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Land Use Planning for Lawngtlai District, Mizoram, India: A Remote Sensing and GIS perspective

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A B S T R A C T

Land development and its consequent use has a large impact on its immediate environment and sustainability. Hence, land use planning forms an important core component in development programmes of hilly areas for evolving effective plans at regional level. Hilly terrains offer a lot of challenges in land use planning due to their intricate bio-physical and socio-economic setup. Hence, the integration of scientific input through advanced techniques are required. The north-eastern part of India are well known for its inherent practice of shifting cultivation which have rendered considerable destruction to both land resources and environment. There is a necessity to develop proper strategies or land use plans which can counteract these 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 Lawngtlai 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. Integration of these with collected ground data resulted in generation of 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 which are both productive and sustainable. This information will be very useful at district level to plan according to the schemes and resources available.

Introduction

The utilization of land resources has its impact on the biodiversity and environment of associated region either positively or negatively depending on how it is used in time and space. The southern part of Mizoram has a unique bio-geographic profile with intervening rugged terrain and different types of land use system. The

socio-economic profile is also deeply affected by this pattern with a majority of the population still engaged in the age old system of farming. The need for proper land use planning in the district is of immense importance to preserve the ecological balance between natural resources development and conservation, particularly in fragile and heterogeneous erosion-susceptible ecosystems. Population growth has put tremendous pressure on land for daily requirements. The district has a decadal population growth of 34.08% as per current census (Census,2011) which is the second highest in the state. This has a considerable impact of the land use pattern of the area. There is still a need to evolve proper methods of utilization, conservation and planning of land resource to keep pace with the basic requirements.

Strategical plans and policies based on reliable and sound technologies are the need of the hour. Several plans and policies have been formulated and implemented to eradicate the destructive and old land use system in the state by providing the farmers with alternative solutions and amenities. 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.

Remote Sensing and GIS techniques have large roles in formulation of these plans and policies. Remote sensing is particularly useful in inaccessible areas and GIS is an effective tool for integrating data captured from different sources to produce a picture on which certain decisions can be made. 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 & 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).

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 (Khuswaha *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). On the farfetched end of this technology, research has also been further done on the use of remote sensing and WebGIS for analyzing the development of dynamic

thematics for cropping pattern programmes (Kavitha & Aruchamy, 2013).

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 Methods

Study area

The study area - Lawngtlai District, is located in the southern part of Mizoram, India between 22˚ 47' 08.89" and 22˚ 26' 32.65" N latitudes and 92˚ 31' 03.29" and 92˚ 58' 50.86" E longitudes(MIRSAC, 2007). The district is separated into two parts by Saiha district and has a geographical area of 2557 sq.km. It is bounded on the east by Myanmar (Burma) and Saiha district, on the west by Bangladesh and on the north by Lunglei district (Fig. 1). The study area experiences moderate humid climate conditions owing to its tropical location It is observed that the average mean summer temperature is (April to June) 24.76°C and average mean winter temperature (November to February) is 17.3°C (MIRSAC,2012). The area also receives heavy rainfall as it is under the direct influence of south-west monsoon. The average annual rainfall is 2510.3 mm (MIRSAC,2012).

According to the 2011 census, the total population of the study area is 117,444 (Census,2011). There is only 1 notified town in the study area i.e, Lawngtlai (Economics & Statistics, 2010) and it is also the District headquarter.

Shifting cultivation is still the dominant form of agricultural farming, though there are places where Agri/Horticultural farms and plantations are taken up. The forest type is mainly evergreen and semi-evergreen. The study area is naturally endowed with the presence of two large forest reserves- namely Ngengpui Wildlife Sanctuary and Phawngpui National park (also known as Blue Mountain national park). These two forest reserves adds to a large percentage, the natural dense forest found in the area and also puts the study area on one of the important tourist spots of the state. Moist deciduous bamboo forests are also found towards the western part in the low lying areas. One of the largest rivers of the state - River Chhimtuipui (Kolodyne) also flows on the mid-eastern flank of the study area which is proposed for a gateway for inland-waterway trade route with neighboring Myanmar, Bangladesh and West Bengal.

