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A Remote Sensing & GIS approach for Land Use Planning in Champhai District, Mizoram, India

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Abstract

Planning for sustained and effective land use has been the main focus for developing regions in north-east India, especially in states like Mizoram. The age long practice of shifting cultivation in these regions have rendered considerable destruction to both land resources and environment, as such land uses lack proper scientific inputs and plans. It is, thus, imperative to understand the consequences of these practices and to develop proper strategies or land use plans which can counteract the detrimental effects on environment, and at the same time improve productivity of land. This study deals with the application of remote sensing and GIS for land use planning in Champhai district of Mizoram, India. Indian Remote Sensing satellite data (LISS-III and Cartosat-I) has been used for generating various GIS layers like land use, slope, soil, drainage, etc. They were then integrated with collected ground and socio-economic data to evolve a comprehensive land use plan for the study area. The analysis in a GIS system helped in bringing out maps and statistics with constructive options for alternate land use plans in the study area which are both productive and sustainable. This information will be very useful at district level to plan according to the schemes and resources available.

Keywords: GIS, Champhai, land use plan, remote sensing.

Introduction

Land and its associated resources are important factors on which the livelihood and economic development are based. The utilization of land resources ultimately, has its impact on the biodiversity and environment of associated region. This impact can eventually results in either a positive or negative pattern of land use depending on how it is used in time and space. The land use pattern of the district has undergone profound changes during past decades, which has mainly been unproductive and ecologically destructive due to the inherent system of land plans used during the past decades. With a decadal growth rate of 16.31 in the population of the study area (Directorate of Census, 2011), there is need for proper methods of utilization, conservation and planning of land resource to keep pace with the basic requirements of the study area. Sustained utilization of available resources requires a scientifically approached land use planning process. There is, thus, an urgent need for research and evolution of proper strategical plans and policies based on reliable and sound technologies to find new alternatives.

Several plans and policies have been formulated and implemented to eradicate the age old land use system of shifting cultivation in the state by providing the farmers with alternative solutions and amenities. For example, Garden Colony, Jhum Control Project, Mizoram Intodelh Project (MIP) and New Land Use Policy (NLUP). These policies had basic objectives for improving the rural economy and the socio-economic condition of population. A policy with a coherent approach for balancing productivity and conservation practices through constant monitoring and identification of problem areas (Lallianthanga, 1999) will go a long way in ensuring sustained utilization of natural resources. Information on land use / land cover and possibilities for their optimal use is essential for the selection, planning and implementation of land use schemes to meet the increasing dynamics of land use (Archana and Kaushik, 2013). Previous studies done to map the pattern of spatial distribution of various land use/land cover categories and area coverage in Serchhip rural development block highlighted the need for natural resource based planning for proper utilization and conservation of natural resources (Lallianthanga & Goswami, 1997). Similar studies based on satellite Remote Sensing techniques has also formulated strategic land and water resource development plans for Mat watershed, Aizawl district and has proven the effectiveness of IRS data for micro-level planning of rugged hilly terrain (Lallianthanga & Goswami, 1998).

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Geographic Information System (GIS), which has a strong capacity in data integration, analysis and visualization has become an important tool to support land use planning approaches (Trung et al., 2006). Advancement in this system has also helped in evolving improved techniques of geospatial planning. In the context of land use planning, geospatial techniques and models have been researched and developed for its effective use in sustainable development of natural resources by integration of various GIS layers, which further demonstrates that geospatial techniques help in generation of a reliable spatial and non-spatial information database (Kushwaha et al., 2010). Geospatial modeling techniques used for locating various levels of biological richness has also been envisaged to be useful in land-use zonation and planning for sustainable use of natural resources (Chandrashekhar et al., 2003).

Mapping of spatial patterns of land use, slope, drainage and other related natural landforms and features based on fine resolution Indian satellite data provides relevant, reliable and timely information as shown during the course of this study. Besides facilitating the creation of a comprehensive geo-database, spatial analysis in GIS has enabled the generation of an environmentally and economically sound land use plan for implementation in the study area.

