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Integrated Land Use Planning of Aizawl District, Mizoram, India Using Geospatial Techniques

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Abstract This paper deals with the land use planning for improved land use system in Aizawl district, Mizoram wherein an integrated approach of land use planning had been derived using geospatial techniques. As geospatial planning has emerged as an effective and reliable platform to assist in this process of developmental planning even at the grassroots level, the present study incorporates remote sensing and GIS techniques to map land use, land cover, slope, and soil, and also to formulate viable land resource management plans for improved land use system which will be more sustainable and productive. Integration of the thematic layers in a GIS system helped in formulation of different suitable land use scenarios with economic and biophysical benefits. The study further reveals that the district has a very good potential for Agro-horticultural systems and Agri/horticultural plantations which could increase productivity of land use systems.
Keywords *Aizawl; Geospatial; GIS; Land Use Planning; Remote Sensing*

1. Introduction

Resources in the study area have constantly been under pressure to suffice the needs of increasing population. With a decadal growth of 24.07% in the population of the study area [1], the need for proper planning of land use and conservation of resources becomes a much concerned issue in the present scenario. Sustained utilization of available resources requires a scientifically approached land use planning process which incorporates integration of various data, analysis of these data, faster or precise information generation for participants in the land use planning approach. There is, thus, an urgent need for research and evolution of proper strategically plans and policies based on reliable and sound technologies to find new alternatives.

Several plans and policies have been formulated and implemented to eradicate shifting cultivation in the state by providing the practicing farmers 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 rural 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. On a holistic view point, improved land use planning lies in recognizing the importance of various natural resources in sustaining the livelihood of the locals and considering its optimized utilization and strategic management according to its capability, as an essential input during the planning process.

Land resource inventory, prepared using topographical map and updated from the satellite imagery data on the same scale, is essentially qualitative as it reveals ground truth to the extent the scale of the map permits. 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 [3]. 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 [4]. 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 [5]. 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 land 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 [6]. 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 [7].

Mapping of spatial patterns of land use, slope 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-water resource plan for implementation in the study area.

2. Materials and Method

2.1. Study Area

The study area - Aizawl district, is located in the northern part of Mizoram. It lies between 24°25'16.04" and 23°18'17.78"N latitudes and 92°37'03.27" and 93°11'45.69"E longitudes [7]. It is bounded by Champhai district and Manipur state in the east, in the west by Mamit district and Kolasib district, in the north by Assam state and in the south by Serchhip district (Figure 1). The geographical area of the study area is 3576 sq km, occupying 16.96% of land cover of Mizoram.

