CHAPTER VI
DISCUSSION

6.0 DISCUSSION:

The applications of Remote Sensing (RS), Geographic Information System (GIS) and Global Positioning System (GPS) to forestry in India are not new. The venerable State of Forests report, published biannually by the Forest Survey of India, provides broad scale estimate of forest cover at district, state and national level (FSI, 1999). However, the broad national extent of the analysis does not focus on the applications of RS to the study and promotion of regional and local forest management.

Role of remote sensing technique in the field of local forest management institutions such as JFM can be categorized as a step towards understanding the spatial distribution of forest cover with respect to their structure, composition and condition, changes among them over the time. Thus the main applications of RS and GIS in the field of JFM are creation of data base of all spatial and non-spatial data, their integration, analysis and modeling. The spatial data acquired through remote sensing techniques and from other conventional sources and the non-spatial data are integrated and processed using Geographic Information System (GIS).

The present study on the assessment of JFM program using the integrated approach of RS, GIS and GPS had been conducted at district level rather than at the units of forest management such as division, range, round or beat. The reason behind this was, in majority of the case studies, the unit chosen for reporting the forest related studies was found to be the general administrative units of districts, rather than the forest management units of divisions, suggesting that the primary consumers are administrators and the general public, rather than the forest managers (Agarwal, 2004). Also there is a need for regional analysis of JFM at scales higher than the single Forest Protection Committee i.e. at village level or taluka level, but smaller than the state that can benefit from the application of remote sensing and GIS methods. Thus, JFM study at district level is the best option. For any of the studies related to JFM, the forest of that particular area need to be assessed first as JFM are the local forest management programs operated within the forest areas.

6.1 FOREST DENSITY CLASSIFICATION:

Forest density mapping is very much important in terms of forest management operations and also in preparing management plans. It plays a vital role in providing relevant information and therefore becomes a prerequisite for the effective management of forests. Even micro-level management programs such as JFM needs information on different levels of forest densities and forest classification.

Forests are classified on the basis of physiognomy, structure, function, composition, height classes, and distinction of woody tissue. Champion and Sheth (1968) classified Indian forests on the basis of physiognomy, climate, succession and ecological status. This can neither provide spatial maps nor facilitate integration of collateral data. Satellite remote sensing data presents the above given information in an integrated manner and has been used for vegetation stratification by several authors (Botkin *et al.,* 1984; William and Nelson, 1986; Roy and Joshi, 2002).

For the present study, three different forest density classes were decided viz. closed, open and degraded forest. In addition to these, it also included an intermittent class of forest and landuse i.e. Sparse Tree cover with Agriculture (STA). This intermittent class along with the non-forest categories viz. agriculture, canal, waterlogged areas and river found with in the forest boundaries were also demarcated.

The classification system designed for the present study was based on the criterion given by earlier worker, Singh, 1988. These criteria are:

- Classification system should have categories which could be directly interpreted from the imagery.
- Level of interpretation accuracy should be high (minimum 85%). The thumb rule is that interpretation accuracy is inversely proportional to the number of categories used.
- Results can be repeated by a number of interpretations using imageries of different seasons.
- Classification system should be applicable over large areas

- Categories should be divisible into more detailed sub-categories that can be obtained from large scale imagery or ground surveys.
- Aggregation of categories is must.

In the initial stage of the study the selection of broader forest categories were attempted along with the delineation of degraded forest patches within the forest boundary which can be developed into potential sites for JFM. Thus, the present study, not only focused on mapping of the JFM areas but also to search for forest areas for the development of such plantations. The digital remote sensing technique attempted to highlight these forest categories based on the reflectance characteristics could highlight these features of interest to some extent but had certain limitations due to resolution factor.

6.1.1 Season Selection for RS Analysis:

One of the important aspects for the study of the natural resources using remote sensing technique is selection of the season for the analysis of satellite data. October/November is the best season for differentiating the vegetation types, since at this time of the year the croplands, grasslands and forests are in their full foliage conditions. Due to the differences in the amount of foliage and geometric patterns, the three classes are easy to segregate.

Pandeya *et al.,* 1986, have proposed that the above ground live biomass reaches its maximum in September-October months. Since this period coincides with the post monsoon period, during which the cloud free data is available, October/November was the season selected for distinguishing the different forest classes. Jadhav *et al.,* 1991 have also reported that post monsoon (October/November) data is the best for studying vegetation cover changes.

6.1.2 Digital Analysis:

In the present study, the digital analysis technique concentrated on extracting the different forest and non-forest categories and enhance the separability of different forest classes.

6.1.2.1 Image Enhancements:

Techniques for improving image contrasts are among the most widely used enhancement processes (Sabnis, 1986). Algorithms for Linear stretching, Gamma, Gaussian, Standard deviation and Histogram equalization attempted helped in sharpening the edges between the brighter pixels and others. In general, all of them utilize the entire brightness range of the display medium. Among all the stretches tried; histogram equalization gave the best results, since in this enhancement technique, the classes with relatively low frequency had been amalgamated, while the classes with higher frequency had been spaced out more widely than they were originally occurring (Mather, 2003). Thus this contrast stretch helped in increasing the contrast in the centre of the range while reducing contrast at the margins.

