Journal of Geography and Regional Planning Vol. 5(16), pp. 437-448, December, 2012
Available online at http://www.academicjournals.org/JGRP
DOI: 10.5897/JGRP12.0054
ISSN 2070-1845 ©2012 Academic Journals

Full Length Research Paper

Characterization and evaluation for integrated development of Umtrew river basin in Meghalaya Plateau, North East India

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Accepted 20 September, 2012

A drainage basin in a mountainous region has a direct impact on its physical, environmental and ecological setup as it is the source of human beings fundamental needs. Umtrew river basin is spreading over the Indian states of Meghalaya and Assam, is located between 25°35'15'' to 26°14'18''N latitude and 91°35'17''to 92°00'15''E longitude. The river Umtrew is one of the major drainage systems in Meghalaya plateau, it originates in Meghalaya and flows down to Assam plain and merges with mighty Brahmaputra. Modern tools i.e. remote sensing and GIS techniques have been used to analyze the basin characteristics. Various thematic maps like Contour, Drainage, Road Network, Settlement, Land capability and Land Use/Land cover have been prepared to highlight the present scenario of the study site. Satellite image of 2004, 2007 and 2010 were used to understand the land use/land cover change in the basin area. Result shows that there is a decrease of 5.93% of semi evergreen forest from 2004 to 2010. This paper also attempts to identify the land use / land cover change pattern of the basin from 2004 to 2010.

Key words: Umtrew river basin, Meghalaya, Assam, thematic maps, land use/land cover, land capability.

INTRODUCTION

Land is the most valuable natural resource, which needs to be harnessed according to its potential. Due to over exploitation and mismanagement of natural resources coupled with socio-economic factors, the problem of land degradation is on the rise. However, management of land resources is inevitable for both continued agricultural productivity and protection for the environment. Land is a limited resource and with increasing population, the demands for land become more competitive. Any given area of land can have a multitude of potential uses and all may need to be considered in planning and the management of a land resource. The common way of determination of land quality from land characteristics is mainly by assessing and grouping the land types in orders and classes according to their aptitude. The order of suitability ranges from suitable, that characterizes a land were sustainable use and will give good benefits to not suitable which indicates a land qualities do not allow the considered type of use, or are not enough for sustainable outcomes (IAO, 2003). United States Department of Agriculture (1973) has provided specific guidelines for Land Capability Classification. The criteria for placing a given area in a particular class involve the landscape location, slope of the field, depth; texture and land use/land cover (Tideman, 1990). Thus, the capability units are groupings of soils that have common responses to pasture and crop plants under similar systems of farming. Ekanayake et al. (2003) has also made an attempt to identify land suitability by applying GIS technique for forest. Similar kind of studies were reported for integrated watershed developments in Dudhganga basin of Kholhapur district (Sachin panhalkar, 2011). The

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aim of the present study is to evaluate a new approach for the conservation of basin area from gradually mounting anthropogenic interferences. The current research intend to do land use / land cover change in the Umtrew basin from 2004 to 2010, generation of different thematic database necessary to create a broad land capability classification and to protect the area from further environmental deterioration, collection and integration of different datasets for preparation of a proposed land utilization and management plan and assessment and observation of all the associated factors behind the changes responsible for the alteration of geo-environmental condition in the basin area

STUDY AREA

River Umtrew and its tributaries has a basin area of 1369.6 km^2 and most of its part falls under the northern hill ranges of Meghalaya plateau and rest is under the low lying areas of Bharamaputra plain (Figure 1). The catchment area lies between 25°40'00'' N to 26°10'00''N latitude and 91°30'00'' E to 92°00'00''E longitude (location map). The topography is undulating having elevation of 171 m in the plains of Assam and about 1799 m at highest peak of basin area. Physiographically, Umtrew basin has two regions such as (i) Hilly Southern region and (ii) Northern plains. However, the presence of Umtrew dam, a project for generation of hydro power has brought a drastic hydrological and environmental change in the lower reach of the basin area. Umtrew river basin comprises of the elongated hilly terrain of different altitudes along with inter-mountain deep gorges, small stretch of plains and marshy areas. A sub-tropical climate is dominant in the areas adjacent to Assam to a temperate climate in the upper reaches close to East Khasi hills (Anon, 2007). The rock formation includes Shillong group of rocks which comprises of Phyllites, Quartz schists, Quartzite and Intra formational conglomerates in the Meghalaya part of the basin to unconsolidated alluvium sediments in the plain land areas of Assam (Chottopadhyay et al., 1984).

DATABASE USED

The database consists of different sets of primary, secondary and integrated database of spatial and non-spatial nature on different components of the study site. Satellite imageries of mention time of imagery 2004, 2007 and 2010 (Table 1 and Figure 2) were used to analyze various spatial components relevant to the study. Survey of India toposheet of 1:50000 scale were collected and georefernced to delineate the different geographical features like roads, places and drainage and geospatial parameters relevant to the study. ASTER G-DEM data of 30 m resolution was downloaded from the open sources to monitor different topographic aspects of the study site. Database related to soil study were collected from Soil and Water Conservation Department, of Meghalaya for the year 2009. IRS P6 LISS-IV satellite image was collected for the preparation of land capability classification in later stage.