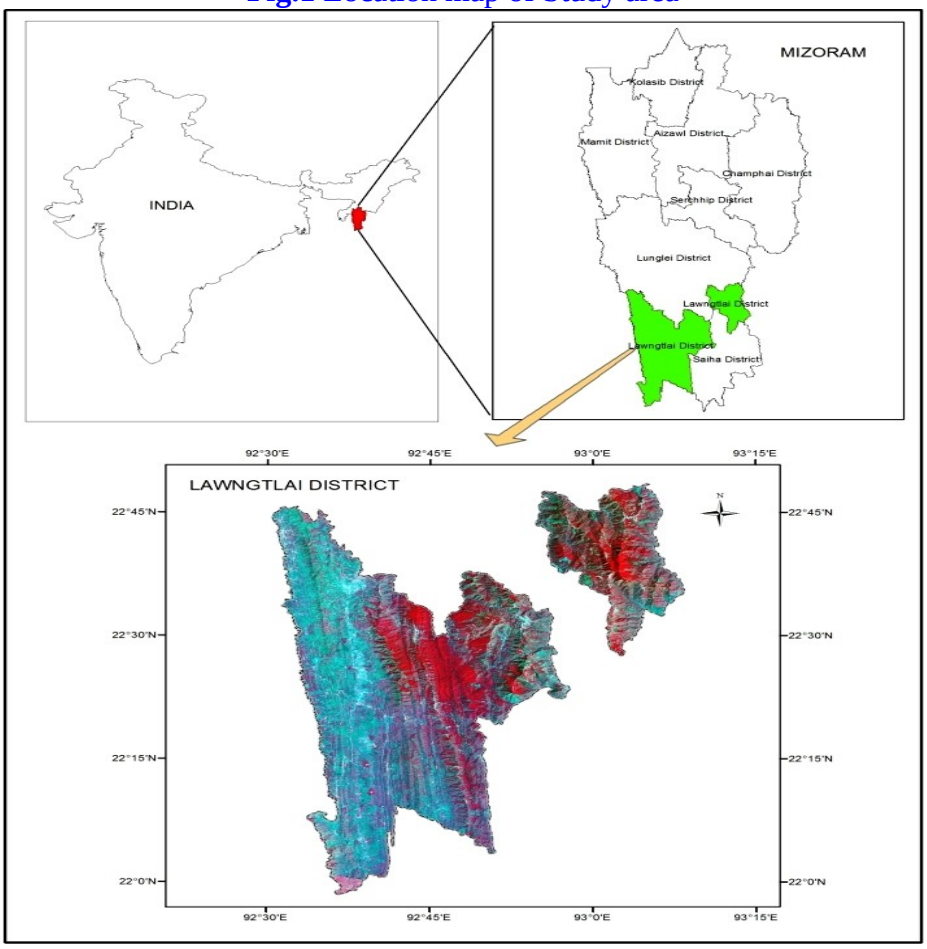
Data used

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

Fig.1 Location map of Study area



the land use/ land cover features. Image processing and enhancements was done 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. 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

