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Site Suitability Analysis for JFM Plantation Sites using Geo-Spatial Techniques

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Abstract The Joint Forest Management (JFM) programme is an institutional innovation that has much potential in any country confronting the disempowerment of indigenous communities and environmental degradation. The implementation of JFM in different states of India initiated in the year 1992. This plantation strategy succeeded as well as failed depending on the existing conditions of that area. Out of the several factors contributing to the failure the most significant was the site selection. This factor can be rectified using the advanced Remote Sensing-Geographical Information System (RS-GIS) approach. The present study was undertaken for identifying suitable areas for JFM plantation in the Nandod taluka of Narmada district. The weighted overlay analysis of different themes like landuse, slope, settlement/etc. in GIS mode has aided in giving the precise number of villages in this taluka which are found highly, moderately and least suitable for implementation of JFM strategy, thereby providing a useful input to the forest planners.
Keywords *GIS; JFM; Spatial Modeling; Weighted Overlay*

1. Introduction

Forest protection and the participation of local communities in forest management have attracted greater attention in recent years. The guidelines from the Government of India stressed on the involvement of the local communities and voluntary agencies in forest protection, management and regeneration which would help in rejuvenating the degraded forest lands. Decentralizing the forest administration under the Joint Forest Management (JFM) Programme has gained momentum with the recently introduced forest development agencies (FDAs) (NAEB, 2002). Basically the success of JFM strategy depends upon the confidence of people involved. The JFM methodology currently being applied around the globe is not generating much confidence with the people since the local forest dwellers are tribes and there existed no awareness (Banerjee, 1992; Malla, 2000; Lasco & Pulhin, 2006). Indian experiences related to this strategy also have the same view and have emphasized the

need to have a fresh look towards the approach.

Earlier studies have emphasized on various factors like evaluations of technical aspects such as plantation techniques, choice of species, site suitability, nursery techniques, survival of plantations and the factors responsible for mortality and community participation which have an essential role in successful implementation of JFM. In Gujarat, this programme was launched vide government resolution in March 1991, it is more than a decade old programme and still has not reached its marked success, therefore we took the present study to analyse the basic factor of site suitability in the Rajpipla taluka of Narmada district of Gujarat to check whether this factor was having any concrete impact on the JFM programme going on. Out of all the different factors understanding of site productivity and suitability is of prime importance. Site suitability is a broader concept tied to the sustainability of plantations. It takes into account forest management aspects and land degradation hazards as well as site quality. The determination of site suitability can be accomplished by analysing the interaction between three sets of mutually related factors namely: locations, developmental actions and environmental effects (Lyle & Stutz, 1986). It is necessary to assess the site suitability for JFM plantation in the area by integrating various kinds of information with spatial analysis technique. Site selection and decision making could be effectively done based on Geographical Information system GIS spatial modeling (Jayakumar et al., 2002; Maguire et al., 2005).

The evolution of GIS made this field much easier and manageable. GIS gave the ability and functionality to find best location for certain purposes with many limitations. GIS has very distinguishing, powerful functions and can play an important role in decision making and planning process. The most distinguishing parts of a GIS are its functions for spatial analysis, i.e. operators that use spatial data to derive new geoinformation. Spatial queries and process models play an important role in satisfying user needs.

Conceptually the key objective of developing site suitability map is to improve the methodology to be used for potential and suitability of sites for tree planting and natural regeneration. Site selection for JFM activities has to be done scientifically taking into account various criteria, which are involved in the successful implementation. The analysis of the existing data and available maps supplemented with on- ground verification would certainly help in implementing the agencies to realistically assess potential suitability of the site and match suitable species for reforestation in a way that JFM interventions effectively support rural livelihoods.

Assessment of suitable sites for JFM plantations if done precisely can definitely yield better output. The present research was carried out to provide the forest planners information on forest village suitable for plantation activities under JFM strategy in different areas of Rajpipla taluka of Gujarat. This paper also describes the significance of new technologies of RS-GIS in the evaluation of these sites.

2. Study Area

Rajpipla is located at 21°47′N 73°34′E and 21°78′N 73°57′E coordinates (Figure 1). It has an average elevation of 148 meters (485 feet) spread in an area of 3,929 km^2. The area lies at the junction of Semi-arid, Western Ghats and Deccan peninsular biogeographic zones. The area of this tract lies along the tract of Narmada River. The forests are mainly confined to hilly tract and are prominently situated in the eastern part. The western part of the district is mostly the revenue area and is more or less flat.

