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Land use planning for sustained utilization of resources using Remote Sensing & GIS techniques: A case study in Mamit District, Mizoram, India

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Abstract: - Proper land use planning for sustained and productive yields is the immediate need in north-east India, especially in states like Mizoram where the practice of shifting cultivation have rendered considerable destruction to both land resources and environment. It is imperative to develop land use plans which can counteract the detrimental effects on environment, and at the same time improve productivity of land. The present study deals with the application of remote sensing and GIS for land use planning in Mamit district of Mizoram. Indian Remote Sensing satellite data (LISS-III and Cartosat-I) had been used for generating various thematic layers like land use, slope, soil, drainage, etc. They were then integrated in conjunction with the ground and socio-economic data to evolve a comprehensive land use plan. The analysis in a GIS system helped in bringing out maps and statistics with constructive options for alternate land use plans which are expected to be both productive and sustainable.

Keywords: - *GIS, land use plan, Mamit, remote sensing*

I. INTRODUCTION

Land use planning in the context of this study, refers to the assessment of physical land resources and associated socio-economic factors in such a way that it can assist the farmers and planners in selecting options that not only increase land productivity but also are sustainable to meet the long term needs of the society. The present land use pattern of the district is unproductive and ecologically destructive due to the inherent system of shifting cultivation. The utilization of land resources had its impact on the biodiversity and environment of the region as much of the land use changes depended on how it was used in time and space. With a decadal growth rate of 36.59% in the population of the study area [1], 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 land use 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. 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 [2] 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 [3]. 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 [4]. 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 [5].

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 [6]. The system's capacity to manage large amount of spatial data and derive additional information has also been proven [7]. 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 [8]. 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 [9].

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.

II. STUDY AREA

The study area - Mamit District, is located in the north-western part of Mizoram, India between 23° 15' 21.25" and 24° 15' 16.80" N latitudes and 92° 15' 44.54" and 92° 40' 39.63" E longitudes [10]. It is bounded on the north by Assam and Kolasib District, on the south by Lunglei District, on the east by Aizawl District and on the west by Tripura and Bangladesh (Fig. 1). The total geographical area of the district is 3025 sq. km.

The study area experiences moderate climate conditions owing to its sub-tropical location. It is observed that the average mean summer temperature is (April to June) 24.20°C and average mean winter temperature (November to February) is 18.85°C [11]. The area also receives heavy rainfall as it is under the direct influence of south-west monsoon. The average annual rainfall is 3067 mm [11].

According to the 2011 census, the total population of the study area is 85,757 [1]. There are 3 notified towns [12] in the study area. The District headquarter- Mamit is well connected by road, and distance from the state capital, Aizawl is 112 km [13].

Although shifting cultivation still dominates the agriculture farming system, the study area is well known for its agricultural/horticultural plantations, forest plantations and vast areas of bamboo forest. The well-known "Dampa Tiger Reserve" is located to the western fringe of the study area and accounts for a larger percent of dense forest cover. Owing to flat plains to the north-western edge, these areas are dotted with ponds and lakes, both naturally and artificially formed

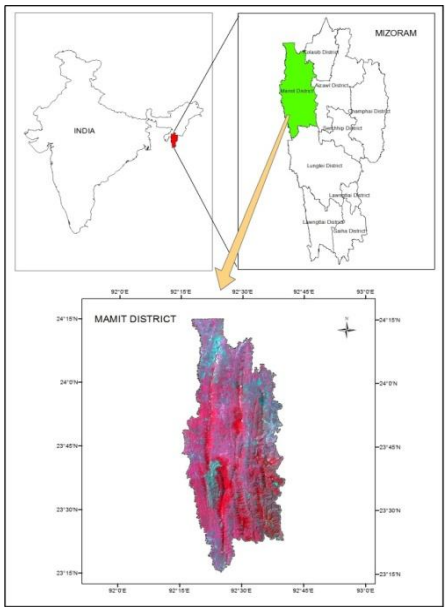

Figure 1. Location map of study area

. The forest type is mainly tropical evergreen forest mixed with semi evergreen forests. Among the forest resources, bamboo forests occupy a vast stretch and constitutes a larger fraction of tropical moist deciduous forests. The study area represents a monotonous sequence of argillaceous and arenaceous rocks. Apart from several minor ridge lines, the area is also characterized by three main ridgelines, intervening valleys and less prominent ridges [10].

III. MATERIALS AND METHOD

3.1. Data used

IRS P6 LISS III and Cartosat I (stereo pair ortho kit) satellite data were used to prepare thematic maps, and the ancillary data including past records/reports/maps collected from various sources were used for reference. Survey of India Toposheets were also referred for preparing base maps and obtaining physiographic information.