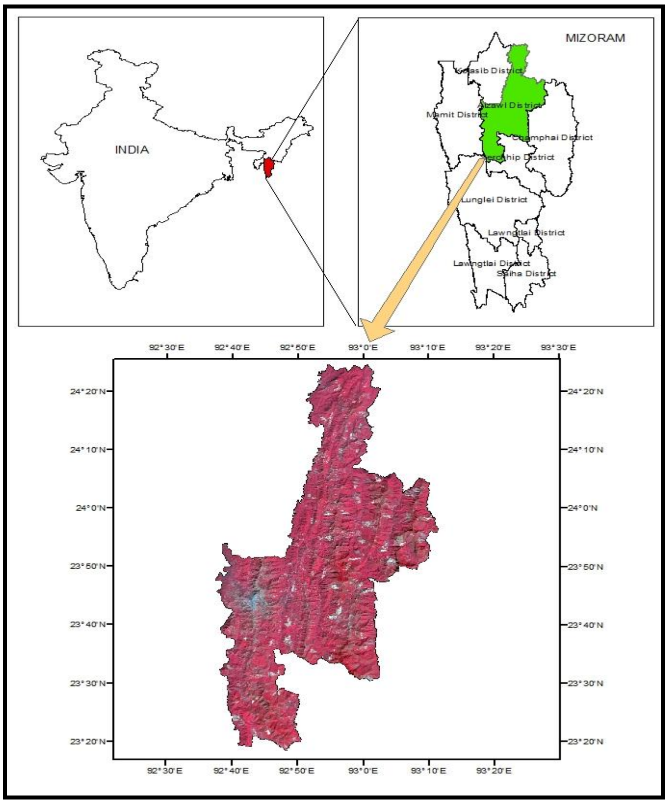

Figure 1: *Location Map of Study Area*

The study area experiences moderate humid tropical climate owing to its tropical location. It is observed that the average mean summer temperature is (April to June) 23.83°C and average mean winter temperature (November to February) is 19.05°C [8]. The area also receives heavy rainfall as it is under the direct influence of south-west monsoon. The average annual rainfall is 3155.3 mm [8].

According to the 2011 census, the total population of the study area is 404,054 [1]. Aizawl city, the capital of Mizoram is situated in the central part of Aizawl District. There are three notified towns namely Sairang, Darlawn and Saitual, and 98 villages. The forest cover type of Aizawl district is mainly tropical wet evergreen forest mixed with semi evergreen and tropical moist deciduous forests comprising mainly of bamboo. Aizawl district has good road networks. The whole length of the district is traversed by various road networks [7].

2.2. Data Used

IRS LISS III and Cartosat I (stereo pair ortho kit) satellite data were utilized to prepare base maps and to map the existing land use/ land cover of the study area. Ancillary data including past records/reports/maps collected from various sources like Department of Environment and Forest, Government of Mizoram, Department of Agriculture, Government of Mizoram and others were used for reference and collection of primary data. Survey of India Toposheets was also utilized for preparing and obtaining base maps and physiographic information.

2.3. Method

In the present study, a standard technique of remote sensing and geographic information system (GIS) was followed 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. The pattern of land use and extent of land cover was mapped focusing on the level at which features could be extracted at the given scale. Cartosat I data was utilized to derive and generate other ancillary information (eg. roads, drainage) and also effectively used for generation of slope maps. These maps and GIS layers are first prepared prior to generating land resources plans. They constitute important base layer information of existing natural resources which will later assist in preparation of proposed plans.

A geospatial plan for improved land use system 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. Most of the proposed land use systems require the integration and analysis of base layers like drainage, contour, soil, road, and slope layers, which become important pre-requisite data during the land use planning process.

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. Participation of local village representatives in the plan preparation was also solicited during the field visits. Data from these surveys were then incorporated during the final stages of map corrections, accuracy assessment and plan preparation at operational village level.

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	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 communication.	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	More than 50%	Loamy Skeletal Typic Dystrochrepts and Loamy Skeletal Typic Hapludults, deep,	Afforestation

			moderate moisture	
7	Forest (dense & open) and bamboo	-	-	To be conserved as forest and bamboo reserves

3. Results and Discussion

3.1. 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 corresponding map is shown in Figure 2.

Table 2: *Land Use/ Land Cover Statistics of Aizawl District*

Land Use/ Land Cover Categories	Sq.km	%
Built-up	66.77	1.87
WRC	16.53	0.46
Agri/Horti Plantations	24.32	0.68
Dense Forest	482.18	13.48
Open Forest	1320.15	36.92
Forest Plantation	19.45	0.54
Bamboo	1134.45	31.72
Scrubland	12.77	0.36
Water Body	18.66	0.52
Current Jhum	177.55	4.96
Abandoned Jhum	303.16	8.48
Total	**3576.00**	**100.00**