The two properties of the band ratioing, that is, reduction of the 'topographic effect' and correlation between ratio values and the shape of the spectral reflectance curve between two given wavebands, have led to the widespread use of the spectral ratios (Bannari *et al.*, 1995, Baret and Guyot, 1991; Curran, 1980, 1983; Gilabert *et al.*, 2002; Tucker, 1979; van der Meer *et al.*, 1995). For the present study, two band ratioing were used viz. simple ratio and NDVI, of which NDVI was quite successful in segregating the vegetated areas from non-vegetated areas since this ratio exploits the fact that vigorous vegetation reflects strongly in the near infrared and absorbs radiation in the red waveband. However, NDVI did not give good discrimination among the forest density classes for the study area. The reason behind this may be attributed to the saturation of NDVI levels beyond 40% crown density (Dutt *et al.*, 1994) as observed in the study area. Greater the amount of photosynthesizing vegetation present, brighter the pixel will be (Jensen, 1996). This technique also provided information at pixel level on the vigour of the canopy with less degree of structural relationship of canopy closure.

Principal Component analysis gave much better results in discrimination of forest density classes when compared to NDVI, owing to its decorrelating nature. Multispectral data acquired from most remote sensors exhibited high interband correlation (Fung & LeDrew, 1987). Band 1 (green) and band 2 (red) are highly correlated because of relatively low reflectance of vegetation. Bands 3 and 4, the two infrared bands, are highly correlated because of high reflectance of vegetation. PCA bring in data compression and reduces band redundancy (Ingebritsen and Lyon, 1985). It has been shown to be of value in enhancing regions of localized change in Landsat multispectral image data (Byrne and Crapper, 1979; Byrne *et al.,* 1980). Richards, 1984, had used principal components transformation to highlight regions of localized change evident in satellite multispectral imagery associated with bushfire damage and with vegetation regrowth following fire burns.

Different attempts of spectral and radiometric enhancement techniques could not bring the desired discrimination among the classes. The reason was evident from the ellipsoidal plots showing the spectral overlap between the different classes in different band combinations. Maximum overlap was seen between the classes STA, agriculture and degraded forests due to the mixed pixels. In order to over come this, different images with varying capability to discriminate the forest and non-forest classes were combined together in order to get the desired separatibility. This layering consisted of the NDVI image which could successfully discriminate the vegetated and non-vegetated areas, the NIR band of histogram equalized image successfully separated the forest and agriculture and finally PC1 image helped not only in the discriminating of different forest density classes but also removed the shadow effect. Thus the layer stacked imaged aided in achieving the classes of STA and agriculture. This results correlated with the work carried out by Shubash, 2002, wherein he used layer stacked image of bands of LISS-III and 2 PCs for spectral discrimination of tree cover from other vegetation types.

6.1.2.2 Supervised Classification:

This method employs the knowledge of the area shown in the image in the form of fieldwork data, GCPs etc. Thus, the statistical algorithm use parameters derived from the sample data in the form of training classes. Both parametric and non-parametric methods were employed, but the parametric maximum likelihood method could generate a better output in relation to forest and other landuse classes in the present study area. Krishna *et al.,* 2001, have shown the utility of this algorithm in canopy cover monitoring. Similarly, Steven & Bradley, 1991, have attempted it during vegetation mapping and change detection.

In certain areas on the image there was overlap between vegetation classes, which could not be demarcated digitally. The low mapping accuracy in case of digital classification approach was due to the mixed pixel problem. Maximum misclassification was seen between the classes STA, Agriculture and Degraded forests due to greater spectral overlap between these vegetation classes and hence resulted in mixed pixels. While in visual because of the experience and knowledge regarding the distribution the forest type, there was a clear delineation of the class.

Although the training areas were refined in digital supervised classification, there was no change in the separability even with increasing or changing the number of pixels in the training areas resulting in misclassification of the pixels. Perhaps digital classification algorithm exclusively depends on spectral reflectance of the ground features without considering topographic factors.

Vegetation cover type information is important for forest conservation planning and management therefore higher mapping accuracy is required (Singh *et al.,* 2005a). Thus visual interpretation was also attempted for the study area.

6.1.3 On-screen Visual Interpretation:

The forest cover mapping involves a major problem of delineation of tree cover from other type of vegetation like bushes, agriculture, etc specifically when they are very close in the vicinity. One of the major problems faced during the present study was due to mixing of the classes degraded forests, sparse tree cover with agriculture (STA) and agriculture. This problem was because of overlapping spectral signatures which make their identification subtle and resulting in poor accuracy. In addition to this, shadow effect hindered the delineation of the forest density classes. This confusion can be attributed to topographical and phenological changes along with the vegetational gradation. In such cases, visual interpretation supplemented with homogeneity of certain classes generated by digital technique, field inventory, topographical features, location of forest types proved beneficial in separating the forest classes. The layer stacked image comprising of NDVI, PC1, and NIR band could accurately separate the forest and non-forest categories. This further when supplemented with other non-spatial data set along with precise GCPs enabled in increasing the accuracy when compared to the accuracy obtained from the digital technique because of its pixel based approach (Estes *et al.,* 1983).

The limitations and advantages of visual and digital technique have been worked out by several workers.

6.1.4 Merits and Demerits of Visual and Digital Interpretation:

Both visual and digital analyses of Remote Sensing imagery have their own merits and are not mutually exclusive. In majority of the cases both the methods are usually employed. The analysis and the use of the data depend upon the user requirements In Brazil, a combination of manual interpretation and computer aided techniques are involved in mapping areas of deforestation and forest plantations on an annual basis (Carnerio, 1981).

The comparison of visual interpretation with digital image classification demonstrated that the visual interpretation method allowed the most detailed differentiation of structures and objects as obtained in the present study and thus they can be used best for detection of landscape changes. Also, visual interpretation approaches do have certain advantages in terms of infusing the ancillary knowledge, like elevation, context etc. while interpreting the data whereas, computer assisted pattern recognition methods inherently had limitations in mapping forests but certainly had other advantages (Singh *et al.,* 2005b).