Table.1 Guidelines for generation of Proposed Land use systems

(a) Present Land Use, (b) Slope & (c) Soil	**Proposed Land Use**
(a) Single cropped agricultural land, current jhum, abandoned jhum, Scrubland, Grassland. (b) 0 – 25% (c) Fine Loamy Fluventic Dystrochrepts and Fine Loamy Fluvaquentic Dystrochrepts, very deep, good moisture.	Wet Rice Cultivation (WRC)/ Pisciculture.
(a) Single cropped agricultural land, current jhum, abandoned jhum. (b) 25 – 35% (c) Fine Loamy Fluventic Dystrochrepts and Fine Loamy Fluvaquentic Dystrochrepts, deep, good moisture.	Terrace cultivation
(a) Current jhum, abandoned jhum. (b) 35 – 50% (c) Fine Loamy Typic Dystrochrepts. Loamy Skeletal Umbric Dystrochrepts and clayey, Typic Haplohumults, very deep, good moisture.	Agro-Horticulture
(a) Existing plantation. current jhum & abandoned jhum adjacent to road. (b) 25 – 50% (c) Fine Loamy Typic Dystrochrepts. Loamy Skeletal Typic Hapludults and clayey, Typic Haplohumults, very deep, good moisture.	Agri/Horti plantations
(a) Scrub lands, hill top/crest, grassland (b) 25 – 50% (c) Loamy Skeletal Typic Dystrochrepts, deep, moderate moisture.	Silvi-pasture
(a) Current jhum, abandoned jhum, Scrubland, grassland. (b) More than 50% (c) Loamy Skeletal Typic Dystrochrepts and Loamy Skeletal Typic Hapludults, deep, moderate moisture.	Afforestation
(a) Forest (dense & open), Forest plantations and bamboo. (b) Any slope (c) Any soil type	To be conserved as forest and bamboo reserves

collected during ground truth surveys. These were then incorporated during the final stages of map corrections, accuracy assessment and plan preparation at operational level.

Result 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.2.

Slope

The study area has several important plain areas located to the south-west hosting a network of streams and rivers and is extensively utilized for wet rice cultivation. The north-eastern parts consists of steep slopes and cliffs, while western parts are characterized by gently sloping and low lying hills (Fig. 3). Narrow valleys separate some of the hill ridges and few of them have gentle to steep slopes with visible escarpments on hillside slopes. The hills in the eastern and north-eastern part are larger in areal extent compared to those in the central and western part of the study area.

Soil

The soils found in the study area were mostly of red and yellow loamy. It is acidic in nature and contained high amount of organic carbon and available nitrogen, where as low in phosphorus and potassium content (MIRSAC, 2007). 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). On the basis of rainfall and humidity, soil moisture regime is classified as Udic.

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. 4. Various sustainable land use practices (as discussed below) were modeled using the layers generated in GIS environment and incorporating data from ground surveys.

Wet Rice Cultivation / Pisciculture

There are a number of potential wet rice cultivation areas in the study area along valley plains on the western flanks. These areas can be brought under crop cultivation 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 177.93 sq.km, which is 6.96% of the total study area.

Terrace Cultivation

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 44.04 sq.km or 1.72% of the total study area.

Agro-Horticultural system

This system of farming refers to cultivation of fruit bearing trees and field crops in many variations. Perennial crops, seasonal crops and nitrogen fixing plants may be grown in rotations. The recommended crops for this system include Maize (*Zea* mays), Pineapple (*Ananus comosus*), Butterfruit (*Avocado sps.*), Sugarcane (*Saccharum officinarum*), etc. with vegetables and other root crops. The proposed area for this system is 106.34 sq.km which is 4.16% of the total study area.

Agriculture-Horticulture Plantation

Sites for plantation of agriculture and horticulture crops has been identified in several places which suits the criteria of its feasibility in terms of existing land use and slope. 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 Banana (*Musa paradisiaca*), Citrus (*Citrus reticulata*), Broomgrass (*Thysanolaena maxima*), Ginger (*Zingiber officinale*), etc. The area proposed for taking up these plantations covers 8.28 sq.km or 0.32% of the total study area.

Silvi-pastoral system

In this system, fodder crops are cultivated along with trees. 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 Agri-silvicultural systems, Agri-horti-pastural systems, etc. can also be practiced on suitable identified sites. The area proposed for this system of land use is 56.68 sq.km which covers 2.22% of the total study area.

