CHAPTER - 5
DISCUSSION

5.0 Discussion

5.1 Imagery based forest cover and land use classification

5.1.1 Forest Analyses

5.1.1.1 Forest Class Mapping

Forest class mapping is an essential prerequisite for any management operation as the forest type is a direct indicator of the ecology of the area. Understanding of different levels of forest densities is also important in terms of forest management operations and preparation of working plan. The most acceptable classification of the forest, of the country with immense diversity in their floristic composition is the one given by Champion & Seth (1968). There is not much information regarding the forest of this area. According to the Champion & Seth classification, forests of Vadodara district fall in 5A/CIB dry teak forest in the north east of the division and 5A/C3 southern dry mixed forest in the south east region.

Ambiguity in the mapping and classification criterion many a time causes significant differences in the result of interpretation (Singh, 1986). The problem gets compounded by the absence of a uniform terminology and presence of different concepts of forest cover categories. Hence the previous applications of satellite remote sensing of vegetation have been generally restricted to land cover classification such as hierarchical Anderson level association (Anderson et al 1971). Later investigations extended the satellite based classifications to a framework of somewhat ecologically more meaningful relationship such as age dependent timber harvest classes (Beaubien, 1979 and Horler & Ahern 1986). Classification system designed in this study to generate eight different forest classes was based on the criterion designed by earlier worker, Singh, 1988 and modified from Anderson et. al. 1976. These criteria are:

- Classification system should have categories which could be directly interpreted from 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 must be possible.

Remote sensing is usually concerned with characterization of plant formations in terms of stand height and crown cover. This factor was also given due importance while classifying forests of Vadodara district. The area covered for forest categorization covered three rounds with 213 compartments in Pavijetpur and Boriad range of ChhotaUdepur division. Eight different forest classes viz. closed teak forests, closed mixed forests, open mixed forest, degraded forests, scrub, scrub with coppice forest, sparse tree cover and sparse tree cover with agriculture have been identified through IRS LISS III image-based classification. Recent advances in the quality and analytical technology of satellite imagery have made it possible to achieve high precision in forest resource inventories. Forest categorization earlier was solely based on the photointerpretation elements. The tonal variation between different forest classes was very distinct, varying from red to reddish pink. In this study, the scrub category exhibited a slightly different tone with a bluish tinge in the red due to the presence of stony waste area in this class. Similarly, a greenish tinge was observed in the red in the case of open mixed forest.

In this study, the use of the November data brought out better discernability in forest categorization. Most of the forest trees had maximum foliage during the month of November as observed from the phenological calendar prepared for this area. This contributed to the suitability of the November data.

In 1970, SOI (Survey of India) identified six forest classes (fairly dense mixed forest, fairly dense mixed forest mainly teak, open mixed forest, open jungle, open mixed forest mainly *Mahuwa*). These classes got redefined into eight classes in 1989 and remained the same in 1999 in the study area. None of the three rounds selected during the study exhibited the presence of all the eight categories i.e. closed teak forests, closed mixed forests, open mixed forest, degraded forests, scrub, sparse tree cover, and sparse tree cover with agriculture. Among the three rounds, the Kalarani round had the highest number of classes i.e. seven both in the year 1989 and 1999 while Boriad had only three in the year 1989 and two in the year 1999. The reason for the decrease in classes in the Boriad round was the conversion of degraded areas into scrub lands. The percentage forest cover did not correlate with presence or absence of classes and so, though Boriad had just two classes, the percentage forest cover was higher than Kalarani and Sajwa.

5.1.1.2 Forest Monitoring / Change detection

Satellite remote sensing technique seems to constitute a system of continuous operational monitoring of forest cover. With certain limitations, it has proven its utility for survey and monitoring of forest (Singh, 1987). It has also helped in generation of a reliable database on the extent and rate of deforestation taking place in different areas. Different forest studies using satellite data have proved that remotely sensed data can generate much of the information needed for proper forest management in a short time, at low cost and in the format desired by the forest department. This technique has proved its utility even when put to severe test under different conditions and settings (Walker, 1999 and Bist, 2000). The present study has exploited this technique in monitoring few forest areas of Vadodara district.

Monitoring of these forests has been done from 1970-1999. IRS LISS III data for forest cover map generation for the year 1989 and 1999 have proven its potential in forest inventory. It has vegetation specific spectral bands suited for forestry studies. Mapping was done at 1:50,000 scale as it facilitates the use of multispectral characteristic for monitoring vegetation at regular intervals.

The forest map for the year 1970 prepared from the toposheet taken as a base for the year 1989 and 1999 had five different forest categories which over the years transformed into eight categories. In 1970, the density and area of the forest was very good and the monitoring of this forest from the 1989 and 1999 data showed the trend of development of different forest classes. Changes even at microlevel were brought out through change detection technique. Change detection technique is used to determine the change between two or more time periods of a particular object of study. It is a vital process in monitoring and managing natural resources as it provides quantitative analyses of the spatial distribution in the population of interest.