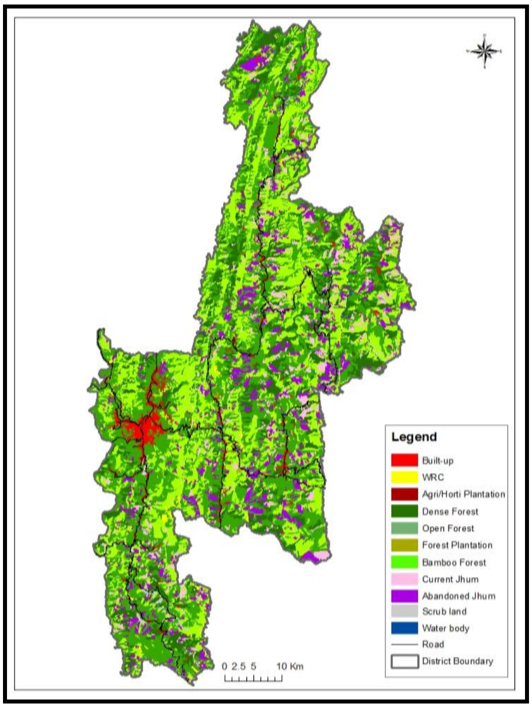

Figure 2: *Land use/ Land cover Map of Aizawl District*

3.2. Soil

The soils found in the study area were mostly of red and yellow loamy. They were also acidic in nature due to heavy rainfall [7]. They contained high amount of organic carbon and were high in available nitrogen, low in phosphorus and potassium content. On the basis of rainfall and humidity, the soil moisture regime was classified as Udic. The soils found at order level were - Entisols, Inceptisols and Ultisols [10]. The classification of soil in the study area upto Family level was referred to as per previous project work done by MIRSAC.

3.3. Slope

The study area is uniquely characterized by several prominent hill ridges running parallel to each other, most of which roughly runs from north to south, except the southernmost hill ridges, where the hill ridges run in north-west to south-east direction. It may be roughly stated that the eastern part of the study area (Figure 3) is comparatively higher in elevation than the rest of the study area, while the northern part is uniformly characterized by lower elevation.

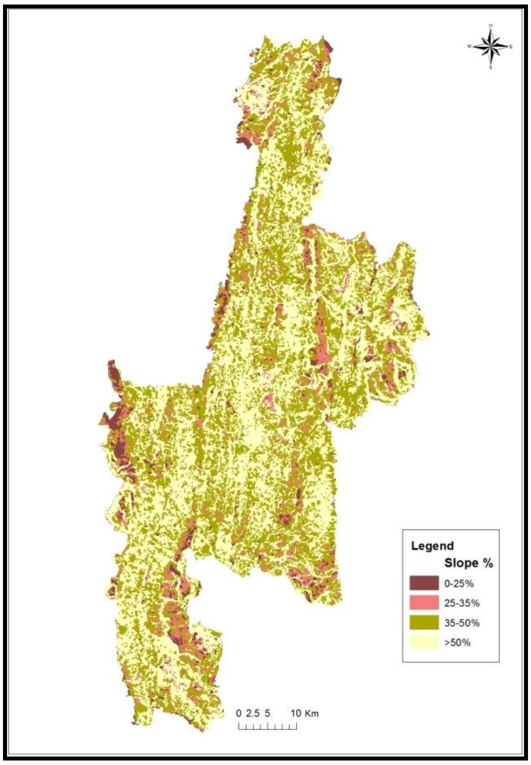

Figure 3: *Slope Map of Aizawl District*

3.4. Integrated Land Use Plan

The land use planning for development of land resources in the study area was prepared 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. 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 development activities are shown in Figure 4.

