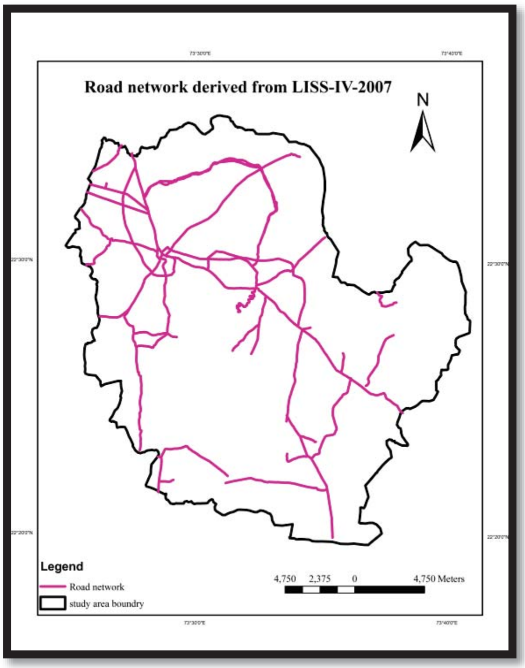
Chapter 4
Results

4.1. Thematic Maps of Forest Cover and other landuse themes

In the present research work, geospatial tool has been used extensively to prepare different land use themes and thematic maps of forest cover based on which ecologically sustainable development plan has been generated. Various thematic maps have generated based on the spatial and non spatial attributes of that particular theme. According to different maps viz., road, drainage, slope & aspect, demography, village and vegetational community structure were prepared as described below.

4.1.1. Thematic Map of Road network:

Halol taluka of Panchmahal district is well connected to the major cities of Gujarat and India through three State Highways and one National Highways respectively. It has the largest GIDC area (461 ha) among the entire Panchmahal district. The geographical location of the Halol taluka on the map makes it favourable as a developing and industrial and automobile hub. It is also well known for its World heritage site called as Chapaner-Pavagadh Archeological Park. All these characteristic features of Halol taluka facilitate the well developed transportation network in the form of good roads which can accelerate the speed of its economy. Government of Gujarat has declared Halol as Special Investment Region along with the Savli Taluka of Vadodara District, with an area of 123 sq km (**Panchmahal District Profile, 2007-2008**). According to the District Statistical Report, the total road length of the taluka is 92 kms (**District statistical Report, 2008-09, Godhara**).



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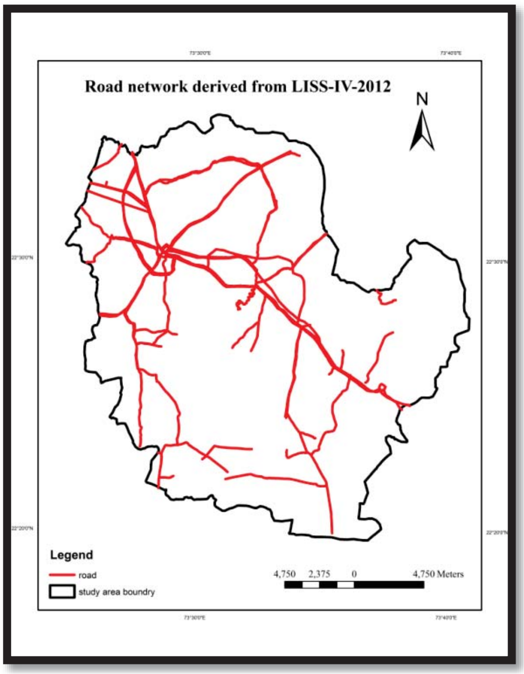

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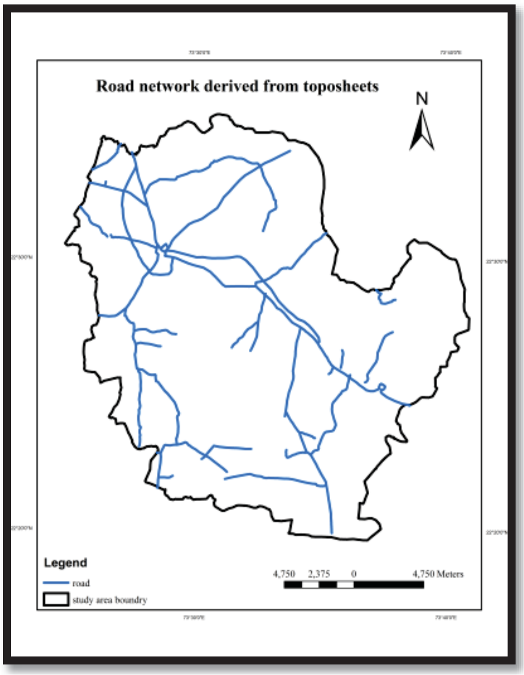


[c]

Plate 8. Road Network of Halol Taluka

Of these some of the important roads are described as follows:

A) Vadodara Halol Toll Road (VHTR):

The Vadodara Halol Toll Road has been one of the first State Highway widening projects developed on a Public Private Partenership basis in India and it has subsequently paved the way for a large number of projects to be undertaken on a similar format in Gujarat and the rest of India. VHTR was an initiative commissioned as a part of the Vision 2010

an infrastructure masterplan developed by the Government of Gujarat (GoG) by attracting private sector participation. This project involved widening and strengthening of existing two lane State Highway (SH 87) into a four –lane tolled expressway which connects Halol to Vadodara. This was commenced on 1st March 1999 and completed on 15th September 2000.

B. Halol – Godhra Corridor

Another important road of the Halol taluka is named as Halol-Godhra Corridor which falls in the district of Panchmahals, and passes through the major settlement of Kalol. This link forms a section of the corridor which is an alternative route to NH-8, for traffic moving between Vadodara and Shamlaji. The project corridor takes off from the intersection of Halol bypass and Vadodara – Halol toll road. This corridor has been widened to two-lane with paved shoulders, with World Bank funding under the GSHP.

C. State Highways:

Halol and Pavagadh area is connected to the other cities of the state through the State Highway Numbers 5, 87 and 150 (**Table 15).** Through the **state highway number 5**, Halol taluka is connected to Jamughoda taluka in the south east side and to Ghoghmba taluka in the North direction. This highway approaches to Halol Taluka at the Maghsar

Village. At the junction of Champaner village, it is further bifurcated into two, of which the one passes on the left side in the North direction, and connects Halol taluka with Ghoghamba taluka. This road connects the villages of Vada talav, Rayanwadia, Sura sultanpura, and ultimately ends at the Ranjitnagar of Ghoghamba Taluka. The another one proceeds further in South-east direction and passes through the villages of Halol taluka like Jambudi, Champaner, Rampura, Kansarivav, Kathola, Palanpur, Shivrajpur and Bhat. From this State highway only, at the junction of Champaner- Archeological Park, 4.7 km diversion named as a State Highway No 5A has been applied, the only motorable road connecting Pavagadh hill to the real world. This road converges at the Manchi of Pavagadh hill. The hill can further be accessible only through foot steps. **State highway number 87** is another important road which enters into the Halol taluka at the village Baska from the west side of Halol. It forms a link between the Waghodia Taluka of Vadodara district and villages like Halol, Rampura and Baska of Halol Taluka. At the junction of the Rampura Village, this state highway forms an another diversion which connects to the Industrial area of the Halol taluka. i.e. Panelav, Ujeti, Vanseti, Madar and Rameshra. **State highway number 150,** also passes through the Halol taluka in the North direction and links to Radhanpur, Abhetwa, Itwadi, Tarkheda and Arad to the taluka head quarter.

Table 15: Total length of different State highways passing through Halol Taluka

Sr.No.	Name of State highways	Total length in Halol Taluka (km)
1	State highway number 5	13.57
2.	State highway number 87	2.24
3.	State highway number 150	10.56

D) Other roads:

Besides these roads, the hill can be accessed through another unmetaled road which passes through the forest area. This road, also called as Jungle trail, is favourable among the poors and trekkers since it provides good scenery and it is economical. This provides a direct access to the places but at the same time they play a key role for the exploitation of the forest resources present over there by allowing the direct access to the people. Those who can afford, they can reach up to Manchi by a cable car. Manchi onwards the hill is approached by the steps only.

To achieve the targets of sustainable development within the stipulated time-frame the application of modern geospatial technology has been recognized to provide efficient and effective means towards the planning, preparation & implementation of appropriate sustainable development plans. Utility of this technology very much significant with respect to thematic maps generation of the road network and these thematic maps serve as an important input for the determination of optimal road link for connecting villages. It enables a faster response to the changing ground realities in the development planning, owing to its in-built scientific approach and open-ended design.

Thematic maps of road network generated from the different spatial data have shown the difference in length as well as the quality of the roads with change in time. Thematic map of road network generated from the Survey of India (SoI) toposheets showed moderately developed road network. Only major villages were connected through these roads; whereas the road connectivity was poorly developed in rest of the villages. According to the toposheets, the Halol talika was having approx. 110.4 km road length (**Plate 8(c)**). Results of thematic map of roads using remote sensing data suggested that the area has faced a rampant development and industrialization which ultimately affect the length as well as the quality of the road network. From the LISS-IV image of the year 2007 & 2012, the total road length of the Halol taluka was found to be approx.150.6 km and 164.07 km. respectively (**Plate 8(a&b)**). All these roads form a linkage between the villages and therefore they are considered to be “life line” in true sense. Looking to present structure of the roads, linking the area with other region, gives a sound network but with few flaws and so it still need to be strengthened for ecologically sustainable development.

4.1.2. Thematic Map of Slope and Aspect:

Slope and aspect are significant factors which contribute greatly in plant dispersal and growth as compared to other factors. Moreover these factors also have significant effect on composition, structure and density of the plant communities (**Sternberg & Shoshany, 2001**). The reason for this can be attributed to the fact that biomass, structure, and composition of the plant communities are greatly influenced by the habitat conditions which are reflected through these features. The present study area reflects a distinct variation in slope and aspect classes. The slope of the entire study area ranged between 2-42% and 5 different classes viz., less than 2%,2-6%,6- 15%,15-42% and lastly greater than 42% were defined **(Plate 9).**

Aspect is an another physiographic factor which influences the vegetation growth since it is associated with the moisture content of the slopes, variation in sunlight and wind blow. This factor is especially crucial for the area which faces low moisture and rainfall levels (**Christine and Mc Carthy, 2005**). Four different aspects viz., East, West, North & South were taken into consideration to understand the impact of this component on species diversity and richness (**Plate 10**). A distinct correlation was seen with respect to species distribution due to variations in the solar energy obtained by the terrain of different aspects (**Perring, 1959**). In the area under study south aspect exhibited the highest number of species (**Figure 7**).

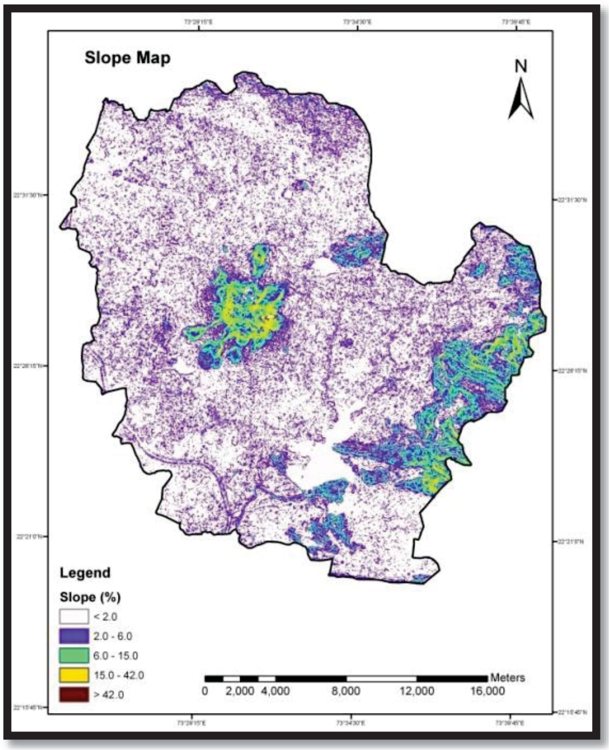


Plate: 9 Slope Map of Halol Taluka

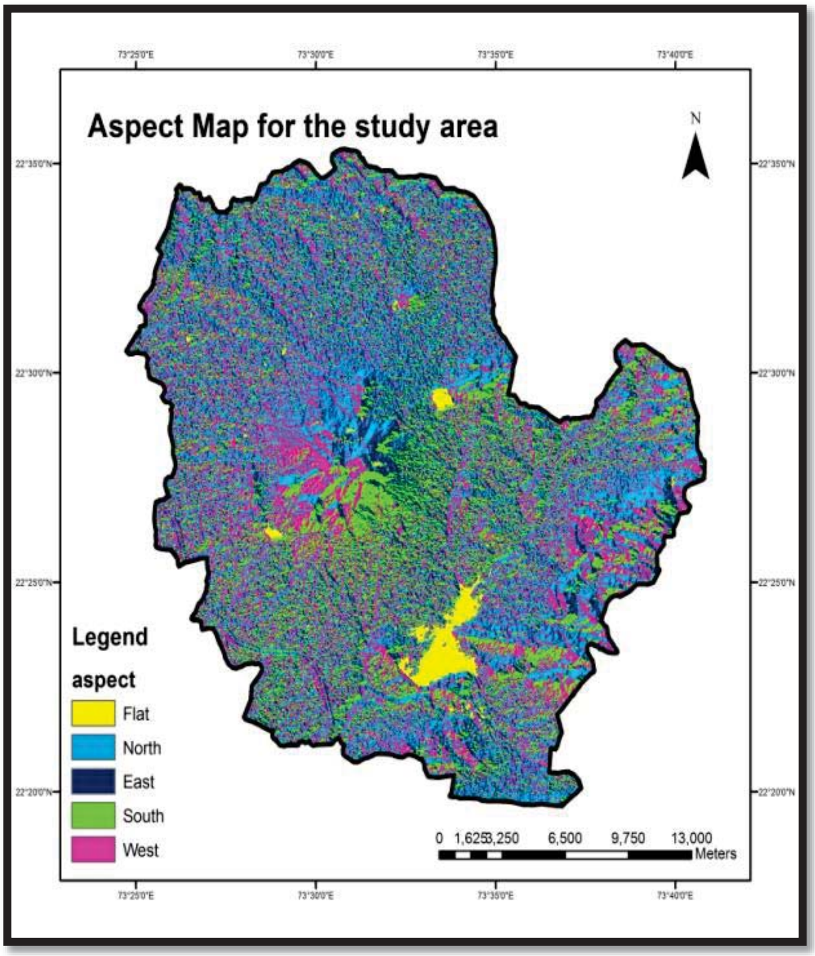


Plate: 10 Aspect Map of Halol Taluka

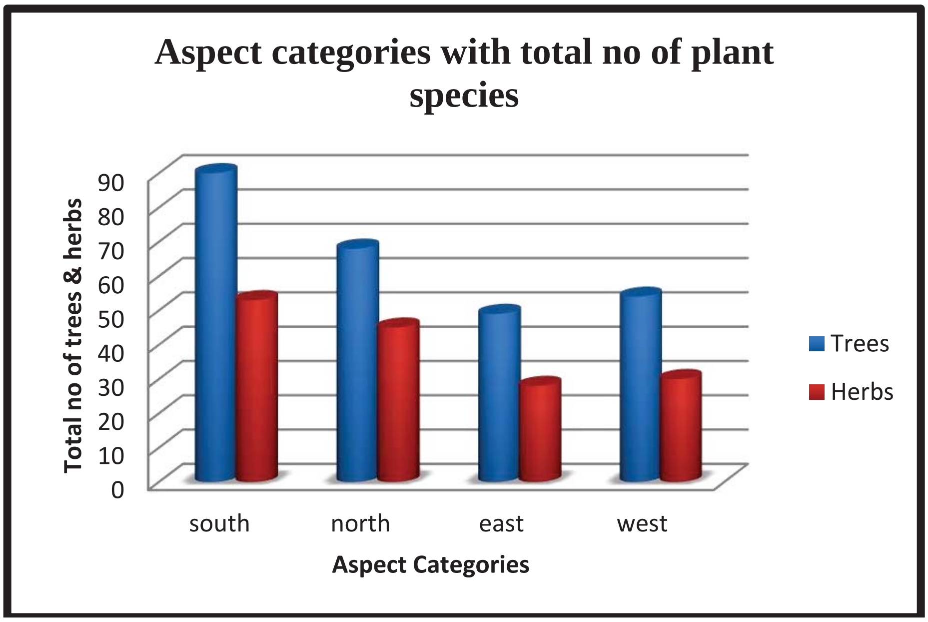


Figure 7. Graph of aspect categories and no of species

4.1.3. Thematic Map of Drainage:

In order to understand the drainage pattern various components viz., drainage density, stream frequency, drainage texture are significant to know the geologic structure of an area. Drainage density is the total length of streams of all orders per drainage area whereas stream frequency, which the total number of stream segments of all orders per unit area. **(Horton, 1932.)** It has been observed that the area for both that is density and frequency seem to be approx. same viz., 1.925 sq km and 1.936 sq km respectively. These values exhibit that the area to be falling under moderate density condition which means it has moderately permeable sub soil and fine drainage texture. The stream frequency values on the other hand from first to fourth order exhibited a decreasing trend and were seen to be quite correlating with the drainage density suggesting that there is an increase in stream population with respect to increasing drainage density.(**Das et al, 2012.)** The value of drainage texture ratio is an about 8.047 sq.km exhibiting to be a very fine drainage texture (**Smith, 1950**). Such fine texture also exhibits a good degree of slope. **Plate 11** shows drainage network of the study area.