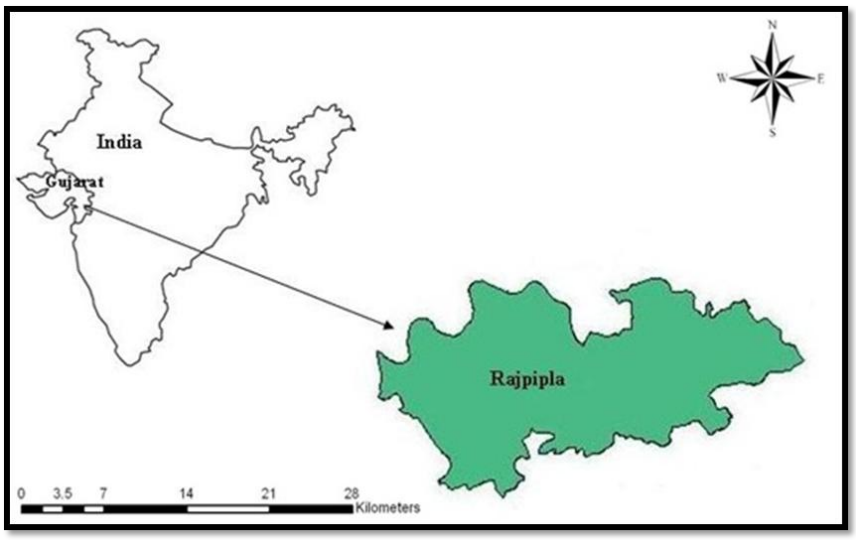

Figure 1: *Location Map of the Study Area*

3. Materials and Methods

For the present study we used IRS 1D LISS III satellite digital data of November 2005, Survey of India (SOI) topographical maps of 1:50,000 scale, ERDAS Imagine version 9.2 image processing software, Arc-GIS version 9.3, Magellan Global Positioning System (GPS). The modelling was done using the ArcGIS® software suite produced by the Environmental Systems Research Institute (ESRI) because of its ability to accommodate various file formats in common use. The locations of JFM plantations were collected using GPS during intensive field survey. The field data and secondary data of the related factors and forest resource variables such as climate, topography, soil, land use type and economic condition in JFM plantation were collected from the study area. The above collected information was used to construct geographical databases using GIS approaches.

A brief flowchart of methodology has been shown to explain the method used (Figure 2).

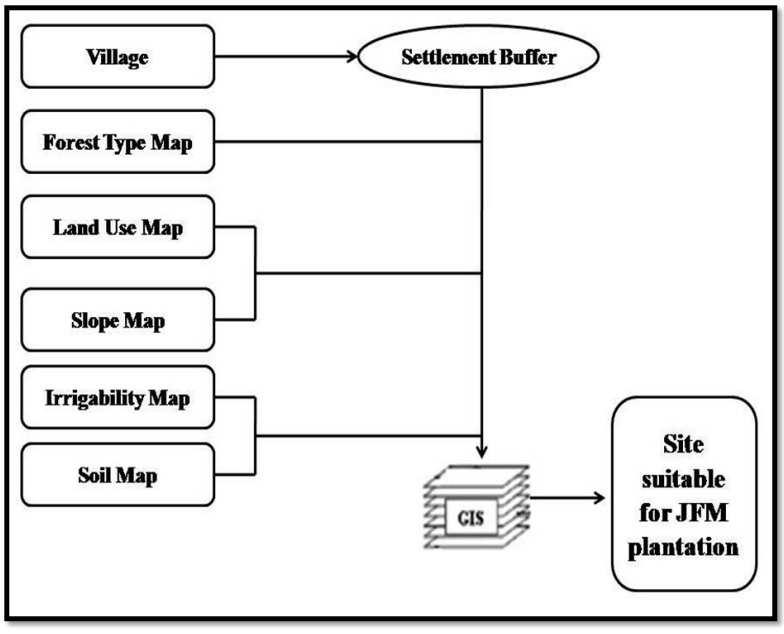

Figure 2: *Methodology Flowchart*

The IRS 1D digital data of 23.5 m ground resolution, were corrected geometrically taking sufficient ground control points (GCPs) from the SOI maps using ERDAS Imagine version 9.2 software. The geometrically corrected data were subsequently mosaiced. After necessary geometric corrections, False color composite (FCCs) were prepared from the digital data of LISS III and TM with the following band combinations 2,3,4 and 1,2,3 in RGB respectively. Onscreen visual interpretation method was followed to prepare forest type map (Figure 3).

