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Geospatial planning for improved land use system in Saiha District, Mizoram, India

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Abstract

Scientific inputs and analysis of land and water resources are important units for effective land use programmes to optimize the use of available resources. The success of these plans relies on the careful assessment of qualitative and quantitative information derived from the analyses. Geospatial planning has emerged as an effective and reliable platform to assist in this process of developmental planning even at the grassroot level. In this context, the present study incorporates remote sensing and GIS techniques to map the natural resources and to formulate viable land and water resource management plans for improved land use system which will be more sustainable and productive. The study was done in the southern part of Mizoram, i.e. Saiha district wherein an integrated approach of land use planning had been derived that encompassed every aspect of land, water and socio-economic component of the district. Integration of these components in a GIS system helped in formulation of different suitable land use scenarios with economic and biophysical benefits. The result of this study presents maps with constructive options for land and water resource developments in the study area. This information will be very useful for decision makers to plan according to the schemes and resources available at hand.

Key words: Geospatial planning; GIS; land use; remote sensing; Saiha.

Introduction

The pressure on land for sustenance of livelihood has immensely increased over the past decades due to increase in population which in turn has its effect on the socio-economic condition of the population. With a decadal growth of 19.71% in the population of the study area,[1] the need for proper planning of natural resource and conservation becomes a topic of much concern 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 re-

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search 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 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.

Land and water 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 and water 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, 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-water resource plan for implementation in the study area.

MATERIALS AND METHOD

Study area

Saiha district, is located in the south-eastern part of Mizoram. It lies between 22°38'01.19" and 21°56'22.20"N latitudes and 92°49'21.37" and 93°12'10.55"E longitudes.[8] It is bounded by Lawngtlai district to the west and north. The study area also shares a long international boundary with Myanmar to the eastern and southern side (Fig. 1). It is the second smallest district of the state with a geographical area of 1399 sq km, occupying 6.63% of land cover of Mizoram.

The study area experiences moderate humid tropical climate owing to its geographical location. It is observed that the average mean summer temperature is (April to June) 24.96°C and average mean winter temperature (November to February) is 19.7°C.[9] The area also receives heavy rainfall as it is under the influence of south-west monsoon. The average annual rainfall is 2616 mm.[9]

According to the 2011 census, the total population of the study area is 56,366.[1] There is only one notified town, i.e. Saiha[10] in the study area. The District headquarters, Saiha is well connected by road and distance from the state capital, Aizawl is 378 km.[11]

The main occupation of the population is agriculture farming, mostly shifting cultivation. The forest type found in the study area is mainly montane sub-tropical forests along with tropical wet evergreen forest mixed with semi evergreen and tropical moist deciduous forests comprising mainly of bamboo. The famous and largest natural lake in Mizoram, i.e. *Palak* lake is found to the southern part of the study area.

The rocks found in the study area are generally sandstone and shale, and the derived soils are mostly red and yellow loamy. The eastern and northern part consist of steep slopes and cliffs, with higher and prominent ridges to the east. The western and southern parts are, however, characterized by gently sloping and low-lying hills. The rest of the study area consists of rather rugged hilly ridges with many narrow valleys and small streams.[8]

Data used

IRS LISS IV, Cartosat I (stereo pair ortho kit) and Quickbird 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 were also utilized for preparing and obtaining base maps and physiographic information.

Method

In the present study, standard techniques 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 at 1:10,000 scale. 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 (e.g. roads, drainage) and also effectively used for generation of slope maps. These maps and GIS layers are first prepared prior to generating land and water resource 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 adequate supply of water not only for improved crop production but also to facilitate a balance in soil moisture content. Therefore, the planning of water resources has to go in tandem with the planned land use systems. The inclusion of base layers like drainage, contour, soil, road, and slope layers are also important prerequisite data during this planning process. The placement of proposed water resource structures in the study area relies on the integration of these layers as well as the proposed land use plan in a GIS environment. To facilitate the identification of these placement points, various criteria were also adopted following the above mentioned guidelines as well as physical characteristics of the land. E.g. intake weirs placement at perennial water source/rivers, irrigation channels to follow the contour lines to reduce vertical drops, check dams on small streams with capability to feed nearby proposed command areas, rainwater harvesting tanks on dry but proposed cultivable lands with slope less than 35%, etc. All these criteria were geospatially plotted in the GIS system by executing relevant spatial queries and commands. There are also some structures like distribution tanks that require the combination of visual and query-executed plotting, as well as plotting based on data collected from field surveys.