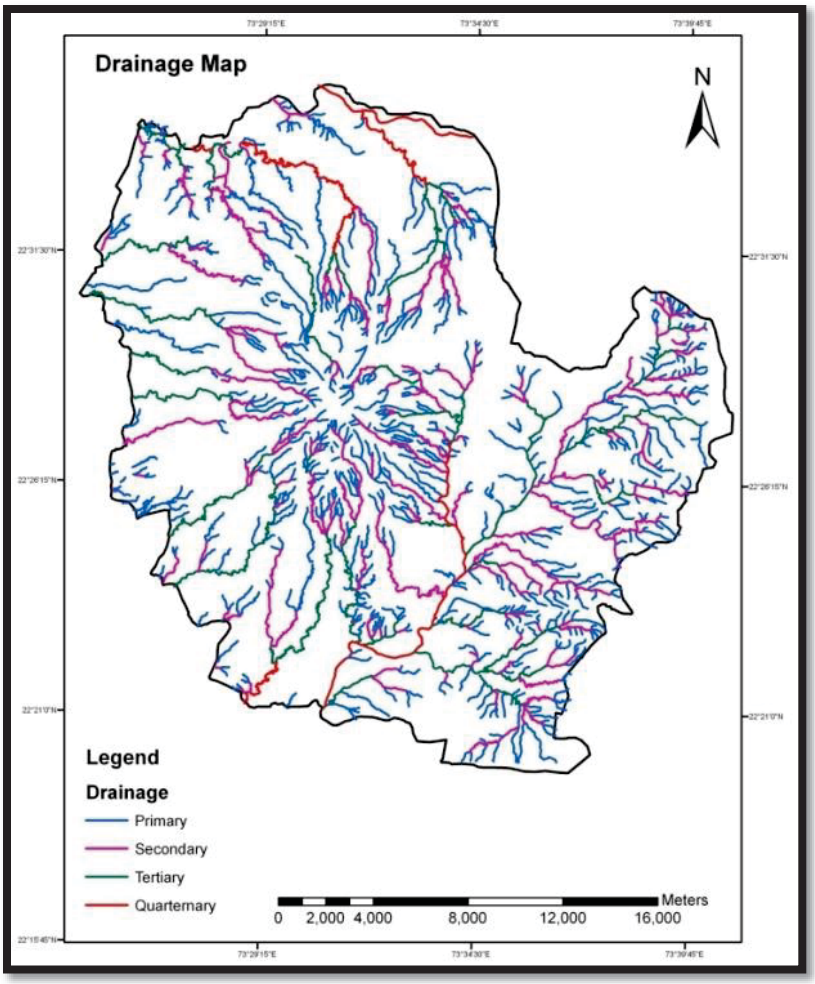


Plate: 11 Map showing Drainage network of the study area

4.1.4. Thematic Maps of villages of Halol taluka:

The developing countries like India is facing a big challenge to improve the economic and social well being of the fast growing population with its limited resources. Moreover, the Socio-economic planning and development is meaningful only when it is localized and viewed in its spatial perspective. Thus the geographical distribution/spatial specificity is a vital factor to derive, any meaningful policy that can have "the relevance over an area (village or cluster of villages). The geospatial technology has made this task more easier in the form of thematic maps. Since it provides comprehensive and essential information for the policy makers to ensure the optimum utilization of natural resources present therein. Keeping this in mind the ecologically sustainable development plan has been generated for the smallest geographical unit. i.e. village.

Halol taluka has total 123 villages and one town, of which 3 villages are unhabited **(Plate 12)**. Total area of the taluka is 49,105.4 ha. out of which 59.9% area is cultivable area. Analysis of population density showed that 31.7 per cent of the total villages of the taluka fall in the population density range of 500 – 999 persons. All the villages are avail all kinds of basic amenities (**Table 16).** Out of the total population, 49.6% are main or marginal workers, 42.8% are cultivators, 35.1% are agricultural labourers, and 0.8% are associated with household industry workers whereas 21.3% are other workers. These 120 villages occupy total 36,885 number of households, of which 67.3% use fire wood for cooking and this figure goes higher for the rural area where 82.3%the people use fire wood for cooking purpose.

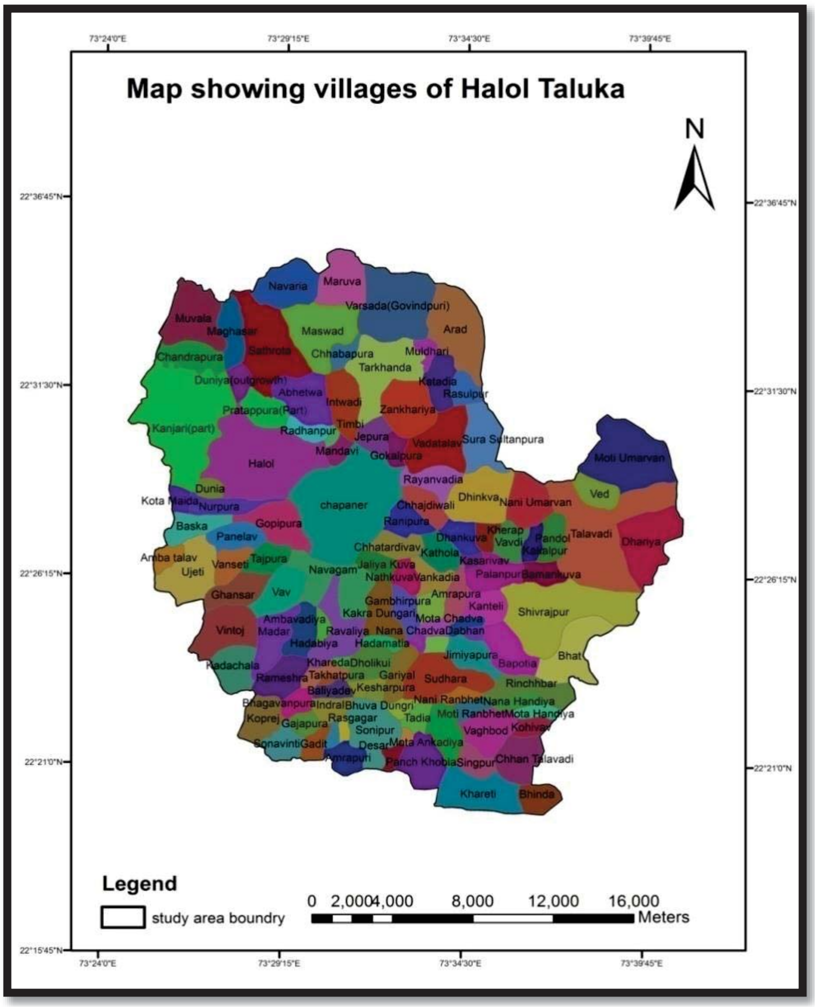


Plate: 12 Map showing Villages of Halol Taluka

Table: 16 Available basic amenities of the villages of Halol Taluka

Sr. No.	No. of Villages	Per cent of villages	Available Facility
1	87	72.5	at least one kind of medical facility
2	118	98.3	improved drinking water facility
3	91	75.8	well connected with the transport facility
4	83	69.2	linked by the pucca roads
5	120	100	Power supply

4.1.5. Thematic Map of population:

The rapidly rising population has resulted in a sharp increase in the biotic pressure on land in the study area. In order to generate the sustainable development plan, it is highly significant to consider population and other demographic features to analyze the impact of biotic pressure on the forest of the area. As per the Panchmahal Census Survey 2001, the total population of the Halol Taluka is 195,300. Out of this, 102,029 are Male and 93,271 are females, of which the percentage of Scheduled Caste and Schedule Tribes of the total population is 3.2 and 10.8 respectively. The population density is 378 persons per sq km. Halol taluka exhibits the highest decadal growth for the year 1991-2001 among all talukas of the Panchmahal district. Highly populated villages are Kanjari, Talavadi, Shivrajpur Sathrota and Champaner with the population of 8031, 4891, 5876, 4377 and 3249 respectively (**Plate 13) (Census, 2001).**

Educational infrastructure is another important indicator that demonstrates the development of an area. Almost 100% villages of the Halol taluka have Primary Schools, while only 14.87% have secondary school. Being Industrial Hub, the role of Industrial Training Institute (ITI) has become significant. Halol taluka has only one I.T.I. at the Champaner. (**Plate 14)** The literacy rate of Halol taluka is 61.1% with 74.9 % males are literate while 46.1 % females are literate.

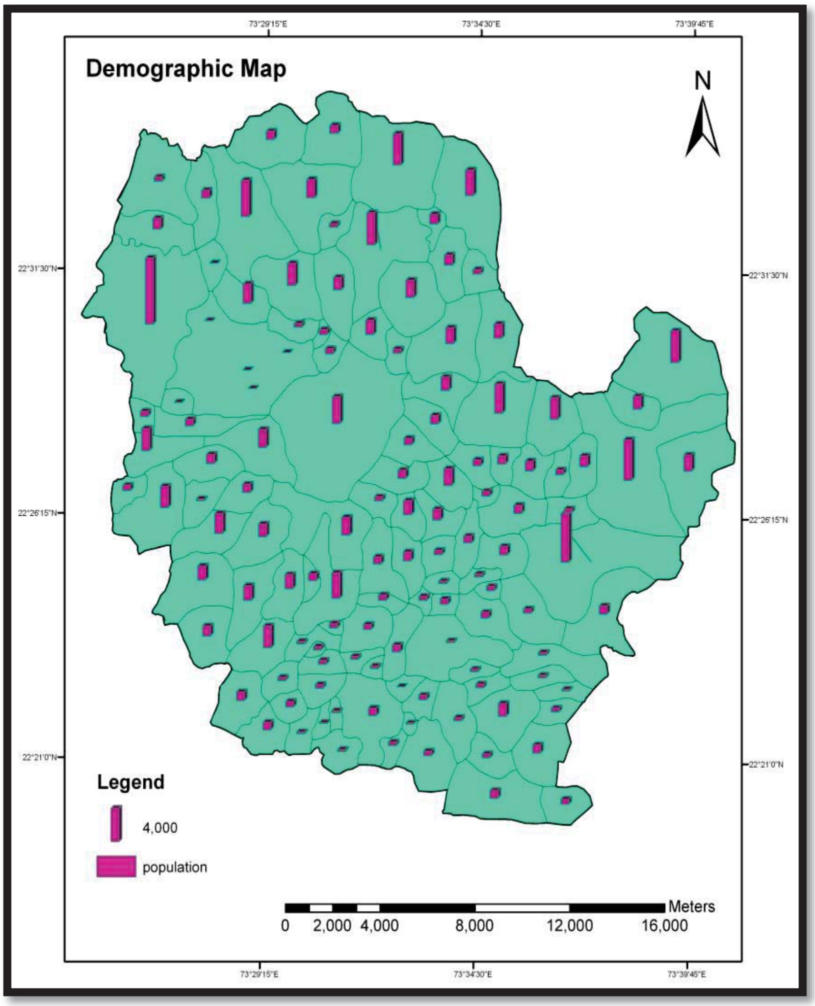


Plate: 13 Population Map of the area

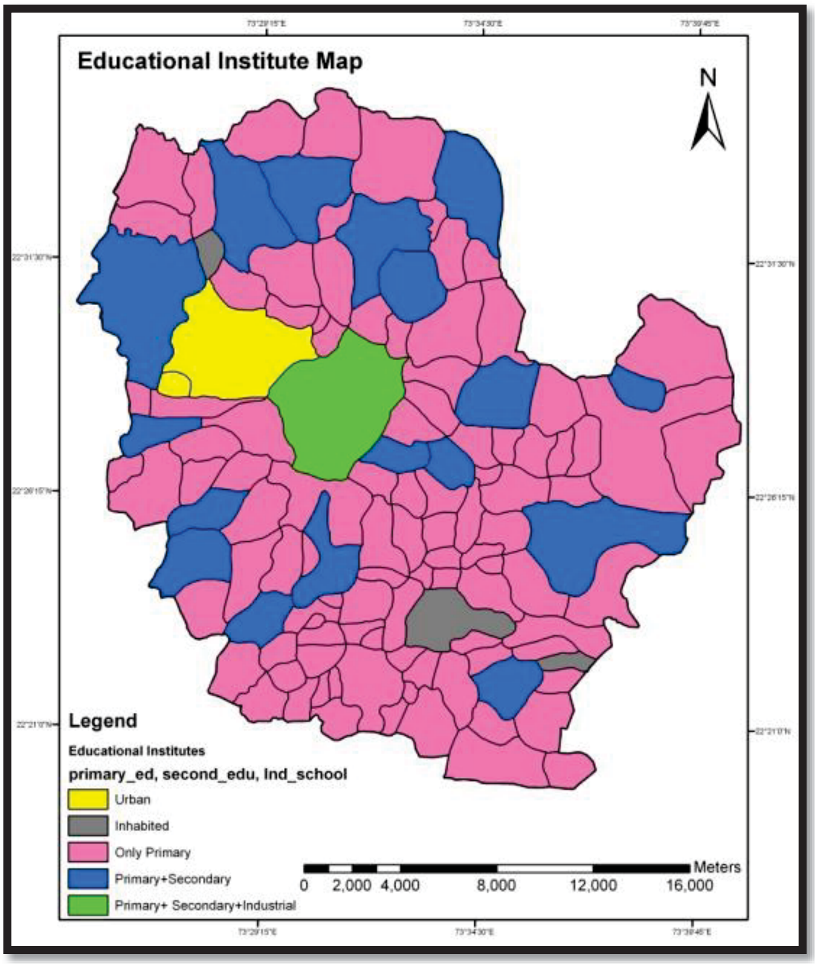


Plate 14. Map showing educational and technical Institutes of the study area

4.1.6. Thematic Map of arable land:

Forests are crucial for maintaining and improving the productivity of agricultural land. At the same time, due to a mounting world timber trade and fuel wood demand, the agriculture land gets expanded enormously. This has become a greatest challenge in tropical forests of the developing countries. On the other hand, growing populations and the decreasing availability of arable land lead poor farmers in these countries to seek new land in forests to grow more food. Some government policies also encourage the conversion of forests to pastures and others encourage large resettlement schemes in forests. Though forest provide many benefits such as support for settlements, watershed protection, best land for new farming, clearing these forests for the development is but obvious, but more often it has been cleared without proper planning. This issue can be resolved by appropriately planned utilization of the available arable land of an area. According to FAO, Arable land (in hectares) is the land under temporary crops (double-cropped areas are counted once), temporary meadows for mowing or for pasture, land under market or kitchen gardens, and land temporarily fallow. Land abandoned as a result of shifting cultivation is excluded. Understanding of arable land is very important feature for the management of the land cover with respect to the urbanization. In the current study area villages like Mota Handiya, Mandavi, Tajpura, Kakalpur, Bapotia and Champaner do not possess any arable land. Village Talavadi has the highest i.e. 747.20 ha arable land area, while it is least in the Nana Handiya village, i.e. only 18.70 ha. Bhuva Dungri has the maximum per capita arable land i.e. 4.55 ha since it has very less population as compare to the arable land of the village (**Plate 15 & 16).**