Coppin & Bauer, 1994, report on development of methods for operational monitoring of forest change in Minnesota US. Their methods have identified changes in forest cover due to variety of reasons. Another kind of change in vegetation of great interest is wholesale conversion of vegetation types. The most obvious example of this kind of change is deforestation which is one of the most significant forms of land use change occurring on earth. The other uses can be either agriculture or urban uses or finally the change can lead to the development of wasteland. There are a variety of reasons for monitoring forests. One reason is to understand the role of forest change in the global carbon budget (Skole & Tuckur 1993). Another reason is for the local land management (Varjo, 1997). India is suffering from serious depletion of its forest cover and remote sensing is playing a valuable role in providing information on the location and extent of forest clearing (Singh, 1986). Research is still ongoing to monitor forests over larger areas. Though earlier work was based on visual interpretation of images, recent efforts have indicated the viability of using automated analysis of multitemporal images to monitor forest change (Cohen et at 1998).

Change detection studies provide an improved understanding of the health and condition of vegetation as well as rate of conversion of vegetation to other land uses. To date, landscape changes of major interest have been those induced by man. Papers concerned with detecting change concentrate on the change detection in the landuse in or near urban areas (Wilson et al 1976, Ellefsen and Peruzzi 1976, Rubec and Thie 1978). Only a few deal with the natural environment (De Gloria et al 1975, Brera and Shahrokhi 1978). Various different change detection methods have been used in all these earlier studies, but the method used in the present study involved the overlay of maps of different years in GIS mode.

Skidmore et al. (1997) have brought out the significance of GIS and remote sensing in vegetation mapping. The output in the form of change detection maps for the period 1970-1989 and from 1989-1999 depicted the changes brought about in the forest cover of all the three rounds viz. Sajwa, Kalarani and Boriad over a period of 30years. These changes were very significant in terms of sustainable forest management. Changes in the forest classes over a period of three decades have witnessed maximum degradation. In all the three rounds either degraded forest or the scrub dominated the forest classes.

Sajwa Round

In the Sajwa round 70% of the total forest area was affected by degradation. The disappearance of closed teak forest or closed mixed forest or open mixed forest in some areas or their conversion into degraded or scrub land could easily be attributed to the escalating population pressures in this area.

It has been seen that during the first two decades of a span of 30 years, a slight decrease of just 25 sq.km was observed. The last decade of 1989-1999 showed a tremendous decrease of almost 437 sq.km. The impact of increased human and livestock population has become evident here. The number of villages in this round is about 50, with population ranging from 56 to 3100. A few villages like Athavali, Bhorda, Bhidol, Chalamali, Chatrali and Kadachhala had a consumption of fuel wood above 1300 kg/day with total absence of forest.

Increase in the class sparse tree cover with agriculture showed a greater dependency of people of this round on forests. Consumption exceeded demand, resulting in encroachment in the forest area and increase in the agriculture areas i.e. 169 hectares. Continuous cropping on the same land with no additional inputs decreased the fertility of these agricultural fields, converting them into wastelands and about 7.75 ha of forests have become wasteland.

Kalarani Round

The Kalarani round has a slight different picture. People here have definitely exerted pressure on the forest cover of this area as could be seen from the decrease in the forest cover and absence of total forest with high consumption rate. There is a total absence of forest cover in some of the villages like Baravad, Chhatrali, Nana Amadra, Ratanpur abd Sakhandra. In addition to this, certain villages like Moti Amrol and Aniyadari which had fuel wood consumption of 3390 and 1422 kg/day respectively had just 5% and 1% hectare of land under forest cover which can be considered as negligible area when compared to the population therein. At the same time, it is good sign that the local inhabitants of this area have on their own grown and are still growing shrubs and other trees around the agriculture fields to suffice for their needs of fuel wood instead of completely depending on forests. The decrease from 1970-1989 was about 4 sq.km., but an increase of 0.7 sq.km. was observed from 1989 to 1999. Forest cover in this area had a better density. A new class of open mixed forest has been developed over the years in this round.

Thus, in the case of Kalarani, the total area of the forest remained relatively constant from 1970 to 1999. Out of 1844 ha of dense jungle which include fairly dense mixed jungle mainly teak and fairly dense mixed jungle, only 445.27 ha remained as dense forest i.e. closed mixed forest and closed teak forest.

The remaining area under dense forest classes have got shifted to low density forest classes such as degraded scrub, sparse tree cover and sparse tree cover with agriculture . Such observations have also been made by Dhinwa et al, (1992) and Murthy & Rao, (1997).

Boriad Round

Forest cover of the Boriad round runs on the parallel track of the Sajwa round. Increased forest cover area seen on the image and estimated in the tables should not be misinterpreted as a good forested region. Thus fairly dense mixed jungle mainly teak and fairly dense mixed jungle covering 2,331 ha forest classes observed in this round in 1970s have degraded and their place has been taken up by the scrub with coppice forest or the scrub. The remaining area has been taken up by agriculture. Forests shows the domination of forest cover class scrub and scrub with coppice. There is total absence of any good dense forest class. A large part of the fairly dense mixed jungle mainly teak got converted into scrub with coppice forest. This may be because of the cutting of the other teak associated species showing degradation of forest. Teak trees as such were also cut but due to vegetative regeneration in some parts of the area, teak trees are still present. In other parts like Nanikadai, there has been a total felling of trees, and at the same time, plantation in the form of orchards of *Anona* and other fruits trees has been done, thereby making an attempt to revegetate the forest cover. However, decrease in the density of forest cover in this round may be attributed to anthropogenic pressures only.

