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Site Suitability Assessment for Joint Forest Management (JFM) - a Geospatial Approach

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Abstract : Joint Forest Management (JFM) is a concept of developing partnerships between fringe forest user groups and the Forest Department (FD) on the basis of mutual trust and jointly defined roles and responsibilities with regard to forest protection and development. In India, JFM was started during 1992 and it was implemented in many states. However success rate of JFM activity was not promising. Though there are many factors attributed to the failures, one of the main factors is the JFM site. This paper deals with the significant ground works to be done before planning for JFM using recent technologies such as remote sensing (RS) and Geographic Information System (GIS). Also it deals with the advantages of weighted overlay analysis in selecting suitable sites for JFM taking into consideration the various criteria. As a result of weighted overlay analysis, there were four types of suitability classes viz., less, moderate, highly and un-suitable. The moderately suitable class occupied maximum area (13209.64 ha) than less and highly suitable classes. If JFM is implemented on the suitability area, then the failure could be avoided in the future.

Key Words : Joint forest management (JFM), Kolli hill, Eastern Ghats, Geospatial technique.

1. Introduction

In India, several efforts were made to control the biotic pressure on forests, by enforcement of various acts viz., forest act, cattle trespass act, land encroachment act, timber transit rules etc., enacted time to time, but it hardly had any desirable result to retain the virgin forests in the original vigor and growth. Hence, it has been accepted that the forests cannot be protected and developed without the participation of the local people (Jain, 1998). It was also realized that without accepting the local villagers as the joint custodian of forests, the natural forest wealth of the locality cannot be managed sustainably. As a consequence, the initiative on Joint Forest Management (JFM) program was started in the year 1992 when the proposals were formulated for the implementation of JFM as per the Government of India guidelines issued on 1st June 1990.

Under JFM, village communities are entrusted with the protection and management of nearby forests. The areas concerned are usually degraded or

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even deforested areas. In many parts of India, small village groups have started to protect and reclaim degraded forestlands through collective action. The JFM program seeks to develop partnerships between local community institutions and state forest departments for sustainable management and joint benefit sharing of public forest lands. The primary objective of JFM is to ensure sustainable use of forests to meet local needs equitably while ensuring environmental sustainability. The evolution and development of the concept of people's participation in forest management in Tamil Nadu could be traced from Farm Forestry through Social Forestry and Interface forestry and finally to JFM under Tamil Nadu Afforestation Project (TAP).

2. Background

Assessment of JFM activities was carried out in many states of India from the year 2000 onwards. Kashwan (2003) discussed the conflicts and failure issues in joint forest management. He raised several issues in JFM such as a) forest areas to be considered for JFM activities, b) deciding authority for selection of forest patch that is to be protected, c) boundary conflicts between neighboring villages, d) customary use of forest patch for non-timber forest produce and e) non-consumptive usage like using forestland for passage, etc. Among the many issues, the forest areas to be considered for JFM activity is the key issue, which decides the success and failure of JFM in most of the cases (Murali *et al.*, 2003). Kashwan (2003) also discussed the problem in relation to arbitrary selection of site for JFM without any scientific basis.

Thus, for successful implementation of JFM, the selection of site plays a major role apart from people participation/involvement. The site selection for JFM should be done based on various criteria such as proximity of the forest land to villages, nature of forest land, areal extent, properties of soil and water, etc. To understand these factors and to implement the JFM strategies effectively, it is advisable to adopt the recent technologies like remote sensing and GIS, which have been proved to be advantageous over conventional methods.

There are many reports with use of remote sensing technique for identification of nature of forest land in terms of canopy density (Toll, 1984; Hall *et al.*, 1988; Martin *et al.*, 1988; Sader and Joyce, 1988;) and types in various scale and their areal extent (Iverson *et al.*, 1989; Green and Sussman, 1990; Hall *et al.*, 1991; Jha *et al.*, 2000; Jayakumar *et al.*, 2002; Ramachandran *et al.*, 2007). The properties of soil in any region could be studied by doing primary ground survey with soil profile studies and laboratory analysis (Brady and Weil, 2002). The status of water potential in any region could be studied based on hydrogeomorphology, drainage network and rainfall pattern (Strahler, 2004; Strahler and Strahler, 2006). Site selection and decision making could be effectively done based on GIS spatial modeling (Jayakumar *et al.*, 2002; Maguire *et al.*, 2005). Therefore this study was taken up to identify sites suitable for JFM activities based on various criteria.