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.

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), scrub land and water body. Areas falling within existing planned areas (e.g. areas of government complexes, plantations, farms, etc.) were also mapped which would be later used in the final geospatial planning process. The land use / land cover statistics is given in Table 2 and corresponding map is shown in Fig. 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.[8] 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.[12] The classification of soil in the study area (Table 3) up to family level was referred to as per previous project work done by MIRSAC.

Slope

The general topography of the northern parts of the study area are represented by steep slopes and cliffs. The western part of the study area is characterized by gently sloping and low-lying hills. Narrow valleys separate some of the hill ridges and few of them have gentle to steep slopes. The north-eastern and south-eastern parts are characterized by steeply sloping scarps and cliffs. It may be roughly summarized that the eastern parts of the study area are steeper as compared to the western parts. To assist in the geospatial planning of the study area, the slope facets were generated and classified into 6 classes, represented in slope percent.

Land Resources Planning

The geospatial 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 4 and the map showing areas for various proposed land development activities are shown in Fig. 3.

Wet Rice Cultivation / Pisciculture: Most of the agricultural lands are confined in the river valleys and foot hills. Wet land rice cultivation is practiced on large scale along the banks of River Palak near Phura village and River Sala. A few

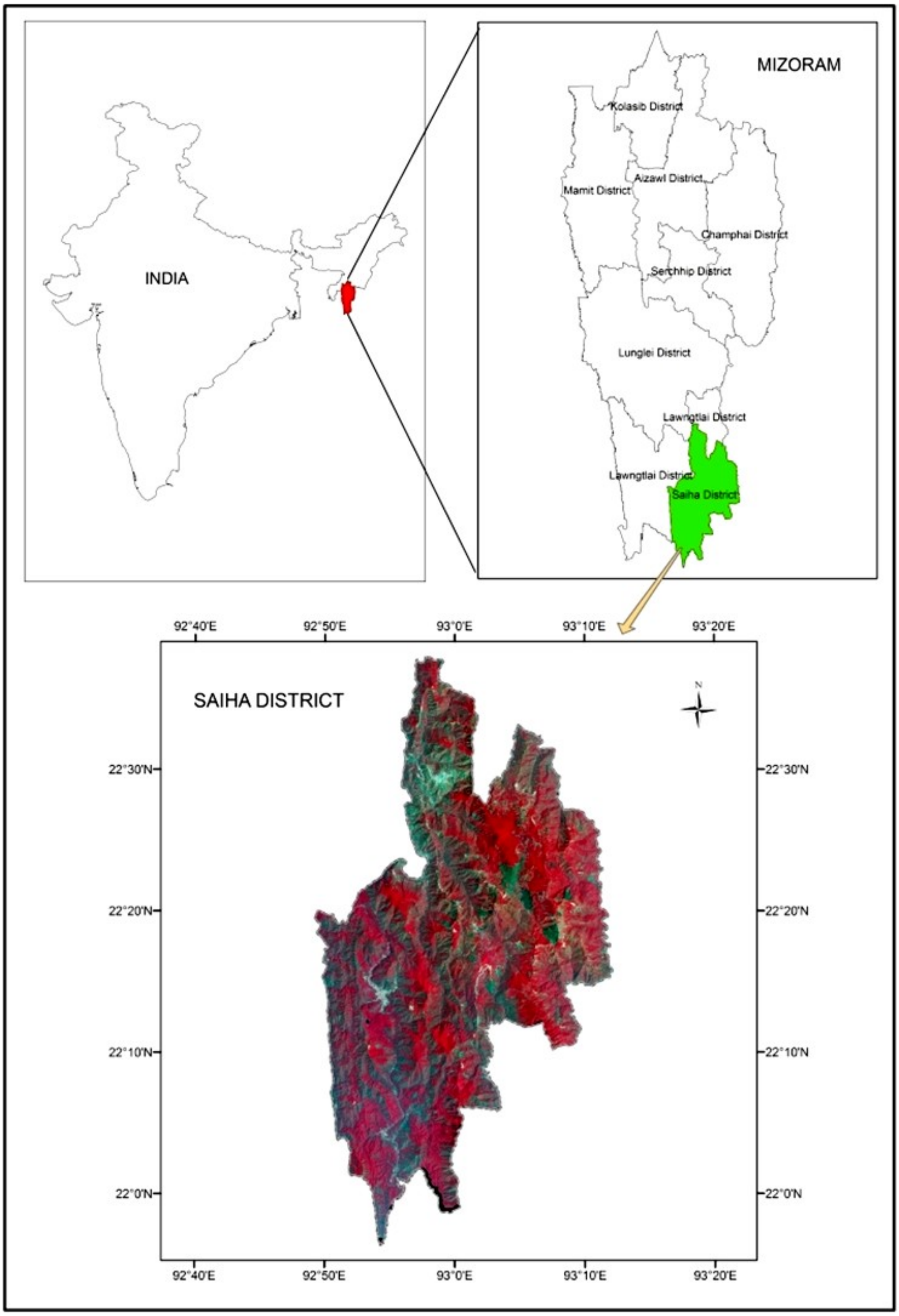

Figure 1. Location map of study area.