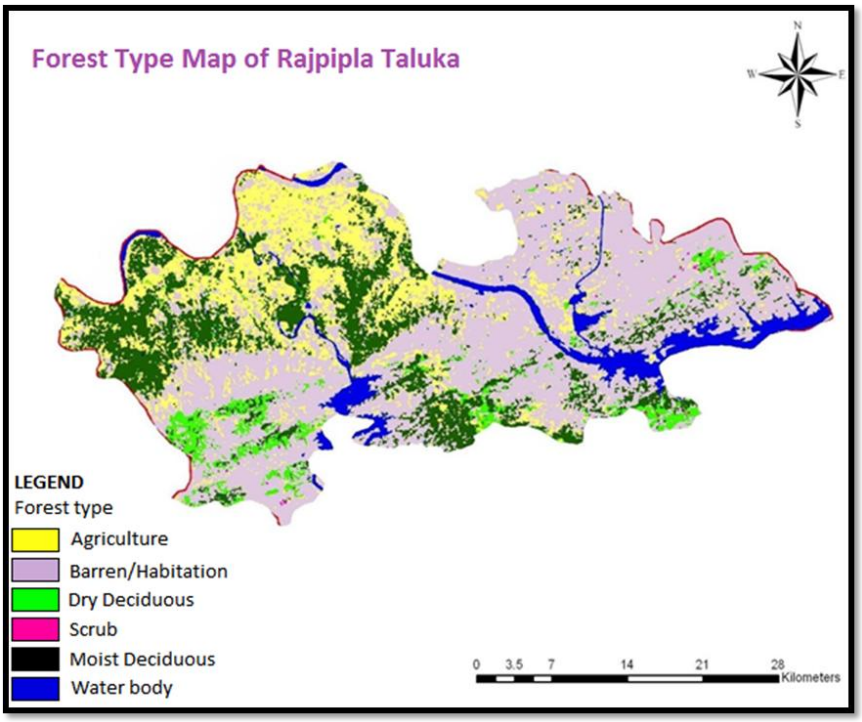

Figure 3: *Forest Type Map of the Study area*

Thematic maps such as Land use, Slope Map, Soil irrigability, Soil Map, Settlement Buffer were generated using Arc-GIS software version 9.3. The landuse map, slope maps were integrated to generate land resource potential layer. Landuse map for the area has been prepared using IRS 1C Panchromatic PAN data. Following categories of landuse classes were identified; agriculture, forest, dense forest, water body, river and unclassified (Figure 4).