Out of the 51 villages, 30 did not have any forest and out of these villages, Jamli had fuel wood consumption of 1326 kg/day and more than 10 villages had the consumption rate of 400kg/day.

Reasons for changes

Anthropogenic factors have induced major changes in the forest cover of this area. In all the three rounds, the majority of the population dependent on the neighbouring forest villages are tribals or adivasis of these areas. Their principal means of livelihood is agriculture and forest labour. Land holdings are generally very small. They do not use any improved implements, seeds and manures. As a result, the crop production is very poor and villages keep indulging in unauthorized cultivation, particularly in the area adjoining forest cover. Cultivation is practised even on slopes without realizing the ill effects. Villagers in the forests remain engaged in agricultural activity from early monsoon till the crop is harvested. The rest remain dependent on forests either by working in various forest operations such as coupe working, plantations, soil and moisture conservation work, or collection of minor forest produce like *Maduca* flowers and fruits, Buchanania fruits, gums, etc. Some people who reside in the vicinity of bigger towns and villages, indulge in the sale of illicitly cut material. The local residents have very simple habits and their requirements are few. They live in ordinary huts with thatched roofs supported on teak poles. Their agricultural implements are also of a primitive type. The requirements of the people are timber and bamboo for agriculture purposes, huts and cattle sheds. They also require grass for grazing their cattle. The privilege of free grazing in forest areas has encouraged the villagers to maintain large herds of cattle.

The attempt to classify the forests through image based classification has been quite precise and accurate. The forest maps generated for different years for all the three rounds showed 85-95% of correspondence between field and map data. It was also clear from the study that forest cover misclassification was not frequent. Problems usually involved confusion between similar classes like scrub and scrub with coppice in Boriad, sparse tree cover and sparse tree cover with agriculture in Sajwa and finally scrub and sparse tree cover in Kalarani. The good resolution of IRS data has prevented the misclassification of poorly stocked forest or young plantation or sparse tree cover into barren land. IRS LISS III data had proved itself to be one of the best for forest monitoring. As such, remote sensing tools are the best suited for producing continuous and up to date forest maps. However, the use of space borne remote sensing has been hindered by the relatively coarse spatial resolution of yet available satellite data. The new generation of very high resolution satellite sensors like IKONOS-2 or Quickbird should permit fine mapping except for certain difficulties related to the processing of very high resolution image data in regard to the current image data analyses used in remote sensing (Kayitakire et al., 2002). Forest mapping can also be improved by using hyperspectral imagery, radar imagery and high spatial resolution imagery.

5.1.1.3 Vegetational Status

Microlevel vegetational studies aided in bringing out sharp differences in the vegetation of this area. Basically eight different forest cover classes were demarcated from each other based on their percent canopy cover. Closed type of forest class with crown cover of more than 30% showed 53% of dissimilarity from a similar category of closed teak forest ie. Panchpadha and Phenaimata of the Sajwa round. Phenaimata exhibited a decrease in teak status with an increase in the number of other plant species. These species included *Holarrhena antidysentrica, Tectona grandis, Butea monosperma, Morinda tomentosa, Azadirachta indica* etc.

Pachpadha on the other hand had a better teak status, exhibiting less of disturbance in this part of the forest cover. Such differences could also be seen in other categories of forest cover. The degraded forest of Jhanpa in Kalarani and that of Panchpadha in Sajwa had little similarity. When compared with Jhanpa, Panchpada has high species diversity with less of dominance and evenness of species. Panchpadha being on a slope, and facing the south east aspect, gets subjected to more of environmental stress like soil erosion, grazing and anthropogenic activity resulting in large scale teak removal. There was no trace of teak in this area but there was a preponderence of other species. This may either be due to the existence of fairly dense mixed forest in this area in the earlier days or due to different activities to prevent erosion on slopes. Excessive grazing by cattles many a time also leads to lack of regeneration in forests, thereby converting good forests into degraded ones (Krishnaswamy, 1953 and Chandra, 1975). Similarly, trampling also creates problems for the germination and establishment of tree seedlings (Swirnov, 1972 and Liddle, 1975).

The difference in the scrub category of the Sajwa and the Kalarani rounds with less than 5% of crown cover was mainly in terms of species composition and diversity.

Koywav of Kalarani had only nine species and had a preponderance of grass species and a few tree species like *Diospyros melanoxylon* and *Holarhena antidysentrica*. Scrub of Sajwa on the other hand had high species diversity. Surrounding areas of the scrub forest class in both the areas viz. Kalarani and Sajwa showed the occurance of degraded forest. This was the only common feature shown by the scrub class of both the areas. It clearly indicated the retrogression of degraded forest into scrub forest.