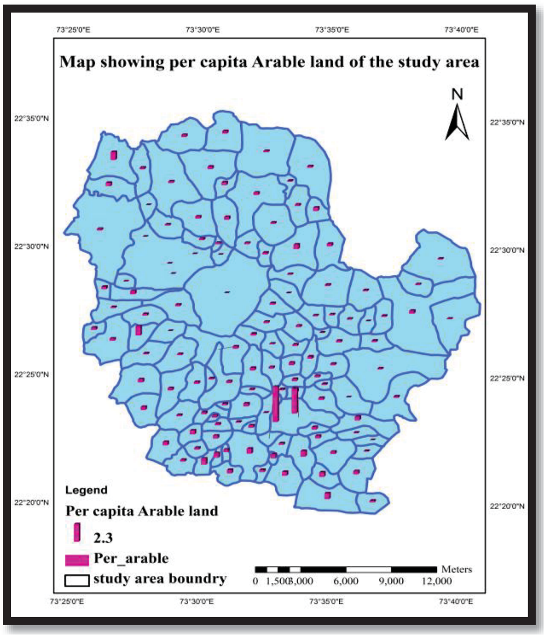


Plate : 15 Map showing per capita available arable land

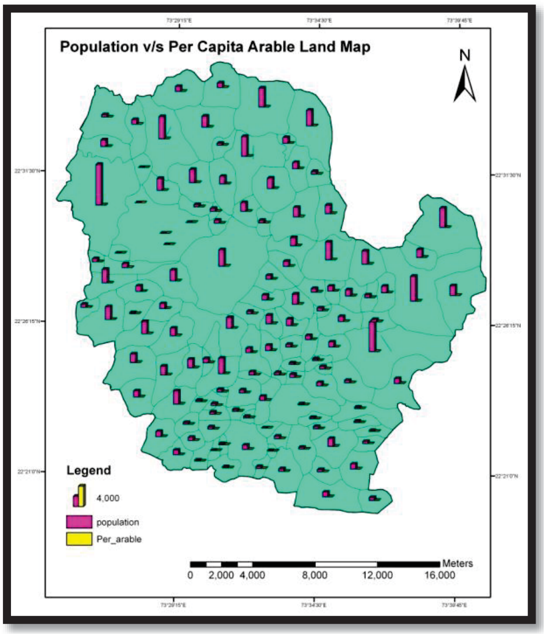


Plate: 16 Map showing per capita available arable land with respective population of the village

4.1.7. Thematic Map of Soil:

Soil indices report from District agriculture plan of Panchmahal district shows that the soil of the Halol taluka has covered by either Deep Black or shallow black type of soil and it is Black salt or mixed red and brown salt in terms of its texture. The soil is generally neutral in pH and low in Electrical conductivity. The Organic carbon is low and Phosphorus content of the soil is high and Potash content is also high. So, overall, the soil fertility indices are good from the agriculture point of view. The soil in the hilly areas is subjected to constant erosion due to lack of vegetation cover. The northen part of the taluka is having a soil of interfluves, (i.e. The region of higher land between two rivers that are in the same drainage system.) whereas the southern part has regions with hill slope or slight to moderate erosion. The eastern part of the area exhibited excessively drained loamy soil and slope of the hill. In the western part, the soil is having a low intensity of erosion as compare to other parts of the taluka **(Tyagi, 2008)** (**Plate 17**).

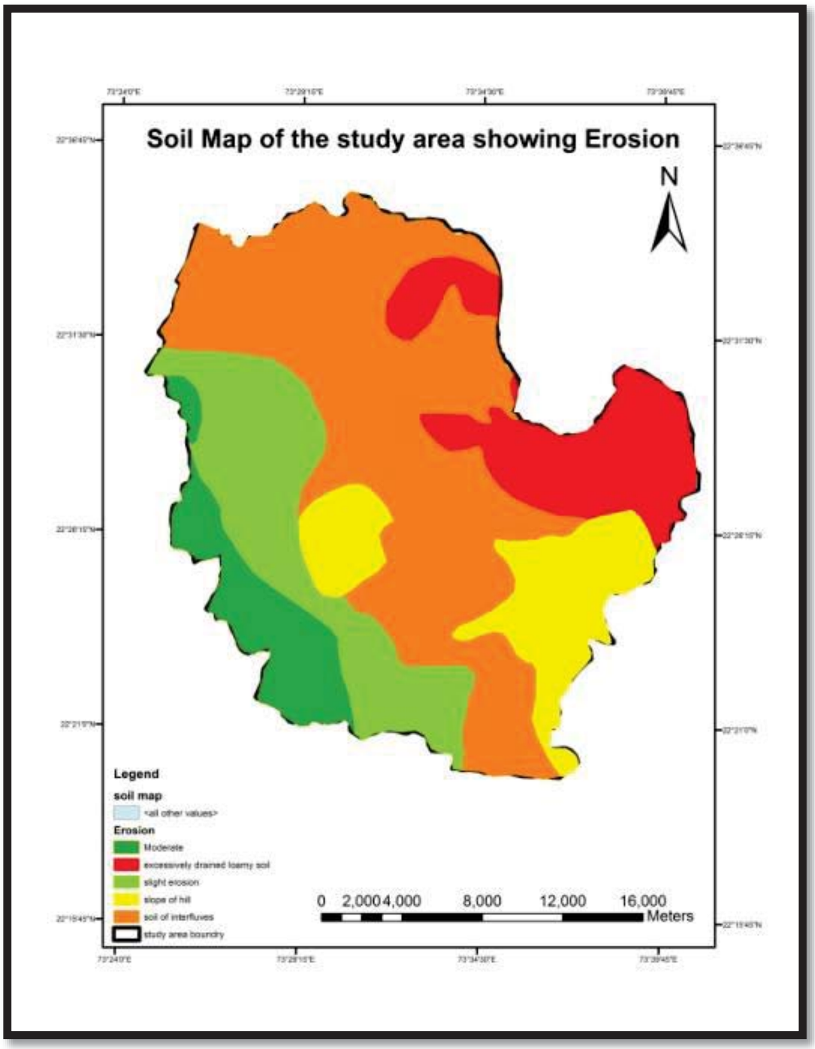


Plate: 17 Soil map of the study area with erosion status

4.1.8. Thematic Map of Air pollution:

Air pollution is having a potential to cause minor to severe impacts on the forests, since the industrial revolution (**Smith, 1981; Innes, 1993; Percy and Ferretti, 2004**). To study the spatial patterns of forest injury from the air pollutants, the distribution of deposition of relevant air pollutants in any region are to be understood (**Shadwick and Smith, 1994, Southern Appalachian Man and the Biosphere, 1996**). Considering this phenomena, the air pollution assessment in the form of concentration of gases like SO_2, NO_x and CO showed the amount of these gases at different sites. The analysis indicated that all these values were much below the permissible limits of CPCB. (**Plates 18, 19 & 20).** Based on their sensitivity classes, major part of the study area falls under extremely and very highly SO_2 and NO_x pollutant sensitive category that includes major forest cover of the study. In these areas, SO_2 and NO_x concentration was low but to avoid future deposition of this content, the areas were categorized under extremely and very highly sensitive zones. Villages covering industrial area namely Chandrapura were found to be highly to moderately sensitive. In villages namely Kanjari, Khareti, Chhan Talvadi and Bhinda, level of SO_2 and NOx concentration was high and which indicated that these areas are already polluted and thus are less, very less or negligibly (for NO_x) sensitive zones. As far as CO concentration is considered, major part of the area fall under moderately or less CO sensitive zone. Extremely, very highly and highly CO pollutant sensitive areas were identified as villages namely Maruva, Navaria, Maswad, Chhabapura, Khareti, Bhinda, Moti Umarvan, Arad, etc. Negligibly or very less CO sensitive areas includes villages Dhankuva, Dhinkva, Kanteli, portion of Dhariya village, part of Kanjari village etc.

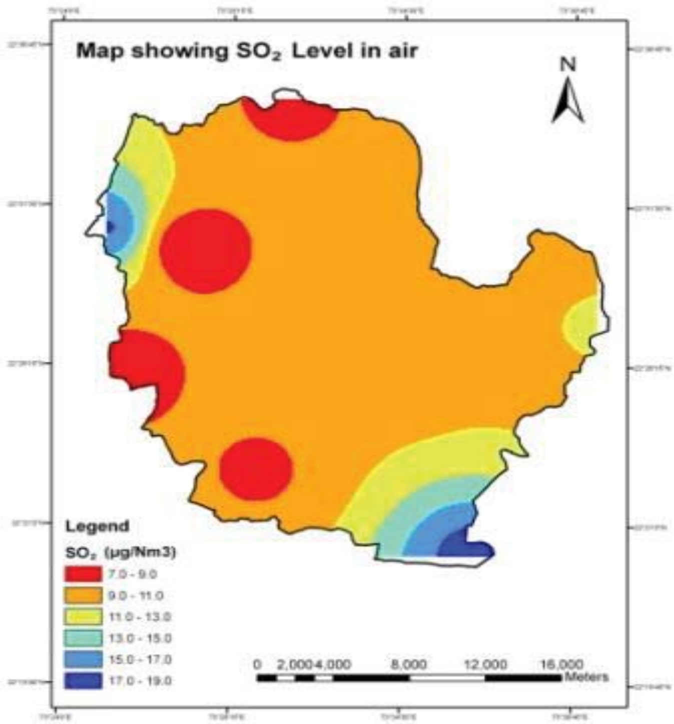


Plate: 18 Map showing SO_2 concentration

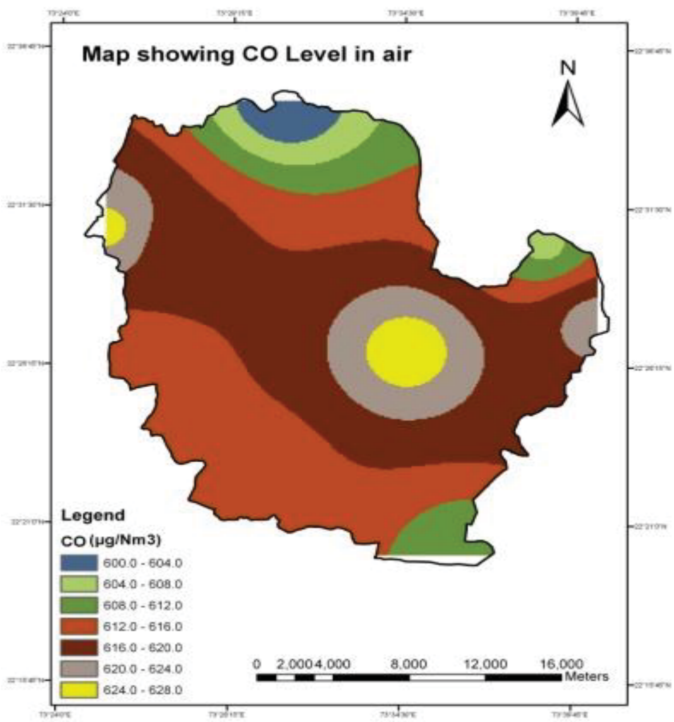


Plate: 19 Map showing CO concentration

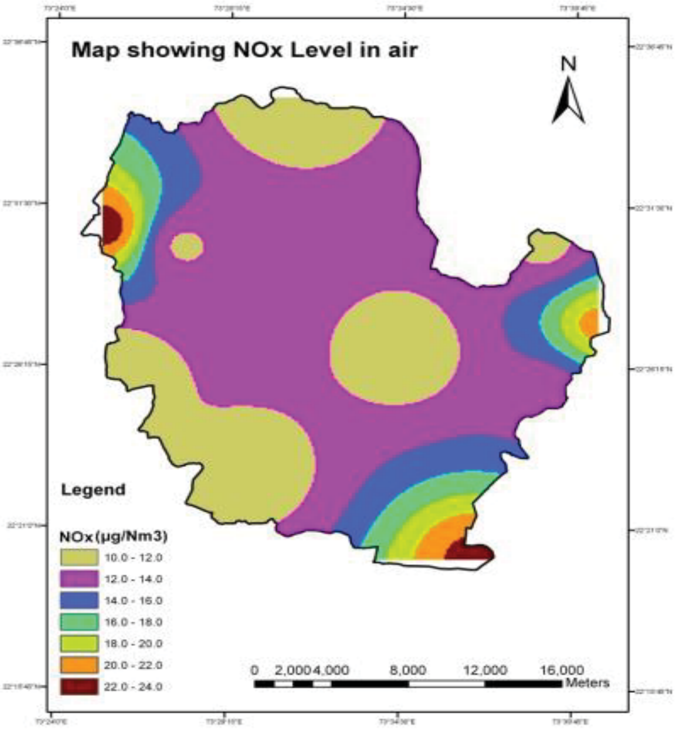
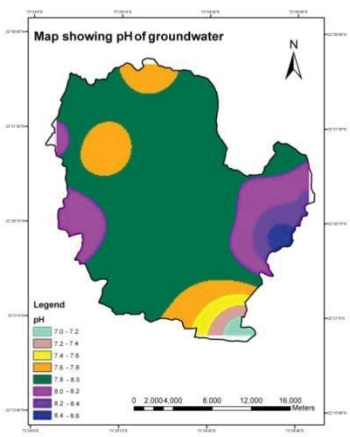
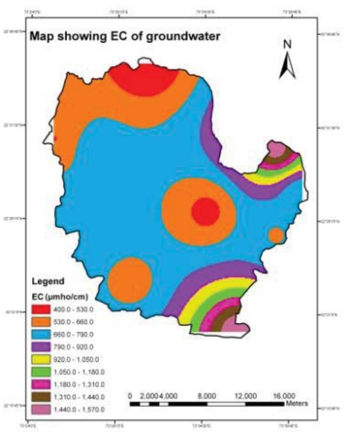