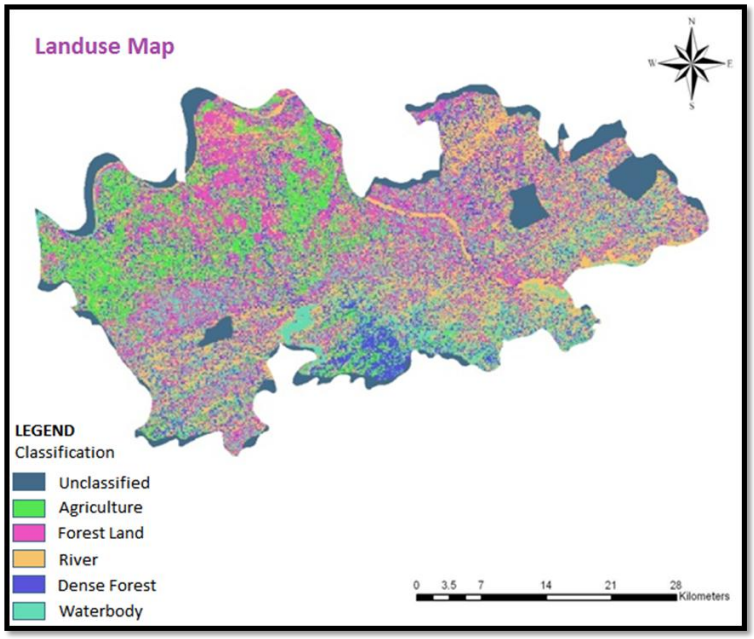

Figure 4: *Land use Map of the Study Area*

The slope map was prepared with the contour information generated from the Advanced Spaceborne Thermal Emission and Reflection ASTER Data of 30 meter resolution. Slope map was prepared using ARCGIS spatial Analyst (Figure 5). The soil irrigability map was created with the following categories; Land Unsuitable for irrigation, Land with moderate irrigation, Land with severe irrigation, Land with very severe irrigation, Land (others, including submerged and barren areas) (Figure 6). The soil map also has been prepared based on the tone, texture and pattern. The Soil map is divided into got five categories viz; River, fine, coarse loamy, clayey, and hill clayey (Figure 7). The thematic map of settlement buffer was created around each settlement for 2500 m and divided equally into 5 categories with 500 m intervals (Figure 8). Forest land within 500 m proximity is given high weightage value compared to than the forest situated at 2500 m proximity.