However, visual interpretation is a time consuming method and the quantum of work increases when working on large scales. Whereas digital technique reduce the time drastically and offer a more objective assessment of forest cover at large scales and better cartographic representation. Though visual interpretation is time consuming than the computer-automated methods, experienced analyst can produce highly accurate results. Trisurat *et al.,* 2000 classified Landsat TM data with both supervised and unsupervised method followed by visual interpretation of preliminary classes. Their results showed that high accuracy was attained by supervised classification and unsupervised classification could not differentiate between the primary vegetation classes. They also inferred that digital classification help in improving the vegetation mapping by allowing the interpretation of small mapping units over the visual method.

Roy *et al.,* 1991 adopted both visual and digital techniques for forest mapping of Baratang division (Andaman group of Islands) using Landsat TM data and aerial photographs and concluded that digital enhancement technique proved to be more advantageous in mapping than visual. Improved digital classification algorithms, which used contextual approach and parcel based classification may give results comparable to visual technique. Jensen *et al.,* 2004 in their neural network based photo interpretation approach emphasized the use of hybrid approach that is visual interpretation and digital interpretation as maximum interpretation accuracy achieved during digital image processing technique has been reported upto 70-80% (Jensen, 1996). There is a need of combining visual interpretation with that of digital to achieve high accuracy in near future. In the present study also the combined knowledge of visual and digital techniques helped in refining the vegetation classes to produce more accurate vegetation type map of the study area.

During the present study two factors one related to band width of the data i.e. 80-100 nm and other related to topography i.e. higher correlation of vegetation type with topography lowered the accuracy to 74.24% reducing the preciseness of the boundary separation between the forest types.

6.1.5 Spectral Profile of Different Classes:

In the present study, the DN values of the forest categories in the visible region ranged between 13-126 and that for IR ranged between 67-245. These values correlated with the min-max DN values reported by Roy *et al.,* 1996 in the visible and IR i.e. 28-103 and 14-162 for forest vegetation.

Each class identified in this study had a unique spectral signature. Band 2 of IRS LISS III data (0.62-0.68, red) is a chlorophyll absorption band. Most of the energy in wavelength centered around 0.65 um striking healthy green vegetation is absorbed (Hoffer, 1978). Hence the spectral curves tend to dip at this particular band. As the spectral response recorded by the sensor is not from a single leaf but over a small portion of land cover, crown density of trees play a very important role in forest mapping. The forests with high crown density have higher absorption or less reflectance in band 2. The forest cover class of closed forest therefore showed higher absorption when compared to open forest and similarly open forest had higher absorption when compared to degraded forests.

Spectral separation was also highest in the NIR regions of LISS III data. In the NIR, healthy vegetation reflected very high energy and the reflectance depended upon the internal structure of leaf and number of leaf layers (Gausman *et al.,* 1972). Similar to chlorophyll absorption band i.e. band 2, in NIR band also the crown density has its own impact. Further the trend shown by various forest classes with respect to crown density in NIR band is also reverse to that of red i.e. classes with high crown density have higher reflectance in NIR band and lower reflectance in the red band.

Different landuse classes have been distinct in their spectral characteristics. The differentiation of water body, river and canal could be achieved due to the change in reflectance with water depth (Katiyar & Rampal, 1991).

6.1.6 Landuse/ Landcover Statistics of the Study Area:

The numbers of forest classes in Tilakwada taluka are quite less owing to very less percentage of the geographic area under the forests. Thus in talukas like Tilakwada where in forest area available is quite less JFM program should be encouraged in non-forest areas as well.

In Rajpipla taluka, a substantial forest area comes under the waterlogged state due to the construction of the Narmada dam, which led to submergence of forest area. This is the only taluka wherein the non-forest category i.e. agriculture was found within the forest area. The reason for this also goes to Narmada dam, due to which thousands of farmers lost their agricultural land and the farmers had no other resource rather than to cut open the forest for the purpose of agriculture. In addition to this, there is wide spread occurrence of the category of STA, again showing the extent of forest encroachments.

The forests of Dediyapada taluka stand out qualitatively as well as quantitatively as this taluka possessed the largest as well as the best forest cover. This could be attributed to the fact that most of the forests of this taluka falls under the Shoolpanesher sanctuary area.

Among all the talukas of the study area, Sagbara showed the maximum degradation, due to the higher influence being anthropogenic either in the form of authorized cultivation practices or illegal cutting of the forests.

6.3 JFM MAPPING:

The spectral and spatial resolutions are major constraints for mapping resources at microlevel. Singh *et al.,* 2005 have suggested the potentials of LISS III and PAN merged data in delineation of tree cover within and outside the forest areas. However single row plantations, which do not have good crown cover, could not be identified. In order to overcome such limitations, further high resolution data becomes imperative.

The combined use of IRS-1C, IRS-1B and IRS-P2 data would provide better feasibility and enhanced capability to evolve new programs in the forest management sector, especially in the forest inventories and microplanning like Joint Forest Management (JFM) activities (Roy *et al.,* 1996).

The plantations of the study area mainly followed two plantation strategy viz. monoculture and polyculture plantations, which showed variation in the spectral response. Changes in the plant characteristic like chlorophyll content, cell structure or leaf anatomy result into change in reflectance even in plant species with similar crown density and vice versa. Spectral response study has clearly indicated that not only crown density but other plant characteristics are also responsible for the variation in the spectral response within different miscellaneous forest classes and plantations. This feature aids in classification of forest.