3. Study area

Kolli Hill, the study area lies between 11° 10′ 54″ - 11° 30′ 00″ N latitude and 78° 15′ 00″ - 78° 30′ 00″ E longitude (Fig. 1). It is situated in the Namakkal District of Tamil Nadu above the river Cauvery covering an area of about 503 sq. km.

Physiographically it is a mountainous region with elevation ranging from 200 to 1415 mts. at the foothill and Bail Nadu respectively. The slope of this region varies from gentle to very steep.

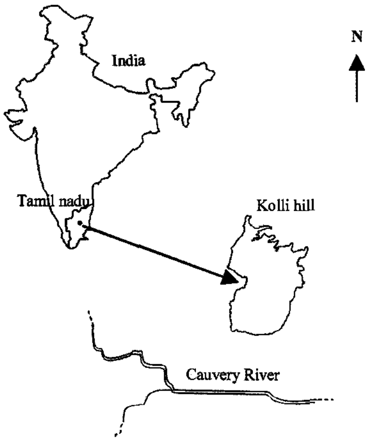

Fig. 1. Location map of the study area.

Geologically the study area is occupied by acid charnokite with minor bands of pyroxene granulate and magnetite quartzite (Mani, 1976). The plateau of the hill is highly undulating, cut by a network of streams and most of them are semi perennial or seasonal flowing in all directions but mostly in a eastern and south east direction which are ultimately draining into Ayyar river. The mean annual rainfall is 1318 mm, which is received largely between June and December. Annual mean maximum and minimum temperatures are 35°C and 18°C respectively.

4. Materials and Methods

IRS 1D LISS III satellite digital data of April 2003 of path 101 and row 65 and 66, Survey of India (SOI) topographical maps of 58 I/7 and 8, of 1:50,000 scale, ERDAS Imagine version 9.1 image processing software, ArcGIS version 9.1, Global Positioning System (GPS), secondary data were used and field survey was conducted in the present study.

1) Preparation of forest type map

The IRS 1D digital data (2 scenes), of 23.5 m ground resolution, were corrected geometrically, taking sufficient ground control points (GCPs) from the SOI maps.

All of the satellite data were geometrically corrected using, with ERDAS Imagine software, a first-order polynomial geometric model with a root mean square error (RMSE) of less than 0.5 pixels. The geometrically corrected data were subsequently mosaiced. The reserved forest (RF) boundary was traced from the SOI maps and digitized. After creating the topology with the ArcGIS software, it was overlaid onto the digital data using ERDAS Imagine software. The RF areas were subset from the digital data and the RFs subs*et al*one was processed in order to avoid misclassification. False color composites was generated from the IRS LISS III data using bands 3,2,1 in RGB, and printed on 1:50,000 scale.

A normalized difference vegetation index (NDVI) was generated from the LISS III satellite data. An interactive method of display was used to assign threshold values for each density class viz., dense (>40% crown cover), open (10 - 40%) and degraded (<10%), on the basis of field knowledge (Rawat *et al.*, 2003), and a density map of the forests was prepared. According to this method, the NDVI map and its attribute table are displayed in the Erdas Imagine software. Threshold of NDVI value for each density class is assigned interactively using the field experience and ground inventory data. A forest-type map was prepared following an expert classification technique (Ramachandran *et al.*, 2007). Generally the forest types are determined by altitude, climate and previous forest management practices (Champion and Seth, 1968). In the Eastern ghats of India, different forest types occur at different altitude in the hilly terrains. In the present study, the forest type of the study area was prepared based on the NDVI and altitude. Altitude map was prepared using contour lines from the SOI topographical map. Hypothesis and rules were set for each forest types using Knowledge Engineer module available in the ERDAS Imagine software. The forest type map was prepared using Knowledge Classifier module. The classified forest cover and density map was printed on 1:50,000 scale using HP plotter.