METHODOLOGY

LISS-IV satellite data with a spatial resolution of 5.8 m was georefernced to UTM/WGS 84 projection system to generate different thematic components. Visual interpretation technique was adopted to prepare thematic maps like drainage map, road network map, settlement and land capability map of Umtrew river basin. Satellite imageries pertaining to the year 2004, 2007 and 2010 were used to analyze the land use/land cover change dynamics of Umtrew river basin. Radiometric corrections of all the images were done using dark pixel subtraction technique (Lillesand et al., 2004). Subset operation of toposheet and satellite imageries of 2004, 2007 and 2010 were carried out by creating an area of interest (AOI) vector layer of the basin boundary, which was digitized from the 1:50000 Survey of India toposheet. After completing the subset operation the spectral enhancement operation was performed by using "image enhancement" function of ERDAS Imagine 9.2 software package. Principal component analysis (PCA) was carried out to all the images. PCA is often used as the method of data compression. The bands of PCA data were none correlated and independent, and are often more interpretable than the source datasets (Jensen, 1996). Finally, the PCA images were classified by using supervised classification using the maximum likelihood algorithm to assess the land use/land cover changing pattern of Umtrew river basin. Supervised classification is a process where the image analyst supervised the pixel categorization process by specifying to the computer algorithm and numerical descriptors of the various land cover present in the scene (Lillesand et al., 2004). Finally, in later stage ground verification was conducted by using a GPS MAP 60 Csx (Global Positioning System) receiver. A total of 150 GPS points were collected from different parts of the basin area to analyze the proper representation of different land use/land cover categories. The entire satellite image processing was done using the ERDAS 9.1 software (ERDAS, 2008).

THEMATIC COMPONENTS

Land use/land cover analysis

Information on land use/land cover pattern, especially the extent and spatial distribution is a pre-requisite to derive information on temporal changes. The land use /land cover information helps in identification of the areas for prioritization and reviving various landscape elements. The present status of land use in the basin area is useful for identifying locations for taking up soil conservation measures by involving village communities, for minimizing further land degradation.

Slope

Information relevant to slope is vital for suggesting actions related to restoration plans in any landscape. Slope related information is useful for checking the rate of ongoing soil erosion, preparation of land capability classification and adopting a drainage related measures in the study area. The slope map has been prepared by using "3D Analyst" tool of Arc GIS 9.3 software. The DEM (digital elevation model) file has been considered as an input layer and then final slope map was prepared in degree format.

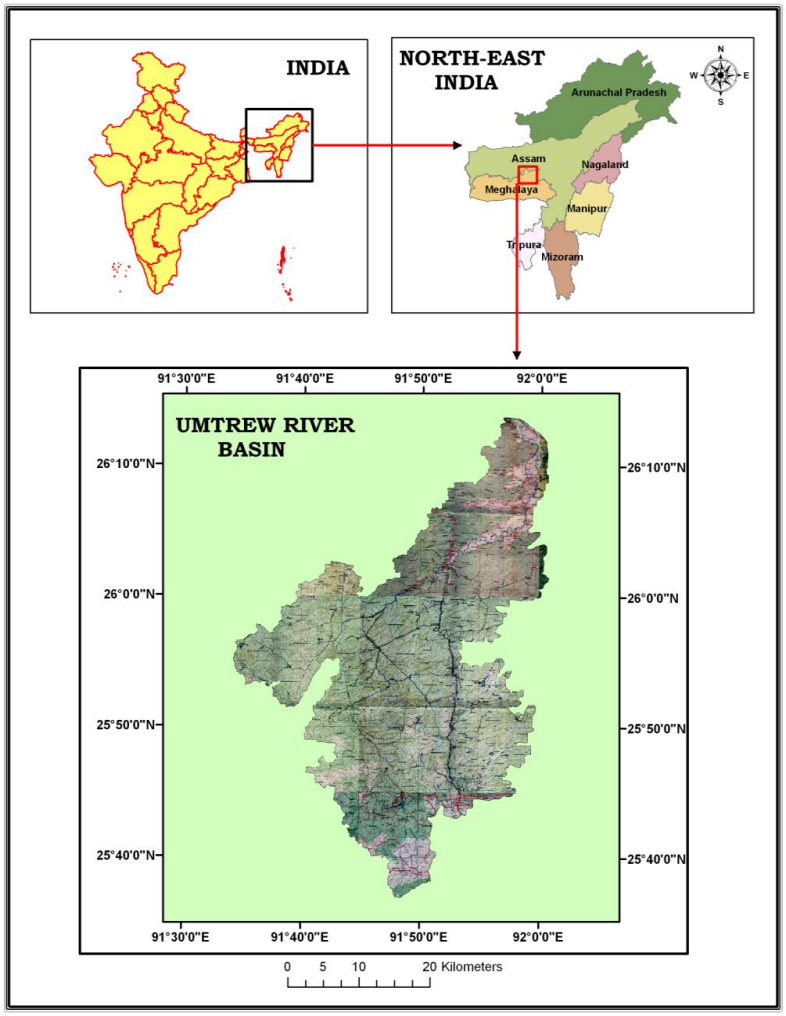

Figure 1. Location map of Umtrew River Basin.

Drainage network

The drainage map of the study area was prepared by using "Digitization" function of Arc GIS 9.3 software. A very high resolution LISS-IV (Linear Imaging Self Scanner) satellite data in conjunction with 1:50000 scale SOI toposheet. The drainage map of the study area will help in assessing the actual extent of the basin area. Besides, it will be helpful to prioritize the basin area on the basis of its status of criticality.

Road network and settlement pattern

The road network and settlement areas of the Umtrew river basin has been identified with the help of 5.4 m resolution LISS-IV satellite data and 1:50000 scale SOI (Survey of India) toposheet. Road network and settlement pattern of any area are some of the vital characteristics of basin area which can help in the identification of critical areas and formulating a suitable capability class.