6.4 POTENTIAL SITES FOR JFM PLANTATIONS:

The purpose behind the forest density classification was to find out the potential sites such as degraded forest where in the JFM program can be implemented with the active participation of the locals. Dediyapada taluka was found to be the most potential taluka for future implementation of the JFM program owing to the maximum forest area under the degraded category. Dutt *et al.,* 1994 with the help of remotely sensed surveillance forest maps have suggested the degraded sites with the forest crown density less than 10% to be considered for the gap planting with JFM activities. For the present study sparse tree cover with agriculture was also considered for the implementation of the JFM program since the crown density of such mixed class was less than 10% owing to unauthorized cultivation carried out in such areas.

The 500 m buffers created around these degraded patches brought the potential number of villages coming in the vicinity of the degraded patches and where the JFMC can be formed.

6.4 MICRO-LEVEL ASSESSMENT OF JFM PROGRAM:

Gujarat is one of the pioneer states to implement Joint Forest Management program since the per capita forest area is one of the lowest among Indian states i.e. 0.05 ha (FSI, 1999). In Gujarat state, one of the best forests is present in the Narmada district. This district has always been in limelight due to India's largest river valley project on the life line of the state that is Narmada River. The creation of the Sardar Sarovar reservoir which submerged 13,744 ha of forest invoked a concern among the ecologist and the forest department officials to substitute for the lost forest cover. Thus, in order to restore the lost biodiversity and also to suffice the needs of the local dependent people whose major means of livelihood got submerged due to the dam, the forest department encouraged the local communities to form Forest Protection Committees (FPCs). These FPCs were supposed to take the lead in developing new access controls and micro-forest management plans. Looking at its potential of being a major forest restoration program in this district, it is necessary to monitor the JFM program as a long-term process which is greatly affected by social and economic conditions of the locals managing these ecosystems. Sreedharan & Dhanapal, 2005 have suggested that for the assessment of any JFM program, ecological, economical, social and institutional aspects are the four major parameters which need continuous monitoring. Thus the present study was designed for micro-level assessment of the JFM villages based on these four major parameters.

Selection of 13 JFM villages falling in three talukas of Narmada district was based on the pre-decided criterions which could affect the success of any JFM plantation. The major factor affecting the ecological sustainability of any JFM plantation or forest area is the biotic pressure on that particular area. Greater the biotic pressure, larger will be the gap between the supply and the demand. Thus, biotic pressure in terms of both cattle and human population was selected as a major criterion for selection of JFM villages. In addition to the ecological sustainability, the economic sustainability was also checked in terms of percentage landless. The years of protection given to each plantation was selected as another criterion as it gave an indication of the institutional set up of each JFM village. In addition to criterion based selection, 3 best villages from each taluka viz. Nani Chikhli, Kunbar and Godada were selected for their detailed assessment.

6.4.1. Geographic and Socio-economic Features:

Of all the talukas of Narmada district maximum number of the JFM villages was seen in Dediyapada taluka owing the maximum forested area in this taluka. Majority of the villages were tribal dominated, hence the dependence on the forest was also much high in these villages. However there was no correlation between the percentage of tribal people and the forest area in each village to that of JFM area allocated to a particular village. Villages such as Tilipada of Dediyapada taluka with maximum tribal population had the least JFM area and also, villages with maximum forest area such as Godada did not possessed correspondingly higher JFM area. The reason behind this may be because, JFM in majority of the cases has not been taken up as forest restoration program but is the out come of willingness of the concerned villagers. Thus the forest allocated to each village is based on the willingness of the villagers as well as the past performance of that particular FPI.

Absence of any correlation between the grazing area and cattle population in the study area indicated the lack of awareness among the villagers. Most of the villages such as Pansar and Naghatpur were maintaining a huge cattle population even though they are neither productive in agriculture nor for milk production. Such unproductive cattle create a major stress on the JFM area.

6.4.2. Forest Protection Institute:

Each village has a distinct identity in the physical, socio-economic and political aspects in terms of its unique combination of material resources, human capital and socio-political ethos (Mukherjee, 1991). Several efforts have been initiated to empower village communities through JFM both socially and economically (Singh & Varalakshmi, 2000; Bojvaid, P.P & Pawar, 2000; Joshi, 2000; Bhattacharya & Basnyat, 2002; MPFD, 2002; Sharma, 2003). Several studies are reported related to the performance and impact of FPI on the JFM program in Gujarat state (Bora & Bhalani, 2000 and Singh *et al.*, 2000). Similar studies were conducted by different workers in Uttara Kannada, Jammu & Kashmir, Orissa and Rajasthan (Bhatt *et al.*, 2000; Gulati, 2000; Jonsson & Rai, 1994; Goyal, 2000).

In majority of the selected villages of the study area, JFM program was initiated by the forest department. Das *et al.*, 2000, have pointed out that forest department acts as a catalyst leading to the formation of FPCs. Also, it is an established fact that training and demonstrations are effective tools for motivating and mobilizing the rural masses for enhancing people's participation in forestry

(Kumar & Tripathi, 2005). In this aspect, NGOs such as WWF and AKRSP have played a major role in creating awareness and motivating the villagers of Tilipada, Dabka and Kunbar for the forest protection and conservation under the JFM program. Nayak *et al.*, 2000 have observed that NGOs helped to strengthen protection in the villages by working in close association with the Forest Protection Committee. The presence of NGOs in some of the villages of Uttara Kannada have improved awareness among the communities regarding forest conservation and protection, policy advocacy and other environmental issues (Potter, 1996). Also, the presence of NGOs had made a difference to the community participation in JFPM activities.pp68

