

**ECOLOGICAL ASSESSMENT OF VEGETATION IN JFMP
ADOPTED AND NATURAL FOREST-VILLAGES**

**THE THESIS SUBMITTED TO
THE MAHARAJA SAYAJIRAO UNIVERSITY OF BARODA
FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY
IN
BOTANY**

**BY
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CERTIFICATE

This is to certify that the thesis entitled “**Ecological assessment of vegetation in JFMP adopted and natural forest-villages**” which is submitted by me in partial fulfillment of the requirement for the award of degree of Doctor of Philosophy in Botany, to The Maharaja Sayajirao University of Baroda, Vadodara, Gujarat is a record of the my own work and due acknowledgement has been made in the text to all other material used. The matter embodied in this thesis is original and has not been submitted for the award of any other degree.

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I certify that the above statement is correct.

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(Guide)

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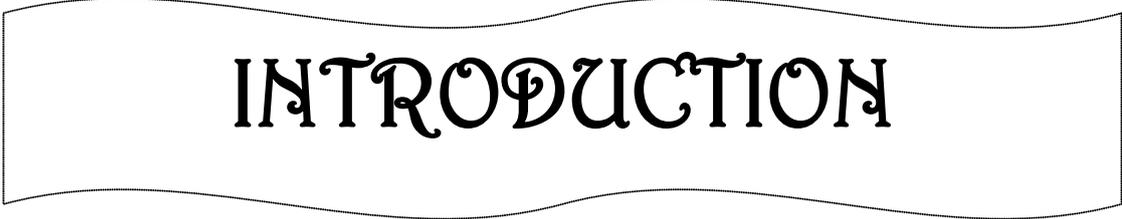
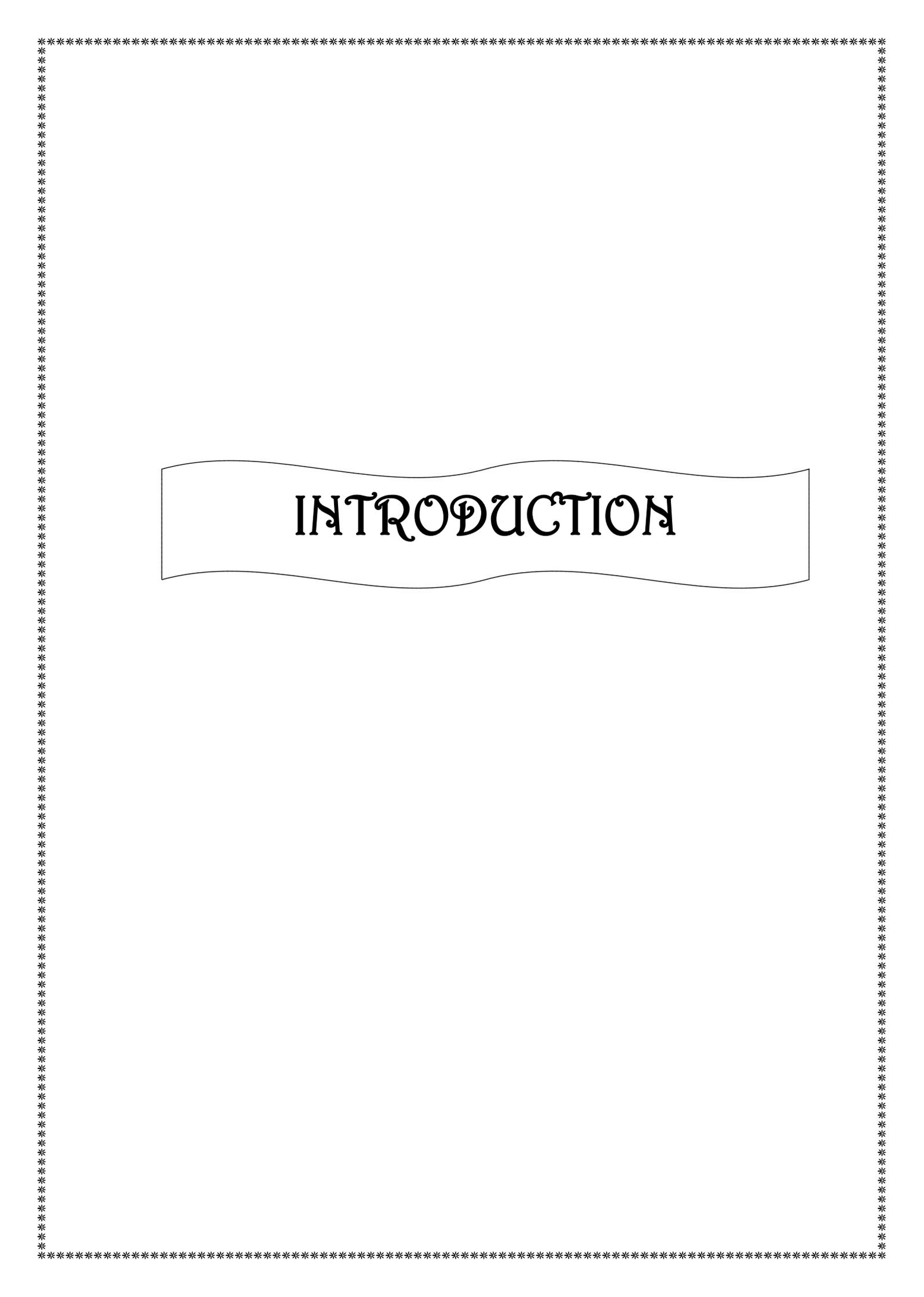
List of Abbreviations

ACF	Assistant Conservator of Forest
A/F Ratio	Abundance/Frequency Ratio
ASTER	Advanced Space borne Thermal Emission and Reflection Radiometer
BA	Basal Area
BTR	Buxa Tiger Reserve
BARO	Baroda Herbarium
CA	Correspondence Analysis
CCA	Canonical Correspondence Analysis
CADD	Computer-Aided Design and Drafting
CIFOR	Center for International Forestry Research
DCA	Detrended Correspondence Analysis
DCF	Deputy Conservator of Forest
DEMs	Digital Elevation Models
EDCs	Eco-Development Committees
ERDAS	Earth Resources Data Analysis System
FAO	Food and Agriculture Organization
FC	Forest Communities
FCC	False Colour Composite
FD	Forest Department
FDC	Forest Development Corporation
FPC	Forest Protection Committee
FRI	Forest Research Institute
FSI	Forest Survey of India
GA	Geographic Area

GBH	Girth at Breast Height
GCP	Ground Control Points
GDEM	Global Digital Elevation Model
GIS	Geographic Information System
GoI	Government of India
GPS	Global Positioning System
GVC	Ground Vegetation Cover
Ha	Hectare
HRD	Human Resource Development
IIFM	Indian Institute of Forest Management
IR	Infra Red
IRS	Indian Remote Sensing Satellite
IVI	Importance Value Index
JFM	Joint Forest Management
JFMC	Joint Forest Management Committees
JFMP	Joint Forest Management Programme
km	kilometre
LISS	Linear Image Self Scanning System
LUP	Land Use Planning
MAI	Mean Annual Increment
MCA	Multi Criteria Analysis
MDF	Moderately Dense Forest
METI	Ministry of Economy, Trade, and Industry
MLP	Micro Level Planning
MIR	Mid Infra Red
MoEF	Ministry of Environment and Forest

MSS	Multi Spectral Sensor
NASA	National Aeronautics and Space Administration
NBSS	National Bureau of Soil Survey
NDVI	Normalised Differential Vegetation Index
NGO	Non Government Organisation
NMDS	Nonmetric Multidimensional Scaling
NMSDDS	National Map Seamless Data Distribution System
NTFPs	Non Timber Forest Products
NWFPs	Non Woody Forest Products
PAN	Panchromatic Camera
PAST	Paleontological Statistics
PCA	Principal Components Analysis
P.W.D.	Public Works Department
RD	Relative Density
RDA	Redundancy Analysis
RDo	Relative Dominance
RF	Reserved Forest
Rf	Relative frequency
RFO	Range Forest Officer
RS	Remote Sensing
RUPFOR	Resource Unit for Participatory Forestry
SC	Schedule Caste
SOI	Survey of India
SR	Species Richness
SRTM	Shuttle Radar Topography Mission
ST	Schedule Tribe

STA	Sparse Tree cover with Agriculture
SWB	Standing Woody Biomass
TOF	Tree Outside Forest
UNICEF	United Nations Children's Fund
USDA/FS	United States Department of Agriculture/Forest Service
USGS	United States Geological Survey
UT	Union Territory
VDF	Very Dense Forest
VFCs	Village Forest Committee
VLO's	Village Level Organizations
WP	Working Plan



INTRODUCTION

1.0) Basic concept of Ecology:

Modern ecology is a multi disciplinary science which depends on a variety of disciplines such as statistics, meteorology, climatology, geology, **forestry**, horticulture, agricultural science etc. All these disciplines have helped in a better understanding of many ecological principles.

Technically speaking, an ecosystem is a biological term applied to a part of nature, which includes both living organisms and non-living material. Within a forest ecosystem there occur interactions that produce an exchange of materials between the living trees and other living organisms and non-living materials (Anderson & Holland, 1997).

1.1) Forest Ecology and its importance:

Forest ecology, is concerned with the forest as a biological community. The forests are studied at a number of organizational levels, from the individual organism to the ecosystem. However, as the term forest express an area inhabited by more than one organism; forest ecology most often concentrates on the level of the population, community or ecosystem. Thus, forest ecology is a highly diverse and important branch of ecological study.

Ecologically forest is said to be the plant community dominated by trees and other woody vegetation with a closed canopy. This green blanket of earth not only provides valuable natural resources but also maintains ecological balance which is vital for preserving life supporting system of the globe (Raju, 1997).

It plays a vital role in social, cultural, historical, economic and industrial development of any country and in maintaining its ecological balance. They are the resource base for sustenance of population and a storehouse of biodiversity. Forests

not only maintain and improve the moisture regime and provide clean air but also produce humus and maintain soil fertility. The Hindi proverb “Vano ke hain teen upkar, Mitti, Pani Aur Bahar” beautifully brings forth the varied utility of forests.

In India the forest wealth is extremely diverse as a result of the huge variation in the topography of the country, but due to the impact of biotic pressure on our forests, many forest areas spread across the country have been depleted and degraded which is a matter of serious concern. Loss of forest biodiversity is both due to the total loss of forest cover (deforestation) as well as due to the loss of biodiversity components within forest (degradation).

Conservation of forest is certainly a necessity that needs to be addressed as a priority basis. A very practical action plan has to be formulated to prevent any kind of ecological imbalance. Many legislations have been enacted in India to achieve the same, but still there are number of problems and constraints in forestry sector which includes;

- Poverty and Unemployment,
- Pollution,
- Lack of effective land use policy,
- Lack of awareness about the multiple roles and benefits of forests,
- Deforestation, Continuing forest/land degradation,
- Inadequate forest protection,
- Loss of biodiversity and genetic resources,
- Declining productivity of forests/forest plantations,
- Low level of technology,
- Inadequate research and extension,

- Insufficiency of trained manpower,
- Widening demand/supply gap,
- Lack of people's participation and NGO involvement,
- Lack of private sector participation,
- Inappropriate laws,
- Lack of a database and information system, and;
- Loss of indigenous knowledge about plants and their uses.

1.2) Forest cover in India:

The forest cover of our country as per 2007 assessment by FRI (2007) is 690,899 km². As per the statistics given in Table 1, it is 21.02 percent of the geographic area of the country.

Table 1: Status of forests cover of India in 2007

Class	Area (Km ²)	% of Geographic Area
Forest Cover		
Very Dense Forest	83,510	2.54
Moderately Dense Forest	319,012	9.71
Open Forest	288,377	8.77
Total Forest Cover*	690,899	21.02
Non Forest		
Scrub	41,525	1.26
Non Forest**	2,554,839	77.72
Total Geographic Area	3,287,263	100

* Includes 4,639 Km² under mangroves ** Excludes scrubs and includes water bodies

Very dense forest constitutes 83,510 km² (2.54%), the moderately dense forest 319,012 km² (9.71%), open forest constitutes 288,377 km² (8.77%) and the scrub accounts for 41,525 km² (1.26%) of the geographical area. The distribution of the forest cover is shown in Plate 1.

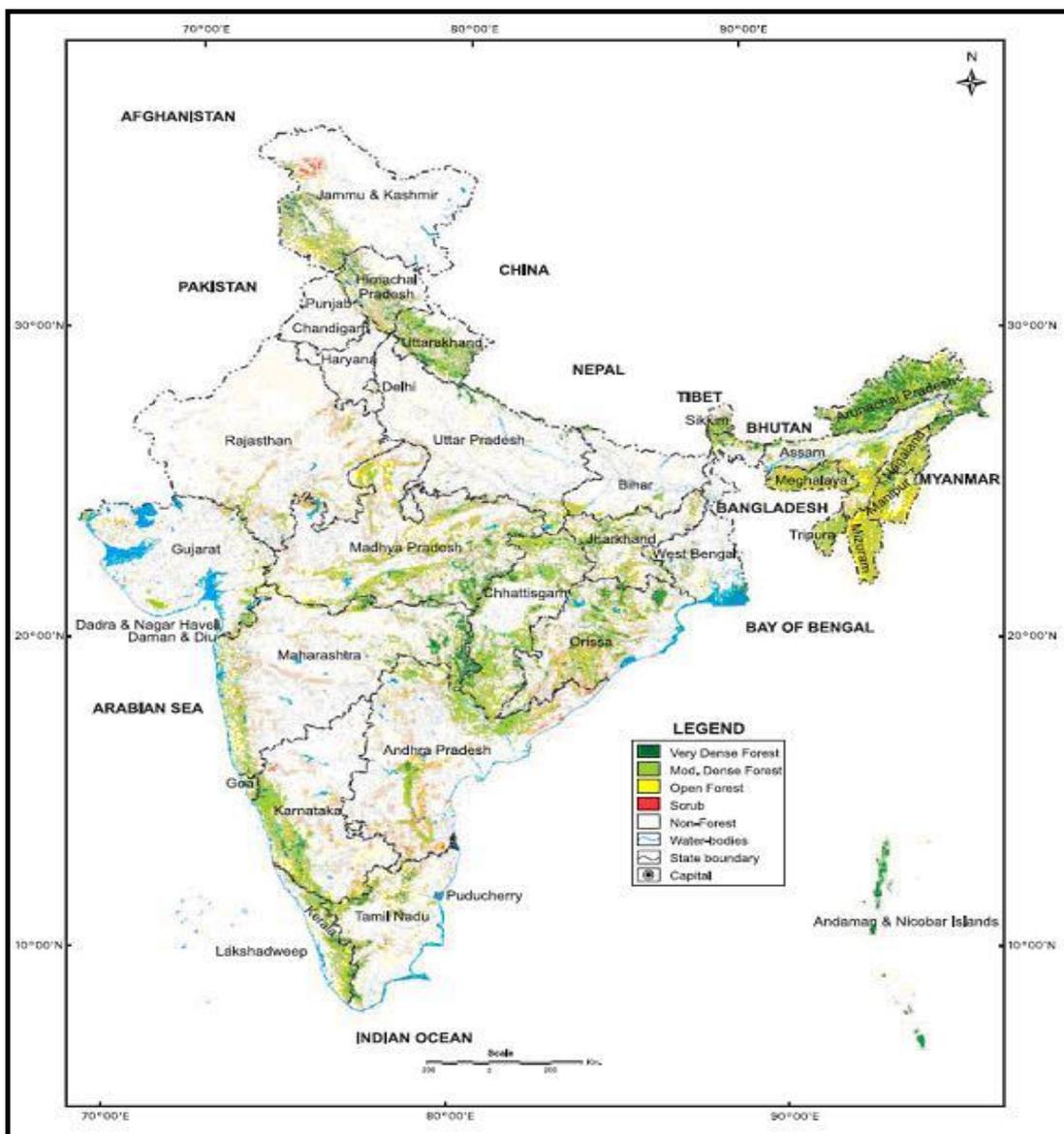


Plate1: Forest Cover map of India, 2007

1.2.1) State wise forests cover of India:

Forest cover of each state and Union Territories of the country has been presented in the Table 2. Madhya Pradesh has got the largest forest cover in the country followed by Arunachal Pradesh, Chhattisgarh, Maharashtra and Orissa. In terms of percentage of forest cover with respect to total geographic area, Mizoram with 91.27% leads the table, followed by Lakshadweep (82.75%), Nagaland (81.21%), Andaman & Nicobar Islands (80.76%), Arunachal Pradesh (80.43%), Manipur (77.40%), Meghalaya (77.23%) and Tripura (76.95%). Arunachal Pradesh has got the largest area of very dense forest cover and Andhra Pradesh has got the largest area under scrub (Fig 1) (FRI, 2007). It is to be noted that Gujarat stands 19th rank all over in India, it is about 7.46 %.

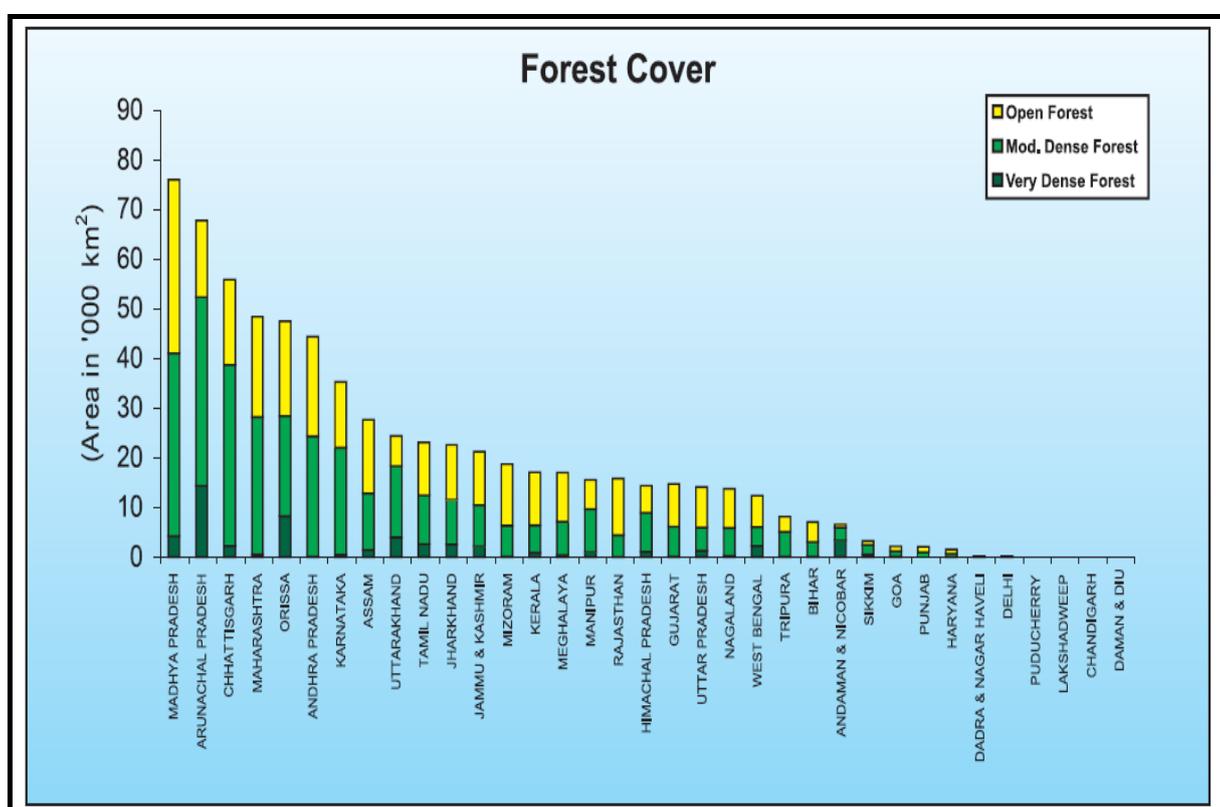


Fig 1: Class wise forest cover in different States and Union Territories of India

Table2: Forest cover in States/UTs in India in 2007 (area in km²)

State/UT	Geo-graphic Area	Forest Cover				% of Geo-graphical Area	Change* in forest cover	Scrub
		VD Forest	MD Forest	Open Forest	Total			
Andhra Pradesh	275,069	820	24,757	19,525	45,102	16.4	-129	10,372
Arunachal Pradesh	83,743	20,858	31,556	14,939	67,353	80.43	-119	111
Assam	78,438	1,461	11,558	14,673	27,692	35.3	-66	179
Bihar	94,163	231	3,248	3,325	6,804	7.23	-3	134
Chhattisgarh	135,191	4,162	35,038	16,670	55,870	41.33	-59	107
Delhi	1,483	7	50	120	177	11.94	0	1
Goa	3,702	511	624	1,016	2,151	58.1	-5	1
Gujarat	196,022	376	5,249	8,995	14,620	7.46	16	1,463
Haryana	44,212	27	463	1,104	1,594	3.61	-10	145
Himachal Pradesh	55,673	3,224	6,383	5,061	14,668	26.35	2	327
Jammu & Kashmir	222,236	4,298	8,977	9,411	22,686	10.21	-3	2,036
Jharkhand	79,714	2,590	9,899	10,405	22,894	28.72	172	683
Karnataka	191,791	1,777	20,181	14,232	36,190	18.87	-10	3,176
Kerala	38,863	1,443	9,410	6,471	17,324	44.58	40	58
Madhya Pradesh	308,245	6,647	35,007	36,046	77,700	25.21	-39	6,401
Maharashtra	307,713	8,739	20,834	21,077	50,650	16.46	-11	4,157
Manipur	22,327	701	5,474	11,105	17,280	77.4	328	1

Table2 contd.								
State/UT	Geo-graphic Area	Forest Cover				% of Geographical Area	Change* in forest cover	Scrub
		VDF	MDF	Open Forest	Total			
Meghalaya	22,429	410	9,501	7,410	17,321	77.23	116	211
Mizoram	21,081	134	6,251	12,855	19,240	91.27	640	1
Nagaland	16,579	1,274	4,897	7,293	13,464	81.21	-201	2
Orissa	155,707	7,073	21,394	20,388	48,855	31.38	100	4,852
Punjab	50,362	0	733	931	1,664	3.3	4	20
Rajasthan	342,239	72	4,450	11,514	16,036	4.69	24	4,347
Sikkim	7,096	500	2,161	696	3,357	47.31	0	356
Tamilnadu	130,058	2,926	10,216	10,196	23,338	17.94	24	1,206
Uttar Pradesh	240,928	1,626	4,563	8,152	14,341	5.95	-5	745
Uttarakhand	53,483	4,762	14,165	5,568	24,495	45.8	2	271
West Bengal	88,752	2,987	4,644	5,363	12,994	14.64	24	29
Andaman & Nicobar	8,249	3,762	2,405	495	6,662	80.76	-1	53
Chandigarh	114	1	10	6	17	14.91	0	1
Dadra & Nagar Haveli	491	0	114	97	211	42.97	-5	1
Daman & Diu	112	0	1	5	6	5.04	0	3
Lakshadweep	32	0	16	10	26	82.75	0	0
Pondicherry	480	0	13	31	44	9.14	2	0
Grand Total	3,287,263	83,510	319,012	288,377	690,899	21.02	728	41,525

* The change in the above table refers to change in the area with respect to revised assessment for 2005-07

(VDF =Very Dense Forest, MDF =Moderately Dense Forest, Open Forest)

1.2.2) The forests of the Gujarat State:

The forest areas of Gujarat are unevenly distributed (Plate 2). As per the India State of Forest Report (2009), Gujarat has 7.46% of its total geographical area under forest cover.

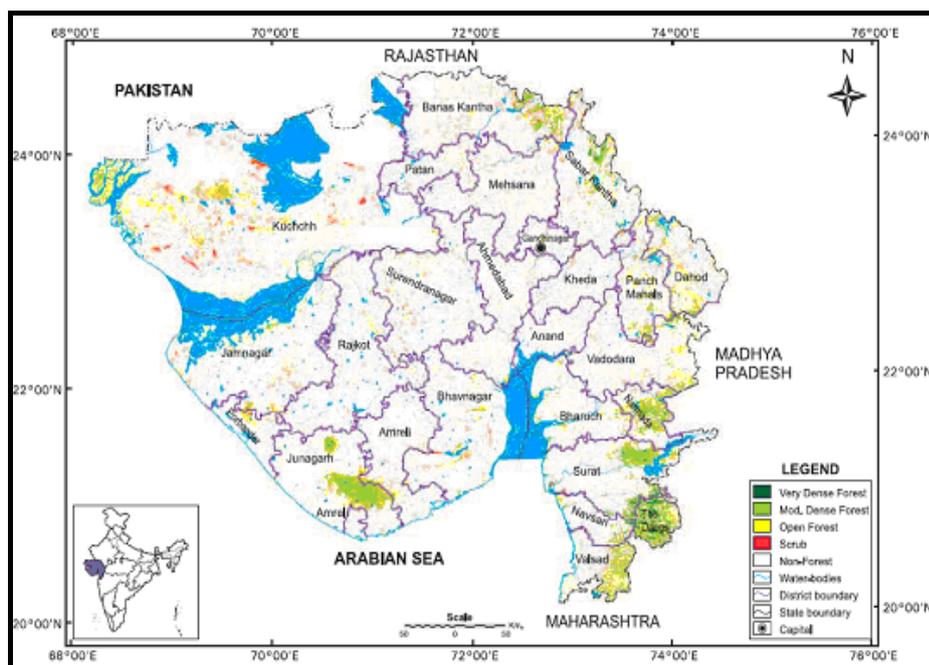


Plate2: Forest cover map of Gujarat

1.2.2 a) Forest and Tree Cover: In terms of forest canopy density classes, the Gujarat has 376 km² of very dense forest, 5249 km² of moderately dense forest and 8,995 km² of open forest (FRI, 2007). The estimated tree cover in the State is 8,390 km². These tree cover includes patches outside recorded forest areas, such as trees on village common land, farmland, roadside, railways and canal.

The recorded forest area in the State is 18,927 km², which is 9.66% of the geographic area. Recorded Forests can be broadly classified into three categories Reserved Forests, Protected Forests and Unclassed Forests. Reserved, Protected and Unclassed Forest constitutes 74.61%, 2.53% and 22.86% of the total forest area

respectively (FRI, 2007). This clearly indicates that the total forest cover of the state is much lower than the ideal requirement of a one third of the total land. The distribution of forest cover of the State is shown in Fig 2.

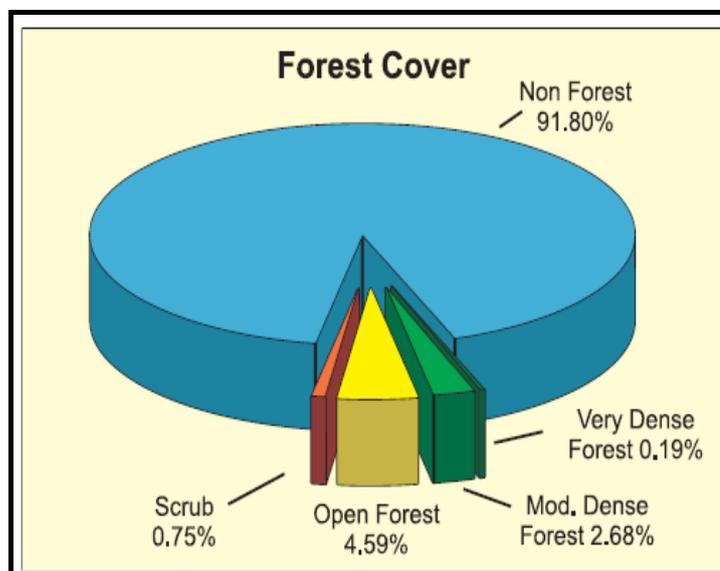


Fig 2: Pie Chart Showing Forest Cover of Gujarat

Loss of forest cover has always been one of the main concerns of the state forest department and the effort towards increasing the green cover has been going on since decades. The loss of forests has serious socio-economic and environmental consequences, therefore, the government is increasing their efforts to protect them and incorporate them into various forest policies which encourage plantation through re-plantation or protection through collaboration efforts.

1.2.3) Origin of forest plantations: For sustaining forest cover, a scientifically designed forest plantations should be undertaken for optimum productivity of the commercial plantations. Such managed plantations could reduce the pressure on natural forests to meet future demand. One extreme estimate is that world demand for wood could be met by managed plantations (Oliver 1999; Sedjo, 2001). For large scale plantations, Forest Development Corporation (FDC) was established in 1975 however, plantation activity got an upliftment only after the launch of Social Forestry

programme. The first social forestry scheme in the country was initiated in Gujarat in 1969 with planting of areas along road and canal and distribution of seedlings under farm forestry. Along with the social forestry programme, the government also, tried to conserve the forests of the villages and its surrounding by bringing them under the regulations of village panchayat.

1.2.4) Forests in villages: Under the Indian Forest Act., the forest in villages is called as Communal forests or Panchayat forest. These are the part of a reserved forest land which is assigned to a village-community for their use (Sinha H., 2003). There are 18,028 villages in the state of which 4,732 have forest as a recorded land use. In these villages about 1.35 million ha is classified as forest.

Introduction of such model created assets for the village communities and promoted a massive public support for various such schemes leading to origin of JFM.

1.3) Origin of Joint Forest Management in India:

Over the years more than half of India's forests have got degraded, bringing about an ecological crisis and immense suffering for the forest-dependent people. A new forest policy issued in 1988, emphasized on meeting the local communities' needs. The outcome was the implementation of the Joint Forest Management Program (JFM or JFMP) in 1990. The Joint Forest Management (JFM) program was described as “a forest management strategy under which the government represented by the Forest Department and the village community entered into an agreement to jointly protect and manage forestlands adjoining villages and to share responsibilities and benefits” (GoI, 2000). This programme issued policy guidelines for the JFM in 1990 for “involvement of village communities and voluntary agencies in the regeneration of degraded forests” (MoEF, 1990). It initiated a pilot project basis

in West Bengal as early as 1971 and again in the late 1980s with considerable success. Under this strategy different village community were formed through an institution specifically formed for the purpose. This institution is named differently in different states. Most commonly it is referred to as the Forest Protection Committee (FPC). The FPC takes the responsibility of protecting a forest patch from fire, grazing and illegal harvesting. In return, it gets greater access to forest produce and a share in income earned from that forest patch. The expectation from JFM was to ensure sustainable use of forests to meet local needs equitably while ensuring environmental sustainability. **Plate 3** shows the spread of JFM programme in India.

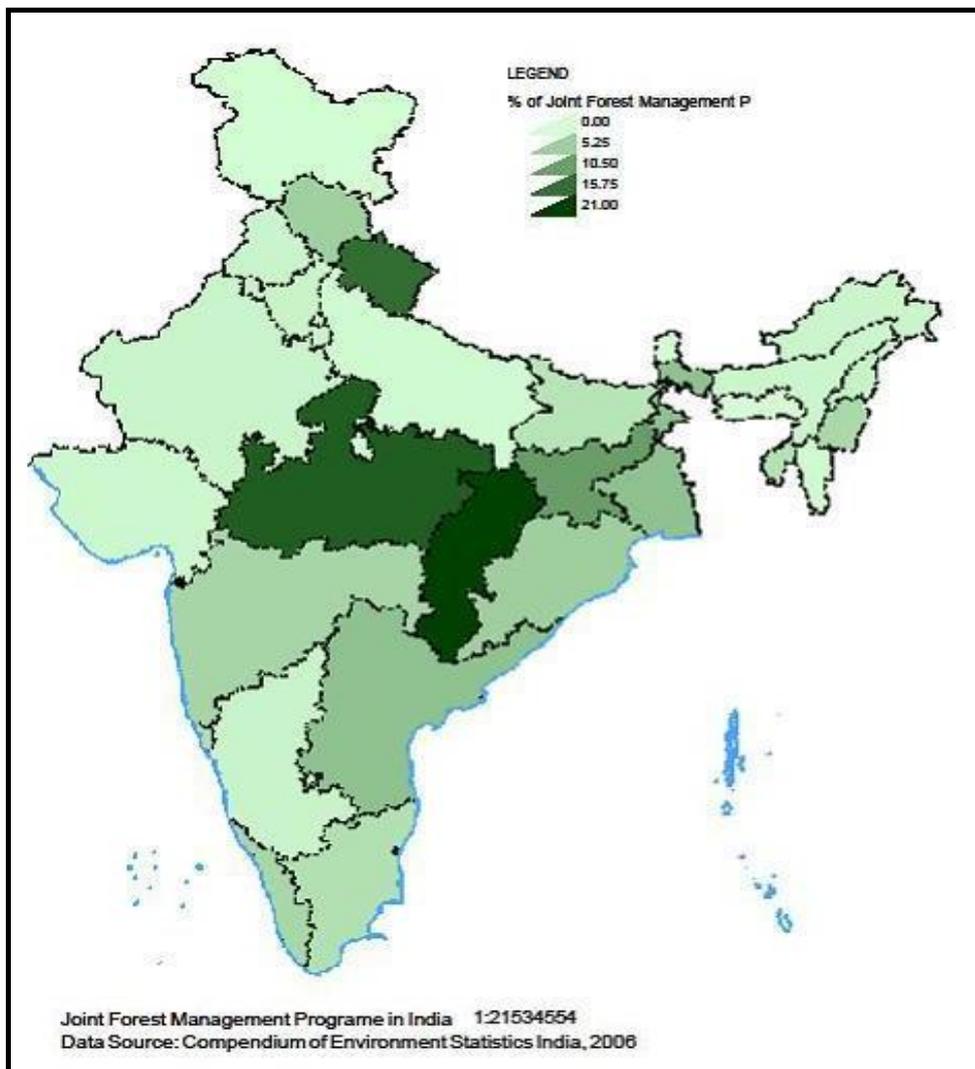


Plate 3: JFM Cover in India (2005) (RUPFOR-About JFM)

JFM program in India is one of the biggest co-management efforts of the world that acted as a policy vehicle for resolving forest resource conflicts. Recent data have indicated that 99,000 registered JFM committees are involved in managing 214,300 square km of forests in 28 states of India involving 13.8 million families, 28.75 percent of which are tribal (FSI, 2005). In India the programme is being monitored by a Joint Forest Management Cell in the Ministry in the Forest Protection Division.

1.3.1) JFM in Gujarat:

Gujarat is considered as a pioneering state in India in the context of JFM. It was among the first states to have implemented the Government of India (GoI) Resolution of June 1990. The JFM program was formally initiated in Gujarat, with the state government passing resolution on March 13, 1991. Starting with three to four villages and a few hectares, JFM in Gujarat today encompasses more than 1734 villages and an area over 2,38,242 hectares (Table 3). The total number of families involved in JFM is 0.2 million, of these 0.14 million families belong to Scheduled Tribes (MoEF, 2005).

Table 3: Present Status (March, 2005) of JFM in State:

(a)	No. of Van Kalyan Samiti	1734
(b)	No. of Samities Adhikar Patra given	1355
(c)	No. of Samities registered as Societies	488
(d)	Forest area allotted	2, 38,242 ha.
(e)	No. of meetings	20

As the concept of People's Institutions for JFM picked up momentum in Gujarat, more and more forest dependent villages showed interest. The working of Joint Forest Management has been appreciated by the Government of India (GoI) in three of the Van Kalyan Samities of Gujarat state namely- Pingot, Bapda, Balethi and Motia, which have been awarded Priyadarshani Vriksha Mitra Award in recognition of their services for the protection and regeneration of the degraded forest.

1.3.1A) JFM Impact studies: The JFM Programme has displayed several positive impacts which are as follows:

- Improvement in the condition of forests – There is evidence that JFM has improved the condition of the country's forests. Incidence of illicit felling has declined. According to Poffenberger *et al.*, (1996), "In less than one decade, large tracts of state lands that recently existed as scrub covered wastes are now regenerating into biologically diverse, closed canopy secondary forests that produce a broad range of forest goods and ecological services."
- A study carried out by the Andhra Pradesh Forest Department has indicated that between 1996 and 1999, dense and open forest covers have increased by 18 percent and 22 percent respectively.
- One of the more immediately visible ecological effects of JFM has been the recovery of fodder resources in JFM areas.
- At several places, JFM has helped to reduce the area under illegal encroachment and the rate of fresh encroachments. For instance, in Andhra Pradesh, nearly 12 per cent of the encroached forestland (38,158 Ha) has

reportedly been vacated since the JFM programme was initiated (MoEF, 2002).

- Awareness amongst the local villagers and JFMC members was created by the involvement of NGOs in the forestry sector. In the six states, as per figures available from Andhra Pradesh, Manipur, Tamil Nadu, Tripura, Uttar Pradesh and Uttaranchal, 1061 NGOs are actively participating in JFM Programme (MoEF 2002).
- The committees have benefited from the employment generated under JFM Project through sale of non-timber forest products and bamboo yield, etc. Many VFCs have sustained the level of community funds, which are used for local developmental activities and personal loans, thus lessening the bondage of money lenders.
- The study by Indian Institute of Forest Management (IIFM) of village forest committees in the Jhabua Division of Madhya Pradesh, exhibited that the average saving of a household by augmentation of fodder from the area has been Rs. 3000 per annum (Bahuguna 1993).
- One of the most significant impacts of JFM programme has been the change in the attitude of local committees and forest officials towards each other and towards forests. Several JFM related training programmes have been initiated.

Considering the success of the JFM approach in the past decade, it has been decided to merge all existing schemes of the National Afforestation and Eco-development Board into a National Afforestation Programme, which will be implemented through the JFM approach from the Tenth Plan onwards.

1.3.1B) Success/Failure Stories of JFM: By and large, the JFM programme could be said “a success” but not all parts of the country had similar experiences. In places where the FPC’s have been successful, the dependence on forest products were high among the members and the committees had able leadership. In Harda division of Madhya Pradesh, irrigation facilities developed under JFM have increased the crop yield by two to five times. In Gujarat, better availability of grass and tree fodder after the initiation of JFM has led to increase in milk production in several villages like Balethi village in Rajpipla West division and Nisana village of Vyara division (Khanna & Prasad, 2004).

In some states like Gujarat, Maharashtra and Andhra Pradesh, FPC’s have started earning through sale of produce from their forest patches. In West Bengal, even though the sharing percentage is one of the lowest in the country (25 per cent), it is estimated that on an average each FPC has received about Rs 70,000 as share in timber revenue. Income from non-timber forest produce (NTFP) is even greater. Women in several FPC’s in West Bengal are able to earn between Rs 4,500 and 6,000 annually through sale of Sal leaf plates.

Both FPC’s and Eco-development committee’s (EDC’s) arrived late to the tribal areas of northern West Bengal, and the relative success in other parts of India, have not been taken place there (Karlsson,1997). On initiation of Buxa Tiger Reserve (BTR) in 1990, an attempt was made to involve the local communities, mainly adivasis (tribal’s), in protecting the reserve. This made the adivasis to give up their traditional ways of subsistence, cattle, forestry and wood collecting. After complete establishment of BTR the members instead of receiving 25% share of the profit, received high-milking hybrid cattle, irrigation canals smokeless chullahs and

beekeeping. However, the EDC did not succeed in BTR. The failure is mainly due to the fact that the local forest dwellers are poor adivasis who were not invited to take part in the creation of the EDC, thus there existed no awareness in the creation. Moreover, the introduction of high-milking hybrid cattle, irrigation canals, smokeless chullahs and beekeeping was not supplemented with additional training and information. Thus, for the adivasis EDC meant they had to protect the forest without getting anything substantial in return.

1.3.1C) Benefits Provided by JFM to the local villagers: Development works carried out by the forest departmental officials in the villages of Gujarat include:

- Land development works- land leveling
- Creation of irrigation facilities like Van Talavadies/Check Dams and drinking water facilities
- Energy saving devices such as Bio gas / gobar gas plants, solar cookers and solar lights, Community utensils, improved chullahas and improved crematories has been promoted
- Distribution of grafted fruit trees
- Construction of school buildings and anganwadis
- Fish rearing
- Construction of link road

All these forest conservation measures taken up by government have definitely brought some amount of change in the forest cover and its status directly or indirectly. The assessment of forest cover is essential for effective and conserved forest resources. These assessments provide information necessary for decision-making in forest policy and management. There are many approaches i.e.

conventional and non-conventional, for assessing forest cover status which varies with respect to sampling intensity and requirement and cost. As resources are often limiting, approaches need to be as efficient and cost effective as possible so that they can be sustained over time. However, assessment of forest presents a number of challenges. In recent years, there has been an increasing effort to establish non conventional approach for assessment of various forest studies.

1.4) Conventional Methods Non-Conventional methods for forest management:

Using a compass for forest mapping was a common conventional method, having low work efficiency and making mapping task much more tedious and much more time consuming. To eliminate such demerits and bring efficiency and ease while carrying out a forest survey, a new and more advanced and more sophisticated technique called Remote Sensing (RS) and Geographic Information System (GIS), was used in the present study for better monitoring and management. RS and GIS analyses have great potential for providing relatively cheap data to assist in the efficient management of plantations. In recent years, continued progress made in the field of digital image processing has provided improved capabilities for forest management (Franklin, 2001).

1.4A) Remote Sensing (RS): Remote sensing is the science of obtaining and interpreting information from a distance, using sensors that are not in physical contact with the object being observed (Jensen, 2000). Without direct contact, some means of transferring information through space must be utilized. In remote sensing, information transfer is accomplished by use of electromagnetic radiation (EMR). EMR is a form of energy that reveals its presence by the observable effects it produces when it strikes the matter.

The advantage of using remote sensing for forestry applications is that it provides data on three dimensional forest structures characterizing vegetation heights, vertical distribution of canopy materials, crown volume, sub canopy topography, biomass, vertical foliage diversity & multiple layers, height to live crown, large tree density, leaf area index, physiographic or life form diversity etc., through direct and indirect retrievals.

Forests are generally spread on rugged terrain and different elevations. Site factors such as location, elevation from sea level, aspect and slope are effective on an ecosystem and hence its vegetation. A digital terrain model can be used to determine the physiographic characteristics of a terrain (Yener, 1993). Today, using different sources and methods, digital terrain models and digital elevation models can be generated by certain satellite data (Ikonos, Spot, Quikbird etc.) by photogrammetric method, digitization of available topographic maps, Radar interferometry technique (for example, Shuttle Radar Topography Mission (SRTM) satellite data), Light Detection and Ranging (LIDAR) sensor data. Many satellite and sensor systems like SPOT series, ASTER, RADARSAT, SRTM have been developed to produce global elevation data in digital formats (Hirano et al, 2003). Using ancillary information such as advanced very high resolution radiometer (AVHRR) data and digital elevation model (DEM) derivatives from the national to continental level surveys is among the most promising tools for foresters, geographers and soil surveyors (Ali and Kotb, 2010). Although several DEM accuracy assessment studies could be found for different satellite sensor and SRTM data, there have not been extensive studies of Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM) since these data have released recently.

1.4 B) Geographical Information Systems (GIS) is an information technology that has been used in public policy-making for environmental and forest planning and decision-making over the past two decades (Bassole *et al.*, 2001). Typical GIS applications include several digital thematic map for forest planning such as compartment map, cadastral map, forest road map, soil type map, topographic map, forest inventory, land use mapping and political boundaries (Heit *et al.*, 1996). It provides foresters with powerful tools for record keeping, analysis and decision making. GIS can be established to provide crucial information about resources and can make planning and management of resources easier, e.g., recording and updating resource inventories, harvest estimation and planning, ecosystem management and landscape and habitat planning. Nowadays, with improved access to computers and modern technologies, GIS is becoming increasingly popular for resource management.

1.4C) Reasons for the increasing trends towards GIS use by forestry professionals:

- GIS approaches allows for the integration of multiple data sources, visual representations of complex geographic data, and the application of various spatial analytic techniques to answer a variety of questions. GIS allows people with a range of expertise in a variety of settings to integrate and analyze spatial data to answer pertinent questions in a vivid and meaningful way (Ammerman, 1997).
- GIS capabilities that benefit natural resource applications including measurements of landscapes or structures, Resource mapping, Overlays or integration of multiple information layers, Modeling resources (Bettinger and Wing, 2004).

- GIS are more user-friendly software. Usability barriers are reduced. GIS can be successfully used as a tool in participatory processes to facilitate spatial comprehension, enhance transparency and stimulate debate (Jordan, 1998).
- The GIS can quickly search through map data, looking for features with certain characteristics, or inspecting spatial relationships among features. Moreover, graphic data and attribute data are explicitly linked (Korte, 2001).
- GIS provide crucial information about resources and make planning and management of resources easier, e.g., recording and updating resource inventories, harvest estimation and planning, ecosystem management, and landscape and habitat planning. GIS technology is most commonly used for comprehensive planning, zoning, land use inventories, site suitability assessments, and socio-demographic analysis, and generally for mapping purposes (Warnecke, *et al.*, 2002).

1.4D) Applications of RS-GIS in Forestry: The combination of ground data and satellite remote sensing data are very useful for describing biodiversity and monitoring changes in biodiversity. There is a large potential for savings, if ground data and image data could be collected simultaneously and stand delineation and characteristics usable for stratification could be derived from existing auxiliary data and automated methods.

Based on the data collected so far, it was found that RS and GIS was used in assessment of the status of the world's closed forests and protected areas in global biodiversity hotspots (Hua Shi & Singh, 2002). It was also a great help to the forest department in the enhancement, updating and diversifying the forestry knowledge of the state and national levels (Khan & Saxena, 1997) and monitoring and planning of

forest, (Krishna, 2001). Nigam (2000) also investigated the application and evaluation aspects of RS and GIS in the biomass estimation. While Singh (2004) and Karia & Garge (2006) used both these technologies for preparing forest management plans. For the present study the help of this non-conventional method was used to generate the village microplan, forest condition map, site suitability map, forest biomass map, forest type and density map and forest ecograde map which helps us to understand the existing position and future planning of forest resources.

1.5) Need of the present study: According to Adams & Hulme 2001, several efforts by governments and development organisations have been carried out to establish and implement collaborative forest management plan, little is known about what has been achieved so far in terms of improving forest ecological conditions, local people's welfare and the resource base condition. But still very scanty information is available for wise management of forest, like the details on the forest composition and its status which is essential in terms of ecological, economic value and regeneration potential (Wyatt-Smith 1987), of these forests. The lack of information hampers our ability to comprehend the magnitude of the loss of biodiversity and to formulate sustainable alternative for resource depletion. Though the efforts are largely from the government, the impacts of such efforts on the ecology are not properly understood. The JFM programme now is over a decade old and no attempt has yet been made to understand the impact of protection towards vegetation recovery, regeneration potential and species composition either at local or regional level (Murali *et al.*, 2000; Murali *et al.*, 2002).

Implementation of JFM was done because various anthropogenic activities like illegal tree cutting, cattle grazing and browsing, encroachment were posing problems for the floristic and natural regeneration of the forests. The steady

depletion and decreasing forest resources in many parts of the country led to the realization of the fact that without active and willing participation of the local communities it is not possible to achieve success in forest regeneration and protection. This has been achieved by implementation of JFM plantations. JFM involves sharing of responsibilities and rights of local communities and forest department (FD) as primary stakeholders in forest management system. It is also supposed to invoke active participation of local people and application of their traditional wisdom and knowledge in countering ecological and economic vulnerabilities in the form of soil erosion, drought condition, loss of soil productivity and scarcity of timber, fuel wood and NTFPs like food, fodder, plant leaves etc. which are very likely to have a worsening impact on rural peoples' livelihood including the tribal folk.

Forest resource assessment is an essential element for obtaining credible estimates of forest resources. Monitoring of forest resources is crucial on deciding the multiple possibilities that forests bear, including sustainable utilization and biodiversity conservation. Many studies including both conventional and non-conventional methods have been done to analyze the present status of forests. Conventional method of forest resource assessment includes number of studies among which Phytosociological studies are the primary one. Phytosociological studies involve the study of vegetation and its internal "social" relationships. It analyses plant communities structure, composition, successional relations, relationship with environmental factors, as well as comparison of different communities (Fujiwara, 1987). Along with phytosociological studies forest regeneration assessment is also an important factor to be looked into while analyzing JFM impacts as the whole aim behind JFM is to conserve, protect and

regenerate the degraded forests. Forest regeneration is the act of renewing tree cover by establishing young trees naturally or artificially, generally promptly after the previous stand or forest has been removed. It involves study on forest trees seedling, sapling and coppice density and also anthropogenic activities leading to regeneration.

A good rate of forest regeneration is an indicator of good forests. It means that an excellent sustainable forest will include diverse floral and faunal populations, native understory plants, and conditions that reflect natural succession. Thus, assessment of forest condition has also been one of the focal works as it would provide information on the condition of the forests in terms of productive capacity and conservation. It is also needed for future planning processes and to ensure sustainable forest management practices. As the changes in forest are complex and are difficult to monitor, foresters, scientists and policy makers are increasingly relying on indicators to help guide decision making. Forest indicators are tools which summarize and communicate complex information and allow for the monitoring and examination of the status and conditions of forest ecosystem through time.

Studies about forest type and density map could not give a precise idea about the present status of forest while forest condition map and ecograde map can give an exact picture of the condition prevailing in the forests. Generation of forest condition map and Ecograde map was an pioneer attempt in the present study using RS-GIS approach. The utility of eco-grading the ecosystem helps in interaction of ecosystem with each other when compared to a large complex ecosystem.

Another important indicator of good forests is the productivity of forest, which can be assessed based on the biomass generated by them. The quantification

of biomass is required for the primary inventory data to understand pool changes and productivity of forest (Esser 1984). Terrestrial ecosystems of India are extensively studied for point biomass and productivity estimation. However, extension of these observations in space and time has obvious limitations using conventional methods. Studies with remote sensing have indicated that the integrated vegetation index can be related directly to vegetation amount (above ground phytomass) and primary productivity (Tucker et al 1983; Goward and Dye 1987).

All forest managers need accurate and timely information to make wise decisions on resource management. There is often a direct relationship between the quality of information and cost of collection, handling and storage (Bettinger and Wing 2004). All these can together be achieved by preparing a plan which is scientifically based. These plans should involve the local people in identifying the needs and generating the available resources for preparing village micro level plan. Micro planning of various dimensions in arresting fast depletion of forest land, regeneration of degraded forest and development of watersheds, ensuring conservation of valuable and important species of forest timber and products seem to be of utmost importance in sustaining forest based livelihood. These may be well served in the structure of JFM through community's active involvement coordinated by the efforts of FD.