Land capability

The aim of this study is to generate a suitable and effective land capability classification based on its general degree of "goodness" in the sense of "possible intensity of use" that is Class I = *Best* to Class VIII = *Worst*. For the preparation of land capability class map parameters like soil, slope, relief and present land use/land cover pattern of the study area were considered. Finally, the concept of "Overlay" analysis in GIS environment was applied to delineate the extent of different land capability classes.

RESULTS AND DISCUSSION

Land use/land cover pattern

The entire Umtrew river basin was extensively surveyed to collect the training sets of different land use / land cover categories. The land use/land cover pattern of study area have been categorized into eleven classes based upon the field knowledge and collection of training sets of different land use / land cover types. The different land use / land cover classes are as follows:

Table 1. List of datasets used in the study.

S/No.	Satellite Data	Date
1	IRS 1 D LISS-III	12th March 2004
2	IRS P6 LISS-III	4th December 2007
3	IRS P6 LISS-III	20th February 2010
4	SOI toposheet No: 78 N/16, 787 O/9, 78 O/13, 78 O/14	1973
5	IRS P6 LISS-IV	3rd January 2010

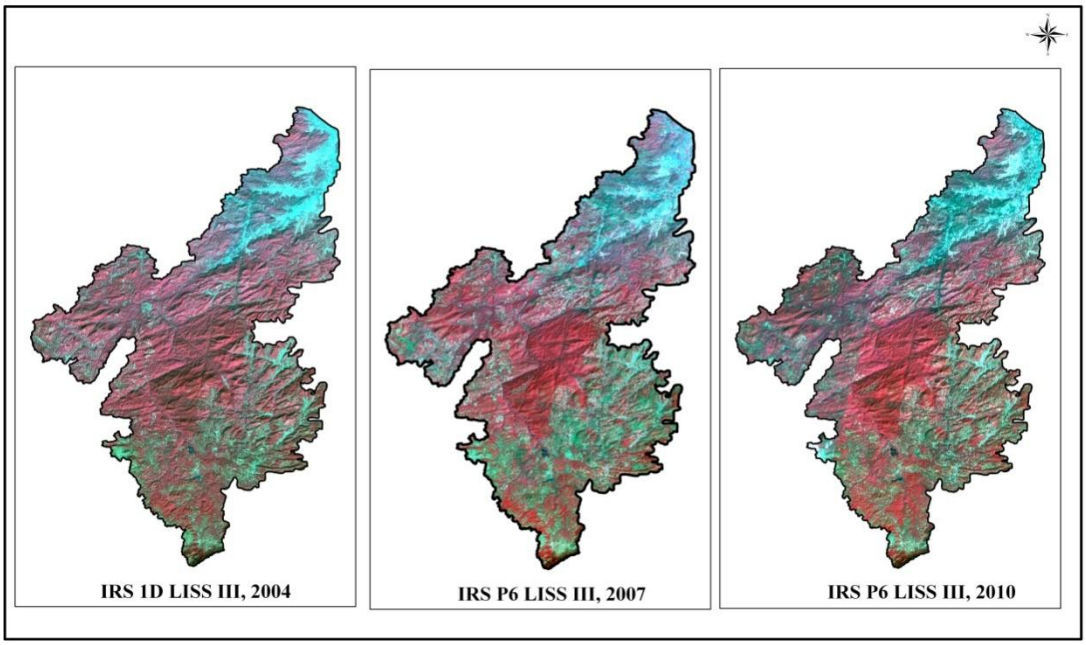

Figure 2. Satellite dataset used in land use/land cover analysis.

(i) Semi evergreen forest
(ii) Moist mixed deciduous forest (Dense)
(iii) Moist mixed deciduous forest (Open)
(iv) Mixed bamboo forest
(v) Scrub forest
(vi) Degraded forest
(vii) Settlement area
(viii) Agricultural land
(ix) Jhum cultivation
(x) Marshy/swampy land
(xi) Water body

For the analysis of land use / land cover change in Umtrew river basin three datasets of satellite imagery pertaining to the year of 2004, 2007 and 2010 were used (Figure 3). A supervised classification method was used to prepare the land use / land cover map of Umtrew basin for the years 2004, 2007 and 2010. Comparative analysis of land use pattern of 2004, 2007 and 2010 clearly depicts the changes: the categories like agricultural land, degraded forest, scrub forest, settlement area, jhum cultivation and marshy/swampy land have been presented and rising trend in its area extent. While, on the other hand all the forest categories like semi evergreen forest, moist mixed deciduous forest (dense and open), and mixed bamboo forest shows a declining trend.

The analysis and elaboration of the satellite imageries for the years 2004, 2007 and 2010 had provided the land use/land cover types and changes there in within a time span of six years. The most prominent estimated change of Umtrew river basin during six years (2004 to 2010) was the decrease in forest cover. The semi evergreen forest has been reduced significantly from 21.49% in the year 2004 to 15.55% in the year 2010. Similarly, other three forest categories- mixed moist deciduous forest (dense), mixed moist deciduous forest (close) and mixed bamboo forest has been reduced significantly in a sort span of six years (Table 2). The entire forested areas are gradually losing its share to the categories like agricultural land, settlement area, shifting cultivation, degraded forest and scrub forest. The study shows that