Materials and Method

Study area

The study area - Champhai District, is located in the north-eastern part of Mizoram, India between 24˚ 05’ 03.99” and 23˚ 00’ 03.25” N latitudes and 93˚ 00’ 31.29” and 93˚ 26’ 17.66” E longitudes (MIRSAC, 2006). It is bounded on the east by Myanmar (Burma), on the west by Aizawl and Serchhip District, on the north by Manipur state and on the south by Serchhip District and Myanmar (Fig. 1). The total geographical area of the district is 3185 sq. km, and accounts for 15.10% of the total geographical area of the state.

The study area experiences moderate climate conditions owing to its sub-tropical location and high elevation ranges. It is observed that the average mean summer temperature is (April to June) 23.5°C and average mean winter temperature (November to February) is 15.7°C

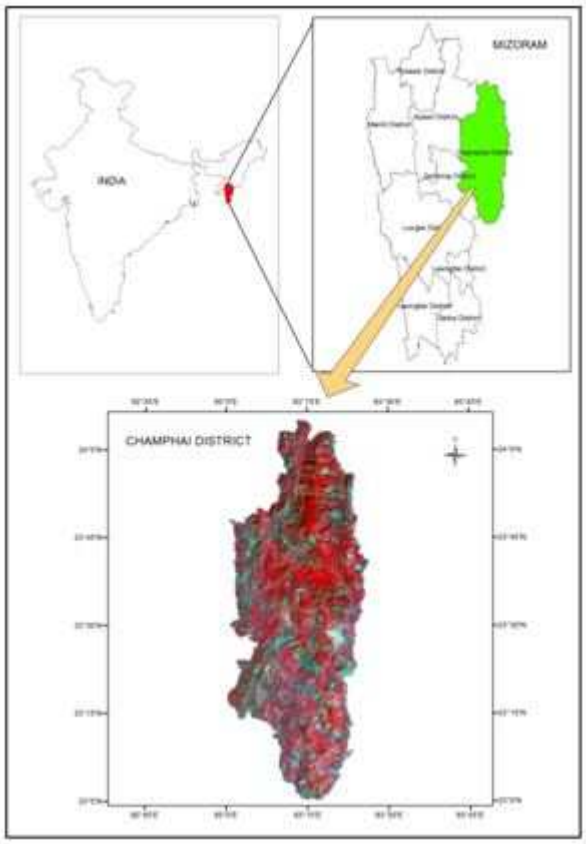

Figure 1. Location map of study

(MIRSAC, 2012). The area also receives heavy rainfall as it is under the direct influence of south-west monsoon. The average annual rainfall is 2346.2 mm (MIRSAC, 2012).

According to the 2011 census, the total population of the study area is 125,370 (Directorate of Census, 2011). There are 4 notified towns (Economics & Statistics, 2010) in the study area. The District headquarter- Champhai is well connected by road and distance from the state capital, Aizawl is 192 km (NIC Champhai, 2013).

Although shifting cultivation still dominates the agriculture farming system, the study area is well known for its horticultural plantations like passion fruit and grapes. Production of grape wine under the brand name of "Zo-wine" is being commercially carried out and has provided socio-economic sustenance for the farmers taking up grape cultivation. The study area is also known as the "Rice bowl of Mizoram" owing to its vast stretch of wet rice cultivation to the eastern fringe of the district. The forest type is mainly montane sub-tropical forest especially to the eastern side of the district, where the altitude is higher. There are also tropical wet evergreen forest mixed with semi evergreen and tropical moist

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deciduous forests comprising patches of bamboo on the western side.

The study area represents a monotonous sequence of argillaceous and arenaceous rocks. Apart from several minor ridge lines, the area is also characterized by six main ridgelines and intervening valleys and less prominent ridges. (MIRSAC, 2006).