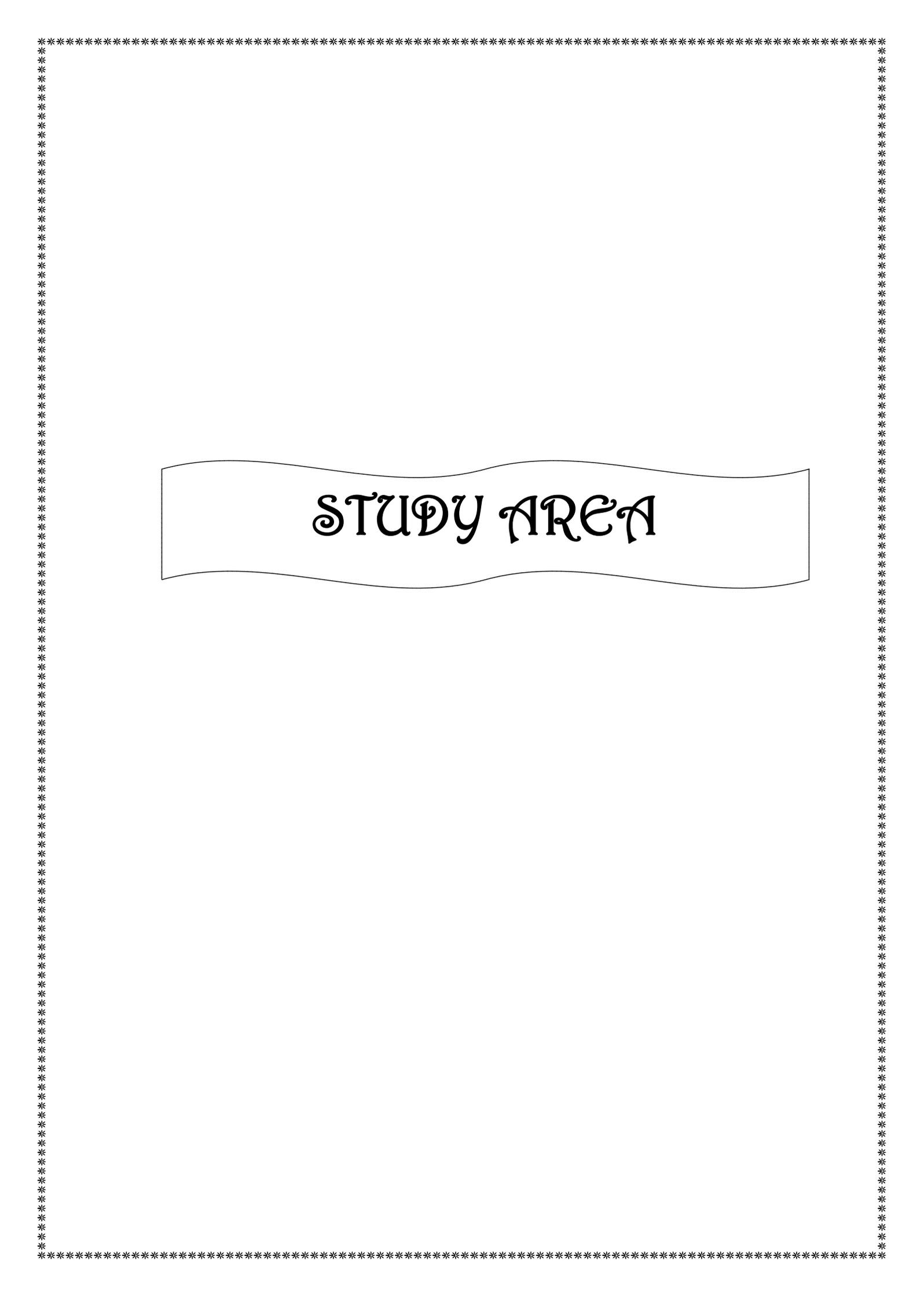
The JFM methodology currently being applied around the globe is not generating much confidence with the people since the local forest dwellers are tribes and there existed no awareness (Banerjee, 1992, Malla 2000, Lasco & Pulhin 2006). Indian experiences related to this strategy also have the same view. They have emphasized the need to have a fresh look towards the approach. Using

remote sensing techniques for preparation of soil erosion inventories by integration of physiography, soils, landuse/ land cover, slope map layers and use of ancillary data of agro-met and soil physico-chemical properties (Saha & Pande, 1994 and Saha, 1996) is a useful and detailed way to improve the selection of areas designed to forest plantations. The determination of site suitability can be accomplished by analyzing 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 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.

In the present study, therefore an attempt has been made to test that community forestry like, JFM plantations can foster the regeneration of indigenous woody species and improves the vegetation conditions prevailing there. Further, an attempt to examine whether the JFM programme, which aims to fulfil the requirements of the locals and facilitates the improvement in their socio-economic condition, have succeeded and to what extent. This was done using the latest technology of RS-GIS. Looking at the importance of all these factors, which have a great impact on the success of JFM the following objectives were designed keep in mind a holistic development of community and forests.

1.6 OBJECTIVES:

- To assess ecological status of different plantation and natural forest villages, both conventionally as well as non-conventionally i.e. using satellite information.
- Monitoring the regeneration status along with other parameters to produce forest condition map, both in natural as wells as JFMP plots
- To Collect study and analyze different non-spatial data related to Socio-economic aspects in the form of extent of responsiveness of these areas to the needs of the poor forest dependents along with the contribution of different tribes for the development of these forests.
- Recommendations and suggestions for the ecological sustainability of these areas.



STUDY AREA

2.0) Study Area:

Narmada district is located at the southern part of Gujarat. Headquarter of Narmada district is **Rajpipla**, which is also known as **Nandod**. In June 1997, under the restructuring of districts and talukas of Gujarat, Narmada emerged as a new district. The district has four talukas viz., Tilakwada, Rajpipla, Dediapada and Sagbara. Only the city of Rajpipla has the honour of having Municipality, all other villages have Gram Panchayats. A sketch of the study area is given in Plate 4.

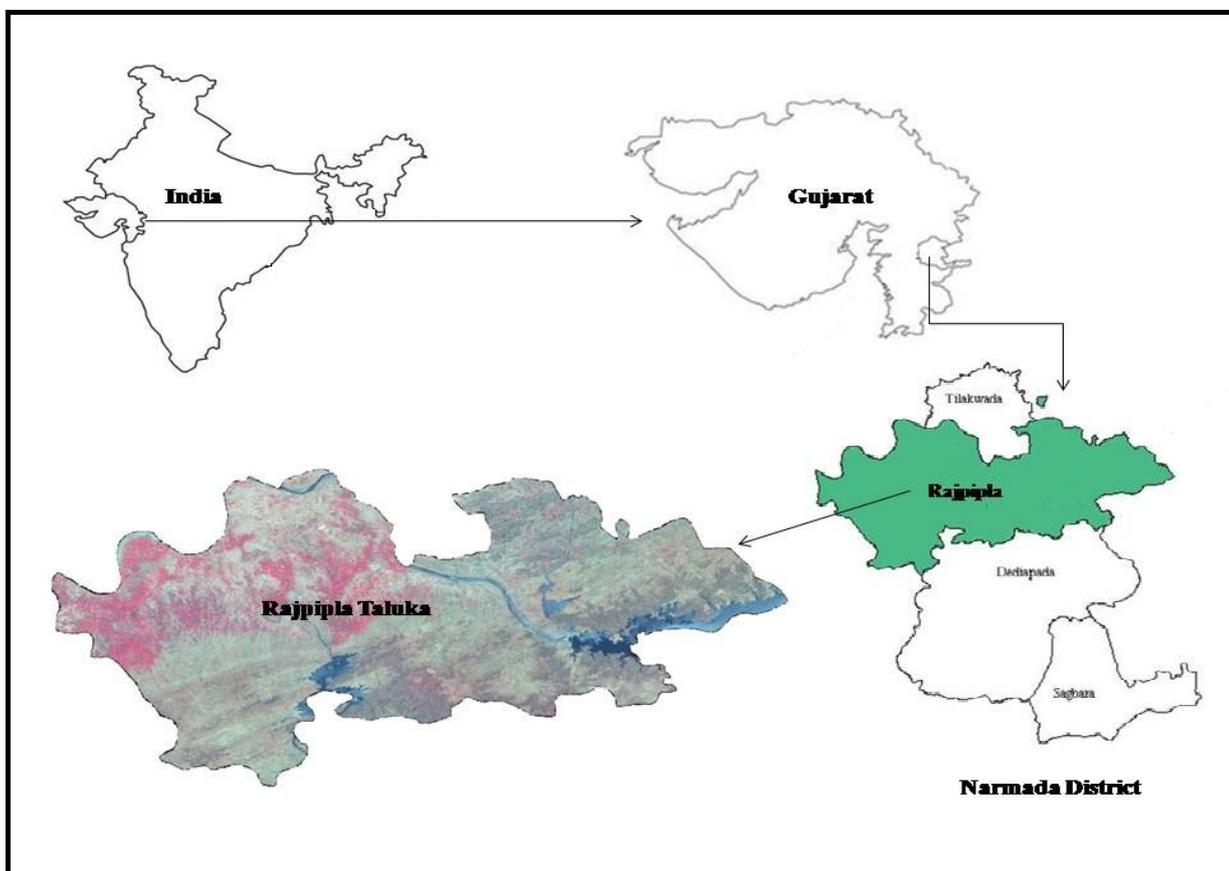


Plate 4. Map of Study Area

The present study was carried out in JFM and adjoining natural forests that are located in the Rajpipla Taluka of Narmada district in Gujarat state of Western India. Most of the field studies were done along the randomly spread areas of two

ranges of taluka i.e., Rajpipla range and Kevadia range stretching from Koliyapada Reserve forest to Jharwani Reserve forest up to Vaghadia and Kalvani Reserve forest.

2.1) Topography/Geography:

Rajpipla is located between 21°52' N 73°17'E to 21°52' N 73° 56'E coordinates. Rajpipla grew to be one of the most prosperous princely states in Gujarat, second only to Baroda. It has an average elevation of 148 meters (485 feet) above mean sea level. Rajpipla Division was bifurcated in 1972 to form Rajpipla East and Rajpipla West divisions. 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 of the taluka are spanning in an area of over 600 mi² (1550 km²) of the total 1500 mi² (4,000 km²), and the rest area is covered by fertile agricultural plains and river valleys.

The western part of the district is mostly the revenue area and is more or less flat. The northern and eastern portion of this area is hilly and rugged. Southern part also has row of hills with gentle undulation, while western portion is comparatively flat and at some places shows gentle slopes.

2.1. A) Soils:

Soils of this taluka tract vary in colour, texture, depth and stoniness depending upon the rock and topography. The soil conditions are normal with the pH values ranging from 6.7 to 7.4. The values of Electrical conductivity ranges from 0.01 dS/m to 0.14 dS/m, which indicates that the soil have no salt problem (WP of Surat Circle).

The soil type of the taluka can be classified as Rocky, Alluvial and Medium soil. The alluviums are clayey loam, light brown to grayish black in color and form excellent forest soils being deep and rich. Some of the best teak stands grow on such alluvial strips along the riverbanks. It is only in these patches that we find some natural regeneration of teak in the whole area.

2.1. B) Climate:

Climate of the area is tropical and semi-arid. The minimum temperature observed during the last ten years is 6.5° C, while the maximum temperature observed was 43°C. Monsoon is irregular and erratic. The average rainfall of the taluka is 800-1000 mm. Winter is mild and of short duration.

Easterly winds flow during the winter months. South westerly winds of moderate velocity flow almost during the rest of the year. Uprooting of trees is seen during rainy season due to winds but these are negligible. The season is humid during rains with relative humidity as high as 100 percent. The humidity is quite low during the dry summer months.

2.2) Forest cover of the study area:

The forest cover of the district is spread in an area of 1005 km² of which 507 km² is moderately dense forest and 498 km² is open forest. The geographic area of Rajpipla taluka is 1105.47 km² with 351.52 km² or 31.80% is the forest area. The Forest tract of the area is highly undulating. The forests are mainly confined to hilly tract and are prominently situated in the eastern part. The forests lie in the Satpura, Vindhayachal hill ranges. According to the identification of forest types by Champion and Seth (1968) two distinct forest types are found in this area:

1. Southern tropical moist deciduous forests, subtype slightly moist teak forests
2. Southern tropical dry deciduous forests, subtype dry teak forests

These two types are not defined by distinct topographical features. They may occur in one and the same locality within a short distance. Slightly moist teak forests are seen in some parts of Rajpipla taluka. These are mixed deciduous forests with teak usually forming about 25% of the tree population. According to the forest department of Rajpipla division the total forest area is 23025.68 ha. of which 22117.10 ha. is reserve forests, 103.14 ha protected forest and 805.44 ha is of unclassified reserved forests (Table 4).

Table 4. Classification of Forest area of Rajpipla East Division

Division	District	Taluka	Range	Forest Area (Ha.)				Total
				Reserve Forest	Protected Forest	Section 4 Area (Unclassified Reserve Forests)	Un-Class forest	
Rajpipla (East)	Narmada	Rajpipla/ Nandod	Kevadia	12696.56	102.64	----	4.37	12803.57
			Rajpipla	10641.7	0.5	-----	155.9	10798.1

(Source: Forest Department Rajpipla East Division)

The characteristic species of the top canopy are *Tectona grandis* L., *Terminalia crenulata* Roth., *Dalbergia latifolia* Roxb, *Diospyros melanoxylon* Roxb. etc. Dry teak forests are found in rest all parts of the taluka. Here also, the main species is teak but associates are more of drier type. Common associates of teak are *Anogeissus latifolia* Wall., *Terminalia crenulata* Roth., *Garuga pinnata* Roxb. etc.

2.3) Human impact on Forest cover:

The vegetation of Rajpipla have been and is still subjected to various degrees of human impact including commercial logging, extraction of firewood, fencing poles, lopping of branches for leaf and twig mulch, grazing, fire and other anthropogenic disturbances. The forests have been subjected to heavy biotic influences, like fires, illicit cutting, over grazing, encroachments etc. However the intensity of illicit cutting in the interior parts of the forests is limited. The existing stand contains high proportion of miscellaneous species with teak as the main species.

2.3A) Demographics:

As of 2001 India census, Rajpipla had a population of 34,923. Males constitute 51% of the population and females 49%. Rajpipla has an average literacy rate of 77%, higher than the national average of 59.5%: male literacy is 82% and female literacy is 71%. In Rajpipla, 10% of the population is under 6 years of age. The population is predominantly comprised of tribes namely Vasavas, Chowdharies, Bhils, Gamits, Chodharas, Dhodias, Nayaks. Majority of the tribal agriculturists have small holdings and adopt traditional methods of cultivation. As income from the agriculture is insufficient, the local forest dwellers supplement their income from non-agricultural works such as labour work in forestry and P.W.D. works etc. Few tribals earn their livelihood by making articles from bamboos.

2.3B) Livestock:

Cattle wealth occupies a pivotal place in the rural economy of the district. Cows and bullocks occupy the major livestock population of the district closely

followed by buffalos and goats. Number of horses, ponies, camels, mules, pigs, sheep and donkeys is quite less.

2.3C) Agriculture:

The major cash crops of the taluka are jowar, cotton, groundnut, bajara, wheat and rice. The food crops irrigated in the taluka are wheat, rice, chilies and sugarcane whereas non-food crops irrigated are cotton and fodder crops. A shortage of productive irrigated agricultural lands in non-forest areas has led to mounting levels of forest encroachment by cultivators. India's population has tripled over the past 50 years; however the total amount of cultivated or agricultural area has just increased by 20% only. Most of the increase in cultivated area has come from encroachment into forest and grazing lands.

2.4) Site Selection for Study:

The above said features were taken into consideration while selecting the villages for various ecological and socio-economical studies for complete understanding of the forest resource in villages.

Rajpipla shows a mixed culture in terms of land use patterns. The western area of the taluka is more or less undulating with degraded forest while the eastern part of the taluka is more of open type of forest mainly for the agriculture purpose. Plate 5 shows the two different sites i.e., the degraded natural forest and the JFM area.



Plate 5. Degraded natural forest and flourishing JFM Forests

The implementation of earlier discussed JFM Programmes is mainly done in the area of degraded forests. There are about thirty two JFM sites in twenty seven villages of the Rajpipla taluka. Six sites comprising of eighteen villages were selected for the present research work, which were segregated to cover all the JFM areas. These sites were mainly located in both eastern and western parts of taluka. In these sites the JFM program had been implemented over a past decade. So, these were ideal for conducting the studies.

There are a total 203 villages in Rajpipla taluka, out of the total villages 72 villages are inhabited by forest, 7 villages were unhabited and 32 villages were those where JFM activities was practiced and remaining 92 villages are those where no forest or only agriculture pattern is observed (Plate 6). It is to be noted that the villages selected were those where JFM strategy have been implemented. However, in villages like, Bamanfalia, Khamar, Handi, Chatwada, Vanji, Drucha, Survani, Panchala, Bhumalia and Vaghadia, the natural forest was not present. This was due to other forest conservative activities like forest nursery, forest revenue areas, social

forestry and van panchayat. Also in few villages all the areas of the village were allotted for JFM activities, so there were no natural forest area left, which could be taken up for comparative studies as it was already under protection or conservation measures. A profile of the selected villages is shown at Table 5 and Annexure-1 shows profile of selected JFM villages in detail.

Table 5. The Selected Sites of JFM villages

Site	Sl. No	Village Code	Villages	Range
Site 1	1	136	Bamanfalia	Rajpipla
	2	135	Medgam	Rajpipla
	3	153	Dochki	Rajpipla
Site 2	4	152	Handi	Rajpipla
	5	151	Chatwada	Rajpipla
	6	159	Khutamba	Rajpipla
Site 3	7	125	Nanaraypara	Rajpipla
	8	126	Khamar	Rajpipla
Site 4	9	079	Vaghadia	Kevadia
	10	060	Kothi	Kevadia
	11	061	Bhumalia	Kevadia
	12	062	Gadkoi	Kevadia
Site 5	13	075	Survani	Kevadia
	14	076	Drucha	Kevadia
	15	076	Zer	Kevadia
Site 6	16	073	Vanji	Kevadia
	17	068	Amba	Kevadia
	18	068	Panchala	Kevadia

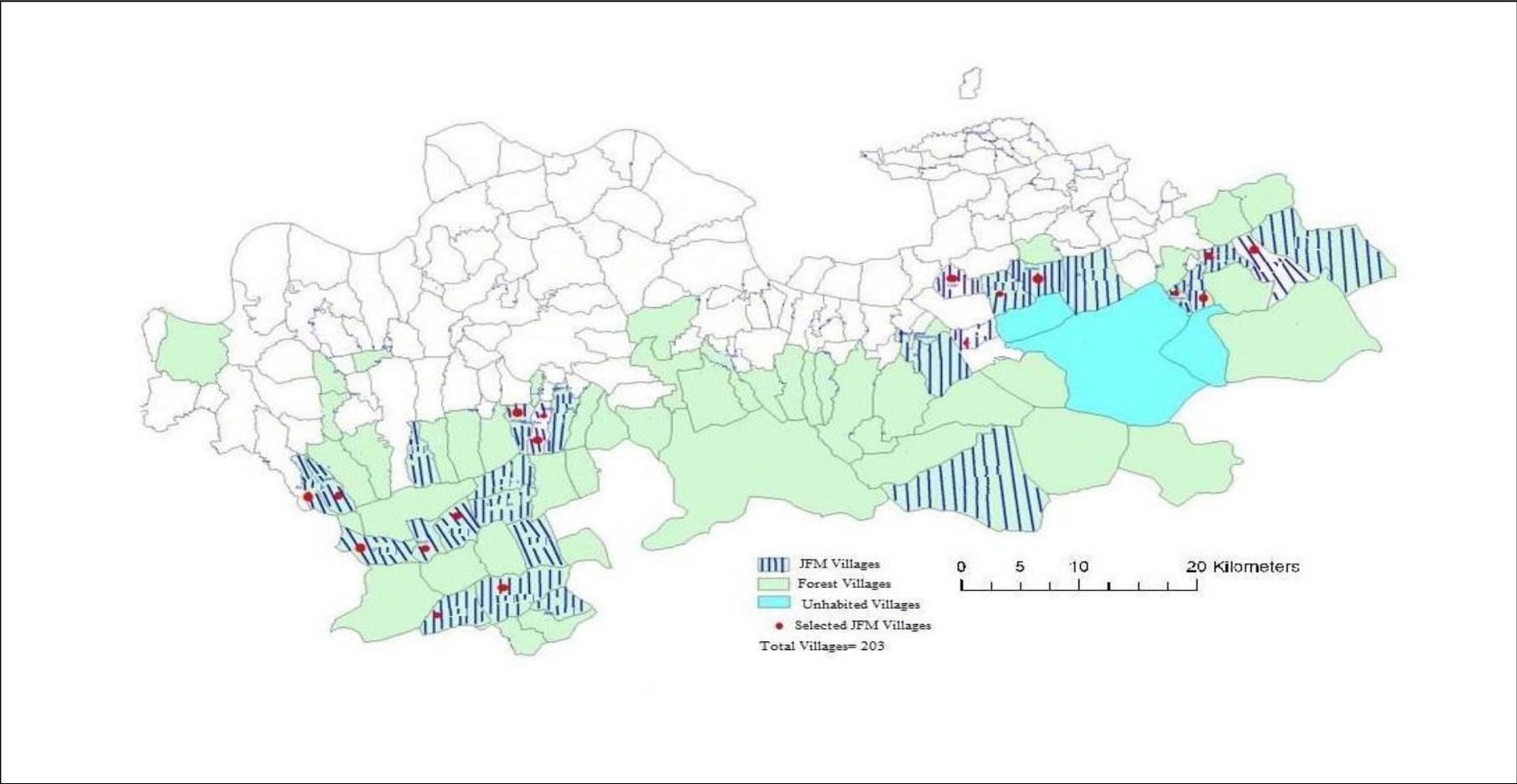
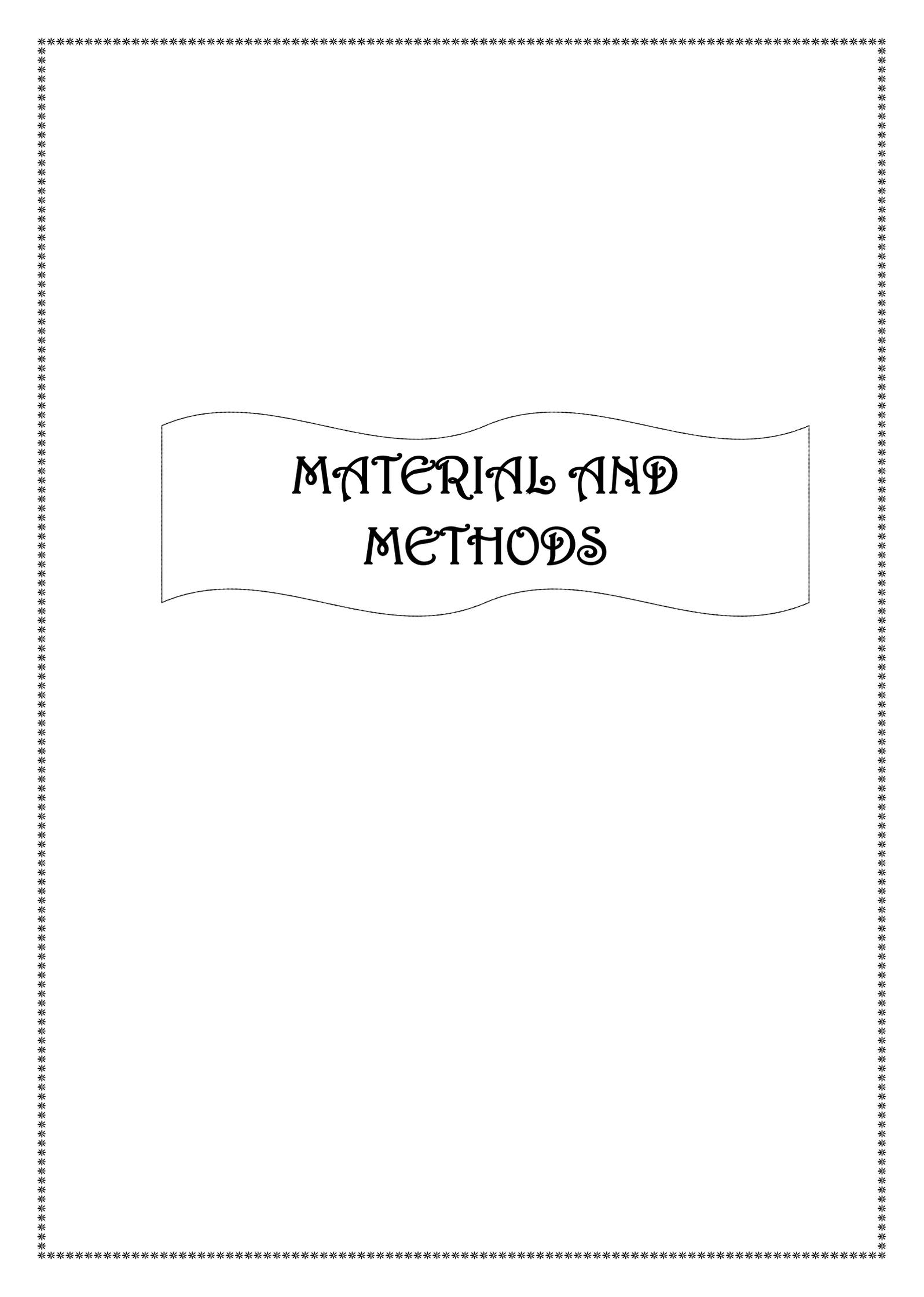


Plate 6: Details of study area sites



MATERIAL AND
METHODS

3.0) Methods of assessment:

The entire study of vegetational assessment of JFM and natural forests areas was carried out into two distinct ways, one which followed the conventional method and other, the non conventional method.

3.A) Conventional Method for forest assessment:

Assessment of the forest area was done using conventional method which mainly involved detailed field assessment for understanding of the different components related to JFM. Vegetational status study was the first step for understanding the difference between the JFM and natural forest areas and the second was the socio economic surveys. Details of different components and methods adopted for their assessment are mentioned in the following paragraph.

3.1) Vegetational Status Studies:

It involves studies that are useful to collect data that describes the population dynamics of each species studied and how they relate to the other species in the same community. All the selected JFM and natural forest plots were analyzed for the comparison of various phytosociological attributes on the basis of data recorded to cover overall spectrum of vegetation. Exact geographical coordinates (Latitude and Longitude) were recorded for each plot using a Global Positioning System (GPS) Device. The occurrence and numerical strength of each species was noted carefully in each quadrat for assessment of frequency and density. The number of quadrats of occurrence of a species, expressed as percentage of the total number of quadrats sampled i.e., frequency.

The number of individuals of a species in all quadrats, expressed as the fraction of the number of total quadrats sampled, was density of that species (Misra, 1968). The relative values of these vegetational parameters were calculated to derive Importance Value Index (IVI) for each species (Misra, 1968). A Phytograph which is a polygonal graph showing the IVI of a species along with its constituent indices – relative frequency (Rf), relative density (RD) and relative dominance (RDo), was drawn for different areas to compare the overall phytosociological importance of the species common to both the areas.

All plots were systematically surveyed for all trees with 10 cm girth at breast height (gbh above 130 cm from the ground). The tree species in each plot were identified with the help of Flora of Gujarat (G.L.Shah, 1978) and Bombay Flora (T.Cooke, 1958). The nomenclature of the species follows the regional flora. The vernacular names of the tree species from the local villagers were also noted down for the identification.

3.1a) Primary vegetation assessment:

Assessment of different primary vegetational parameters i.e, Frequency, Density, Abundance and Basal Area of tree species was determined as per Curtis and McIntosh (1950).

- 1) Species Frequency (%)** =Frequency tells about the occurrence of the species in a community. It is calculated as follows:

$$\text{Species Frequency (\%)} = (\text{No. of sampling units in which the species occurred} / \text{Total no. of sampling units studied}) \times 100$$

- 2) **Density (D)** = Frequency alone does not give correct idea of the distribution of any species, unless it is correlated with other characters, such as density etc. Density represents numerical strength of a species in the community and gives an idea of competition. It is calculated as follows:

Density (D): Total no. of individuals of the species in all the sampling units / Total no. of sampling units studied

- 3) **Abundance (A):** It is the number of individuals of any species per sampling unit of occurrence. It is calculated as follows:

Abundance = Total no. of individuals of the species in all the sampling units/ No. of sampling units in which the species occurred

- 4) **Basal area (BA)** = It refers to the ground actually penetrated by the stems and is readily seen when the leaves and stems are clipped at the ground surface. This is usually a measurement taken at 2.5 cm above ground level.

$$BA = \pi r^2$$

- 5) **Dominance:** = Total basal area value for a species /Area sampled

The Relative values of Frequency, Density & Dominance were calculated as per that given by Philips, 1959.

6) Relative density (RD) = (Density of the species/Total density of all species) x 100.

7) Relative frequency (RF) = (Frequency of the species /Total frequency of all species) x 100.

8) Relative dominance (RDo) = (Basal area of the species/Total basal area for all species) x 100.

9) Importance Value Index (IVI) This index is used to determine the overall importance of each species in the community structure. The Importance Value Index (IVI) for the tree layer was determined as the sum of the relative frequency, relative density and relative dominance for each species (Curtis, 1959).

10) Spatial Distribution: A spatial distribution is the arrangement of individuals in a space and a graphical display of such an arrangement is an important tool in geographical and environmental statistics. This may summarize raw data directly or may reflect the outcome of more sophisticated data analysis. The Spatial distribution of species in different stands has been derived from Whitford index of A/F Ratio (Whitford, 1949).

Where, A is the abundance of the species and

F is the frequency of that species

The A/F Ratio below 0.025 indicates regular random distribution, between 0.025-0.05 indicates random distribution and when >0.05 indicates a contagious distributions (Curtis & Cottam, 1956).

3.1b) Secondary vegetation assessment:

The Secondary vegetational parameters for assessment of the diversity were estimated using following methods using BioDiversity Pro and PAST (PALaeontological STatistics) software:

1) Species Richness: Species richness or variety index (d) is the mean number of species per sample and determined using the formula of Margalef (1958).

$$d = S/\sqrt{N}$$

Where, S = number of species, N = number of individuals of all species.

2) Species Dominance Index: It is used to compare the dominance of the same species in different ecosystems. Ecological dominance is the degree to which a species is more numerous than its competitors in an ecological community. Most of the ecological communities are defined by their dominant species. The Species Dominance Index (SDI) indicates ecological integrity by identifying dominant species and categorizing their behavior.

2a) Simpson's Diversity Index: This index is used to measure diversity; is usually expressed as value of D. It is often used to quantify the biodiversity of a habitat. It takes into account the number of species present, as well as the abundance of each species.

$$D = \frac{\sum_{i=1}^S n_i(n_i - 1)}{N(N - 1)}$$

Where, S = the number of species,

N = total percentage cover or total number of organisms and

n = percentage cover of a species or number of organisms of a species. This quantity was introduced by Edward Hugh Simpson (Simpson, 1949).

2b) Shannon-Wiener diversity index / -H Diversity Index/ Information Index:

Shannon and Wiener independently derived the function which is known as Shannon index of diversity. This index assumes that individuals are randomly sampled from an independently large population. The index also assumes that all the species are represented in the sample. Log₂ is often used for calculating this diversity index but any log base may be used. It is of course essential to be consistent in the choice of log base when comparing diversity between samples or estimating evenness. This can be calculated using the formulae given by Magurran (1988):

$$H' = - \sum_{i=1}^S p_i \ln p_i$$

Where, p_i = relative abundance of each species, calculated as the proportion of individuals of a given species to the total number of individuals in the community: ($p_i = n_i/N$)

* n_i = The number of individuals in each species; the abundance of each species

N = total number of all individuals

S = number of species. Also, called as species richness

This information index takes into account the evenness of the species distribution as well as the absolute number of the species. (Hurlbert, 1971; Martin & Rey, 2000; Southwood & Henderson, 2000; Magurran, 2006).

3) Evenness (E): Evenness index quantifies the equality of species abundances, whereas maximum value (1.0) of evenness is reached in the case of an equal distribution of species abundances, and more the relative abundances of species differ, lower is the evenness. It is also an important component of the diversity indices. This expresses how evenly the individuals are distributed among the different species.

Using Species Richness (S) and the Shannon- Wiener index (H), we can also compute a measure of evenness:

$$E=H/\text{Log} (S)$$

Evenness (E) is a measure of how similar the abundances of different species are. When there are similar proportion of all subspecies then evenness is one, but when the abundances are very dissimilar (some rare and some common species) then the value increases.

4) Rank Abundance Plot: Comparative studies of diversity are often hindered by variety of methods used to display species abundance distribution in different ways. One of the best known and most informative methods is the rank/abundance plot or

dominance/diversity curve. In this, species are plotted in sequence from most to least abundant along the horizontal (or X) axis. Their abundances are typically displayed in a log₁₀ format (on Y axis) so that species whose abundances span several orders of magnitude can be easily accommodated on the same graph. In addition, and in order to facilitate comparison between different data sets or assemblages, proportional or percentage abundances are often used. This simply means that the relative abundance of the each species is given as a proportion or percentage of the total.

These rank abundance plots provide us with a more accurate measure of diversity than simple diversity indices. They provide a complete picture of the distribution of species abundance. These diagrams can be drawn for the number of individuals, biomass, ground area (and other variables). It is best fit for communities of relatively few species, where a single environmental factor predominates.

5) Similarity index, (Sorensen,1948): The Sorensen index, also known as Sorensen's similarity coefficient, is a statistic used for comparing the similarity of two samples, it measure the proportion of species shared between any two plots. The formula, as applied to qualitative data, is

$$QS = \frac{2C}{A + B}$$

Where, *A* and *B* are the number of species in samples A and B, respectively,

C is the number of species shared by the two samples;

QS is the quotient of similarity and ranges from 0 - 1.

This expression is easily extended to abundance instead of presence/absence of species. After the assessment of different diversity parameters the data collected was further subjected to ordination analysis to bring out unique feature in the form of species group or linkages between different tree species.

6) Ordination technique: It is a widely-used family of methods which attempts to reveal the relationships between ecological communities. It may be defined as the collective term for multivariate techniques that arrange sites along axes on the basis of data on species composition (Ter Braak, 1987). Ordination orders objects which are characterized by values on multiple variables (i.e., multivariate objects) so that similar objects are near each other and dissimilar objects are farther from each other. These relationships between the objects, on each of several axes (one for each variable), are then characterized numerically and/or graphically. Many ordination techniques exist, including Principal Component Analysis (PCA), Non-Metric Multi Dimensional Scaling (NMDS), Correspondence Analysis (CA) and its derivatives Detrended CA (DCA), canonical CA (CCA), Bray–Curtis ordination and redundancy analysis (RDA). For the present study PCA and NMDS were chosen because of their simplicity and popularity.

6a) Principal Component Analysis (PCA):

PCA is a procedure for finding hypothetical variables (components) which account for the retrieval of maximum variance existing in multidimensional data (Davis 1986, Harper 1999). It was carried out by considering the distribution of species in the samples. The principal axis corresponding to the largest eigenvalue is the dimension that accounts for the greatest amount of variance from the sample. The second principal axis accounts for the second largest amount of variance from the sample, the third axis for

the third largest amount of variance. Plotting the taxonomic units in the space produced by the three axes gives a graphical representation of the similarity of the tree species group. In community ecology we need to find whether there are hidden factors or gradients along which our samples vary with respect to the species composition. The data cloud therefore was rotated and standardized by subtracting the mean value of the species dividing by the standard deviation. By standardizing all the species are given the same variations. PCA allows use of variables which are not measured on same group. It is often useful for analysis of sample in species or environmental space. This is because, it is likely for most environmental factors to be monotonically related to underlying factor and each other.

7) Bray-Curtis Cluster Analysis:

Cluster analysis or clustering is the assignment of a set of observations into subsets (called clusters) so that observations in the same cluster are similar in some sense. Clustering is a method of unsupervised learning and a common technique for statistical data analysis used in many fields. Cluster analysis permits the comparison of similarity among three or more communities. It is used when research is being conducted on more than one site and starts with a table or matrix giving the similarity between each pair of sites (by using any similarity coefficient). This analysis was used to compare the similarity of JFM and natural forest sites. The two most similar sites were combined to form a single cluster. The analysis was then preceded by successfully combining the similar sites until all are combined into a single figure (dendrogram). Bray-Curtis Analysis is one of the methods for Cluster analysis to assess the species assemblages in the forests using species distribution data from the site.

8) Non-metric multidimensional scaling (NMDS):

NMDS was first used as an ordination method in plant ecology by Anderson (1971). It is a set of related techniques that uses rank order information's in a matrix of dissimilarities between quadrats or species. In NMDS, points representing quadrats or species are positioned within a few dimensions or ordination axes, so that distance between the points representing quadrats or species in ordination have the same rank order as the inter point dissimilarities in the dissimilarity matrix calculated between all pairs of quadrats or pairs of species.

9) Rarefaction:

It is a technique to standardize and compare species richness computed from samples of different sizes. Rarefaction allows the calculation of the species richness for a given number of sampled individuals and allows the construction of so called rarefaction curves. Rarefaction diversity were first computed and then compared, based on their validity and the information that these values were provided in describing the forest communities in the Rajpipla area. This index relates sample size (number of organisms) with numbers of species. This was very much helpful in comparing the diversity of tree species in healthy JFM and degraded natural forest environments. Rarefaction curves were used to compare the species richness computed for samples of different JFM and natural forest sites and also for the standardizing of the sample size (Hsieh and Li, 1998).

3.2) Studies on Forest Regeneration Status:

During the ground survey, a detailed assessment of forest tree regeneration was carried out. Forest regeneration is the act of renewing tree cover by establishing young trees naturally or artificially, generally promptly after the previous stand or forest has been removed. It includes practices such as changes in tree plant density through human-assisted natural regeneration, enrichment planting, reduced grazing of forested savannas, and changes in tree provenances/genetics or tree species. Monitoring tree regeneration gives forest managers a look into what a forest will look like in the future and how resilient it will be to environmental changes. Different tree species have developed different regeneration strategies, which will make them, survive and evolve in years to come. Some trees will exist on seedlings; others will grow from the damaged tree's stumps and roots. More seedlings will develop from seeds stored in the leaf duff on the forest floor and from seed that blows in from nearby trees. Yet other seeds will be carried into disturbed areas by birds and animals.

The regeneration status of any vegetation were assessed by four main methods, they are described as follows:

- a) **Quadrat Method:** The density of seedlings and saplings is considered as an indicator of the regeneration potential (Saxena and Singh, 1984). A stratified random quadrat method was used. In each of the villages, 3 sites in the JFM plantation and natural forests were taken separately. To study regeneration seedlings, saplings and shrub, four quadrats of 2 x 2 m were taken on each site.

Quadrat size was determined by applying species area curve method (Mishra, 1974). All stands were completely and systematically surveyed thrice a year i.e., during spring, summer and autumn.

b) Counting the dead and live trees: Regeneration gets affected by many environmental factors, including invasive species, climate change, anthropogenic activities (including, cutting, logging and Forest fire) and selective browsing by cattle's. To assess the disturbance factor altering the forest regeneration status, the physical condition of every individual tree was noted under live and dead categories. The live categories involved all the individuals that are healthy, lopped, partly broken at the top or were partly dry (Patel *et al.*, 2006). The dead categories include all the individuals that are standing dead, completely dry, logged and fallen (green and dry) by wind breaks or other factors. Also, a note for occurrence of forest fire in the study area was done. All these parameter together constituted the database for regeneration status of the villages. When collecting field data, photographs of the sites were taken for archive and reference.

d) The regeneration status of trees was assessed based on density of their seedling, sapling and adult tree. The species were categorized as (i) good, if seedlings>saplings>adult (ii) fair, if seedling > sapling<adult (iii) poor, if species survives in only saplings stage but not as seedlings (though saplings may be less or equal to adult), (iv) none, if a species was absent both in seedling and sapling stage but present as adult, and (v) new, if a species was present only in seedling / sapling stage but not as adult trees (Uma Shankar 2001).

3.3) Forest Condition Studies:

Forest condition, which is sometimes equated with forest health, is a relative term that depends on how people value forests. For example, intensively managed forest plantations emphasize timber production over nontimber values such as recreational opportunities and wildlife habitat. The condition of a forest can also be determined by various other factors including species distribution, species diversity, species richness, species composition, and forest regeneration, occurrence of forest fires, pest infection / diseases, forest productivity and impact of anthropogenic activities. Some of these factors can be assessed by field methods, survey and observations like species distribution, species diversity, species richness and species composition were assessed during secondary vegetational studies, regeneration assessment was done as discussed earlier. Pest infection and diseases were identified in the form of termites infections, canopy defoliations etc. during the survey.

Human influence affects forests differently, and the magnitude of the effects will depend strongly on the methods employed and on other factors within and around the ecosystem. Status of anthropogenic pressure was recorded using ocular assessment within the sampled plots. Signs of anthropogenic pressure taken into consideration were cuttings and lopping of trees/shrub, grazing and browsing signs. Based on these records the sampled area was subjectively ranked as high, medium and low in anthropogenic pressure.

Productivity of forest was calculated by conventional measures of forest growth, i.e., Mean Annual Increment MAI of stem wood. Forest MAI is the average net annual increase in the yield (expressed in terms of volume per unit area) of living trees to a

given age and is calculated by dividing the yield of a stand of trees by its mean age (CIFOR, 1999). It is also considered as a measure of the rate at which a stand of trees accumulates merchantable volume (Morice & Lakes Innovative Forest Practices Agreement, 2003).

Calculations of MAI were done as follows:

- **Mean Annual Increment (MAI):** Volume of stand cubic meters / Average total stand age

$$\text{MAI} = \text{SWB} / \text{Y} \text{ (Ravindranath } et al., 2000)$$

Where, SWB = Standing Woody Biomass & Y = Age of the plantation

- **Standing woody biomass (t/ha)** = $(8.32 * \text{BA}) - 1.69$ (Ravindranath, 1997)

Where, SE of coefficient = 1.689, BA = Basal area (m²/ha)

- ❖ **The Forest Condition Map** was generated by considering the factors like species richness, species diversity, species regeneration, anthropogenic activities and the forest productivity (Table 6).

Table 6: Criteria's selected for studying Forest Conditions

Village	Species Diversity	MAI	Cattle Activity	Cut trees	Regeneration Rate	Forest Fire	Forest Condition Rank
Nana Raypara	10	4	4	8	2	8	8
Khutamba	10	4	6	10	6	4	10
Panchala	10	2	8	8	8	8	8
Bamanfalia	6	6	6	10	4	8	6
Medgam	8	10	8	10	6	8	10
Gadkoi	8	2	6	4	10	8	8
Kothi	4	6	8	2	6	8	8
Vanji	2	2	6	6	4	4	4
Zer	4	8	6	6	6	4	6
Drucha	10	2	4	10	4	8	10
Chatwada	8	6	2	10	8	8	8
Vaghadia	10	6	6	10	2	4	6
Bhumalia	8	4	4	10	2	4	4
Handi	8	6	4	10	8	8	8
Dochki	8	6	2	10	10	8	10
Survani	2	10	8	8	6	4	8
Khamar	8	10	6	10	4	8	10
Amba	10	6	4	10	10	8	10

These factors were rated on the scale of 1-10 based on the observed values in a particular village. These were then again categorized in five different classes viz., “Excellent”, “Good”, “Fair” when they fall within an acceptable range of variation, “Poor” if they justify concern and “Very Poor” if they require management. Each factor

is further assigned a rating for different ranges of the values based on its impact on forest condition. The typical ratings range from 1 to 10. The higher the rating, the better is the forest condition. Following Table 7, that displays the observed values of factors and their categorization.

Table 7: Categorisation of various factors for generating forest condition

Class	Scale	Species Diversity	MAI t/ha/yr	Cattle Intrusions (in a week)	Anthropogenic Activities (no. of cut trees)	Regeneration Rate (%)	Incidence of Forest Fires in a year
Excellent	8-10	0.87-01.0	2.52-3.05	2-3	3-21	80-93	0
Good	6-8	0.74-0.87	1.99-2.52	3-4	21-39	67-80	0
Fair	4-6	0.61-0.74	1.46-1.99	4-5	39-56	54-67	1
Poor	2-4	0.48-0.61	0.93-1.46	5-6	56-74	41-54	2
Very Poor	0-2	0.35-0.48	0.40-0.93	6-7	74-92	28-41	3

Excellent condition of forest is rated by 10, good by 8, fair by 6, poor by 4 and very poor by 2. The overall condition of the forest was assigned the scale, based on the scale which repeated itself in the majority of the factors. The ArcGIS 9.2 is used to compile the geospatial data and to generate the final condition map. An interpolation method was used to estimate the values at locations where no measured values are available. The general methodology is presented in Fig. 3.

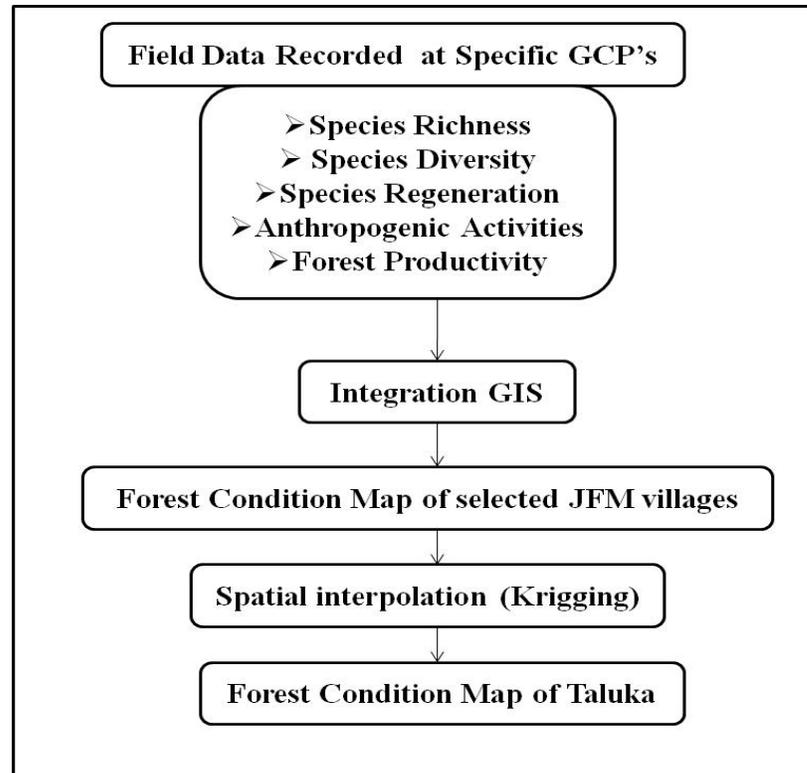


Fig 3. Methodology Flowchart for Preparation of Forest Condition Map

3.3.1) Spatial Interpolation Method: The spatial interpolation method intends to create a surface that represents the empirical reality. The technique used here included the deterministic interpolation method of the stochastic method of KRIGING in an effort to retain actual values obtained for the ecological and other socio-economic parameter. It took the exact data values for the sample points which were included in the final output surface. The datasets were mainly related to various variables like species richness, species diversity, forest regeneration, anthropogenic activities etc. ArcGIS was employed as the software for this study.

As the technique of Kriging uses weighting, it assign more influence to the nearest data points in the interpolation of values for unknown locations. It mainly

depends on spatial and statistical relationships to calculate the surface. Kriging was used to prepare the individual variable maps which finally were then integrated to generate a condition map.

3.3.2) Interpolation accuracy assessment: Errors can enter the spatial database long before any interpolation method is applied to a given data set. However by increasing the sample size improves the accuracy up to a certain level. While performing spatial interpolation often discrepancy of data is seen. To check this in the present study, a precise survey for randomly selected villages was done for assessing all the factors related to understand the forest condition, which were mentioned earlier.

3.4) JFM & Livelihood:

Indian forests are under severe pressure for meeting growing demand for fuel, fodder, grazing, timber and non-wood forest products from ever growing human population, livestock and industrial needs. The growing demand supply gap especially in meeting people's basic needs in rural area & non-involvement of locals in protection and management of forests, are the main reasons for forest degradation.

3.4A) Socio-Economic Analysis of JFM areas: To understand JFM completely the socio-economic factors were also considered. The main objective behind this assessment was to identify main areas of concerned interest of social and economic status and thereby understanding the socioeconomic structure of the study sites.

3.4.1) Socioeconomics Data Collection Method: The data was collected from the field by using both formal and informal interviews methods. There are two tools for data collection, standardized questionnaire and an additional group discussion and observation. Preparation of questionnaire is based on the variables of respective objectives of the study. Primary data collection methods included the following:

3.4.1a) Sample Design made for the survey was primarily based on analysis of many sample respondents through a canvassed structured questionnaire. The sample was constituted following the procedure of random sampling with an attempt to include persons from different forest villager's occupations and different resource endowment positions.

3.4.1b) Questionnaire: Questionnaires were used for household survey to measure general perceptions, attitudes and expectations of people related to JFM. The questionnaires are administered to the individual representative of the household. Some additional information related to the villagers socio-economic activities and culture of people, opinion of the people's participation on forest concession management are also sought from the village leader. The questionnaire also assayed to obtain information on perceptions of people on the nature of degradation and causes of degradation, methods of conservation and the role of their social customs in the depletion of natural resources (Annexure 2). Moreover, the information on problems, constraints and potential in JFM development was collected from other key informants such as village head, community leader, community member and knowledgeable individual forestry people as well. The questionnaire also attempted to elicit information on the households relating to general

particulars viz., availability of electricity, source of drinking water, mode of fuel used in cooking, ownership of land, occupation, income structure and extent of dependence on forest.

3.4.1c) Group Discussion: The informal group discussions were conducted separately. These groups included forest users, local government staffs and community committee members. This was done after data collection in order to know the reasons behind that encouragement or constraints on JFM. The interview with forest officials such as RFO, Beat Guard and other officials was also conducted to understand the structure, strategy, objectives, principles and working mechanism of JFM.

3.5) Data Analysis methods and technique for studying Socio-economics:

The data collected through an intensive field enquiry covering all members from forest protection committee (FPC) of different villages under JFM programme for measuring forest dwellers' participation in reforestation and development of forest areas. The respondents were asked a set of questions that addressed forest dwellers' participation in reforestation and development of JFM forest areas. These statements were rated on a point scale of 0 and 1, where 0 represents complete dissatisfaction and 1 shows high satisfaction levels amongst people. These statistics were then utilized for generating various factors like Degree of Satisfaction, Degree of Awareness and Degree of Participation.

3.5.1) Degree of Satisfaction: This was studied for analyzing the people's satisfaction with the present forest management. Data based on frequency of responses was divided into 5 scales: strongly satisfied, satisfied, neutral, dissatisfied and strongly dissatisfied as shown in Table 8.

Table 8: Point scale with perception factors

Point Scale	1	0.8	0.6	0.4	0.2
Satisfaction	Strongly Satisfied	Satisfied	Neutral	Dissatisfied	Strongly Dissatisfied
Awareness	Very High	High	Neutral	Low	Very Low
Participation	Always	Often	Occasionally	Rarely	Never

3.5.2) Degree of Awareness: This was used to measure the degree of people's awareness toward forestry resource preservation and management. Values are calculated based on frequency of responses, divided into 5 scales: very high, high, neutral, low and very low.

3.5.3) Degree of Participation: To measure the degree of people's participation in the process of management, degree of the participation was employed. A 5-point scale such as: always, often, occasionally, rarely and never were used to measure the degree of participation.

3.6) Non Conventional Methods: This method employed the Remote Sensing and GIS techniques for the assessment of JFM forest areas.

3.6a) Remote Sensing Data: Data used for this study can be categorized in the following two types: Earth Observation Data and Field Survey Data.

➤ **Earth Observation Data includes:**

- LISS III Image: The image was taken of the year 2001-2005.
- Satellite- IRS 1C /1D

Sensors- LISS III

- LISS IV Image of the year 2007 was used for further micro-level studies.

LISS III	LISS IV
<ul style="list-style-type: none"> • Resolution 23.5 m • Swath 127 Km • Bands 2, 3, 4 • Repetivity 25 days • Path/Row- 094/057 • Acquisition Date-May 2001,2005 	<ul style="list-style-type: none"> • Resolution 5.8 m • Swath 71 Km • Bands 2, 3, 4 • Repetivity 5 days • Path/Row- 202/072 • Acquisition Date-April 2007

<p>Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER-30M), Global Digital Elevation Model (GDEM)</p> <ul style="list-style-type: none"> • Resolution- 1ARC-SECOND • Acquisition Date- Oct 2011 	<p>Shuttle Radar Topography Mission (SRTM 90M) data</p> <ul style="list-style-type: none"> • Resolution- 90-m resolution (3 arc seconds) • Acquisition Date- Feb 2002
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3.6b) Software’s used:

i) **ERDAS IMAGINE 9.1:** ERDAS IMAGINE is the world’s leading geospatial data authoring software with raster graphic editor capabilities designed by ERDAS, Inc. It is aimed primarily at geospatial raster data processing and allows the user to prepare, display and enhance digital images for mapping use in GIS or in CADD software.

ii) ARC GIS 9.2: ArcGIS is a suite consisting of a group of GIS System Software's products produced by ESRI. ARCGIS includes the following Window Desktop software:

- **Arc Reader**, which allows one to view and query maps created with the other ArcGIS products;
- ArcGIS Desktop is licensed under three functionality levels;
- **Arc View**, which allows one to view spatial data, create layered maps and perform basic spatial analysis;
- **Arc Editor** which, in addition to the functionality of Arc View, it includes more advanced tools for manipulation of shape files and geodatabases;
- **Arc Info** includes capabilities for data manipulation, editing and analysis.

iii) Other Software – Microsoft Excel, Word, Power Point.