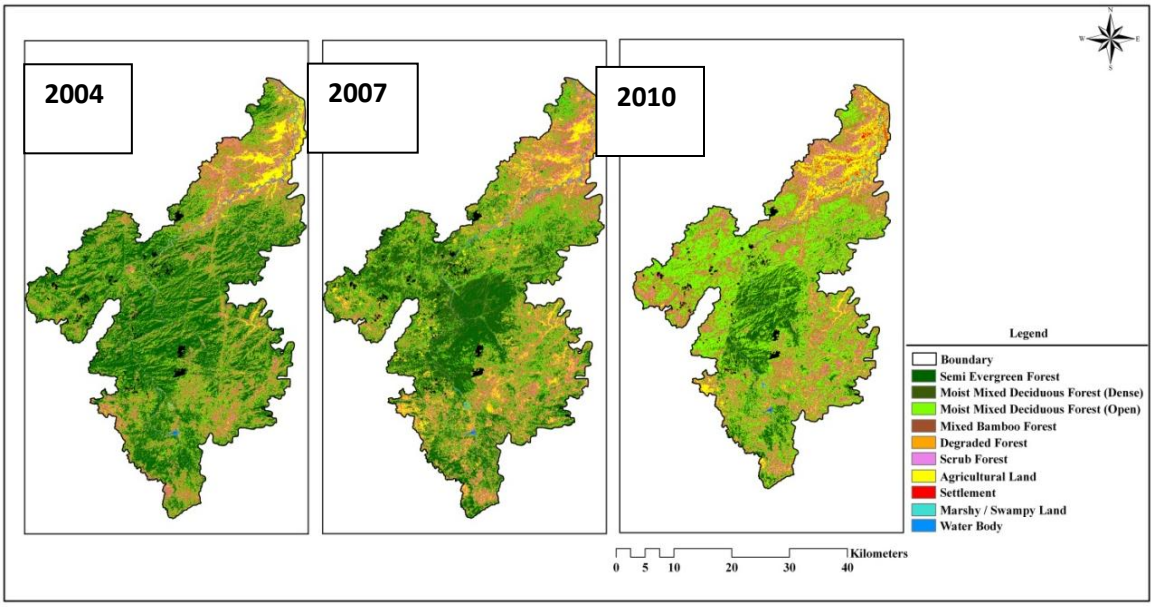

Figure 3. Land use/Land cover change scenario from 2004 to 2010.

Table 2. Land use/Land cover changing pattern in Umtrew river basin since 2004-2010.

Class name	Area (km^2)			Net change (%)		
	2004	2007	2010	2004	2007	2010
Semi evergreen forest	294.43	228.44	213.07	21.49	16.68	15.55
Moist mixed deciduous forest (dense)	192.68	161.32	113.45	14.07	11.78	8.28
Moist mixed deciduous forest (open)	345.41	320.65	298.45	25.22	23.41	21.79
Mixed bamboo forest	183.72	129.97	106.98	13.41	9.49	7.81
Scrub forest	71.72	123.16	138.12	5.26	8.99	10.08
Degraded forest	96.97	136.23	165.78	7.08	9.94	12.10
Settlement area	16.33	24.22	48.1	1.19	1.77	3.51
Agricultural land	72.32	110.54	140.41	5.28	8.07	10.25
Jhum cultivation	21.56	56.19	68.12	1.57	4.10	4.97
Marshy/Swampy land	8.25	10.09	15.74	0.60	0.73	1.15
Water body	66.21	68.79	61.38	4.83	5.02	4.48
Total	1369.6	1369.6	1369.6	100		

the scrub forest of Umtrew river basin has significantly increased from 5.26% in the year 2004 to 10.08% in the year 2010. This increase of scrub forest is mainly because of massive deforestation of the primary and secondary forest areas and generation of scrub forest in those areas. Similarly degraded forest has increased in an alarming rate from 7.08% in the year 2004 to 12.10% in the year 2010. This indicates that the Umtrew river basin is facing tremendous forest degradation due to anthropogenic intervention. In case of settlement it has increased from 1.19% in the year 2004 to 3.51% in the year 2010. This indicates that human settlement has increased in the basin from 2004 onwards. In case of agricultural land result shows that the area has increased from 5.28% the year 2004 to 10.25% in the year 2010. This indicates that the agricultural practices in the basin have increased significantly during the six year period. The most prominent change in land use in Umtrew basin has been observed in case of Jhum cultivation. Jhum cultivation areas in the basin have increased from 1.57% in the year 2004 to 4.97% in the year 2010. This indicates that Jhum cultivation practices among the communities of Umtrew basin is still going on and immediate attention should be given to control Jhum cultivation in the basin to conserve the forest resources of the basin. The marshy /swampy land in Umtrew basin has also increased from 0.60% in the year 2004 to 1.15% in the year 2010. This change is mainly observed in the low lying areas of the