Each of the species within the community has a large measure of its structural and functional individualism and has more or less different ecological amplitude and modality (Singh and Joshi, 1979). This requires the understanding of the phytosociological status of each species within a community. Importance Value Index is a measure of plant status which brings out the overall role of a plant in a community (Ambast, 1990). The study of phytosociology along with floristic composition prove useful in comparison of species from season to season and year to year (Singh, 1976).

This study has done spatial distribution and vegetation analyses of different forest classes and have indicated that commercial extraction of natural forests has set in retrogression.

Shorter rotations of the forest areas have resulted in the invasion of seral deciduous species. The closed teak forest which should exhibit the highest status of teak showed the status of *Holarrhena antidysenterica* to be dominant with highest IVI of 161.45. *Capparis decidua*, *Butea* and other similar species also had a better status. This could be correlated with the emergence of seral species and decrease in climax species like teak. It was interesting to note that *Lagerstroemia parviflora* and *Butea monosperma* are present in most of the forest classes ie. the closed mixed forest, open mixed forest and degraded forest. *B. monosperma* has also been observed in scrub with coppice forest. Porwal and Roy, (1991) in their studies also observed *B. monosperma* and *L. parviflora* dominating a seral formation that encroaches on grasslands.

Dominance and diversity indices generated for different classes showed an inverse relationship between the two. Pande et al, 2000 also noted such a type of relationship between different species. Gradual increase in species from closed teak forest to degraded forest with a parallel decrease in dominance of the species have resulted in the conversion of a good forest to a degraded forest. The next stage of conversion of degraded forest to scrub forest is not very far as has been observed from the scrub class analysis in two regions of Sajwa and Kalarani.

Usually the diversity of species depends on the adoption of species and then increase in the stability of communities. Monk, (1967) reported that diversity tended to reach a maximum level after a community is composed of more than 12-15 species. But this variation may be because of its partial dependence on equitability of individuals among species (Saxena & Singh, 1982). Also the lower diversity in the forest classes can be attributed to lower rate of evolution and diversification of community (Fischer, 1960 & Simpson, 1964) or it can also be attributed to the severity in the environment (Cornell & Orias, 1964). In this study, a variation in species diversity from the normal trend has occurred. The scrub had a higher species diversity i.e. 0.14 when compared with degraded forest where the species diversity was 0.11. In the other case, the class scrub with coppice forest, there was no correlation between dominance and diversity but it exhibited different species diversity in all the three areas ie. Jamli, Bagalia and Nanikadia.

It is a fact that vegetation is responsible for generating energetics in the ecosystem, a function that is essentially coupled with resource cycling. Structural characteristics and associated functional properties of the vegetation reflect the resultant of many environmental components such as climate, physiography and soil. The present study which involved different phytosociological attributes along with floristic composition can prove useful in the comparison of species along the years, in different forest classes mentioned. Also, it has been shown that different species are competing with teak and have invaded teak areas. With the changing environmental conditions, the vegetation may reflect changes in structure, density and composition as observed by Gaur, (1982).

5.1.1.4 Soil Status

The common problem for the forester with regard to refreshing the area is to make strategies for improvement of the soil condition and to raise the biomass production. Different cover types affect downward movement of water in the soil in different ways

(Megalan et al. 1962, Nazaror, 1969). Similarly, different tree species may have their different effects on soil nutrients. It is also observed that many soil properties change as a result of different management practices or biotic and abiotic influences on soil properties (Holland 1969, Norris 1970). But, at the same time it is imperative to maintain the productive and protective role of forests in perpetuity. Not much information is available regarding the soil status of this forest area. There is a possibility that over the years fertility exhaustion could have occurred due to some high nutrient demanding species or due to soil erosion. This can bring about a premature end to the generation of tree species. This emphasized the need for evaluating the nutrient status of the soils. The attempt made in these regards in this study and has assessed different soil physicochemical attributes in soils of all the forest classes.

The chemical and physical properties of soils are controlled largely by clay and humus as it acts as the center of activity around which chemical reactions and nutrient exchange occurs (Buckman and Brady 1967). Presence of clay in soils of most of the forest classes is an indication of the better quality of soil except for some parts of degraded forest, open mixed forest and closed mixed forest which have sandy loamy soils. The soil colour ranged in 10YR of soils of all the forest classes. This has also been confirmed earlier by Totey et. al. 1986.

Moisture is one of the most important determinants in the decomposition process (van der Drift, 1963). There has been a lot of inconsistency in the percentage of moisture present in the top and bottom levels of soils of all the forest classes. This may be due to the dependency of moisture regime of a stand on different biotic and abiotic factors. Rainfall, amount of radiation received on the forest floor, its acidity, humidity and temperature are amongst the abiotic factors; whereas structure and function of the stand are the biotic factors. Great stress has been laid on protection of soil and moisture conservation in the earlier working plan but still a lot more needs to be done in this area.