3.6c) Other materials used:

- (i) Hand held **GPS** (Magellan)
- (ii) The Survey of India (SOI), **topographical maps** at 1:50,000 scale was used as reference map for the base map preparation. The entire taluka is covered by four topographical maps i.e., 46G/5, 46G/9, 46G/1 and 46G/6, depicted in Spatial Framework of Study Area (Plate 7).
- (iii) **Census maps** (from Census of Narmada District) and **Cadastral Maps** provided by forest department were used for digitizing taluka as well as village boundaries.
- (iv) Camera for photography

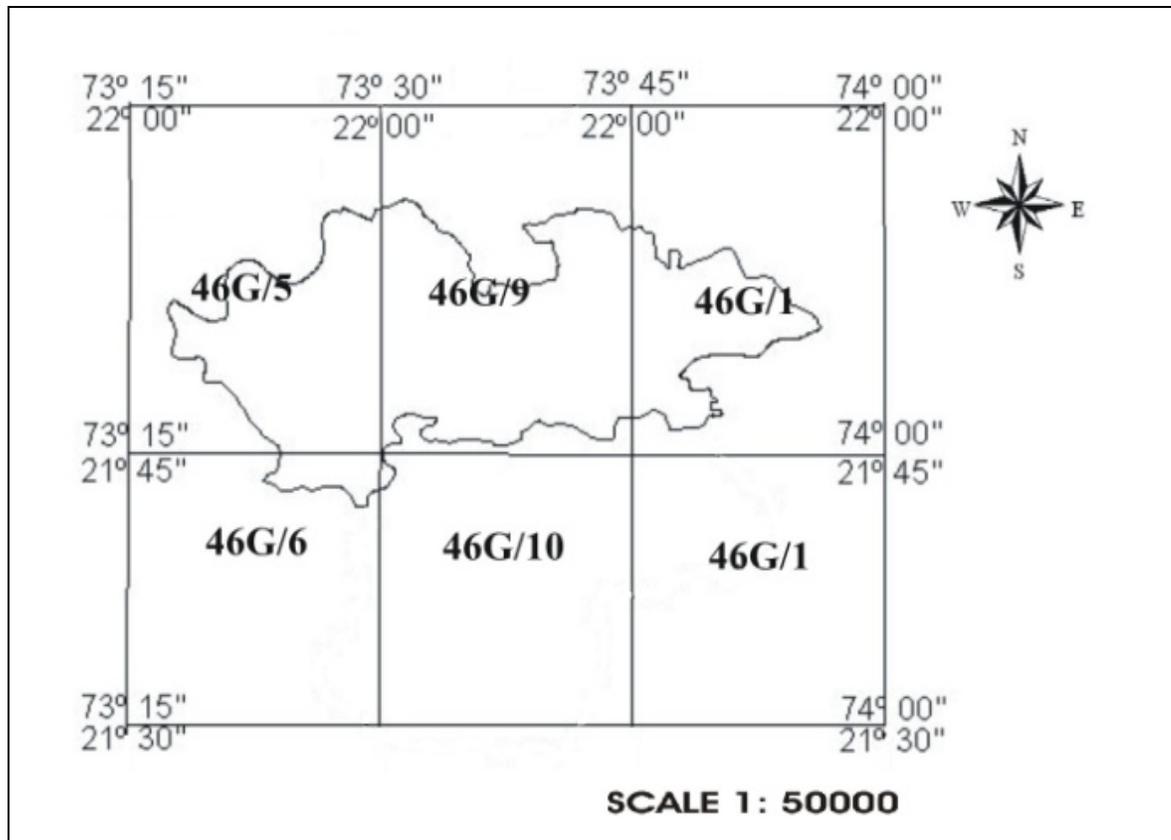


Plate 7. Spatial Framework of Study Area

3.7) Satellite Data Analysis: The satellite data, LISS III and LISS IV was imported into ERDAS IMAGINE 9.1 software and georeferenced.

The 1:50,000 topographic maps of the study area were scanned, georeferenced and projected to Geographic Lat/Long, Spheroid and Datum Modified Everest using GPS points collected in the field. The ASTER and SRTM data were originally orthorectified and therefore did not require georeferencing.

3.7.1) Subsetting: After rectification of raw image, the study area was clipped out by using “Subset” function in ERDAS 9.1.

Data Analysis: The enhanced and rectified satellite image was subjected to both visual interpretation as well as digital classification for the purpose of forest density/type classification.

3.7.2) Visual Interpretation Method: Preparation of forest vegetation and land use/cover map was accomplished through visual interpretation of satellite images on the basis of image elements like size, shape, pattern, association, tone and textural variations within a given scene. Considering these basic elements of interpretation along with ground truth and ancillary information collected during the preliminary reconnaissance survey, an interpretation key for different classes was developed (Table 9).

The difference in the reflectance of various forest cover classes is determined by spatial, spectral, radiometric and temporal resolutions. Landsat TM FCC of bands 4, 3, 2 was used for reconnaissance survey of entire area to correlate image characteristics and ground features as a standard visual technique.

Table 9. Key for visual interpretation of predominant vegetation types

No.	Classes	Tone	Texture	Association
1.	Dense forest	Deep red	Coarse	Irregular
2.	Open forest	Pinkish	Smooth	Irregular
3.	Degraded forest	Greenish-white	Smooth/ Coarse	Irregular with grains
4.	Spare tree cover with agriculture (STA)	Greenish white with scattered bright red to pink color patches	Coarse	Irregular
5.	Agriculture	Mosaic of red and deep green	Coarse	Irregular-rectangular to squarish
6.	Canal	Cyan-whitish	Smooth	Regular
7.	River	White-deep blue	Smooth	Regular

The spectral signatures for such vegetation types were ascertained and FCC was interpreted based on image elements. Ground truth was collected from study area to

identify different elements. Survey of India toposheets were also used as reference material. Based on the evidence available from images and ground information the forest density/forest type map and land use/cover map was prepared for entire study area.

3.8) Digital Image classification: In the digital classification technique all the pixels in image are categorized into different classes or themes. There are two primary types of classification algorithm applied to remotely sensed data. These are unsupervised and supervised.

In unsupervised approach the image data are first classified by aggregating them into the natural spectral grouping or clusters, present in the scene. It is most useful when no previous knowledge or ground truth data of an area is available. However, the classes determined by the algorithm still require land cover identification by an experienced analyst, which has a disadvantage in using this method. Whereas, in supervised classification, the analyst ‘supervises’ the pixel categorization process by specifying, to the computer algorithm, numerical descriptors of the various type present in a scene. Supervised classification approach was adopted for this study; as it is much more accurate method for mapping classes.

3.9) Preparation of Forest Type and Forest Density Map:

A brief flowchart of methodology has been shown to explain the method used (Fig. 4). Onscreen visual interpretation method was followed to prepare forest type and forest density map from 2001 and 2005 FCC image. Intensive field verification check was carried out and corrections were made. The reserved forest (RF) boundary was traced from the SOI maps and digitized. After creating the topology with the Arc-GIS

software, it was overlaid onto the digital data using ERDAS Imagine 9.1 software. NDVI was generated from IRS LISS III data. The density of the forest was divided into three categories according to crown closure: Dense (40% crown closure), Open (10–40%) and Degraded (10%) (Rawat *et al.*, 2003).

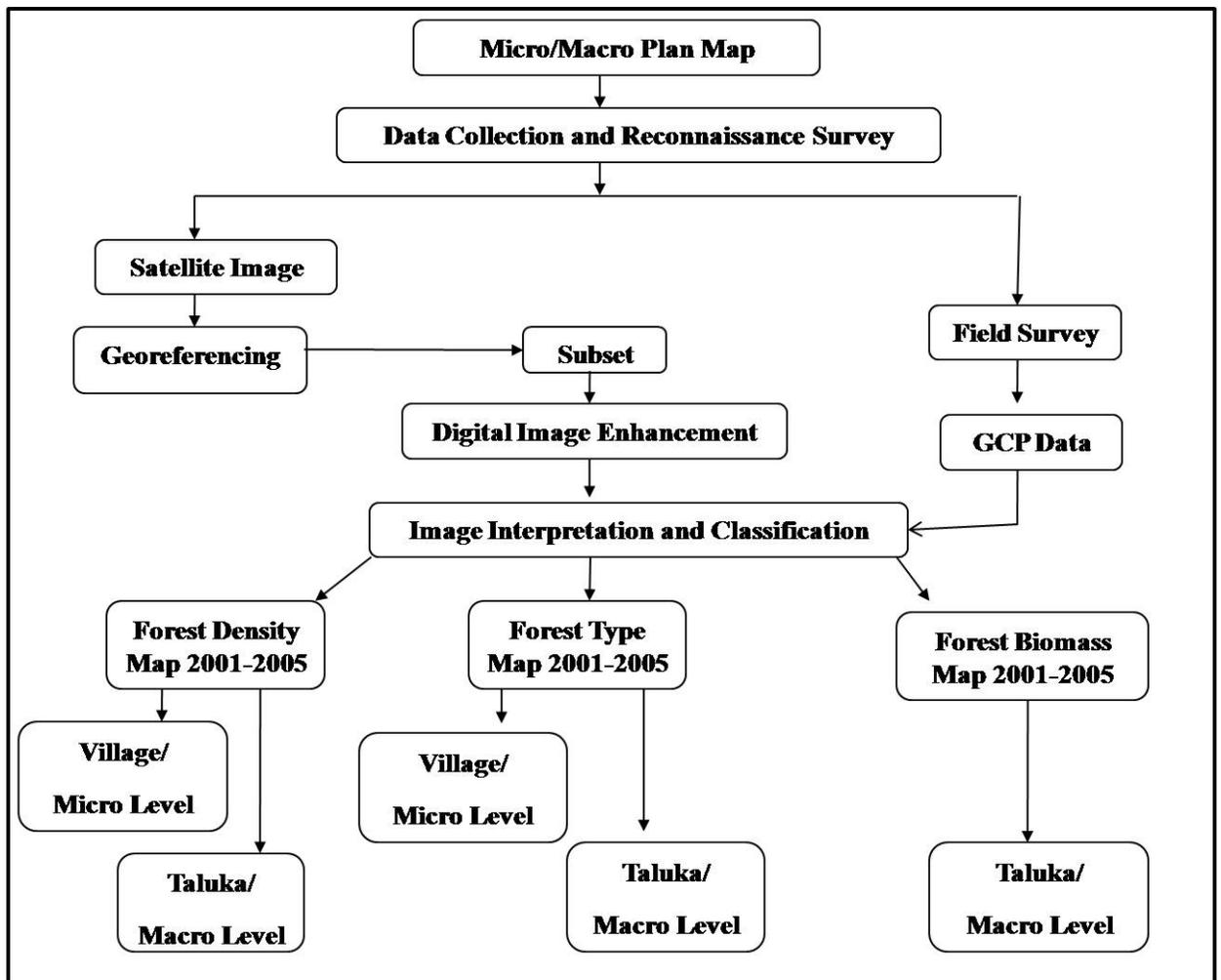


Fig 4. Micro/Macro-Plan methodology Flowchart

3.10) Preparation of Forest Biomass Map: Forest biomass is the mass of the aboveground portion of live trees per unit area. It is a basic forest property linked to productivity and forest ecosystem processes. The biomass map having the areas

producing different levels of biomass in hectares was generated integrating the satellite information and then subjecting the same to the supervised classification.

3.11) GIS based thematic Map Generation: The major primary data required for the study has been extracted from satellite images. The SOI topo maps were also used for generation of thematic layers for the study area. These maps were then digitized using ArcGIS. The four major thematic layers generated from the topographical maps are-

- Settlements
 - Forest boundary
 - Road Network
 - Rivers and Streams
- ◆ **Landuse Map:** The land use /land cover data sets are generated from the digital image classification of IRS-1D, LISS-III satellite images using Erdas Imagine software. This classification is performed taking six classes within the entire study area, namely dense forest, open forest, agriculture, unclassified, river sand and water body.
 - ◆ **Slope map** was prepared with the contour information generated from the ASTER Data of 30 meter resolution. The DEM was generated through 30 m contour lines which were obtained from SOI toposheet (1:50,000). The slope (%) was derived from DEM.
 - ◆ **Soil map** published by National Bureau of Soil Survey and Landuse Planning (scale 1:5,00,000) and geological map published by Geological Survey of India (scale 1:2,50,000) were used. The Soil map has got five categories viz; River, fine, coarse loamy, clayey and hill clayey.

The **Soil irrigability map** was created with the following categories; Land with Unsuitable for irrigation, Land with moderate irrigation, Land with severe irrigation and Land with very severe irrigation Land (others).

- ◆ **Groundwater Prospect map** was generated from the National Bureau of Soil Survey and Land Use Planning (NBSS&LUP) Atlas after proper geo-referencing.
- ◆ **Demography Map:** Using records of census information regarding demography, a GIS map was generated using graduated color scale having population class interval of 0-1000.
- ◆ **Crop Pattern Map:** The information collected by questionnaire survey and the census information were used to generate crop pattern map, which was based on suggestions and preferences about crops given by the farmers. Considering this information the crop pattern were given the ranks, like the most preferred crop pattern was given 1st rank and least preferred was given 3rd rank. These ranks were incorporated in GIS and crop pattern map was generated
- ◆ **Settlement Buffer Map:** All the settlements both inside and outside of the study area were traced and digitized. The thematic map of settlement buffer was created around each settlement for 1600m and divided equally into 4 categories with 400m intervals.

3.12) Site Suitability Analysis for JFM Sites:

Site suitability analysis has been performed using GIS based multicriteria analysis technique. Each thematic layer and its classes were assigned weights and ranks respectively based on their relative importance for suitability analysis.

3.12a) Spatial modeling: Spatial modeling was performed by following weighted overlay technique to identify suitable sites for JFM using Spatial analyst module of the ARCGIS 9.2 software. Each of the thematic layers in GIS was analyzed based on set criteria. Outputs of these thematic maps were integrated to produce the suitability map. Suitability map exhibited the suitability of different villages in the term of JFM implementation. Five classes highly suitable, moderately suitable, less suitable, very less suitable and unsuitable were generated to classify the JFM villages. Spatial modeling was performed by following weighted overlay technique to identify suitable sites for JFM using spatial analyst module of the ARCGIS 9.2 software.

3.12b) 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. 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).

$$\text{Wt. Overlay} = \text{Layer1} + \text{Layer 2} \dots n$$

$$\text{Layer1} = \text{Weightage of each class} * \text{Percentage of importance}$$

- ❖ **Weightages to each theme:** A five point rating scale was used for each theme (1 - very low, 2- low, 3 - medium, 4 - high, and 5 - very high). JFM is usually taken up in the degraded forest, therefore, weightage for dense and open forest were given zero. For land and water potential layers, weightages were assigned to each class

appropriately. Slope has been classified in five classes class 1 ranged from 0-5%, class 2 from 5-11%, class 3 from 11-17%, class 4 from 17-23 and class 5 from 23-29%. The Weightage and description of themes selected are presented in Table 10.

Table 10. Weight and description of different variables/themes selected

Thematic layers		Class Weightage	Percentage Of influence
Irritability Classification	Land Unsuitable for 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%	5	30
	5-11%	4	
	11-17%	3	
	17-23%	2	
	23-29%	1	
Settlement Buffer	400m	1	20
	800m	2	
	1200m	3	
	1600m and above	4	

The distance between the JFM plantations and village settlement is an important factor for selecting a site. Therefore a village settlement buffer was created. Class

weightage value of 5 was assigned to the nearest distance and 1 was assigned for the farthest distance. As the final output layer is discrete, the results of value in weighted overlay will be rounded to the nearest whole number.

3.13) Microplan Generation for JFM villages:

Application and utility of remote sensing and GIS for generating information about forest cover types, crown density, suitable sites for reforestation, and suitable areas for Joint Forest Management proved to be excellent in entire study and so in next step in utility of RSGIS approach in micro plan generation was made. Methodology attempted for generating this micro plan is depicted in (Fig 5).

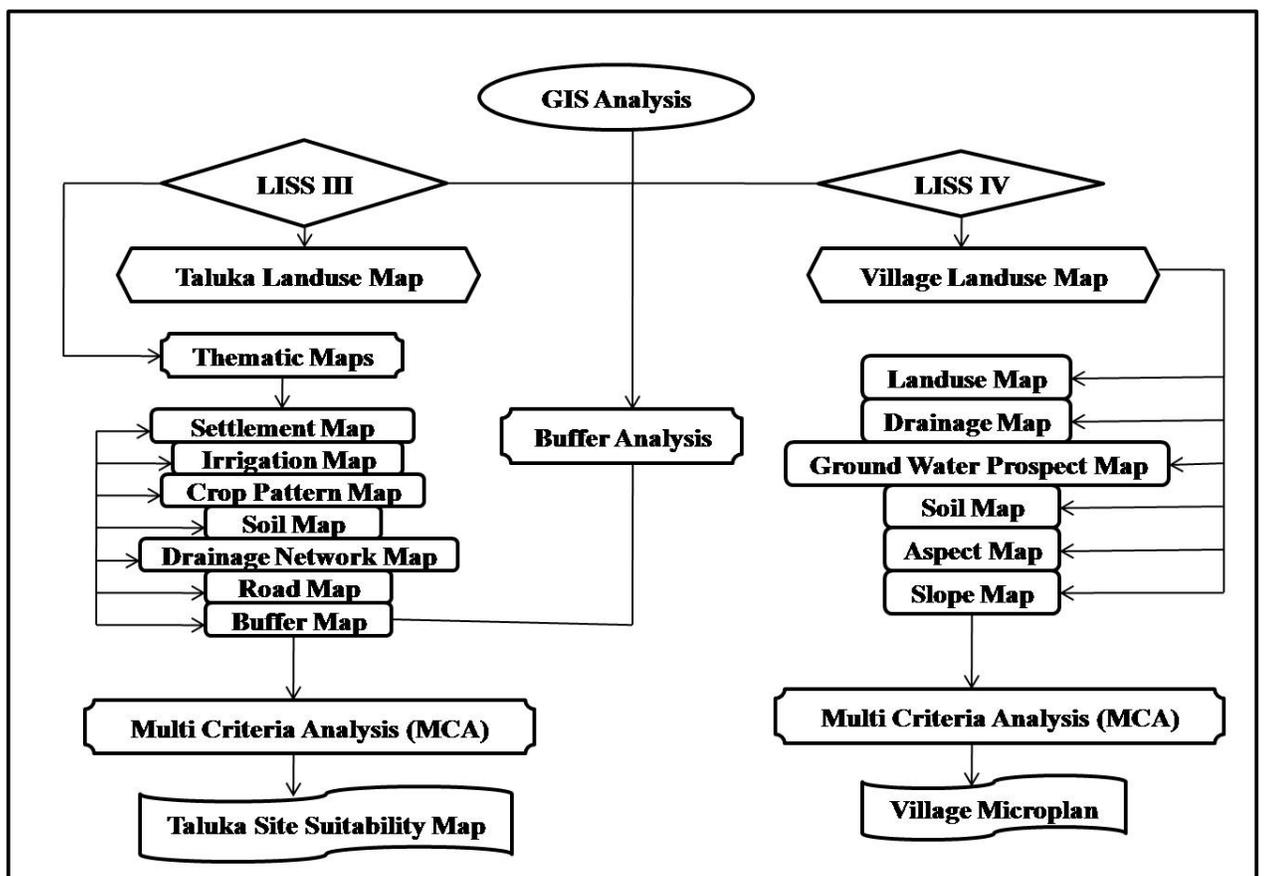


Fig 5: Methodology for Micro plan generation and Site suitability analysis

The spatial data used, consisted of satellite data as LISS III of IRS 1C of the year 2005. Thematic maps of various themes like settlement, road, irrigation, etc prepared at 1:50000 scale were taken for analysis. The village level and Taluka maps obtained from the forest department of Rajpipla were scanned, digitized and overlaid on the supervised output generated at the taluka level. The locations of JFM Plantations were collected during the field study. Each JFM boundary was rectified by virtually going around the village boundary and the JFM plantations with GPS and collecting the GCPs.

3.14) Multi Criteria Analysis (MCA):

The primary issue of MCA is concerned with how to combine the information from several criteria to form a single index of evaluation. To produce forest condition maps and village microplan maps, MCA analysis was used. This method helps decision makers to describe, evaluate, sort, rank and select or reject on the basis of evaluation based on several criteria (Sharifi, 2001). GIS software (ArcGIS 9.2) was used to facilitate this process. The purpose MCA is to condense complex problems involving multiple criteria (e.g. variables) into an optimal ranking of the best variable scenarios from which an alternative is chosen (Jiang & Eastman,2000; Malczewski 1996; Chen & Hwang 1992). In GIS, this involves a set of geographically defined criteria that meet the minimum or maximum of each of the evaluation criteria. Weights can be assigned to the criteria according to the importance of each variable.

3.14A) Spatial multi criteria decision making (MCDM):

The spatial multi criteria decision making involves evaluation of geographical events based on criterion values and the decision maker's preferences to a set of

evaluation criteria. The large number of factors causes difficulties in making spatial decisions, difficulties in attempting to acquire and process data to obtain information for making decisions. Therefore, using GIS and MCDM techniques to support the decision maker achieves greater effectiveness and efficiency of solving spatial decision problems.

3.14B) Defining the Set of Evaluation Criteria:

The evaluations of criteria are important for any decision for a problem. The general rule for selecting evaluation criteria is identified with respect to the problem. It provides a selecting the set of criteria to available data. Each criterion is represented in a criterion map.

3.14C) Generating Criterion Maps:

After establishing a set of criteria for evaluating decisions where each criterion represents as a map layer in the GIS data base. This layer is representing a criterion maps. The procedures for generating criterion maps follow the major functionality of GIS. The relevant data are acquired and stored in a GIS database, and then the data are manipulated and analyzed to obtained information on a particular evaluation criterion for multi criteria spatial decision making. (Malczewski,1999).

3.15) Creating Ecograde Map for Rajpipla Taluka:

The forest ecosystem of Rajpipla taluka was studied based on various factors which helped in generating various Ecograde of the taluka. This was done according to Amin J.V., (1990) & Pradeep G., (1998). Nine different ecogrades were created based on ground studies which involved anthropogenic activities and levels of forest degradations as mentioned in the Table.11.

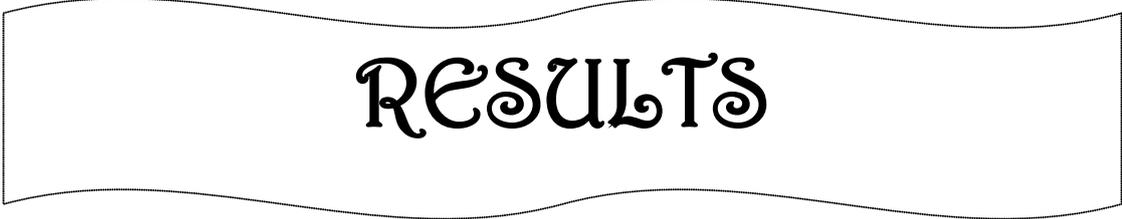
Table 11: Eco-Grades of Rajpipla Taluka

Ecograde	Remarks	Status
Ecograde1	Good forest cover, heavily wooded, very little human interference, cattle grazing and soil erosion. Canopy cover is closed, human inhabitants are very less to negligible	Excellent
Ecograde2	Open forest areas due to human disturbance and cattle pressure. Some signs of soil erosion and good diversity	Very good
Ecograde3	Moderate amount of biotic pressure, distinct thinning of forests, more settlement and cattle grazing because of the increased level of biotic pressure	Good
Ecograde4	Large areas were seen opened out, area is opened and under agriculture	Good
Ecograde5	Thinning of forest cover associated with good signs of soil erosion are observed, deterioration of natural vegetation (fair) declined species diversity, scattered tree distribution, open forests due to biotic pressure, absence of good forest patch	Considerable
Ecograde6	Very scattered tree distribution, severely damaged forest with more open canopy, more and more cattle grazing, agriculture areas, fairly good signs of soil erosion,	Poor
Ecograde7	75% of forest cover area are destroyed, scrub forest	Very poor
Ecograde8	90% of the areas are devoid of forest cover, sparse vegetation, stunted trees, fairly good amount of human population, cattle, sheep and goats	Very poor
Ecograde9	Complete deterioration of forest, undulating to flat topography, organized agriculture	Worst

It has to be noted that Ecograde categorization was done considering various different factors in addition to those mentioned by earlier workers. These factors are

forest cover, Landuse, soil erosion and biotic pressure from the human settlements. The steps followed in the Eco-Grading process are as follows:

- Determining reference conditions for each component.
- Determining the present ecological state for each component
- Determining the trend (i.e., moving towards or away from the reference condition) for each component
- Determining the causes for these.



RESULTS

4.0) Ecological Results:

The conventional ecological studies undertaken in both JFM and natural forests of Rajpipla taluka for analyzing the vegetational profile of these areas have aided in highlighting the significant difference between them in terms of floristic composition, primary and secondary vegetational parameters and species diversity.

4.1) Primary vegetation assessment:

- ❖ **Forest floristic:** During the survey of JFM plantations of Rajpipla taluka, 40 tree species were recorded belonging to 25 families. On the other hand, 29 tree species distributed in 22 families, were reported from neighbouring natural forest areas. The major families for JFM were Mimosaceae, Anacardiaceae and Combretaceae with 4 tree species each, while other major families were Burseraceae (3 species), Verbenaceae, Rubiaceae, Meliaceae, Euphorbiaceae, Sapotaceae with 2 tree species each. In natural forests the families dominant were Combretaceae and Caesalpiniaceae (3 species), others being Mimosaceae, Anacardiaceae, Ulmaceae and Papilionaceae, each with 2 species.

It is to be noted that distinct families for JFM were Simaroubaceae, Sterculiaceae, Flacoriaceae, Celastraceae, Oleaceae, Poaceae and Myrtaceae. These families were not recorded from study area natural forests. For natural forest the distinct families were Bombacaceae, Tiliaceae and Amaranthaceae showing their absence in JFM sites. The important thing which was noted was that, despite of the uniqueness of these sites in terms of presence of common or additional families, the presence of certain common dominant tree species like, *Tectona grandis* L., *Butea monosperma* Lam., *Acacia catechu* Willd. and *Dendrocalamus strictus* Nees. This

similarity of species can be attributed to rainfall distribution and similar topographic conditions. A complete listing of plant species found at JFM and natural forest areas is presented in Table 12a and 12b respectively.

Table 12a: Tree species encountered in the JFM Study area

Species	Common Name	Vernacular Name	Family	Habit
<i>Tectona grandis</i> L.	Teak	Saag	Verbenaceae	Tree
<i>Butea monosperma</i> Lam.	Flame of the forest	Khakhro, Kesuda	Papilionaceae	Tree
<i>Diospyros melanoxylon</i> Roxb.	Ebony Persimmon	Timru, Tendu	Ebenaceae	Tree
<i>Acacia nilotica</i> L.	Black babool	Baval	Mimosaceae	Tree
<i>Lagerstromia parvifolia</i> Roxb.	Crape Myrtle	Barkud	Lythraceae	Tree
<i>Terminalia crenulata</i> Roth.	-	Sadad	Combretaceae	Tree
<i>Morinda tomentosa</i> Heyne.	Indian Mulberry	Al, Aal	Rubiaceae	Tree
<i>Holoptelea integrifolia</i> Roxb.	Indian – elm	Kanjo, Audo, Kanji	Ulmaceae	Tree
<i>Anogeissus latifolia</i> Roxb.	Axle Wood Tree	Davdo	Combretaceae	Tree
<i>Boswellia serrata</i> Roxb.	Incense tree	Gugal	Burseraceae	Tree
<i>Moringa oleifera</i> Lam.	Drumstick Tree	Saragwo	Moringaceae	Tree
<i>Ailanthus excelsa</i> Roxb.	Tree of Heaven	Arduso, Moto Arduso	Simaroubaceae	Tree
<i>Terminalia chebula</i> Retz.	Chebulic myrobalan	Harde	Combretaceae	Tree
<i>Terminalia bellirica</i> Gaertn.	Belleric Myrobalan	Baheda	Combretaceae	Tree
<i>Acacia catechu</i> Willd.	Cutch Tree	Khair	Mimosaceae	Tree
<i>Melia composite</i> Willd.	Persian Lilac	Ambir	Meliaceae	Tree
<i>Flacourtia indica</i> Burm. f.	Governor's Plum	Reckel	Capparaceae	Small Tree
<i>Zizyphus mauritiana</i> Lamk.	-	Bordi	Rhamnaceae	Tree
<i>Emblica officinalis</i> Gaertn.	Indian Gooseberry	Amla	Euphorbiaceae	Tree

Table 12a contd.				
Species	Common Name	Vernacular Name	Family	Habit
<i>Azadirachta indica</i> A.Juss.	Neem	Limdo	Meliaceae	Tree
<i>Sterculia urens</i> Roxb.	Gum Karaya	Kadayo, Khadidiyo	Sterculiaceae	Tree
<i>Manilkara hexandra</i> Roxb.	Ceylon Iron Wood	Rayan	Sapotaceae	Tree
<i>Semecarpus anacardium</i> L.	Marking Nut	Bibba, Bhilva	Anacardiaceae	Tree
<i>Casearia esculenta</i> Roxb.	-	Thavad, Tandol	Flacourtiaceae	Small tree
<i>Cassine glauca</i> Rottb.	-	Aahad, Alan	Celastraceae	Tree
<i>Albizia lebeck</i> L.	Indian walnut, Parrot tree	Saras, siris	Mimosaceae	Tree
<i>Lannea coromandelica</i> Houtt.	Odina Indian Ash Tree	Moyno, Modad	Anacardiaceae	Tree
<i>Wrightia tinctoria</i> R. Br.	Sweet Indrajao	Dudhi, Kadi, Dudhkadi	Apocynaceae	Tree
<i>Madhuca indica</i> J.f Gmel.	Mowra-butter tree	Mahudo	Sapotaceae	Tree
<i>Bauhinia racemosa</i> Lam.	Mountain Ebony	Ashotri, Apto	Caesalpiniaceae	Tree
<i>Prosopis juliflora</i> Swartz. DC.	Mesquit	Gando baval	Mimosaceae	Small Tree
<i>Nyctanthes arbortristis</i> L.	Tree of sorrow, Night Jasmine	Parijat	Oleaceae	Tree
<i>Holoarrhena antidyenterica</i> L.	Indrajao	Khani, Kanaji	Apocynaceae	Small Tree
<i>Bridelia squamosa</i> Lam.	-	Asan	Euphorbiaceae	Tree
<i>Gmelia arborea</i> Roxb.	-	Seven	Verbenaceae	Tree
<i>Dendrocalamus strictus</i> Nees.	Calcutta Bamboo	Bamboo	Poaceae	Tree
<i>Eucalyptus globulus</i> Labill.	-	Niligiri	Myrtaceae	Tree
<i>Garuga pinnata</i> Roxb.	-	Kakad	Bursaceae	Tree
<i>Mangifera indica</i> L.	-	Ambo	Anacardiaceae	Tree
<i>Morinda tinctoria</i> Roxb.	-	-	Rubiaceae	Tree

Table 12b. Tree species encountered in the natural forest study area

Species	Common Name	Vernacular Name	Family	Habit
<i>Lagerstromia parvifolia</i> Roxb.	-	Barkud	Lythraceae	Tree
<i>Prosopis juliflora</i> Swartz. DC.	Mesquit	Gando baval	Mimosaceae	Small Tree
<i>Tectona grandis</i> L.	-	Sag	Verbenaceae	Tree
<i>Butea monosperma</i> Lam.	-	Khakhro, Kesuda	Papilionaceae	Tree
<i>Diospyros melanoxylon</i> Roxb.	Coromandel Ebony	Timru	Ebenaceae	Tree
<i>Madhuca indica</i> J.f Gmel.	Mowra butter tree	Mahudo	Sapotaceae	Tree
<i>Morinda tomentosa</i> Heyne.	-	Al, Aal	Rubiaceae	Tree
<i>Acacia catechu</i> Willd.	Black cutch	Baval	Mimosaceae	Tree
<i>Bombax ceiba</i> L.	Silk Cotton Tree	Shimlo	Bombacaceae	Tree
<i>Holoarrhena antidiyenterica</i> L.	-	Khani, Kanaji	Apocynaceae	Small Tree
<i>Bauhinia racemosa</i> Lam.	Mountain Ebony	Ashotri, Apto	Caesalpiniaceae	Tree
<i>Grewia tiliaefolia</i> Vahl.	-	Dhaman	Tiliaceae	Tree
<i>Lannea coromandelica</i> Houtt.	Odina	Moyno, Modad	Anacardiaceae	Tree
<i>Terminalia crenulata</i> Roth.	-	Sadad	Combretaceae	Tree
<i>Holoptelea integrifolia</i> Roxb.	Indian – elm	Kanjo, Audo, Kanji	Ulmaceae	Tree
<i>Terminalia bellerica</i> Gaertn.	-	Beheda	Combretaceae	Tree
<i>Flacourtia indica</i> Burm. f.	-	Reckel	Capparaceae	Small Tree
<i>Emblica officinalis</i> Gaert.	-	Amla	Euphorbiaceae	Tree
<i>Trema orientalis</i> L.	-	Gol	Ulmaceae	Tree
<i>Zizyphus mauritiana</i> Lamk.	-	Bordi	Rhamnaceae	Tree
<i>Milliusa tomentosa</i> Roxb.	-	Umbho	Annonaceae	Tree
<i>Mangifera indica</i> L.	-	Ambo	Anacardiaceae	Tree
<i>Azadirachta indica</i> Juss.	-	Limdo	Meliaceae	Tree
<i>Anogeissus latifolia</i> Wall.	-	Davdo	Combretaceae	Tree
<i>Pongamia pinnata</i> L.	-	Karanj	Papilionaceae	Tree
<i>Moringa oleifera</i> Lam.	-	Saragwo	Moringaceae	Tree
<i>Boswellia serrata</i> Roxb.	Incense tree	Gugal	Burseraceae	Tree
<i>Cassia auriculata</i> L.	-	-	Caesalpiniaceae	Tree
<i>Bridelia squamosa</i> Lam.	-	Asan	Euphorbiaceae	Tree

❖ **Spatial distribution of Species:** Abundance/Frequency (A/F) ratio in the plantation area showed that there is no species with regular distribution; all species had aggregated distribution. Only 3 species showed random distribution pattern (Table 13). Greater proportion of aggregated distributed species made the forest community homogenous in composition (Curtis and Coltam, 1956). In species that have aggregated distribution, individuals of the population are often attracted to one another for protection or other evolutionary adaptations (Sanford, 2007).

Table 13) Species Distribution at all JFM Sites

Species	Aggregation	
	JFM Sites	Natural Forest Sites
<i>Butea monosperma</i> Lam.	Aggregated	Aggregated
<i>Diospyros melanoxylon</i> Roxb.	Aggregated	Aggregated
<i>Lagerstromia parvifolia</i> Roxb.	Aggregated	Aggregated
<i>Acacia nilotica</i> L.	Random	-
<i>Terminalia crenulata</i> Roth.	Aggregated	Aggregated
<i>Morinda tomentosa</i> Heyne.	Aggregated	Aggregated
<i>Holoptelia intrifolia</i> Roxb.	Aggregated	Random
<i>Anogeissus latifolia</i> Roxb.	Aggregated	Aggregated
<i>Boswellia serrata</i> Roxb.	Aggregated	Aggregated
<i>Moringa oleifera</i> Lam.	Aggregated	Random
<i>Morinda tinctoria</i> Roxb.	Aggregated	-
<i>Ailanthus excelsa</i> Roxb.	Random	-
<i>Terminalia chebula</i> Retz.	Aggregated	-
<i>Terminalia bellirica</i> Gaertn.	Aggregated	Random
<i>Acacia catechu</i> Willd.	Aggregated	Aggregated
<i>Melia composite</i> Willd.	Aggregated	-
<i>Flacourtia indica</i> Burm. f.	Aggregated	Aggregated
<i>Zizyphus mauritiana</i> Lamk.	Aggregated	Random
<i>Emblica officinalis</i> Gaertn.	Aggregated	Aggregated

Table 13 contd.		
Species	Aggregation	
	JFM Sites	Natural Forest Sites
<i>Azadirachta indica</i> A.Juss	Aggregated	Aggregated
<i>Sterculia urens</i> Roxb.	Aggregated	
<i>Manilkara hexandra</i> Roxb.	Aggregated	-
<i>Semecarpus anacardium</i> L.	Aggregated	-
<i>Casearia esculenta</i> Roxb.	Aggregated	-
<i>Cassine glauca</i> Rottb.	Aggregated	-
<i>Albizia lebbeck</i> L.	Random	-
<i>Lannea coromandalica</i> Houtt.	Aggregated	Aggregated
<i>Wrightia tinctoria</i> R. Br.	Aggregated	-
<i>Madhuca indica</i> J.f Gmel.	Aggregated	Aggregated
<i>Bauhinia racemosa</i> Lam.	Aggregated	Aggregated
<i>Prosopis juliflora</i> Swartz. DC.	Aggregated	Aggregated
<i>Nyctanthus arbortristis</i> L.	Random	-
<i>Holoarrhena antidysenterica</i> L.	Aggregated	Aggregated
<i>Bridelia squamosa</i> Lam.	Aggregated	Random
<i>Gmelia arborea</i> Roxb.	Aggregated	-
<i>Dendrocalamus strictus</i> Nees.	Aggregated	-
<i>Eucalyptus globulus</i> Labill.	Aggregated	-
<i>Garuga pinnata</i> Roxb.	Aggregated	-
<i>Mangifera indica</i> L.	Aggregated	Random
<i>Tectona grandis</i> L.	Aggregated	Aggregated
<i>Bombax ceiba</i> L.	-	Random
<i>Cassia auriculata</i> L.	-	Random
<i>Trema orientalis</i> L.	-	Aggregated
<i>Pongamia pinnata</i> L.	-	Aggregated
<i>Milliusa tomentosa</i> Roxb.	-	Random
<i>Grewia tiliaefolia</i> Vahl.	-	Aggregated

The structure and composition of vegetation across various JFM and natural forest villages have been compared in terms of different primary vegetational parameters like frequency, abundance, density and basal area of major species. These parameters showed distinct features which were specific for each site (Table 14).

Table 14. Primary Analysis of JFM and Natural Forest of Rajpipla Taluka

Site	Village	Species Frequency		Species Abundance		Species Dominance		Species Density (trees ha ⁻¹)	
		JFM	Natural Forest	JFM	Natural Forest	JFM	Natural Forest	JFM	Natural Forest
Site 1	Bamanfalia	10	*	1.63	*	2469.7	*	440	*
	Medgam	11	7	2.54	2.68	7149	6312.59	600	470
	Dochki	25	20	3.89	3.66	2994.8	3719.67	1050	930
Site 2	Handi	22	*	3.36	*	3075.5	*	980	*
	Chatwada	24	*	3.24	*	3857.3	*	890	*
	Khutamba	27	13	3.16	1.32	8051.7	5298.52	670	330
Site 3	Nanaraypara	14	10	2.53	4.73	9381.7	6362.9	1170	930
	Khamar	22	*	2.76	*	7602.4	*	660	*
Site 4	Vaghadia	28	*	4.38	*	4039.7	*	1260	*
	Kothi	12	9	2.41	2.8	4786.6	3021.83	1680	790
	Bhumalia	23	*	4.98	*	4576	*	1410	*
	Gadkoi	17	11	5.34	1.86	14066.6	3021.83	1220	530
Site 5	Survani	11	*	6.66	*	14063.7	*	1990	*
	Drucha	29	*	3.30	*	6224.2	*	830	*
	Zer	14	09	5.79	3.08	15999.76	6031.80	1230	790
Site 6	Vanji	10	*	7.01	*	39387.5	*	1890	*
	Amba	31	16	2.67	2.04	3391.12	2208.96	790	510
	Panchala	24	*	3.99	*	4249.0	*	1030	*

*absence of natural forest sites

The species frequency for 50% villages ranged from 20 to 30. In the natural forests the uniformity was observed to be more with the mean incidence to be 11.87, which was 18.87 at JFM sites showing more variation in these sites. Species abundance values showed how common a particular species was in a given community. The commonness feature between JFM and natural forest with respect to tree species as revealed by abundance values, confirmed the observations of floristic survey. Species Abundance values varied from a low of 1.32/m² at Khutamba natural forest of site 2 to a high of 6.66/m² at Survani JFM forest of site 5. Frequency values for tree species like *Tectona grandis* L. and *Butea monosperma* Lam. were high. These tree species were the most frequent and dominant both at natural and JFM villages, while other species were less frequent in both cases. The reason for the reduced frequency could be related to anthropogenic activities.

❖ Species Density:

Evaluation of density-dependent status of species is important for conservation and management of forests. A 60% increase in tree density in JFM plantation sites in comparison with natural forests areas can be attributed to good protection efforts. Density of trees per hectare in different tropical forests ranged from a low value of 550 to 1800 individuals ha⁻¹ (Visalakshi, 1995) and 3700 individuals ha⁻¹ in lowland Neotropical dry forests (Gentry, 1995). The tree density was higher in the JFM areas (Less disturbed sites) compared to natural forest area (disturbed sites). The range of trees density for JFM sites was 440 to 1990 trees ha⁻¹ and for natural forest 330 to 930 trees ha⁻¹ (Table 14). These values are quite comparable to the values from studies carried out in tropical forests of Western Ghats of India i.e., evaluated 320 to 1260 trees ha⁻¹. The present result showed the density

to be higher for JFM sites than for natural forest sites. This difference of densities can be attributed to the increased percentage density for different tree species like *Tectona grandis* L. (74.63%) at Survani JFM and *Butea monosperma* Lam. (68.57%) at Kothi JFM which was just 67.53% and 46.17% respectively for Medgam and Gadkoi natural forests.

❖ **Basal Area:**

Basal area in JFM plantations ranged between 2.19 to 16.18 m² ha⁻¹. Khamar village of JFM had the highest basal area of 16.18 m² ha⁻¹. Tree basal area of natural forests on the other hand ranged between 4.36 to 16.86 m² ha⁻¹. *Tectona grandis* L. exhibited maximum basal area in both the sites. Zer natural forests had the highest basal area of 16.86 m² ha⁻¹ (Table 15). The average basal area of the trees in JFM plantations and natural forests was almost similar. A slight increase in basal area of natural forests can be attributed to the difference in altitude, species composition, age of trees and degree of disturbance and successional stages of the stands.

Species dominance varied from a low of 2208.96 at Amba natural forest of site 6 to a high of 39387.5 at Vanji JFM forest of site 6. These results can be further elaborated by IVI.

❖ **Importance Value Index (IVI):**

The Importance Value Index is imperative to compare the ecological significance of species (Lamprecht, 1989). It indicated the extent of dominance of a species in the structure of a forest stand (Curtis and McIntosh, 1951). It is stated that species with the greatest importance values are the leading dominants of the forest.

Tectona grandis L., with its increased dominance, density and abundance showed maximum IVI value of 185.47 at Kothi and 173.31 at Medgam for JFM and natural forests respectively.

Table 15. Basal Area and IVI values of dominant trees of the Study area

Site	Villages	Basal Area (m ² ha ⁻¹)		IVI (<i>Tectona grandis</i> L.,)		IVI (<i>Butea monosperma</i> Lam.)	
		JFM	Natural Forest	JFM	Natural Forest	JFM	Natural Forest
Site 1	Bamanfalia	9.17	*	120.33	*	25.08	*
	Medgam	15.66	10.63	152.97	173.31	41.06	51.49
	Dochki	8.23	9.23	54.02	80.3	44.44	-
Site 2	Handi	8.18	*	61.54	*	48.89	*
	Chatwada	9.27	*	89.37	*	47.3	*
	Khutamba	7.52	4.36	117.83	62.6	32.04	117.36
Site 3	Nanaraypara	4.26	6.22	120.33	142.92	25.08	-
	Khamar	16.18	*	-	*	90.37	*
Site 4	Vaghadia	8.25	*	50.23	*	38.47	*
	Kothi	8.37	9.13	185.47	138.23	37.38	109.09
	Bhumalia	7.56	*	85.69	*	43.70	*
	Gadkoi	4.63	5.99	148.18	104.74	-	134.17
Site 5	Survani	13.5	*	161.53	*	81.78	*
	Drucha	2.19	*	88.68	*	36.5	*
	Zer	11.30	16.86	171.37	25.92	49.7	130.01
Site 6	Vanji	2.79	*	138.62	*	-	*
	Amba	10.53	8.04	83.52	103.82	43.80	63.26
	Panchala	4.04	*	80.39	*	32.92	*

*absence of natural forest sites

This is more than the values 119.8 and 153.50 as observed by Tiwari et.al (1989) and Pande; (1999) respectively; however, *Butea monosperma Lam.*, *Acacia catechu Willd.* and *Morinda tomentosa Heyne.* the associate species exhibited IVI value of 97.3, 48.41 and 30.69 respectively at JFM sites. Whereas, *Butea monosperma Lam.*, *Holoptelia intigrifolia Roxb* and *Terminalia crenulata Roth*, with IVI values of 134.17, 44.71 and 28.8 respectively were dominant tree species in natural forests (Fig. 6a & b).

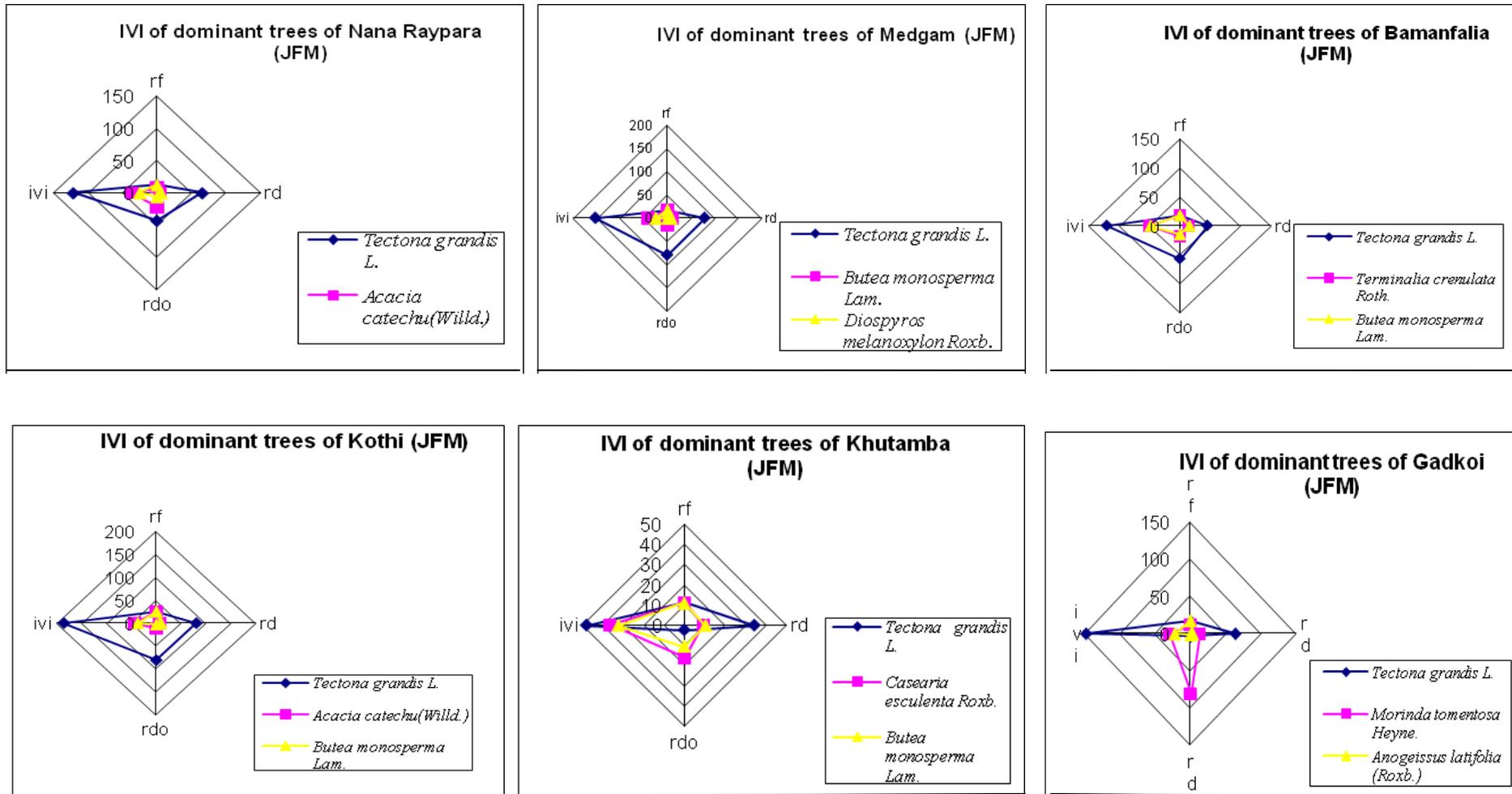


Figure 6a). IVI Phytograph of Dominant tree species of JFM areas

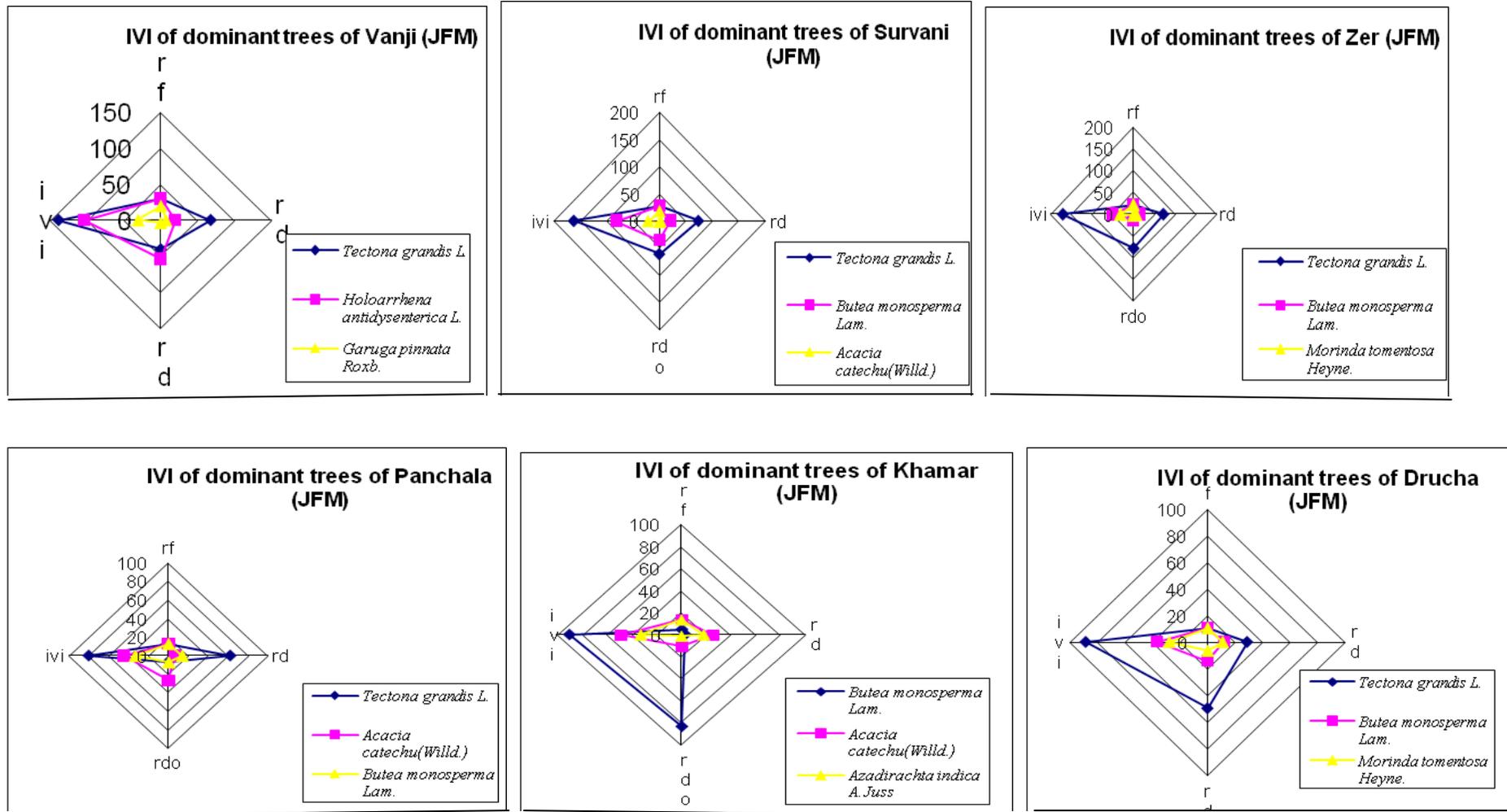


Figure 6a). IVI Phytograph of Dominant tree species of JFM areas (contd.)