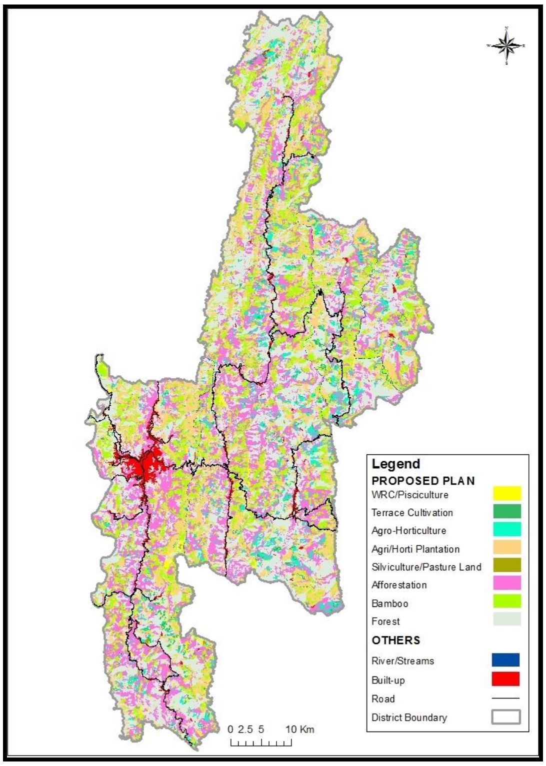

***Figure 4:** Land Use Plan Map for Aizawl District*

3.4.1. Wet Rice Cultivation/ Pisciculture

The wet rice cultivation areas are usually located at the banks of rivers and streams. A small patch of the wet rice cultivation is found to scattered at the central and southern part of the district. From the studies and field verifications, it is found that most of the wet rice cultivation areas are found at the banks of R.Tuivawl, R.Tuirini and R.Tuivai, which eventually irrigates the paddy fields either directly or through its tributaries, and small patches are found near R.Tuirial, R.Chite, R.Changte, R.Lik, R.Lao and R.Mat. In addition to paddy cultivation, these areas can be further brought under cultivation of other crops along with practice of Pisciculture. Such a system refers to a form of farming called agro-aquaculture system. The main components of the system are composite fish culture with paddy or vegetables. Terrace farming is also possible in such category of sloping lands. The area proposed for this land use system is 29.65 sq.km, which is 0.83% 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.

3.4.2. Terrace Farming

Terrace farming occupies an important proposed form of farming in the study area, which not only ensures soil and water conservation but also suits the cropping needs of the farmers on sloping lands. Good irrigation facilities are the basic needs prior to lying out of a terrace farm. Paddy cultivation can be also carried out in the terraces. Other crops and vegetables can be cultivated in rotation. These areas are also suitable for double cropping. The analysis has shown that terrace farming can be carried out in several places within the study area. The proposed area for this form of farming occupies 41.82 sq. km or 1.17% of the total study area.

3.4.3. Agro-Horticultural System

In this farming system, 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 an alternate manner. Crop rotation will be necessary in case of seasonal crops. The recommended crops for this system include Citron (*Citrus medica*), Valencia Orange (*Citrus sinensiis),* Banana (*Musa paradisiacal*), Orange (*Citrus reticulate*), Passion fruit (*Passiflora spp*), Pineapple (*Ananas comosus*), Red oil palm (*Elaies guinensis*), Jatropha (*Jatropha curcas)* etc. with vegetables and other root crops. The proposed area for this system is 182.24 sq.km which is 5.10% of the total study area.

3.4.4. Agricultural/Horticultural Plantation

The study area has several sites suitable for agriculture/horticulture plantations. However, the existing land use and slope factor determine the selection of suitable places for these plantations. Some plantations have to be confined to specific locations keeping in mind the socio-economic value of such plantations. Some of the species identified as suitable crops for plantation under this system includes Tea (*Camellia sinensis*), Coffee (C*offea spp*), Sugarcane (*Saccharus officinarum*), Broomgrass (*Thysanolaena maxima*), Ginger (*Zingiber officinale*), Turmeric (*Curcuma domestica*), etc. The area planned for taking up these plantations covers 597.55 sqkm or 16.71% of the total study area.