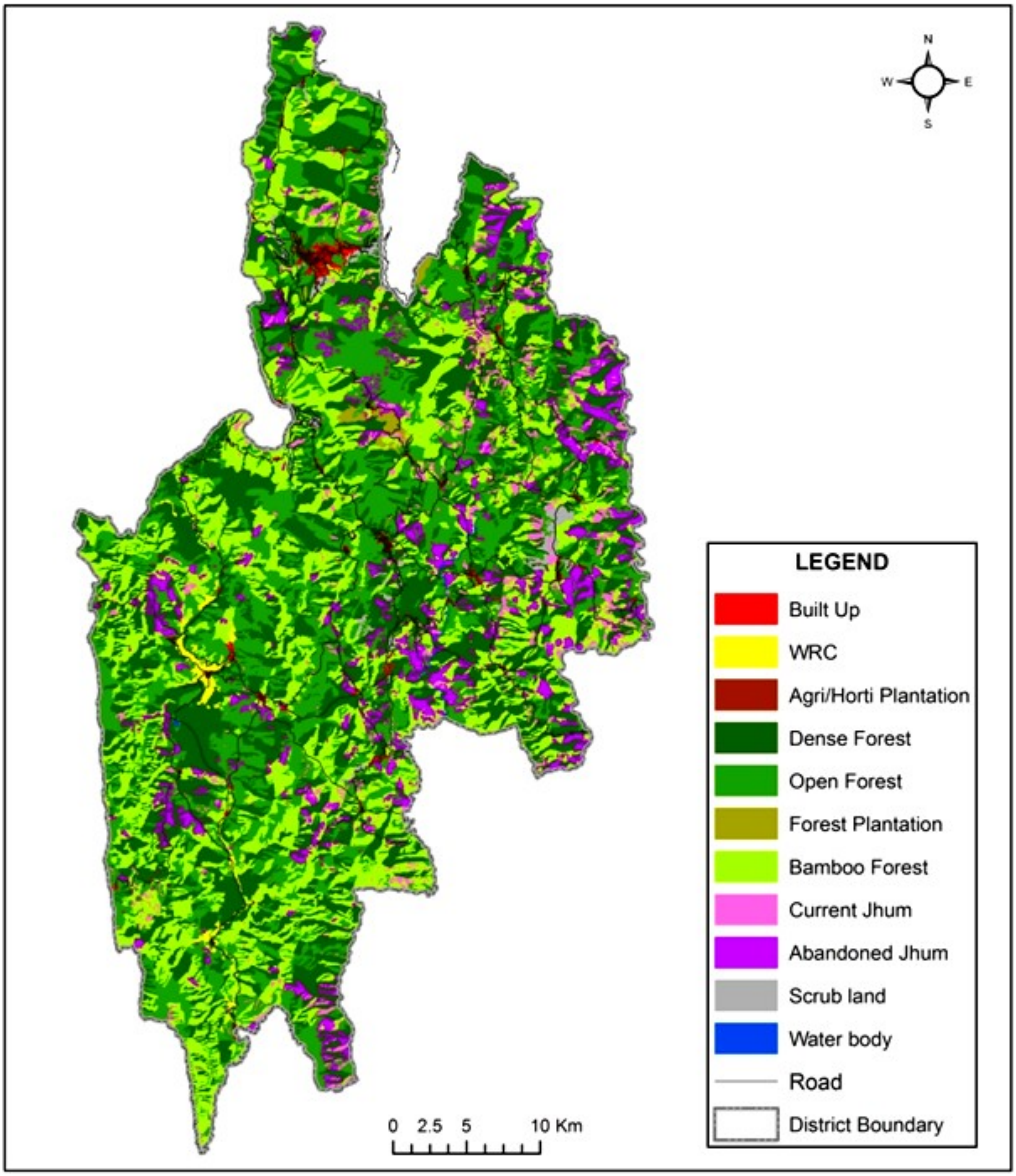

Figure 2. Land use / land cover map of Saiha district.