Data used

IRS P6 LISS III and Cartosat I (stereo pair ortho kit) satellite data were used to prepare base maps as well as map the existing land use / land cover of the study area. Ancillary data including past records/reports/maps collected from various State Departments were used for reference and collection of primary data. Survey of India Toposheets were also referred for preparing base maps and obtaining physiographic information.

Method

The study incorporates standard techniques of Remote sensing and geographic information system (GIS) for mapping of the land use/ land cover features. Image processing and enhancements was carried out using Image Processing system (Erdas Imagine) and Geographic Information System (Arc Info) to increase the visual perceptibility of land use features.

Visual interpretation and on-screen digitization techniques were used for classifying and delineating the various land use / land cover classes from the satellite data. Cartosat I data was utilized to derive and generate other ancillary information (eg. roads, drainage) and also used for generation of slope maps. These maps and GIS layers constitute important base layer information of existing natural resources which will later assist in preparation of proposed plans.

A land use plan was generated on the basis of various parameters of the present land use, slope percent and soil conditions in the study area (Fig.2). There are various criteria adopted for this purpose as given in Table 1 and the process of generating these proposed land use systems were done in a GIS environment. The inclusion of base layers like drainage, road and slope were also important data during this planning process. All these criteria were geospatially plotted in the GIS system by executing relevant spatial queries and commands.

Ground truthing forms the core activity of the study. Pre-field interpretations and plans prepared in map forms were, therefore, subjected to evaluation on-site. Various field information necessary for assessing and validating the accuracy of the maps prepared were collected during ground truth surveys. Data from these surveys were then incorporated during the final stages of map corrections, accuracy assessment and plan preparation at operational level.

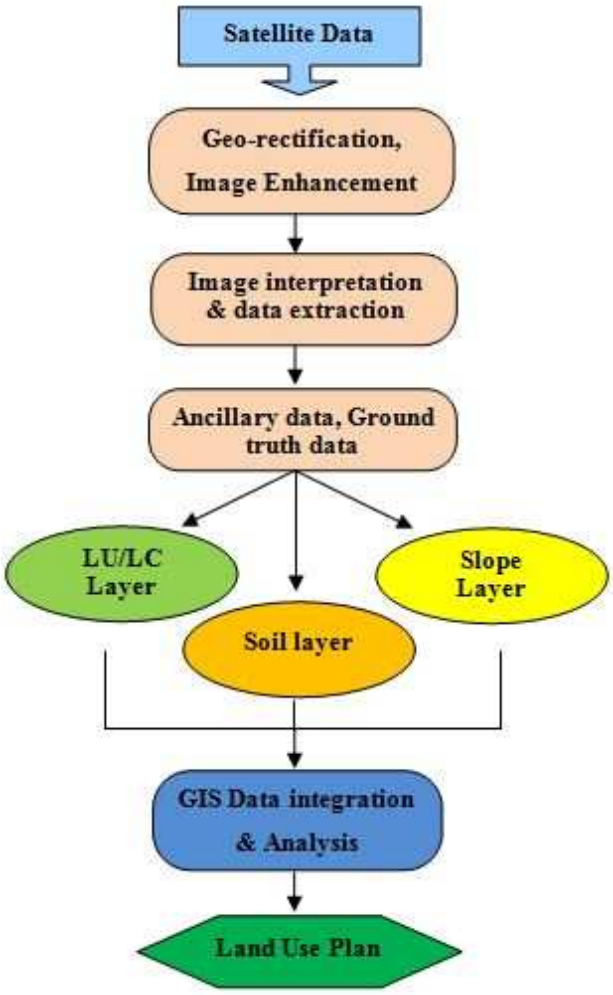

Figure 2. Methodology for Land use Plan

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Table 1. Guidelines for generation of Proposed Land use systems