Afforestation

Various afforestation programmes in which commercial tree species are planted as Government or private plantations like Teak (*Tectona grandis*), Gamari (*Gmelina arborea*) plantations have been taken up. The wastelands can also be reclaimed through reforestation programmes. The additional recommended species for this system are –*Acacia auriculiformis*, *Acalypha indica*, *Michelia oblonga*, *Albizzia chinensis*, etc and other native tree species found in the area may also be planted under such programmes. The area proposed for afforestation is 130.43 sq km of land or 5.10% 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 constitutes 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 through NGO initiatives, and additional conservation techniques may be adopted to prevent encroachment and exploitation of forests for unsolicited commercial purposes. The proposed area under tree forest is estimated to be 1156.74 sq km, constituting 45.24 % of the total study area.

Table.2 Land Use / Land Cover statistics of study area

Land Use / Land Cover categories	Sq.km	%
Built-up	22.58	0.88
Wet Rice cultivation (WRC)	21.48	0.84
Agri/horti plantation	8.36	0.33
Dense Forest	495.12	19.36
Open Forest	658.88	25.77
Bamboo	844.89	33.04
Forest plantation	18.18	0.71
Current Jhum	93.60	3.66
Abandoned Jhum	270.11	10.56
Scrubland	19.42	0.76
Grassland	80.27	3.14
Water Body	24.11	0.95
Total	**2557.00**	**100.00**

