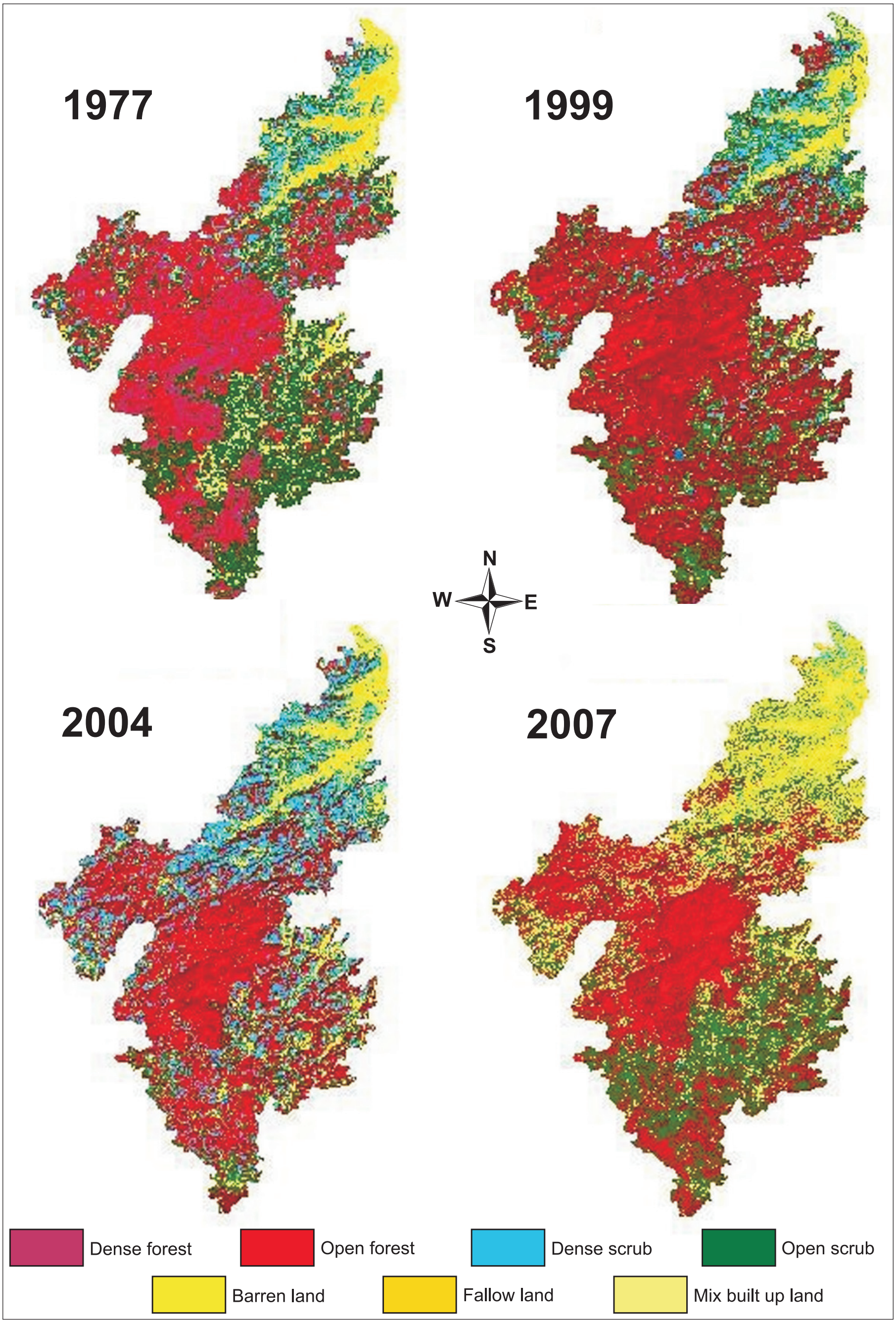


*Fig. 3b.* Satellite imagery of different years and land use map showing pattern of change during 1977–2007