Plate: 20 Map showing NO_x concentration

4.1.9. Thematic Map of Ground water quality





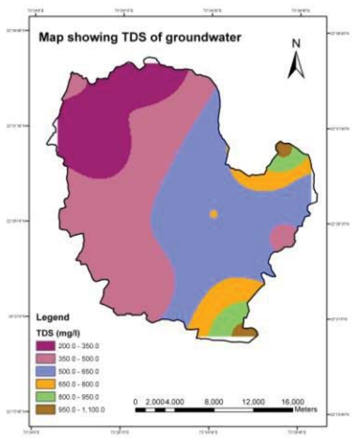


Plate:21 Map showing pH

Plate :22 Map showing Electrical Conductivity

Plate :23 Map showing Total Dissolved Salts

Ground Water quality

It is increasingly recognized that availability and quality of ground water are strongly influenced by forests. Ground Water quality indicators a simple readily understandable tool for managers and decision makers to transmit information on the quality and potential uses of a given water body based on a number of criteria (**Sedẽno-Díaz and López-López, 2007**). Moreover, climate change is altering forest's role in regulating water flows and thus, influencing the availability of water resources (**Bergkamp et al., 2003**). Therefore, the relationship between forests and water is a critical issue that must be accorded high priority. Taking this fact in to consideration, the evaluation of ground water quality of the present study area, in the form of pH, electrical conductivity (EC),and Total dissolved salts (TDS) showed a distinct variation from site to site. It indicates higher concentration of electrical conductivity, and total dissolved solids and thus affects drinking water quality standards of the study area.

pH: pH is one of the important factor of ground water. In the study area, pH of ground water varied from 7.05 to 8.50 indicating the slight alkaline nature of the ground water. The pH of none of the sample exceeds the permissible limit prescribed by CPCB. It is essential to know the nature of ground water in order to maintain its limit which is a prerequisite for the generation of the sustainable development plan. In this context, based upon the sensitivity the majority area falls under the moderately sensitive, whereas Shivrajpur, Dharia, Talavadi show high values of Ph and so considered as highly sensitive villages. Chhan talavadi, Bhinda, Khareti, Singpur, Waghbod, Kohivav, Marua and Halol villages fall under category of less sensitive area (**Plate 21).**

Electrical conductivity: Electrical conductivity (EC) is an important parameter for groundwater quality assessments. It is a measure of capacity of a substance to conduct the electric current. Most of the salts in water are present in their ionic forms and capable of conducting current. In the present study, the values ranged between 402 – 1536 µmho/cm which is beyond the BIS standards. The entire taluka comes under the high sensitive area **(Plate 22).**

Total dissolved solids (TDS): The total dissolved solids (TDS) are the concentrations of all dissolved minerals in water indicate the general nature of salinity of water. The total dissolved solids in all the study area varies from 248 -988, of which the four sites show the values beyond the desirable limit, but all values are below the permissible limit **(Plate 23).**

4.1.10. Thematic map of forest area:

According to the National forest policy, sustainable development of a forest has become imperative, under which maintaining the ecological balance has been considered as a primary objective. **(Anon, 2001).** In this context, the thematic maps of the forest area have been generated using two different attribute data through which the changes that have occurred in this forest area during different time series have been analysed. The first thematic map is generated from the SoI toposheets showed Pavagadh area during 1970s having 8960 ha. of thick forest cover which was protected mainly under Reserve Forest category. This Reserve Forest was comprised of different forest categories viz. open forest, open jungle, open scrub, eucalyptus plantation, fairly dense mixed jungle mainly teak, dense mixed jungle mainly teak, etc. The second thematic map was generated from the data available in Census of the year 2001. According to it, Halol taluka had 9145.5 ha of land area under different categories of forest. This forest area was recorded for 27.04% of the total 122 villages of Halol taluka. The least forest area has been recorded for village Nani ranbhet which is only 13.08 ha; whereas Champaner village possesses the maximum forest area. i.e. 1979 ha **(Plate 24, 25 and 26).**

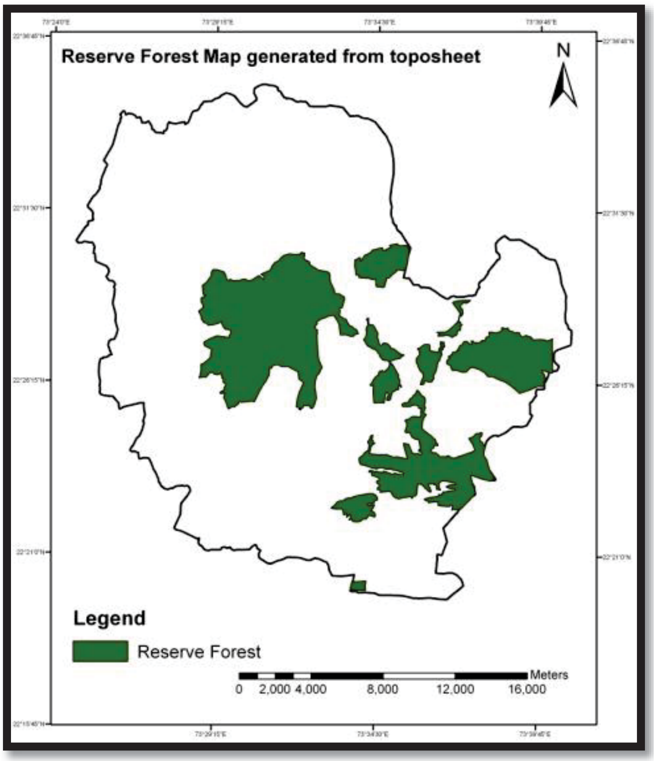


Plate 24 Thematic map of Reserve Forest area generated from SoI Toposheets

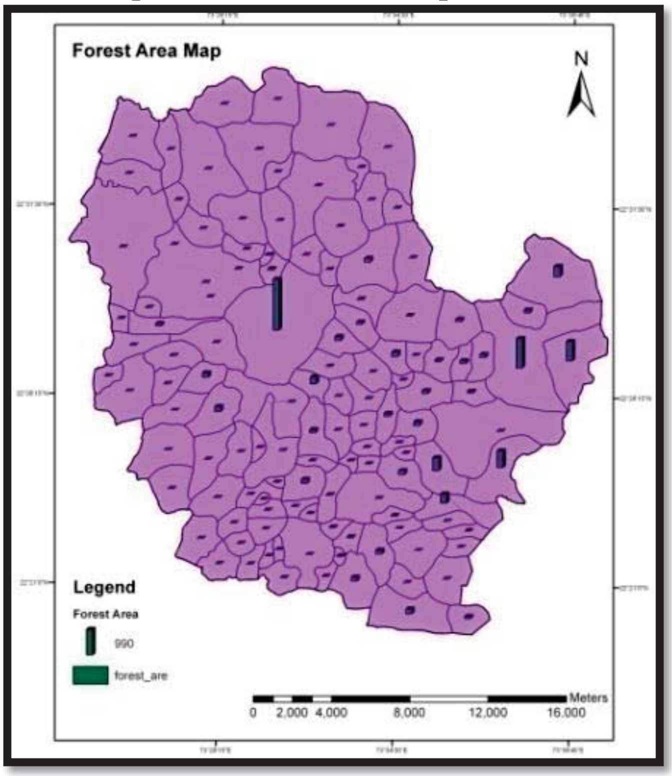


Plate 25 Thematic map of Recorded Forest area generated from Census data

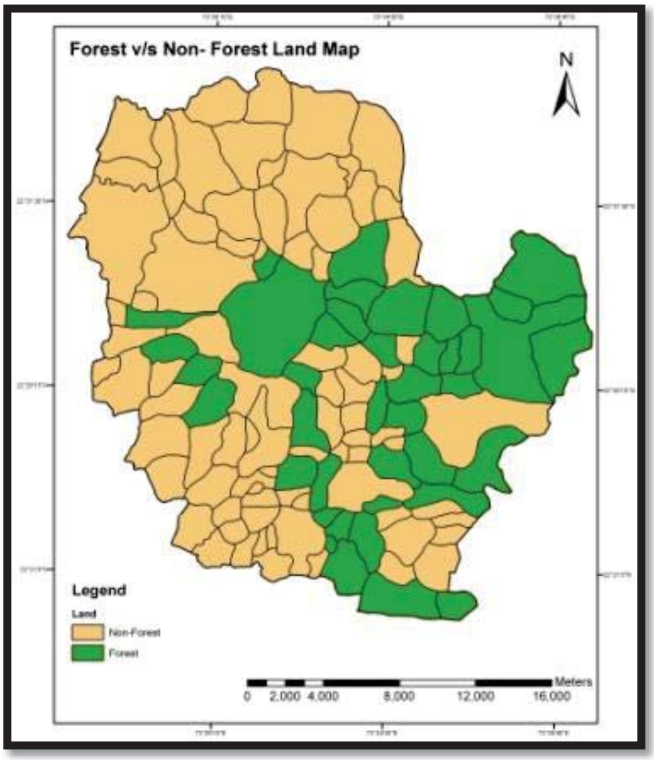


Plate 26. Thematic map of Forest v/s Non-Forest area generated from Census Data

4.1.11. Thematic Map of Forest Ecology:

To maintain the biodiversity and ecological integrity, not only for the present, but also for future generations, the understanding of forest of that area is a prerequisite. This requires its assessment with respect to its status, condition and conservation value at a specific spatial scale (**Noss, 1999).** A significant challenge in this assessment is the limited ability to know forest conditions quantitatively since it is an enormous task but can be achieved through community Phytosociological studies and Diversity analysis.

4.1.11.1. Primary Vegetation Analysis:

A total of 100 trees and herbaceous species belonging to 40 families of vascular plants were observed from the study area. Caesalpiniaceae & Mimosaceae (20%), the most predominant family in the study area, followed by Combretaceae (15%), Apocynaceae (12.5%), Rhmnaceae, Euphorbiaceae & Malvaceae (10%), Asteraceae, Convolvulaceae, Moraceae & Verbenaceae (7.5%), Anonaceae, Anacardiaceae, Rubiaceae, Myrtaceae, Sterculiaceae, Burseraceae, Meliaceae, Acanthaceae, Cucurbitaceae (5%) constituted bulk of the flora of Pavagadh whereas the rest 19 families were monospecific **(Table 17).**

Table 17. Number of Genera under different families

Sr. No.	No. of Genus	Families
1	8	Caesalpiniaceae & Mimosaceae
2	6	Combretaceae
3	5	Apocynaceae
4	4	Rhmnaceae, Euphorbiaceae & Malvaceae
5	3	Asteraceae, Convolvulaceae, Moraceae & Verbenaceae
6	2	Anonaceae, Anacardiaceae, Rubiaceae, Myrtaceae, Sterculiaceae, Burseraceae, Meliaceae, Acanthaceae, Cucurbitaceae
7	1	Sapotaceae, Fabaceae, Capparaceae, Alangiaceae, Bombacaceae,Celastraceae, Ulmaceae, Flacourtiaceae, Ehretiaceae, Ebnaceae, Umbeliferae, Tiliaceae, Aracaceae, Commelinaceae, Musaceae, Boraginaceae, Poaceae,Liliaceae,Plumbaginaceae

Dominant trees species included were *Tectona grandis, Butea monosperma, Wrightia tinctoria, Wrightia tomentosa, Capparis sepiara, Morinda tomentosa, Holoptelea integrifolia, Albizia lebback, Carrisa congesta* etc. while under storey was comprised of *Urena lobata, Helictreres isora, Cassia tora, Cassia auriculata, Phyllanthus niruri, Trichodesma indicum, Amorphophallus commutatus*. The occurance of *Lantana camera*, which is a weed, probably affecting the understorey species at many places. A complete listing of plant species found in forest areas of Pavagadh is presented in **Table 18.**

Table 18 List of Plant species encountered during Field visits

Sr.No.	Botanical Name	Family
1	*Wrightia tinctoria* (*Roxb*.) R.Br.	Apocynaceae
2	*Holarrhena antidysenterica* (L.) R.Br.	Apocynaceae
3	*Miliusa tomentosa (*Roxb.) J. Sinclair	Annonaceae
4	*Wrightia tomentosa* Roem. & Schult.	Apocynaceae
5	*Capparis sepiara* L.	Capparaceae
6	*Nerium oleander* L.	Apocynaceae
7	*Annona squamosa* L.	Annonaceae
8	*Ficus religiosa* L.	Moraceae
9	*Phyllanthus emblica* L.	Euphorbiaceae
10	*Tamarindus indica* L.	Caesalpiniaceae
11	*Terminalia bellerica* (Gaertn.) Roxb.	Combretaceae
12	*Tectona grandis* L.f.	Verbenaceae
13	*Cassia fistula* L.	Caesalpiniaceae
14	*Alangium salvifolium* Lamarck.	Alangiaceae
15	*Morinda tomentosa* (Heyne ex Roth) Hk. f.	Rubiaceae
16	*Albizia lebback* (L.) Bth.	Mimosaceae
17	*Bombax ceiba* L.	Bombacaceae
18	*Maytenus emarginata* (Willd.) Ding Hou	Celastraceae
19	*Holoptelea integrifolia* (Roxb.) Planch.	Ulmaceae
20	*Cassia siamea* Lam.	Caesalpiniaceae
21	*Pithocelobium dulce* C. E. P. Mart.	Mimosaceae
22	*Zizhyphus mauritiana* Lamk.	Rhamnaceae
23	*Carrisa congesta* Wight.	Apocynaceae
24	*Syzygium cumini* (L.) Skeels.	Myrtaceae
25	*Anogeissus latifolia* Wall. ex. Bedd.	Combretaceae
26	*Flacourtia indica* (Burn.f.) Merr.	Flacourtiaceae
27	*Sterculia urens* Roxb.	Sterculiaceae
28	*Bauhinia racemosa* Lam.	Caesalpiniaceae
29	*Terminalia arjuna* (Roxb.) W. & A.	Combretaceae
30	*Cordia dichotoma* Frost. f. Prodr.	Ehretiaceaea