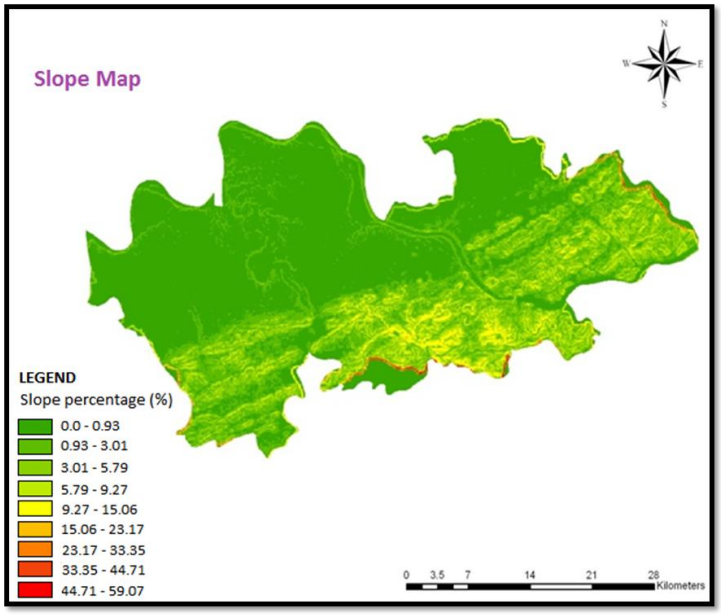

Figure 5: *Slope Map of the Study Area*

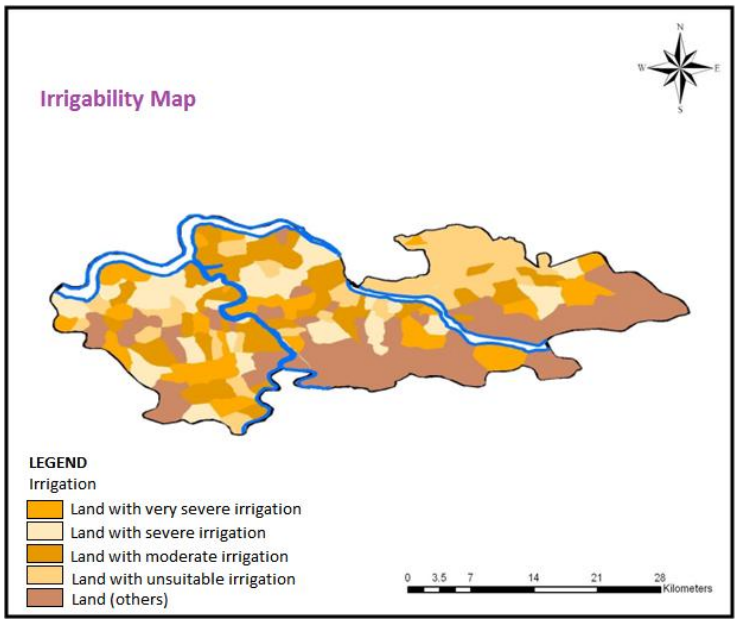

Figure 6: *Irrigability Map of the Study area*

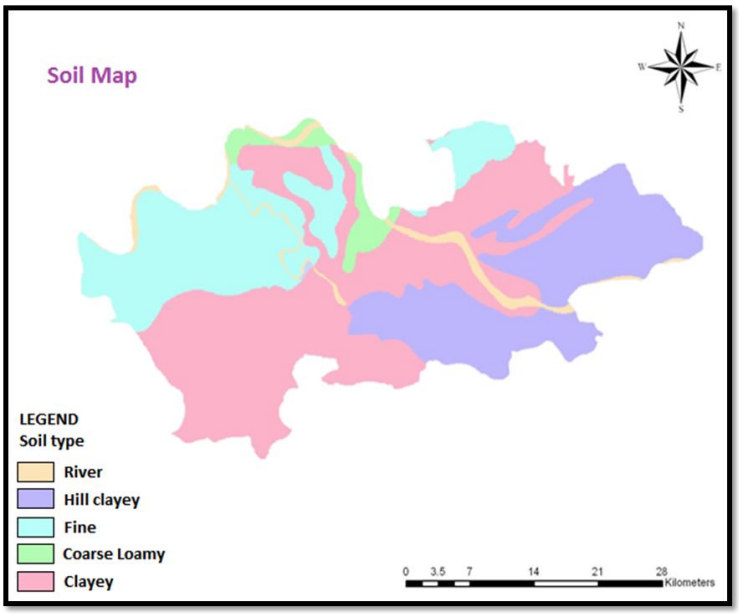

Figure 7: *Soil Map of the Study Area*

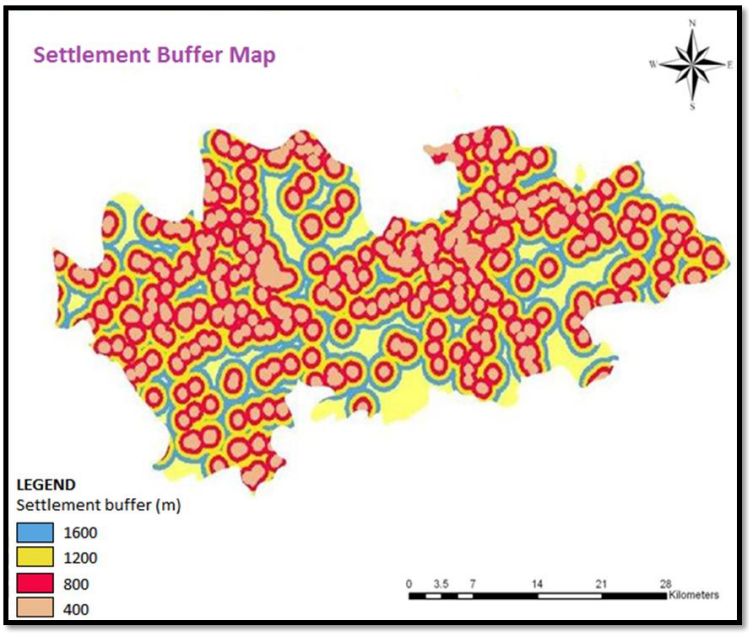

Figure 8: *Settlement Buffer Map of the Study Area*

4. Spatial Modeling and Weighted Overlay

Each of these layers in GIS was analyzed based on set criteria based on scientific standards and measurements. Outputs of all these thematic maps were integrated to produce the final output, which indicated the villages that satisfied the set criteria's in four ranges. These ranges indicate the priority of villages for JFM plantations.

Wt. Overlay = Layer1 + Layer 2… n

Layer1 = Weightage of each class * Percentage of importance

The Weightage and description of different themes selected are presented in Table 1. As the final output layer is discrete, the results of value in weighted overlay will be rounded to the nearest whole number. In the present study, five point rating scale was used (1 - very low, 2- low, 3 - medium, 4 - high, and 5 - very high). The weight and scores were based on those given by Hackett and Carolane (1982); Griffiths (1994).

Table 1: *Weight and Description of Different Variables/Themes*

	Thematic Layers	Class Weightage	Percentage of Influence
Irritability Classification	Land with Unsuitable irrigation	5	30
	Land with moderate irrigation	4	
	Land with severe irrigation	3	
	Land with very severe irrigation	2	
	Land (others)	1	
Soil Data	Coarse Loamy	5	20
	Hilly Clay	4	
	Fine	3	
	Clay	2	
	River	1	
Slope	0-5%	10	30
	5-11%	9	
	11-17%	8	

	17-23%	7	
	23-29%	6	
Settlement Buffer	400m	1	20
	800m	2	
	1200m	3	
	1600m and above	4	

Spatial modeling was performed by following weighted overlay technique to identify suitable sites for JFM using spatial analyst module of the ARCGIS 9.3 software.