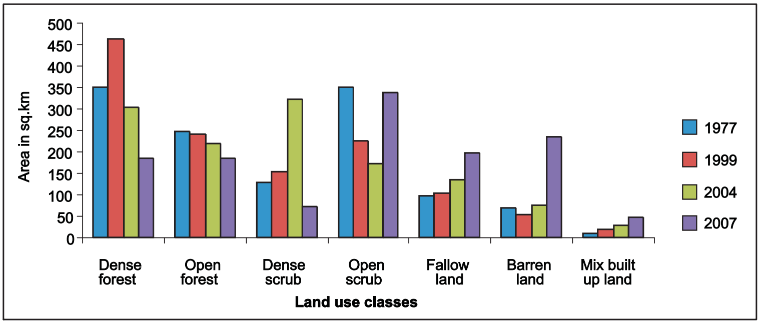


*Fig. 4.* Category wise land use change in different years

*Table 2. Area and net change of land use/land cover from 1977–2007*

| Land use class/ Area | 1977 (sq km) | 1999 (sq km) | 2004 (sq km) | 2007 (sq km) | Net change (1977–99) | Net change (1999–2004) | Net change (2004–07) |
|---|---|---|---|---|---|---|---|
| Dense Forest | 350.38 | 461.35 | 302.06 | 185.84 | +110.97 | -159.29 | -116.22 |
| Open Forest | 248.22 | 239.68 | 219.00 | 182.82 | -8.54 | -20.68 | -36.18 |
| Dense Scrub | 129.49 | 153.76 | 321.70 | 71.17 | -24.27 | -167.94 | -250.53 |
| Open Scrub | 351.20 | 225.62 | 172.78 | 338.09 | -125.58 | -52.84 | +165.31 |
| Fallow Land | 95.37 | 103.58 | 139.95 | 195.39 | +8.21 | -36.37 | +55.44 |
| Barren Land | 68.81 | 53.15 | 75.87 | 233.50 | +15.66 | +22.72 | +157.63 |
| Mix built up Land | 10.00 | 17.31 | 28.01 | 46.41 | +7.31 | +10.70 | +18.40 |

to open scrub before ending up as either agricultural land, fallow land, or barren land. The statistics show the same pattern across the entire study area. Significantly, since 1977 to 2004 some of the area under open scrub land has been converted not only to agricultural land but reclaimed as forest and dense scrub, partly due to the afforestation programme. The area under open scrub was 351.20 sq. km (1977), then decreased to only 172.78 sq. km in 2004, but rose again up to 354.09 sq. km by 2007, which indicates an increased degradation of forest within the basin since 2004. As reflected in the above data and graph it is established that as the open scrub land increased, while the area under forest and dense scrub decreased during this period.

*Mixed Built up Land:* The mixed built up land category includes settlement as well as agri-plantation areas. It increased from 10 sq. km to 28.01 in 2004 then to 46.41 sq. km in 2007. From 2004 the growth rate has accelerated to around 4.5 sq. km per year.

*Fallow Land:* Acquisition of satellite data took place in February and March. As a result all the agricultural land looked fallow in the imageries. The category of fallow land has been continuously increasing since 1977 but was very high between 2004 and 2007 attaining an average increase of 20 sq. km per year i.e. from 139.95 sq. km to 195.39 sq. km. This indicates the increasing pressure of population on the land.

*Barren Land:* The category of barren land showed a decreasing trend from 68.81 sq. km to 53.15 sq. km between 1977 and 1999. However, a slow increasing trend from 1999 to 2004 accelerated from 2004 to 2007, attaining an average of around 40 sq. km per year i.e. from 75.87 sq. km to 233.5 sq. km in absolute figures. This happened mainly due to the establishment of a large number of brick industries in lower part of the basin and presence of high amount of abandoned jhoom or jhum (shifting cultivation) fields in the upper basin.

## Accuracy assessment

Accuracy of the supervised classification of the satellite imagery was derived by using a reference template from the margining data with 50 randomly selected samples on the latest imagery, from which overall accuracy and Kappa statistics were derived. The Kappa statistics incorporated the diagonal elements of the error matrices and represents agreement obtained after removing the proportion of agreement that could be expected to occur by chance (Yuan, F. *et al.* 2005). The overall accuracy was found to be 90 per cent whereas overall Kappa statistics was 0.8899. The statistics shows that the result was overall good.