Intensive field verification was carried out with SOI maps, an FCC hard copy, classified maps, a compass and GPS. Corrections were made in the interpreted maps wherever necessary, forest-type and density map for 2003 was finalized.

The forest area was classified into 7 categories viz., semi-evergreen, dry deciduous, riverain, southern thorn, southern thorn scrub, bamboo plantation and barren/rocky.

2) Preparation of land resource potential layers

In order to understand the status and properties of soil, sample pits were excavated in the field representing all landform, land use/land cover and relief according to United States Department of Agriculture Soil Conservation Service (USDA-SCS, 1975) standards. About 90 Profile pits were excavated in the following dimension $3 \times 3 \times 5$ feet i.e., 3×3 feet pit was excavated to a depth of 5 feet or till the parent rock whichever is less. Soil samples from each horizon were collected for laboratory analysis apart from field study. Thematic maps such as soil taxonomy, texture, capability and irrigability were prepared based on field and laboratory analysis and with the help of FCC. Landform map was prepared using FCC (LISS III - 2003), SOI maps and secondary data according to Strahler (2001). Contour lines were traced and digitized. Triangulated irregular network (TIN) was created from the contour lines and slope of the area was also calculated using the TIN. Finally, the landform, soil capability, soil irrigability, texture and slope maps were combined to produce land resource potential layers with five categories (Maguire *et al.*, 2005) (Table 1).

Table 1. Preparation of land potential layer from various thematic layers.

Sl. No.	Thematic layers		Class weightages
1	Soil capability	Good cultivable lands	5
		Moderately good cultivable land.	4
		Fairly good cultivable lands	3
		Very well suitable for grazing and forestry	2
		Well suited for grazing and forestry	1
2	Soil irrigability	Land with moderate limitations for sustained use under irrigation	4
		Land with severe limitations for sustained use under irrigation	3
		Land with very severe limitations for sustained use under irrigation	2
		Land that temporarily unsuitable for irrigation	1
3	Soil texture	Sandy	1
		Sandy clay	2
		Loamy	3
		Sandy loam	4
		Sandy clay loam	5
4	Slope	0 degree	5
		0 - 5 degree	4
		5 - 10 degree	4
		10 - 15 degree	3
		15 - 20 degree	3
		20 - 25 degree	2
		25 - 30 degree	2
		> 30 degree	1

3) Preparation of water resource potential layers

From the FCC (printed on 1:50,000) detailed Hydrogeomorphology map was prepared (Strahler, 2001). Hydrogeomorphology is the hydrological status of geomorphological features. From the SOI map, drainage network was traced and drainage density was calculated (Strahler, 2001). From the rainfall data collected from Kolli hills and surrounding rainguage stations, rainfall isohyets was prepared (Strahler, 2001). All the layers pertaining to water resources (hydrogeomorphology, drainage density and rainfall isohyets) were combined together to create water resource potential layer of the study area with five categories (Maguire *et al.*, 2005) (Table 2).

Table 2. Preparation of water potential layer from various thematic layers.

Sl. No.	Thematic layers		Class weightages
1	Hydrogeomorphology	Linear ridges	1
		Composite slope	2
		Hill and valley complex	3
		Valley fill	4
		Bazada	5
2	Drainage density	Low	1
		Medium	3
		High	5
3	Rainfall isohyets	Low	1
		Medium	3
		High	5

4) Other layers

For JFM activities, distance of forest region from the settlements play a major role. Therefore, all the settlements both inside and outside of the study area were traced and digitized. Buffer was created around each settlement for 2500 m and divided equally into 5 categories with 500 m intervals. Forest land within 500 m proximity is given high weightage value than the forest situated at 2500 m proximity (Table 3).

Table 3. Thematic layers, class weightages and the percentage of influence.