In Tilipada and Kunbar villages, formation of efficient institutional setup with the involvement of NGOs not only led to the restoration of the degraded forest but the villagers also derived benefits from the program. In Tilipada, money obtained from harvesting the timber from the forest was used for other developmental activities in the village. The 50% share received by the villagers after harvesting 10yrs old eucalyptus plantations was used for buying large utensils which is given on rental basis to all the neighboring villagers at the rate of Rs. 100/day. Also, in order to overcome the water shortage, a pool-type check dams with the total cost of Rs.5 lacs was constructed. AKRSP provided the money and villagers provided the labour. In Kunbar village, apart from the protection, the fund of the VSS was involved in various other developmental activities such development of school building, better transportation facility etc. In addition a mobile grocery van visits the village every week while a dairy van visits the village every day for collection of milk. Bamboo has been harvested twice since 1993 and 144 villagers have procured bamboo poles at subsidized rates. The members of the VSS have also contributed free labour to construct a forest pond and check dams with funds provided by WWF, while nursery has been established by the fund provided by the forest department. In Kodba village special incentives were provided by the forest department such as musical instruments to 10-15 artisans of the village and brass/aluminum vessels were provided to each household. Bhattacharya & Basnyat, 2003, had also discussed about resultant societal benefits due to the implementation of the JFM program.

On one hand if the villages such as Tilipada, Kunbar, Dabka and Kodba derived benefits from the JFM program then, on other hand villages such as Nani Chikhli and Koyalivav faced many problems. It has been observed that low awareness among the villagers and poor economic conditions of villagers had created many problems in implementation of the program. Presently in both Nani Chikhli and Koyalivav, the strength of the JFMC has tainted, as a result the forests of both these villages are fast approaching the degradation state. In case of Nani Chikhli, the major problem which led to the loss of interest among the villagers was the lack of legal action against the neighboring villagers involved in illicit felling and also the exhaustion of the external financial fund received from OECF. As the JFM projects have largely been implemented with external funding, after the expiry of the project term, the JFM has become ineffective and unsustainable despite the huge institutional arrangement (Mudrakartha *et al.*, 2004). However in case of Koyalivav, the villagers could not get benefit sharing was not satisfied, when 100 tonns of bamboo was harvested from the plantation site after 10 years (In spite of several meeting with the villagers and the forest department the reason behind this could not be sorted out). As a result, the forest was again subjected to heavy degradation. Other than these the major challenges faced by the program was its failure to establish appropriate linkages for addressing livelihood issues. Mudrakartha *et al.*, 2004 had also pointed out that the major lacuna of the program is the generation of alternate employment schemes for the villagers.

Majority of JFM villages of the study area, showed complete participation by the villagers in the JFM program except in Pansar village where negligible participation was seen. Khanna & Sama, 2001 observed that all JFM programs offered membership to all the local people with no inability clause yet rarely does the entire community participates. The reason for the non-cooperation of Pansar villages in the JFM program was- before the initiation of JFM these villagers were practicing unauthorized cultivation in the forest area and with the initiation of

JFM all their unauthorized cultivation practices and open grazing of their cattle was prohibited in the plantation area. In Pansar village the non-cooperation of the villagers was seen ever since commencement of JFM program but in Dhanor village of Dediyapada taluka a different scenario was seen.

In Dhanor village of Dediyapada taluka the VSS was initially established with the cooperation of the villagers but after a few years VSS had completely stopped functioning and people were not involved in any of the forest protection and management activities. The reason behind this can be attributed to lack of awareness among the executive committee and the members, as they are merely forming the groups as per request made by the forest department. Similar observations were made by Bhattacharya & Basnyat, 2002. Studies indicate that most women are not aware about JFM activities in the villages and they do not know when the committee was formed and what type of JFM it was, though they are using different forest products for meeting their daily needs (Sharma, 2003).

In contradiction to Sharma's observations active involvement of women was observed in this area, in Kunbar and Dabka village, as they formed women's organization- *Mahila mandal* which worked under the VSS. In case of Kunbar village the fund of this mandal provided financial support to the poor farmers in terms of seeds, fertilizers or insecticides.

6.4.3 Vegetational Analysis:

The vegetational analysis carried out in all the villages brought out the impact of Joint Forest Management activities on the structure and composition of the forest in Narmada district. In addition it also brought out the choice of species and level of community participation in the plantation strategy adopted in each JFM village. In all the selected JFM villages the selection of species was made by the forest department only and the villagers were not involved in it. Kothiyal *et al.,* 2005 have advocated a need to review and select suitable timber species for large scale plantation programs taking a holistic view on the end utilization characteristics and productivity aspects. However the needs of the local dependent community were taken into consideration by the forest department before making the choice of species for the plantation. Both timber and NTFP value of trees influence the species choice for the JFM plantation. However, people also perceive that forest should be maintained in order to have good ground water potential and water supply for agriculture. In most of the JFM sites of the study area irrespective of the plantation strategy adopted, *Tectona grandis* Linn was found to be the most preferred species because of its timber value and also as it grows naturally in this area. Next to teak, *Butea monosperma* (Lamk.) Taub, *Acacia catechu* Willd and *Madhuca indica* J. F. Gmel. were most preferred due to the NTFP returns obtained from these trees. While considering tree plantation programs, the indigenous species that support biodiversity should be given preference over exotic tree species like Eucalyptus and *Acacia auriculiformis* (Patwardhan & Gandhe, 2001). Fire resistant species such as *Anogeissus latifolia* which can indirectly help in checking spread of forest fires and subsequent release of carbon in atmosphere due to trash burning should be promoted for plantation program. Rai *et al.*, 2000 had suggested that differential management options for various forest types indicate that some species are valued more than others as they have greater bearing on the livelihood patterns of the villagers. Also, these plantations which are managed on natural forests have a tendency of becoming man-made as they are molded according to the needs of the locals.