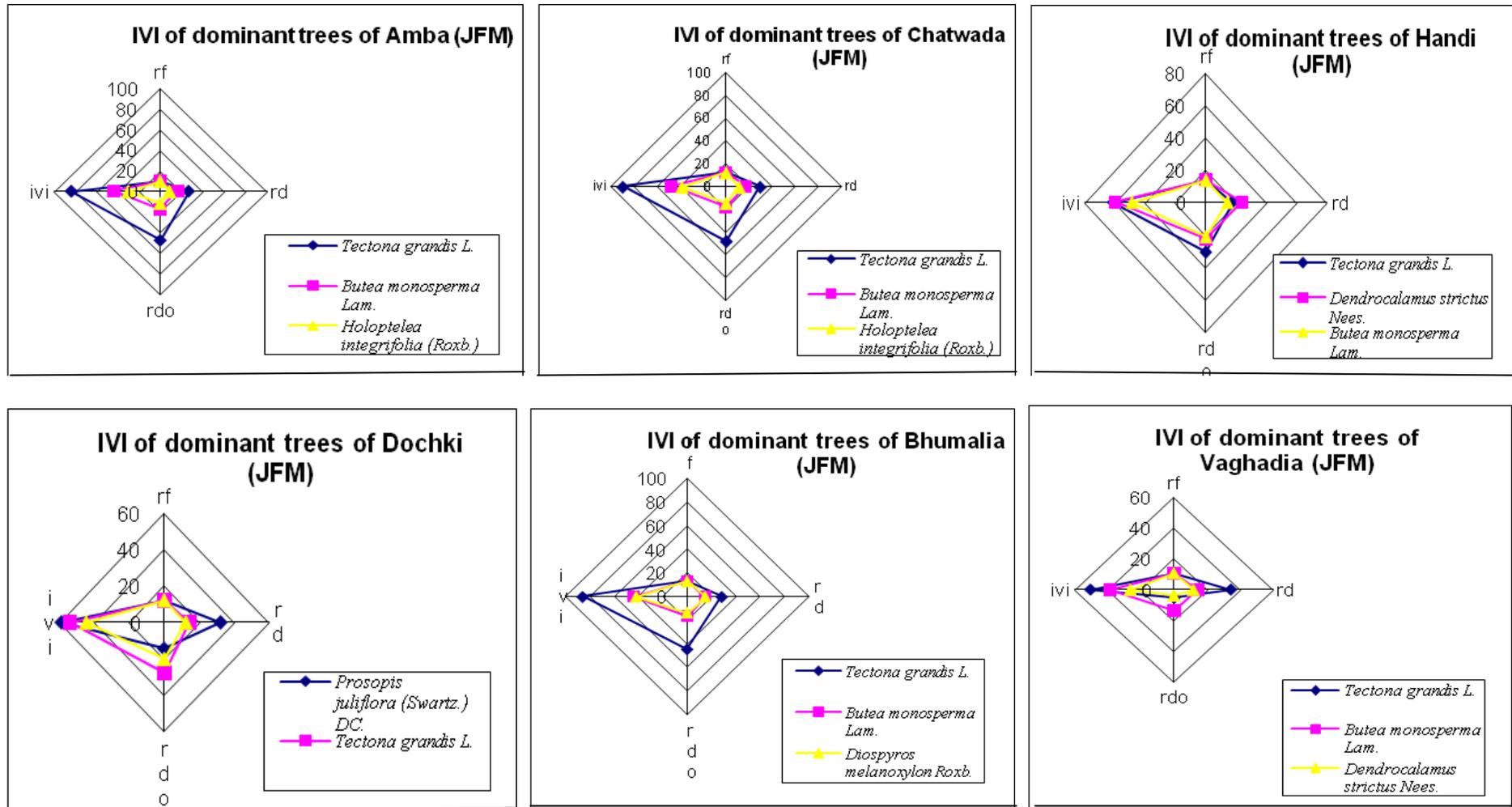


Figure 6a). IVI Phytograph of Dominant tree species of JFM areas (contd.)

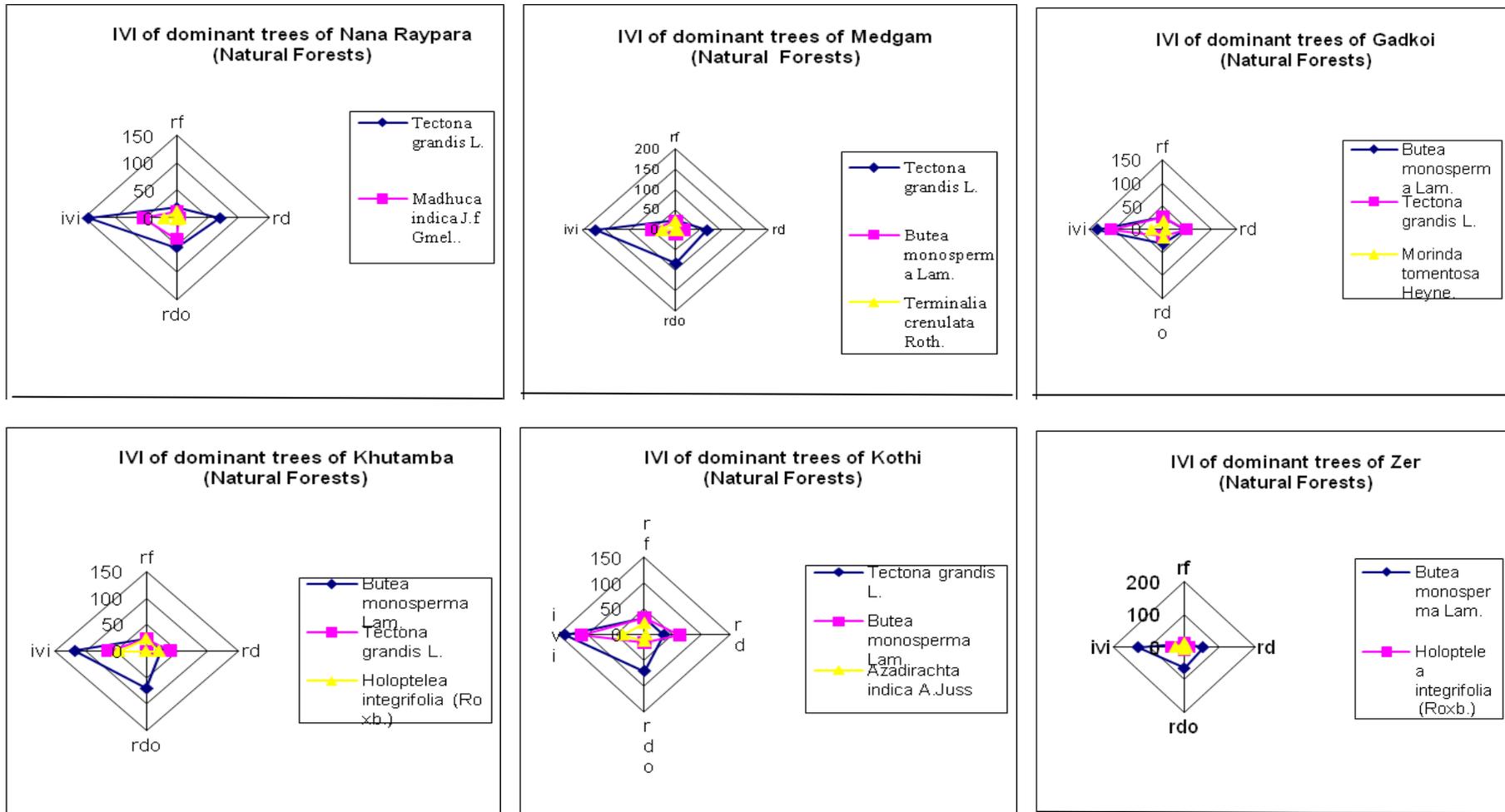


Figure 6b). IVI Phytograph of dominant tree species at Natural forest villages

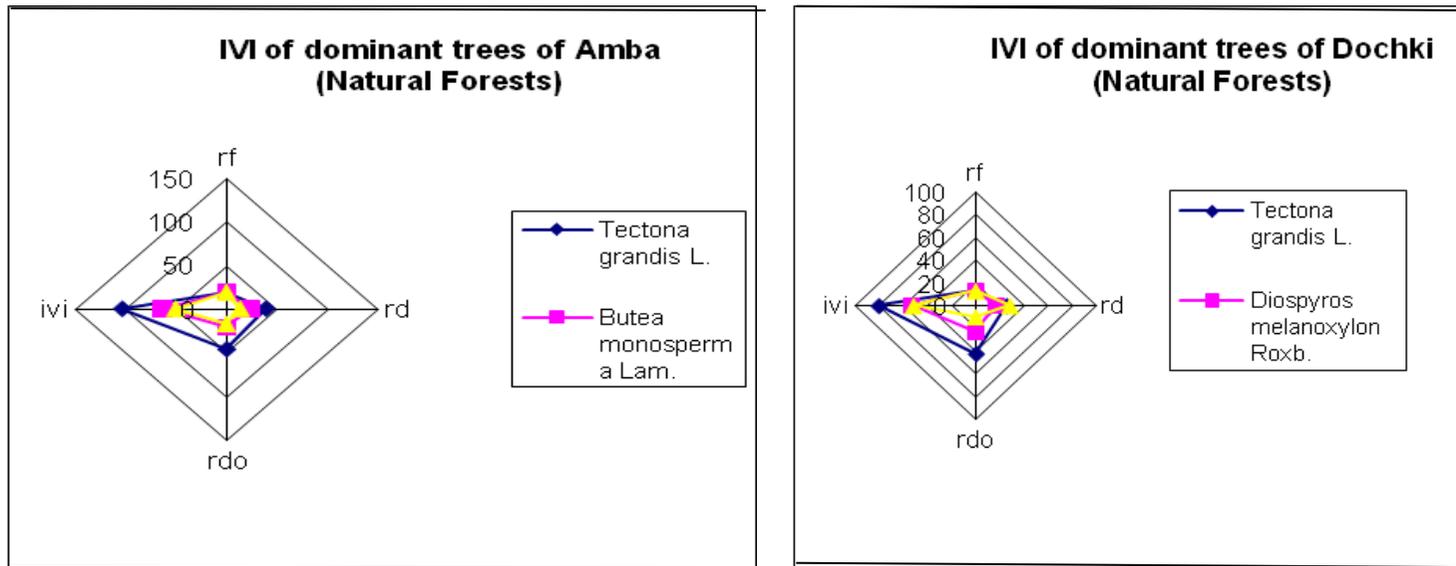


Figure 6b). IVI Phytograph of dominant tree species at Natural forest villages (contd.)

The difference in IVI among the study sites is due to the impact of disturbance. The higher IVI value indicates the utility of entire available resources by that species. The left over is being trapped by other species as competitors and associates. It indicates the dominance and ecological success of that species, in the form of its better regeneration and greater ecological amplitude. The leading dominant trees found were *Tectona grandis* L., *Butea monosperma* Lam., *Acacia catechu* Willd., *Dendrocalamus strictus* Nees., *Azadirachta indica* A.Juss, *Morinda tomentosa* Heyne., *Diospyros melanoxylon* Roxb. and *Madhuca indica* J.f Gmel., in both JFM and natural forests.

4.2) Secondary vegetation assessment:

❖ Measures of Diversity:

Each community is characterised by its species diversity, growth forms, structure, dominance and successional trend etc. There are reasons why ecologists are interested in ecological diversity and its measurement. First, diversity remains a central theme in ecology and secondly, the measures of diversity are seen as indicators of the well being of an ecological system. Investigators of ecological diversity are often restricted to species richness that is a straight forward count of the number of species present i.e. it is a measure of diversity which has been successfully used in many studies because it provides an instantly comprehensible expression of diversity.

Diversity indices also take into account the distribution of species i.e. species evenness. The frequently used index, both in theoretical and applied research is Shannon index (1949). This index seeks to characterise the diversity of a sample or community by a single number.

❖ **Species Richness:** The species richness of trees ranged from a low of 5 (Zer & Survani /Site5, Vanji/Site6, Kothi/Site4) to a maximum of 14 (Khutamba/Site2) at JFM forest area and the range for species richness at Natural forest villages was 4 (Kothi/Site4) to 11 (Zer/Site5) (Table 16). Other studies have also reported a similar range of species richness (Brockway, 1998; Tripathi, 2001). The high richness of trees at JFM may be due to diverse habitats and suitable edaphic and climatic factors supporting growth and survival of the species. The lower value of species richness in the degraded area clearly indicated its ecological poverty & the higher value of species richness clearly indicated its ecological richness. The overall picture of species richness is presented in a map using the data in spatial mode (Plate 8).

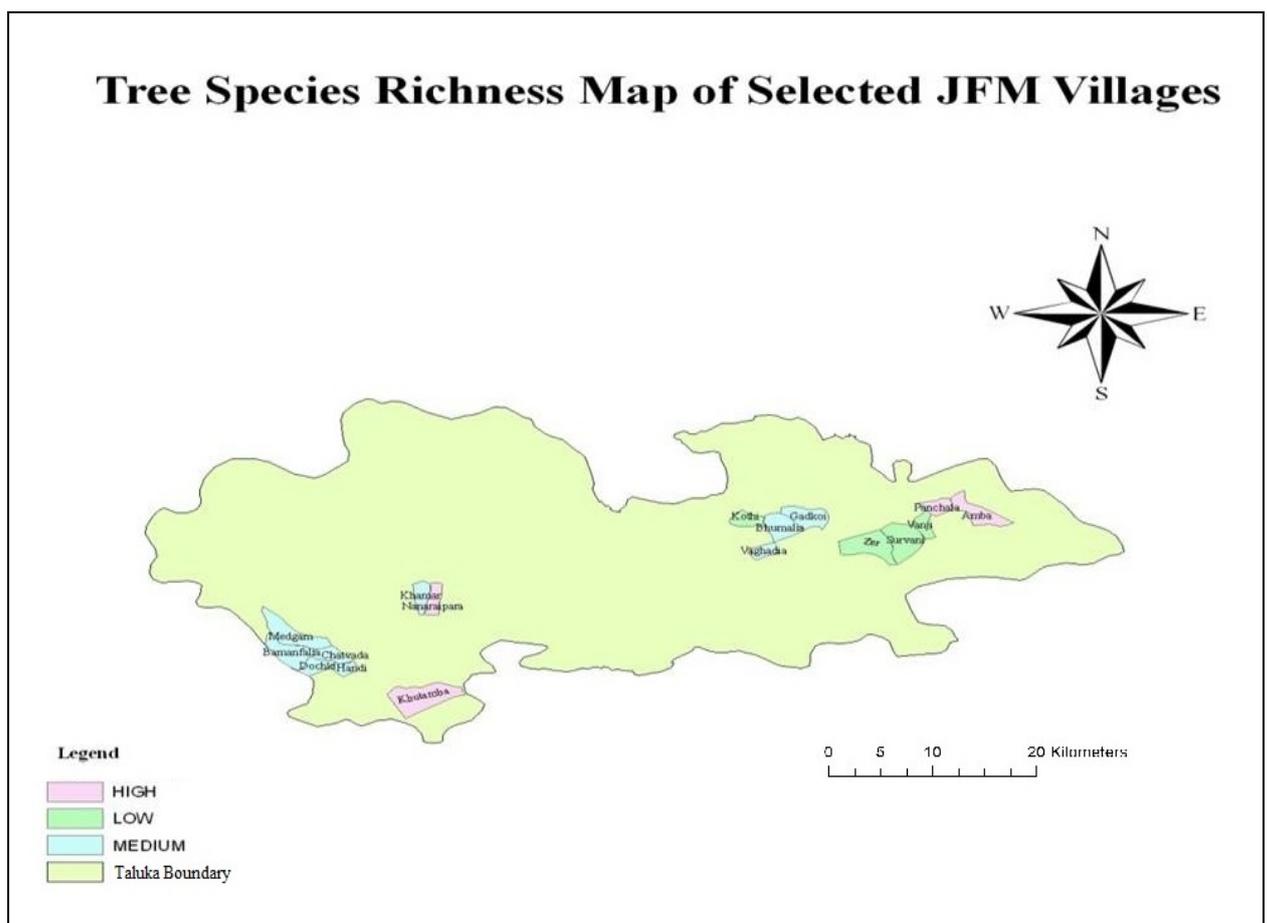


Plate 8: Tree species richness map of the selected JFM villages

❖ **Simpson Diversity Index, D:** The values of Simpson index were slightly in a high range of 0.09 to 1.10 at Khutamba & Amba JFM sites respectively. And 0.11 to 0.85 at Nanaraypara & Kothi at natural forest sites respectively (Table 16). Abundance and Simpson's diversity index were both high at JFM sites, the reason for which can be attributed to the man made culture of tree plantations at JFM, where more number of diverse trees is planted. The value of Simpson Diversity Index at JFM site coincided with those reported by Singh and Singh (1991) and Jha (1991) in the tropical dry forest communities of the Vindhyan region.

❖ **Shannon and Wiener Index:** The value for this area ranged from 0.35 (Survani/Site5) to 0.99 (Nanaraypara/Site3) at JFM site and at natural forest it ranged from 0.47 (Kothi/Site4) to 0.95 (Amba/Site6). In all JFM sites higher species diversity was exhibited when compared to natural forests (Table 16). Though the diversity index is generally high for tropical forests which is obvious from the reported range of 5.1-5.4 for young and old stands, respectively (Knight, 1975). This value for Indian forests ranges from 0.8 to 4.1 (Parthasarthy, *et al.*, 1992; Visalakshi, 1995).

Thus, the values obtained are within the reported range for Indian Tropical forest they do not match the world tropical forest figures. Jayasingam and Vivekanantharaja, in 1994 have already reasoned out for these low values. The tree diversity status of the whole taluka is depicted in the Map (Plate 9).

Table 16. Secondary vegetation analysis of the study area

Site	Villages	Species Richness		-H Diversity Index		Simpson's Diversity		H Diversity Evenness	
		JFM	Natural Forest	JFM	Natural Forest	JFM	Natural Forest	JFM	Natural Forest
Site 1	Bamanfalia	7	*	0.80	*	0.17	*	0.92	*
	Medgam	9	5	0.96	0.903	0.13	0.33	0.95	0.85
	Dochki	10	9	0.79	0.903	0.20	0.21	0.83	0.83
Site 2	Handi	8	*	0.74	*	0.19	*	0.88	*
	Chatwada	9	*	0.85	*	0.13	*	0.94	*
	Khutamba	14	6	0.72	0.602	0.09	0.26	0.92	0.83
Site 3	Nanaraypara	11	10	0.99	0.584	0.09	0.11	0.96	0.95
	Khamar	9	*	0.83	*	0.14	*	0.92	*
Site 4	Vaghadia	10	*	0.90	*	0.12	*	0.95	*
	Kothi	5	4	0.51	0.477	0.31	0.85	0.85	0.29
	Bhumalia	9	*	0.79	*	0.17	*	0.88	*
	Gadkoi	10	5	0.77	0.602	0.19	0.68	0.81	0.46
Site 5	Survani	5	*	0.35	*	0.58	*	0.58	*
	Drucha	12	*	0.98	*	0.09	*	0.94	*
	Zer	5	11	0.51	1.0	0.34	0.29	0.85	0.69
Site 6	Vanji	5	*	0.44	*	0.43	*	0.73	*
	Amba	11	7	0.95	0.951	1.10	0.21	0.95	0.89
	Panchala	13	*	0.89	*	0.16	*	0.83	*

*absence of natural forest sites

❖ **Rank Abundance Plot:** The species abundance curve showed the presence of less abundant and more abundant individuals of the study area. Rare and less frequent species are shown in the extreme tail of the graph. These species share the lower ranks in the plot because of their equality in existence in that area (Fig.7a & 7b). Usually the lower ranked species are the rare species but here the rarity is not natural but can be attributed to the polyculture plantation strategy at the JFM sites adopted by forest dept. This is also supported by the absence of less abundant species in the natural forests. The natural forests due to the absence of any conservative activities had only few abundant species.

In order to analyse the total population structure, there is a simple graphical method of expressing the relative abundance of species which is called as k dominance. In this each species is identified and counted. The abundance of each species is then plotted as a percentage of total number of individuals with the species ranked in order of decreasing dominance. This rank abundance of species are now plotted cumulatively to give k dominance curve. The k dominance plot (Fig.7a&b), drawn for comparing the assemblage of species for different sites of JFM and natural forest exhibited that the diversity is quite comparable to the assemblage of the sites in terms of their diversity though they appeared distinct in the initial stages of sampling.

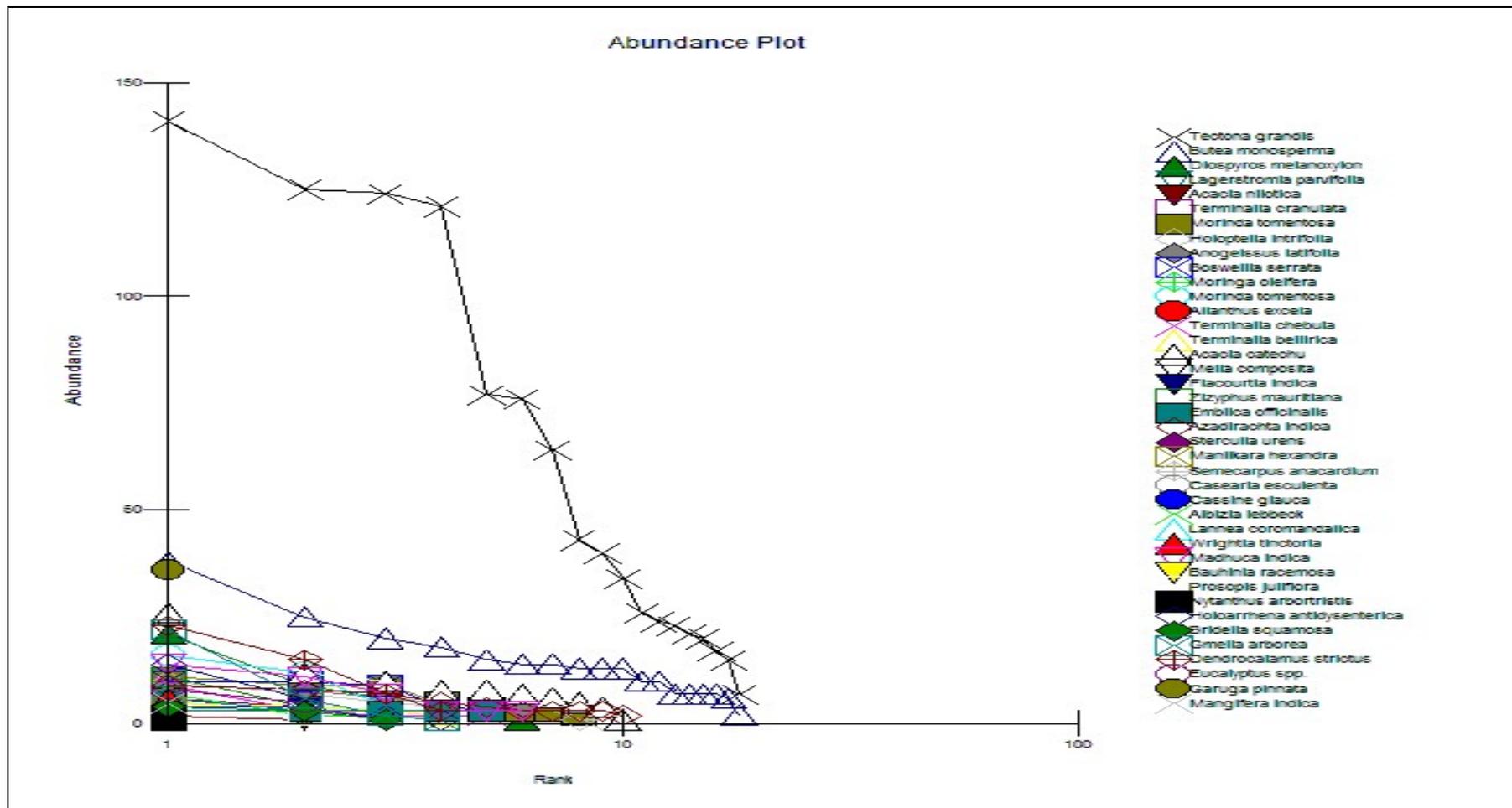


Figure 7a. Abundance Plot Curve for JFM Sites

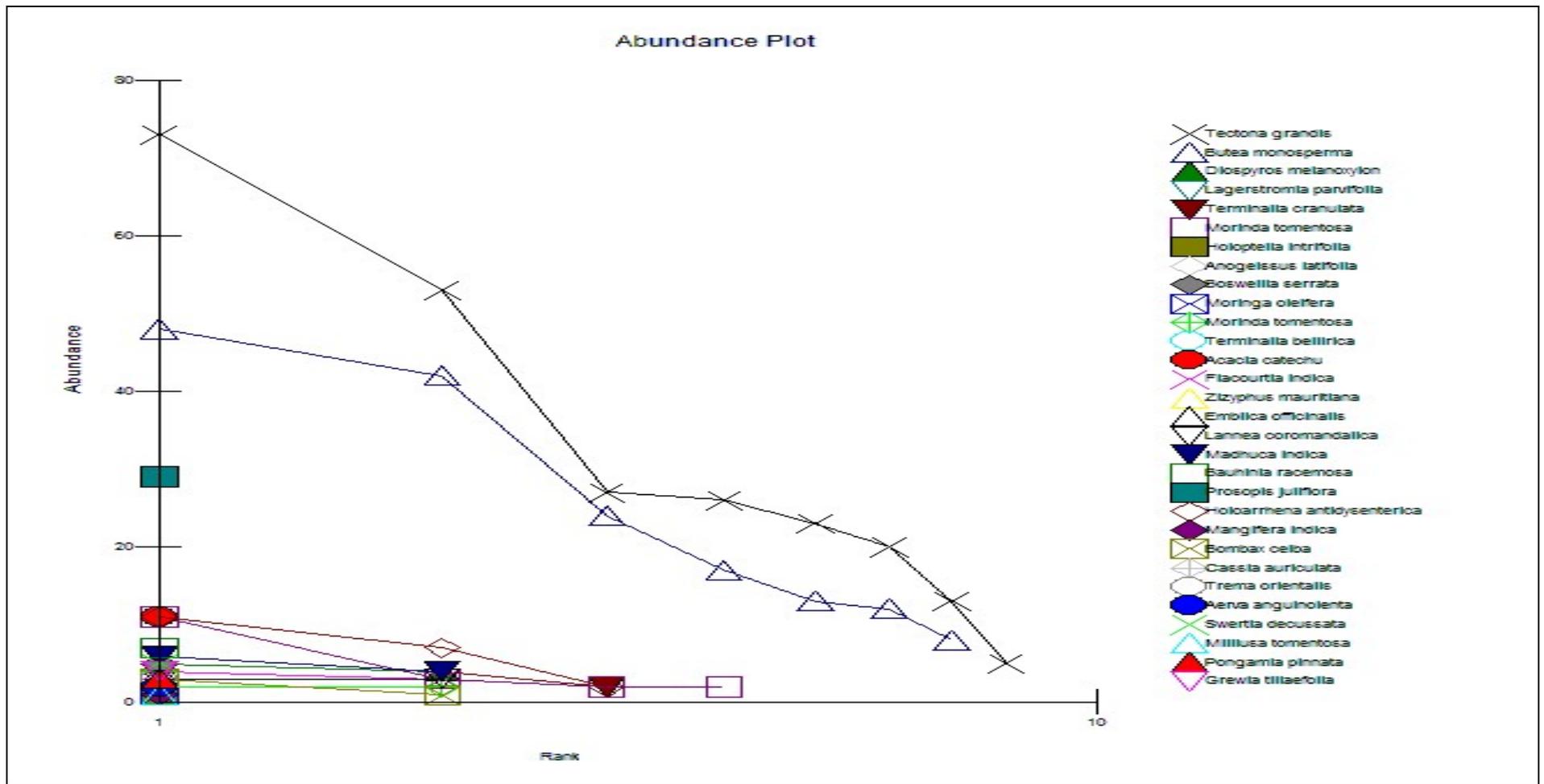


Figure 7b. Abundance Plot Curves for Natural Forest Sites

- ❖ **Similarity Indices:** Similarity indices indicate the proportion of species common to the communities being compared. Sorensen's similarity index is used to compare diversity among areas and also to compare diversity indices of the areas.
- ◆ **Sorensen's Similarity Index:** Survani and Zer JFM village were similar as they had higher similarity index where Kothi and Gadkoi natural forest villages were similar. Dissimilarity between Gadkoi and Dochki JFM and Zer and Nanaraypara natural forest villages were dissimilar (Table 17a&b). The analysis also brought out that these exhibited similarity of villages in both the JFM sites when compared to the natural site.

Table 17a. Similarity Index of JFM Villages

Villages	Medgam	Baman-Falia	Khut-Amba	Khamar	Handi	Chatwada	Dochki	Gad-Koi	Kothi	Vanji	Zer	Dru-cha	Survani	Panchala	Bhumalia	Vag-Hadia	Amba
Nanaraypara	0.31	0.33	0.25	0.60	0.42	0.40	0.38	0.38	0.37	0.25	0.50	0.34	0.50	0.41	0.40	0.38	0.36
Medgam	-	0.66	0.28	0.47	0.37	0.23	0.44	0.33	0.46	0.30	0.30	0.30	0.30	0.38	0.47	0.33	0.42
Bamanfalia		-	0.40	0.37	0.40	0.37	0.35	0.35	0.33	0.33	0.50	0.31	0.50	0.30	0.37	0.35	0.33
Khutamba			-	0.27	0.28	0.36	0.26	0.26	0.33	0.22	0.33	0.32	0.33	0.23	0.36	0.26	0.25
Khamar				-	0.35	0.53	0.42	0.31	0.42	0.28	0.71	0.47	0.71	0.54	0.44	0.42	0.40
Handi					-	0.35	0.44	0.44	0.30	0.30	0.46	0.40	0.30	0.47	0.70	0.66	0.52
Chatwada						-	0.21	0.73	0.71	0.42	0.61	0.76	0.57	0.45	0.66	0.63	0.50
Dochki							-	0.20	0.26	0.40	0.40	0.27	0.40	0.69	0.63	0.30	0.66
Gadkoi								-	0.57	0.28	0.42	0.76	0.42	0.36	0.55	0.73	0.50
Kothi									-	0.40	0.60	0.58	0.60	0.44	0.71	0.40	0.37
Vanji										-	0.40	0.35	0.40	0.22	0.28	0.26	0.25
Zer											-	0.588	1.0	0.55	0.57	0.53	0.50
Drucha												-	0.58	0.48	0.66	0.72	0.52
Survani													-	0.55	0.38	0.36	0.34
Panchala														-	0.54	0.52	0.83
Bhumalia														-	-	0.42	0.40
Vaghadia														-	-	-	0.76
Amba															-	-	-

Table17b. Similarity Index of natural forest Villages

Villages	Medgam	Khutamba	Dochki	Gadkoi	Kothi	Zer	Amba
Nanaraypara	0.42	0.26	0.33	0.14	0.15	0.10	0.12
Medgam	-	0.54	0.28	0.40	0.44	0.25	0.33
Khutamba		-	0.26	0.36	0.40	0.35	0.46
Dochki			-	0.42	0.46	0.20	0.37
Gadkoi				-	0.66	0.25	0.50
Kothi					-	0.40	0.54
Zer						-	0.33
Amba							-

- ❖ **Ordination Techniques:** “Ordination” is a collective term for multivariate techniques, it serves to summarize community data by producing a low-dimensional ordination space in which similar species and samples are plotted close together, and dissimilar species and samples are placed far apart.

- ❖ **Principal Component Analysis (PCA):** The total variation accounted for the PCA in JFM on species composition was approx 17.5%. The first component PC I contributed to about 50% of variation distributed species. It has also been noticed that *Tectona grandis* L., *Butea monosperma* Lam., *Morinda tomentosa* Heyne and other 16 species were contributing maximum in the variance in all the three axes of JFM (Fig 8a & b).

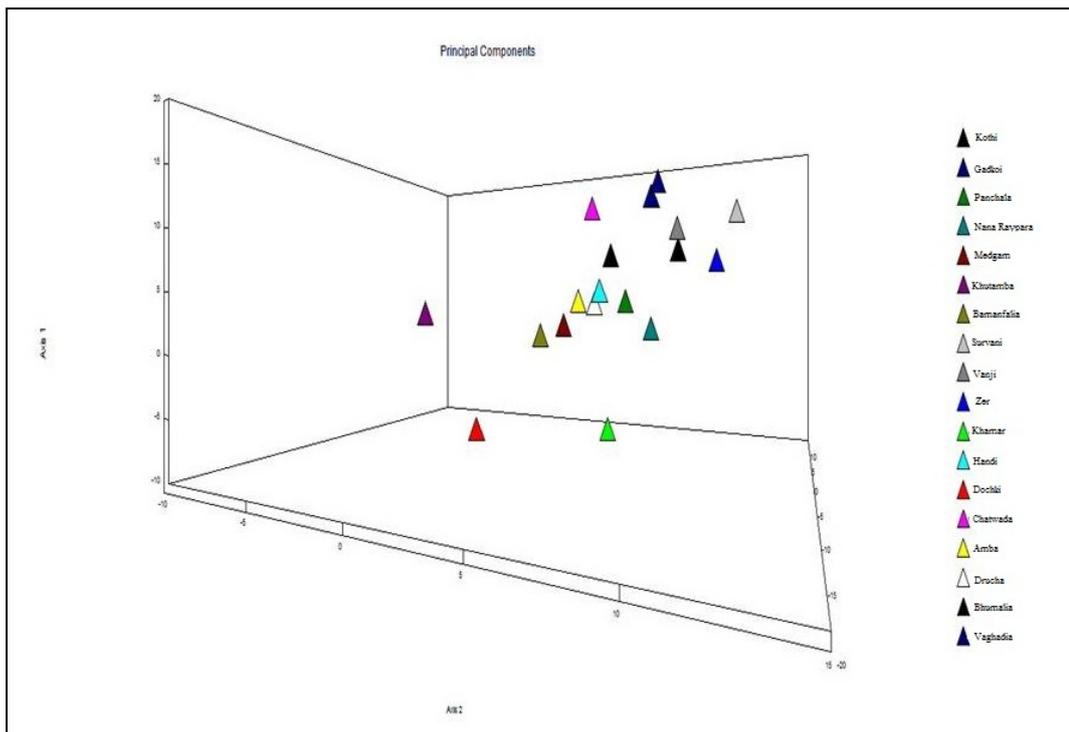


Figure 8a. PCA analysis in JFM area

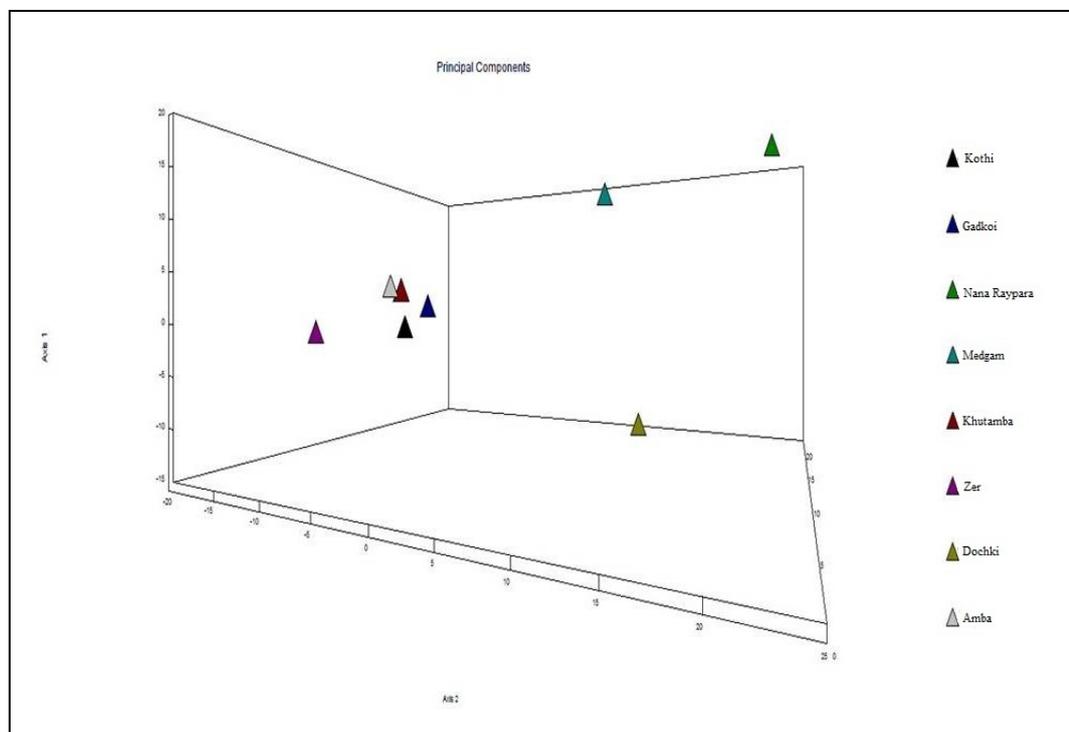


Figure 8b. PCA analysis in Natural Forest area

In case of natural forest maximum variance extracted was about 22% approximately. The first PCA component contributed maximum to this variation. 7 species viz., *Tectona grandis* L., *Terminalia crenulata* Roth, *Flacourtia indica* Burm. f., *Zizyphus mauritiana* Lamk, *Trema orientalis* L., *Aerva sanguinolenta* L. and *Azadirachta indica* Juss., all were positively contributing without the dominance of any specific tree in all the three axes. Moreover, such diversity was more in the Gadkoi and Survani JFM sites and Nanaraypara and Medgam natural forest sites appears to be contributing to the diversity.

The principal component analysis which was used to interpret and highlight the major variations within the natural and JFM sites indicated a clear distinction between these sites in terms of their species. PCA axis 1 accounted for maximum variation in both the sites and there occurred variation in dominant species this axis. In natural forest *Tectona grandis* L. and *Diospyros melanoxylon* Roxb. contributed to the variation but in JFM only *Butea monosperma* Lam. and *Acacia catechu* Willd., were dominant. Earlier primary studies brought out *Tectona grandis* L. as dominant species but the PCA studies highlighted that the dominance of *Tectona grandis* L. was due to the equal contribution of the species in all the principal axes.

❖ **Cluster Analysis and non-metric multidimensional scaling (NMDS):** The number of tree species observed to be distributed in entire area was 69. Out of which 40 species were found in JFM and 29 species were found in natural forests. This diversity of species in JFM and natural forest were distributed over 18 different villages, which when analysed for cluster analysis using Bray-Curtis similarity index suggested three major groups with smaller other overlapping groups in natural forests (Fig. 9 a&b).

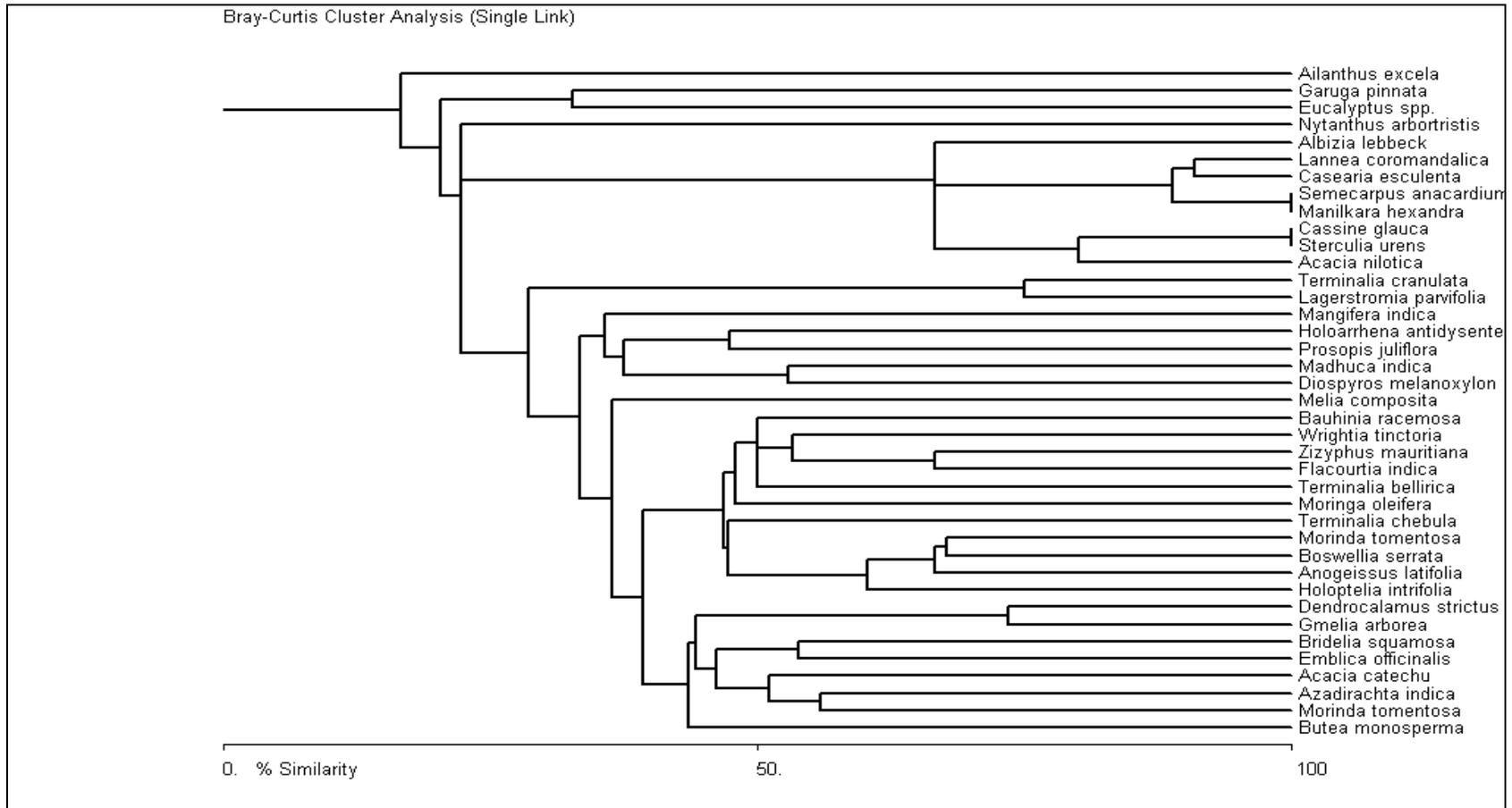


Figure 9a. Bray-Curtis Cluster analysis for JFM area

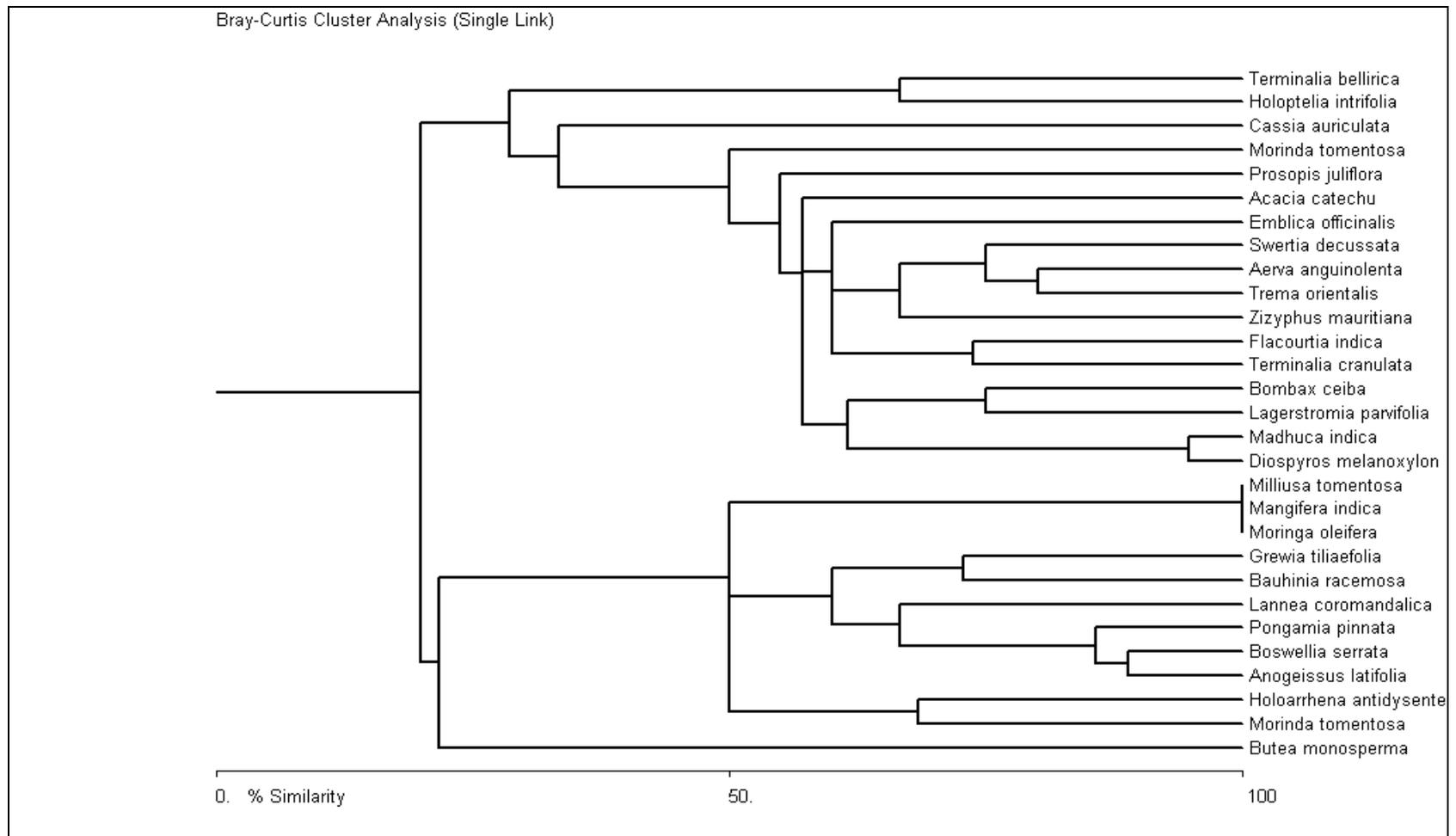


Figure 9b. Bray-Curtis Cluster analysis for natural forest area

The non-metric multidimensional scaling (NMDS) on this data confirmed three groups in natural forests. But in JFM plantations there were no such distinct group formation (Fig 10 a&b). Each species emerged out separately or was linked with one or two species due to the polyculture plantation strategy. This was explained by the radiating lines originating from a single line generated when the data was subjected for NMDS.

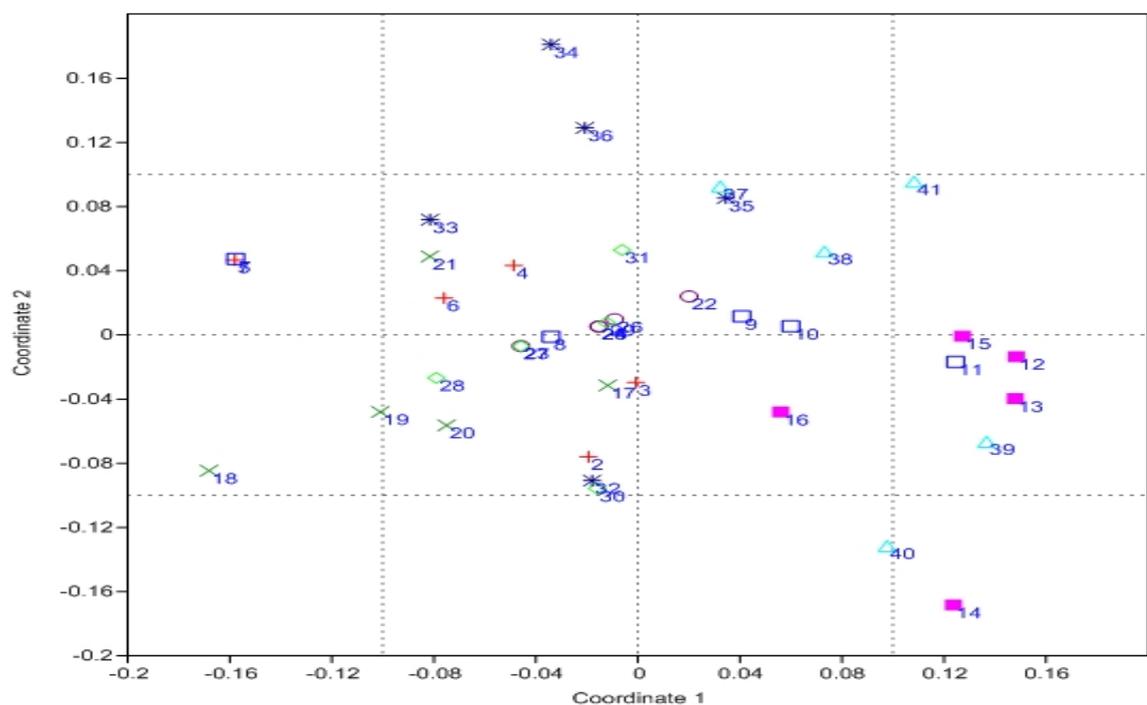


Figure 10a: NMDS Plot for JFM and Natural forest villages

(1-*Tectona grandis*, 2-*Butea monosperma*, 3-*Diospyros melanoxylon*, 4-*Lagerstromia parvifolia*, 5-*Acacia nilotica*, 6-*Terminalia crenulata*, 7-*Morinda tomentosa*, 8-*Holoptelia intrifolia*, 9-*Anogeissus latifolia*, 10-*Boswellia serrata*, 11-*Moringa oleifera*, 12-*Morinda tomentosa*, 13-*Ailanthus excelsa*, 14-*Terminalia chebula*, 15-*Terminalia bellirica*, 16-*Acacia catechu*, 17-*Melia composite*, 18-*Flacourtia indica*, 19-*Zizyphus mauritiana*, 20-*Embllica officinalis*, 21-*Azadirachta indica*, 22-*Sterculia urens*, 23-*Manilkara hexandra*, 24-*Semecarpus anacardium*, 25-*Casearia esculenta*, 26-*Cassine glauca*, 27-*Albizia lebeck*, 28-*Lannea coromandalica*, 29-*Wrightia tinctoria*, 30-*Madhuca indica*, 31-*Bauhinia racemosa*, 32-*Prosopis juliflora*, 33-*Nytanthus arbortristis*, 34-*Holoarrhena antidyserterica*, 35-*Bridelia squamosa*, 36-*Gmelia arborea*, 37-*Dendrocalamus strictus*, 38-*Eucalyptus spp.*, 39-*Garuga pinnata*, 40-*Mangifera indica*)

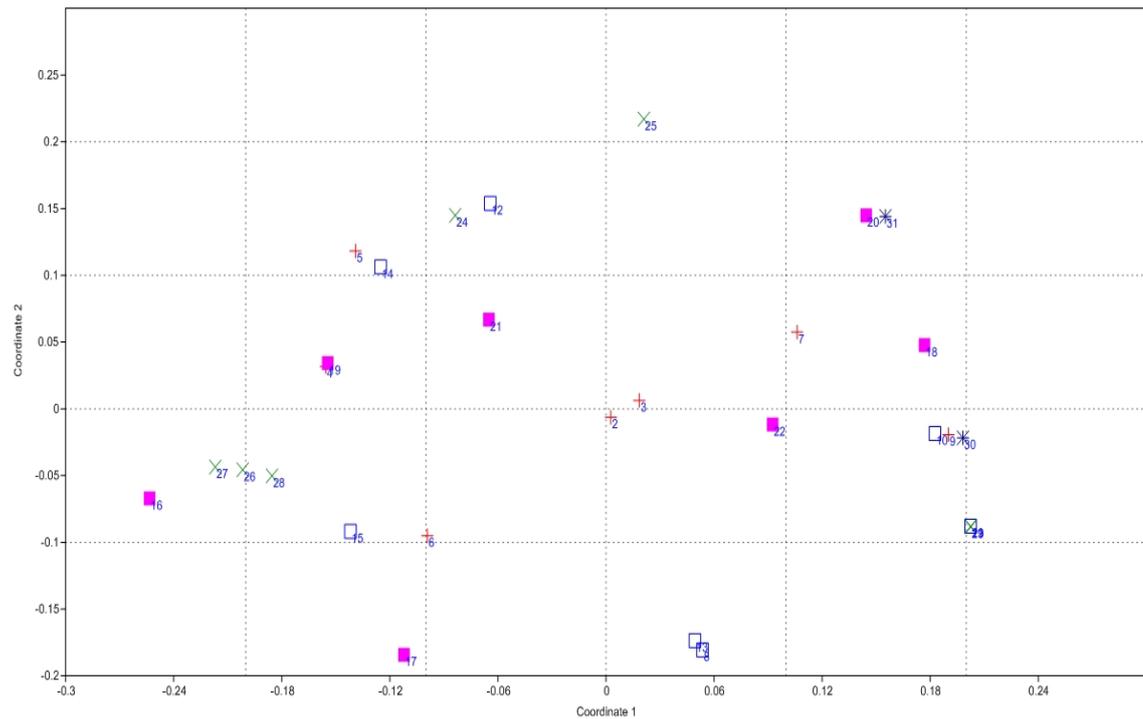


Figure 10b: NMDS Plot for JFM and Natural forest villages

(1-*Tectona grandis*, 2-*Butea monosperma*, 3-*Diospyros melanoxylon*, 4-*Lagerstromia parvifolia*, 5-*Terminalia crenulata*, 6-*Morinda tomentosa*, 7-*Holoptelia intrifolia*, 8-*Anogeissus latifolia*, 9-*Boswellia serrata*, 10-*Moringa oleifera*, 11-*Morinda tomentosa*, 12-*Terminalia bellirica*, 13-*Acacia catechu*, 14-*Flacourtia indica*, 15-*Zizyphus mauritiana*, 16-*Emblica officinalis*, 17-*Lannea coromandalica*, 18-*Madhuca indica*, 19-*Bauhinia racemosa*, 20-*Prosopis juliflora*, 21-*Holoarrhena antidysenterica*, 22-*Mangifera indica*, 23-*Bombax ceiba*, 24-*Cassia auriculata*, 25-*Trema orientalis*, 26-*Aerva anguinolenta*, 27-*Swertia decussate*, 28-*Milliusa tomentosa*, 29-*Pongamia pinnata*, 30-*Grewia tiliaefolia*)

❖ **Rarefaction:** Rarefaction represents a powerful analytical approach in ecology for estimating the expected number of species within a given study area. Rarefaction curves are directly related to the environmental heterogeneity of the area sampled. In the present study the rarefaction curves of the tree species showed close similarity in the sampling patterns for the tree species diversity between villages of JFM sites (Fig.11 a) and also in the villages of natural forest sites (Fig.11 b).