S.No.	Present Land Use	Slope	Soil	Proposed Land Use
1	Single cropped agricultural land, current jhum, abandoned jhum, Scrubland	0 – 25%	Fine Loamy Fluventic Dystrochrepts and Fine Loamy Fluvaquentic Dystrochrepts, very deep, good moisture.	Wet Rice Cultivation (WRC)/ Pisciculture.
2	Single cropped agricultural land, current jhum, abandoned jhum	25 – 35%	Fine Loamy Fluventic Dystrochrepts and Fine Loamy Fluvaquentic Dystrochrepts, deep, good moisture.	Terrace cultivation
3	Current jhum, abandoned jhum	35 – 50%	Fine Loamy Typic Dystrochrepts. Loamy Skeletal Umbric Dystrochrepts and clayey, Typic Haplohumults, very deep, good moisture.	Agro-Horticulture
4	Existing plantation. Bamboo, current jhum & abandoned jhum adjacent to road.	25 – 50%	Fine Loamy Typic Dystrochrepts. Loamy Skeletal Typic Hapludults and clayey, Typic Haplohumults, very deep, good moisture.	Agri/Horti plantations
5	Scrub lands, hill top/crest	25 – 50%	Loamy Skeletal Typic Dystrochrepts, deep, moderate moisture	Silvi-pasture
6	Current jhum, abandoned jhum, open forest, Scrubland	More than 50%	Loamy Skeletal Typic Dystrochrepts and Loamy Skeletal Typic Hapludults, deep, moderate moisture	Afforestation
7	Forest (dense & open), Forest plantations and bamboo	-	-	To be conserved as forest and bamboo reserves

Results and Discussion

Land use / Land cover

The major land use/land cover classes in the study area were broadly classified into built-up land, agricultural land/horticultural land, forests (dense and open), bamboo forest, forest plantation, jhum land (current and abandoned jhum/shifting cultivation), scrubland and water body. The land use / land cover statistics is given in Table 2 and the map shown in Fig. 3.

Table 2. Land Use / Land Cover statistics of Champhai District

Land Use / Land Cover categories	Sq.km	%
Built-up	23.26	0.73
Wet Rice cultivation (WRC)	46.54	1.46
Agri/horti plantation	19.73	0.62
Dense Forest	715.85	22.48
Open Forest	1374.39	43.15
Bamboo	457.35	14.36

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Forest plantation	10.61	0.33
Current Jhum	187.69	5.89
Abandoned Jhum	328.43	10.31
Scrubland	9.81	0.31
Water Body	11.34	0.36
Total	**3185.00**	**100.00**

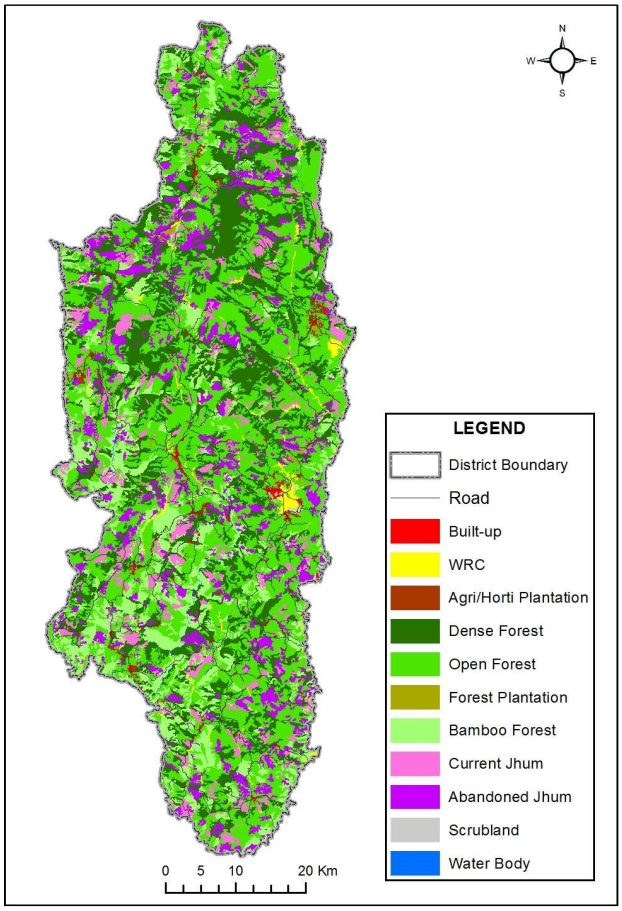

Figure 3. Land use / Land cover Map of Champhai District

Soil

The soils found in the study area were mostly of red and yellow loamy. They contained high amount of organic carbon and were high in available nitrogen, low in phosphorus and potassium content (MIRSAC, 2006). On the basis of their physico-chemical and morphological properties, the soils found at order level are: - (1) Entisols (2) Inceptisols and (3) Ultisols (USDA, 1988).