The ecological analysis carried out in JFM site clearly revealed the impact of years of protection provided to these plantation sites in maturation of these ecosystems managed by the local community. Increase in number of years of protection clearly correlated with the maturation age of the plantation. Murthy *et al.*, 2000 have inferred that longer the forest protection period, higher is the number of tree species. Schmelz and Lindsey, 1965 and Robertson, 1978, have analyzed girth class diversity in order to understand regeneration, disturbances and future stability of tree species populations in forest communities.

In the study area, JFM plantations of Naghatpur village in Rajpipla taluka, Tilipada of Dediyapada taluka and Godada in Sagbara taluka, showed highest density of trees in their respective talukas owing to the maximum years of protection. Though the years of protection provided to all these 3 villages were same but still the girth class diversity analysis showed that the density of trees in Tilipada was much higher than that of Naghatpur and Godada. High density of trees in Tilipada may be attributed to the better protection provided to the plantation therein. Low percentage in the higher DBH class implies that there is still some anthropogenic pressure on the forest or the protection given is not sufficient. Similar observations were also made by Bora & Bhalani, 2000.

The percentile of shrub population in Limkhetar of Rajpipla and Dhanor of Dediyapada taluka were at par, owing to similar years of protection but still the condition of both these JFM sites was different. More number of trees in lower size class and with no occurrence of cut stems gave the scenario of the forest stand structure of Limkhetar as expanding type. This suggest that the JFM of this site have good regeneration capacity, and if protected well there is a good potential for these saplings to attain larger girth and also increase the density under the tree population (Ravindranath *et al.,* 2000). Contradictorily in Dhanor, even though the shrub population was found to be similar to Limkhetar but shrubs were interspersed with few large trees and a number of cut stems, at an average of 8 cut stems in each quadrate. Gulati, 2000 have suggested that presence of only a few large trees indicates poor management practices, inhibiting regeneration. Also, presence of live stumps indicates current disturbances of the site which reflects that the forests may be degraded at faster rate if not protected. The poor regeneration of different tree species may be due to various biotic disturbances like grazing, illicit felling, lopping etc (Pande, 2006). Similar condition of JFM plantation was also seen in Koyalivav plantation of Dediyapada taluka.

Importance value index of species indicated the species richness in a community. Higher IVI values indicate high ecological abundance and it is a reflection of better regeneration status of species. To understand the dominance and ecological success of a species, determination of Importance value is well accepted (Das & Lahiri, 1997). As teak was found to be most preferred species for JFM plantations it exhibited highest phytosociological status in JFM villages like Naghatpur, Kunbar, Bore and Singalvan. Among these villages, except Singalvan, rest all had adopted monoculture plantation strategy. However a difference was observed among the monoculture plantations of Rajpipla (Naghatpur) and that of Dediyapada (Kunbar & Bore). Lower IVI values of teak in Naghatpur plantations may be attributed to natural regeneration of teak associated species. Kunbar and Bore on other hand had pure stands of teak and did not support natural regeneration. In fact naturally regenerating species were removed by the villagers in Kunbar and Bore. In case of Tilipada, over dominance of *Butea monosperma* (Lamk.) Taub with IVI value of 212.75 was noteworthy. This may be because it was most preferred species with a regular flow of income to the villagers as it sufficed two basic requirements of the local people i.e. firewood and fodder. Thus propagation of single species had lead to decrease in the heterogeneity and correspondingly lowering the diversity values of this JFM site.

For the diversity studies of the JFM sites, the Shannon function or H index used, is considered to be one of the best for making comparisons, specifically where one is not interested in separating out diversity components. Also it is reasonably independent of sample size (Pianka, 1994). Species diversity tends to be low in physically controlled ecosystems and high in biologically controlled ecosystems (Odum, 1971). The JFM site being controlled and managed by the locals of the area can be considered as physically controlled ecosystem leading to lesser heterogeneity and thus greater dominance index values. Highest tree species diversity found in Limkhetar (Rajpipla taluka) can be attributed to the polyculture plantation practice adopted in this site as well as due to the protection provided in the initial years of protection. However, lowest diversity seen in JFM sites of Kunbar and Bore is attributed to monoculture plantation practice adopted in these villages. Monoculture plantations promote homogeneity and hence these plantations exhibited the highest dominance index values. Higher dominance index values were also found in polyculture plantations of Tilipada due to the over dominance of *Butea monosperma* (Lamk.) Taub. However the dominance value was lower than those found in monoculture plantations such as in Kunbar and Bore. If abundant species are more, community showed low diversity and high evenness as in case of moist deciduous forests. High heterogeneity in turn may be due to the unpredictable natural factors like tree felling by storm or rainfall or other environmental factors. Dominants largely account for the energy flow in each trophic group and it is the large number of rare species that largely determines the species diversity of trophic groups and whole communities.

Species diversity is positively correlated with the annual rainfall or to climate (Zhang, 1999). Generally in terrestrial ecosystems, factors like low temperature and high precipitation increases species diversity. High species diversity also implies many speciation events and relatively low extinction rates and usually diversity varies with the extent of disturbance. Low diversity in moist deciduous forest could be due to the easy approachability by people into the forest area for domestic purpose, resulting in high disturbances. Increased productivity supports greater species diversity due to the climatic stability and increased habitat heterogeneity (Murali *et al.*, 2003).