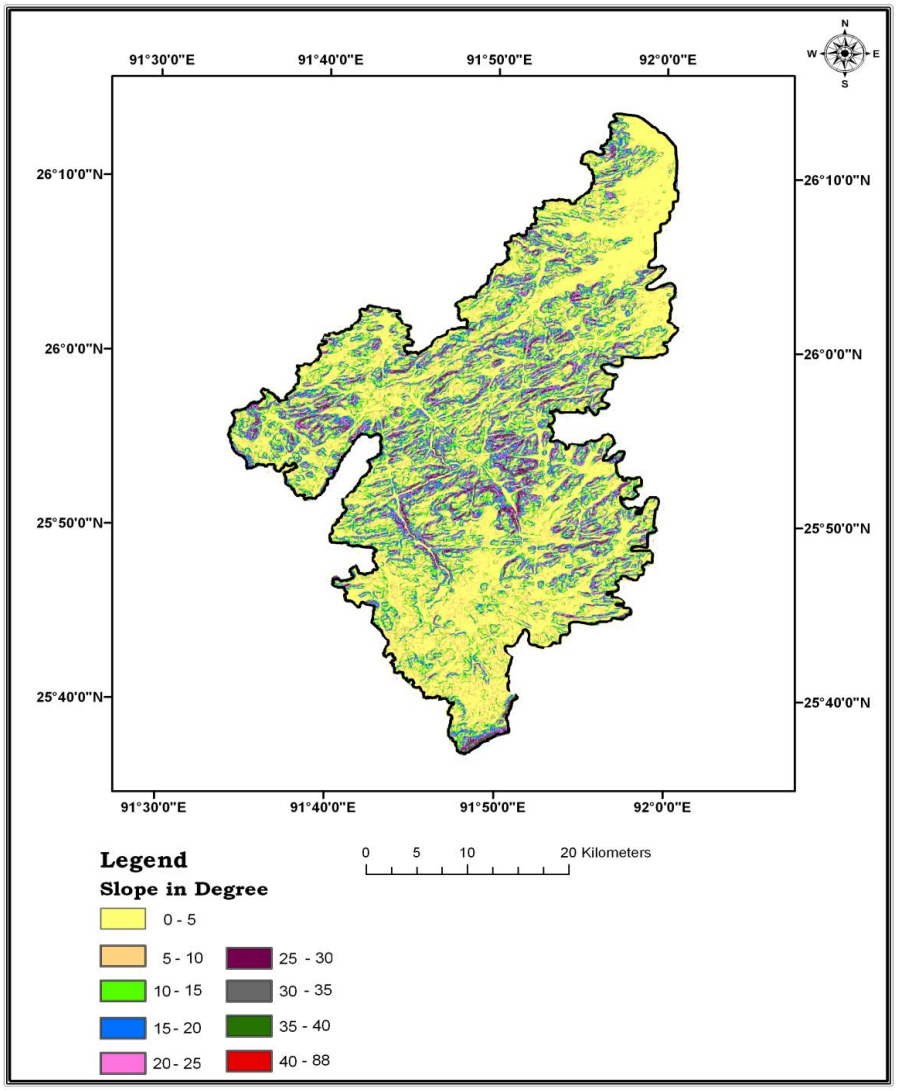

Figure 4. Slope map of Umtrew river basin.

basin particularly in the Assam part. In case of water body there was an increasing trend from 2004 to 2007 but from 2007 to 2010 it has reduced. This happened mainly due to the fluctuation of rainfall in the basin. In 2010 drought like situation occurred in the states, Assam and Meghalaya and this lead to minimize the water body in the basin.

Land form analysis

The slope analysis of Umtrew river basin shows that a substantial portion of area fall under the slope category of more than 15° (Figure 4). Though 0 to 5° slope category is dominant in northern and southern uplands (505.65 km^2) but 15 to 20 slopes are spreading everywhere in the basin area. Low slope (0 to 5°) areas are mostly visible in the plain patches of land which fall in the Palin areas of Assam. Highly steep slope areas (more than 25°) are located in the central-mid land to entire eastern and western part of Umtrew river basin. So, a higher rate of deforestation in the steep slope areas may further aggravate the process of soil erosion in the study area in the coming years. The area wise slope category distribution in various parts of the study area has been mentioned in Table 3.

Drainage pattern

The Dendritic (tree like and fern like shape with branches) drainage network with heterogeneity in texture and more structural control (Figure 5). While parallel and radial pattern indicating dipping, folded and highly jointed hilly terrains. Parallel drainage pattern suggests a gentle that the area has a gentle uniform slope in the north-

Table 3. Area wise distribution of slope in Umtrew river basin.

S/No.	Slope category	Area (km^2)	Percentage
1	0 - 5	505.65	36.91
2	5 - 10	288.45	21.05
3	10 - 15	195.11	14.24
4	15 - 20	132.67	9.68
5	20 - 25	128.67	9.41
6	>25	119.39	8.71