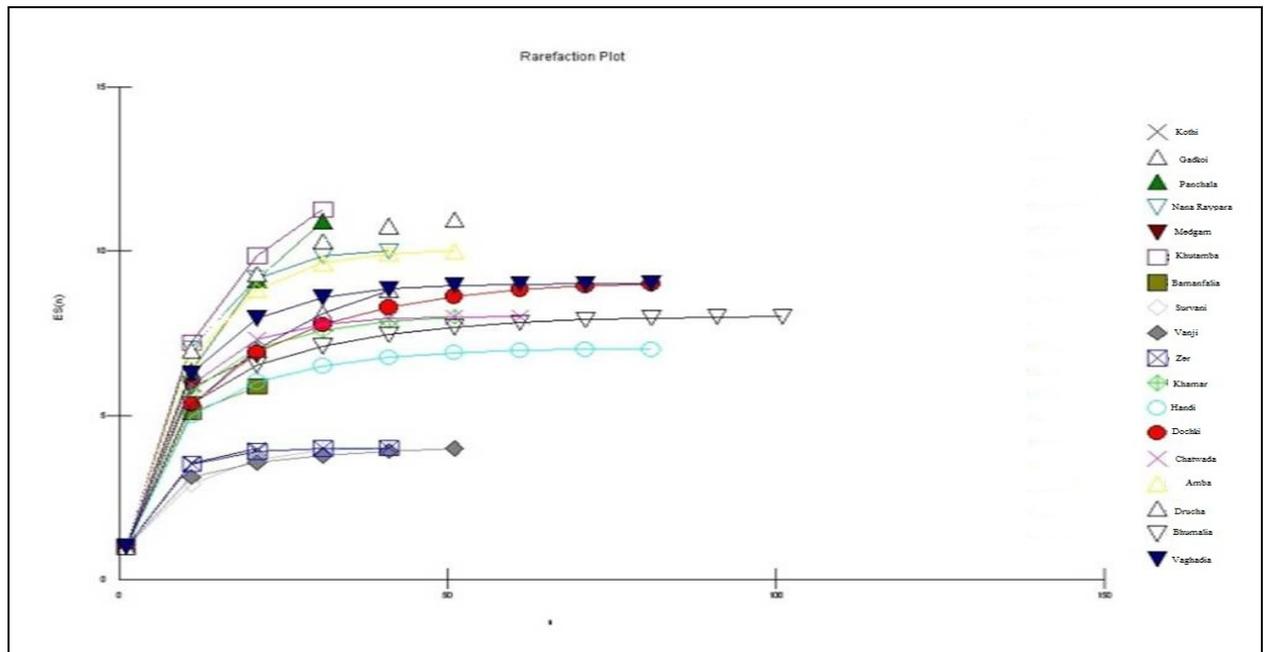


Figure 11 a. Rarefaction Plot of JFM area

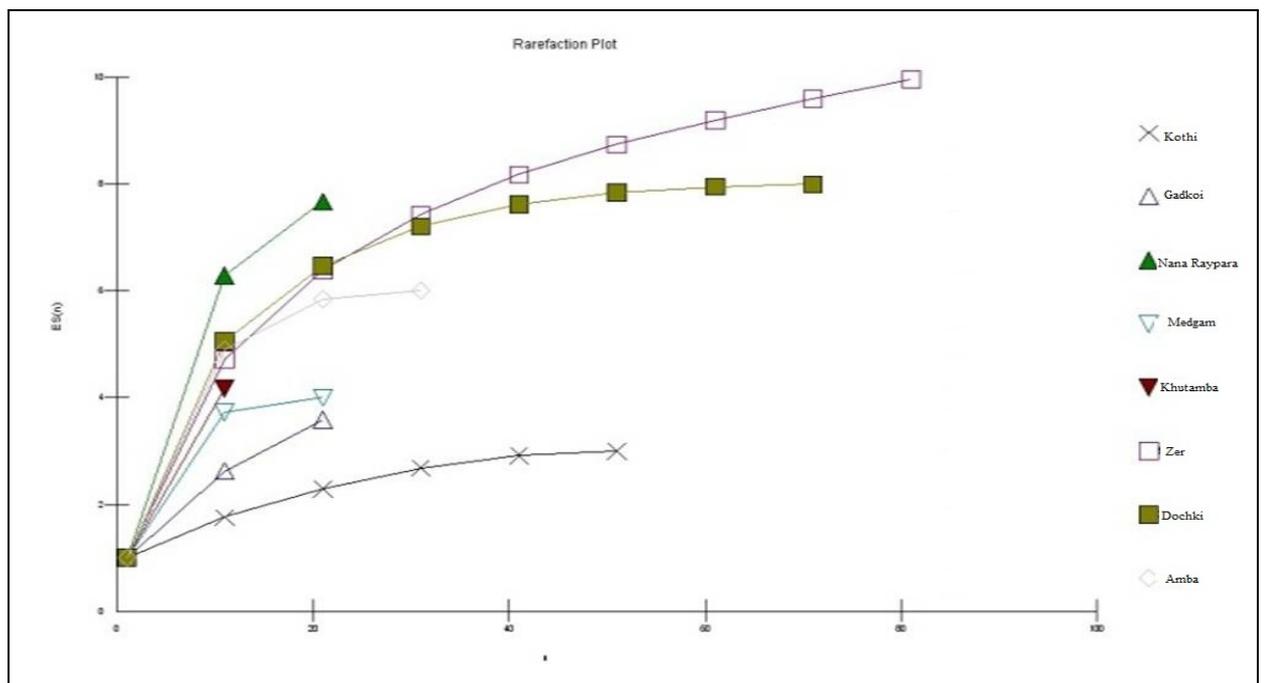


Figure 11 b. Rarefaction Plot of natural forest area

The overall vegetational structure in these sites can be considered to represent the complete vegetational profile of the study area. These revealed that for the JFM sites, in the initial stage of sampling, the curves were steeper indicating that more

intense sampling is required to discover more species diversity in the area. However the curves becomes stable and flatten at Gadkoi, Nanaraypara, Amba, Vaghadia, Dochki, Vanji, Bhumalia, Handi and Zer indicating the sampling to be reasonably good and increase in sampling would not yield any further additional diversity. At Khutamba and Panchala the curves were still getting elevated indicating the possibility of discovering more diversity in the added sample.

4.3) Regeneration Status Analysis:

The population structure, characterized by the presence of sufficient population of seedlings, saplings and adults indicated the future composition of a community and successful regeneration of forest species. Regeneration status of trees can also be predicted from the age structure of their populations. The three regeneration means viz., seedling, sapling and coppicing ability of the tree were showing higher values in all the villages of JFM when compared to the natural forest sites, except for the coppice formations which was more in Nanaraypara and Zer natural forest sites. The increased seedling, sapling and coppice densities in the JFM sites exhibited the favourable environment for forest regeneration (Plate 10). It was also observed that regeneration from vegetative sprouts was dominant in the intensively disturbed sites. Out of the total JFM villages, 33% of the JFM sites showed good regeneration rate whereas in case of natural forest site only 12% showed good rate of regeneration. Regeneration was good in species of *Tectona grandis* L., *Madhuca indica* J.f Gmel., *Butea monosperma* Lam. and *Azadirachta indica* A. Juss.



i)Seedlings

ii) Saplings



iii)Coppices

Plate 10. Seedling, Sapling and Coppices of different tree species in the study area

The density of seedlings, saplings and coppices of species found in the JFM area during the time of survey are presented in Table 18.

Table 18. Number of Seedlings, Saplings and Coppices of tree species per sq.mt in the area

Site	Villages	Seedlings/ m ²		Saplings /m ²		Coppices/ m ²	
		JFM	Natural Forest	JFM	Natural Forest	JFM	Natural Forest
Site 1	Bamanfalia	07	*	03	*	14	*
	Medgam	31	15	17	05	09	09
	Dochki	131	126	115	43	17	10
Site 2	Handi	57	*	53	*	23	*
	Chatwada	70	*	52	*	14	*
	Khutamba	93	17	73	03	10	04
Site 3	Nanaraypara	127	17	118	07	0	17
	Khamar	17	*	12	*	11	*
Site 4	Vaghadia	72	*	15	*	21	*
	Kothi	172	41	170	13	18	05
	Bhumalia	143	*	26	*	09	*
	Gadkoi	175	117	140	39	25	11
Site 5	Survani	93	*	26	*	0	*
	Drucha	37	*	29	*	09	*
	Zer	61	23	27	21	0	25
Site 6	Vanji	51	*	16	*	31	*
	Amba	97	53	80	13	03	11
	Panchala	139	*	127	*	33	*

* absence of natural forest sites

The spatial display of the regeneration through different means using GIS technique, in different villages is as seen in Plate 11. Such display can help in understanding the regeneration capacity of forest tree species at a glance.

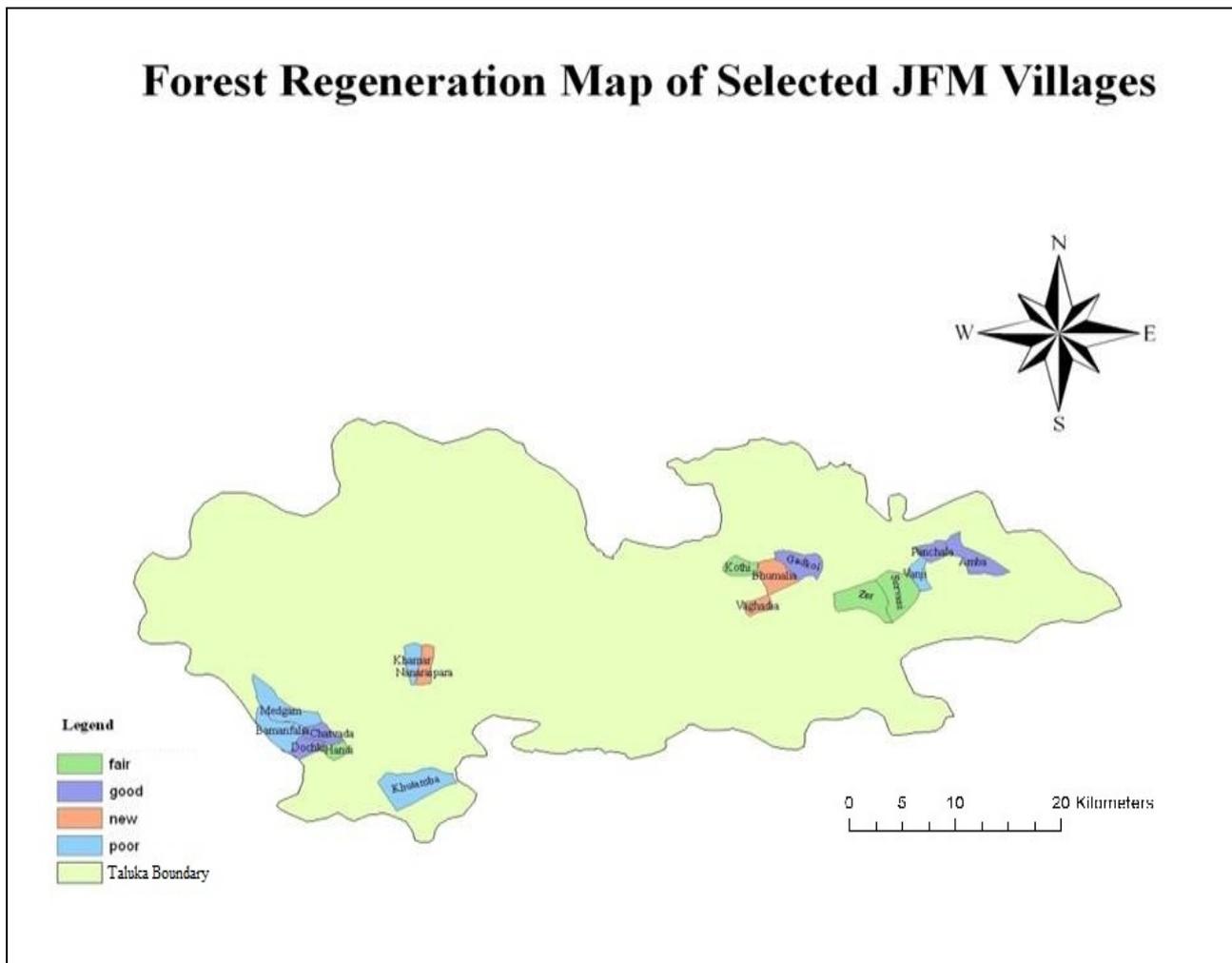


Plate 11. Forest regeneration map of the selected JFM villages

The overall status of the regeneration of the JFM and natural forest areas are presented in Table 19. The regeneration status of the JFM and natural forest sites were classified as good, fair, poor, none or new based on the densities of the seedlings, sapling and the mature strata. It was observed from the results that the rate of regeneration was good at 33.33% of JFM sites whereas at natural forest sites it was merely 12.5%.

Table 19. Regeneration Status of JFM and Natural forest sites

Site	Villages	Regeneration Status	
		JFM	Natural Forest
Site 1	Bamanfalia	Fair	*
	Medgam	Fair	Fair
	Dochki	Good	Fair
Site 2	Handi	Fair	*
	Chatwada	Fair	*
	Khutamba	Good	Fair
Site 3	Nanaraypara	Good	Fair
	Khamar	Fair	*
Site 4	Vaghadia	Fair	*
	Kothi	Good	Fair
	Bhumalia	Fair	*
	Gadkoi	Good	Good
Site 5	Survani	Fair	*
	Drucha	Fair	*
	Zer	Fair	Fair
Site 6	Vanji	Fair	*
	Amba	Good	Fair
	Panchala	Fair	*

*absence of natural forest sites

4.4) Forest Conditions of Study area:

The different parameters related to forest condition i.e., forest regeneration, species richness, anthropogenic activities, cattle grazing, pest, infection, standing woody biomass and productivity aided in depicting the overall conditions prevailing in this area.

The number of cut stem and damaged trees in JFM sites were very low or negligible when compared to natural forest sites. The dead tree count also had same pattern of low and high in JFM and natural forest sites respectively (Table 20).

Table 20. Cut stem, damaged tree and standing dead tree count in study area

Site	Villages	Cut Stem		Damaged Tree		Dead Tree	
		JFM	Natural Forest	JFM	Natural Forest	JFM	Natural Forest
Site 1	Bamanfalia	05	*	0	*	0	*
	Medgam	11	25	0	2	0	0
	Dochki	07	19	2	3	0	5
Site 2	Handi	17	*	2	*	1	*
	Chatwada	10	*	2	*	2	*
	Khutamba	14	06	0	4	0	3
Site 3	Nanaraypara	22	25	0	2	0	4
	Khamar	16	*	0	*	0	*
Site 4	Vaghadia	07	*	5	*	2	*
	Kothi	32	19	4	7	2	21
	Bhumalia	10	*	0	*	0	*
	Gadkoi	57	70	2	23	5	7
Site 5	Survani	24	*	0	*	4	*
	Drucha	08	*	1	*	3	*
	Zer	38	33	0	3	3	6
Site 6	Vanji	48	*	11	*	6	*
	Amba	03	16	1	7	0	4
	Panchala	23	*	0	*	0	*

*absence of natural forest sites

The completely disturbed site had many defoliated trees and dead or broken stumps. Forest fires, felling for non-timber use and cultivation by the locals were another issues at these disturbed sites (Plate 12). The occurrence of forest fire was noted from 33% of the JFM villages, viz., Khutamba, Survani, Vanji, Zer, Bhumalia and Vaghadia. The frequency of forest fire was only once in a year, however at the rest of JFM villages no occurrence of forest fire was reported. It was therefore clear that in the 33% of above said villages the effective measures of forest fire control was not adopted and there were loop holes in the management.



Plate12. Various disturbances in study area forests

Cattle grazing are one of the major issues which adversely affect the forest condition and the condition of the forest ecosystem. It opens up the forest floor and results in damaging fine roots resulting in soil erosion. The level of cattle intrusion and grazing depicts the level of protection provided to these forests (Plate 13). The level of intrusion was more in the natural forest. Absence of protection in these areas allowed the cattle's to graze freely in these areas.



Plate13. Grazing activity in study area

Presence of pest and diseases has a negative impact on the forest conditions (Plate 14).



Plate14. Termite infestation and Leaf Defoliation in the forests of study area

The level of pest infection and diseases observed here was very low to negligible in all the JFM sites, but in natural forest it was on a little higher side (Table 21).

Table21. Disturbances by Cattle intrusion, Pest and diseases

Site	Villages	Cattle intrusion in a week		Pest and Disease	
		JFM	Natural Forest	JFM	Natural Forest
Site 1	Bamanfalia	4	*	Low	*
	Medgam	2	6	Low	Moderate
	Dochki	3	5	Low	Low
Site 2	Handi	5	*	Low	*
	Chatwada	3	*	Low	*
	Khutamba	1	Daily	Low	Moderate
Site 3	Nanaraypara	5	6	Low	Moderate
	Khamar	3	*	Low	*
Site 4	Vaghadia	4	*	Low	*
	Kothi	2	6	Low	Low
	Bhumalia	2	*	Low	*
	Gadkoi	3	6	Low	Moderate
Site 5	Survani	2	*	Low	*
	Drucha	4	*	Low	*
	Zer	3	Daily	Low	Above Moderate
Site 6	Vanji	3	*	Low	*
	Amba	3	6	Low	Low
	Panchala	2	*	Low	*

*absence of natural forest sites

4.4.1) Standing Woody Biomass (SWB): Standing woody biomass is an important indicator of the potential of forests to provide wood and to sequester carbon. Tree biomass may affect the ecosystem condition in many direct and indirect ways. A forest with high biomass, displays improvement in local microclimate and soil properties, protection of wildlife and biodiversity. They act as wind breaks and provide shelters reducing soil erosion and thereby resulting into water conservation. These factor together help in constituting a better forest condition. In an estimate of

the standing woody biomass of forests in India, Ravindranath *et al.* (1992) calculated that tropical moist deciduous and tropical wet evergreen forests were the most productive, accounting for 66% of total standing biomass with an overall mean biomass of 126 t/ha of forest. Rai (1982) found the above ground biomass in tropical rain forests of Karnataka to be 465.61 t/ha. The mean biomass density in Indian forests was estimated as 135.6 t/ha and amongst the states it varied from 27.4 t/ha in Punjab to 251.8 tonnes/ha in Jammu and Kashmir (Chhabra *et al.*, 2002). In the present study, the average SWB according to conventional method of the JFM plantations was found to be 55.86 t/ha and for natural forests it was 71.62 t/ha (Table 22).

The biomass estimation was done by both the conventional and non conventional ways, i.e. using the satellite data. The delineation of satellite data was used to generate biomass map of the Rajpipla taluka (Plate 27) exhibiting categorization of areas based on biomass production. By conventional method the biomass of tree layer found in JFM villages varied from a minimum of 14.52 t/ha at Drucha village to maximum of 107.28 t/ha at Khamar village. For natural forest areas the biomass varied from a minimum of 34.58 t/ha at Khutamba village to 138.85 t/ha at Zer village. Decreased values for biomass were noted from villages which were more close to the settlements. The higher values of SWB found in tree layer of natural forests make an evident that the forests are been taken care and conserved properly. By non conventional method, it was found that at taluka level, the distinction between areas with different biomass production was quite evident. It showed that the JFM and natural forest site villages were falling under area with the

biomass production <100 t/ha, this seems to be correct as observed by basic ground conventional method (Table 22).

Table22. Productivity of the JFM and Natural forests

Site	Villages	MAI (t/ha/year)		SWB (t/ha)	
		JFM	Natural Forest	JFM	Natural Forest
Site 1	Bamanfalia	1.73	*	60.81	*
	Medgam	2.96	8.68	103.84	86.75
	Dochki	1.55	9.39	54.57	75.10
Site 2	Handi	1.54	*	54.24	*
	Chatwada	1.75	*	61.46	*
	Khutamba	1.42	2.88	49.86	34.58
Site 3	Nanaraypara	0.80	5.01	28.24	50.06
	Khamar	3.05	*	107.28	*
Site 4	Vaghadia	1.55	*	54.70	*
	Kothi	1.58	8.25	55.50	74.27
	Bhumalia	1.42	*	50.13	*
	Gadkoi	0.87	3.70	30.70	48.15
Site 5	Survani	2.54	*	89.51	*
	Drucha	0.41	*	14.52	*
	Zer	2.13	23.13	74.93	138.84
Site 6	Vanji	0.53	*	18.50	*
	Amba	1.98	10.87	69.82	65.20
	Panchala	0.76	*	26.78	*

*absence of natural forest sites

4.4.2) Mean Annual Increment (MAI): Mean Annual Increment (MAI) is an indication of the productivity of forest area and is influential in management decisions, especially those decisions dealing with timber production (CIFOR, 1999). The MAI shows variation in its value across the country, this can be attributed to different geographical aspects. The MAI of India's forests is assessed to be less than 0.18 t/ha/year as against the world average of about 0.71 t/ha/year (FSI, 1995).

Murali, Murthy and Ravindranath (2002) reported a national MAI of 3.6 t/ha for plantations. In the present study the average MAI recorded at JFM villages was 1.59 t/ha/year (Table 22), this was found to be little higher than the average MAI recorded at national level. This evidences the fact that the JFM plantations in the present study area are showing high productivity due to the good protection and management of these areas.

4.5) JFM and Forest Socio-Economics:

A majority of the village people are directly dependant on forests and its products for their livelihoods. People living around the forest areas may increase their income by selling forest products and/or operating forest-based industries. Forests provide timber, fodder, firewood, medicinal and herbal plants and other forest products. The JFM village survey has shown substantial dependence on natural forest for firewood and fodder. Additional firewood demand is being met from agricultural lands and JFM plantation areas. Even the village common lands and gouchar areas contribute to fuel wood and fodder needs of the local communities to a much limited extent. Firewood collection from JFM area is prevalent where the areas are opened and with less protection for cut back, clearing, thinning or for collection of dried twigs/ branches, etc.

The implementation of JFM strategy has definitely helped in reducing the collection of the firewood and fodder because of the restriction imposed. The needs of the local communities are completely satisfied from these JFM areas alone, which are opened up for fodder and fuel wood collections (Plate 15). The additional products generated from these areas are also significant as they contribute to food security, income and employment generation to the forest dwellers. These products also provide opportunities for forest based enterprises and enhance potential for

export market. They constitute major forest outputs and generate considerable income and employment for the rural poor.



Plate15. Fodder and Fuel wood collections from the forest fringes

About 20 percent of the rural population in the taluka villages depend on NTFPs for about 10 percent of their income. The most important extracted products in this respect are fuel wood, fodder and various foods. The major NTFP products as shown in Plate 16 are leaves of Timru (*Diospyros melanoxylon* Roxb.), flowers of Mahua (*Madhuca indica* J.f Gmel.) and Baheda (*Terminalia bellerica* Gaertn.). Many other NTFP's such as Safed musli (*Chlorophytum borivilianum*), Dhavda gum

(*Anogeissus latifolia* Wall.) and Khakra leaves (*Butea monosperma* Lam.), are collected and sold by villagers, providing them an extra income.



Dry Butea Flowers

Timru dry leaves

Dry Mahuda Flowers



Dhavda Gum

Dry roots of Safed Musli

Mahuda fruits

Plate 16: NTFP products in the JFM areas

4.5.1) Socio-economic Survey: The different characteristics about forest socio-economic revealed interesting facts. Approximately 60 percent members of almost all JFM villages are either schedule caste (SC) or schedule tribe (ST), more than 70 percent households in each JFM village live below poverty line and major part of income for all the households in JFM villages and natural forest is from forest sources. These factors have led to comparatively better economic and social status of forest fringe communities. Results also show that annual income for all categories of households has increased in JFM villages. The higher increase in income for

landless and marginal categories of households under JFM villages has been made possible only due to substantial increase in income from forest source.

Eighteen villages and 120 households were involved in the questionnaire survey. Further the output from the questionnaire survey exhibited that out of the total household surveyed approximately 7.8%, 18% and 74% belonged to rich, medium and poor class respectively. During the interview sessions details regarding JFM strategies and local's perspectives were also noted (Plate. 17).



Plate17. Interview session with the JFMC member and villagers

In terms of gender, male and female respondent were 65% and 35% respectively. Landholding size varied significantly among rich, medium and poor households. The total land differed significantly by economic condition of the households. A little increase in economical condition is seen in the categories of households under JFM villages. The higher increase in income for landless and marginal categories of households under JFM villages was possible due to increase in income from forest source after JFM initiation. This suggests that the dependence on forest for income for many households under JFM villages has increased due to JFM programme. Most of the smaller landowners household now use kerosene

stoves, which was possible by implementation of JFM; earlier they were totally dependent on the nearby forest resources as they had no alternative for fuel woods. It was also revealed that before JFM the amount of firewood collected for cooking per month per household was 20 head loads as compared to only 7 head loads now, because of availability of the cooking stoves. The forest department has also provided community vessels, tent, chairs and solar lantern to the JFMC's.

The villagers therefore were completely satisfied with this strategy as it aided not only in improving the forest ecosystem but it also improved the livelihood of local communities (Fig.12).

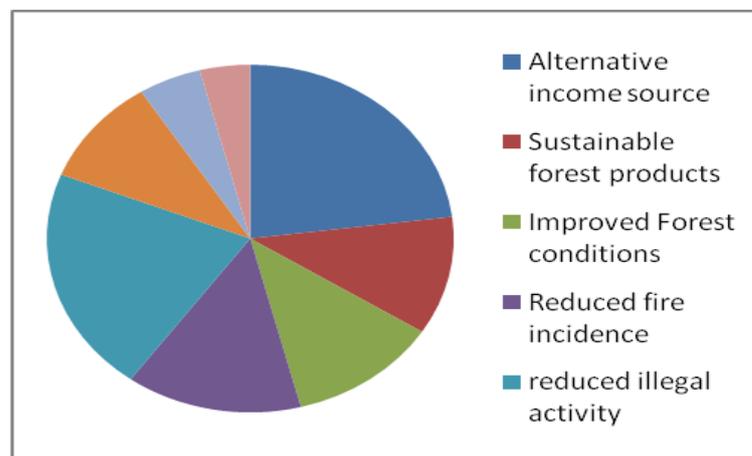


Figure 12 . Perceptions by communities on the benefits of JFM

4.5.2) Percentage of Satisfaction, Participation and Awareness in the JFM

villages: Activities in which the local JFMC members participates include: attending forest meetings, conducting forest patrolling, forest boundary clearing, planting and weeding, gap restoration, forest fire fighting, forest boundary resurveying, trees planting, formulation of village laws and preparation of JFM agreements, demarcation of village forest management areas and preparation of village forest management area plans. Income generating activities was the major reason that motivated people to accept and be involved in JFM activities. The survey for

understanding such different types of involvement in the JFM villages of this area has shown a significant contribution in terms of participation, satisfaction and awareness. Participation is the process of involvement in any institution or raising concerns over the given situation or issues, or interferences over disputed matters. In the present study area 39% of the villagers occasionally and 17% rarely participated in these types of activities (Table 23). An active member of JFMC is seen protecting these areas from fire in Plate 18.



Plate 18. Active member of JFMC participating in forest fire extinguishing

Prior to JFM, most households had been dissatisfied with the lack of effective controls on forest protection and resource utilization. After implementation of JFM strategy 67% of villagers are seen to be completely satisfied, 28% neutral and 5% dissatisfied with the management of the system which can be clearly seen in the following Table 23.

Table 23. Satisfaction, Participation and Awareness Level among JFMC member across JFM villages

		Satisfaction Level	Participation Level	Awareness Level
Site	Villages	JFM	JFM	JFM
Site 1	Bamanfalia	Satisfied	Occasionally	Moderate
	Medgam	Neutral	Often	High
	Dochki	Neutral	Rarely	Low
Site 2	Handi	Dissatisfied	Rarely	Low
	Chatwada	Satisfied	Occasionally	Moderate
	Khutamba	Satisfied	Often	High
Site 3	Nanaraypara	Satisfied	Occasionally	High
	Khamar	Satisfied	Often	Moderate
Site 4	Vaghadia	Neutral	Occasionally	Moderate
	Kothi	Satisfied	Always	High
	Bhumalia	Satisfied	Always	High
	Gadkoi	Satisfied	Often	Moderate
Site 5	Survani	Neutral	Occasionally	Moderate
	Drucha	Satisfied	Occasionally	Moderate
	Zer	Satisfied	Often	High
Site 6	Vanji	Satisfied	Occasionally	Moderate
	Amba	Neutral	Rarely	Low
	Panchala	Satisfied	Often	High

The awareness about the environmental and forest regulations has increased substantially after the implementation of JFM. The level of awareness regarding the JFM strategy was generally fair in the Taluka. About 44% of the locals were moderately or fairly aware of the system, 39% highly aware whereas 17% of them were least aware of the current JFM policies. From the Table 23, it can be seen that villagers of Medgam, Handi, and Amba had lower participation level, as the villager were not well educated and were having lack of interest for the strategy.

It has been perceived that study area showed a positive attitude towards the JFM system. The socio-economic status of JFM villages can be seen in map displayed in Plate 19.

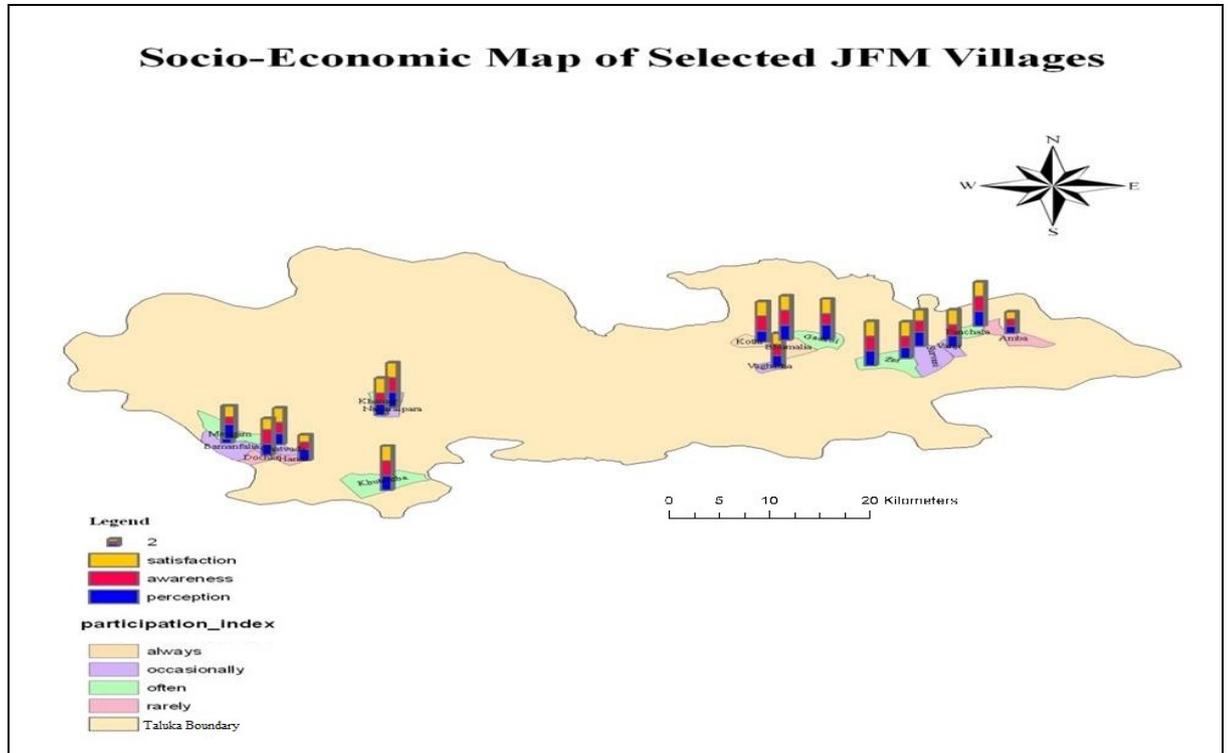


Plate 19. Socio-economic map showing Satisfaction, Participation and Awareness rate among JFMC member

Conventional inventory methods as generally applied in forestry, involve gathering information on the ground from a series of sample plots, and then estimating the overall forest inventory accordingly. The conventional approach works, but it's slow, labour-intensive and not always accurate. In response to these problems the use the non conventional method in terms of emerging technology of aerial and satellite remote sensing in conjunction with conventional methodologies is been utilized for a better management of the entire range of natural resources.

4.6) Non Conventional Methods in JFM and natural Forest studies:

The use and management of forest resources need to be based on the mapping and inventory of the forestry environment. In addition to the static data, the changing state of the forest as a result of natural or human-induced causes (felling, clearing, fire, reforestation, decline, regeneration, etc.) also needs to be monitored. Using a compass for forest mapping was a common traditional method having low work efficiency, making mapping task much more tedious and much more time consuming. The utility of Remote Sensing and Geographic Information Systems (RS-GIS) developed in the recent past helped in eliminating these demerits. It also provided the continuous monitoring of forest developments by detecting changes and integrating the results into existing databases. Satellite remote sensing has played a pivotal role in generating information about forest cover, vegetation type, forest canopy density and landuse changes. These are the most useful parameters to consider in the planning and implementation of forest rehabilitation program.

The present study conducted in the Rajpipla JFM and natural forest areas using RS and GIS techniques was used to supplement the static data and improve its management. This aided in better understanding of these areas both at macro and micro level. The macro or taluka level studies were carried out for forest type, density and biomass.

4.6.1) Macro/Taluka level Studies: The image analysis of LISS III data for the year 2001 and 2005 was carried out for the assessment of forest type, density and biomass is distinct in its own way and has been described separately.

4.6.1a) Forest Type: The ultimate result of the classification distinguished the area into various forest and non-forest categories. Important vegetation types of the study area included Moist Deciduous Teak forests and Dry Deciduous Teak forests and three non forest categories i.e. Agriculture land, Barren land/Habitation and Water Bodies (Plate 20 and 21). After agriculture the Dry Deciduous forest was observed as dominant vegetation type during both the years i.e. 2001 and 2005. An increase in dry deciduous forest type with slight decrease of moist deciduous teak forests was observed (Table 24). An increased trend was observed in areas under Dry Deciduous forest, Agriculture and Water Bodies with a parallel decrease in the Moist Deciduous forests and Barren/Habitation areas in the year from 2001 to 2005. The decrease can likely be due to heavy biotic influences, like fires, illicit cutting, over grazing, encroachments etc. A similar work was done by Jayakumar S., et al., 2002 and Ravindranath et al., 1997 at Kolli hills of Tamilnadu state..

Table 24: Percentage Change in Forest type in Rajpipla Taluka (2001-2005)

Forest Type	Rajpipla Forest type area (Ha.)		
	2001	2005	% of Change
Moist Deciduous	7765.0	6610.0	-1.063
Dry Deciduous	9266.0	20264.0	+9.831
Agriculture	13668.0	26463.0	+11.427
Barren/Habitation	76449.0	52438.0	-21.799
Water Bodies	3929.0	5733.0	+1.604
Total	111077.0	111508.0	0.0

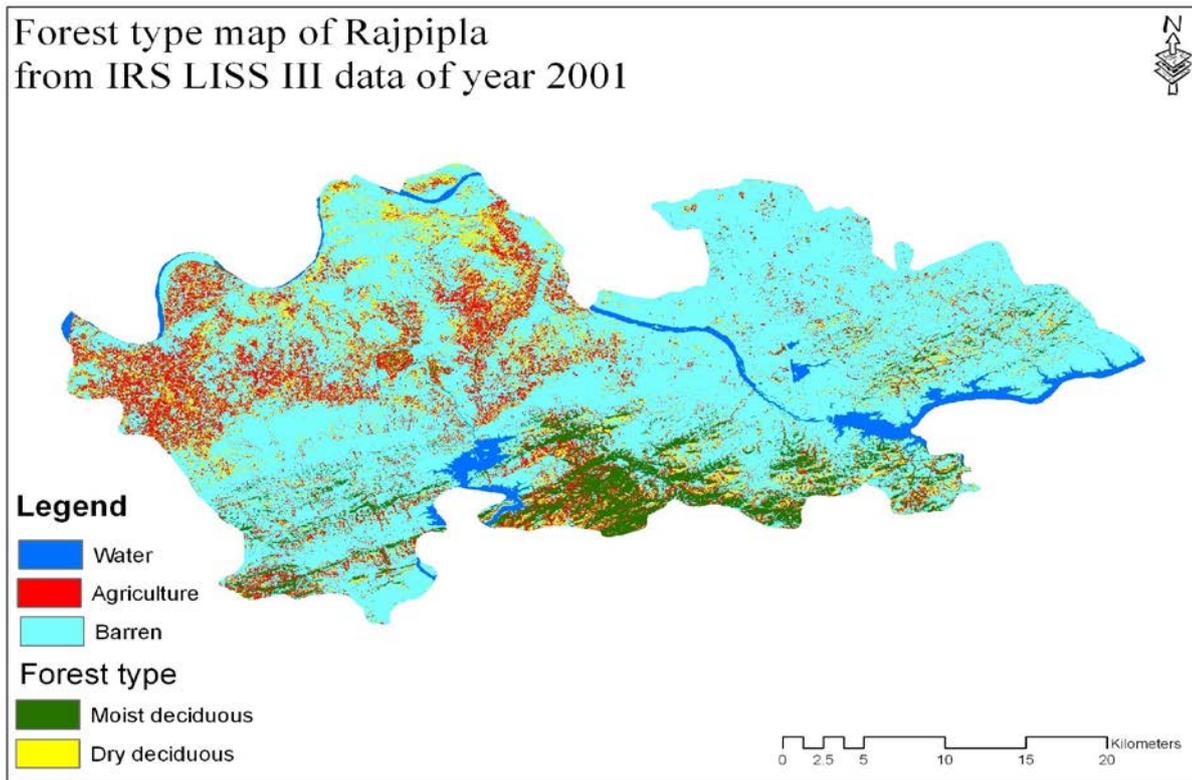


Plate 20: Forest type Map derived from IRS LISS-III of November 2001

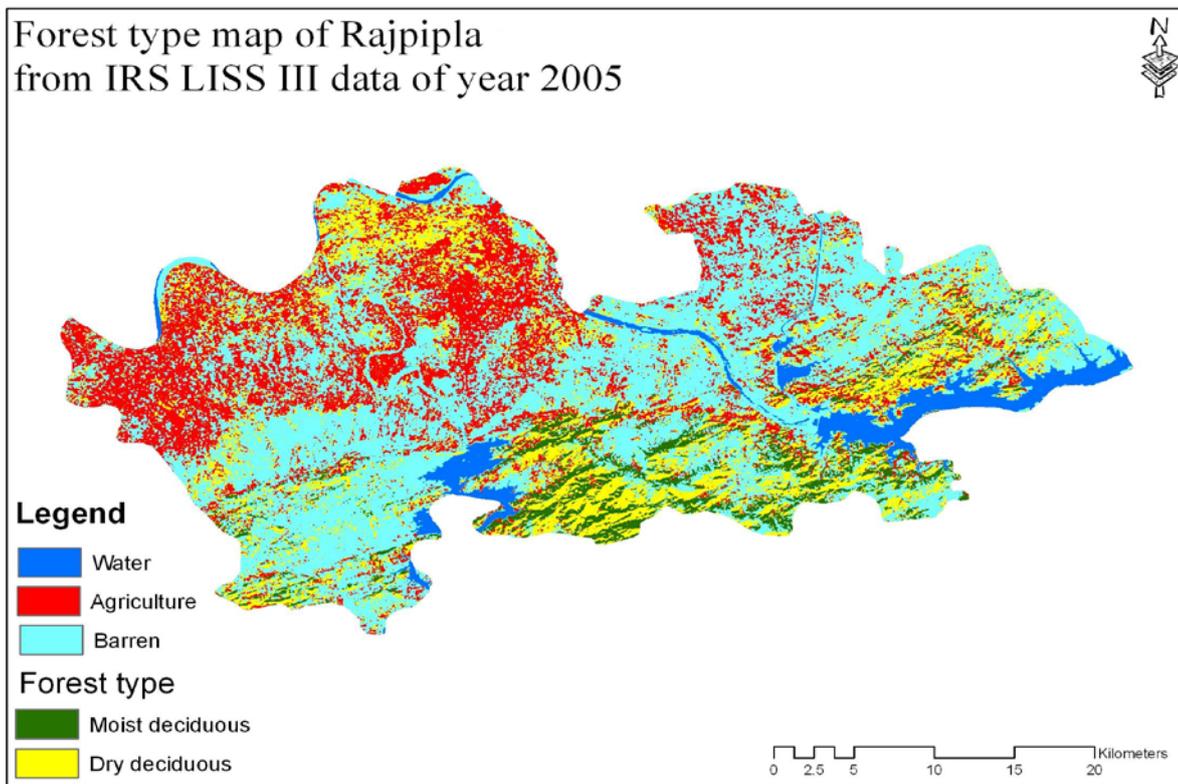


Plate 21: Forest type Map derived from IRS LISS-III of November 2005

4.6.1b) Forest Density: The vegetation map derived from the LISS III data show three major forest density classes viz. Dense/ closed forest (more than 40 per cent canopy cover), open forest (canopy cover between 20 and 40 per cent) and degraded forest (canopy cover with less than 20 per cent). There was an increase in all major classes i.e., open forest, degraded forests and agricultural areas, except for dense forest and Barren/Habitation areas which showed a decrease (Table 25). The area of dense forests has decreased from 2001 to 2005; this essentially means the loss of quality habitat in the area. Logging is thought to be the most important factor of forest cover loss connected with the human activity over the studied area. The forest density classification for year 2001 and 2005 are shown in Plate 22 and 23 respectively. A similar pattern of decrease in the dense forest and increase in total open forest cover was recorded in Western Ghats of Maharashtra by Panigrahy *et al.* (2010). Jha *et al.*, (2000) also reported decrease of dense and open forest due to degradation.

Table 25: Percentage Change in Forest Density in Rajpipla Taluka (2001-2005)

Forest Density	Rajpipla Forest Density area (Ha.)		
	2001	2005	% of Change
Dense forest	7777.0	6072.0	-1.556
Open forest	4261.0	8786.0	+4.043
Degraded forest	5000.0	12016.0	+6.273
Agriculture	13668.0	26463.0	+11.427
Barren/Habitation	76469.0	52438.0	-21.799
Water Bodies	3929.0	5733.0	+1.604
Total	111084.0	111508.0	+0.0073

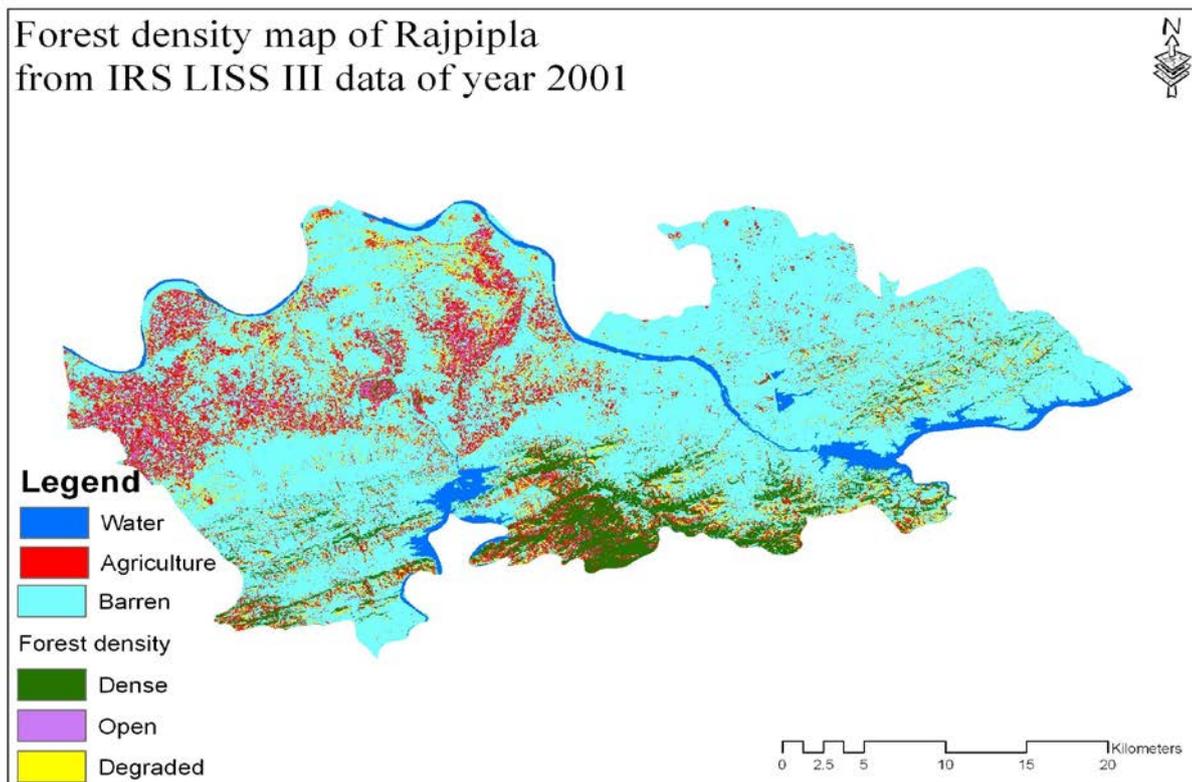


Plate 22: Forest Density Map derived from IRS LISS-III of November 2001

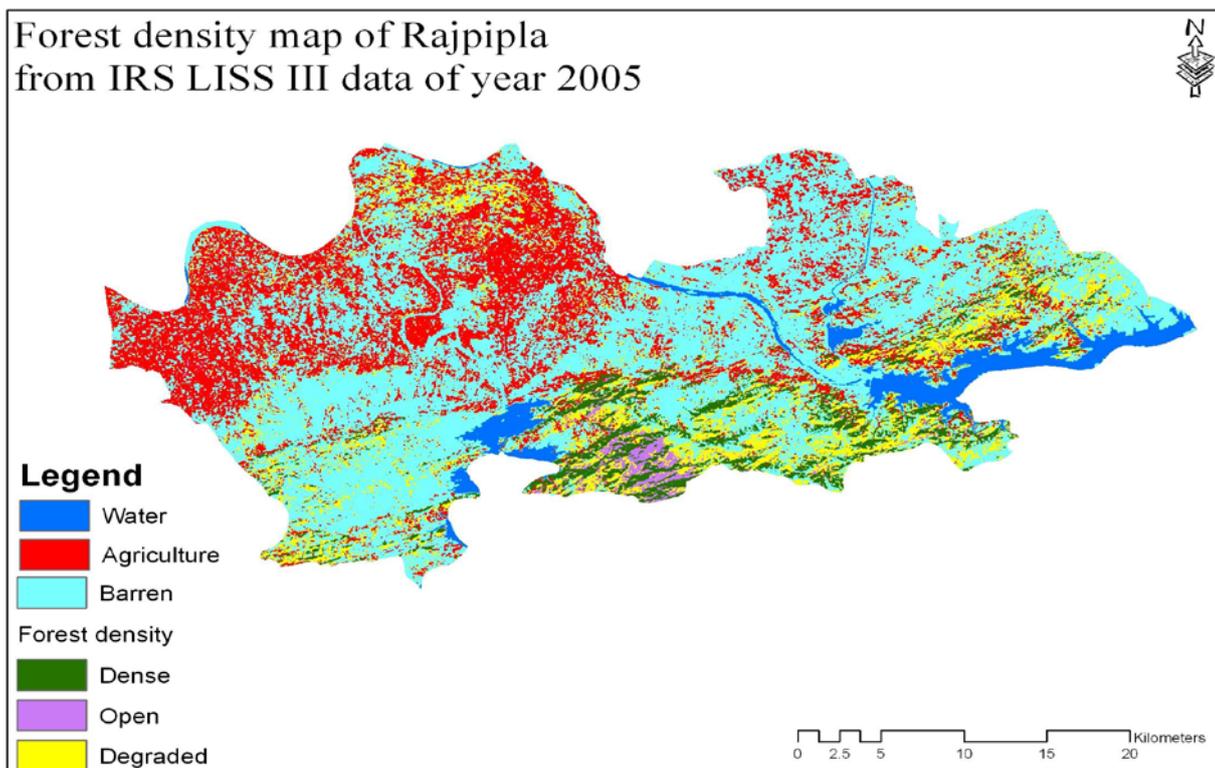


Plate 23: Forest Density Map derived from IRS LISS-III of November 2005

4.6.1c) Forest Biomass Map: The biomass map generated for Rajpipla taluka showed 4 different categories of forests biomass production areas and 3 different non forest categories contributing to biomass production. The predicted biomass values across the forest areas in Rajpipla taluka ranged from <100 to 350 tons/ha. The biomass with highest values was 200-350 tons/ha. A considerable increase was observed in areas contributing <100 t/ha, similarly a parallel increase was noted in non forest agriculture area in the year from 2001 to 2005. The biomass production in the range of < 100tons/ha was observed from an area of 44.11 sq. km in the year 2001 (Plate 24) however in the year 2005 the area had increased to 229.36 sq. km (Plate 25). All other categories showed a decrease in its area (Table 26). Similar studies have been done by various workers (Zheng *et al.*, 2004; Lu, 2005 and Roy, *et al.*, 1993). They suggested that RS data can effectively and greatly increase the efficiency and usefulness of limited conventional methods and can be used in above ground biomass estimation.