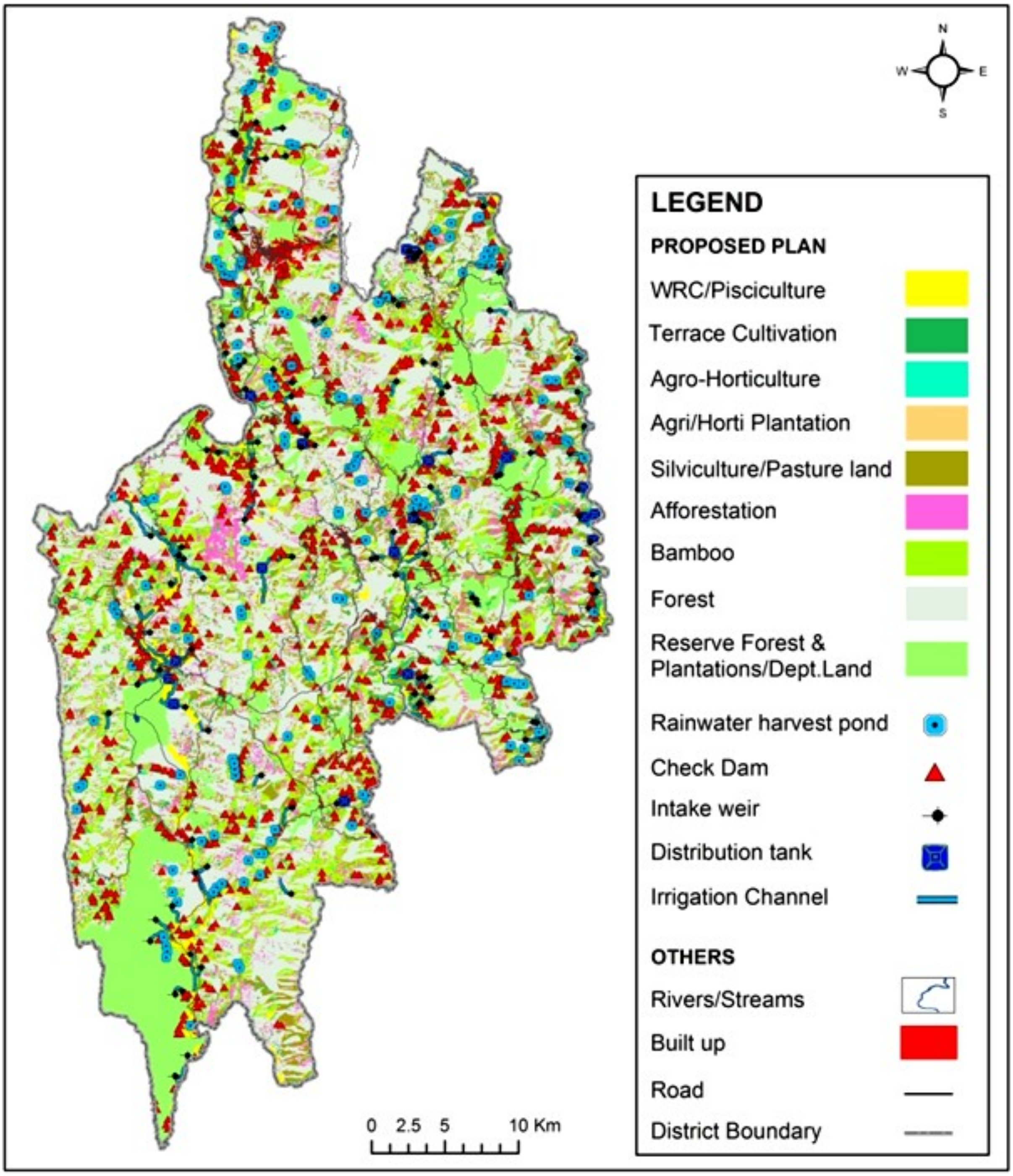

Figure 3. Geospatial plan map for Saiha dstrict.