31	*Ficus racemosa* L.	Moraceae
32	*Albizia odoratissima* (L. f.) Bth.	Mimosaceae
33	*Vitex negundo* L.	Verbenaceae
34	*Acacia auriculiformis* A. Cunn.	Mimosaceae
35	*Trema orientalis* (L.) Bl.	Ulmaceae
36	*Terminalia catappa* L.	Combretaceae
37	*Ficus benghalensis* L.	Moraceae
38	*Peltophorum pterocaroum* (DC.) K. Heyne	Caesalpiniaceae
39	*Terminalia crenulata* Roth.	Combretaceae
40	*Diospyros melanoxylon* Roxb.	Ebenaceae
41	*Garuga pinnata* Roxb.	Burseraceae
42	*Azadirachta indica* A. Juss.	Meliaceae
43	*Mitragyna parvifolia* (Roxb.) Korth.	Rubiceae
44	*Buchanania lanzan* Spreng.	Anacardiaceae
45	*Acacia leucophloea* Willd.	Mimosaceae
46	*Soymida febrifuga* (Roxb.) A. Juss.	Meliaceae
47	*Acacia nilotica (L.) Del. Sub sp indica*	Mimosaceae
48	*Gmelina arborea* L.	Verbenaceae
49	*Zizyphus xylopyra* (Retz.) Willd.	Rhamnaceae
50	*Lannea coromandelica* (Houtt.) Herrill	Anacardiaceae
51	*Zizyphus mauritiana* Lam.	Rhamnaceae
52	*Acacia chundra* (Roxb. Ex Rottl.) Willd.	Mimosaceae
53	*Madhuca indica* J. F. Gmel.	Sapotaceae
54	*Mitragyna parvifolia* (Roxb.) Korth.	Rubiceae
55	*Butea monosperma* (Lam.)	Papillionaceae
56	*Boswellia serrata* Triana & Planch.	Bursuraceae
57	*Parkinsonia aculeata* L.	Caesalpiniaceae
58	*Prosopis juliflora* Swartz. DC.	Mimosaceae
59	*Eucalyptus hybrid (Cittidora globulus)*	Myrtaceae
60	*Zizyphus*	Rhamnaceae
61	*Pongamia pinnata*	Papillionaceae
62	*Sida acuta* Burm.f.	Malvaceae
63	*Trachyspermum stictocarpum* Wolff.	Umbelifereae
64	*Triumfetta annua* L.Mant.	Tiliaceae
65	*Acalypha indica* L.	Euphorbiaceae
66	*Sida veronicaefolia* Lam.	Malvaceae
67	*Sida orientalis* Cav.	Malvaceae
68	*Eclipta prostrata*(L.)L.Mant.	Asteraceae
69	*Vernonia anthelmintica* (L.)Willd.	Asteraceae
70	*Cassia occidentalis* L.	Caesalpiniaceae
71	*Amorphophallus commutatus* (Schott)	Araceae

72	*Achyranthus aspera* L.	Amaranthaceae
73	*Phyllanthus niruri* L.	Euphorbiaceae
74	*Blumea bifoliata* DC.	Asteraceae
75	*Commelina benghalensis* L.	Commelinaceae
76	*Helictreres isora* L.	Sterculiaceae
77	*Cassia tora* (L.) Roxb.	Caesalpiniaceae
78	*Cucumis setosus* Cogn.	Cucurbitaceae
79	*Ipomea nil* (L.) Roth	Convolvulaceae
80	*Combretum ovalifolium* Roxb.	Combretaceae
81	*Hygrophylla auriculata* (Schumach.)	Acanthaceae
82	*Carvia callosa* (Wall.) Bremek.	Acanthaceae
83	*Evolvulus alsinoides* (Linn.) Linn.	Convolvulaceae
84	*Ensete superbum* Roxb.	Musaceae
85	*Trichodesma indicum* (L.) R.Br.	Boraginaceae
86	*Urena lobata* L.	Malvaceae
87	*Cassia auriculata.L*	Caesalpiniaceae
88	*Luffa acutangula(* L.) Roxb.	Cucurbitaceae
89	*Dendrocalamus strictus*	Poaceae
90	*Aloe vera* (L.) Burm.f.	Liliaceae
91	*Plumbago zeylanica* Linn.	Plumbaginaceae
92	*Euphorbia hirta* L.	Euphorbiaceae
93	*Dicanthium annulatum* Forsk.	Poaceae
94	*Sphaeranthus indicus* L.	Asteraceae
95	*Haplanthus verticillatus* Roxb.	Acanthaceae
96	*Pimpinella sp.*	Umbelifereae
97	*Barleria prionitis* L.	Acanthaceae
98	*Glinus oppositifolius (*L.)Aug.DC.	Molluginaceae
99	*Eclipta alba*(L.)Hassk.	Asteraceae
100	*Senecio dalzellii* Cl.	Acanthaceae

The commonness feature with respect to tree species as revealed by abundance values, confirmed the observations of floristic survey. Species Abundance values varied from a low of 6.33/m^2 at site 3 to a high of 37.55 /m^2 at forest of site 22. Frequency values of Tree species like *Tectona grandis L., Wrightia tomentosa* Roem. & Schult. and *Wrightia tinctoria* (*Roxb*.) R.Br.were high. In case of understorey layer, plant species like *Sida acuta* Burm.f., and *Cassia tora* (L.) Roxb were the most frequent and dominant with their higher a frequency and dominance value. The lowest abundance was observed as $3.73/m^2$ at the site no. 8 and the highest was recorded as $17.33/ m^2$ at site no. 5. For the Understorey layer the less frequency of other species could be related to anthropogenic activities. Per hectre stem density of trees was evaluated considering its significance for the conservation and management of forest area. It was found to be varied from 440 - 1250 individuals/ha with highest at site no. 22 and lowest at site no.3. The reason for lower density could be that the site no.3 was young plantation site with the saplings of the tree species. The higher density value reflects that the site no.22 is having less anthropogenic disturbances. The basal area of Understorey exihibited the values between 1.3- 9.42 cm^2/m^2.This lowest value was recorded for *Aster* sp. at site no. 4 & and highest was for *Achyranthus aspera* at site no.15. The Basal area for the tree layer has been calculated in the form of Total Basal Area (TBA). It was highest (67.78) for site 29 and lowest for site 20. (1.43). Site no 29 has been dominated by Tectona grandis (70%.). This could be attributed by its higher girth classes as compared to other species of the sites. Out of total 35 sites approx. 50% sites showed lower TBA (< $20m^2$/ha) which could be due to either higher level of disturbance or the species with lower girth classes. At site 29, Tectona grandis accounted for the greater portion of total basal area. The other species with higher TBA were *Morinda tomentosa* and *Butea monosperma*, accounted for more than 40% of total basal area. This could be attributed to the high proportion of trees of greater diameter. Trees with larger diameter have wider canopy cover and as canopy becomes close, plant competition intensifies and slow growing trees become stunt and die.

Importance Value of Index (IVI) is imperative to compare the ecological significance of species **(Lamprecht, 1989)**. It indicates the extent of dominance of a species in the structure of a forest stand **(Curtis and McIntosh, 1951)** and thereby species with the greatest importance values are considered as the leading dominants of the forest.

Table 19. IVI of dominant tree species at different sites

Site No.	Scientific name	IVI
1	*Butea monosperma* (Lam.)	57.74
2	*Butea monosperma* (Lam.)	60.94
3	*Madhuca indica* J. F. Gmel.	167.3
4	*Prosopis juliflora (Molina)* Stuntze.	177.33
5	*Prosopis juliflora (Molina)* Stuntze.	195.93
6	*Bombax ceiba* L.	94.13
7	*Tectona grandis* L.f.	83.31
8	*Butea monosperma* (Lam.)	58.56
9	*Terminalia arjuna* (Roxb.) W. & A.	85.65
10	*Wrightia tomentosa* Roem. & Schult.	87.36
11	*Tectona grandis* L.f.	66.98
12	*Butea monosperma* (Lam.)	83.92
13	*Pithocelobium dulce* C. E. P. Mart.	121.48
14	*Tectona grandis* L.f.	102.74
15	*Holarrhena antidysenterica* (L.) R.Br.	81.82
16	*Tectona grandis* L.f.	58.27
17	*Wrightia tomentosa* Roem. & Schult.	100.6
18	*Butea monosperma* (Lam.)	67.01
19	*Eucalyptus hybrid (Cittidora globulus)*	119.71
20	*Acacia nilotica* (L.) Del. *Sub sp indica*	165.27
21	*Holoptelea integrifolia* (Roxb.) Planch.	78.05
22	*Albizia lebback* (L.) Bth.	40.08
23	*Tectona grandis* L.f.	54.99
24	*Pithocelobium dulce* C. E. P. Mart.	65.22
25	*Zizhyphus mauritiana* Lamk.	135.66
26	*Tectona grandis* L.f.	28
27	*Tectona grandis* L.f.	29.45
28	*Tectona grandis* L.f.	84.23
29	*Tectona grandis* L.f.	142.34
30	*Tectona grandis* L.f.	95.4
31	*Tectona grandis* L.f.	85.21

32	*Tectona grandis* L.f.	48.57
33	*Tectona grandis* L.f.	74.77
34	*Tectona grandis* L.f.	138.35
35	*Eucalyptus hybrid (Cittidora globulus)*	95

The results obtained from the relative abundance, relative dominance and relative density summed up to get the values of IVI. It revealed that, *Prosopis juliflora* in tree layer (**Table 19**), and *Cassia tora* in Understorey layer exihibited the maximum IVI value and these are considered as leading dominants in the study area **(Figure 8).** This table indicates that *Prosopis juliflora* occur only at few sites, but its dominancy could be related to the higher basal area which directly influences the IVI.

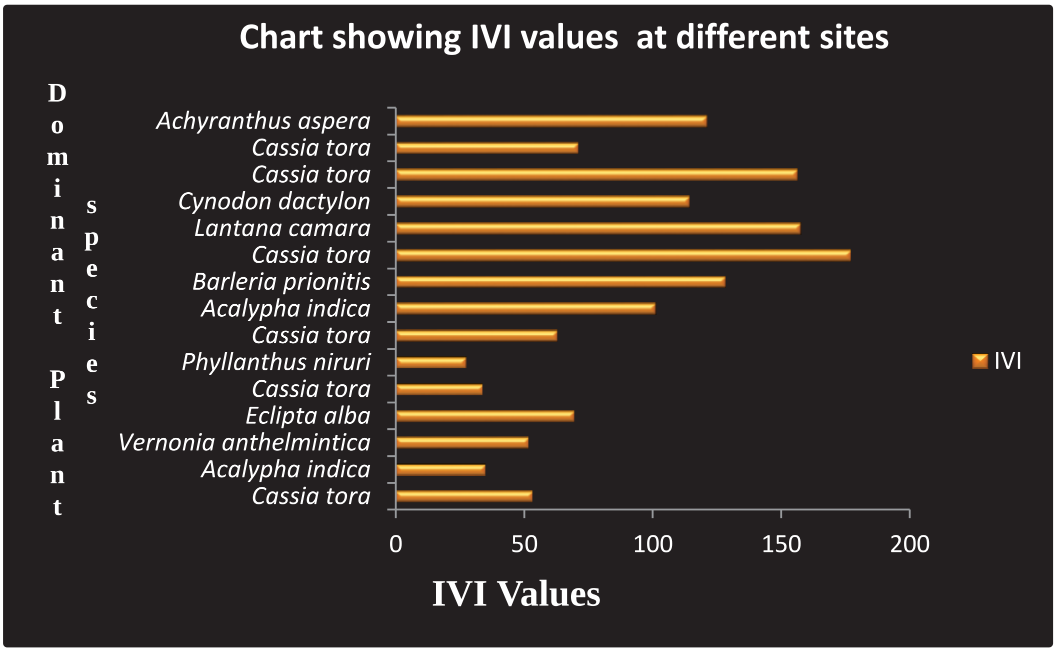


Fig 8. IVI for herabaceous layer at different sites

4.1.11.2. Secondary Vegetation Analysis

Based on the results of Primary vegetation analysis, the secondary vegetation analysis was performed. This includes analysis of Diversity indices like Shannon –

Wiener diversity index, Evenness & Species richness along with estimation of above ground biomass. To measure the attributes of community structure of all these studies been used in this study and results were generated which are as follows:

Diversity indices: Forest biodiversity studies involved the use of diversity indices which often served as an ecological indicators to measure the attributes of community structure. (**Magurran, 1988).** Species richness and species evenness are the two different components which formulate the structure of any community and thus, ultimately contribute to the species diversity. **Table 20 & 21** showed the overall structure of plant community for Tree and Understorey layer respectively in the form of vegetation indices found at different sites of the study area. For Tree layer, the highest H- Index was found 1.26 for site no.26, while the lowest was 0.30, for the sites 4, 5 & 19. Majority study sites showed evenness values between 0.9 to 1, except site no. 17 & 26.Species richness values ranged from 0.33 -1.68. Index of dominance stretched from 0.03 to 0.51 across the study area supporting the finding that the species diversity is inversely proportional to the Index of dominance (**Odum, 1971**). The Above ground biomass of trees was highest for site 29 (112.58t/ha) while site no 20 had the lowest value (9.46 t/ha). The higher value of biomass could be attributed to the *Tectona grandis* at the site no 29; whereas site no 8 also showed high AGB value which could be resulted by the species other than the *Tectona grandis* , like *Butea monosperma,* and *Morinda tomentosa,* sp. The values for the Shannon-Wiener diversity index for Herbaceous layer ranged between 0.4 to 1.32. Most of study sites showed greater than 0.9 evenness index value, except site no. 8,10,11,12,& 13. Species richness values were observed from 0.34 – 1.16 and this higher value could be attributed to the maximum no of individuals (427) found at site no. 5. It has been also found that, like tree layer, values for Index of dominance was inversely proportional to that of the species diversity, ranging from

0.002 – 0.21.

Table. 20 Status of TBA, diversity indices & biomass of tree layer

Site No.	TBA of sps(m^2/ha)	Diversity Index ($\bar{H}$)	Evenness (e)	sp.richness (d_2)	Index of dominance (c)	Biomass (t/ha)
1	33.02	1.00	0.96	1.00	0.11	18.94
2	40.42	0.88	0.98	0.73	0.14	68.04
3	44.51	0.47	0.98	0.46	0.35	95.13
4	4.55	0.30	1.00	0.33	0.50	30.14
5	2.31	0.30	0.99	0.42	0.51	15.30
6	31.62	0.82	0.97	0.69	0.16	109.68
7	28.34	0.81	0.96	0.69	0.17	87.94
8	17.75	0.90	1.00	0.73	0.13	86.88
9	27.74	0.70	1.00	0.60	0.20	83.97
10	12.35	0.68	0.98	0.64	0.21	81.91
11	17.27	0.76	0.99	0.67	0.18	104.48
12	26.40	0.84	0.93	0.87	0.17	75.08
13	6.19	0.58	0.96	0.54	0.28	41.01
14	26.67	0.60	0.99	0.69	0.25	76.85
15	32.34	0.76	0.39	0.73	0.21	14.48
16	21.97	0.77	0.99	0.90	0.17	105.71
17	27.97	0.62	0.89	0.71	0.27	85.46
18	37.10	0.88	0.96	1.14	0.14	46.03
19	4.89	0.58	0.97	0.63	0.27	32.43
20	1.43	0.30	0.98	0.46	0.51	9.46
21	8.93	0.68	0.97	0.72	0.22	59.18
22	18.23	1.12	0.91	1.31	0.09	100.91
23	16.46	1.05	0.92	1.26	0.11	109.13
24	3.53	0.76	0.99	0.75	0.18	23.42
25	2.88	0.56	0.93	0.63	0.31	19.11
26	46.03	1.26	0.87	1.68	0.03	105.22
27	25.40	1.19	0.97	1.35	0.03	108.42
28	16.58	0.90	0.95	1.06	0.14	109.95
29	67.78	0.71	0.91	0.64	0.22	112.58
30	66.17	0.63	0.90	0.57	0.27	108.78
31	20.21	0.76	0.97	0.66	0.18	104.04
32	10.25	0.87	0.96	0.98	0.14	54.54
33	18.72	0.82	0.97	0.90	0.16	78.89
34	18.77	0.58	0.96	0.55	0.28	78.69
35	18.93	0.69	0.99	0.53	0.21	105.52

Table 21: Status of diversity indices of Understorey

Site No	Diversity Index ($\bar{H}$)	Evenness (e)	sp.richness (d_2)	Index of dominance (c)
1	1.21	0.93	0.75	0.08
2	1.18	0.94	0.78	0.07
3	0.95	0.95	0.75	0.12
4	0.74	0.96	0.62	0.19
5	1.32	0.95	1.16	0.05
6	1.27	1.01	0.88	0.07
7	0.88	0.97	0.53	0.14
8	0.61	0.89	0.37	0.96
9	0.54	0.90	0.35	0.97
10	0.40	0.57	0.34	0.97
11	0.49	0.71	0.48	0.98
12	0.50	0.83	0.36	1.00
13	0.40	0.84	0.34	0.002
14	0.72	0.94	0.47	0.21
15	0.72	0.94	0.47	0.21

4.2. Land use Classification:

In the present day world, Land Use mapping is of great significance in scientific, scholarly research, planning and management management (**Sarojini Devi et al., 2013; Rajesh, 2014; Sathya et al., 2014**). Land use relates to the human activity or economic function associated with a specific piece of land (**Lillesand et al. 2004**). Examples of land use include agriculture, urban development, grazing, logging, and mining. In contrast, land cover relates to the composition and characteristics of land surface elements **(Cihlar 2000**). Land cover change is one of the most important variables of environmental change and represents the largest threat to ecological systems (**Foody 2003**). Now, landuse has become a central component in current strategies for managing natural resources and monitoring environmental changes (**Brandon 1998; Tiwari and Khanduri, 2011; Mmom and Fred-Nwagwu, 2013**). Time series analysis of land use/cover (LU/LC) change and the identification of the driving forces responsible for these changes are needed for the sustainable management of natural resources and also for projecting future LU/LC trajectories (**Giri et al. 2003; Kilic et al., 2006**).