Sl. No.	Thematic layers		Class weightages	Percentage of Influence
1	Forest type map	Dense semi evergreen	0	35
		Open semi evergreen	0	
		Degraded semi evergreen	4	
		Dense riparian	0	
		Open riparian	0	
		Degraded riparian	4	
		Dense deciduous	0	
		Open deciduous	0	
		Degraded deciduous	4	
		Southern thorn	5	
		Southern thorn scrub	5	
		Bamboo plantation	0	
		Barren / Rocky	0	
2	Land potential	Least potential	1	20
		Less potential	2	
		Moderate potential	3	
		High potential	4	
		Very high potential	5	
3	Water potential	Least potential	1	20
		Less potential	2	
		Moderate potential	3	
		High potential	4	
		Very high potential	5	
4	Hamlet buffer	0 - 500	5	25
		500 - 1000	4	
		1000 - 1500	3	
		1500 - 2000	2	
		2000 - 2500	1	

5. Spatial modeling

Spatial modeling was performed by following weighted overlay technique to identify suitable sites for JFM using Spatial analyst module of the ARCGIS 9.1 software (Fig. 2).

1) Weighted overlay

Weighted overlay is a technique for applying a common scale of values to diverse and dissimilar inputs in order to perform an integrated analysis. Though we use many input layers to create a single output layer, it is well known that all the input layers are not equally important.

Some of the layers are more important than others.

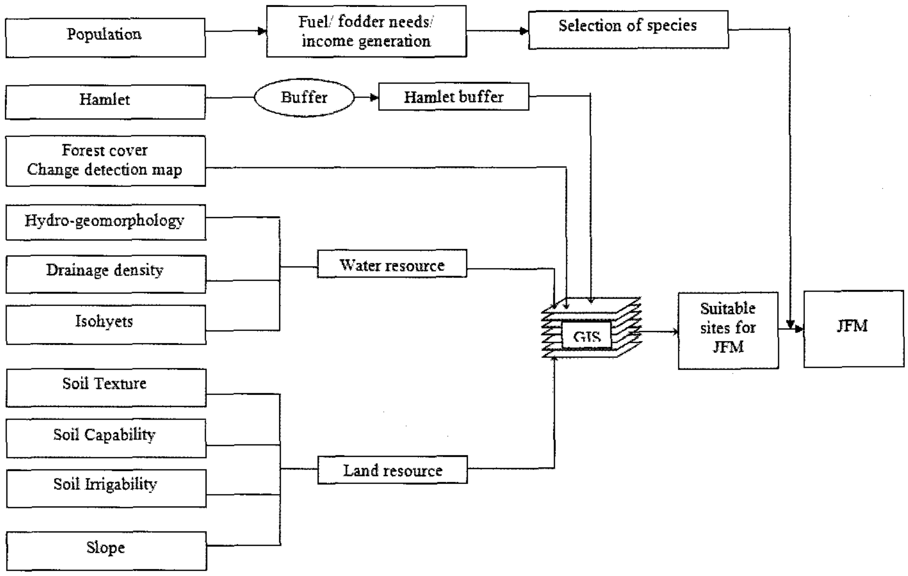

Fig. 2. Paradigm for spatial modeling.

This is the advantage of weighted overlay approach where one can assign weightage to each class in a layer and the percentage of importance/influence to that layer (Maguire *et al.*, 2005).

Wt. *Overlay* = *Layer1* + *Layer2* ··· *n*

Layer1 = *Weightage of each class* * *Percentage of importance*

As the final output layer is discrete, the results of value in weighted overlay will be rounded to the nearest whole number.

2) Weightages to each theme

In the present study, five point rating scale was used (1 - very low, 2- low, 3 - medium, 4 - high, and 5 - very high). Once all the layers were prepared, each layer was distributed to three renowned scientists in the respective field for weightage assignment. Finally weightage to each theme was assigned according to the recommendation of the expertise. Generally JFM will be taken up in the degraded forest, therefore, class weightage for dense and open semi-evergreen, riparian, deciduous were given to zero. However, the degraded semi-evergreen, deciduous, riparian forest types could be considered for JFM along with southern thorn and southern thorn scrub forest types. Therefore in the present study the weightages for these classes were assigned to 4 and 5 respectively. For land and water potential layers, weightages were assigned to each class appropriately (Table 3). To implement JFM, it is necessary to take into account the distance between JFM area and the village. Therefore hamlet buffer map was created. Class weightage value of 5 was assigned to the nearest distance and 1 was assigned for the farthest distance.