Except for the bottom soils of open mixed forest in Kalarani and degraded forest in Jhanpa, which can be categorized into slightly alkaline and slightly acidic, the soils of other forest classes seem to be perfectly normal, between 6.5 to 7.5. The macronutrients and micronutrients are influenced by soil reaction (pH). A normal pH range promotes the most ready availability of plant nutrients. It also aids in ion accumulation (Seth 1960). The soils of all the forest classes therefore had a higher nutrient status (both macro and micro) in their topsoils. Relationships between the neutral pH and better micronutrient status like Fe, Mn and Cu have been brought out by Brady (1995), Wild (1996), Millan et al 1995. Slightly acidic soils reduce the retention capacity (Nandi and Barari, 1997). This may be the reason for the increased P and K in bottom layers.

The effect of texture is reflected in the presence of nitrogen content in all the soils except for the bottom soils of closed mixed forest which was high due to the fine texture of the soil. Walker and Brown (1936) have shown the correlation between the texture and nitrogen content. The finer the texture, the more is the nitrogen content.

The C/N ratio is a good index of fertility of organic manures and it varies depending upon the source and the stage of decomposition of the litter. The C/N ratio in soils of all the forest classes was high in topsoils. Even the soils of degraded forests had good C/N ratio indicating good fertility of soils and regeneration capacity of soils.

The quality of soils of all the forest classes present in the three rounds viz. Sajwa, Kalarani and Boriad cannot be the cause of the degradation of forest cover in this area. In some places where slight deterioration of soil has occurred, timely soil improvement measures will bring the soil back to normalcy.

Forest composition and structure also get affected by horizontal and vertical texture variations in soil (Host et al 1988). Similarly, local terrain, water availability, surface temperature and other factors also affect forest composition and succession (Attig, 1985). These factors also might have been one of the causes for the degradation of forests in certain areas but they have not been assessed in this study.

5.1.1.5 Litter Studies

Litter fall and its subsequent decomposition forms the major source of energy and nutrient for the soil and litter organisms of the forest. Good knowledge is needed about how the climatic factors such as temperature and moisture and chemical composition of the litter material influence the decomposition rate and are to be used in analyzing biological or chemical changes in natural or manmade forest ecosystem. Probably the prevailing climate and litter substrate quality control the decomposition of litter (Meentmeyer 1978). A lot of work has been done on decomposition of litter (Edwards and Heath, 1963; van Cleave, 1971; Howard and Howard, 1974; Pande and Sharma, 1989) but there is still a dearth of information regarding the contribution of different species to nutrient cycling, specifically in terms of mineralisation and uptake. A small attempt to understand the seasonal contribution of nutrient by leaf litter of a few dominant species like *Tectona grandis, Lagerstroemia parviflora, Madhuca indica, Butea monosperma* & *Buchanania lanzans* has been done in this study. The nutrient analyses of different litter samples showed season-wise variations in the nutrients of different species. It appeared that *Tectona, Butea* and *Madhuca* having the maximum accumulation of nitrogen during the winter, the pre monsoon, and the post monsoon seasons respectivly are the major contributors of nitrogen to the soil. *Madhuca* also seemed to be the major contributor of phosphorus. *Buchanania* and *Lagerstroemia* due to their poorer accumulation of nutrients could be considered as weak contributors of minerals to the soil. The relationship between the soil ionic status and that of litter is too subtle to be established. Osman & Sikdar in 2000 also could not correlate the nutrient content of soil and of litter. This may be because either the number of litter samples were inadequate for drawing out a logical conclusion or maybe the roots of the plants had extended to soils deeper than those sampled (Evans 1980). It can also be possible that since forest trees are long duration plants, during the past period of growth, nutrients must have got recycled (Sugur, 1989; George & Varghese, 1990) and retranslocated (Helmisari 1992) several times.

5.1.2 Landuse Classification

The phenomenal growth in population has put these forests under pressure quite beyond their capacity. The extent of biotic pressures could be judged from the changes which have been observed in these forests over a period of thirty years and the forest management should aim at optimization of landuse, in particular linking forestry and agriculture or other resources often under complex natural and socioeconomic circumstances. The management therefore should rest on classification of the forests based on landuse capability and then find solutions through ecodevelopment (Roy et al. 1992).

IRS FCC proved to be useful in identifying different landuse classes and can be considered as unbiased records of different landuse patterns at different times. It seems to be a big aid in planning strategies for landuse at the microlevel. Satellite data have been used in a number of landuse or landcover schemes at local, regional and continental levels (Townshed, 1992). Image based landuse classification of this area was done, giving thought to all these factors. Classification accuracy was similar to that of forest cover i.e. above 90% in all the three rounds with no misclassification. Six different landuse classes, the wasteland, waterbody, agriculture, canal, plantation and stony waste were identified in this area. Agriculture utilises a big chunk of the landuse classes in all the rounds. Forests are no longer able to sustain the increasing population of jungle dwellers, mostly tribals. This has given rise to the problems of encroachment. Barred from other places, the tribals find forested land a territory easy to occupy for agriculture purposes. This has resulted in encroachment on a large scale in forested regions resulting in percentage increase in agriculture areas. Presence of wasteland in all the three rounds is a cause for concern for the fertile lands of these regions. The identification of Acacia and

Eucalyptus plantation was the outcome of the positive step of the forest department towards increase of green cover.