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	>50%	Loamy Skeletal Typic Dystrochrepts and Loamy Skeletal Typic Hapludults, deep, moderate moisture	Afforestation
7	Forest (dense & open) and bamboo	-	-	To be conserved as forest and bamboo reserves

WRC plains are also found along the banks of River Chhimtuipui and Tuipui in isolated patches. 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 37.59 sq. km, which is 2.69% 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 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 laying 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 analyses 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 38.24 sq km or 2.73% of the total study area.

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 banana (*Musa paradisiacal*), orange

Table 2. Land Use / land cover statistics of Saiha District.

Land Use / Land Cover categories	Sq. km	%
Built-up	12.57	0.90
WRC	12.12	0.87
Agri/horti plantation	1.05	0.08
Dense Forest	448.72	32.07
Open Forest	384.97	27.52
Bamboo	362.03	25.88
Forest plantation	5.69	0.41
Current Jhum	46.43	3.32
Abandoned Jhum	103.59	7.40
Scrubland	12.78	0.91
Water Body	9.05	0.65
Total	**1399.00**	**100.00**

Table 4. Proposed Land Development Plan for the Saiha District.

Sl. No	Proposed Land Development Plan	Sq Km	%
1	WRC/Pisciculture	37.59	2.69
2	Terrace Cultivation	38.24	2.73
3	Agro-Horticultural system	64.11	4.58
4	Agri/Horti Plantation	58.54	4.18
5	Silvi-pastoral system	137.71	9.84
6	Afforestation	100.87	7.21
8	Forest	584.81	41.80
7	Bamboo forest	178.12	12.74
	Non-Planned area		
9	Water body	9.05	0.65
10	Built-up	12.57	0.90
	Total	**1399.00**	**100.00**

Table 3. Soil classification of study area (MIRSAC, 2007).

S. No	Order	Sub-order	Great soil group	Sub-group	Family
1	Entisols	Orthents	Udorthents	Typic Udorthents	Loamy skeletal, mixed, Hyperthermic
2	Inceptisols	Ochrepts	Dystrochrepts	Aquic Dystrochrepts	Clayey, mixed, Hyperthermic. Fine loamy, mixed, Hyperthermic.
				Fluventic	Fine loamy, mixed, Hyperthermic.
				Dystrochrepts	Clayey, mixed, Hyperthermic.
				Typic Dystrochrepts	Fine Loamy, Mixed, Hyperthermic. Loamy skeletal, mixed, Hyperthermic.
				Umbric Dystrochrepts	Fine loamy, mixed, Hyperthermic. Loamy skeletal, mixed, Hyperthermic.
3	Ultisols	Udults	Hapludults	Humic Hapludults	Clayey, mixed, Hyperthermic. Fine loamy mixed, Hyperthermic. Loamy skeletal, mixed, Hyperthermic.
				Typic Hapludults	Fine loamy mixed, Hyperthermic. Loamy skeletal, mixed, Hyperthermic.

(*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 64.11 sq km which is 4.58% of the total study area.

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 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 58.54 sq km or 4.18% of the total study area.

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 137.71 sq km which covers 9.84% of the total study area.

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 100.87 sq km of land or 7.21% of the total study area.

Forest: Forests of the study area comprises dense and open forests, as well as other reserve forests and forest plantations (Government 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.[13] 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. Community forest lands to meet the fuel wood requirements can also be allocated where proper management for extraction of wood is maintained. The steps taken by the Government through Village Councils, Village Forest Development Agency and various management schemes under Joint forest management (JFM), Entry point Activities (EPA) is noteworthy and can be made more effective for this purpose. The proposed area under tree forest is estimated to be 584.81 sq km, constituting 41.80 % of the total study area.