Slope

The study area has prominent hill ridges running parallel to each other. The southeastern and southern part have steep slopes and high elevated cliffs. The western part has gently sloping and low-lying hills (Fig. 4). The study area shows the presence of several evenly distributed plain areas with larger plain areas confined to the eastern part. Majority of these plain areas are utilized for wet rice cultivation. The hills in the eastern part are larger in areal extent compared to those in the central and western part of the study area.

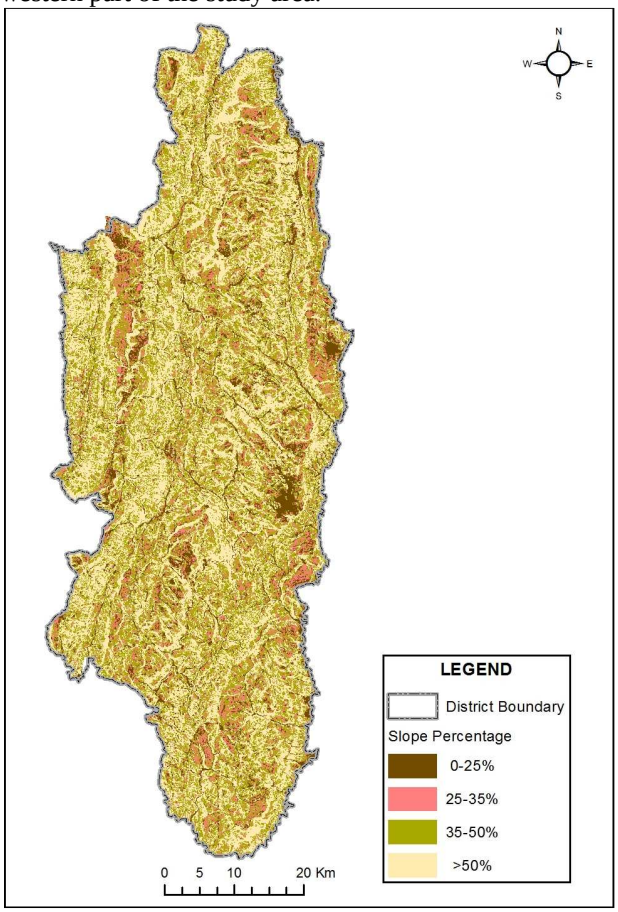

Figure 4. Slope Map of Champhai District

Land Use Planning

Land use planning using remote sensing and GIS techniques in the study area was done keeping in mind the objectives of making best use of available land for socio-economic improvement and to facilitate dependence of farmers on permanent farming system. The area statistics is given in Table 3 and the map showing areas for various proposed land development activities are shown in Fig. 5. Various sustainable land use practices (as discussed below) were modeled using the layers generated in GIS environment and

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considerations were also given to the socio-feasibility and implementation by incorporating data from ground surveys.

Wet Rice Cultivation / Pisciculture : The study area has a number of potential wet rice cultivation areas along river banks and valley plains on the eastern side. Infact, it also has one of the largest wet rice cultivations in the state. Such areas can be further brought under cultivation of other crops along with the practice of Pisciculture. The main components of the system are composite fish culture with paddy or vegetables. The area proposed for this land use system is 97.80 sq.km, which is 3.07% of the total study area. *Oryza sativa* (rice) is recommended as the main crop during the kharif season. The Rabi crops recommended are legumes and vegetables.