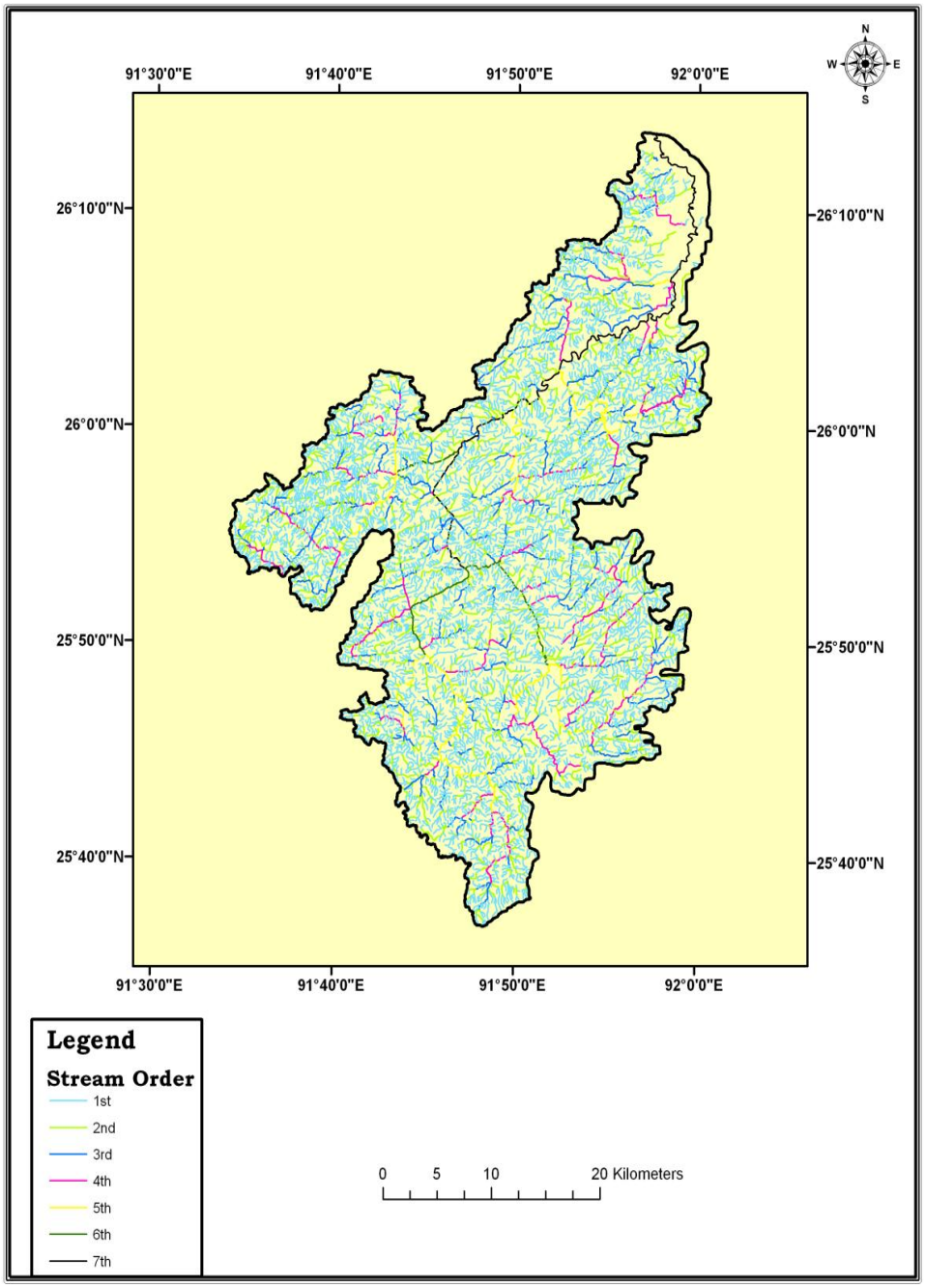

Figure 5. Drainage pattern of Umtrew river basin.