3.4.5. Silvi-Pastoral System

This proposed system refers to cultivation of fodder crops along with trees and occupies the largest portion for proposed land development in the study area. The inclusion of tree component in the system can also suggest an initiation towards conservation of forest resources. Besides providing fuel and fodder, the system helps in maintaining a good vegetative cover. Degraded forest areas in the study area have potential for cultivation of grasses and trees and such sites have been selected for this system. Species having fodder, firewood and fruit bearing values as well as adaptable to the sites may be selected. Generally, the tree species such as *Ficus hirta*, *Litsea semicarpifolia*, *Ficus spp., Mangifera indica, Leucaena leucocephala,* etc. are recommended for plantation and the grass species such as *Stylosanthes spp., Pennisetum pedicellatum, Thysonalaena maxima, Erianthus longisetosus,* etc. are recommended for cultivation in this system. Other agroforestry systems such as Horti-olericultural systems, Agri-silvicultural systems, Agri-horti-pastural systems, Horti-sericultural system, home gardens, etc. can also be practiced depending upon the terrain and the local needs. The area proposed for this system of land use is 11.07 sq.km which covers 0.31% of the total study area.

3.4.6. Afforestation

The pressure on land for food production has resulted in deforestation which continues to prevail due to practice of shifting cultivation. Therefore, there is need for taking up afforestation programmes in such affected sites. 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)* plantations have been taken up. The wastelands can also be reclaimed through reforestation programmes. The recommended species for this system are – *Michelia oblonga, Quercus serrata, Acacia auriculiformis, Albizzia odoratissima, Albizzia chinensis, Gmelina arborea,* etc and other native tree species found in the area may also be planted under such programmes. The area proposed for afforestation is 871.76 sq km of land or 24.38% of the total study area.

3.4.7. Forest

Forests of the study area comprise dense and open forests, as well as other reserve forests and forest plantations (Govt. owned and private). Most of the open forests are also 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 [11]. 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. Declaration and demarcation of forest areas as Reserve Forests/Supply Reserve forests in areas where their conservation is needed can help in preservation of the adjoining natural forests. Voluntary organizations/NGOs may be encouraged and entrusted the task of further protection of these forests as well as extension of the forests in the form of parks, etc. The steps taken by the Government through Village councils, Village Forest Development Agency and various management schemes is noteworthy and can be made more effective for this purpose. The proposed area under tree forest is estimated to be 1197.33 sq km, constituting 33.48 % of the total study area.

3.4.8. Bamboo Forest

Bamboo forests are more confined to lower altitudes and are generally found between 80-1400 m MSL [12]. The study area also has bamboo growing stock within this altitudinal range. The genetic stock of these bamboos needs to be conserved and propagated to continue the existence of the bamboo forests. 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, besides the existing reserves, an estimated proposed area of 559.09 sq km or 15.63% of the total study area has been demarcated.

Table 3: *Proposed Land Development Plan for the Aizawl District*

S. No.	Proposed Land Development Plan	Sq.Km	%
1	WRC/Pisciculture	29.65	0.83
2	Terrace Cultivation	41.82	1.17
3	Agro-Horticultural system	182.24	5.10
4	Agri/Horti plantations	597.55	16.71
5	Silvi-pastoral system	11.07	0.31
6	Afforestation	871.76	24.38
7	Forest	1197.33	33.48
8	Bamboo forest	559.09	15.63
	Non-Planned Area		
9	Water body	18.71	0.52
10	Built-up	66.77	1.87
	Total	**3576.00**	**100**

4. Conclusion

The study area, i.e., Aizawl district shows diverse forms of land uses with fragmented structures of natural land cover. A considerable percentage (4.96%) of land is still used for shifting cultivation, which forms the main farming system adopted for crop production. Land use planning in shifting cultivation areas is a challenging task, as it is deeply rooted in the cultural life of the farmers. Hence, an integrated planning approach which considers both socio-economic conditions and scientifically proven technologies of remote sensing and GIS is required. The present study has adopted such approach in order to find an alternative to shifting cultivation and identifying appropriate land use systems that are practically feasible and acceptable by the farmers. Efforts under Government schemes to bring land under sustained utilization has shown progress, yet there is still potential for increased crop productivity under Agriculture/Horticulture plantation and Agricultural/Horticultural farming systems. These system of land use, as proposed in the present study, could not only increase land productivity but also focuses on conservation of natural resources and maintaining ecological balance in the study area.

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