Fig.2 Land Use / Land Cover map of study area

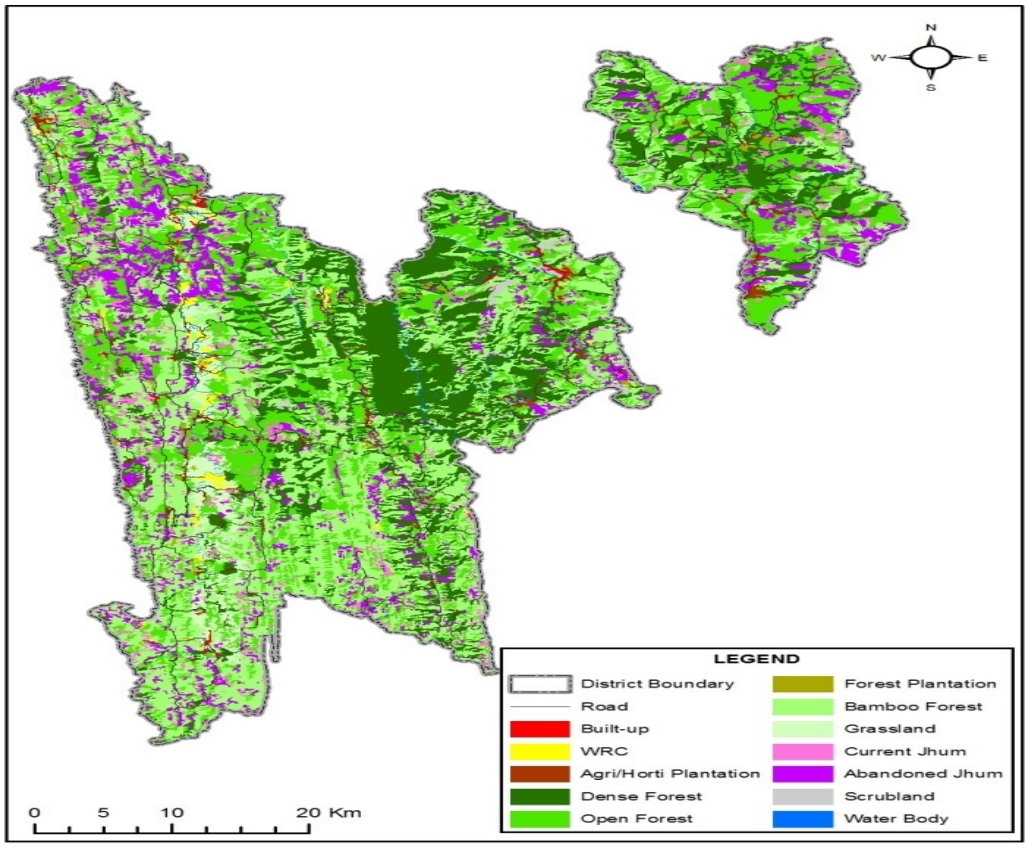


Fig.3 Slope map of study area

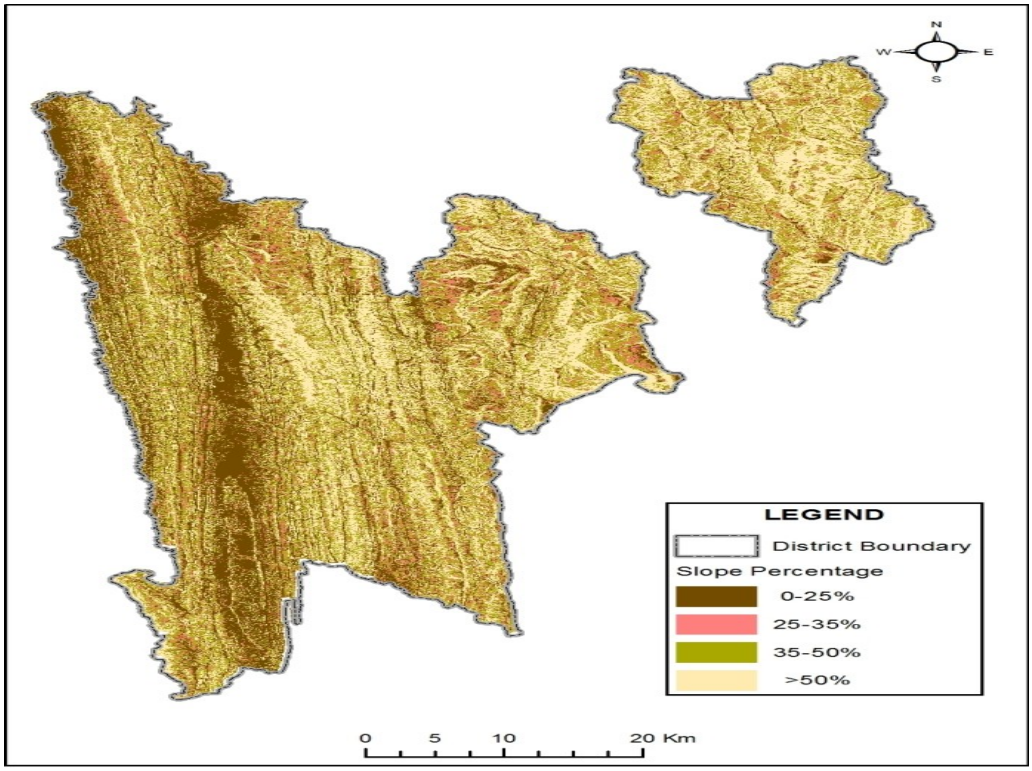
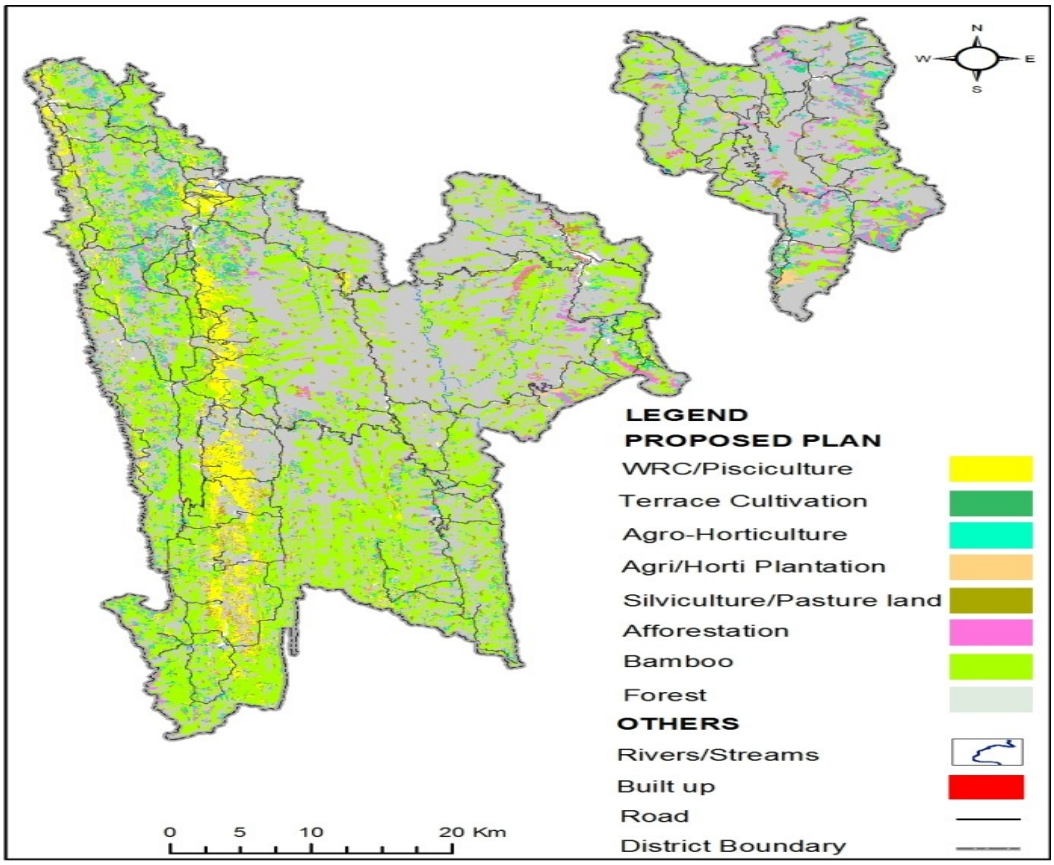