In an effort to have a sustainable future it is important to know the impact of the developmental activities on the environment which will help in long term planning. As a result of rapid urbanization and development, the natural areas are being fragmented and have reduced important species of the ecosystem (**Marzluff and Ewing, 2001; Mckinney, 2002**). This loss of the species has also aggravated due to the negligence towards sustainable conservation efforts. The future patterns of land use must be understood at a series of spatial and temporal scales to distinguish and predict the behavior and impacts of local land use as well as other environmental and social systems. The lack of such data at different scales has made it difficult to accurately plan the current land use land cover pattern with in the country.

At this point, remotely sensed satellite images provide a synoptic overview of the whole area in a very short time span (**Singh and Dubey, 2012; Khadri et al., 2014**). This leads to quick and truthful representation of the real world in the best possible manner (**Bandyopadhyay et al., 2014**). The land use classification was performed using images of different years and resolution for understanding the landuse changes occurring in the Pavagadh forest area.

4.2.1. Land use classes derived from the Image of LISS-IV of year 2007:

The result of supervised classification for the LISS-IV image of the year 2007 showed different land use classes, namely, Built up/settlement, Waterbodies, Agriculture, Wasteland, Scrub and forest (**Plate 27**). The Kappa statistics generated for this image showed 87% accuracy. It was distinct from the classified output that forest occupied equal proportion of land along with wasteland. i.e. 121.55 and 113.56 sq km respectively. Scrub constituting 21% of the total area whereas builtup, agriculture and waterbodies occupied 90.41 sq km, 60.61 sq km & 15.23 sq km respectively **(Figure 9)**.

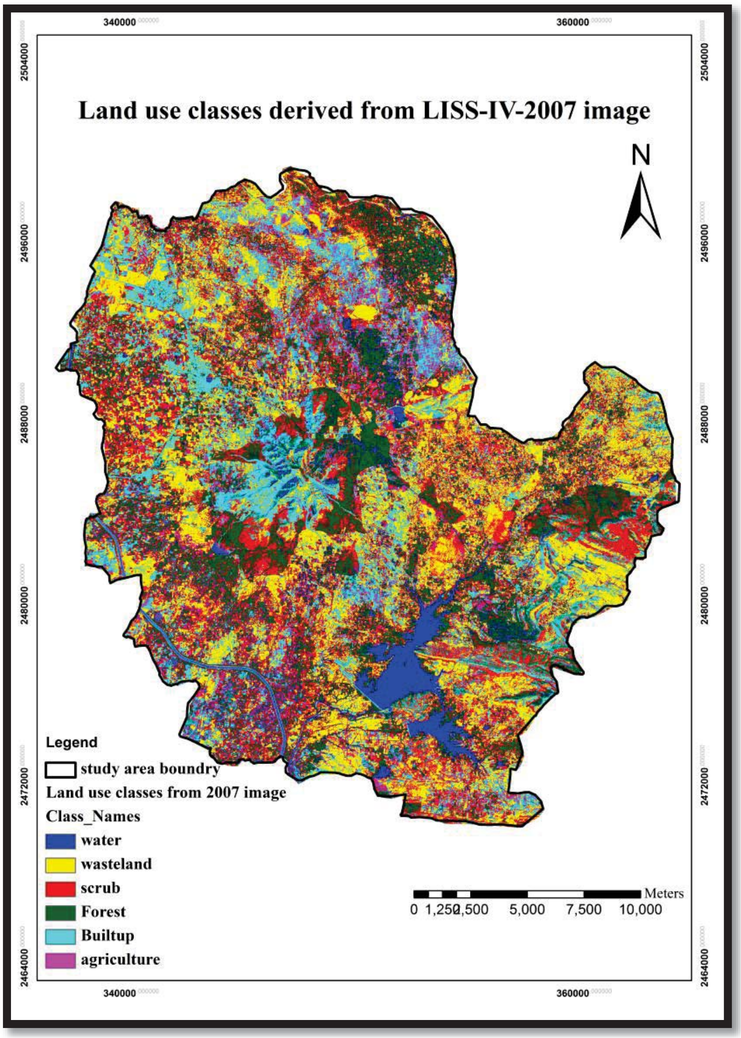


Plate 27. Supervised Classification of the Image LISS-IV-2007

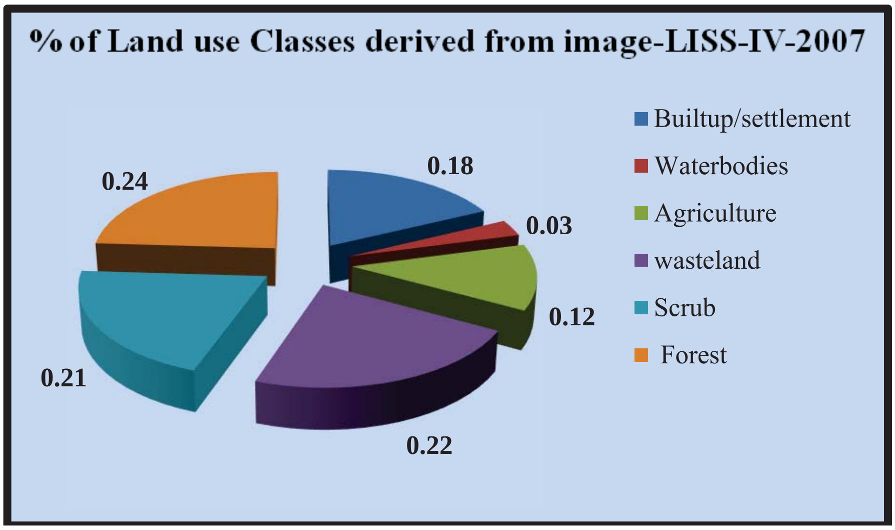


Figure 9. % of Land use classes from Image – LISS-IV-2007

4.2.2. Land use classes derived from the Image of LISS-IV of year 2012:

The supervised classification of the LISS-IV image of year 2012 highlights the overall scenario of all land use classes (**Plate 28**). This generated output showed 92% accuracy. The builtup occupied the majority land area by 112.84 sq km, whereas minimum land area was recorded for the waterbodies which is only 13.72 sq km. The area in percentage occupied by each class is shown in **Figure 10.**

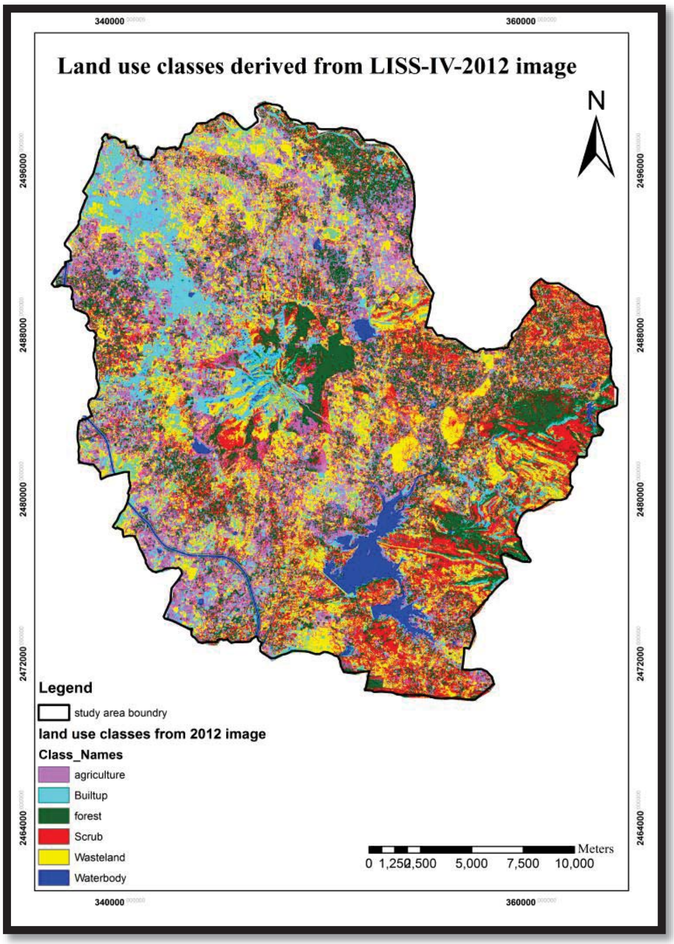


Plate 28. Land use Map for year 2012 derived from LISS IV

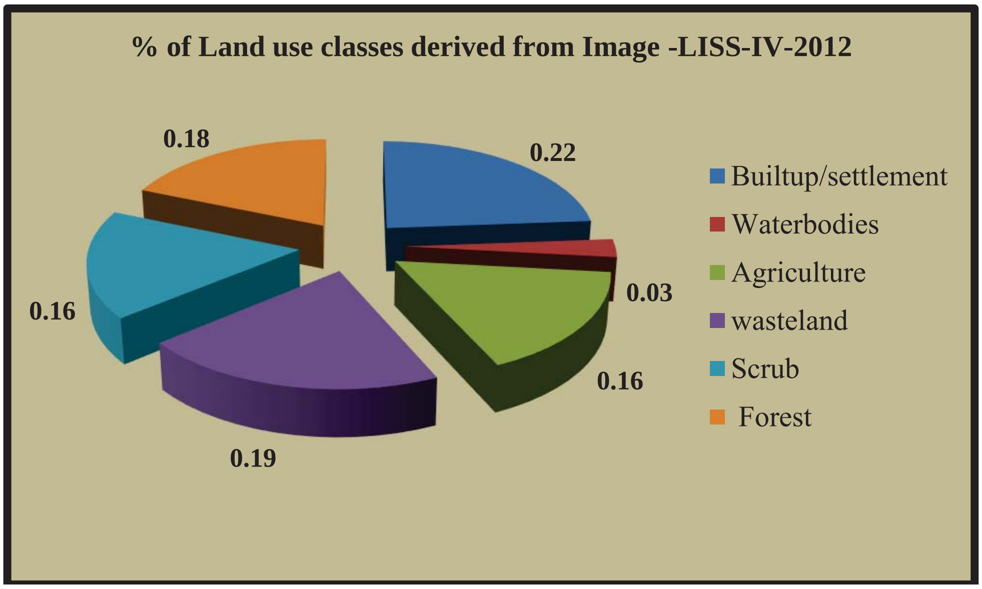


Figure 10. Percentage of Land use classes from Image –LISS-IV-2012

4.2.3. Change detection map:

Areas of classified changes related to land use was done by GIS overlay analysis. This process intersects change classes and thus quantifying the amount of change for land use in the study area. **Table 22** summarizes sq km and percent of classified change for each landuse type. Comparison of classified images of the year 2007 & 2012 has highlighted the areas which have a distinct change **(Plate 29).** Among all the land use classes, there is a decrease in forest, scrub and wasteland whereas the classes like built-up and agriculture show increase in area and the water bodies indicates very negligible change. The maximum change was observed in case of forest area. This decrease was of about 33.08 sq km area from 2007 to 2012 with a per year change of 6.616 sq km was found.

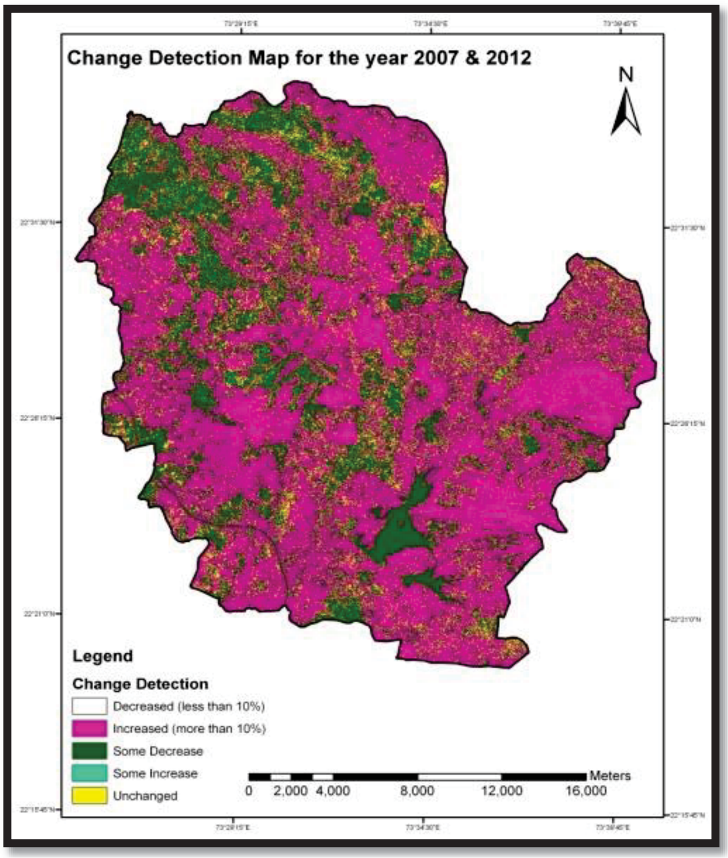


Plate 29. Change Detection Map for the year 2007 and 2012

There was a decrease of 21.57 sq km area in scrub, 15.06 sq km in wasteland and 1.51 sq km in waterbodies from 2007 to 2012. On the other hand, area of land use classes like built up and agriculture have been increased by 4% during the year 2012 which constituted 4.486 and 3.546 sq km respectively.