Terrace farming : Terrace farming proposed in the study area can ensure soil and water conservation as well as suit the additional cropping needs of the farmers on sloping lands. Good irrigation facilities are the basic needs prior to laying out of a terrace farm. Paddy as well as other crops can be cultivated in rotation on these terraces. The analysis have shown that terrace farming can be carried out in several places within the study area. The proposed area for this form of farming occupies 64.54 sq.km or 2.02% of the total study area.

Agro-horticultural system : In this system of farming, both fruit bearing trees and field crops can be grown together in many variations. Perennial crops, seasonal crops and nitrogen fixing plants may be grown in rotations. The recommended crops for this system include Passion fruit (*Passiflora edulcis*), Grape (*Vitis labrusca*), Kiwifruit (*Actinidia chinensis*), Banana (*Musa paradisiacal*), Orange (*Citrus reticulate*), etc. with vegetables and other root crops. The proposed area for this system is 188.56 sq.km which is 5.92% of the total study area.

Agricultural/Horticultural Plantation : The study has identified several places suitable for such plantations. Existing land use and slope plays an important factor for selecting plantation sites. Some plantations have to be confined to specific locations keeping in mind the socio-economic value of such plantations. The species identified as suitable crops for plantation under this system includes Coffee (C*offea spp*), Tea (*Camellia sinensis*), Broomgrass (*Thysanolaena maxima*), Ginger (*Zingiber officinale*), Lemon (*Citrus limon*), Pineapple (*Ananus comosus*), Grape (*Vitis labrusca*), etc. The area proposed for taking up these plantations covers 244.27 sqkm or 7.67% of the total study area.

Silvi-pastoral system : This system refers to cultivation of fodder crops along with trees. The tree component in this system can assist in conservation of forest resources. Besides providing fuel and fodder, the system helps in maintaining a good vegetative cover. Species having fodder, firewood and fruit bearing values as well as adaptable to the sites may be selected. Degraded scrublands and forests can be utilized for this system. Other agroforestry systems such as Horti-olericultural systems, Agri-silvicultural systems, Agri-horti-pastural systems, Horti-sericultural system, etc. can also be practiced depending upon the terrain and the local needs. The area proposed for this system of land use is 14.63 sq.km which covers 0.46% of the total study area.

Afforestation : Degradation of forest lands and its adjoining areas have necessitated taking up of afforestation programmes in the study area. Various afforestation programmes in which commercial tree species are planted as Government or private plantations like Teak (*Tectona grandis),* Michelia (*Michelia champaca*), Pine *(Pinus kesiya),* Oak (*Quercus spp*.) plantations have been taken up. The wastelands can also be reclaimed through reforestation programmes. The additional recommended species for this system are – *Gmelina arborea, Acacia auriculiformis, Ficus spp., Alnus nepalensis, Grevelia robusta, Prunus cerasoides,* etc and other native tree species found in the area may also be planted under such programmes. The area proposed for afforestation is 790.37 sq km of land or 24.82% of the total study area.

Forest : Forests of the study area comprises dense and open forests, as well as forest plantations (Govt. owned and private). Open forests generally refer to successive secondary successions of fallow lands (7 years and above), once used for shifting cultivation, but have remained unused for a long period of time (Lallianthanga et al., 1999). It is proposed that the existing forest cover and the supply/community reserves be preserved, and additional conservation techniques may be adopted to prevent encroachment and exploitation of forests for unsolicited commercial purposes. Voluntary organizations / NGOs can be entrusted the task of forest conservation as well as extension of the forests in the form of parks, etc. The proposed area under tree forest is estimated to be 1516.62 sq km, constituting 47.62 % of the total study area.

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Bamboo Forest : Bamboo forests are not prominent in the study area, except to the western fringes. They are confined to lower altitudes and are generally found between 80-1400 m MSL (Lallianthanga & Sailo, 2012). The limited bamboo forests in the study area requires conservation. Projects under the state and central government can assist in ensuring the conservation and rehabilitation of stocks. Initiative taken up by the village communities in the form of bamboo reserves can be encourage by providing proper incentives. The present bamboo growing stock in the study area needs conservation as it is also affected by shifting cultivation. The bamboo flowering phenomenon in 2007 also had a drastic effect on the bamboo cover of the study area. To recoup the bamboo forest, an estimated proposed area of 233.61 sq km or 7.33% of the total study area has been demarcated.