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. 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 other layer (Maguire et al., 2005).

5. Results and Discussion

A reliable assessment of the suitability of landscape patches for distinctive land uses is an essential prerequisite for sound JFM Planting land planning. Land best suitable for growing JFM Plantations in the Rajpipla East forest division, in Narmada district of Gujarat was identified using GIS with spatial analysis.

During Site Suitability analysis, along with the forest type map, the selected variables have been grouped into five environmental factors on the basis of their specific relationship with the assessment of land suitability for JFM plantation, namely:

(1) Landuse (Figure 4)
(2) Topographic: slope (Figure 5)
(3) Supplementary water: irrigation (Figure 6)
(4) Soil Property: Type & Quality of Soil (Figure 7)
(5) Habitation: Settlement & Buffer around Settlement Settlement's Buffer (Figure 8)

These five environmental factors were basically different in their dependence on JFM land suitability. The weightage of factors and variables were determined depending on the importance of each variable in comparison with the others in the same factor group as well as between the environmental factors. The more important the factor and variable, the higher was the weight. The Suitability map generated (Figure 9 & Figure 10) using above said points brought out five different suitability categories Viz. 1) Highly suitable 2) Moderately suitable 3) Less suitable 4) Very less suitable 5) Unsuitable.

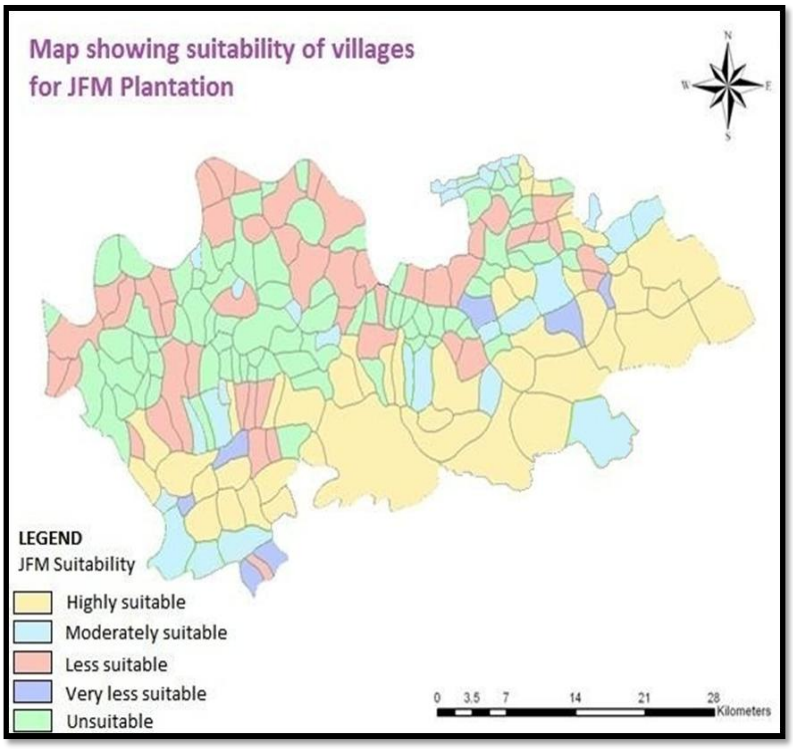

Figure 9: *Map Showing Suitability of Villages for JFM Plantation*

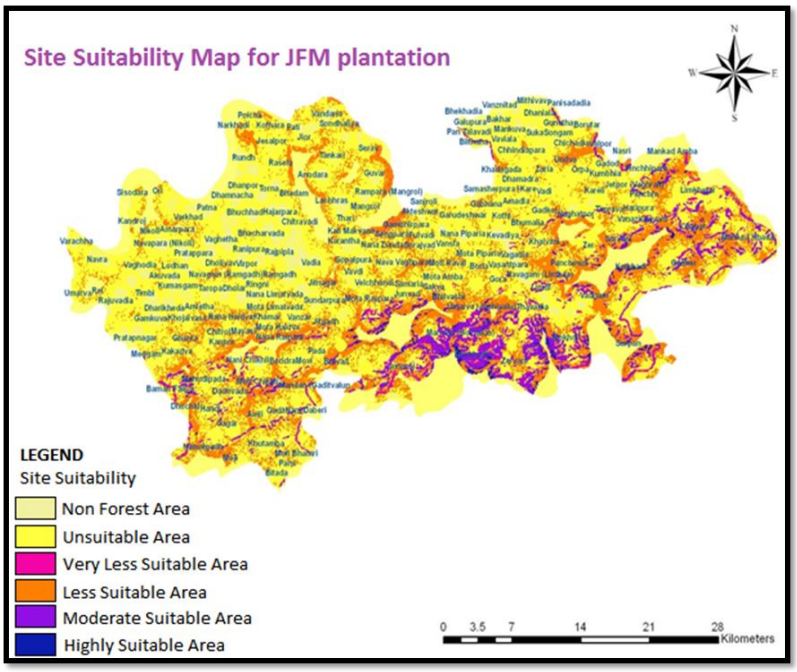

Figure 10: *Site Suitability Map for JFM Plantation*

Out of total 206 villages of Rajpipla taluka, 43 villages were highly suitable, 29 villages were moderately suitable, 47 villages were less suitable, 7 villages were very less suitable and 80 villages were unsuitable for JFM plantations in the area (Figure 11).