Among the four layers a high percentage of influence value (35) was assigned to forest area because the forest land is more important for JFM activity and a value 25 was assigned to settlement buffer because the distance between JFM area and settlement is more crucial in all the activity, and for land and water potential layers, percentage of influence was assigned to 20 each as these two layers were related to quality of the land (Table 3).

6. Results and Discussion

The result of weighted overlay analysis is given in Fig. 3. In the present study, only three classes were obtained as a result of weighted overlay analysis. The very low and very high suitability classes were absent in the study area. The less suitable class occupied 3723.72 ha and medium suitable class occupied 13209.64 ha areas.

These two classes were distributed all through the hill and mostly belonged to southern thorn and southern thorn scrub forest types. The highly suitable class was present mostly at the northern and eastern side of the Kolli hill, which occupied 802.65 ha (Table 4). This category was mostly occupied by the degraded deciduous, southern thorn and southern thorn scrub forest types.

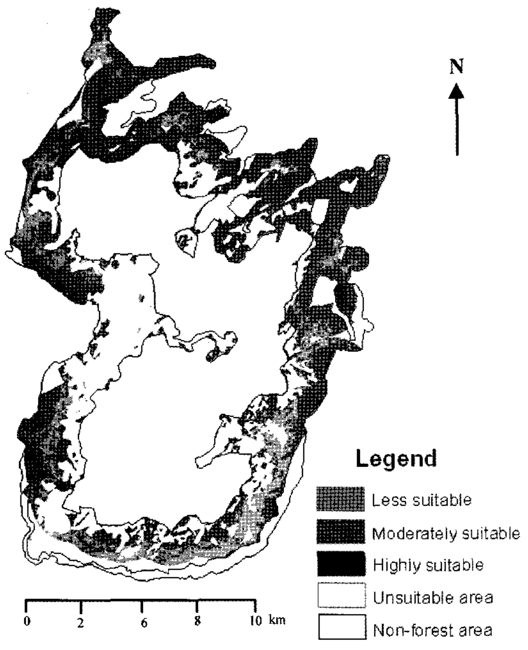

Fig. 3. Spatial modeling of suitability area for joint forest management in Kolli hill.

Table 4. Various level of suitability for joint forest management in Kolli hill and their aerial extent.

Sl. No.	Suitability classes	Area in hectare
1	Low	3723.72
2	Medium	13209.64
3	High	802.65

Though JFM is the ultimate solution for involving people in the conservation strategy, the success or failure is based on various factors. It would be more appropriate and successful if necessary groundwork is done before commencing JFM, which are discussed in this paper. At this juncture RS and GIS with GPS are very good handy tools to work with.

They provide reasonable and reliable solutions to most of the time consuming process such as identification of suitable sites for JFM, understanding its present potentials and limitations, their aerial extent, distance from the villages, etc., easily. Finally the most important factor that decides the success of JFM is the selection of plant species. Selection of species should be done taking into account various socio-demographic details such as, population density, their fuel wood needs, cattle population, fodder needs, economy, etc. Therefore utmost attention is necessary while selecting the plant species, which is need based. If all these criteria are taken care before implementing any JFM in any region, then success rate will be increased.

7. Conclusion

Need for site selection using spatial modeling for JFM was discussed in this paper. Site selection for JFM activities has to be done scientifically taking into account various criteria, which are involved in the successful implementation.

IRS 1C LISS satellite data was found to be good source of information for forest density and type mapping. However, high-resolution data such as IKONOS or QuickBird might be more useful for this kind of study. GIS was a handy tool to integrate various spatial layers and to select area with different suitability classes. If JFM is implemented in the selected areas, then the problems related to sites could be overcome.

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