## Discussion

This study shows the changes in pattern of land use/land cover in Umtrew River Basin. These have caused a number of environmental problems like soil erosion in the upper part and siltation, river bank erosion and flooding in the downstream part; all natural processes but accelerated by human interference in the study area.

The main cause of the soil erosion is the large scale deforestation in the upper part of the basin. The local tribes of the area still depend on jhoom particularly in the upstream areas, and with increasing population pressure the previous 6/7 years jhoom cycle has come down to 3/4 years i.e. a plot of hill land used for shifting cultivation left fallow for 6 to 7 years for restoration of natural soil quality is now being used with a gap of only 3 to 4 years. The impact of these fragile hillslopes is accelerated topsoil erosion and deterioration of the soil quality.

River flooding is not a problem of the Umtrew River Basin, but the area is often affected by flash floods caused by heavy rainfall. Standing crops, dwellings, household properties, cattle etc. are damaged by such flash floods. More damage has taken place in recent years due to the increasing siltation of the river bed and also in downstream areas where wetlands suffer encroachment by the brick industries. As many as 15 brick factories have been established in the lower part of the Umtrew River Basin since 1990 to 2003 and their impacts are expanding. From the primary survey conducted in the study area revealed that more than 30 to 40 percent of agricultural land was sold to the brick kilns during that period.

Burning of coal in the brick kilns release particulates like ash, dust and smoke and gaseous pollutants like carbon dioxide, carbon monoxide, sulphur dioxide, nitrogen oxide etc. The brick kilns of lower Umtrew River Basin operates for 6 to 7 months in a year. During this period, total amount of coal burned for making brick is about 1200–1400 tons.

The magnitude of atmospheric pollution being resulted by the brick kiln can be gauged form the fact that burning of 1 kg of coal releases about 3 to 4 kg of harmful and toxic gases like carbon dioxide, sulphur dioxide. Presence of 3 to 5 percent organic sulphur in Assam coal release more sulphur dioxide resulting itching eyes and skin of the residents in neighbouring villages.

The demand for bricks continuously increases in Guwahati city, only 10–15 km away. This is the commercial heart of the entire Northeast India where large scale constructions are going on. In addition, the great demand of coarse sand for brick making as well as building constructions means sand quarries are being created on the sites near the bank of Umtrew River. As a result, the course regime of the river is changing.

With the growth of brick industries and sand quarries, the traditional human occupation has changed. As the people living in this part are economically poor, they have been selling their croplands to brick industries to meet their immediate need of money.

As soon as money goes to their hands they usually spend more in buying consumer goods rather than the essentials. As the money comes once only they suffer as it gets exhausted. As a consequence they have to work as daily labourers either in the brick industries or in sand extraction works under the contractors at a very low wage. Such change in their occupation makes them poorer and brings about drastic changes in social life.

The possibilities of micro climate change due to alteration in land use and other associated activities cannot be ignored. It has been reported that the rainfall in Cherrapunjee–Mousinram, the wettest part of the earth, which is only 50 to 60 km away from the study area, has declined substantially (22,987 mm in 1860–1861 and 11,931 mm in 1973–2006 average). As such the study area needs more afforestation including social forestry programmes to restore the previous conditions.

## Conclusions

Remote sensing and GIS techniques are important tools for measuring land use/land cover change (Sharma, P.K. *et al.* 2008) The study made in a mid-altitudinal watershed in Northeast India shows the dynamics of the land use and land cover. Since 1977, there has been an increase in areas under mixed built-up land, barren land and other associated land use patterns. The increase of scrub area and barren land in the study area is the result of deforestation and industrial growth. The downstream part of the Umtrew Basin has been worst effected by deforestation and other anthropogenic activities with far-reaching consequences. There is an urgent need to take protective measures, particularly in the lower part of the Umtrew Basin, to maintain the environmental quality, restrict the possibilities of change in microclimate and to maintain the age old socio-economic traditions of its people. It is hoped that the methodology adopted for this study could be extended towards more across the region.

***Acknowledgement:*** University Grants Commision (UGC), New Delhi for funding, Data source- National Remote Sensing Centre, Hyderabad, NRC Land-use Land-cover Manual, North Eastern Space Application Centre, Umium, Shillong, Department of Geography, Cotton College, Guwahati, Aaranyak, (A Society for Bio-diversity Conservation of NE India), Guwahati.

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