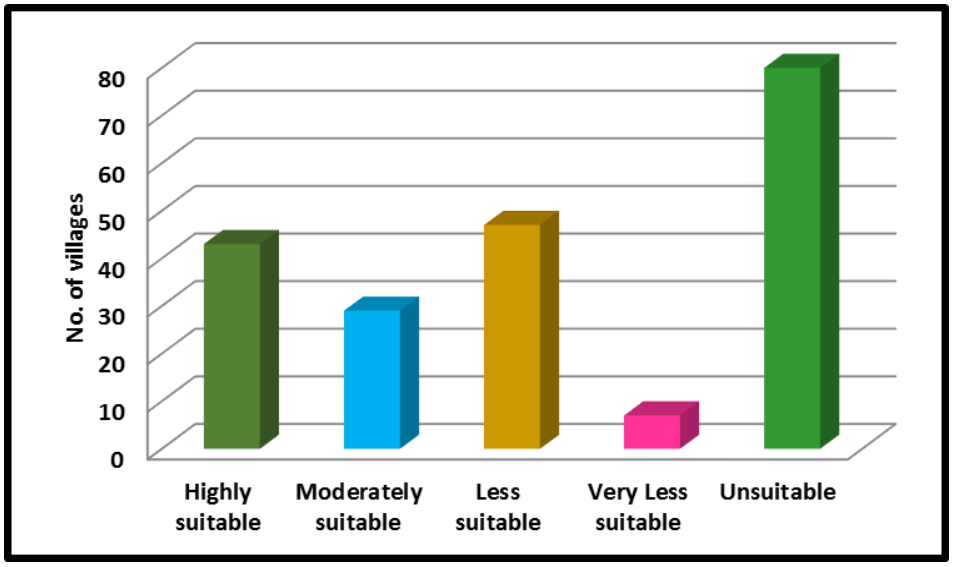

Figure 11: *Graph Showing Suitability of Villages for JFM Plantations*

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 programme, which is discussed in this paper. Advanced Computer program, that includes decision support systems (models) and GIS have contributed to the speed and efficiency of overall planning process. GIS can be effectively applied to handle such kinds of work and to complete study objectives.

The land suitability assessment presented in the form of map and report is meaningful to a local user. Selection of species is also an important factor that decides the success of JFM; it should be done taking into account various socio-demographic details, as it is the prime factor which affects the local villagers around the forest vicinity. If all these criteria are taken care before implementing any JFM in any region, then success rate will be increased.

6. Conclusion

GIS provides a great advantage to analyse multi-layer of data spatially and quantitatively. Depending on the available spatial data, the accuracy and reliability of the result using GIS application could be high. The mismanagement and underutilization of the forest land affects the forest productivity and environment. This in turn could affect the local population of the nearby area. GIS could effectively be used as a management and an analysis tool that facilitates planning process. In this research, the potential of Remote Sensing and GIS was used to locate the best sites suitable for JFM plantations at Rajpipla Taluka of Narmada district by creating maps according to scientific criteria and standards. The suitability maps generated can serve as a significant input for planning and selecting JFM plantation sites.

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