5.2 Digital Analyses

Image classification of multispectral data is limited with respect to the vegetation attributes that can be provided in a reliable manner. Particularly apparent in this regard is the difficulty of differentiating some specific forest types from agriculture or may be at the level of detail of individual plant species. This problem arises because many species often have overlapping spectral signatures which make their identification impossible or of poor accuracy. In the present study such misinterpretation and inseparability occurred within certain forest cover classes and between the forest cover class and agriculture. Misinterpretations occurred at some points in separating scrub (S) from sparse tree cover (STC), scrub from scrub with coppice forest (SWC) and sparse tree cover from sparse tree cover with agriculture (STC+A). In addition, in some areas agriculture and sparse tree cover were totally inseparable visually. Digital techniques employed to overcome these problems, showed their potential in bringing out solutions to these difficulties.

Development in image processing techniques along with understanding of temporal characteristics and standardization of ground sampling methods have brought about a wider acceptance of application of remote sensing in forest inventories. Analysis of the IRS LISS III digital data carried out to solve the problems encountered during the visual interpretation of the data could bring out the separation of these classes very easily. In view of the high seasonal variability in land use and vegetation phenology, digital data was subjected initially to different band combinations. Only Band combination 3,2 and 1 which correlated with 2,3 and 4 of visual interpretation was better; other combinations failed even to distinguish between different forest classes. Digital enhancement techniques like contrast enhancements, vegetation indices and principal component analysis attempted to achieve better interpretability and contrast between the features which had varying capabilities of enhancing different classes. Histogram equalization and Guassian and linear stretch expand the total range of brightness values (Jensen, 1996). Histogram equalisation, even though it proved to be the best when compared to linear and Guassian stretch, it could neither separate STC+A nor differentiate between STC and SWC.

Normalised difference vegetation index and principal component analysis also failed to improve the differentiation. Normalised vegetation index is one of the easiest and simplest methods to highlight and discriminate between vegetation types. It is one of the ratios which has been shown to be highly correlated with vegetation parameters such as green leaf biomass and green leaf area and hence is of considerable value for vegetation discrimination (Curran and Franquin, 1980, Holben & Frasher, 1984; Tucker et al., 1981; Hatfield, 1983; Jackson et al., 1983; Justice et al. 1985 and Roy, 1993). It also reduces variation due to surface topography. Though ecological variability was highlighted in NDVI, it did not offer much in this area simply because of the similarity or closeness of ratio values of misinterpreted classes.

The principal component or Karhunen L'oeve tranformation essentially separates non-random variance from random variance, while concurrently decorrelating the transformed axes. This reduces redundancies due to interband correlation and compresses the data (Anuta, et al 1984). The data compression effect which has been brought out by the PC transformation was found to be effective in delineating vegetation classes. More specifically, PC-2 was the most variable linear transform having high eigen value thereby having maximum vegetation information. But similar to NDVI, it also failed in discriminating between scrub from sparse tree cover and scrub with coppice forest.

The assumption that vegetation could be separated distinctly by using data set, comprising PC2, NDVI, R and NIR band proved valid. The image generated by layer stacking these four layers highlighted the vegetation precisely. The contrast between forest and agriculture along with the discrimination between different forest types was very clear. Use of such data set has been earlier attempted for Biome level classification.

Separation of all these forest categories and the agriculture and forest class, STC+A, could be achieved through supervised classification. Input of many training sets seemed to be fruitful in this regard. Misinterpretation of scrub with sparse tree cover and scrub with coppice or sparse tree cover and sparse tree cover with agriculture occurred due to the similarity in the vegetational pattern resulting in quite similar spectral response. The mixing up of agriculture with STC occurred either because of smaller size of agriculture fields or due to the similarity in the ratio values of sparse tree cover and crops of these agricultural fields. Increase in the number of ground control points for each of these classes could separate S from STC and SWC. It could not only separate STC and

STC+A but could also separate the smaller areas of agriculture mixing with STC and forming the class STC+A. The class sparse tree cover & agriculture were therefore reallocated to their respective classes of the STC and the agriculture respectively. Earlier workers have shown the significance of supervised classification in forest mapping (Singh, 1988 and Kachhwaha, 1990)

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 μm 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 closed mixed forest and closed teak forest (>30%) in band 2 therefore showed higher absorption when compared with open mixed forest (20-30%). Open mixed forest had higher absorption than degraded forest (10-20%). Degraded forest had higher absorption than S, STC, SWC and STC+A all with crown density less than 10%.

Spectral separation was also highest in the NIR region (band 3) of IRS LISS III data. In the NIR, healthy green vegetation reflect very high energy and the reflectance depended upon the internal structure of leaf and number of leaf layers (Gausman et al., 1972). Similar to the chlorophyll absorption band, band 2, in this 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 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. This proved true in the case of classes closed teak forest, closed mixed forest and Eucalyptus plantations. These classes with good crown density had higher reflectance in band 3 (NIR) and lower in band 2 (R). However, this logic could not be fully applied to the spectral pattern of certain forest classes of this area. CTF and CMF both had similar crown density but still their reflectance varied. DN values of CTF were high in all the bands when compared with CMF. This difference could be attributed to interrelationships existing between chlorophyll content, cell structure and reflectance. Changes in the plant characteristic like chlorophyll content, cell structure or leaf anatomy results into change in reflectance even in plant species with similar crown density and vice versa. Band 4 i.e. SWIR had also proved itself vital in forest class separation. With decrease in leaf water content the reflectance increases in band 4 is obvious from the fact that forest classes with less leaf water content like SWC, DF, S and Acacia plantation have very high reflectance in band 4 i.e. DN values above 160. Spectral response study have clearly indicated that not only crown density but other plant characteristics are also responsible for the variation in spectral response within different miscellaneous forest classes and plantation. This feature aid in computer based classification of forest.