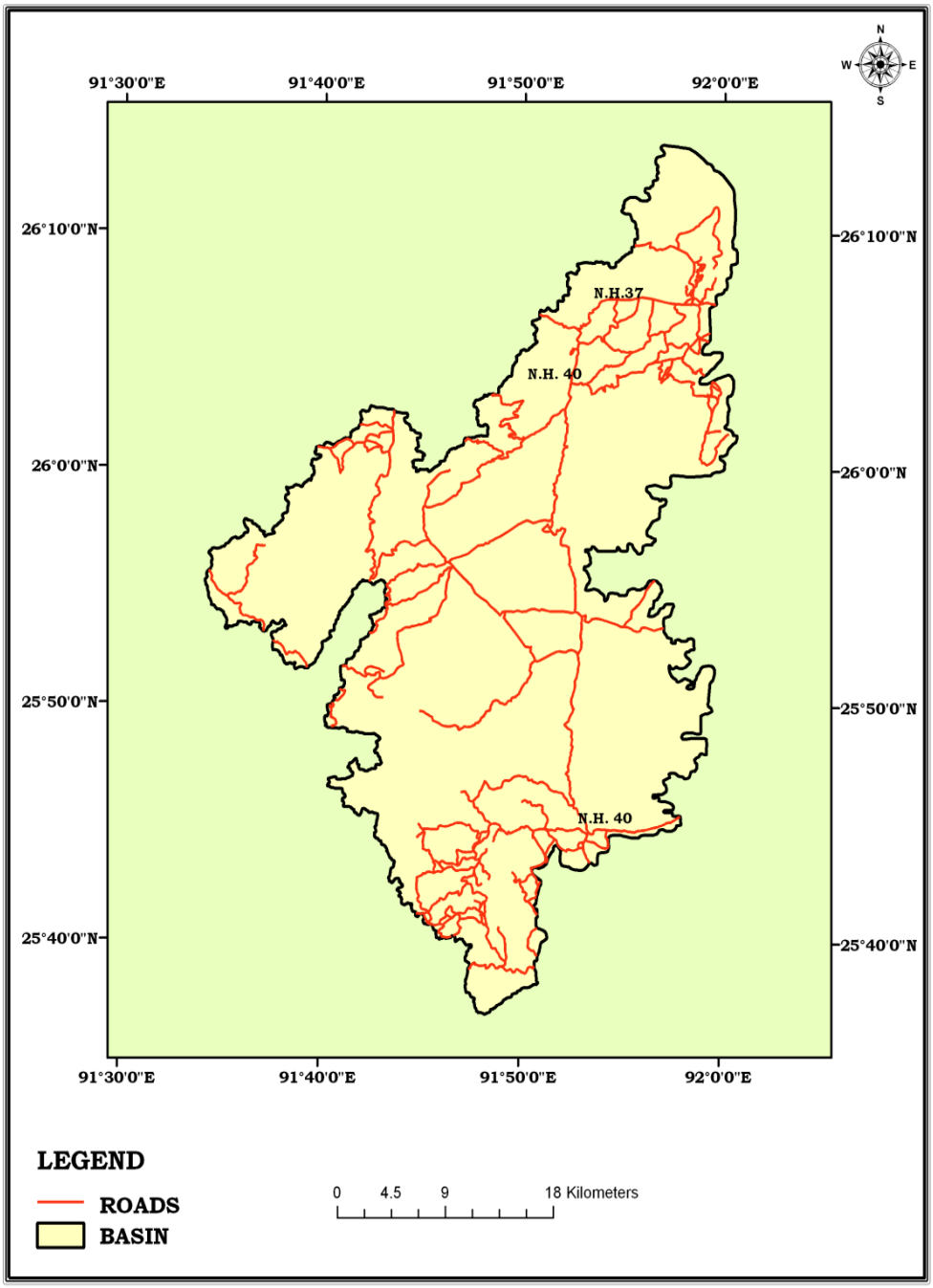

Figure 6. Road network pattern of Umtrew river basin.

eastern part, with less terrestrial bed rock (Jensen, 2006). It means that drainage network in the study area is spreading over a very loose bedrock formation especially in the northern part of the basin.

Socio-economic status

Road network and settlement pattern are some of the vital indicators for analyzing the nature of any basin area. It can be helpful in analyzing the impact of anthropogenic community over the natural setting of any landscape. Road network pattern in the study area has been classified into three different types as national highway, village road and interior footpaths (Figure 6). The total length of national highway in the study area is 182 km, a major part of this national highway passes through the steep and high elevated patches in the upper part of Umtrew

Table 4. Soil pH, moisture content (SMC), organic carbon (SOC) and available Phosphorous (P) in different locations of Umtrew basin.

Locations/Basin area	pH	SMC (%)	SOC (%)	P ($\mu g g^{-1}$)
Lumci	4.33	17.5	1.89	3.08
Umtring	5.37	21.7	2.17	2.68
Shokhwai	5.23	17.5	3.07	4.64
Narang	5.21	19.7	2.5	2.68
Aamchang	5.17	19.7	1.52	2.54
Umdor	5.24	24.8	2.73	2.80
Nongkhyllem	5.24	13.6	1.55	2.08
Upper Nongpoh	5.14	25.2	1.28	2.18
Umran	7.81	34.9	2.43	2.84
Tilibasti	5.01	21.5	1.05	2.74
Belguri	5.25	22	2.34	3.34

Table 5. Distribution of area under different land capability class.

Land capability class	Area (km^2)	Area (%)
Class I	34.24	3
Class II	137.51	10
Class III	151.38	11
Class IV	95.01	6
Class V	95.57	7
Class VI	106.24	8
Class VII	259.17	19
Class VIII	490.48	36
Total	1369.6	100

basin. Besides, a substantial presence of different kinds of road network has been flourishing settlement areas in the environmentally fragile parts of Umtrew basin. Places like Nongpoh, Umshing, Byrnihat, Umling and Umdihar have been developed in such a kind of topographically and environmentally fragile areas.

Soil

Soil texture is clay loam to sandy clay loam in the upper part of the area where as fine loam and coarse loam soil are predominant in the lower territory. Soils are permeable and generally acidic in nature in most of the parts. Owing to highly undulating landform and absence of good vegetation cover, most of the areas are exposed to erosion hazard. Sheet, rill and gully types of erosion pattern are prominent throughout the study area (Anon, 2007). The depth of the soil varies from 1 to 3 m in few places, particularly in the upland areas (Table 4).

Land capability classification

In general land capability classification is the grouping of soil based on (a) inherent soil characteristics (b) external and internal features (c) environmental factors that limit the use of the soil. But in the present study the purpose of capability classification is to categorize the land according to their possible intensity of use. Only 3% of the total area falls in class I which is the least sensitive area from geo-environmental perspective. Land capability class I to III can be termed as the land suitable for agriculture and other purposes. Similarly class IV to class VII can be grouped under the group of land not suitable for agriculture and other purposes. The distribution of area under different land capability class has been shown in Table 5 and Figure 7.

The land capability classification in this study has been performed on the basis of capability classification by Klingebiel and Montogomery (1961). Which is developed mainly based on the soil, slope and relief pattern of the