Table 3. Proposed Land Use Plan for the Champhai District

Proposed Land Use Plan	SqKm	%
WRC/Pisciculture	97.80	3.07
Terrace Cultivation	64.54	2.02
Agro-Horticultural system	188.56	5.92
Agri/Horti Plantation	244.27	7.67
Silvi-pastoral system	14.63	0.46
Afforestation	790.37	24.82
Forest	1516.62	47.62
Bamboo forest	233.61	7.33
Non-Planned area		
Water body	11.34	0.36
Built-up	23.26	0.73
Total	**3185.00**	**100.00**

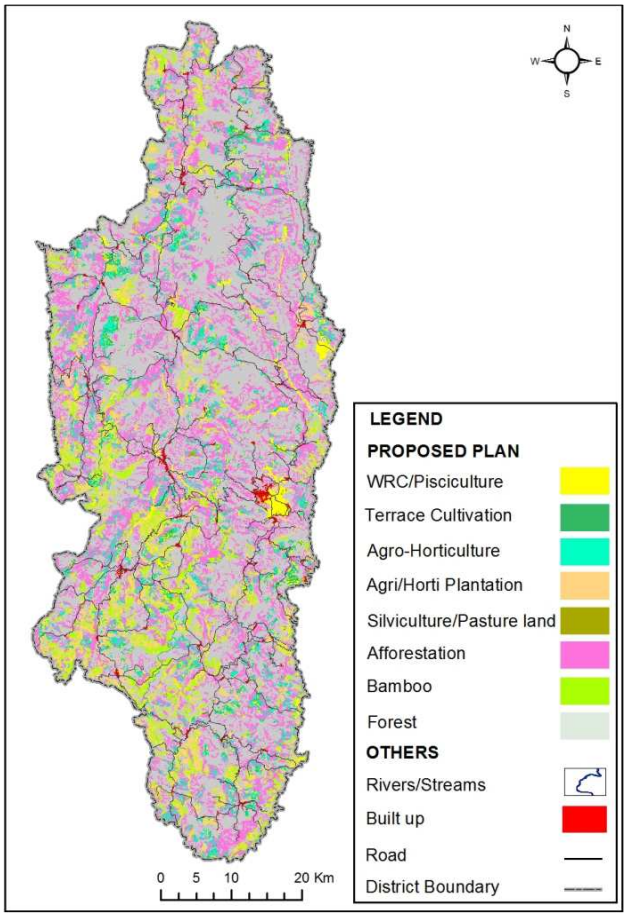

Figure 5. Land Use Plan Map for Champhai District

Conclusion

Planning for improved land use systems in hilly areas has been a challenging task as there are many bio-physical and socio-economic factors to consider. The same case has been encountered in the present study where 5.89% of cultivated land is still occupied by shifting cultivation. Permanent agricultural/horticultural lands constitute only a fraction of the total land used for food and cash crop production. It is observed that there is good potential for Agricultural / Horticultural system and Agriculture /Horticulture plantations. The land use plan prepared in the study has also considered the conservation of the existing forests including bamboo forests to maintain ecological balance while taking up improved and alternate farming practices. As the primitive form of agricultural practice in the study area is deeply rooted in the cultural life of the farmers, such problems should not be considered in isolation but has to be solved through integrated planning with scientifically sound approach, and also considering the socio-economic obligations. This is where remote sensing and GIS can play an important role with its ability to

incorporate both spatial and non-spatial data to generate realistic and effective land use plan. Land use planning in the study area, thus, focuses on finding an alternative to shifting cultivation and indentifying land where alternative and productive form of crop production can be adopted as well as are acceptable by the farmers.

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