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 and Rampal, 1991). Lower spectral value of stony waste in all the four bands separated it from wasteland. This was because the wastelands were totally barren with scarcely any vegetation and therefore had higher reflectance in all the bands compared with stony waste. The importance of SWIR band in LISS III data was very significant as the distinction of all classes in this band could be very clearly correlated with their water content.

5.3 Working plan inputs using RS-GIS

The forest working plan in this area is being presently managed under the working plan of K.P.Ladwa, implemented since 1975. This plan has now been subjected to revision. The revised plan is yet to be implemented.

The inventories of the working plan are primarily designed to provide the estimates of the current values of timber only. Even if the working plan is designed to provide additional information, it could not be retrieved and aggregated owing to the lack of a common classification system, definition, and resource management criteria along with compatible precision. This problem has been realised by the National Commission on Agriculture (NCA) (Anon., 1976). The working plans therefore do not entirely meet the requirements of the foresters.

The working plan should therefore be such so as to aid the forest managers in performing the core functions like planning, implementation, control and organisation of forests. It should be potential enough to answer the queries of foresters like :

- what treatment is required in which part of the forest ?
- what are the viable alternative available ?
- which is the best alternative ?
- what will be the sequence of activity ?
- who will be responsible for carrying out each of the actions ?

- who will be monitoring the plan ?

Ample data are required to answer the queries of the above kind. These include information on forest cover, composition, structure, crown density, regeneration status, site quality, vegetative influence, sensitive spots, boundaries, topofeatures, soil, climatic data, moisture regime, biotic influence and a few others.

A well structured GIS can assist in answering all the above questions which are crucial for ensuring sustainable management of forests. It helps foresters in meeting the challenges by integrating this information and drawing inferences regarding the complex interaction between people and their environment. This it achieves by overlaying the maps of spatial and non-spatial attributes (Williams, 1985, Wheeler and Ridd, 1985, Johnston et al. 1988, Lindhult et al., 1988, Hathout, 1988, Berry and Berry, 1988). It also enables foresters to incorporate the knowledge and participation of different members linked to forests, in planning, managing, evaluating different forestry projects which ultimately link the people's needs with project benefit. Grewal, (1999) has shown the potentials of GIS in forest management. Further, the adoption of RS-GIS techniques in working plan designing comply with the aim of the forest policy 1998, which states that survey of the forest resources should be done on scientific basis and important inputs should be provided to the forest officials regarding forest management. It also ensures the All India Working Plan Code, which emphasizes that three factors viz. cost, time and accuracy have to be kept in view during the preparation of the forest working plan. It is this dimension of relationship between different forest related spatial and non-spatial variables and GIS which has been emphasized during this study.

Considering the vulnerability of this area it was necessary to bring changes in the existing working plan so that the working plan officer and the forest staff can accord priority to the highly affected areas and implement various forestry programmes. Thus criterion based classification attempted in this study in GIS environment took into consideration the existing working circles and current forest or land use status. It showed significant changes in the existing working circle of this area.

In some areas of Vadodara district the per capita land is 0.25 hectares and per capita forest is 0.026 hectares. However, the corresponding figures for the whole of Gujarat state are 0.49 hectares and 0.05 hectares respectively. In the present study high value of per capita land in all the three rounds viz. Sajwa, Kalarani and Boriad i.e. 0.4, 0.4 and 0.8 approx. respectively, implies a good proportion of land available with man, but the land is not utilised properly which can be perceived from the per capita forest cover. The per capita forest cover in Sajwa, Kalarani and Boriad round is 0.095, 0.05 and 0.1 hectares according to FSI and 0.06, 0.024 and 0.00 hectares, according to NRSA laid criteria, respectively. If the NRSA laid criteria are followed, the status of forest cover is either very poor or totally absent in different rounds of this area.

Biotic factors have influenced both the composition and the condition of the crops to a great extent. During the exstate regime the forests were worked unsystematically and repeated felling was carried out only for the sake of revenue. As a result, the present crops are of coppice origin, mostly of the species which are good coppicer. Teak being an excellent coppicer is found in the dense forest classes. But continuous exploitation of this plant has not allowed this plant to dominate and its place is taken over by other species like *Holarrhena antidysenterica, Butea monosperma* and others.

The criteria for all the suggested working plans i.e. afforestation, preservation, improvement and grass working circle have been maintained in all the three rounds.