Herbaceous species are important occupants of the ground layer of woodlands and are mostly influenced by prevalent tree communities on these landscapes (Shadangi & Nath, 2005). As compared to the forest ecosystem the lesser proportion of herbaceous population in all the JFM plantations was not desirable. Maximum percentile of herbaceous population was found in Dabka, Godada and Kodba JFM sites. The FPI in Dabka had the least years of protection among all the selected JFM villages. The presence of larger number of herb species herein could be due to the open tree canopy that enables greater availability of sunlight in the forest (Roy *et al.*, 2000). In Godada also, though the years of protection provided to these plantations were quite considerable but still here also the density of tree population is quite less and thereby increased under storey cover. Kodba on the other hand, exhibited complete absence of gochhar land compelling the rural to be totally dependent upon the under storey vegetation. They, therefore protected this plantation at least for four months after the rainy season, which has led to greater diversity for the undercover. Same was the case in Kunbar. Pansar JFM site exhibited presence of cultivated species like *Cajanus cajan* (L.) Millsp may be due to unauthorized cultivation practiced in the forest area. The lesser undercover diversity in JFM sites of Koyalivav, Dhanor and Singalvan may be due to open grazing in the plantation area. The amount of grazing reduced the density of dominants, decreasing the competition among species with a better chance to use space and resources. Severe grazing, on the other hand, acted as stress and had reduced the number of species to a few that are unpalatable.

Ground flora diversity, density and nature vary with the type of forest and also they are more sensitive to changes in environment than trees (Pandey *et al.,* 1988). The diversity of ground flora is also closely related to seasonal variation. The structure of ground cover flora is one good index for the realization of the health of vegetation (Malhotra, 1973). Though the ground vegetation comprised only a small proportion of total biomass in the forest ecosystems, it plays a very important role in the ecological characteristics. Ground vegetation constitute only 22% of the total above ground production but provides 41% of the annual litterfall in mixed deciduous woodland (Maurya and Mishra, 1996). Proper undergrowth in a forest is essential for maintenance of nutrient status and ecological balance of any forest ecosystem.

Similarity index drastically demarcates and highlights the type of plantation and the plantation strategy adopted in the JFM sites. Monoculture plantations of Naghatpur, Kunbar and Bore showed a high similarity for tree species. Among these 3 villages, Naghatpur showed comparatively lower similarity due to natural regeneration of associated species. A considerable similarity between the canopy cover was also found between the Singalvan, Koyalivav and Dabka. However no considerable similarity was seen in case of undercover except in Kunbar and Bore. Since the quality and quantity of undergrowth depends on the tree canopy and the edaphic and microclimatic conditions existing under the particular type of forest (Rajvanshi *et al.,* 1987). Similar climatic factors over wide range may be one of the reasons for the uniqueness among the vegetational types.

Secondary plantation analyses are important for any JFM site in order to enumerate the capability of these JFM plantation sites in fostering the needs of the local dependable communities. Standing crop biomass of the JFM plantations also increases with the years of protection. Thus, annual woody biomass was found to be highest in Tilipada, followed by Koyalivav and Nani Chikhli. Ravindranath, 2000, have suggested that basal area of the forest is critical in determining the biomass and higher standing woody biomass implies that the forests are rich in biomass and can cater to the needs of the community. Though Naghatpur and Godada showed greater years of protection but still the standing woody biomass was found to be less when compared to Nani Chikhli. Higher standing woody biomass of Nani Chikhli may be attributed to Acacia which is the most dominant species of this JFM plantation and it is a fast growing species (Nayak *et al.*, 2000) Dabka plantations with the least years of protection also shows considerably good growth rate indicating its potential to attain higher density and diversity.

The standing woody biomass values are important for the estimation of carbon sequestration rates of any ecosystem. Carbon sequestration may be accomplished through forest management techniques to enhance existing carbon sinks by planting on pasture, agriculture land or degraded forest sites; and storing carbon in wood products. According to Winjum *et al.*, 1992 the most promising management practices for CO_2 mitigation are reforestation in the temperate latitudes, and agro-forestry and natural reforestation in tropics. In the forestry sector, we need to identify the best forestry option, which fulfils the demands of wood and its products along with increasing carbon sequestration. Bhadwal and Singh, 2002, have identified plantation-based forestry program as the best land-use pattern which fulfills the demands of future in a sustainable manner. Rates of carbon sequestration on forest lands depend on the management practices adopted, the species of the trees involved, and the geographic area covered. Diverse components of the forest ecosystem that store carbon includes tree trunks, branches, leaves, coarse and fine roots, soils, litter (forest floor detritus), and understory (Stavins & Richards, 2005). The assessment of carbon sequestration rates was associated with the present study in order to assess the potential of community managed forests in carbon sequestration, which was found to be highest in Tilipada followed by Nani Chikhli and Dabka. Gera *et al.*, 2003 have also assessed the potential of community managed forests in carbon sequestration rate in Dhama range of Sambalpur Forest Division in Orissa. Khanna and Sama, 2001 have also mentioned about the wider global implications of the JFM plantations as store house of GHGs.

6.4.4 Carrying capacity:

The census data on human and cattle population in the study area have shown an enormous increase in the past 3 decades, with no increase in the forest area which supported these populations. This resource is getting congested over a period of time. If this process continues, the productivity or sustainability of JFM plantations is totally dependent on the awareness of the locals managing these plantations. Bhattacharya and Bsanyat, 2003, have proposed that for sustainable management of the forests, empowerment of the local community is a must.