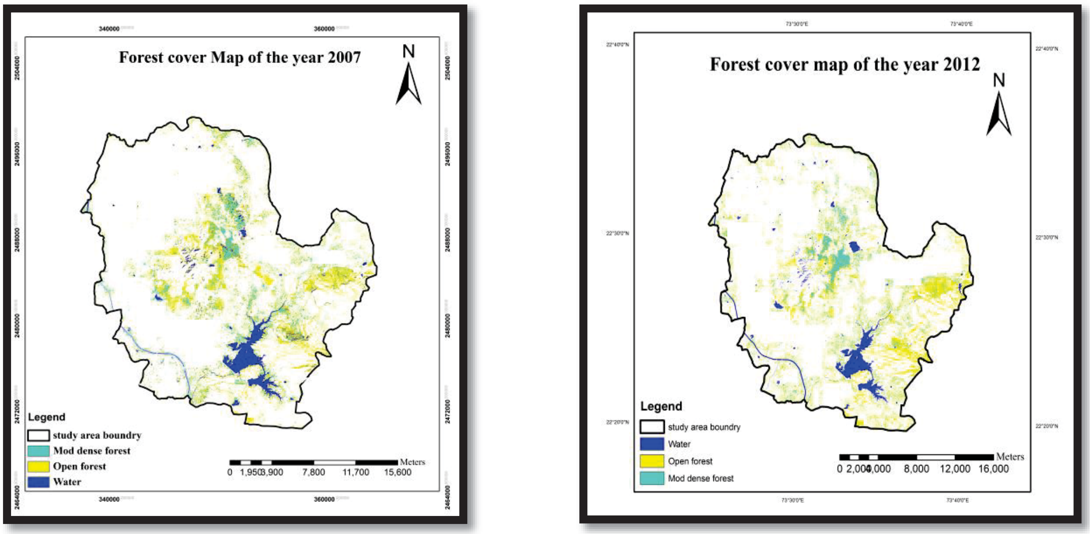
Table 22.Area change in each land use classes

Sr. No.	Class Name	Change in sq km	% Change	Loss/Gain per year(sq km)
1	Builtup/ settlement	+22.43	+4	+4.486
2	Waterbodies	-1.51	---	-0.302
3	Agriculture	+17.73	+4	+3.546
4	Wasteland	-15.06	-3	-3.012
5	Scrub	-21.57	-5	-4.314
6	Forest	-33.08	-6	-6.616

The supervised classification of the LISS-IV image of year 2012 revealed the drastic change in all land use classes. As compared to the previous years, the supervised classification of LISS-IV image of the year 2012 showed there is an increase in built up land and agriculture by 17.35 and 9.94 sq km respectively whereas land use classes like water body, wasteland, Scrub and forest show reduction by 2.01,3.98,19.05& 33.62 sq.km respectively in their areas.

4.2.4. Forest density classification:

Results of forest density analysis for year 2007 and 2012 are shown in **Plate 30(a) and 30(b)** respectively. The forest cover density assessment of 2007 showed that 35.65 sq km of the area was under moderately dense category and 85.90 sq km under open category**.** Forest cover density assessment of 2012 estimated 31.36 sq km of the area was under moderately dense category and 88.47 sq km under open category (**Table 23)**.



[a] **[b]**

Plate 30. Forest cover map for year 2007 and 2012

Table 23. Forest Cover Density of Pavagadh Forest

Sr. No.	**Forest Cover**	**Area (sq km) 2007**	**Area (sq km) 2012**	**Change in Area (+/-sq km) since 2007**	**% Change**	**Loss/Gain per year (sq km)**
1	Moderately Dense forest	35.65	31.36	-4.29	-1%	-0.858
2	Open Forest	85.90	88.47	+2.57	+1%	+0.514
	Total Forest Area	**121.55**	**119.83**	**-1.72**		**-0.344**

Forest cover analysis done for the year 2007 and 2012 highlighted significant loss of 1.72 sq. km in the total forest area since the year 2007. Conversion of approx. 4.29 sq km of moderately dense forest area to open forest area has been also been observed during span of these 5 years. Increase in open forest was also observed as 2.57 sq km area of wasteland, 15.06 sq km area of scrub and 21.57 sq km got converted to open forest. The reason for these changes could be the legal land policy issues between the Forest department officials and Revenue department under which the Forest department had to land the forest land to the revenue department. Moreover, other anthropogenic activities & tourism pressure exerted a tremendous pressure due to which this change has occurred.

4.3. Identification of Ecologically Sensitive Area:

ESA are fragile and vulnerable to damage by human activities and hence require special protection. Identification of ESA is not an easy exercise though efforts are made for demarcating such areas with certain prioritization criteria. However, this task should be initiated with consideration of those areas that are identified as either ecologically important or under ecological stress **(Sudhakar et al., 2006).** Results generated for the identification of ESA included the different steps already described in the methodology as given below.

1) **Generation of Suitability Model:**

The generation of ESA was mainly based on the process of designing an optimal mix of different land use based on their suitability class. It was also significant to understand the existing and future potential landuse of these areas for developing these areas sustainably. The utility of RS–GIS with a modelling approach was mainly to integrate spatially complex and different land attributes. The present study has made use of the output of land use/ land cover classification along with all the significant factors related to it in the form of thematic maps and thus retained their present spatial location during the process of suitability analysis. The use of GIS mode was specifically done to assign values to alternatives that are evaluated along Multi Criteria Decision Analysis (MCDA) (**Mendoza and Martins, 2006; Nyeko, 2012; Alanbari et al., 2014**) which are detrimental to land suitability analysis for different land use types. Accordingly the land suitability was categorized as highly suitable (S1), moderately suitable (S2) and marginally suitable (S3) and the Not suitable land designated as N1 & N2 **(Plate 31**). Evaluation of various alternative land use types using various criteria related to the utilization of these lands was carried out. The coverages of each suitability classes under the present study was calculated in a GIS platform and the findings are as given in **Table. 24**.

The suitable areas delineated were falling under various categories of land use viz. agriculture, wasteland, scrub and forest. The current analysis revealed that, approx. 45% of the area is suitable with 15.30 sq km, 99.45 sq km & 31.30 sq km under highly suitable, moderately suitable & marginally suitable categories. The rest 55% of the study area was falling under not suitable category. Out of Not Suitable category approx. 96.54 sq.km area was taken up by N1 category indicating that if proper planning is done, this area can be utilized further for the forest development.

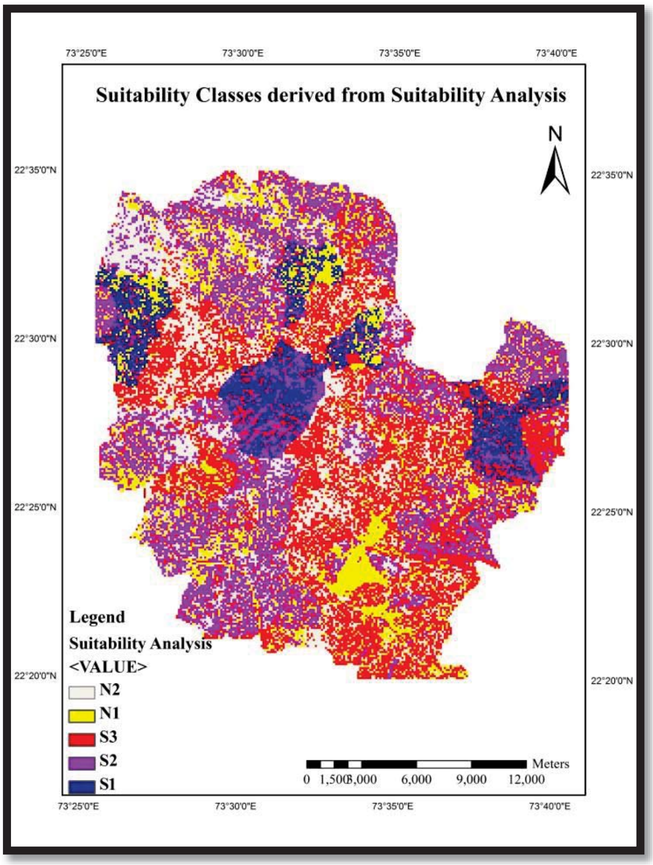


Plate 31. Suitability map of the Pavagadh area

Table 24. Areas under different suitability categories

Sr. No.	**Suitability category**	**Suitability category**	**Area (sq km.)**	**Area (ha)**	**% of area**
1	Not Suitable (N)	(N2) Least	80.86	26266.92	52.0
		(N1) Less	96.5338	9653.38	19.1
2	Suitable (S)	Marginally Suitable (S3)	31.3027	3130.27	6.2
		Moderately (S2)	99.4499	9944.99	19.7
		Highly Suitable (S1)	15.2944	1529.44	3.0
		Total		**50525**	

2) Identification of ESA

Ecologically sensitive areas were identified from each suitability category based on existing land use types (**Plate 32**). At this point, considering the ESA definition, out of the different land use categories forest was considered to be the most sensitive as it is facing a great threat from the anthropogenic activities.

It was observed that forest cover loss in this area has not only diminished the prospects of rural in this area but also have limited the scope of biodiversity and genetic conservation. It was therefore essential that areas should be identified which were specifically in the forest area along with the other land use categories where restoration attempts can be made. Serious efforts in this direction will definitely aid to reach that land to any one stage of ecological integrity (**Anon., 2000**). **Table 25** clearly brings out the conversion of land use in different ESAs over a span of **5** years.

Table 25. Land use status of ESA sites in the year 2007 and 2012

	(S1)		(S2)		(S3)		(N1)		(N2)	
	2007 land use	**2012 land use**	**2007 land use**	**2012 land use**	**2007 land use**	**2012 land use**	**2007 land use**	**2012 land use**	**2007 land use**	**2012 land use**
1	agriculture	open forest+ scrub	open forest+ scrub	agriculture	mod dense+ open forest	agriculture	wasteland+ agriculture	wasteland+ builtup	wasteland+ scrub	builtup
2	agriculture	open forest + scrub	open forest	agriculture+ wasteland+ scrub	scrub+ agriculture+ wasteland	agriculture	wasteland+ agriculture	wasteland+ builtup	wasteland	wasteland
3	agriculture+ wasteland	wasteland	water	agriculture	scrub+ wasteland	wasteland +agriculture	wasteland	wasteland+ agriculture	builtup	builtup
4	agriculture+ wasteland	agriculture	agriculture	agriculture	open forest+ scrub	agriculture+ open forest	wasteland	wasteland+	wasteland	wasteland
5	wasteland	agriculture	agriculture	scrub	open forest	open forest	wasteland	wasteland	builtup+ agriculture	wasteland+ agriculture
6	wasteland+ agriculture	agriculture +wasteland	open+mod dense forest	agriculture+ wasteland	open forest+scrub	open forest	wasteland+ agriculture	wasteland	mod dense forest+ open forest	mod dense forest
7	wasteland+ agriculture	agriculture	built up+ agriculture	agriculture	agriculture+ open forest	wasteland+ open forest	wasteland+ agriculture	wasteland+ agriculture	wasteland+ builtup	wasteland+ agriculture
8	open forest	open forest	open forest	scrub+ mode dense forest	scrub+ open forest	scrub+ open forest	wasteland+ agriculture	wasteland+ agriculture	wasteland+ agriculture	wasteland
9	open forest +agriculture	open forest +scrub	scrub+ open forest	scrub+ wasteland	scrub+mod dense	agriculture+ open forest	wasteland+ agriculture	wasteland	agriculture	agriculture
10	mod dense+ open forest	agriculture +wasteland	Open forest +srcub + wasteland	mod dense forest	open forest+ scrub	open forest+ agriculture	wasteland	wasteland+ agriculture	wasteland+ agriculture	wasteland+ agriculture+ scrub
11	scrub+ open forest	wasteland+ agriculture	scrub+ built up	scrub+ open forest	scrub+ agriculture	wasteland+ agriculture	scrub	scrub+ wasteland	wasteland+ agriculture	builtup+ agriculture
12	scrub+ wasteland	wasteland+ agriculture	agriculture+w asteland	scrub	wasteland+ scrub	wasteland+ scrub	agriculture+ wasteland	wasteland+m od dense forest	wasteland+ agriculture	wasteland+ agriculture
13	wasteland + mod dense forest	agriculture	scrub+wastel and	wasteland+ scrub	open forest +scrub	open forest+ agriculture	scrub	scrub+ open forest	wasteland	builtup+ scrub

Sensitivity status of 13 sites selected under each suitability categories is clearly depicted from **Figure 11.** Indicates that out of 65 selected sites, the majority sites were showing Less sensitive areas, whereas highly sensitive areas have been represented by only 19 sites. Total 21 sites were falling under the moderately sensitive areas. The reason for their identification was the severe degradation and fragmentation of environmentally, economically, and aesthetically important landscape.