Table.3 Proposed Land Use Plan for the study area

Proposed Land Use Plan	SqKm	%
WRC/Pisciculture	177.93	6.96
Terrace Cultivation	44.04	1.72
Agro-Horticultural system	106.34	4.16
Agri/Horti Plantation	8.28	0.32
Silvi-pastoral system	56.68	2.22
Afforestation	130.43	5.10
Forest	1156.74	45.24
Bamboo forest	829.87	32.45
Non-Planned area		
Water body	24.11	0.95
Built-up	22.58	0.88
Total	**2557.00**	**100.00**

Fig.4 Land Use Plan map for the study area



Bamboo forest

Bamboo forests constitutes a majority of the vegetation type found in forests of the study area. They are confined to lower altitudes and are generally found between 80-1400 m MSL (Lallianthanga & Sailo, 2012). This important forest resources has faced the natural phenomenon of flowering and its regeneration (bamboo reserves) has to be protected to ensure diminishing bamboo growing stock. Projects under the state and central government can assist in ensuring the conservation and rehabilitation of stocks. To recoup the bamboo forest, it is proposed to conserve the existing stock which covers an area of 829.87 sq km, constituting 32.45% of the total study area.

Conclusion

The study area represents a unique set of geographical and biophysical features which are closely linked with the cultural and social parameters of the locals. Due to nomadic pattern of agricultural practice by the farmers, large patches of cultivable land are openly exploited through unscientific and age old practice of farming. This has been detrimental not only to crop production but also the immediate environment and biodiversity. Constructive plans for conservation and sustainable production is the need of the hour. This is where the present study reveals the effectiveness of remote sensing and GIS techniques for planning of alternate land

use systems which are not only sustainable and productive but also helps in maintaining ecological balance.

Sustained Land use planning in the hilly terrains can be a challenging task as there are many bio-physical and socio-economic factors to consider. It is observed that there is good potential for Agricultural / Horticultural system and plantations. The land use plan prepared in the study also focuses on conservation of the existing forests including bamboo forests to maintain ecological balance while taking up improved and alternate farming practices. The primitive form of agricultural practice in the study area is deeply rooted in the cultural life of the farmers, hence 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. Thus, 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.

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