3.2. 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 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 information (eg. roads, drainage) and also used for generation of slope map.

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	> 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

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 was done in a GIS environment.

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 land use plan preparation.

IV. RESULTS AND DISCUSSION

4.1. 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.

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

Land Use / Land Cover categories	Sq.km	%
Built-up	16.74	0.55
Wet Rice cultivation (WRC)	7.09	0.23
Agri/horti plantation	8.93	0.30
Dense Forest	406.32	13.43
Open Forest	727.45	24.05
Bamboo	1563.06	51.67
Forest plantation	13.01	0.43
Current Jhum	72.92	2.41
Abandoned Jhum	170.33	5.63
Scrubland	21.43	0.71
Water Body	17.72	0.59
Total	**3025.00**	**100.00**

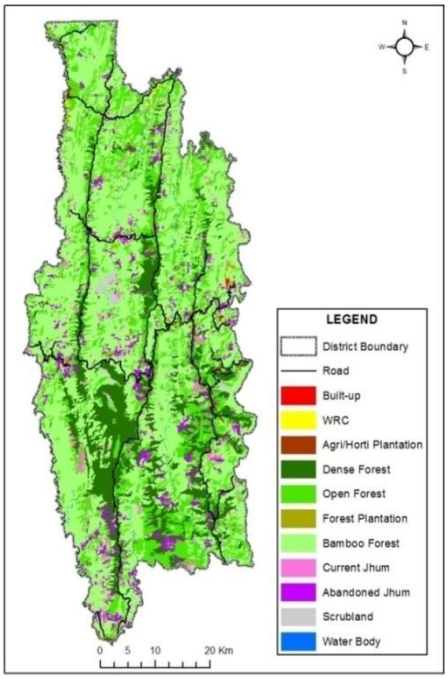

Figure 2. Land use/Land cover Map of Mamit District

4.2. 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 [10]. The soil is also acidic in nature as the study areas experiences heavy rainfall. On the basis of their physico-chemical and morphological properties, the soils found at order level are: - Entisols, Inceptisols and Ultisols [14]. The classification of soil in the study area upto Family level was referred to as per previous project work done by MIRSAC.

4.3. Slope

The study area is characterized by few prominent hill ridges running parallel to each other. The western part constitutes narrow river valley plains which ascend gradually to the east. The southeastern part consists of rather rugged hilly ridges with steep slope, narrow valleys and small streams. The hillside slopes are mostly gentle to steep, and escarpments are also visible in many places of the study area. It can be summarized that the eastern part of the study area has steeper slopes as compared with the western part. For the purpose of this study, the district area has been classified into four slope facets (Fig. 3) to be incorporated during land use plan preparation in a GIS environment.

4.4. Land Use Planning

Various sustainable land use practices (as discussed below) were modeled using the layers generated in GIS environment and considerations were also given to the socio-feasibility and implementation by incorporating data from ground surveys. The area statistics is given in Table 3 and the map showing areas for various proposed land use activities are shown in Fig. 4.

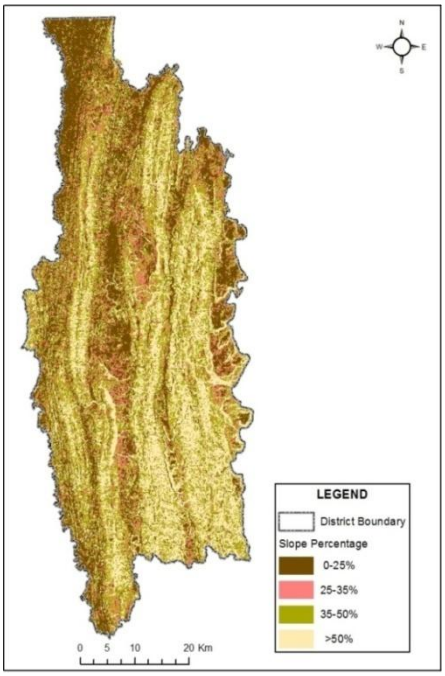

Figure 3. Slope Map of Mamit District

***4.4.1. Wet Rice Cultivation / Pisciculture* :**

The study area has potential wet rice cultivation areas scattered along river banks and valley plains. These areas can be further brought under cultivation of other crops along with the practice of pisciculture. The existing farms and cultivation areas can also be extended The main components of the system are composite fish culture with paddy or vegetables. The area proposed for this land use system is 74.33 sq.km, which is 2.46% 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.