Table 26: Percentage Change in Biomass in Rajpipla Taluka (2001-2005)

Forest Biomass	Rajpipla f Forest Biomass area (Sq.km)		
	2001	2005	% of Change
<100 Tons/Ha	44.11	229.36	+185.25
100-150 Tons/Ha	79.0	20.24	-58.76
150- 200 Tons/Ha	15.4	4.93	-10.47
200- 350 Tons/Ha	31.8	12.62	-19.18
Agriculture	136.68	264.66	+127.98
Barren/Habitation	764.49	521.63	-242.86
Water Bodies	39.29	57.33	+18.04
Total	1110.77	1110.77	0

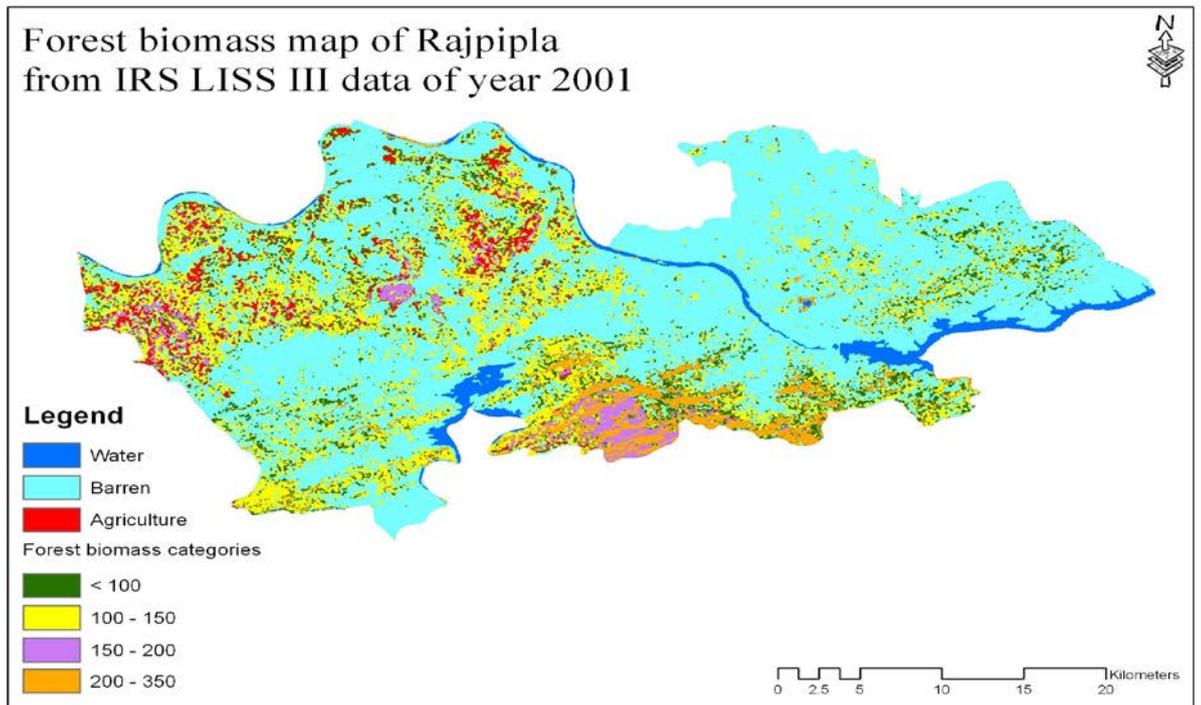


Plate 24: Forest Biomass Map of Rajpipla derived from IRS LISS-III of November 2001

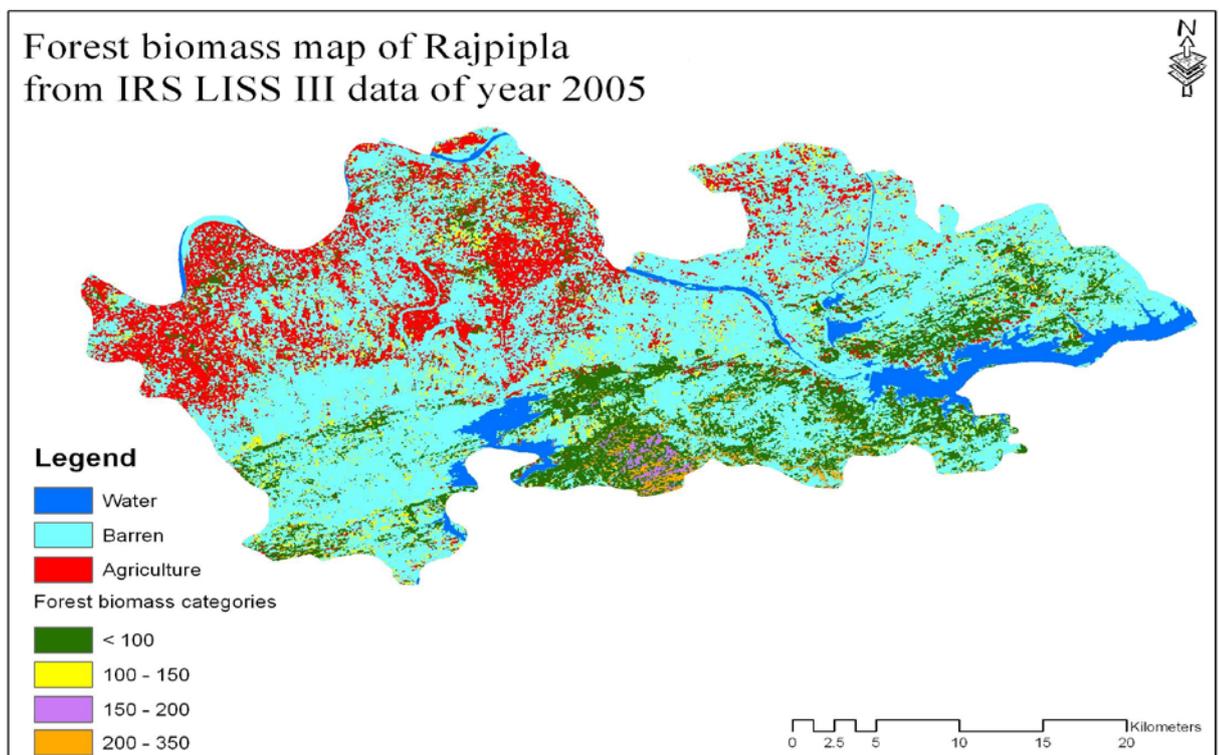


Plate 25: Forest Biomass Map of Rajpipla derived from IRS LISS-III of November 2005

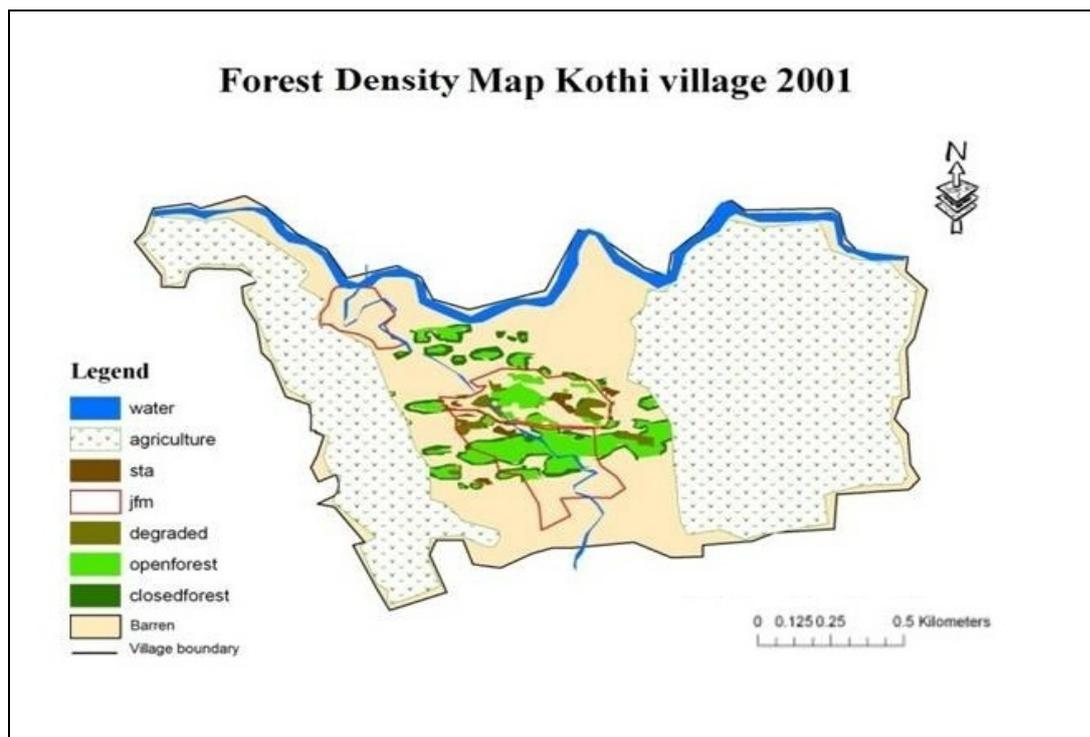
4.7) Forest Micro-level assessment of few villages: Utility of remote sensing and GIS for generating information about forest cover types and crown density for JFM proved to be excellent in entire study and so in next step RSGIS approach was made for its utility in micro plan generation. The outputs for forest density and forest type were utilized for understanding the micro level changes in forest cover. Major forest type categories calculated for the year 2001 and 2005 were categorized into four classes viz., Open, dense, degraded and STA. The change in forest type and forest density from 2001 to 2005 for two different JFM villages i.e., Kothi and Survani has been assessed separately.

4.7.1) Kothi: This village exhibited changes in all the forest categories. The close forest has been increased by 0.37 ha. Also a decrease of 21.79 and 27.114 ha was seen for open forest and barren areas respectively (Table 27) exhibiting a biotic pressure on these forestlands. However an increase in the areas of agriculture lands, degraded forests and STA is well observed. The area under agriculture in 2001 was 175.68 ha. (Plate 26a) which had increased to 201.55 ha. In 2005 (Plate 26b).

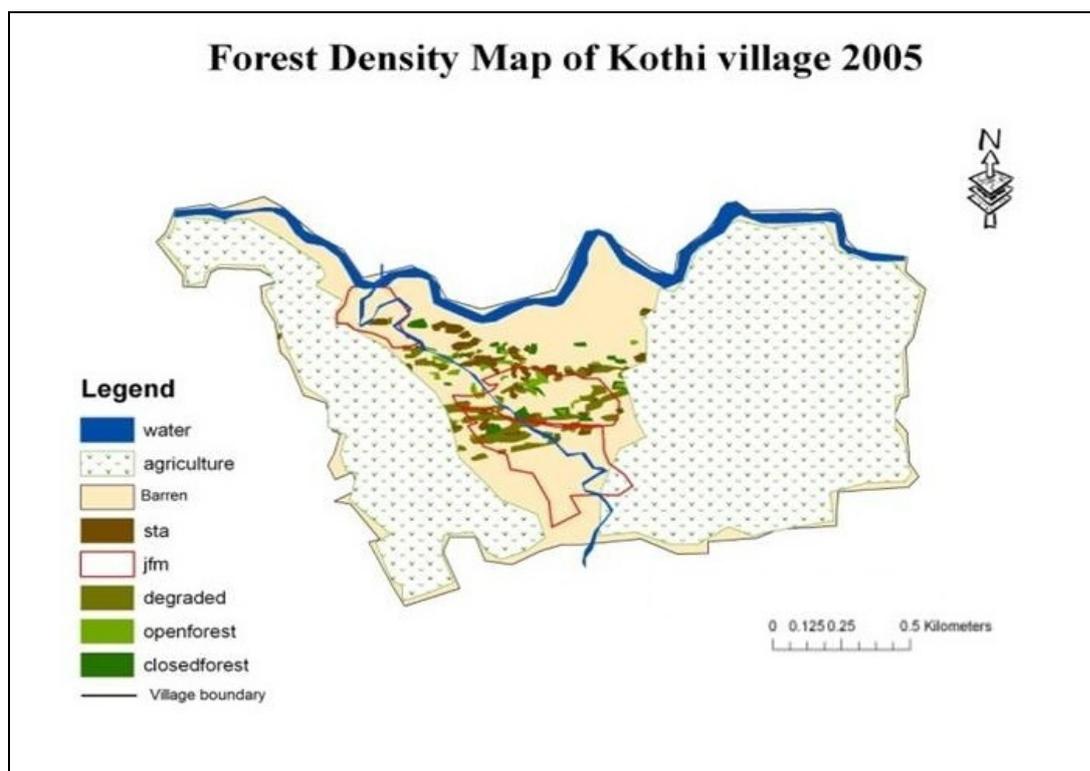
Table 27. Forest Density Change of Kothi Villages (ha)

Forest Density	2001	2005	Forest area change
Agriculture	175.68	201.55	+25.86
Barren	116.12	89.01	-27.11
Open Forest	27.32	5.53	-21.79
Close Forest	9.23	9.60	+0.37
Degraded Forest	4.63	13.60	+8.97
STA*	2.31	16.01	+13.70
Total	335.30	335.30	0.00

*Sparse Tree Agriculture



(a)



(b)

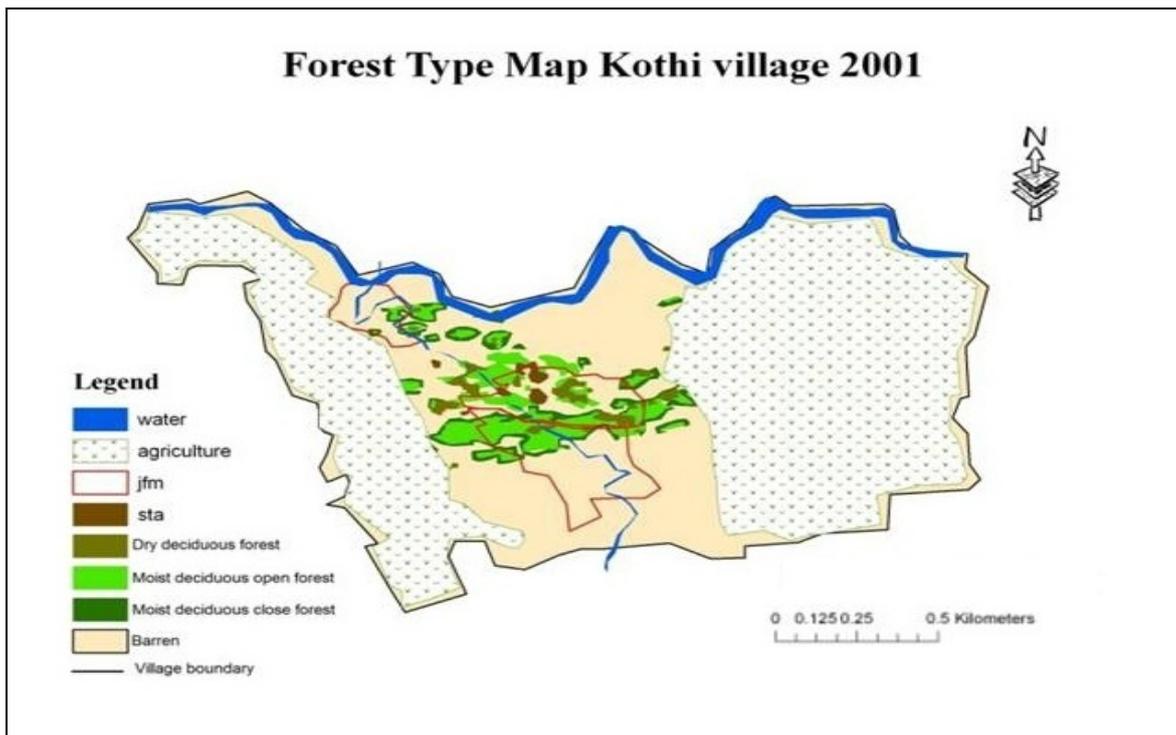
Plate 26 (a & b). Forest Density Map of Kothi village 2001-2005

An increase in different forest type categories such as Dry deciduous, STA and moist deciduous close forest was observed in the village. There was an increase in Dry deciduous, STA and moist deciduous close forest categories (Table 28). A major percentage of decrease in the area of moist deciduous open forest was seen. The area under moist deciduous open forest in the year 2001 was 28.34 ha. (Plate 27a) which decreased to 8.15 ha. in the year 2005 (Plate 27b) by -20.19% as seen in Table 28.

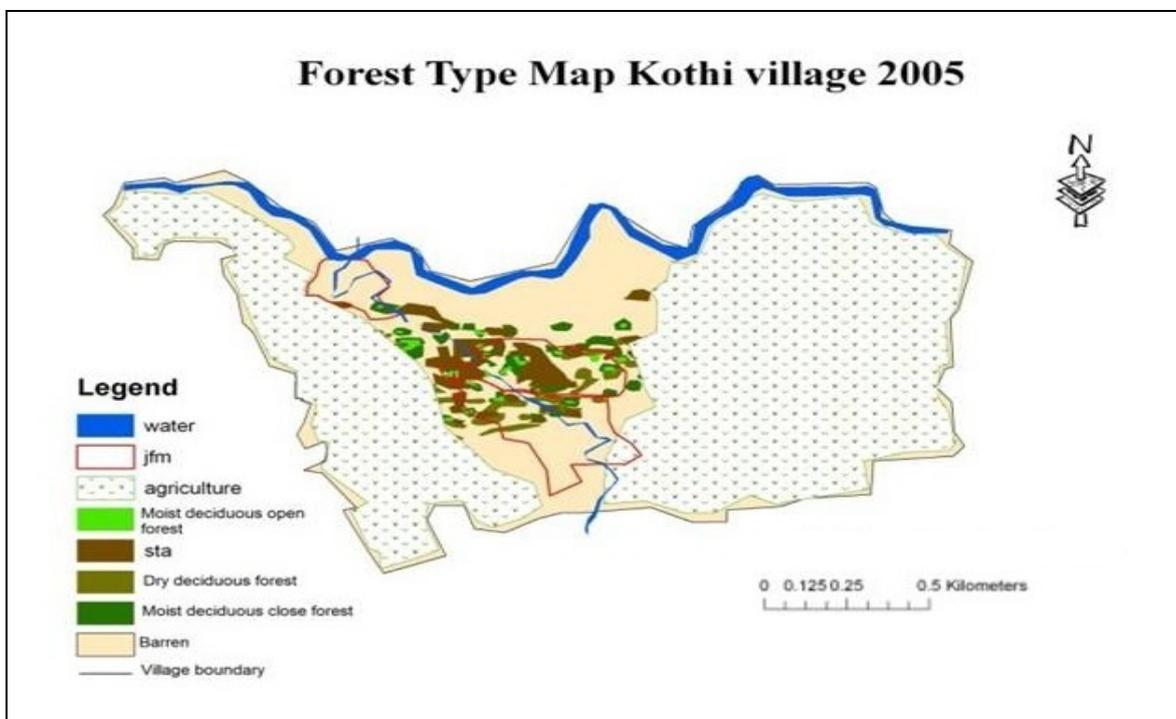
Table 28. Forest Type Change of Kothi Villages (ha)

Forest Type	2001	2005	Forest area change
Agriculture	175.68	201.55	+25.86
Barren	116.12	89.01	-27.11
MD Open	28.34	8.15	-20.19
MD Close	8.01	10.96	+2.95
DD	4.83	9.62	+4.79
STA*	2.31	16.01	+13.70
Total	335.30	335.30	0.00

*Sparse Tree Agriculture



(a)



(b)

Plate 27 (a & b) Forest Type Map of Kothi Village 2001-2005

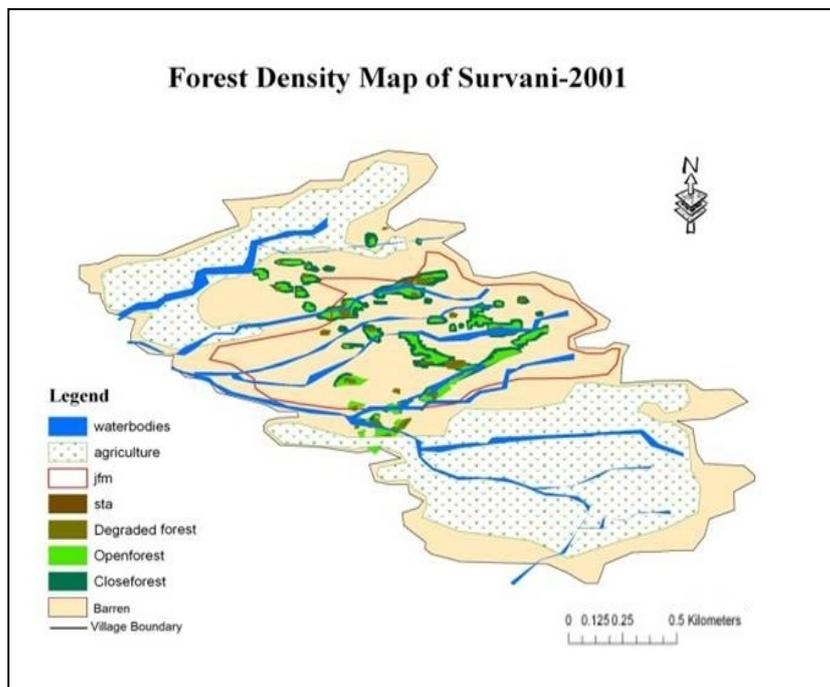
4.7.2) Survani: The village exhibited an increase in agriculture, close, STA and degraded forest with a parallel decrease in the barren areas. It is very much clear from the Table 29 that a major change was observed in the areas of barren land category which was under 60.44 ha. in year 2001 (Plate 28a) & was almost halved by the year 2005 (Plate 28b). Another striking feature observed was the increase in the area of degraded forests by a percentage of +9.62.

Table 29. Forest Density Change Survani Villages (ha)

Forest Density	2001	2005	Forest area change
Barren	60.04	31.76	-28.28
Agriculture	35.40	51.35	+15.95
Open Forest	6.52	4.10	-2.42
Close Forest	5.22	7.15	+1.93
Degraded Forest	2.21	11.83	+9.62
STA*	0.30	3.50	+3.20
Total	109.70	109.70	0.00

*Sparse Tree Agriculture

(a)



(b)

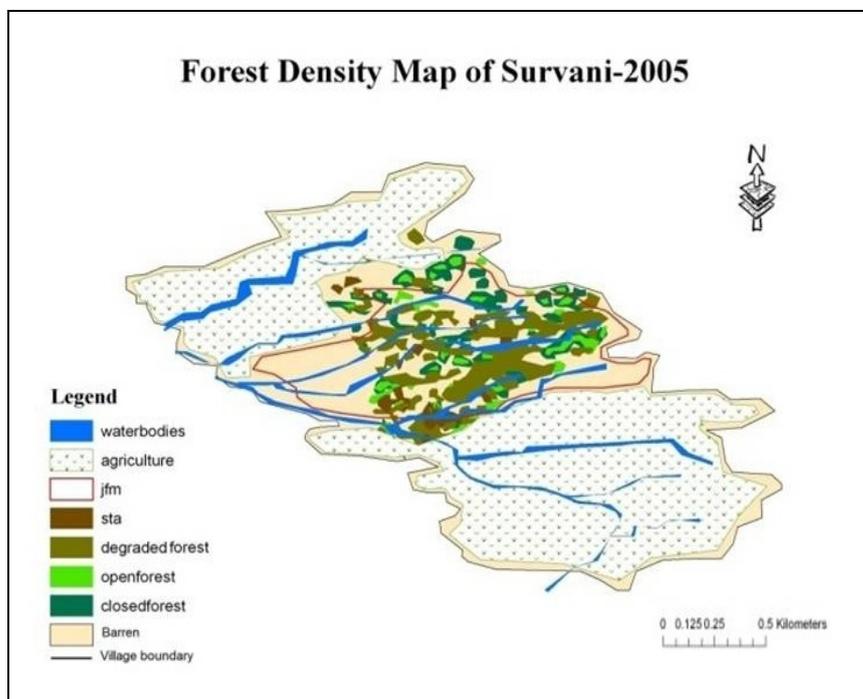


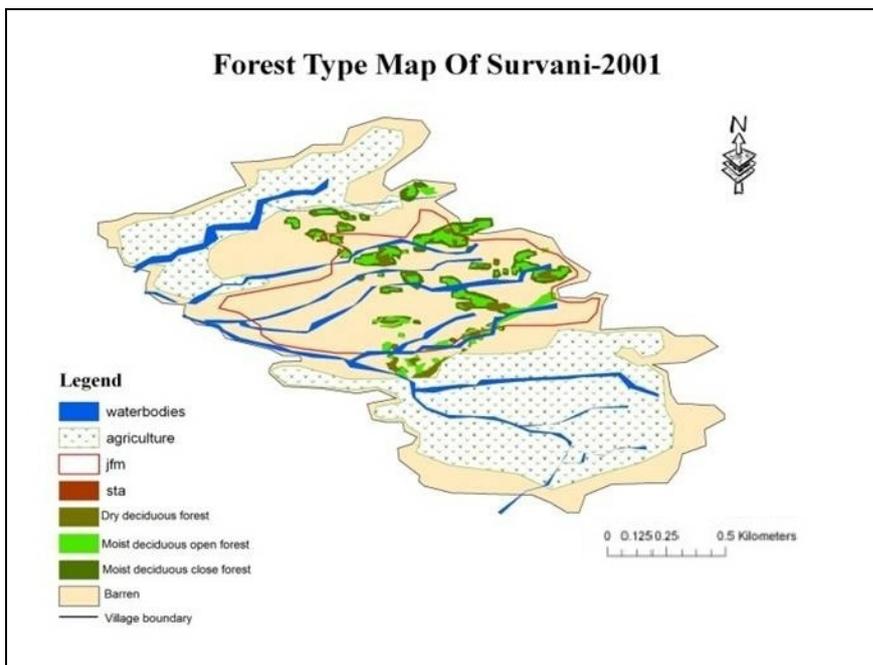
Plate 28 (a & b). Forest Density Map of Survani Village 2001-2005

Forest type of Survani village showed decreased in area by 28.28 ha. in barren land and moist deciduous open forest by 6.28 ha. (Table 30); this may be due to increase in areas of other forest categories, i.e., Agriculture, Dry deciduous forest; Moist deciduous close forest and STA. It is seen from the Plate 29a that the area under moist deciduous close forest was 1.36 ha. and in 2005 it was 3.44 ha. Plate 29b showing an increase by +2.08%.

Table 30. Forest Type Change of Survani Village (ha)

Forest Type	2001	2005	Forest area change
Barren	60.04	31.76	-28.28
Agriculture	35.40	51.35	+15.95
MD Open	11.58	5.30	-6.28
MD Close	1.36	3.44	+2.08
DD	1.01	14.34	+13.33
STA*	0.30	3.50	+3.20
Total	109.70	109.70	0.00

(a)



(b)

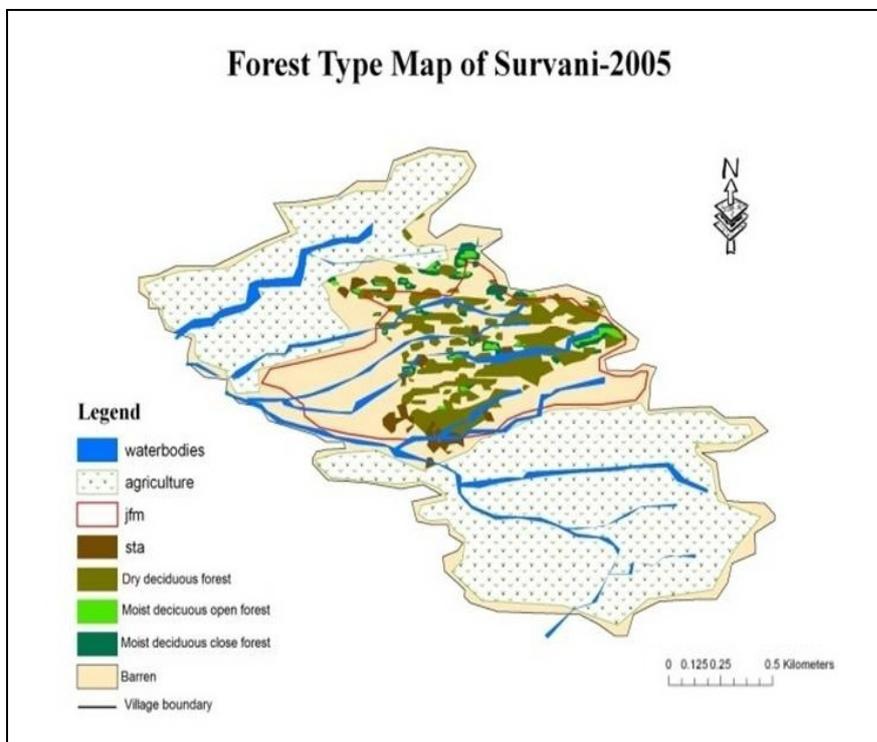


Plate 29 (a&b). Forest Type Map of Survani Village 2001-2005

4.8) Site Suitability: Site suitability is a broader concept tied to the sustainability of plantations so that management decisions can be made in a site-specific manner. It takes into account forest management aspects and land degradation hazards as well as site quality. When deciding where to establish JFM plantation, it is important to consider multiple factors for production, including climate, elevation and suitable tree species varieties. To help in site selection for implementing JFM strategy, maps were generated, which classified the JFM site suitability. The maps are based on GIS in which individual themes of elevation, landuse, slope and aspect are combined into a single, graphic representation that is scored for overall suitability. Each theme generated for this integration is very distinct and explained separately.

4.8.1) Landuse: Although current land use is not a direct indicator of JFM site suitability, it is of prime importance to the feasibility and cost of establishing a plantation. The landuse theme had two forest density categories open and dense and three non forest categories viz., agriculture, water bodies and river along with other non classified classes (Plate 30). The forest areas under open categories can be taken up for JFM strategy implementation.

4.8.2) Topographic/Slope Map: Land slopes are important for surface and, to some extent, internal soil water drainage. The topography of a site will have a bearing on the underlying soil hydrology. With undulating topography, the superior plantation sites will typically be suited on concave land pattern which is an excellent means of restricting water availability. The different types of land like hills & hill slope, foothills, up land and low lands are found in the taluka. The eastern part of the taluka is hillier and sloppy than the rest of the taluka. Nine types of contours based on five meter contour have been calculated from contour lines from the topo map (Plate 31).

Slopes steeper than about 3-10%, are recommended for JFM plantations because of the tree vegetation found in these area prefer elevated areas and also because of the risk of uncontrolled grazing, cutting and other anthropogenic activities will be restricted in these steeply slopes.

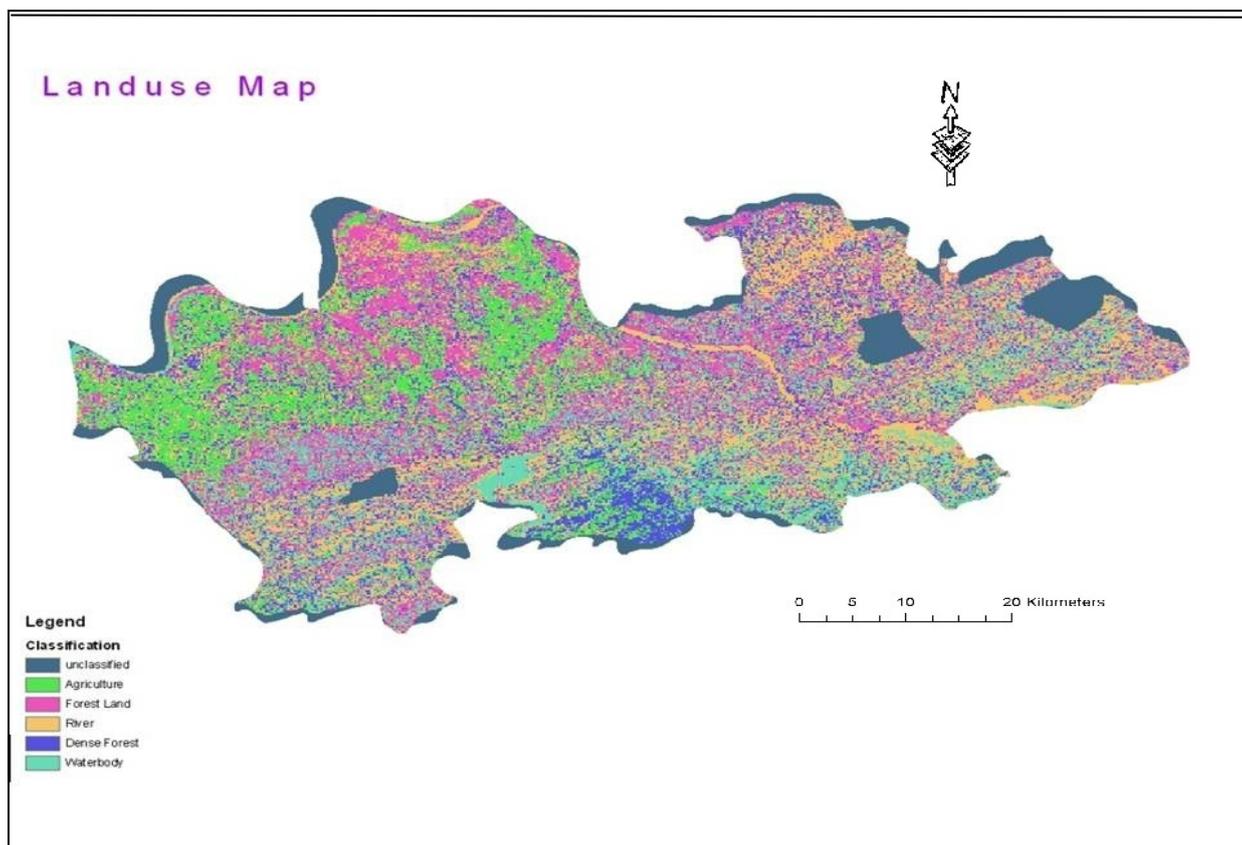


Plate30. Landuse/Land cover map of Rajpipla taluka

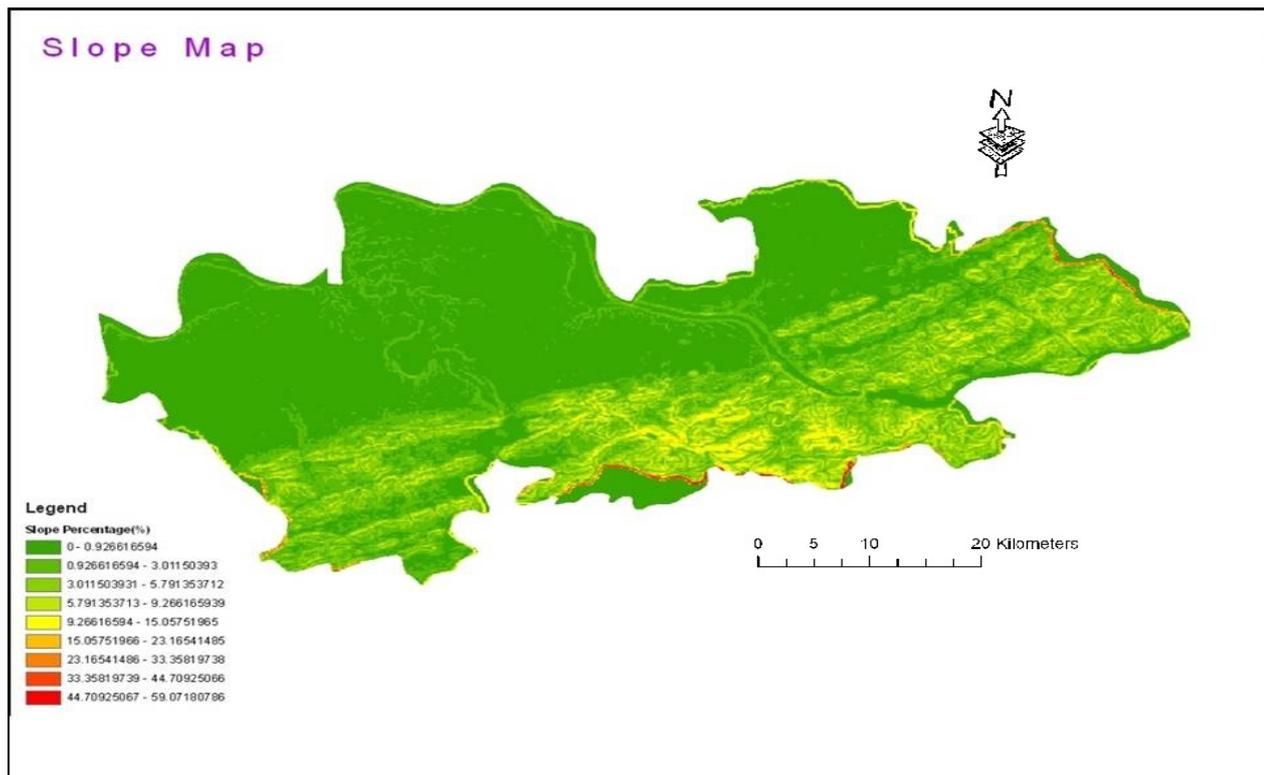


Plate31. Slope Map of Rajpipla Taluka

4.8.3) Soil Property: Type & Quality of Soil (Plate 32): The best of the plantation soil are those that permit deep and spreading root growth and provide a moderate supply of water. Soils to be avoided include those that are compacted and severely restricted rooting, water logged, and soils that are extremely droughty. The soil of the area is classified as clayey, fine soil, coarse and loamy, which is depicted in the map generated. Soils of this tract vary in colour, texture, depth and stoniness depending upon the rock and topography. The soil conditions are normal with the pH values ranging from 6.7 to 7.4. The trap rock disintegrates into reddish brown loamy soil, which is generally shallow on the hilltops and slopes. Such areas are not particularly favourable for tree growth. It is observed from the map that major parts (70%) of the taluka is covered with clayey soil, about 12% with fine, 10% with hill clayey, 5% coarse loamy and 3% with river sand. Presently the JFM plantations are located at

the areas with clayey soil; also it supports the suitable growth factors for the native tree species of the area.

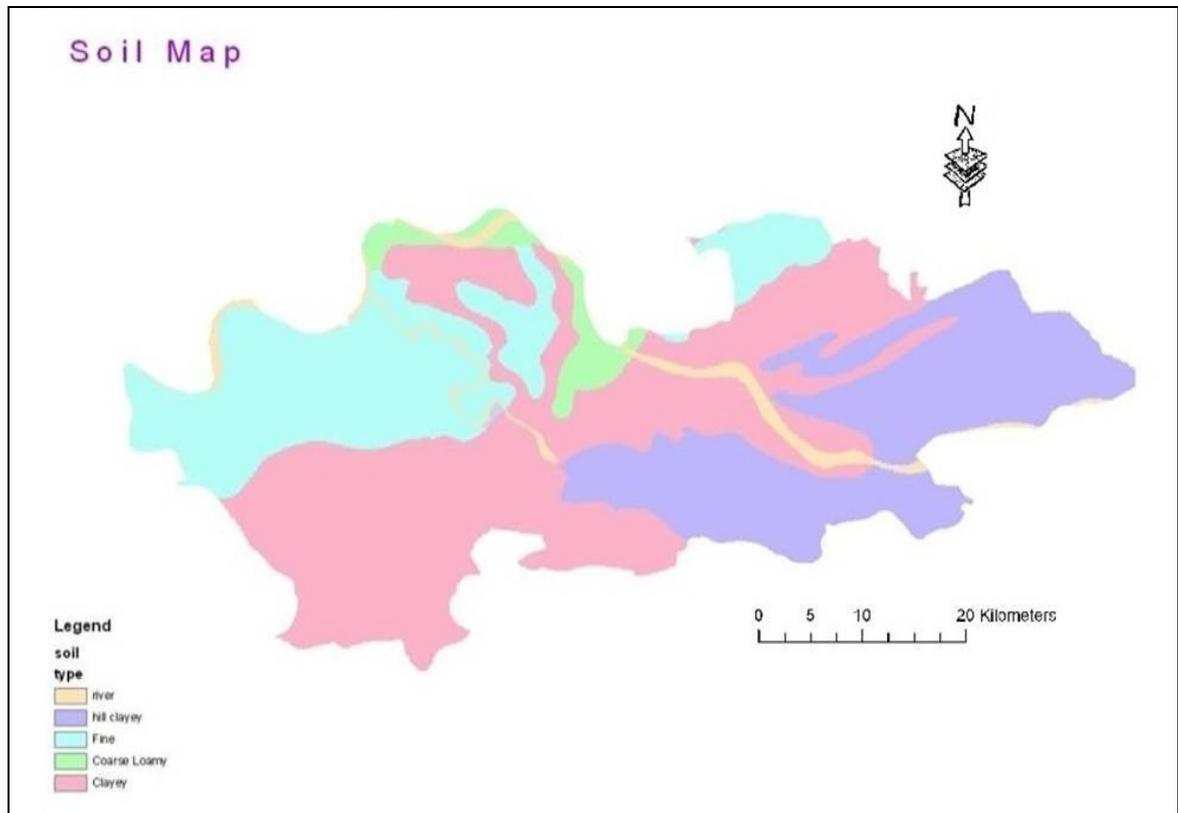


Plate 32: Soil Map of the Rajpipla Taluka

4.8.4) Habitation: Settlement & Settlement's Buffer: The settlement buffer analysis of the study area (Plate 33) precisely brought out 54 villages within the buffer out of the total 313 villages wherein the JFM program can be implemented. The villages coming in 800m radius can be considered as potential sites wherein the JFM can be initiated. The buffer zone area comprises a mosaic of forests, agricultural lands, settlements and other natural areas like river, barren land etc. About 29% of the buffer zone is covered by forest and serve as a main source of forest resources.

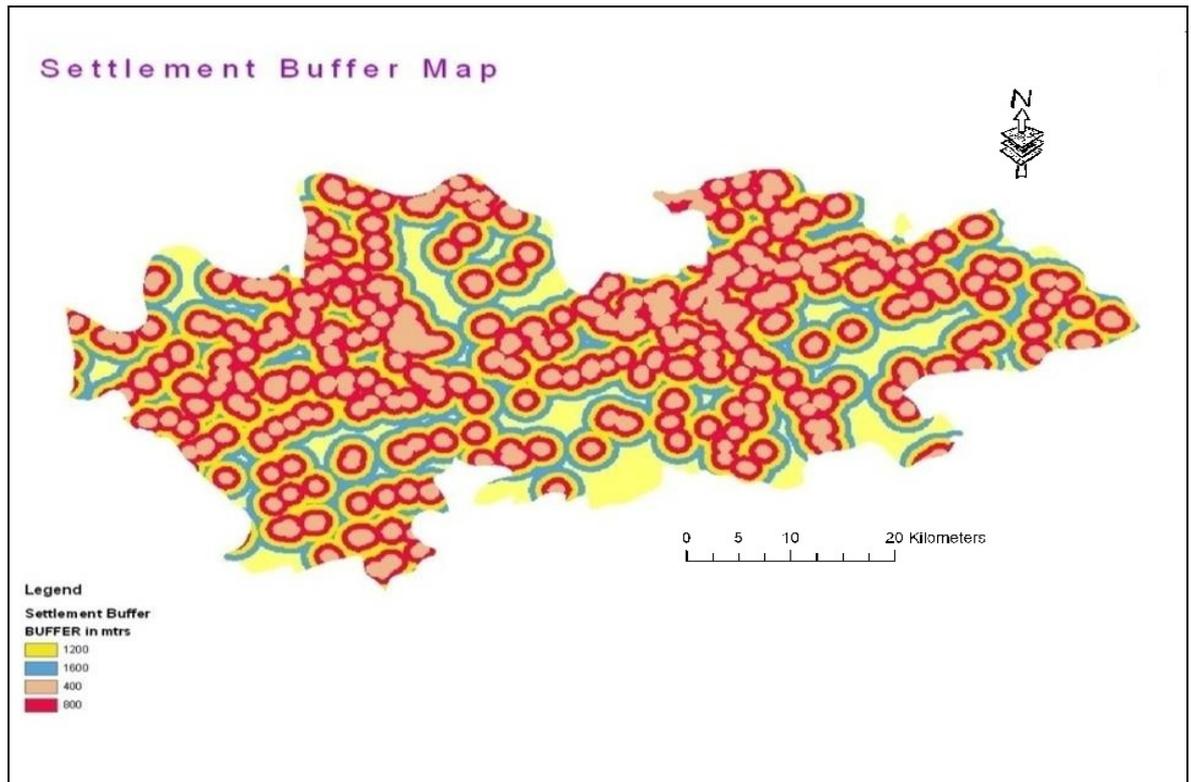


Plate 33. Settlement Buffer Map of Rajpipla taluka

Plate 34 displays the demographic position of the selected JFM villages. The map displays the ratio of number of household to the total population of the village. It is clear from the map that Zer village has a big ratio of household number and by a positive approach many of them can be included in the JFM committees and thus helping in conserving and protecting them.

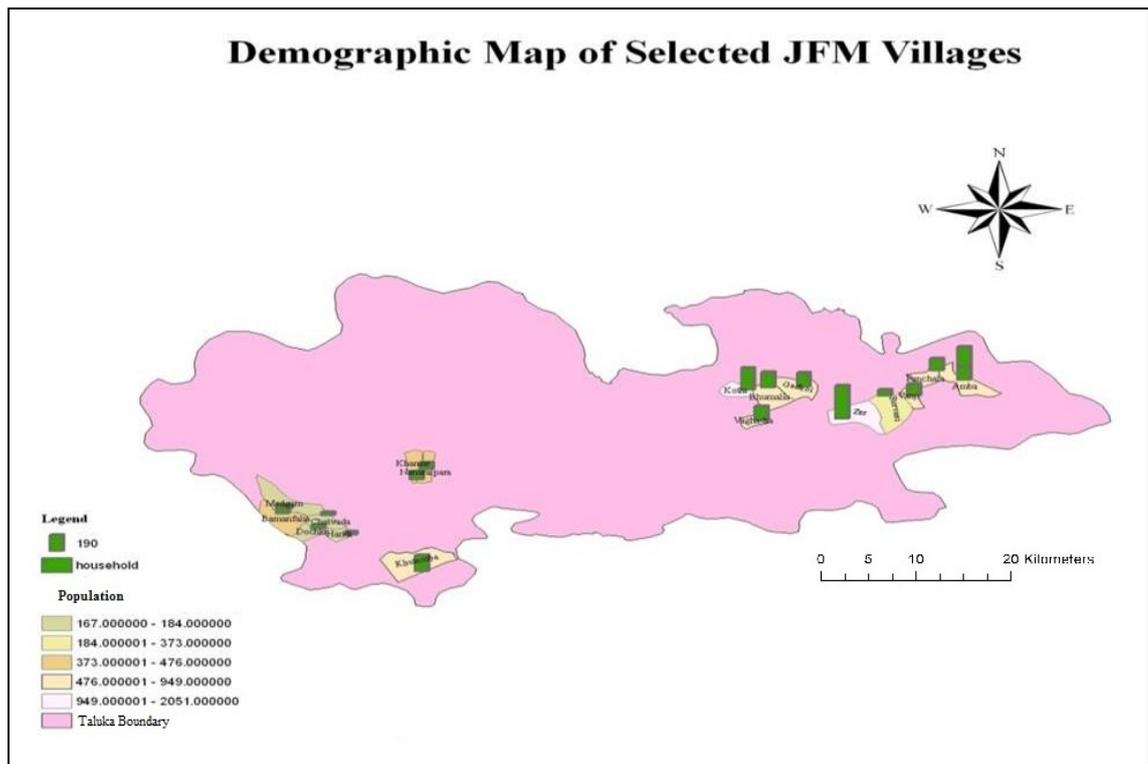


Plate34. Demographic Map of Selected JFM villages of the Taluka

4.8.5) Supplementary water: Irrigation (Plate 35): India's Largest Irrigation Network by the Sardar Sarovar Project on Narmada River passes through this area. The project has immense contribution towards irrigation and drinking water supply. In many areas of the taluka the current water resources scenario is critical especially the status of groundwater and its availability is causing a lot of concern. The result generated for the present study was based on classification of lands with severity of water availability in the taluka. Plate 35 shows the length of the canal that provides seasonal water source for the irrigation of farms cultivated by the local inhabitants. The employment of irrigation mapping results in the sustainable land use management and proper utilization of natural resources.

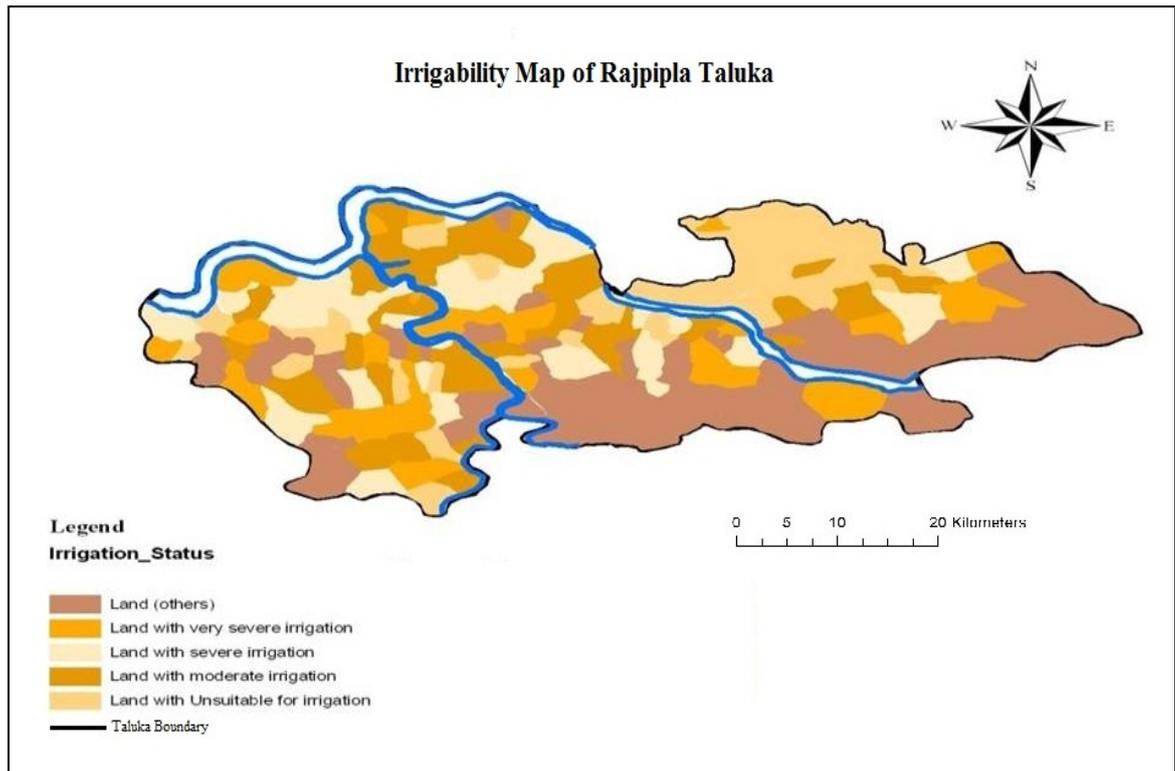


Plate 35. Irrigability Map of Rajpipla taluka

The above said five environmental factors i.e. landuse, slope, soil, settlement and irrigation properties were basically different on their dependence in land suitability. The JFM site suitability map of Rajpipla taluka depicted five classes i.e. highly suitable, moderately suitable, less suitable, very less suitable, unsuitable. Plate 36 & 37 shows that the suitable areas for JFM plantations are very limited and mainly concentrated in the southern part of the study area depicting a scattered pattern. Only 21.18 % of the area under study is suitable for JFM plantations which are mainly located in southeast parts. But other classes with moderate and less possibility exist in the area with a percentage of 7.38 and 26.10 respectively.