Bamboo Forest: Bamboo forests are more confined to lower altitudes and are generally found between 80-1400 m MSL.[14] 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 178.12 sq km or 12.74% of the total study area has been demarcated.

Water Resources Planning

The scope for crop production can be enhanced if the water resources are utilized in an effective manner. The importance of water resource structures are discussed below with reference to water resources development in the study area. The statistics for number of proposed structures is given in Table 5 and the map showing locations for various water resources development activities is shown in Fig. 3.

Table 5. Proposed water resource development plan for Saiha district.

Sl No.	Proposed structures for Water Resource Development Plan	No.
1	Check dams	1094
2	Rainwater Harvesting Ponds	169
3	Intake weirs	119
4	Distribution Tanks	20
5	Irrigation channels	130
	Total	**1532**

Check dams: Check dams are proposed across the streams to tap the stream water for irrigation and soil conservation purposes. It also provides drinking water for livestock and local inhabitants. It reduces run off velocity thereby minimizing soil erosion and secondly, it allows the retained water to percolate and thus results in increased recharge of groundwater in the adjoining downstream side. For this purpose, 1094 check dams have been proposed within the study area.

Rainwater Harvesting Ponds: The study area has a vast scope for adoption of rainwater harvesting techniques as it receives a good amount of rainfall annually. The available excess rain water can be conserved in different storage structures to supply irrigation water for agricultural and horticultural crops. Open flatlands in upper region of the cultivable lands can be excavated to store the rainwater. One hundred sixty nine (169) rainwater harvesting structures are proposed within the study area.

Intake weirs: These structures help in diverting river water to a secondary canal or irrigation channels. The study area has a number of untapped river/stream points from where irrigation requirements can be met. Installation of intake weirs on perennial rivers can assist in providing the water requirement even during post monsoon season. The proposed intake weirs are generally linked to irrigation channels. Considering the river sources and terrain condition, one hundred nineteen (119) intake weirs have been proposed in the study area.

Distribution tanks: Storage of water is an important step to ensure availability of water during dry seasons both for irrigation purpose and domestic consumption. Distribution tanks can serve this purpose by collecting and storing water at specific locations of the study area where consumption is high and vital for crop cultivation. The proposed distribution tanks are connected with irrigation channels which are in turn linked to perennial water sources. Considering their important role and requirement, these structures are proposed in twenty (20) locations of the study area.

Irrigation Channels: One of the important structures for ensuring a thriving crop production is Irrigation channels, as they siphon the water requirements from the source and transports it to cultivation fields. In this planning process, the irrigation channels are linked to intake weirs at the source of rivers and along the path they are also connected to distribution tanks. However, there are areas where irrigation channels do not traverse distribution tanks, and are directly opened up at crop cultivation areas. The length of irrigation channels are also dependent on the distance between the water source and its destination. As such, one hundred thirty (130) irrigation channels are proposed in the study area.

Conclusion

The study area, i.e. Saiha district covers a vast expanse of varied natural resources. Land use planning in these hilly terrains is not an easy task as it involves a lot of parameters to be taken into account during the planning process. The challenge in planning lies on a number of social and cultural obligations that needs to be incorporated to ensure that such land use plans are executed as it should be, even though it may incorporate the most advanced and scientifically sound technology. In the present study, a considerable large percentage (10.72%) of land comes under shifting cultivation, which is the main form of farming system adopted for crop production. Geospatial planning in such shifting cultivation areas is also a challenging task. The primitive form of agricultural practice in the study area is deeply rooted in the cultural life of the farmers, therefore, such problems should not be considered in isolation but has to be solved through integrated planning with scientifically sound approach. This is where geospatial planning can play an important role with its ability to incorporate both spatial and non-spatial data to generate realistic and effective land and water resource plans.

Permanent agricultural/horticultural lands constitute only a fraction of the total land used for food production. Geospatial planning in the study area, thus, also 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. On a holistic view point, the correct approach to 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,[15] as an essential input during the planning process.

The context of geospatial planning in the present study has highlighted the capability of remote sensing and GIS for formulating viable plans that adheres to identify the potential of land/water resources for extensive agriculture and horticulture crop cultivation in suitable areas identified through this technology.

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