The carrying capacity of the JFM plantations of the Narmada district as calculated brought out differential capacity of the different plantation sites to sustain the local dependent population. In terms of the carrying capacity and sustainability of these ecosystems, Sagbara taluka showed a deficit, as all the selected JFM villages therein with a wide gap between the demand and supply potential. While in Dediyapada taluka, except for Pansar village rest all the villages showed surplus of the supply from the plantation area. The reason behind this was smaller human and cattle population and also maximum forest area under the JFM program which in turn lead to greater supply potential.

In Pansar village of Dediyapada and Naghatpur village of Rajpipla taluka, large human and cattle population had resulted into heavy biotic pressure on the JFM plantations. As a result, though the supply potential of the forests in terms of mean annual increment was quite high a wide gap was created between demand and supply potential from the JFM sites. In addition to this, both these villages supported a huge cattle population which was not productive but still the villagers rear them owing to social status associated with the number of cattle.

The reason for non-sustainable JFM site of Dabka village of Sagbara may be attributed to lesser forest area under the JFM program. However in Kodba though substantial JFM area was available but the mean annual increment was found to be much lower in this village, leading to lower potential limit of harvest and supply potential. The MAI values for Bore, Singalvan and Dhanor were found to be lower than Kodba but still they were sustainable owing to maximum forest area under the JFM program which in turn leads to greater supply potential.

This study has brought out the fact clearly that ecological sustainability of JFM plantation is a result of the interplay of several factors. It is manifested by the better protection given to such local managed forests which can be directly correlated to the spectral reflectance pattern on the satellite image. Based on this finding, the extrapolation of the ground estimates of the biomass at large scale with the help of visual remote sensing techniques would therefore provide a reliable data on the supply potential of the JFM plantations.

Though the estimates of primary productivity and the above ground biomass have been attempted by workers using remote sensing techniques (Curran, 1980, Chahabra & Dadhwal., 2004), these are all gross estimates of primary productivity.

JFM villages of the Narmada district selected for carrying capacity calculations demonstrate the possibilities of acquiring the estimation of this features using the conjunctive use of the two techniques, in a routine manner, in future. A case study reported by Dutt *et al.,* 1994, had made similar attempts to estimate the carrying capacity of Nagarjun Srisailam Tiger Reserve in Andhra Pradesh.

Carrying capacity estimations are a must, since human life depends on healthy ecosystems which supply life sustaining resources and absorb wastes. Each system has thresholds beyond which the levels of stress will lead to a breakdown. Understanding the carrying capacity will aid in providing the critical threshold limits. However the enormous growths in the human as well as cattle populations, accompanied by exaggerated rates of consumption pattern, have stressed these ecosystems. Lack of birth control measures only accelerates the system towards breakdown and also maintaining a huge population of unproductive cattle further aggravates the situation. Such ecosystems which are stretched by over harvesting, suddenly breakdown or settle into a system with less resilience. This alarming trend has to be reined in immediately to avoid turning it into an explosive situation. Drastic ameliorative measures have to be taken by the government in consensus with the people.

In a district such as Narmada, which supported maximum tribal population the dependence on the forest is much high. In majority of the cases the fragility of the forest ecosystem in the study area is improving after the implementation of the JFM program. Improvement in the supply potential of the forests after the implementation of the JFM program has been reported by number of workers such as Hegde *et al.,* 2005, Murthy *et al.,* 2000, Pande *et al.,* 2005, Sreedharan and Dhanapal., 2005, Pande, 2006, etc.

The output of the study viz. maps having village level data and statistics can be exploited properly to bring modern day techniques at the tips of the local administration for a scientific and strategic planning out of the action plan.

Using the methodology developed in this research program, a uniform database can be generated for taking a stock of the forest resources in hand. The plans for up gradation and amelioration of those in a degraded state can be made on the lines of the suggestions given at the end. This will indeed pave way for judiciously extracting more from the resources that we have our disposal.

6.4.5 Ranking of the Villages:

The results obtained by assessing the JFM villages on the basis of ecological and socio-economic parameters brought out the success and failure levels of each JFM village selected for the detailed assessment. Ranking of the JFM villages was attempted to understand the indices that have direct relevance on the ecology, socio economic and institutional aspects of the village. This rank qualitatively indicates the success of the village for its efforts in JFM.

Ecological parameters such as, forest available per household as well as gochhar area available per animal cattle unit seems to be determining the success of JFM, by giving a quantitative dimension to the biotic pressure on the JFM plantations. Villages such as Limkhetar, Nani Chikhli, Kodba have shown good regeneration, higher tree diversity and species number, indicating the impact of village activities on the forest is relatively less. Further Bore, Naghatpur villages with low species diversity and stem density shows lower ranking indicating that the chances of sustenance of the JFM program may be less. Murthy *et al.,* 2000 have also adopted weighted sum rank method in assessing joint forest management plantations in Uttara Kannada district, Western Ghats on the basis of ecological parameters.

On the basis of socio-economic parameter Tilipada and Dabka which shared the first rank owing to the complete participation of the villagers in the JFM program and awareness among the villagers for forest protection and conservation. In the present study, Limkhetar did not secured the highest weightage in all the assessment parameters selected but still its management to secure the first position. This proves that the sustainability of any JFM program is not dependent on one or two factors but the amalgamation of number of factors which interplay to give the sum results.

Ranking and assigning values to JFM villages may be useful in management prescriptions or implementing strategies of the program. These indices may prove useful in ranking the villages that need to be strengthened and further also indicate the areas that need improvement. This will aid in bringing out a strategy that could prove useful for any village adopting the JFM program. Further, these indices may help in guiding the JFM village to sustain their program. Such information may help the managers to pay more attention to human and financial efforts and thus assist the villages to use their resources in a sustainable manner.