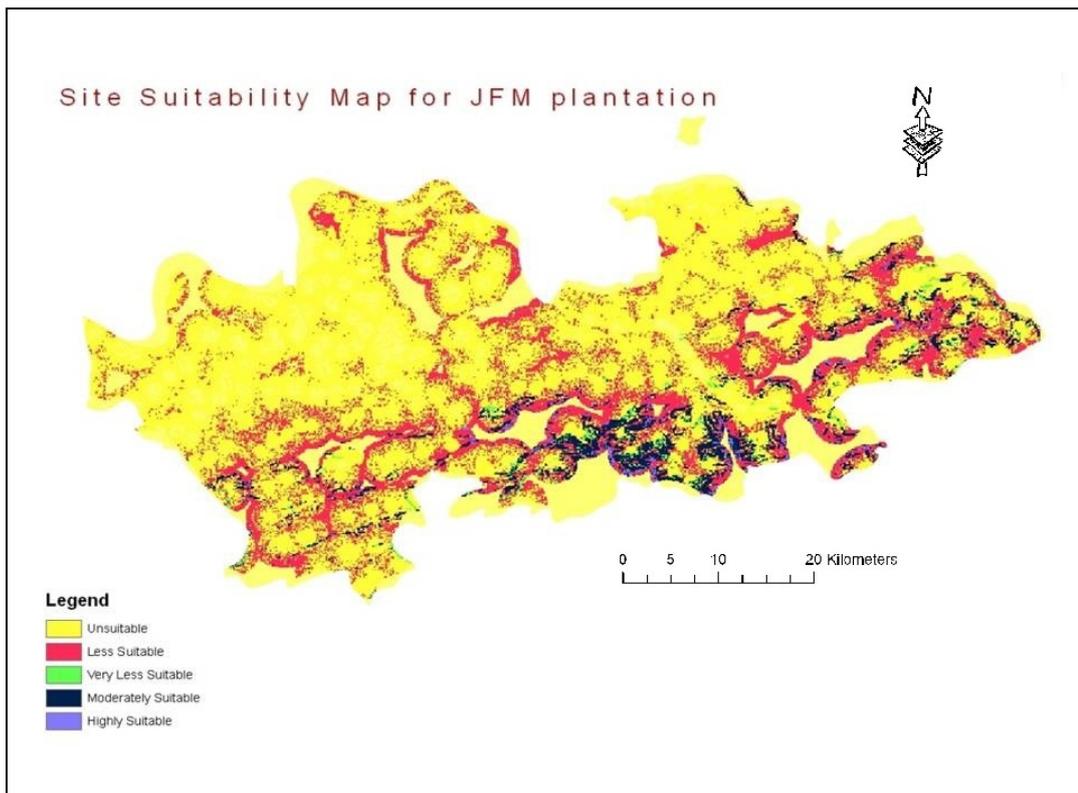


Plate36. Site Suitability Map for JFM plantations of the taluka

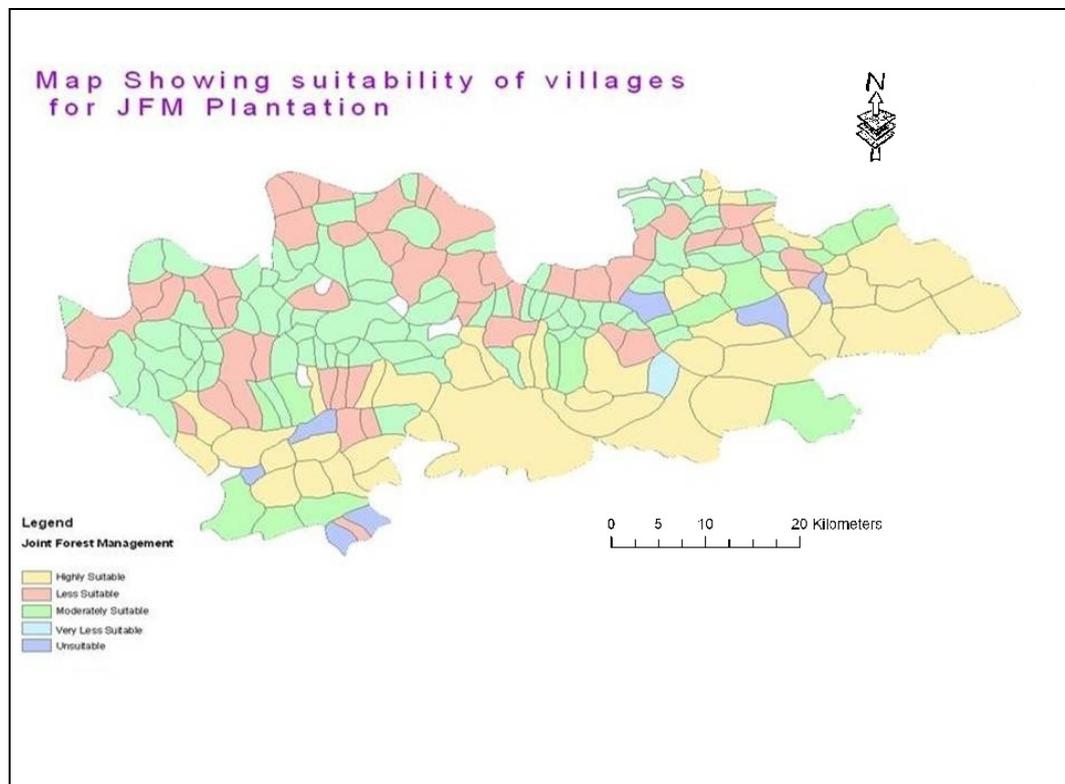


Plate 37. Suitability of villages for JFM plantations

The highly suitable class occupied 43 villages of taluka (Table 31). This category was mostly occupied by the degraded and open forest types. The success or failure of JFM is based on various factors. It would be more successful if necessary groundwork is done before commencing JFM, which are discussed here.

Table 31. No. of villages falling under different categories

Suitability Categories	No. of Villages
Highly Suitable	43
Moderately suitable	15
Less Suitable	46
Very Less Suitable	07
Unsuitable	92
Total	203

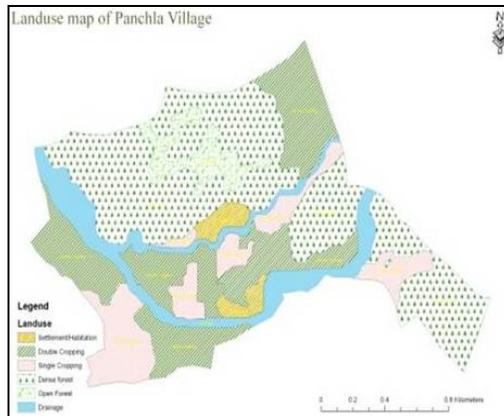
4.9) Preparation of Microplan Map of few JFM villages of Rajpipla taluka:

Today forestry professionals have to understand the interconnectedness and the need to balance, the environmental and economic benefits that forest ecosystems provide (Warnecke *et al.* 2002). Organising, analysing and presenting relevant information to policymakers, planners and managers are also responsibilities of modern foresters (Grove and Hohmann, 1992). These managers need to address the interests and priorities of local communities and involve them in decision making (Jordan, 1998). These plans also require the involvement of the local people in identifying the needs and generating the available resources for generating scientifically based plans.

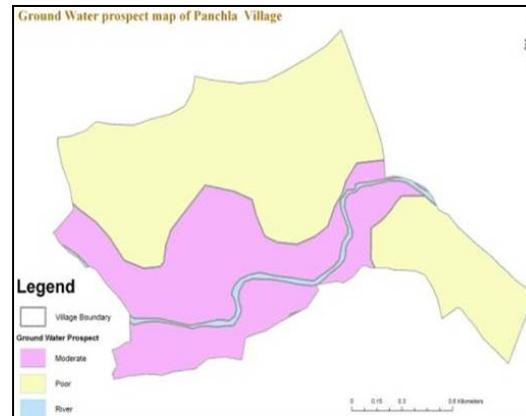
The concept of such micro level plans has been already demonstrated by various workers (Ajai, 2002; Mani, N.D., 2002; Lakshmi & Dutt, 1998). Moreover other workers have developed such plans for different resources like watershed development, urban and rural planning and other natural resources (Baral, 2004; Rao, 2006 and Musinguzi *et al.* 2008). The development of microplan for JFM forest of Rajpipla taluka using RS-GIS approach is a pioneer attempt made for this taluka.

The emergence of better resolution LISS IV spatial data facilitated better discrimination of forest type, accurate and efficient estimation of forest fire, forest biomass, forest health and condition assessment and detailed micro-level planning. For present study, microplan was generated for two villages; these villages are Panchala and Gadkoi. The output for each has been brought out vividly in the following paragraphs.

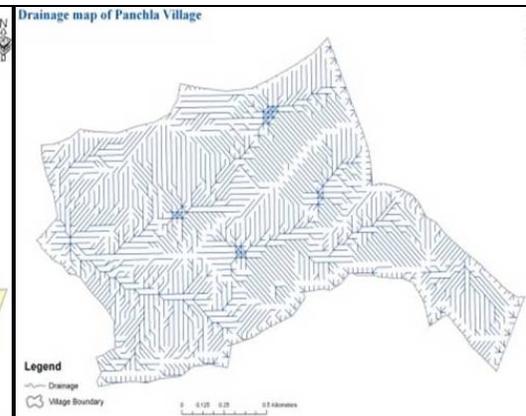
4.9.1) Panchala: Microplan generated for Panchala (Plate 38) was an integrated output generated from six different maps analysed from higher resolution data like Slope, Landuse, Aspect, Soil, Ground water Prospect and Drainage. Microplan generated brought out the need of 12 new checkdam instead of existing 2 checkdam. Checkdam are mainly located at intersection of 2nd order and 3rd order drainage network, construction of such dams would facilitate in going of more of horticulture plantation. It would help in gouchar land in developing of village from the Landuse generated at Cadastral scale. It was observed that earlier the open forest land was not taken into consideration by forest department, but presently the initiation has started. In addition to this, different water conservation strategy like furrowing, trenching, bunding, gradoni, etc could be implemented with availability as precise Slope and Aspect information is available at the cadastral level.



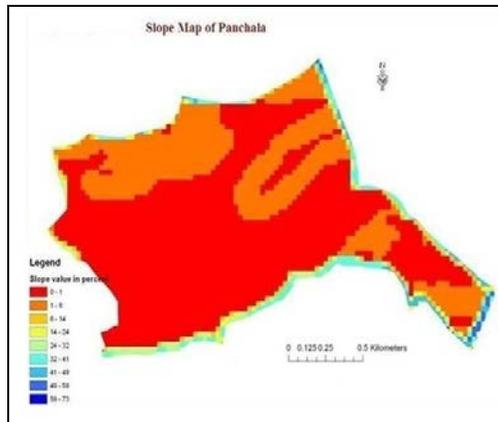
a) Landuse Map



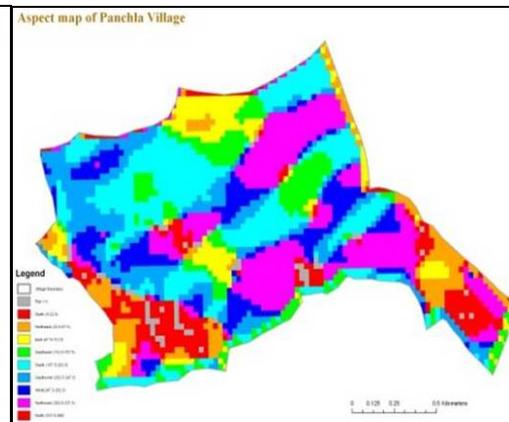
b) Ground Water Prospect



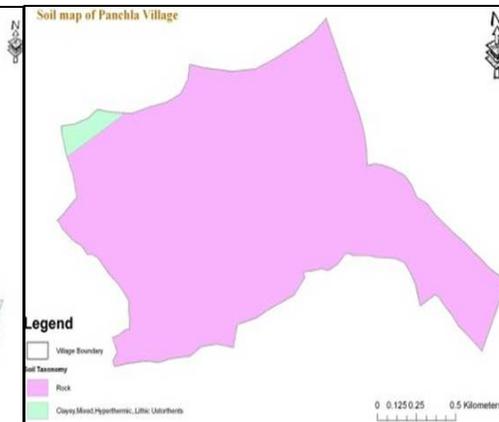
c) Drainage Map



d) Slope Map



e) Aspect Map



f) Soil Map

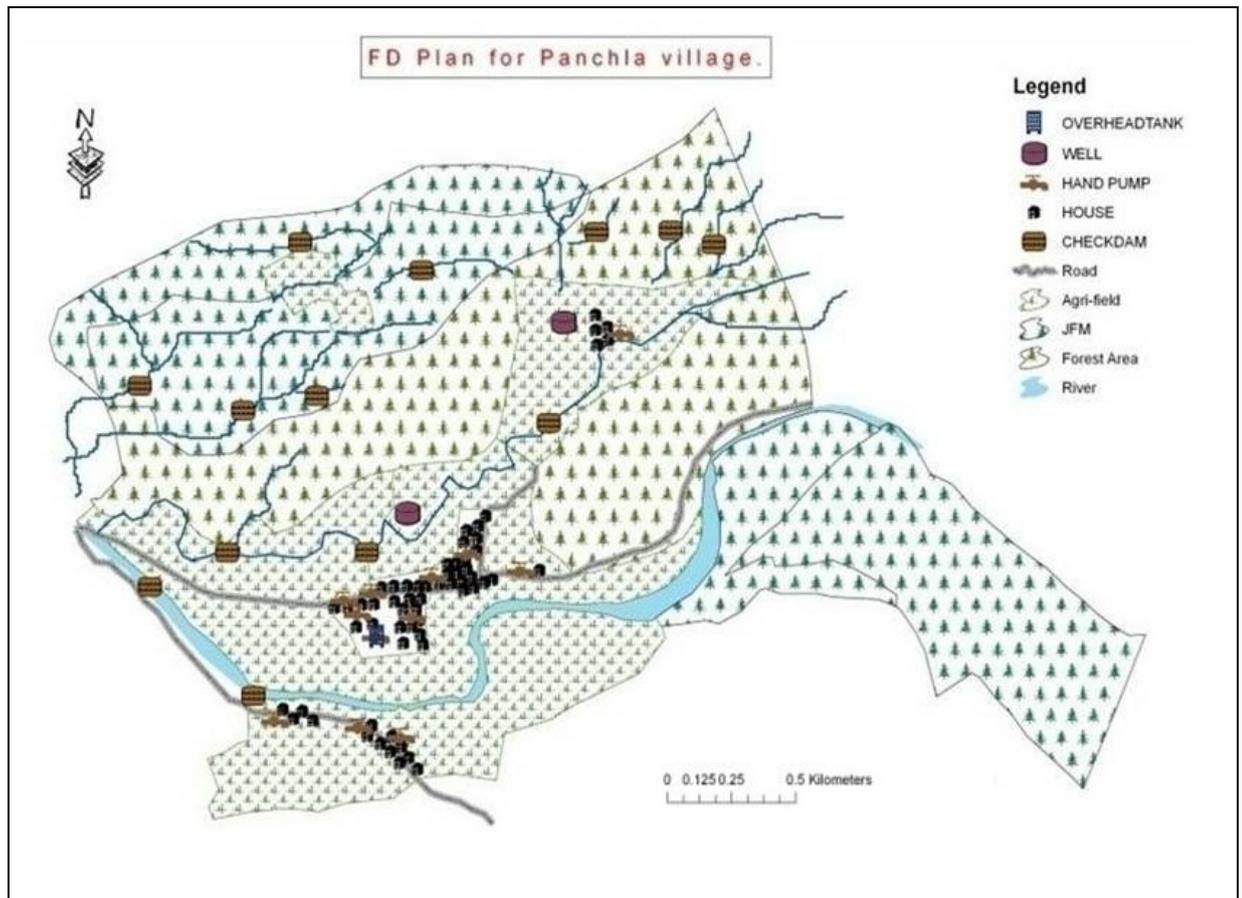
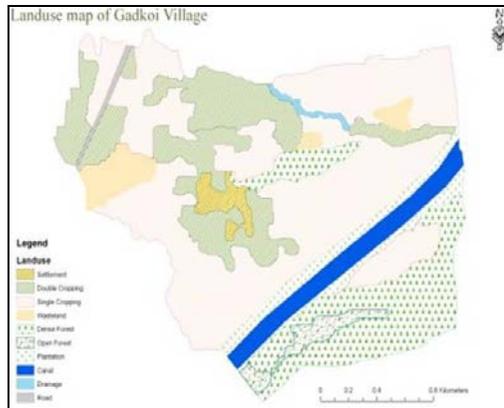
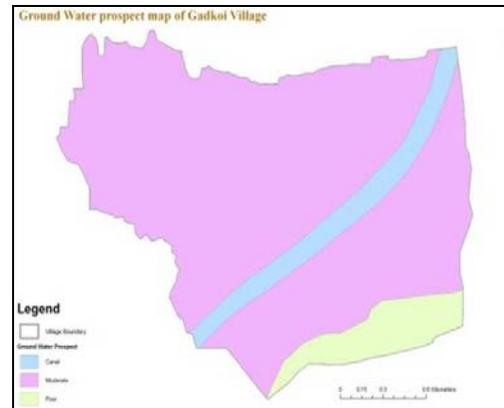


Plate 38. Micro plan for Panchala Village

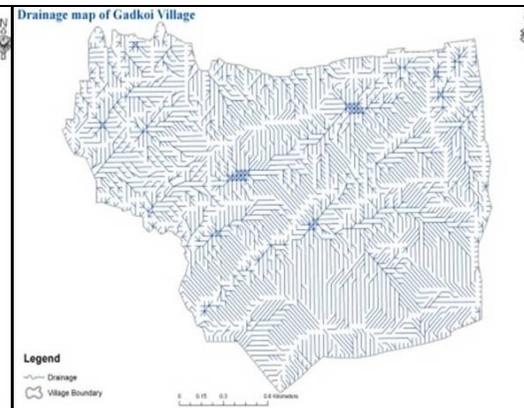
4.9.2) Gadkoi: The microplan of Gadkoi village (Plate 39) brought out the scarcity for drinking water in the village. The main source of drinking water at present are hand pumps & wells and irrigation is rain fed. The Ground water prospect map exhibited the classes of moderate and poor type. It showed the requirement of 5-7 checkdams. These checkdams are in JFM areas and in single cropping land, since ground water prospect is very poor, the construction of these dams needs to be done in the most economical way like going for bore wells (sac dams) for the success of JFM strategy in this village.



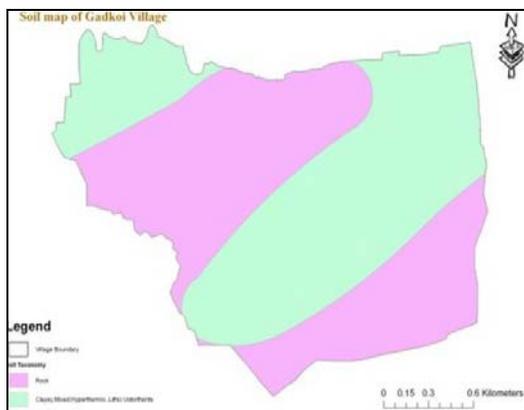
a) Landuse Map



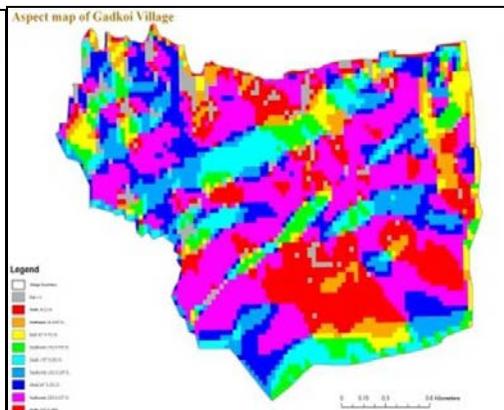
b) Ground Water Map



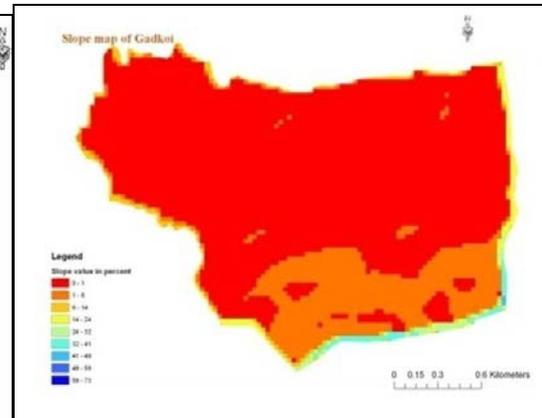
c) Drainage Map



d) Soil Map



e) Aspect Map



f) Slope Map

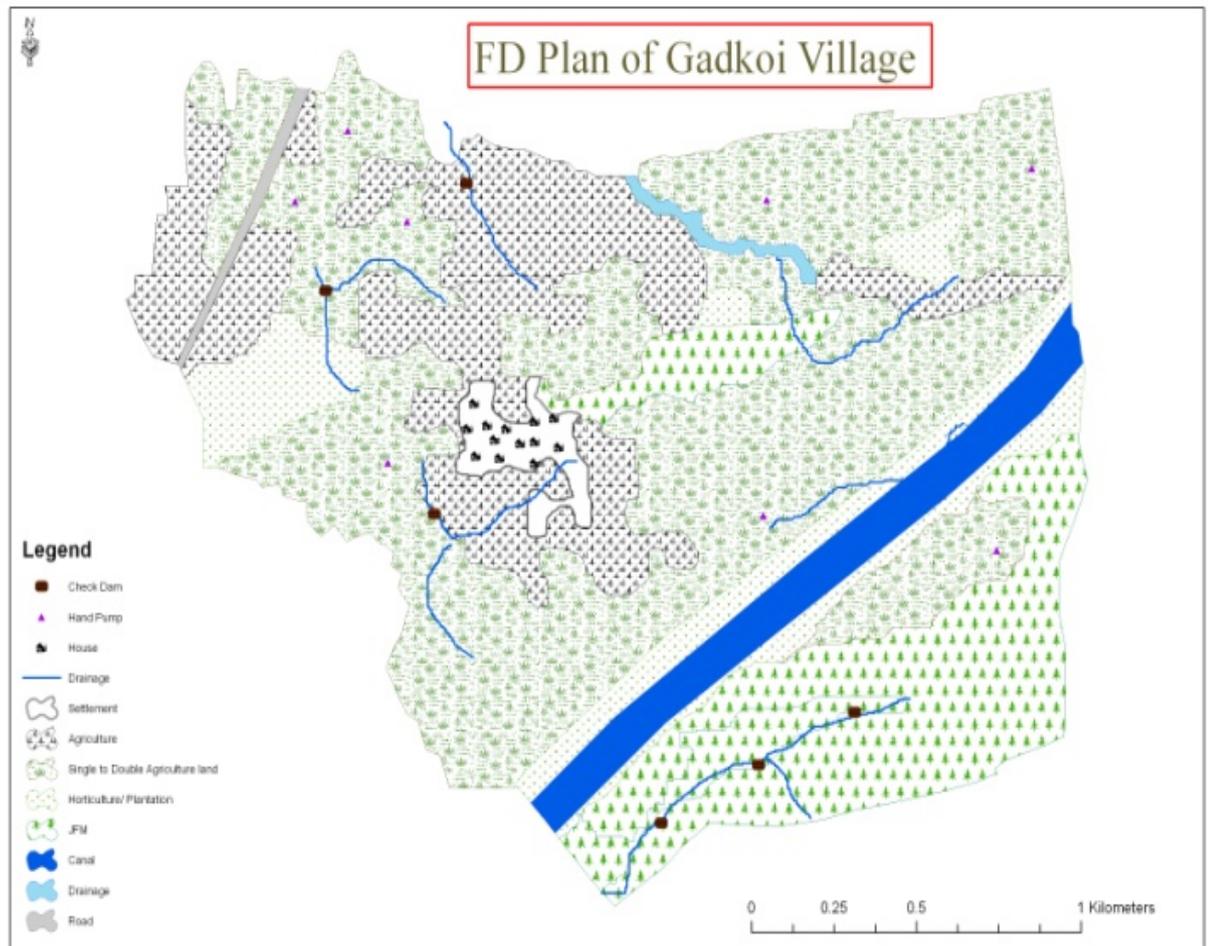


Plate 39. Micro plan for Gadkoi Village

4.10) Forest Condition Mapping: Forest condition and ecosystem health are concepts only recently addressed in the assessment of forest and woodland ecosystems throughout the world. Until recently, condition or forest health studies have largely been concerned with the physiological health of forests, generally as a means of assessing potential threats to the forests commercial values. Few studies currently exist that deal with forest condition holistically in terms of structure, disturbance impacts and habitat values. Forest condition maps developed using this

GIS could be used for the resource reporting, assessing the effects of silvicultural operations, and as indicators of damage and disease outbreaks.

All the previously discussed factors i.e., species richness, forest regeneration, anthropogenic activities, cattle grazing, pest and infection, standing woody biomass and productivity helped in finalizing and depicting the overall conditions of forest of Rajpipla taluka. The map displayed in plate 40 show the observed results in the selected JFM villages, while plate 16 displays the overall forest condition of the taluka.

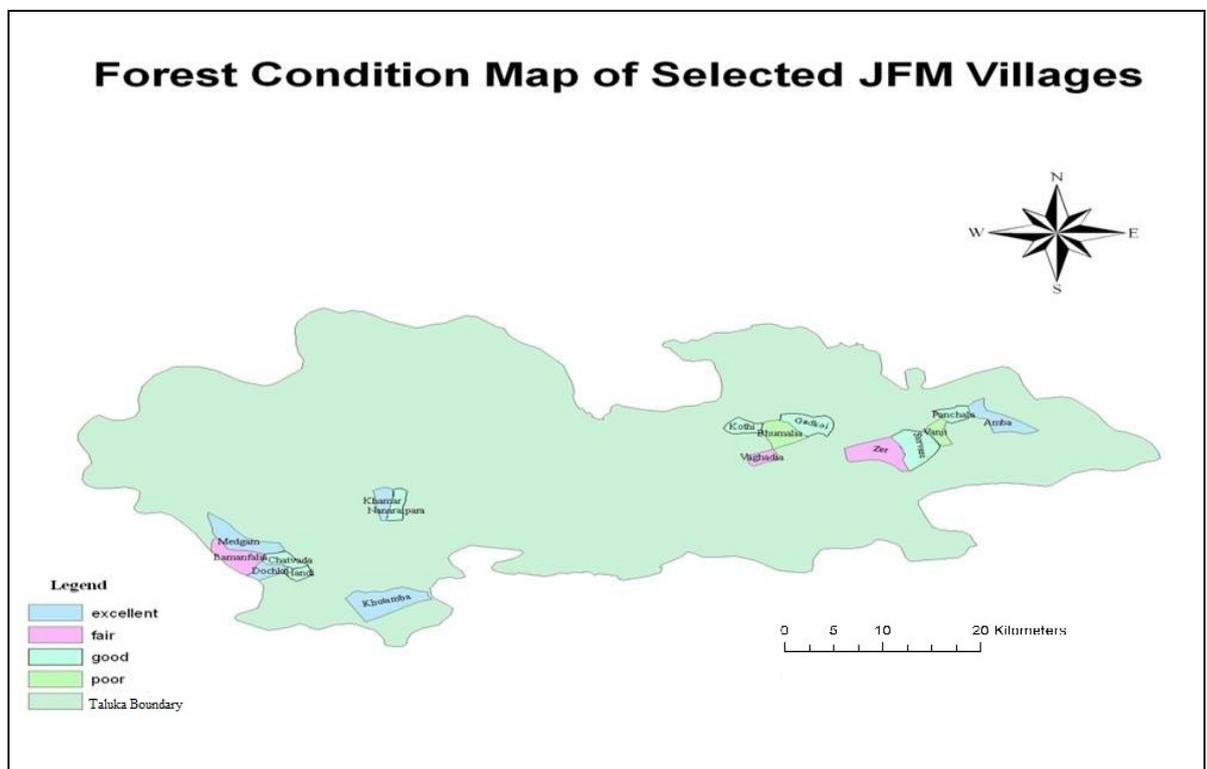


Plate 40. Forest condition map of the selected JFM villages

Plate 40 shows the output generated, having five different categories viz., Excellent, good, fair, poor and very poor. Majority of the villages i.e., 39% were falling in good category, 27% in excellent, 17% in fair and only 11% villages were falling into poor category Table 32.

Table 32: Conditions of forest village by accuracy assessment

Villages	Interpolation Method Condition Assessment	Accuracy Assessment
Nani Chikhli	Excellent	Excellent
Naghatpur	Good	Good
Limkheter	Excellent	Excellent
Navra	Very Poor	Very Poor
Akuvada	Poor	Poor
Rundh	Poor	Poor
Lachras	Fair	Fair
Surajwad	Poor	Poor
Bhilvasi	Poor	Poor
Gora	Fair	Fair
Vaviala	Poor	Fair
Chapat	Good	Fair
Zarvani	Poor	Fair
Namalgadh	Excellent	Excellent
Samaria	Fair	Fair
Taropa	Fair	Fair
Vagetha	Fair	Poor
Garudeshwar	Poor	Fair
Suka	Poor	Fair
Sisodara	Very Poor	Very Poor

The forest condition map generated for Rajpipla taluka by using interpolation techniques from the Arc-GIS 9.2 tool was analysed for the accuracy assessment. Plate 41 shows the accuracy assessment for these parameters displaying 70% of accuracy which was achieved by ground surveying in the randomly selected 20 plots. Six out of 20 villages showed variation from the interpolation results. Villages like Vaviala, Zarvani, Garudeshwar and Suka felled under fair category during accuracy

test, but earlier they were categorised under poor forest category. Similarly, Chapat and Vagetha village were previously under good and poor category but after ground truthing and accuracy assessment they were categorised to poor and fair forest condition respectively. This discrepancy may be attributed to the fact that the anthropogenic, diversity and regeneration condition varied accordingly with the locality population and the distance from settlement.

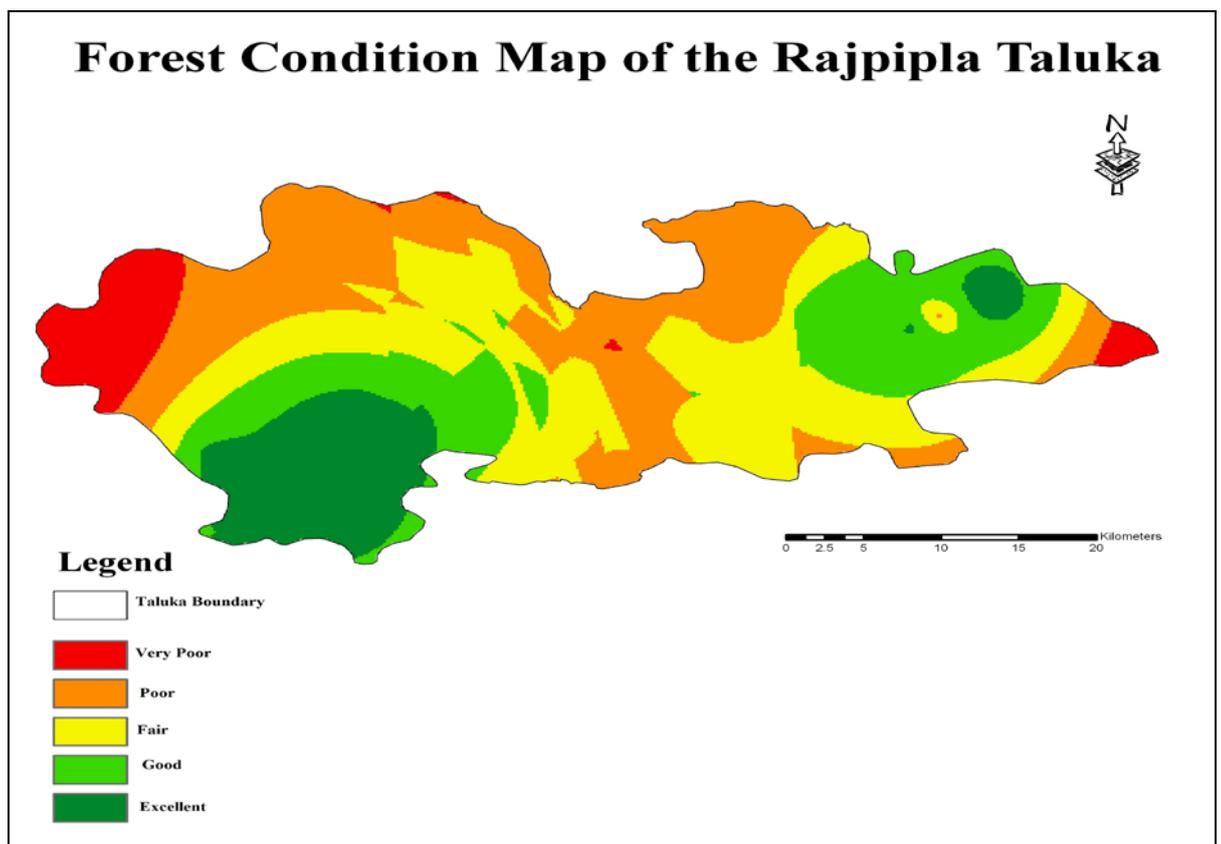


Plate41. Forest condition map of the taluka

4.11) Ecograting of Rajpipla Taluka:

Ecograting classification refers to the categorization of present ecological state of an ecosystem relative to the natural reference condition. The purpose of ecograting was to gain insights and understanding into causes and sources of differences of the features from the reference condition. It provided the information

needed to derive desirable and sustainable ecological conditions. Different classification of ecosystem has been done from time to time by various workers on various bases. These classifications gave informations only about floral and faunal components and did not mention about other factors related to the ecosystem. More over these classifications did not give much importance to the effects of biotic factors, landuse patterns and intensity of anthropogenic activities, diversity and ecosystem degradation. The ecological grading system relates classification which fairly allows for detailed classification of bio-units with a reasonable degree of geological consistency. From the previous analysis of forest classification, it is clear that these ecogrades not only provided information about the vegetation, but also about conditions that determine the suitability of that location particularly when complemented with additional ecological classes.

The categorization of the study area/taluka in different Ecogrades brought out 9 different Ecogrades (Plate 42). Major part of the area was falling into Ecograde1 to Ecograde5. Few villages like Vaghadia and Bhumalia could be considered into Ecograde 9.

An underlying principle is that a forest is considered in good state when the ecological processes inherent to the ecosystem are functioning within the natural range of variability of that ecosystem. This can also be demonstrated by comparing the ecogrades with forest condition classes. Here an attempt was made by comparing ecogrades with forest condition classes which yielded good correlation.

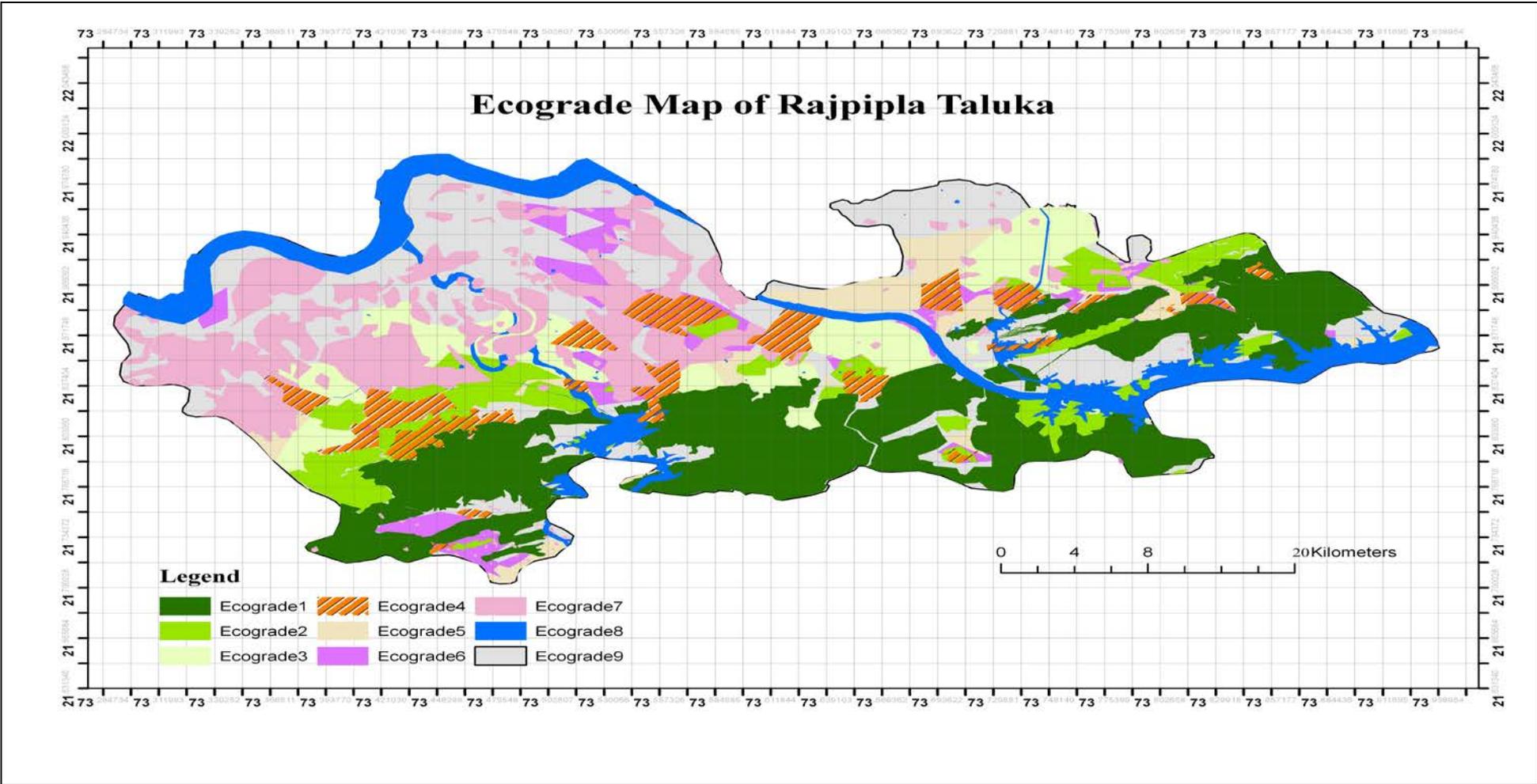


Plate 42. Eco-Grade Map of Rajpipla Taluka

The Ecogrades created, helps in differentiating two similar looking areas in terms of ecological features prevailing in these areas, whereas the condition characterise the area by the total feature present in a qualitative word, giving its full description. The assessment and monitoring of forest condition can provide a basis for managing and conserving forest ecosystems and thereby avoid loss of valuable natural resources.

The overlaying of Ecograde and Forest condition maps was aimed to evaluate whether the features of ecograde map showed a good correlation between two classifications. For example, the areas of Ecograde 1 which were characterised by a very good and dense forest cover exhibited very good to excellent condition. Thus, overlaying of these two maps helped in confirming the results. Out of all the ecogrades in most of the cases the desired result was achieved except for Vaghadia and Bhumalia village, where the correlation was just 23%. A good correlation was seen when comparing the ecogrades and forest condition classes of Bamanfalia (Plate 43) and Dochki (Plate 44) villages. The Bamanfalia village displayed three classes of forest condition good, very good and excellent forest, which were correlating with Ecograde 3, Ecograde 2 and Ecograde 5 i.e., fair, good and very good respectively. Similarly, Dochki village showed excellent condition of forest which matched with Ecograde 3 having very good forest areas. This evaluated the effectiveness of these classifications as a measure of biodiversity conservation and also to increase understanding of the effects of disturbances on the ecology of the forests of the region by using remotely sensed data for obtaining information on forests at a landscape scale.

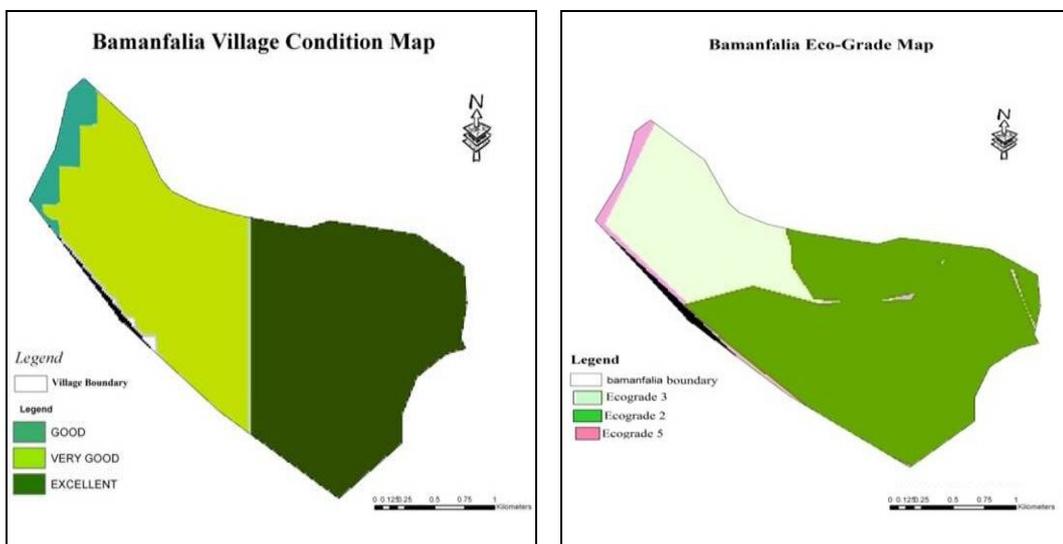


Plate 43. Correlation of Forest Condition and Ecograde Map of Bamanfalia Village

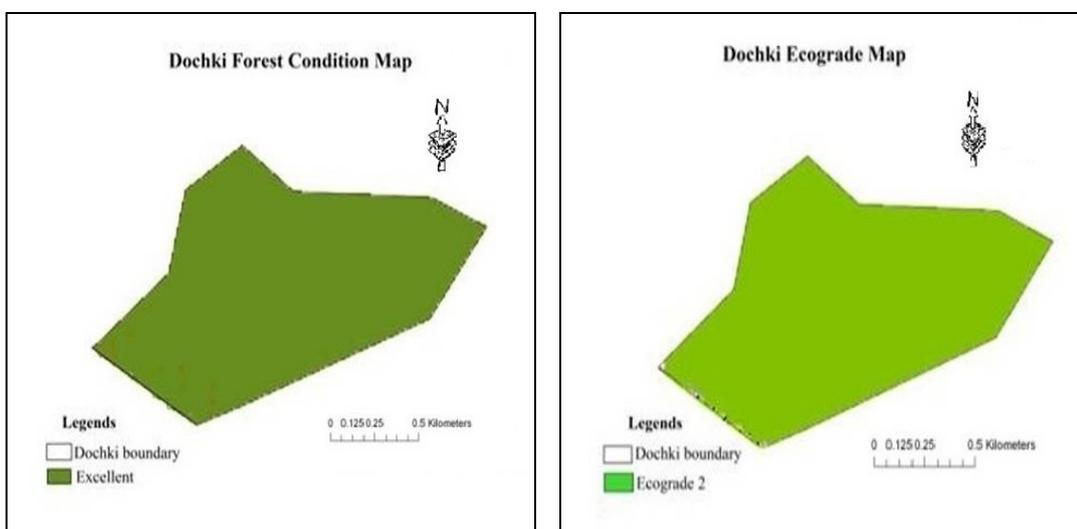
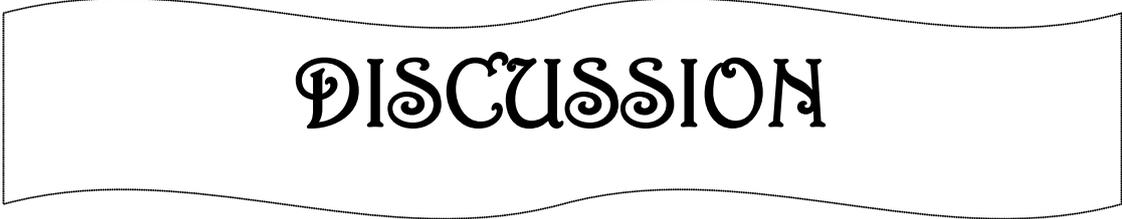
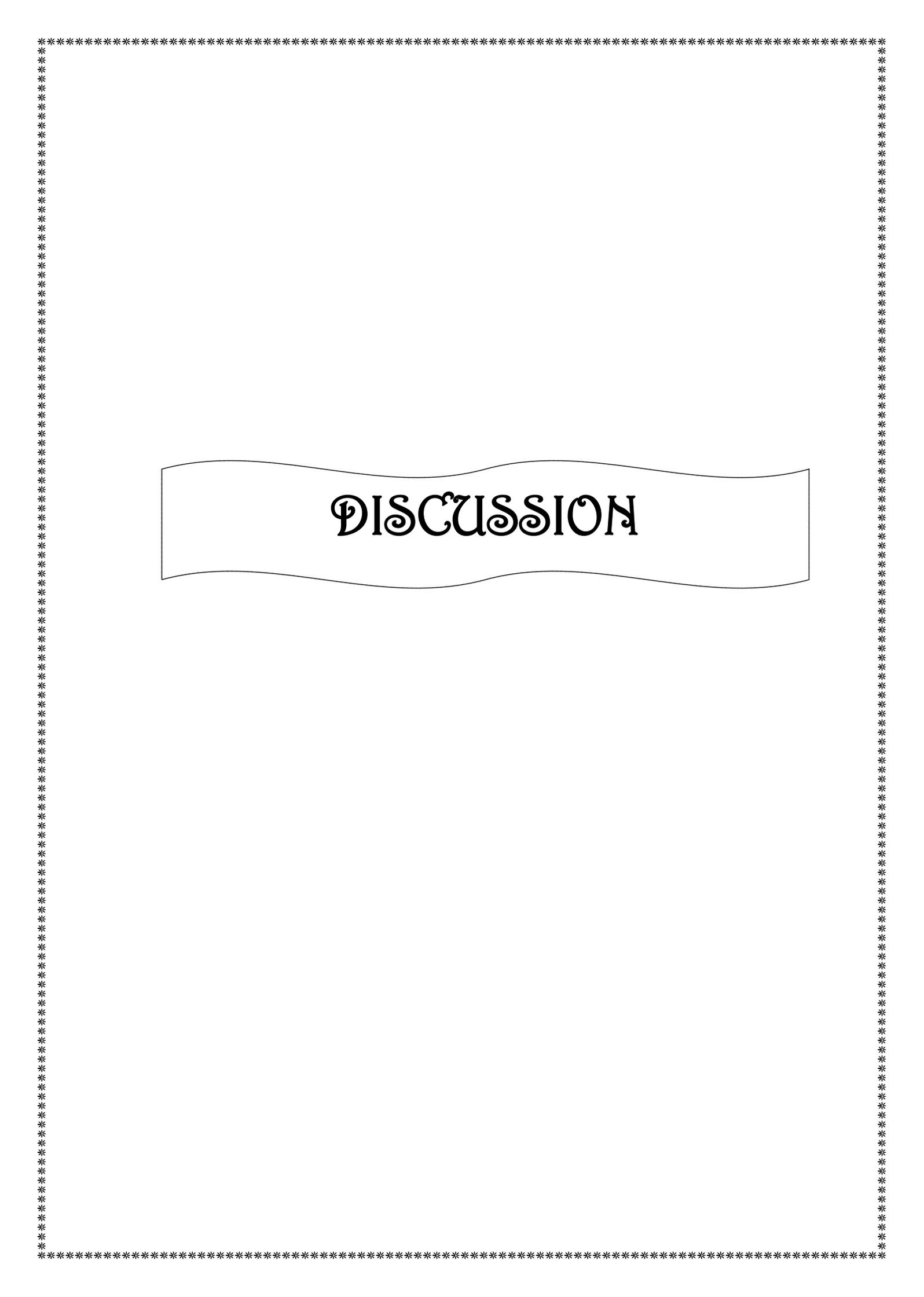


Plate 44. Correlation of Forest Condition and Ecograde Map of Dochki Village



DISCUSSION

5.0) Discussions:

Realising the necessity to undertake monitoring and evaluation of the extent and spread of JFM, the Ministry of Environment and Forest and Forest Department carried out number of studies. These were at national, state, district, taluka and village levels. These studies were undertaken by various agencies such as consultancies, firms, academic institutions and NGO's apart from the forest department's internal monitoring system. These surveys and studies covered different aspects of JFM. But these were carried out independently and not for a given single area. Such studies should cover all the aspects to get a holistic idea of entire study. The JFM is an important programme affecting the livelihood of hundreds and millions of rural population and ecology of forest. Moreover, a large investment is being made to promote JFM in India and thus there is a need or specific national strategy for monitoring and evaluation of JFM to generate information needed for effective policies, programs and practices to promote sustainable JFM in India. Several options have been emphasised in the present study, like:

- Monitoring of JFM at Macro and Micro level
- Understanding of perceptives of village community
- Monitoring of ecological and institutional policy issues
- Identifying indicators of conditions
- Application of precise statistical techniques has been taken care in present studies

5.1) Primary and Secondary vegetation analysis: Various phytosociological techniques are employed to study forest communities and their relationships (Noy-Meir & Austin 1970; Whittaker & Gauch 1973). Studies undertaken issues related to ecological work have adopted sampling plots, measuring basal area (BA), species number, remote sensing etc. The significant points about these studies were that, in these studies ecological issues were not properly addressed, the methods used were insufficient for example, comparison of various ecological parameters of the JFM villages with those of natural forest sites was not done i.e., a control approach was not adopted. Alternatively difference or change in the ecological parameters of the village forest, with the baseline scenario was not shown. This may be primarily because the agencies that implemented JFM did not generate baseline information about the vegetational status of that area. The ecological studies carried out in the present research have attempted to address all these issues to the maximum extent.

The two forest area i.e., protected (JFM) and non protected forest areas were selected from Rajpipla East Forest Division and were analyzed for the comparison of various phytosociological attributes on the basis of data recorded during the different growing seasons. Specific issues related to floristic composition, species diversity and density of the trees, regeneration pattern and condition of the forest were assessed. The floristic composition of JFM area exhibited more number of species when compared to natural forests. The floristic diversity observed in the present JFM areas was remarkable as evident from the current study; wherein 40 various tree species from 25 families were recorded across two forest divisions studied. The number of species reported was good, given the fact that, only 18 JFM villages were sampled. These figures were on a higher note when compared with neighbouring

natural forests. The lower values of species in natural forest area could be attributed to the anthropogenic disturbance.

Being a mixture of dry and mixed deciduous is the characteristics feature of the forest of this area. Foliage becomes markedly thin at the onset of summer with a simultaneous leaf flush during winter. The floristic composition evinces the presence of *Butea monosperma* Lam., *Diospyros melanoxylon* Roxb, *Holarrhena antidysenterica* Heyne, *Holoptelea intergrifolia* Roxb and *Tectona grandis* L., which are main dry deciduous tree species chiefly from families of Combretaceae, Verbenaceae and Mimoseae recorded from both JFM and natural forest sites.

The present study also indicated a high similarity of woody species composition existing between the natural forest and JFM plantation, for most of the sites. This might be due to uniform climatic condition of the area. The most abundant and dominant tree species was *Tectona grandis* L., this was highly valued by locals for its high yield of leaves and as multipurpose trees used for fodder, fuel wood, agricultural implements and timber.

The knowledge on distribution patterns of several tree species is of prime importance in deciding the management options. The understanding of spatial distribution pattern of an individual species in an area is central to the ecological theory (Dale, 1999 and Folt & Burns, 1999). It reflects the utility of resources by a species and throws light on the reproductive biology. Two distribution patterns observed here were the random and aggregated; randomness being restricted to less abundant species and aggregated to the most abundant ones. Aggregation of abundant species emphasises on the attitude of the phenomenon towards monoculture strategy rather than the polyculture strategy which requires more

attention. The significant point to be noted is that the presence of aggregated nature in both JFM and natural forest sites, a similarity between the two environments. According to Odum (1971) occurrence of such pattern is quite common in natural condition. It reflects competition between different species for resource utilisation at a local site (Pielou, 1962).

The different community parameters viz., frequency, density, basal area and IVI helped in understanding the status of a species in a community. These phytosociological attributes aid in achieving a sufficient empirical model of vegetation using a plant taxa combinations that characterize unjustified vegetation units. In JFM area vegetation cover and tree density have shown improvement over a period of almost two decade. In some area the JFM forests have become similar to or better than the natural forest areas. Murthy *et al.*, (2004) have also reported such improvement in JFM areas.