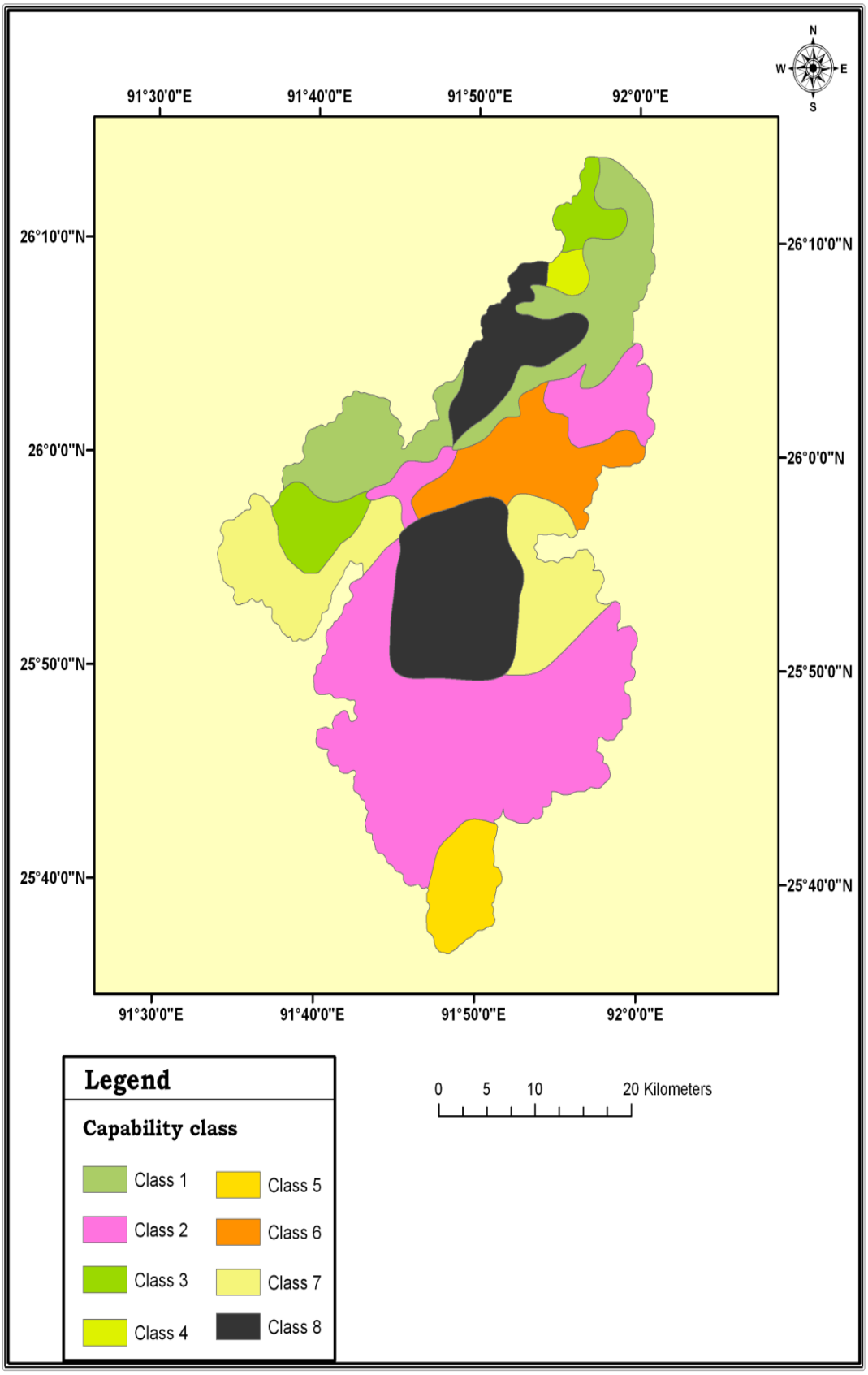

Figure 7. Land capability pattern of Umtrew river basin.

Table 6. Recommendation and suggested land use in different capability class in Umtrew river basin.

Land capability class and location	Major soil types	Recommendation/ proposed land use
Class I- Mostly in very gently sloping to nearly level plains covering areas like- *Sonapur, Jogodol, Chimu and Digaru*	Moderate erosion, Slight stagnation of water, Imperfect drainage.	These lands are suitable for rice and different kinds of horticulture and plantation crops
Class II- Mostly in nearly level to very sloping plains covering areas like- *Umran, Umsining, Umdihar* etc.	Moderately slopes, Moderate erosion, Strong soil acidity, Low CEC and base status.	A variety of horticultural and plantation crops can be grown with proper soil and water conservation practices
Class III- In lower slopes of foot hills covering areas like- *Belguri and Tilibasti*	Very severe water stagnation, Very poor drainage.	Proper maintenance of existing terraces, provision for vegetative waterways, cultivation of plantation crops along with agro forestry.
Class IV- Mostly in plain hills and isolated hillocks covering areas like- *Aamchang* and *Chogligaon*	Moderately steep to very steep slopes, Stoniness, Very strong soil acidity, Low CEC and base status Jhum cultivation.	Maintenance of existing terraces by cover crops and plantation of perennial grass of legume variety; selected areas may be brought under fruit trees and other orchard crops with proper soil conservation and agronomic practices.
Class V- Mostly in hilly terrain covering areas like- *Lumci, Umriachang* and *Umtring* etc.	Moderately steep slopes, Severe erosion, Very strong soil acidity, Low base status, Shifting cultivation.	Provision of diversion channel and vegetation waterways. Terracing by putting the stones to protect the terraces; preservation for existing forest from tree cutting, firing, grazing etc. along with agro silvi pastoral programme.
Class VI- Mostly in hilly terrain covering areas like- *Shokhwai, Narang* and *Umdor*	Moderately steep to very steep slopes, Severe erosion hazard, Stoniness, Very strong soil acidity, Low CEC and base status Shifting cultivation.	Contour terracing to protect the terraces; restriction of free grazing, firing, forest cutting; plantation of forest species are suited in this region.
Class VII- In high hills covering areas like- *Umdongpeh, Garikhana, Mawsymtar* and *Umkyrpiang*	Steep to very steep slopes, Very severe erosion hazard, Very strong to extreme soil acidity, Low exchange capacity, Low base status Jhum cultivation.	Gully erosion control with check dams, restriction of felling, firing, grazing, etc., plantation of forest species with proper soil conservation measures
Class VIII- Mostly in high hills covering areas like- *Nongkhyllem, Umsar* and *Upper Nongpoh* etc.	Very steep slopes, Stoniness, Very severe erosion hazard Very strong to extreme soil acidity, Low exchange capacity and base status, Shifting cultivation and landslides.	Rill and gully erosion control by putting small check dams at frequent intervals; plantation of forest species in open areas with proper soil conservation of existing forest

study area. A proposed land use/land cover plan for different land capability classes of Umtrew river basin has been suggested in Table 6.

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