Sajwa Round

In the Sajwa round, changes in the existing working circle viz. main, afforestation, protection working circle with overlapping Bamboo and Minor Forest produce working circles seem to be very much imperative. Out of all the existing working circles, only the afforestation working circle needs to be retained. Other circles should either be changed or reallocated to other suggested working circles viz. Afforestation, Improvement, Grass and Preservation working circles.

Afforestation Working Circle

This circle covered the forest classes with very low density like STC, SWC, blank areas, plantation and some portion of the DF. This circle should not only be retained but an increase of 37.56% in its area should be made. This should be done as there is an increased susceptibility to soil erosion in this circle. Coppice growth and natural regeneration are extremely poor. Root stock is mostly absent in this area. Miscellaneous species interspersed with remarkably poor quality teak and its associates are found in this area.

Grass Working Circle

This circle covered forest class scrub only. The Grass working circle emerged from the earlier protection working circle (PWC).

PWC, in some areas, had less slope with normal soil. It had dominace of different types of grass species like *Dichanthium annulatum* and *Heteropogon contortus*. Protection and conservation of this grass is sufficient for the increasing livestock population to some extent. Keeping in mind these plans, suggestion of generating a separate grass working circle has been put forward.

Preservation Working Circle

This circle includes forest classes which are prone to soil erosion. It covered the areas which had dense stock and also the patches which at places are understocked due to heavy working in the past. The meager natural regeneration noted is poor in quality. There are large blanks due to heavy pressure of illicit cutting and uncontrolled grazing. At some places where the crop is poor, the areas are characterised by poor deteriorated soil with scattered rocky outcrops. The terrain is mostly undulating interspersed with low lying hills. Because the area is historically a teak area, this species along with its associates can be successfully raised. This working circle also included the areas of poor site qualities, i.e. barren hills, undulating and flat areas without any root stock which need urgent soil moisture conservation work. This becomes all the more important to avoid siltation of these areas.

Improvement Working Circle

Pure patches of teak and pure patches of miscellaneous species are met within this circle. This circle covers the densely crowned forest classes like CMF,CTF and OMF. Teak is at its best at some places but at other places it appeared to be very stunted. Teak is interspered with other teak associates like *Madhuca indica, Butea monosperma, Holarrhena antidysenterica, Morinda tomentosa,* *Capparis decidua,* etc. throughout the area of this working circle, though occurrence of each species varies from place to place. Although edaphic and climatic conditions are favourable, natural regeneration of teak as well as other valuable species is almost absent. Even where it does exist, it is badly suppressed due to adverse biotic factors. Wherever different improvement measures like preventing trees from disease, promoting more regeneration through seed and coppice, timely soil conservation measures and other factors promoting growth of species have been taken by the forestry the condition of the trees has improved. Thus these areas were covered under the improvement working circle so that the status of these forest classes is not only maintained but also improved.

Both Bamboo and MFP (minor forest produce) were removed and incorporated the preservation and the improvement working circles to prevent over exploitation of these resources.

Kalarani Round

In this round, the grass working circle has been distinguished from the existing afforestation and preservation working circles on the criteria laid down in the earlier plan. Increase in the number of working circles is essential for the Kalarani round. The major portion of the area has good crown density and requires further improvement. Some areas have open land with dominating grass species. Inhabitants of this area are co-operative and are aware of forest degradation. But the temptation to exploit different minor forest produce (MFP) is still very much there. So this portion should be taken up under the preservation working circle which will prevent further exploitation of this dense area. The suggested working plan has emphasized more on improvement and on the preservation working circle.

Boriad Round

The Boriad round with no existing working circle needs to have a minimum of three working circles viz. afforestation, preservation and grass working circle. The major portion needs to go under afforestation working circle as this round has a lot of degraded land, where with proper planning, rigorous plantation activities can be carried out. As this round has only the dominance of grass, a major portion of about 11.36% has been recommended to be covered under the grass working circle. Some areas in patches have a good growth of *Butea monosperma, Acacia catechu, Tectona grandis, Holarrhena antidysenterica* and *Azadirachta indica.* These areas are not only under severe biotic pressure but also require proper soil conservation measures to be implemented and so are recommended under preservation working circle.

The working plan when viewed from the angle of GIS has extreme potentials has been proved in this study. This has also been proved by Yadav in 1999. There are very few land based management systems better than the working plan because the latter carries in it the valuable details of the past for more than a century. Thus the misconcept that working plan is a document of management very closely tied with a particular land parcle and that it is clumsy and says to much, too little of a place in too technical language needs to be changed. For correct decision making at the highest level the data base must be built up right from below i.e. at the lowest level. This requires seamless integration and infusion which is achieved by GIS. In addition spatial information from remote sensing when incorporated in such GIS system will provide an added benefit. The cost estimates in this study have already shown that forest studies through satellite data proves to be cost effective with minimum man power. An amount of Rs. 7,20,420/- can be saved for an area of approx. 545 sq.km.

Application of RS-GIS approach in working plan preparation would circumvent the limitations of working plans. These plans will become a vital part of a larger database in the forestry sector. The rigidity that the working plans are supposed to hold will then melt away. Merging GIS into a seamless structure would herald the true era of RS-GIS in forestry sector.