Frequency distributions of plant density, is considered as one of the parameter used to describe species composition and spatial patterns of vegetation in different plant communities (Chen *et al.*, 2008). In this study the results from frequency distribution of the tree species suggested that most of the species had low frequency as would be expected in typical species-abundance distributions. JFM and natural forest sites did not significantly differ in tree species frequency, although JFM had a higher proportion of species in the high frequency range, which indicated that JFM were more heterogeneous compared to natural forests. Tree density assessment brought out that JFM areas had higher values compared to the neighbouring natural forest areas. The densities of tree species like *Tectona grandis* L. (74.63%) at Survani JFM and (67.53%) at Medgam natural forests and *Butea*

monosperma Lam., (68.57%) at Kothi JFM and (46.17%) at Gadkoi natural forests varied greatly. High tree density suggested the diversity and luxuriance of JFM sites. Such status can be maintained if the extent of biotic pressure is maintained to an optimum limit. The lower values of species density in natural forest areas could be attributed to the anthropogenic disturbances. The reason for the lower values of tree density was the occurrence of collection of stumps and stems of trees by the local tribes from the natural forest sites. The JFM sites were the better protected and managed and were saved from such disturbances and exhibited better performance. Such protections also lead to the improvement in site quality as recorded by Singh (2000). This is also proved the increasing basal area in the JFM sites. Basal area provides a better measure of the relative importance of the species than simple stem count (Cain and Castro, 1959; cited in Tamrat Bekele, 1994). Therefore, species with the largest contribution in basal area can be considered as the most important woody species in the forest. JFM areas of Khamar village had the highest basal area of 16.18 m³ ha⁻¹ and natural forest of Zer village had the highest basal area of 16.86 m² ha⁻¹. In the present study *Tectona grandis* L. exhibited maximum basal area in both the sites. The other tree species with high basal area were *Butea monosperma* Lam., *Acacia catechu* Willd., *Dendrocalamus strictus* Nees., *Azadirachta indica* A.Juss., *Morinda tomentosa* Heyne., *Diospyros melanoxylon* Roxb. and *Madhuca indica* J.f Gmel., in both the case of JFM and natural forests. But the value of basal areas were comparatively lower in JFM areas when compared to natural forest areas, this was mainly due to the selective thinning done at regular intervals at JFM sites for commercial purpose. Interestingly, it has also been noted that in few cases after thinning, diameter and basal area increments may triple within 3 years (Bower, 1965). The trees which had high basal area also have higher phytosociological status

as reflected from their IVI. The higher value of IVI indicates that all the available resources are being utilised by that species and left over are being trapped by another species as the competitors and associates. These values of species indicated their dominance, ecological success, good power of regeneration and greater ecological amplitude. *Tectona grandis* L. with its increased dominance, density and abundance showed maximum IVI value (185.47) at Kothi and (173.31) at Medgam for JFM and natural forests respectively. Teak has flourished both in JFM and natural forests and has emerged as a dominant species of ecosystem. Despite of the commonness of *Tectona grandis* L., in both the areas there occurred variation in species richness and diversity. The species richness index showed higher values in JFM sites than natural forest sites. It was observed from the study that species richness decreased with the increasing disturbances. Rahman *et al.* (2009) also found negative relationship between disturbance index and species richness. However, species richness values alone, though interesting, is not informative enough (Onaindia *et al.* 2004).

Diversity, another significant measure of community structure has a very broad concept. Diversity is measured for three main reasons: (1) to measure stability to determine if an environment is degrading, (2) to compare two or more environments, and (3) to eliminate the need for extensive lists. Diversity indices provide important information about the composition of a community. These indices not only measure species richness but also take into account the relative abundance of species or evenness. When measuring species diversity, species richness and evenness both must always be considered. In addition, indices provide important information about species rarity and commonness in a population. These indices are important and common tools used by biologists in order to understand community

structure as it takes into consideration the number of species, the number of individuals and their distribution in an area. It cannot therefore be captured by a single measure. It is more comprehensive value than species richness. Choice of species diversity indices are based on appropriateness of each index on the data to be used. The index should have a statistical comparability and widespread utility. Given the large number of indices, it is often difficult to decide which is the best method of measuring diversity. One good way to get a feel for diversity measures is to test their performance with one's own data. A rather more scientific method of selecting a diversity index is on the basis of whether it fulfils certain functions criteria-ability to discriminate between sites, dependence on sample size, what component of diversity is being measured and whether the index is widely used and understood. There are many indices that can be used to calculate diversity. Some of the more valuable indices that calculate diversity include the following: (1) Berger Index, (2) Simpson's Index; which calculates the probability that two organisms sampled from a community will belong to different species, (3) Shannon-Weiner Index, which accounts for both abundance and evenness of the species present, and (4) Species Evenness Index.

Each of the indices uses different mathematical approaches/calculations to test/calculate diversity between two or more communities. These tools for measuring diversity are often used when determining community similarity, ethnic diversity and biological diversity. A glimpse of various species diversity measures as compared by Danoff-Burg J.A. is given in the Table 34 below.

Table 34. Various diversity Indices and their utility

Index	Discriminant Ability	Sample Size Sensitivity	Richness, Evenness, Dominance	Calculation	Widely Used?	Sensitivity and Abundance Models
Simpson	Good	High	Richness	Simple	Yes	No
Margalef	Good	High	Richness	Simple	No	No
*Shannon	Moderate	Moderate	Richness	Intermediate	Yes	No
Brillouin	Moderate	Moderate	Richness	Complex	No	No
McIntosh U	Good	Moderate	Richness	Intermediate	No	No
*Simpson	Moderate	Low	Dominance	Intermediate	Yes	Yes
Berger-Parker	Poor	Low	Dominance	Simple	No	No
*Shannon E	Poor	Moderate	Evenness	Simple	No	No
Brillouin E	Poor	Moderate	Evenness	Complex	No	No
McIntosh D	Poor	Moderate	Dominance	Simple	No	No

(* these indices were used because of their satisfying observations for the above said factors)

Keeping the comparison in mind, the attempts to assess the diversity of both JFM and natural forest areas using Shannon and Simpson index diversity indices have proven to be beneficial in comparing the diversity status of both these sites. These indices combine both richness and evenness feature in one statistics and have been widely used to estimate species diversity.

One of the species diversity index followed was the Simpson's index. Generally, a perfectly homogeneous population would have a Simpson diversity index score of 0 and a perfectly heterogeneous population would have a diversity index score of 1. For the present study the Simpson index was high at JFM sites than at natural forests sites, which is seen from the values obtained from the village Amba (1.10) at JFM site and (0.21) at natural forest site. These values were much higher than those reported by Uniyal *et al.* (2010) and Rasingam and Parathasarathy (2009) from Garhwal Himalaya and evergreen forest of Andaman Island respectively. It is

clear from the present observation that the JFM sites were more heterogeneous than natural forest villages, natural forests being more homogenous in composition.

The Shannon Weiner Index was another species diversity measure calculated for the present study. Simpson Index takes into account subspecies richness and proportion of each subspecies within a zone, whereas Shannon index is characterised by the number of individuals observed for each subspecies in the sample plot. For the present study it was at Nanaraypara it was (0.99) for JFM site and (0.58) for natural forest site. The present values are comparable to those reported by from Garhwal Himalaya, where it was 1.4 for undisturbed forest and 0.7 for disturbed. Therefore, it is assumed that the higher values of Shannon index at JFM sites than the natural forests makes them more diverse than that for adjoining natural forests.

An attempt to understand the species evenness showed a decreased value of Shannon evenness index in natural forest sites also supported the presence of intense anthropogenic activity in these sites. This index is used for comparing similar ecosystems or habitats, as it highlights one site being richer or more even than another. The lower values of the index indicate a low species richness and evenness and the high value of index depicts high species evenness and richness. It is clear from the above statement that the JFM site of Nanaraypara village was richer (0.96) i.e., with high species richness and evenness than the natural forest site (0.95).

In addition to the previous indices, ecologists employ a rank abundance curve, which graphs the ranking of the most abundant species to the least abundant. They can be shown as a plot of number of species vs. number of individuals on a logarithmic scale that usually yields a normal distribution. This is because environments are usually under-sampled, resulting in many singlets, especially in

high diversity systems. Singlets make up the middle peak of the distribution and the more sampling that is performed; the more the curve will shift to the right. These curve therefore provided us with important information about the community, information accessible at a glance. When there occurs a comparison between two or more assemblages, it is found that one assemblage is more diverse than other when its K dominance is less than or equal to the other. This aspect is clearly understood by reference to a plot of K-dominance where the percentage cumulative abundance is plotted against species rank. Comparison of the different sites of JFM and natural forests highlighted the similarity in the diversity for both the areas reflecting the contribution and affords made towards implementation of JFM Strategy.

Similarity measures are among the most interesting and common measures for comparing two or more sites or samples with respect to their species overlap. These measures are limited to pair wise comparisons. The pair wise comparison of JFM and natural forest sites were done using Sorensen's Similarity coefficient. Spatial homogeneity and heterogeneity within and among JFM and natural forest sites contributes to their current level of diversity. A relatively large number of different species and families were found in these communities. The similarity index varied largely at both the JFM and natural forest site. This at Dochki and Amba JFM site was 0.666 and at natural forest site it was 0.375.

5.2) Ordination techniques: Principal component analysis (PCA)

PCA ordination techniques help in ensuring that all the major groups are represented in the sample selected. It indicates uniqueness of sites in terms of species composition and habitat characteristics. PCA being a multivariate eigen analysis provided a better understanding of the variation in the species across both the natural

and JFM sites. Though there existed a similarity in the dominant species *Butea* and Teak, the other co-dominant species varied and contributed to the variations as exhibited by the components PCI and PCII.

The cluster analysis was performed based on relative density of species in their different life cycle. This aids in identifying groups of items e.g., samples with counts or presence/absence of a number of taxa. Such group may be interpreted in terms of biogeography, stratigraphy, environment or any other factor. Cluster analysis is often criticised for imposing groups even when there are none and it has been argued that it is better to use more neutral ordination techniques such as NMDS.

5.3) Non-metric multidimensional scaling (NMDS): NMDS ordination method was used to examine the changes in plant community composition and species distributions using vegetation surveys in both JFM and natural forest sites. It was found that species distributions and community compositions have varied in JFM and natural forest sites. The magnitude of community compositional change largely depended on location of these sites. The NMDS ordinations of the species and assemblage data were based on Bray-Curtis data (Bray and Curtis, 1957). NMDS was used as a tool in community change analyses (Wentworth and Ulrey, 2000). The application of these techniques on species data of both the sites reflected that both the sites had patchy distribution. Three clusters were formed in natural forests, while at JFM no distinct clusters were seen.

At natural forest sites the NMDS plot comprised of three main clusters, one cluster with 12 tree species, other with 10 and the third one with 7 tree species only. It was seen that at natural forests, each cluster had some similarity of families within them. The Cluster 1 formed had families like Mimosaceae, Ulmaceae, Papilionaceae

and Rubiaceae which were common to the Cluster 2 and Cluster 3 respectively. But still there were few families which were distinct in these clusters and were not common with each other.

5.4) Rarefaction: The height of a rarefaction curve is a function of community species richness and curve steepness is a function of species evenness. It is an estimate of the number of species that would be found in a given number of individuals and was extrapolated from the total number of species and individuals collected (Baco and Smith, 2003). The additional advantage of this method is that differences in species number no longer depended on differences in sample size. They depend on the variety of the community structure and calculate the expected number of species for standardized sample sizes in that community. Hurlbert (1971) used it to compare the samples that contain different numbers of tree individuals. The rarefaction curve revealed that sampling done for the species diversity in both the areas seems to be precise as only 3 villages namely; Survani, Vanji and Zer in JFM sites and at natural forest sites only Zer and Khutamba exhibited the requirement of more sampling. In all other remaining villages of JFM and natural forest sites the sampling done was adequate and the expected species number stabilized as reflected from the curves.

5.5) Regeneration status:

Regeneration is a critical phase of forest management because it maintains the desired species composition. A successful regeneration of forest species requires the presence of a sufficient proportion of seedling, sapling and poles/coppices to ensure replacement of aged trees. In order to ensure and optimise regeneration, foresters have developed silvicultural systems to regenerate forest of different

species mixes and ages. These systems are designed around the regeneration strategies of desired species e.g. selective category and regular thinning of JFM plantations to provide a suitable condition for the germination of seeds in soil and thereby facilitate the colonisation process. These gaps also encouraged reproduction by promoting not only the seed germination but also the development of coppices and/or root system. The enhancement of three different patterns viz. seedling, sapling and coppicing was quite obvious in JFM areas when compared to natural areas. Good and Good (1972) has considered these three components as major functions of regeneration. Disturbances to regeneration due to several factors become another important management catch. The improved regeneration status of JFM could be attributed due to fewer disturbances where in natural forest the density and composition of natural regeneration decreased (Holl, 2002; Chazdon, 2003; Uhl *et.al.*, 1982; Nepstad *et.al.*, 1996; Kennard, 2002). In such situation natural regeneration is preferred when compared to artificial (Champion and Seth, 1968; Marn and Jonkers, 1982).

5.6.1) Forest productivity: Standing Woody Biomass is an indicator of good forest conditions as it serves as a carbon sink and provides wood. Present study reports that in natural forests, there is a net addition to standing biomass than at JFM sites, leading to carbon storage. However, plantation forests with higher annual productivity are reported to be ideal for carbon storage and sequestration (Lal & Singh, 2000) therefore, creation of new plantations similar to JFM on degraded lands is a better option for carbon storage. The biomass maps and estimates were generated in the study for evaluating the productive potential of the JFM and natural forests. Another measure of productivity is the mean annual increment (MAI) of the forests.

In the present study the MAI of JFM sites was almost in comparison with Indian forests, thereby showing good productivity of these plantations. This was because of the two most important tropical hardwoods species, viz. Teak and *Butea* stands which were contributing to about 60% of the forests MAI.

5.7) Socioeconomics:

The discussion clearly indicates that with fast economic development forestry is being redefined. There is greater emphasis on poverty alleviation through forestry programmes. Private participation in forestry is also gradually gaining momentum. Almost 13 years ago the community-initiated management began in Rajpipla in the form of JFM, and it is almost a successful running strategy. Main reason for the success is found to be the effective leadership provided by few persons within the community and collective action. Effective leadership, which could convince everybody in the village about the need to protect forest resource, seems to have made a huge impact in the initial success of collective action and emergence of local institution. Leadership can be informal/traditional or formal, but a leader should have the capability to make the community beneficial (Hardin, 1968). These efforts were supported by the forest department. In addition to this, factors like self-imposed restrictions by the community, monitoring by the members within the community, effective patrolling, verifiable improvement in the quality of the resource, improved flow of forest goods like fuel and fodder have contributed to the effective working of the local institution in Rajpipla. For the successful implementation of JFM, flow of benefits through production of NTFPs offers the best incentives to the participating communities on sustainable basis. However, the current NTFP management practices need reforms in order to make them more ecologically and socially sustainable.

NTFPs have come to centre stage providing year round employment and supplementing income of forest-dependent population and contribute significantly to the income of about 30% of rural people. More than 70% of forest dwellers depend on NTFPs for their basic necessities.

Results also highlighted the fact that both forest officers and local people show a positive outlook for developing a perception towards each other and there is a significant improvement in the inter relationship between the two. Pratima and Jattan (1999) also indicated that commitment of the forest department (FD) staff is the most crucial factor for the success of JFM, which necessitates reorientation of the FD staff's role. The programme has succeeded only where FD staff could be reoriented and trained to handle the new responsibility. In the beginning of any approach, without assuring the minimum motivation and maturity level of people, one can just expect dramatic success with participatory approach. The role of forestry in rural livelihood is indicated by a few studies like Vedeld *et al.* (2004), who observed that forest products contribute between 20-40% of total income of households in forest areas. Other estimates in Indian conditions indicate a range between 10-54% (Bhattacharya and Hayat, 2004; Prasad, 2006).

Villager's expects immediate benefits from JFM. Their poverty, illiteracy and ignorance, limited role of women, limited motivation of people and forest officers and caste conflicts are considered as major constraints for the effective implementation of JFM. Satisfaction and participation of communities living close to forests with forest management authorities is essential for ensuring continued support for conservation efforts. Prior to community forestry, most households had been dissatisfied with the lack of effective controls on forest product extraction. From the

present study it was found that out of all JFM villages studied, villagers of Handi village were most dissatisfied with the system. The study also found a high level of awareness amongst communities about conservation activities, however, recommendation for a better education and awareness raising campaigns, as well as greater community participation in natural resources management is suggested. This was true for villages like Medgam (Site1), Handi (Site2) and Amba (Site6) which had low level of awareness from the locals. There are many factors that affect community participation, the factors which affected community participation that came up from the study, among others, are:

- Household demographic information - age, gender, educational levels, household size,
- Knowledge and skills about silviculture,
- Value of the forest resource,
- Proximity to the forest resource,
- Expected benefits, and
- Policy and legislative framework

The study revealed that some of these factors significantly influenced both the local community members already involved and those not involved in the JFM programme.

5.8) Remote Sensing- GIS:

The potential utility of RS-GIS applications for forest type, forest density and biomass has been carried out by several workers (Jha *et al.*, 2000; Menon & Bawa, 1997; and Prasad, 1998). Moreover several issues, related with forest fires, forest

disturbances (García-Martín *et al.*, 2008), forest productivity (Chirici *et al.*, 2007; Palmer *et al.*, 2009), forest changes over time (Hu & Wang, 2008), or the role of forests in the global carbon balance cycle (Hese *et al.*, 2005) are also dealt with. But the application of RS-GIS in assessment of JFM strategy is very rare except for Jayakumar S. (2007), at Kolli hills in Tamilnadu. Though JFM is a major feature of Indian government forest policy this technique has not been much applied for its assessment, except for some pilot studies. Thus the application of RS-GIS a pioneer attempt in understanding the success of JFM in Rajpipla taluka.

The concept of digital forest given by Hock. B *et al.*(2003) has been help in generating stable database to develop and test models. This database was mainly related to forest type, forest density, forest biomass and other non forest attributes like drainage, road network, settlement, irrigation pattern and landuse can prove to be fruitful in facilitating in research capability related to JFM issues in these areas.

From the maps generated in the present study, it was evident that most of the forest cover has decreased between 2001 to 2005. Specifically decrease in the dense forest was seen, but at the same time a positive change in increase in dry deciduous forest and open forest category highlighted the role of forest department activities with respect to afforestation and planning of plantations. Moreover the biomass map has given an idea of the area under biomass production. It has very clearly brought out that 21% of the area produces less than 100 t/ha which when discussed in terms of JFM strategy has shown that the protection to the JFM has helped in increasing the biomass status. Thus, the wealth of digital data generated can permit the development of new approaches in using spatial information for forest management.

Future development and utility of such data area encourages in particular to those promoting conservation and diversification of an area.

In the present research such type of application is done by carrying out the site suitability analysis for identifying potential sites for JFM plantations. Selection of suitable sites is an important criterion of success of JFM, for which different digital themes were, modelled which proved to be successful in identifying the potential site for JFM in Rajpipla taluka. Of the total 203 villages of Rajpipla taluka, only 21% of villages were found to be suitable for the JFM implementation. Site suitability analysis has already been proved successful in earlier studies in Tasmania, where the suitability was done for commercial plantations. Similarly selection of species is another important criterion for which the input from digital database related to species growth can be incorporated for identification of suitable tree species, which is one step further in this research. Another application for the digital database was made for generation of microplan. The microplan generated has a very vital role to play in the success of the JFM strategy in any village. It is well known fact that for micro planning, the vital aspect is involving the village community for generating local data, assessing and prioritising and their socio-economic needs in relation to the forests. This planning involves ground study and evaluation of data of a specific area of interest, for e.g., rural development schemes, irrigation, ground water development, town planning, mining, road logistics etc., that requires different theme maps and data. Thus, in the present study the microplan generated for the villages brought out the need of new check dams that would facilitate the in going of more of horticulture plantations. This plan also provides inputs for gouchar land development. The need to categorising open forest land into JFM areas should be

included which at present is not taken into consideration by forest department was highlighted in present study. In addition to that different water conservation strategies like furrowing, trenching, bunding etc. could be implemented with availability of precise slope and aspect information available at the cadastral level.

The results in form of microplan generated for Panchala, Gadkoi and Kothi needs to be carefully implemented taking into consideration different points provided, related to the landuse, aspect, slope, drainage, ground water prospect and soil. This if done will not only provide assured water supply with improved ground water potential but also will ensure the further success of JFM strategy.

5.6) Forest condition:

Forest plantations are commonly regarded to be the antithesis of old growth forests because they are thought to be structurally and compositionally uniform. The threats posed by anthropogenic activity in the environment have resulted in a debate about forest plantation condition and growth. Therefore, research into forest condition and vitality has been one of the key areas in forest ecology during the past two decades. Concept of forest plantation condition and health are recently addressed in the assessment of forest through the world. Until recently, condition or forest health studies have largely been concerned with the physiological aspects of forest. Today measures of forest plantation condition include different features like the number of acres of forested land, the size of each block of forest, the rate of growth of trees and other plants, the number of trees that die from natural causes each year, the condition and diversity of plant species below the forest canopy, the species of trees supported by the ecosystem and the intrusion or damages by day to day cattle

activities. Other measures include foliage transparency of tree crowns, tree crown dieback, tree crown density and the size and health of individual tree.

Owing to the complexity of ecosystems, especially forest plantation ecosystems, it is clear that we cannot measure all aspects of ecosystem. Instead, we have to select a few variables that will represent key components of forest condition. These representative elements are indicator-variables that we choose to monitor, reflecting what we consider to be important, based on what is feasible to measure (Ferris, 1999). Indicators are qualitative variables which can be measured or described and which when observed periodically demonstrates trends (Dale *et al*; 2001).

Furthermore, to evaluate forest conditions it is necessary to compare data with data from other forest categories under similar ecological conditions. For this reason, natural forests areas have been included in the study, so that a proper comparison between JFM and natural forest sites could be made.

In all the JFM villages studied, the forest condition is seen to be improving. However, there are also concerns about pressure on community forests in certain areas. The various forest disturbances like cattle activity, anthropogenic activities and infestation of pest and diseases had made the status of these forest poor. JFM has so far proved to be successful in this areas as demonstrated by the existence of a healthy forest condition with little disturbance. More attentions should be paid in those villages of JFM sites, where the results obtained, showed more damages and disturbances.. The villages close to the vicinity of the forest plantation faced more intrusion of cattle causing damages to the trees, seedlings, sapling and that of regenerating species. Thus, the species which are regenerating stops its growth. It is

learned from earlier workers that heavy browsing suppresses the seedlings and saplings (Beguin, *et al*, 2009; Dharani *et al.*, 2009) and that overgrazing leads to the degradation of plant and soil resources (Keya, 1998) and also, the loss of species richness (Mwendera & Saleem, 1997; Beguin, *et al*, 2009). Herbivores also disturb the forests through uprooting and debarking of trees (Pradhan, Wegge & Moe, 2007). These disturbances can be restored by providing protection from extraction and disturbance and recovery of cattle damaged vegetation by enclosures and covers has proved the capacity of vegetation to recuperate. Human-induced disturbances (such as mining, timber extraction, etc.) also impart changes in species number, tree density and basal area. Unrestricted open accessibility and permanent human settlement closer to the forest have been reported to exert enhanced utilization pressure, finally ending in a species-poor state. In few of the villages of Rajpipla, the minor forests were seen subjected to over-exploitation because of open access. A total enclosure, effective and strict monitoring of these JFM areas will result into a better condition of these plantations which will in turn affect the local biodiversity, natural resources and a well maintained ecosystem.

Occurrence of forest fires in the region is less known fact and is mainly observed at the southern part of the taluka. Occurrence of forest fires was seen at villages of Khutamba, Survani, Vanji, Zer, Bhumalia and Vaghadia which are actively participating in JFMP. Generally at JFM sites no record of forest fires is observed, this is because of effective control measure taken against forest fire. It is seen that in most of the cases the main reason for forest fires was not natural but manmade; this is due to lack of knowledge and awareness of the local, who unknowingly set the forest on fire. The forest fires cause a great loss to the forest

ecosystem, its floral and faunal diversity, makes soil prone to degradation and loss of regeneration as there is loss of seedling and saplings. A study done in tropical forests of Cerrados (Brazil) also found that frequent fires reduce species richness (Silva and Batalha, 2008) and also reduces the shrub cover and encourage herbaceous growth (Sankaran *et al.* 2008). Other than forest fire, the pest and diseases also concerns the foresters about the maintaining the forest conditions. Although the infection of pests, like termites and other disease was not much pronounced in Rajpipla forest areas, some amount of spread of termite infections and canopy defoliations can be still seen in few parts of the region. This occurrence was much lesser than at natural forest. This is because the sapling sown at JFM sites were treated with pesticides and insecticides and then transferred to the plantation soil, so the chances of pest and diseases were lowered.

The generation of Ecograde and Forest condition map for the forest area also provided an inside view of vegetation of the area along with displaying condition. Such type of information proves to be an important issue for the forest people as it takes into consideration all the features which are required for planning for a better forest ecosystem. Information's from these maps will definitely prove a helping hand in conservation for the forest managers in identifying the priority areas, designating areas for reserves and other protected areas.

CONCLUSION:

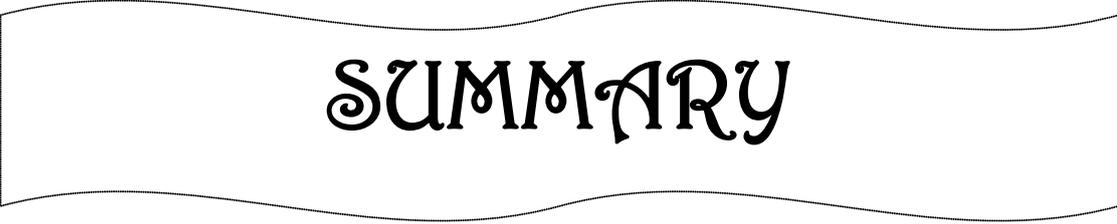
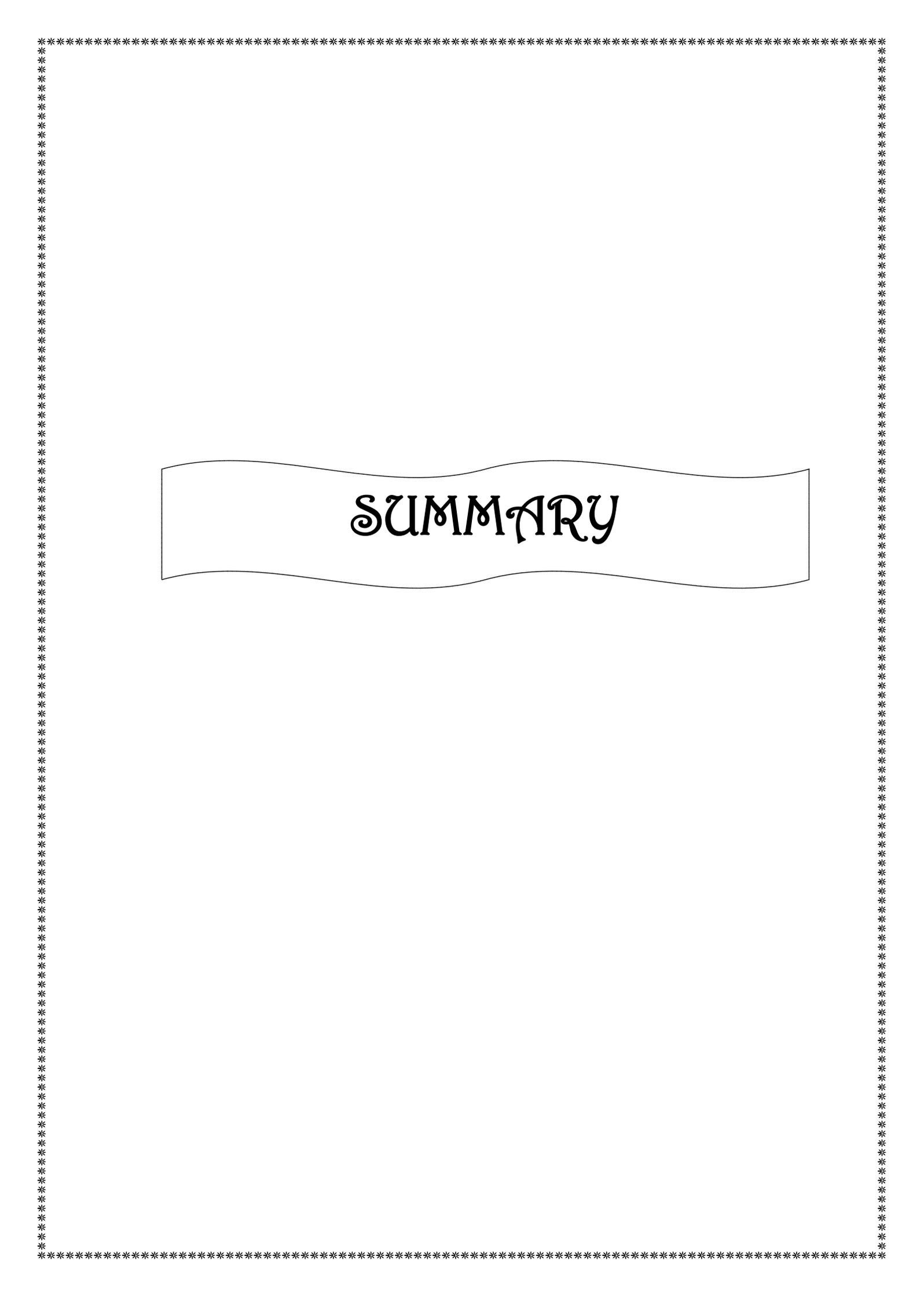
Forest cover in the Rajpipla taluka of Narmada district represents a typical scene where population pressure and the resultant demand from the rural and tribal populations have changed forest and land use status drastically. The destruction and degradation of forests in this area has raised one of the greatest environmental threats wherein quantity and quality of the forest is diminishing. Due to the changed scenario, it is high time that this vital resource is properly evaluated for its sound planning and management. In such circumstances the implementation of Joint Forest Management strategy has proved to be a boon in most of the sites. This would go unnoticed if the changes in the forest cover under JFM plan are not regularly monitored and assessed in terms of their ecological, economical and institutional success. Keeping this in mind hybrid approach wherein both conventional i.e. ground survey and non-conventional i.e. Remote Sensing and Geographical Information System (RS-GIS) together needs to be exploited to a maximum extent in understanding the community based JFM forestry holistically. The monitoring of JFM areas using non-conventional satellite LISS III data for the entire Rajpipla taluka at macro level and 18 JFM villages at micro level have showed that after a decade of active management, JFM plantations from a degraded forest land have got converted to a well productive forests in number of villages.

The detailed ecological assessment in terms of different vegetational parameters using conventional methods have highlighted the role of JFM in upgrading the degraded forest land in terms of floristic composition, plant diversity and bringing these forest closer to or better than the natural forests. Similarly, the socio-economic and institutional aspect studied showed increased participation,

awareness and satisfaction for this strategy amongst the locals of this area which if continues can also play a significant role in the success of this strategy of JFM programme.

The spatial modelling has provided precise inputs and locations for implementing JFM plantations strategy. It also aided in generating a detailed microplan for different JFM villages which if implemented will definitely raise the status of these JFM villages both economically and ecologically. This relationship of forests and its related attribute information's in a GIS mode as carried out in the present study can prove useful for resource inventory both at macro and micro level planning or while revising the existing working plan of this taluka.

Statistics generated from the spatial data during this work also emphasised the fact that future exploitation of the forest as a resource of revenue has to be reduced to a bare minimum as it will lead to an enormous increase in non-tangible benefits of the forest. If this is not done the result will be a virtual point of no return from the forest ecosystem of this area. There will nothing left for posterity. In order to achieve a sustainable development of the forest and success of JFM strategy the introduction of concept of digital forest using RS-GIS approached management system is the need of the hour.



SUMMARY

Summary:

Joint Forest Management (JFM) strategy was specifically designed for people's participation in forestry. It has been gaining ground in the past few years as a mean of regenerating and rehabilitating degraded forest areas with the help of local tribal's. Gujarat is considered a pioneering state in India in the context of JFM. It was among the first states to have implemented the Government of India (GoI) Resolution in June 1990. It introduced this programme with great enthusiasm and has yielded some positive results. However there are some problems related to social, cultural and administrative factors which are obstacles to the achievement of expected results from JFM. These problems can be eliminated through some important changes in the policies of the Forest Department of Gujarat and through proper training to the participants of the programme.

The implementation of non-conventional methods like Remote Sensing (RS) and Geographic Information System (GIS) has also proved its potential in forestry related problems. Therefore, in present study the spatial approach using RS-GIS was taken into consideration to get a complete view of the JFM and the existing forest cover of the Rajpipla taluka forest area to provide some usufruct outcomings. RS-GIS approach for assessment of JFMP in this area is a pioneer attempt which has proved to be successful in understanding whether this programme has been successful in fulfilling its promise or not.

In the present research work a well known conventional and a well developing non-conventional method was used to gain intense knowledge of the forest ecosystem prevailing at the taluka. The integration of spatial information with various important factors related to JFM like, Ecological (including diversity and in-depth floristic

studies), regeneration aspects, Forest Conditions, Baseline information generation and Socio-economical was done to understand the system thoroughly. Also, a strict comparison was done of JFM and neighboring natural forest (as control) to get an idea of different approaches.

The main focus of the present study was to highlight the status of the Joint Forest Management programme in the Rajpipla taluka of Narmada district of Gujarat and to provide some useful recommendations. The thesis summarizes results from various JFM and natural forest villages, studies in Rajpipla taluka, aiming to gain knowledge supporting conservation and rehabilitation efforts in degraded forests.

Various findings related to ecological, economical and social aspects along with spatial inputs are mentioned as follows:

1. Findings from the study conducted in forests of Rajpipla taluka indicated that JFM has been effective in conserving biodiversity.
2. In the study, tree species composition, structure and diversity of both the forest sites was carried out. The structure and composition of vegetation across various JFM and natural forest villages showed distinct features which were specific for each site.
3. The floristic inventory showed the families dominant at JFM sites were Mimosaceae, Anacardiaceae and Combretaceae along with Burseraceae, Verbenaceae, Rubiaceae, Meliaceae, Euphorbiaceae and Sapotaceae. While families including Combretaceae and Mimosaceae were dominant in natural forest sites of this area along with Papilionaceae, Caesalpiniaceae, Anacardiaceae and Combretaceae.

4. Tree density ranged from 440 to 1990 trees ha⁻¹ at JFM area and 330 to 930 trees ha⁻¹ at natural forest areas and basal area ranged from 2.19 to 16.18 m³ ha⁻¹ at JFM sites and 4.36 to 16.86 m³ ha⁻¹ at natural forest sites. These values were greater in all the undisturbed JFM forest sites as compared to the disturbed forests natural forest sites. JFM restored vegetation in degraded forests and greatly reduced soil erosion.
5. The JFM plantation sites were found to be more diverse than the neighboring natural forest sites, which were confirmed by various diversity indices. Species-richness and density of trees and understory plants were investigated in eighteen different JFM and natural forest villages of Rajpipla taluka of Gujarat, India. Tree species richness was as low as 5 at JFM and 4 at natural forest sites in human affected, undisturbed and disturbed forest site.
6. Regeneration potential of the JFM area had increased with increased seedling, sapling and coppice densities of the tree species. Tree regeneration was good at JFM area when compared to natural forest sites which had fair rate of regeneration.
7. Regeneration capacity of trees like *Tectona grandis* L., *Butea monosperma* Lam. and *Diospyros melanoxylon* Roxb, was good at JFM sites. Also, the trees recorded in JFM sites had good regeneration potential than at natural forest sites which were having fair regeneration potential.
8. The productivity of the JFM sites showed a good productivity than the natural forest when compared with the Indian forest, which are evident in these studies.

9. The average SWB of the JFM plantations was found to be 55.86 t/ha, this was lower than the growing stock of Indian forests which is estimated as 135.6 t/ha and amongst the different states of India it varied from 27.4 t/ha in Punjab to 251.8 t/ha in Jammu and Kashmir, respectively. The average MAI recorded in present JFM was 1.59 t/ha which was lower than the report national MAI of 3.6 t/ha for plantations. Fewer estimates are available for plantations on revenue or panchayat lands.
10. The forest condition map generated for the taluka showed five categories viz., excellent, good, fair, poor and very poor forest conditions. Excellent conditions of the forests can be seen in Nanaraypara, Medgam, Drucha, Dochki, Khamar and Amba villages.
11. Various disturbances and ecological successional processes shape the structure of forests and affect biodiversity. The result implies that the villages near natural forests had low tree density and biodiversity when compared with distant JFM sites from human settlement.
12. Biotic pressures has its own impact on JFM and natural forest, these have gone down in recent years. The collection of cut stems as fuel wood from the JFM areas is totally banned in all the JFM villages. The collection of dead wood is however permitted.
13. The resolution on banning the grazing in these areas has been imposed effectively in all JFMC's. However, members are allowed to collect grass for fodder, although lopping of trees for this purpose is not allowed in most JFMC's.
14. Fire prevention measures, such as fire trenching and floor cleaning, adopted in many of the villages lower the occurrence of forest fires.

15. All the forest protection activities were carried out by the JFMC's members themselves. A small group of the male members was formed for protecting the forest on a rotational basis. A general body member was employed as a watchman and was paid from the savings of the other members.
16. Low literacy levels and lack of experience of the JFMC's members has left the decision making power with the concerned member secretary, who was elected by the community members.
17. Results obtained from questionnaire have highlighted the role of tribal's in success of JFM in villages. Participation, Satisfaction and Awareness level of the members had increased due to the effective steps taken up by Forest department people. It was found that JFM is successful in places where community member's participation is effective and all the members including women are keenly involved. It was seen that women equally participated with enthusiasm in all the JFMC activities.
18. The Satellite approach for the taluka brought out the fact that the green cover of the taluka had increased. The image data used for this study were LISS III of the year 2001-2005. The imageries and ancillary data were collected in order to identify recent land-use/land cover.
19. The total area in this taluka under the forest cover was found to be 35,932.94 ha, which is 32.22 % of the total geographic area of the taluka. The forest map generated exhibited five categories namely; Moist Deciduous Teak forests, Dry Deciduous Teak forests and non forest categories i.e., Agriculture land, Barren land/Habitation and Water Bodies.

20. The forest type map generated for the year 2001-2005 exhibited increase in dry deciduous forest type with slight decrease of moist deciduous teak forests. It was found that in these forests, there was a positive trend seen in areas under Dry Deciduous forest, Agriculture and Water Bodies.
21. The forest density map brought out three density classes as Dense/closed (more than 40 per cent canopy cover), opens (canopy cover between 20 and 40 per cent) and degraded forests (canopy cover with less than 20 per cent). The results obtained showed an increase in all major classes except for dense forest and Barren/Habitation area.
22. The biomass map generated for the year 2001 and 2005 exhibited areas which are producing different values of biomass. The results showed that the areas which were generating more biomass has decreased slightly and a marked increase in the area was seen, which generated less than 100 tons/ha of biomass. This is due to the reforestation activities carried out in different villages according to its geographical conditions by the forest department in recent years.
23. The result of Site suitability assessment presented in the form of map and report will be of a great help for Forest Department, local user and for the overall sustainability of forest plantations. The Suitability map generated for the taluka brought out five different suitability categories vis., Highly suitable, Moderately suitable, Less suitable, Very less suitable and Un suitable. Out of total 203 villages of Rajpipla taluka, 43 villages i.e. 21% villages found highly suitable for implementation of JFM villages.

24. Micro-plans for many villages which are a need based and area specific are still at preliminary stage in the taluka. Use of local knowledge has been benefitted for both FDs and villagers. It also helped in preparing the microplan plan.
25. Microplan generated for villages brought out the need of new check dams that would facilitate the growing of more of horticulture plantations. It would help in gouchar land development as suggested from the Landuse map which is generated at cadastral scale.
26. It was observed that Open forest land should be included in JFM which at present not taken into consideration by forest department. In addition to that different water conservation strategy like furrowing, trenching, bunding, etc. could be implemented with availability as precise Slope and Aspect information is available at the cadastral level.
27. The above said, should be done with due regards to the environmental functions and productive potentials of the forests and their carrying capacity as also their conservation and biodiversity values.
28. The micro plan should also take into consideration and provide suitable advice for areas planted/ to be planted on community lands and other Government lands.
29. The Ecograding for the taluka was done to provide an insight view of the vegetation of the area and also the conditions prevailing. The Ecograding done has formed an important base for the forest people, as it includes the entire essential feature required for planning of a better forest system.
30. High priority areas should be identified through local planning systems, which indicate existing and conducive environments for community management. Identifying characteristics may include areas which have a high economic

importance of forests for local communities, existence of indigenous systems of forest control and use, expressed interest of community leadership and local NGOs, forest experiencing medium to high disturbance pressures and degradation and forests with good natural regeneration potential.

31. Modern forestry must be ecologically sound with the goal of conserving biodiversity and ecosystem integrity. To deal with this situation, the forestry services need to be modernized by enhancing technical expertise of the foresters in terms of forest management, preparation of Management and Working Plans need far greater attention and by implementing advanced non-conventional methods like RS-GIS.

RECOMMENDATIONS:

Sustainable forestry denotes managing forests to meet the needs of the present without compromising the ability of future generations to meet their own needs (Georgia forestry commission, 2000). The current case study is an investigation of Joint Forest Management (JFM); which highlights several parameters that should be considered for the sustainable forest ecosystem management.

For this reason, some important recommendations are drawn as outcomes of this research for the effective JFM implementation, which is as follows:

1. For maintaining species diversity, a special attention is to be given towards the forest composition while carrying silvicultural operations in the JFM.
2. Information on the biodiversity values and ecosystem services, existing here at Rajpipla forests should be recognised for encouraging the local people to conserve natural forests and other ecosystems.
3. Natural regeneration also allows a more diverse range of forest product flows, often of greater value to local community groups.
4. It is recommended to leave a certain percentage of total litter and foliage on the forest floor, to imply significant effects on physical and chemical properties of soil due to high nutrient contents of the foliage.
5. The plantation program should be done on barren and degraded forest lands, and the invasive species should be minimized by using appropriate techniques.
6. Protection of individual trees and promotion of a few fast growing tree individuals have enhanced the importance of natural regeneration, which is the

basis for the prolongation of forests. Hence it is recommended that necessary changes in the forestry practices should be done to continue the process of regeneration by seed crop, seed germination, seedling recruitment and establishment and their maturation into trees.

7. Fire line should be maintained regularly.
8. Collection and selling of Non Timber Forest Products (NTFP) needs to be look forward.
9. High priority areas should be identified through local planning systems which indicate existing and conducive environments for community management. Identifying characteristics may include areas which have a high economic importance of forests for local communities, existence of indigenous systems of forest control and use; expressed interest of community leadership and local NGOs, forest experiencing medium to high disturbance pressures and degradation and forests with good natural regeneration potential.
10. Participation of the people ensures a constant vigil to protect the forests; hence more and more membership drive should be done time and now.
11. A conclusive and reasonable act is must to resolve the issues related to the forest dwellers land and forest rights, providing them security for the management of community forests on enhancing both livelihood and ecological security.
12. For the success of any programme there should exist a transparency in the process which will enhance the results effectively, also transparency in system wins the confidence of the people targeted by the programme.
13. The active and timely involvement of NGOs could play a crucial role.

14. More improved facilities should be given to local villagers at subsidized rates for purchase of stove and Biogas, which is best method to minimize the overuse of forest products and loss of biodiversity.
15. Mapping of traditional forest territories, registration of user groups and collaborative agreements should be done to strengthen community actions for sustainable forest management.
16. JFM must be ecologically sound with the goal of conserving biodiversity and ecosystem integrity. To deal with this situation, the forestry services need to be modernized by enhancing technical expertise of the foresters in terms of forest management, preparation of Management and Working Plans need far greater attention.
17. New Working Plans needs revisiting. The revised guidelines for Working Plans need to incorporate digitization of all past Working Plans. Forest managers in the region need to be trained in Wildlife Management, use of modern tools of resource mapping, evaluation and monitoring and stakeholder participation should be incorporated.
18. Communication linkages should be established between government agencies and user groups. Such user groups are often the social unit most closely engaged in forest management. Rural women and low income households, often most heavily dependent on forest resources need a much greater voice in management decision making.

Annexure I: Profile of JFM Villages:

Site 1:

Sl.no	Parameters			
1	Name of Village	Bamanfalia	Medgam	Dochki
2	Area of Village (Hectare)	347.3	360.7	460.1
3	Major occupation/Employment	Farmer, labour	Farmer/ Labour	Farmer/ Labour
4	Available Gouchar land (Hectare)	21.3	8	14
5	Revenue Land (Hectare)	-	-	-
6	Forest Availability	Yes	Yes	Yes
7	Forest Area (Hectare)	187.6	154.5	460.1
8	Forest Division	Rajpipla East Division	Rajpipla East Division	Rajpipla East Division
9	Forest Range	Rajpipla	Rajpipla	Rajpipla
10	JFM Area (Hectare)	347.25	360.69	150
11	Year of initiation	2005	2000	2002
12	Name of Van Samrakshan Samitis Pramukh	Ghelabhai Chathurbhai Vasava	Tulsibhai Sanghabhai Vasava	Ranchodbhai Kalidas Vasava
13	No. of VSS member	115	23	90
14	No. of women members in VSS	45	9	40
15	Distance of JFM plantations from village (Km)	1.5Km	1.5Km	2.5 Km

Site 2:

Sl.no	Parameters			
1	Name of Village	Handi	Chatwada	Khutamaba
2	Area of Village (Hectare)	314.9	416.7	948.1
3	Major occupation/Employment	Farmer/ Labour	Farmer/ Labour	Farmer/ Labour
4	Available Gouchar land (Hectare)	1.5	1.5 acre	100
5	Revenue Land (Hectare)	-	-	934.47
6	Forest Availability	Yes	Yes	Yes
7	Forest Area (Hectare)	314.9	800	548.6
8	Forest Division	Rajpipla East Division	Rajpipla East Division	Rajpipla East Division
9	Forest Range	Rajpipla	Rajpipla	Rajpipla
10	JFM Area (Hectare)	150	150	190
11	Year of initiation	2004-2005	2005-06	1998
12	Name of Van Samrakshan Samitis Pramukh	Shyamalbhai Bhikjibhai Vasava	Fulwantiben Ramanbhai Vasava	Shivabhai Mohanbhai Vasava
13	No. of VSS member	39	38	108
14	No. of women members in VSS	6	6	22
15	Distance of JFM plantations from village (Km)	0.5Km	2.5Km	1Km

Site 3:

Sl.no	Parameters		
1	Name of Village	Nana Raypara	Khamar
2	Area of Village (Hectare)	275.1	269.4
3	Major occupation/Employment	Farmer/ Labour	Farmer/ Labour
4	Available Gouchar land (Hectare)	15.4	71.8
5	Revenue Land (Hectare)	-	-
6	Forest Availability	no	Yes
7	Forest Area (Hectare)	0	25
8	Forest Division	Rajpipla East Division	Rajpipla East Division
9	Forest Range	Rajpipla	Rajpipla
10	JFM Area (Hectare)	275.17	63.05
11	Year of initiation	2000	2000
12	Name of Van Samrakshan Samitis Pramukh	Shubhasbhai Kesarbhai Vasava	Somabhai Parsibhai Vasava
13	No. of VSS member	143	59
14	No. of women members in VSS	54	16
15	Distance of JFM plantations from village (Km)	1 Km	1Km

Site 4:

Sl.no	Parameters				
1	Name of Village	Vaghadia	Kothi	Bhumalia	Gadkoi
2	Area of Village (Hectare)	238.1	335.3	442.1	431.7
3	Major occupation/Employment	Farmer/ Labour	Farmer/ Labour	Labour/Farmer	Farmer/ Labour
4	Available Gouchar land (Hectare)	1-2 acre	30	22	11
5	Revenue Land (Hectare)	-	-	-	-
6	Forest Availability	No	yes	Yes	Yes
7	Forest Area (Hectare)	0	85.82	75.6	107
8	Forest Division	Rajpipla East Division	Rajpipla East Division	Rajpipla East Division	Rajpipla East Division
9	Forest Range	Kevadiya	Kevadiya	Kevadiya	Kevadiya
10	JFM Area (Hectare)	35	85	75	30
11	Year of initiation	2001	2001	2001	1997
12	Name of Van Samrakshan Samitis Pramukh	Jesangbhai Ratilal Tadvi	-	Amrutbhai Lallubhai Tadvi	Sanabhai Tadvi
13	No. of VSS member	35	149	14	
14	No. of women members in VSS	15	3	6	
15	Distance of JFM plantations from village (Km)	5Km	1.5Km	1Km	2Km

Site 5:

Sl.no	Parameters			
1	Name of Village	Survani	Drucha	Zer
2	Area of Village (Hectare)	109.7	1173.3	1173.3
3	Major occupation/Employment	Farmer	Farmer/ Labour	Farmer/ Labour
4	Available Gouchar land (Hectare)	46.8	1.5	43.3
5	Revenue Land (Hectare)	-	-	-
6	Forest Availability	Yes	Yes	yes
7	Forest Area (Hectare)	30.7	805.04	834.8
8	Forest Division	Rajpipla East Division	Rajpipla East Division	Rajpipla East Division
9	Forest Range	Kevadiya	Kevadiya	Kevadiya
10	JFM Area (Hectare)	30	100	500
11	Year of initiation	1998	1998	2004
12	Name of Van Samrakshan Samitis Pramukh	Narayan bhai himatbhai Tadvi	Motibhai Mohanbhai Tadvi	Ranasinhbhai
13	No. of VSS member	65	-	-
14	No. of women members in VSS	5	-	-
15	Distance of JFM plantations from village (Km)	2Km	0.5Km	2Km

Site 6:

Sl.no	Parameters			
1	Name of Village	Vanji	Amba	Panchala
2	Area of Village (Hectare)	272.4	303.1	303.1
3	Major occupation/Employment	Farmer/ Labour	Farmer/ Labour	Farmer/ Labour
4	Available Gouchar land (Hectare)	58.8	1	11.6
5	Revenue Land (Hectare)	-	-	-
6	Forest Availability	yes	-	yes
7	Forest Area (Hectare)	103.5	245.88	201.6
8	Forest Division	Rajpipla East Division	Rajpipla East Division	Rajpipla East Division
9	Forest Range	Kevadiya	Kevadiya	Kevadiya
10	JFM Area (Hectare)	100	25	150
11	Year of initiation	1998	2004	1998
12	Name of Van Samrakshan Samitis Pramukh	Govindbhai Namabhai Tadvi	-	-
13	No. of VSS member	11	238	-
14	No. of women members in VSS	2	126	-
15	Distance of JFM plantations from village (Km)	0.5 Km	0.5 Km	0.5 Km

Annexure 2: Socio-Economic Questionnaire

Sr.No Parameters

- 1 Name of Village.....
- 2 Location/GCP of Village.....
- 3 Taluka.....
- 4 Name of Village Sarpanch
- 5 Nearest Town.....
- 6 No. of households (2001 census)
- 7 Area of Village (Hectare)
- 8 Total Population (2001 census)
- 9 Male Population (2001 census)
- 10 Female Population (2001 census)
- 12 Literacy in Village (%).....
- 13 Source of income of locals.....
- 14 Major occupation/Employment.....
- 15 Migration (Y/N)
- 16 If yes, then for what? For how much period and where?
- 17 Nearest transport facilities available.....
- 18 Irrigation facilities available.....
- 19 School facilities.....
- 20 Health centre facilities.....
- 21 Post Office facility.....
- 22 Bank facility.....
- 23 Available checkdams.....
- 24 No. of households (2001 census)
- 25 Livestock population.....

	a) Buffalo.....
	b) Cow.....
	c) Bull.....
	d) Goat & Others.....
26	Available Gouchar land (Hectare)
27	Revenue Land (Hectare)
28	Forest Availability.....
29	Forest Area (Hectare)
30	Forest Division.....
31	Forest Range.....
32	JFM Area (Hectare)
33	Year of initiation of JFM.....
34	Adhikar Patra Number issued.....
35	JFM Bank Account available.....
36	Name of Van Samrakshan Samitis Pramukh.....
37	No. of VSS member.....
38	No. of women members in VSS.....
39	Distance of JFM plantations from village (Km).....
40	Choice of species for JFM Plantations.....
41	Major NTFPs
42	Amount of Fuel wood, Fodder, Timber collected during the seasons (Kg)
43	Suggestion for improvement.....

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**“What we are doing to the forests of the world
is but a minor reflection of
what we are doing to over selves and to one another”**

-Mahatma Gandhi