4.4.2. Terrace farming :

Terrace farming proposed in the study area can meet the additional cropping needs of the farmers on sloping lands as well as ensure soil and water conservation. This system of land use requires good irrigation facilities. Paddy as well as other crops can be cultivated in rotation on these terraces. The analysis has shown that terrace farming can be carried out in several places and most of the jhum lands can also be converted to terrace farms. The proposed area for this form of farming occupies 25.85 sq.km or 0.85% of the district.

4.4.3. Agro-horticultural system :

This system refers to a farming practice where 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 Betelnut (*Areca catechu*), Tea (*Camellia sinensis*), Banana (*Musa paradisiacal*), Orange (*Citrus reticulate*), Red oil palm (*Elaies guinensis*), etc. with vegetables and other root crops. The proposed area for this system is 73.22 sq.km which is 2.42% of the district.

4.4.4. Agricultural/Horticultural Plantation :

The study area has several places suitable for agriculture and horticulture 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*), Broomgrass (*Thysanolaena maxima*), Ginger (*Zingiber officinale*), Hatkora (*Citrus macroptera*), Pineapple (*Ananus comosus*), etc. The area proposed for taking up these plantations covers 709.33 sqkm or 23.45% of the district.

***4.4.5. 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 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 29.42 sq.km which covers 0.97% of the district.

***4.4.6. 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*), Gamari *(Gmelina arborea),* Toona (*Cedrela toona*) plantations have been taken up. The wastelands can also be reclaimed through afforestation programmes. The additional recommended species for this system are –*Albizia procera, Ficus spp., Grevelia robusta, Gmelina oblongifolia,* etc and other native tree species found in the area may also be planted under such programmes. The area proposed for afforestation is 319.32 sq km of land or 10.55% of the district.

Table 3. Proposed Land Use Plan - Mamit District

Proposed Land Use Plan	SqKm	%
WRC/Pisciculture	74.33	2.46
Terrace Cultivation	25.85	0.85
Agro-Horticultural system	73.22	2.42
Agri/Horti Plantation	709.33	23.45
Silvi-pastoral system	29.42	0.97
Afforestation	319.32	10.55
Forest	904.35	29.90
Bamboo forest	854.72	28.26
Non-Planned area		
Water body	17.72	0.59
Built-up	16.74	0.55
Total	**3025.00**	**100.00**

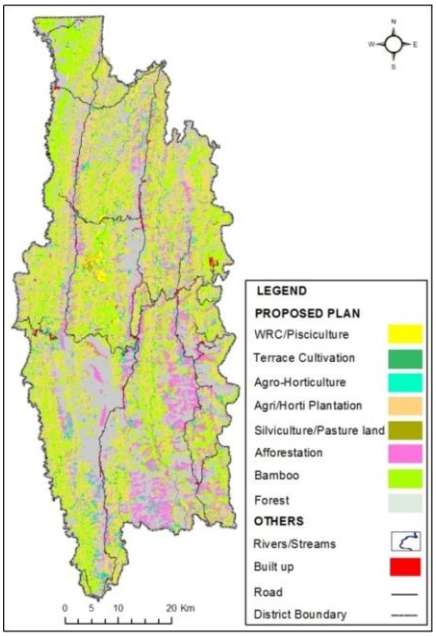

Figure 4. Land Use Plan Map for Mamit District

***4.4.7. 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 [15]. 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 904.35 sq km, constituting 29.90 % of district.

4.4.8. Bamboo Forest :

The study area abounds with bamboo forests and they constitute a larger percentage of forest resources. They are confined to lower altitudes and are generally found between 80-1400 m MSL [16]. Although rich in this forest resources, there are certain areas that require conservation from over exploitation as well as from shifting cultivation. 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. An estimated proposed area of 854.72 sq km or 28.26% of the total study area has been demarcated for conservation of bamboo forest.

V. CONCLUSION

Land use planning in hilly terrains has always been a challenge for planners as there are many bio-physical and socio-economic factors to be considered. 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. The inherent system of land use in the study area has produced a lot of changes in the present land use / land cover pattern. The present land use shows that only a fraction of the total land (0.30%) is used as permanent agricultural/horticultural lands for food and cash crop production. This aspect could be improved as the study indicates that there is good potential for Agricultural / Horticultural system and Agriculture /Horticulture plantations. In addition, the available flat lands could provide extensions for taking up other allied agricultural activities such as WRC, Pisciculture and terrace cultivations. 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. The sustained utilization of forest resources has to be considered while planning for any development that uses these resources.

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