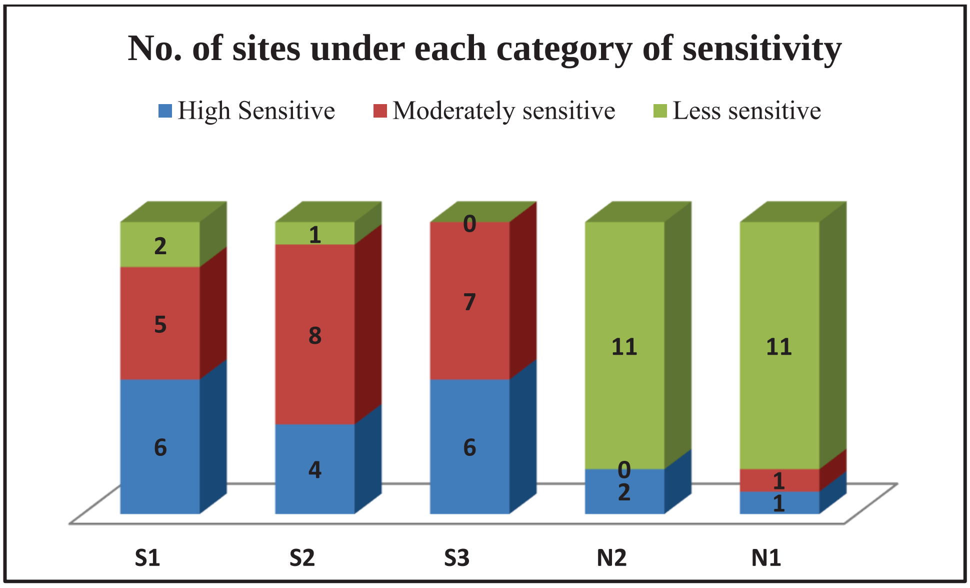


Figure 11. Number of sites under different sensitivity categories

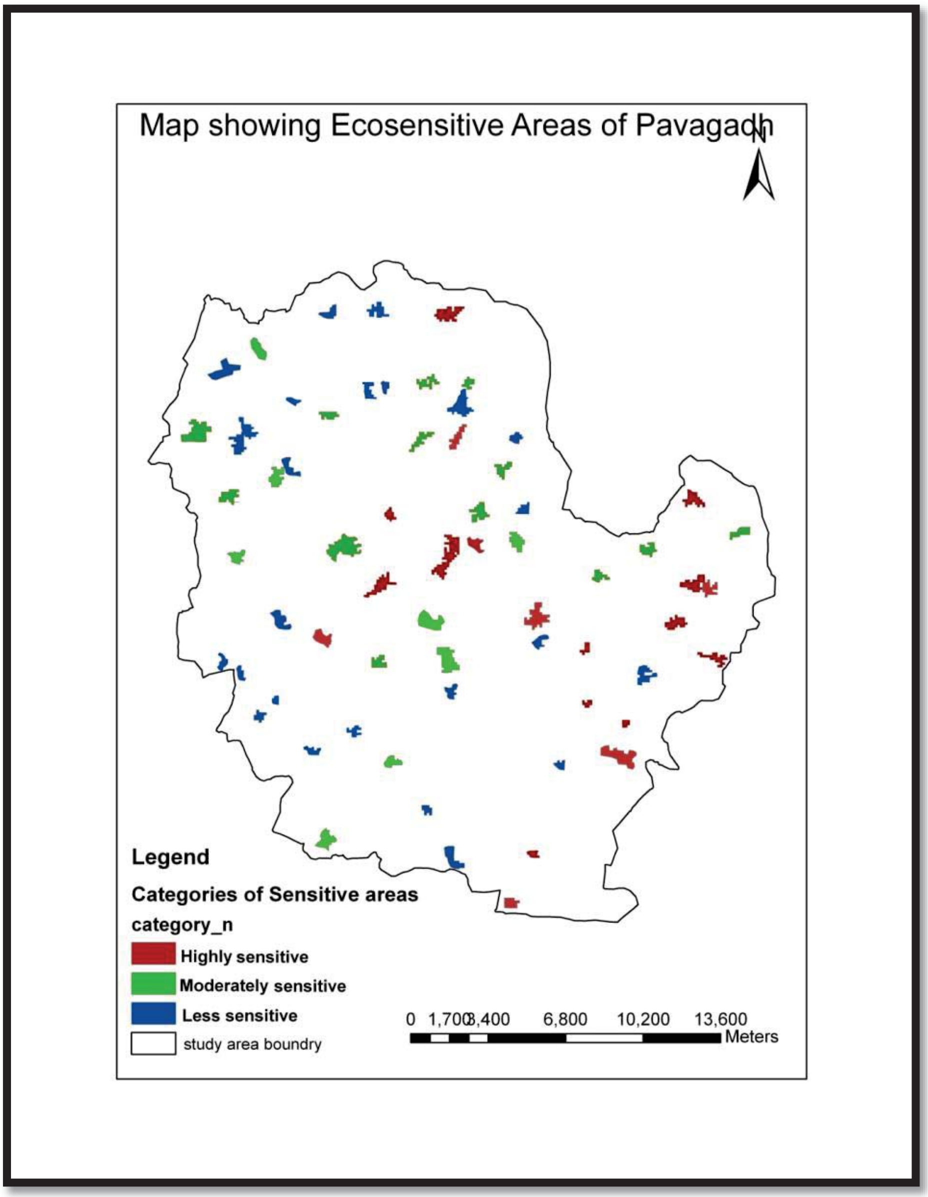
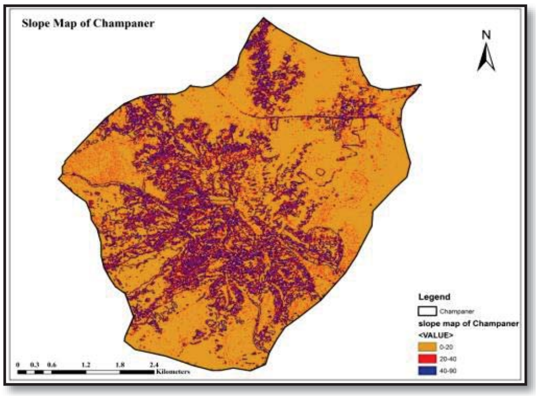
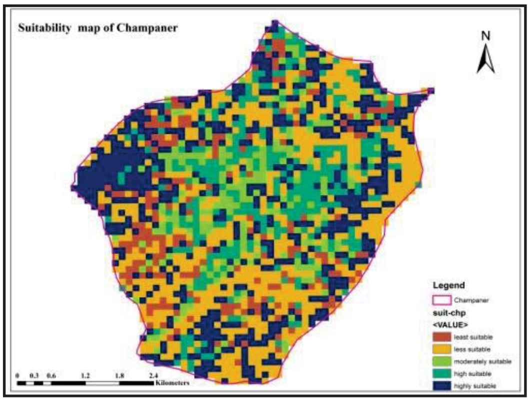


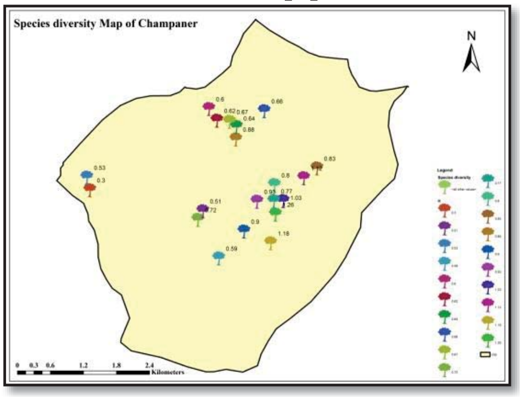
Plate 32. ESA map of the study area

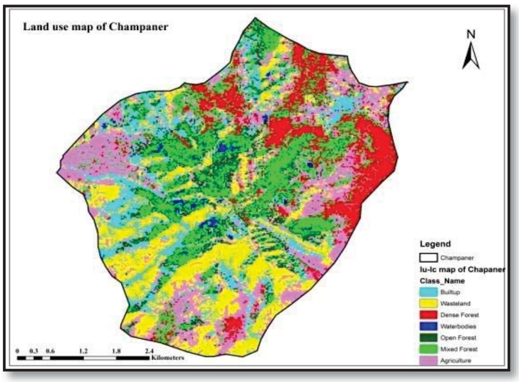
Understanding these areas what proper strategies can be designed for them and what are the prospects available for their sustainability, factors related sustainability of each area were required to be identified. Thus, to check sustainability few more criteria were needed to be integrated in the existing model of suitability requiring a voluminous data difficult to be procured easily. At this point a sample village from this area named Champaner was selected as pilot village for generating ESD. The ESA of this village falling under different landuse themes were integrated with the essential criteria and indicators formulated under Bhopal- India Process along with few other criteria which were thought to be relevant as already shown in methodology.



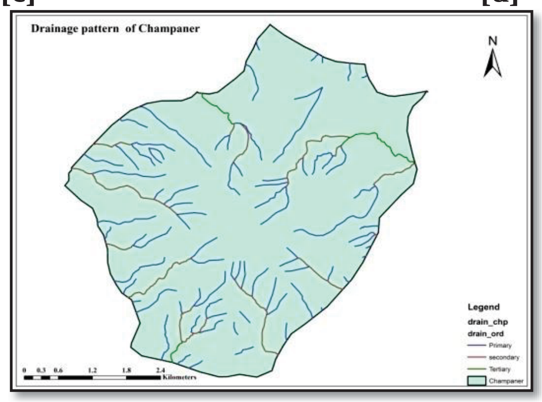


[a] [b]





[c] [d]



[e]

Plate 33. Considered criteria for identification of sustainable development sites

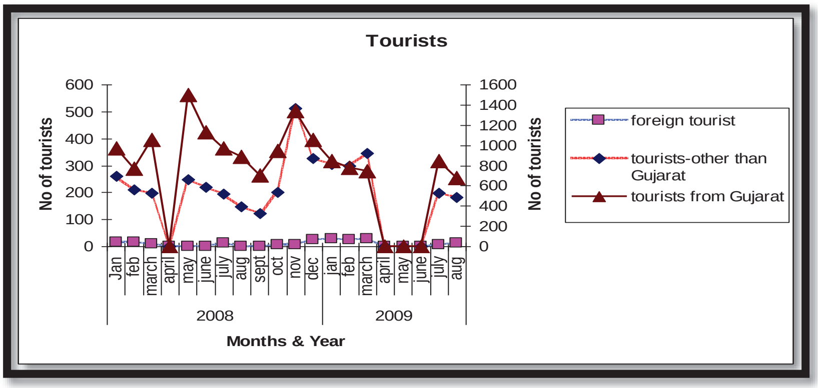


Figure 12. No. of tourists visited during 2008-09

Based on this, the ESD plan for this village was generated (**Plate 34).**

4.4. Ecologically sustainable development plan of Champaner village:

Total geographical area of the village Champaner is approx. 22.44 sq km with the population of 3249. Per capita forest area of Champaner is 0.609 with the basal area of about 32.021 m^2/ha. Along with 5 main, many small and perennial waterbodies sufficed the need of water for the population therein. Soil is moderately fertile with 0.06% - 0.468% of organic carbon. This village has been devoid of any JFM committee. Total 4 areas of ESA were falling under this village, out of which three belonged to highly sensitive areas and only one site represented moderately sensitive area. **Plate 33 and Figure 12** shows the spatial distribution for 13 sq km of the Champaner area by considering different criteria for the sustainability as described in the methodology. Based on this, the distribution of land area under each category of sustainability is shown in the **Table 26** which classified approx 5.6 sq km area as Sustainable and Moderately sustainable Zones; whereas only 1.6 sq.km area identified as less Sustainable Zones. Total nineteen areas were thus identified and designated as Plots, out of which five were sustainable, eight were moderately sustainable, while rest six were categorized as less sustainable areas. The change in land use status of each Plot with their respective sustainability status is described in the **Table 27.**

Table 26. Identified areas under different categories of sustainable development

Sr.No.	Category	Area (sq km)
1	Sustainable	5.638
2	Moderately sustainable	5.65
3	Less Sustainable	1.594
	Total	**12.882**

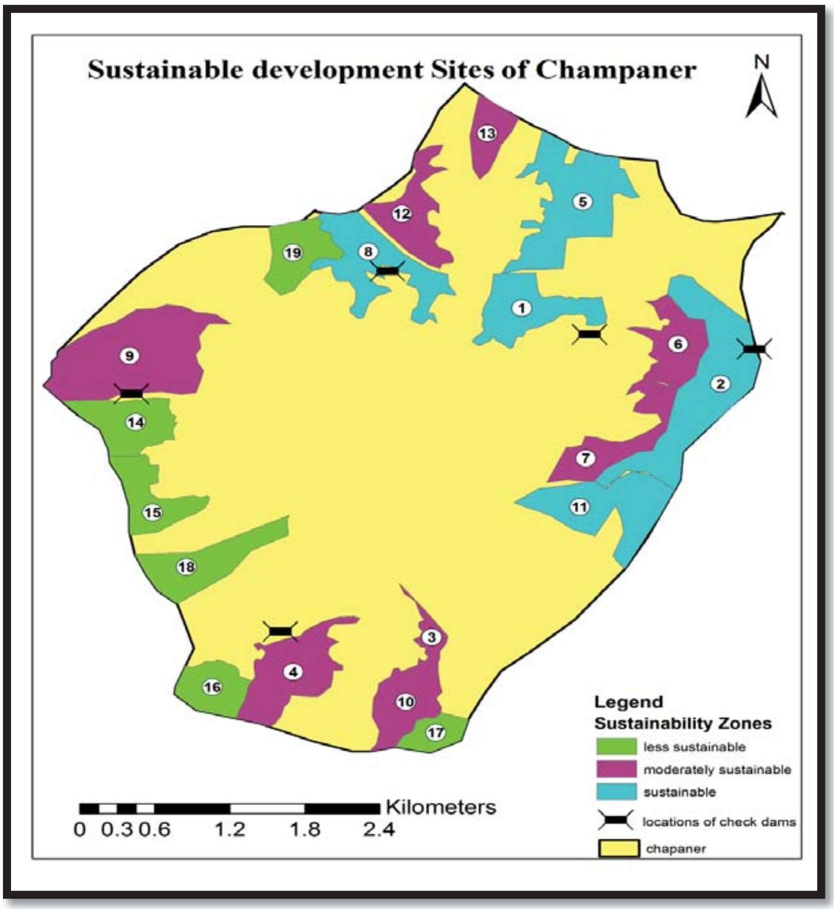


Plate 34. Map showing identified areas with their sustainability status

Table: 27 Land use change of each plot with their sustainability status:

Plot No.	2007 land use	2012 land use	Sustainable category	Change (+/-)
1	Open forest & scrub	Moderately dense forest	Sustainable	+
2	Open forest & Moderately dense forest	Moderately dense forest	Sustainable	+
3	Scrub	Open forest, scrub & agriculture	Moderately sustainable	+
4	Open forest, scrub & Moderately dense forest	Open forest, scrub & wasteland	Moderately sustainable	-
5	Open forest & Moderately dense forest	Moderately dense & open forest	Sustainable	No change
6	Open forest & scrub	Open forest & Moderately dense forest	Moderately sustainable	+
7	Open forest & scrub	Open forest, scrub & Moderately dense forest	Moderately sustainable	+
8	Scrub, Open forest & agriculture	Moderately dense & open forest, scrub	Sustainable	+
9	Scrub, Open forest & agriculture	Open forest, Scrub, & agriculture	Moderately sustainable	+
10	Open forest & Scrub	Open forest, Scrub, & agriculture	Moderately sustainable	-
11	Scrub, Open forest & agriculture	Open forest, Scrub, & agriculture	Sustainable	+
12	Open forest, Moderately dense forest,& scrub	Open forest, Moderately dense forest,& scrub	Moderately sustainable	No change
13	Open forest, scrub	Moderately dense forest, Open forest & scrub	Moderately sustainable	+
14	Wasteland & Open forest	Wasteland, Open forest, scrub & agriculture	Less sustainable	-
15	wasteland & agriculture	Wasteland, agriculture & open forest	Less sustainable	-
16	Scrub & wasteland	Wasteland, scrub & open forest	Less sustainable	+
17	Wasteland & scrub	Wasteland, & scrub	Less sustainable	No change
18	Builtup, wasteland & agriculture	Wasteland, & scrub	Less sustainable	+
19	Scrub & open forest	Wasteland, Open forest, & scrub	Less sustainable	-

It can be seen that each plot has a positive change with respect to the land use category. This could be attributed to the restoration activities carried out by the forest department. Reasoning and description of different plots for their sustainability has been given in the following paragraph.

Sustainable zones: This zone is represented by plot no. 1,2,5,8 and 11 showed higher values for phytodiversity, biomass and basal areas. These areas are having low amount of organic carbon and are in the vicinity of the roads. These areas can be permitted to be utilized for the fuel wood and NTFP purpose of the stack holders with certain limitations. Further, ecotourism activities can be promoted in these areas.

Moderately Sustainable zones: Out of total 19 plots, majority plots have depicted this category and they have been labelled as Plot no. 3,4,6,7,9,10, 12 and 13. These are the areas with moderate species diversity, not easily accessible & having a moderate slope. They require highest attention in terms of forest conservation. At the same time they cannot be exploited for fuel wood and other NTFPs but can be developed for adventurous activities like paragliding, eco- trail, rock-climbing, bird watching etc.

Less Sustainable zones are represented by the Plot no 14, 15, 16, 17, 18 and 19. & Areas under agriculture, wasteland and scrub land were considered for this category. These areas can be served as potential areas as far as the forest resource development is concerned. Within these areas some can be developed as a recreational area. These areas require moderate attention in terms of conservation.

Table 28. Proposed Activity Planning for all Identified sites regarding ESD

No of Plots	Sustainability Category	Current Situation	Proposed Activity
1.	Sustainable	Moderately dense forest;Close vicinity of road & water body	Promotion of Ecotourism activities, restoration of soil required, Ideal for check dem construction
2	Sustainable	Moderately dense forest;Close vicinity of road	Require Restoration activities, collection of NTFP can be allowed. Ideal for check dem construction
3	Moderately sustainable	south facing slope, Previosly under forest, Observed Enchrochment	Ideal site for Afforestation

4	Moderately sustainable	Previosly under forest, Enchrochment started	Afforestation, collection of NTFP should be strictly restricted
5	Sustainable	Heritage Forest, Popular tourist place, Facing high tourist pressure	Can be Model forest site for further development, only Eco friendly activities can be allowed to tourists
6	Moderately sustainable	Young Forest Plantation Stand, Absence of herbaceous species	Restoration activities, growth of Understorey should be promoted
7	Moderately sustainable	Open forest, Previosly under forest, Observed Enchrochment	Participatory forest development like JFM can be promoted
8	Sustainable	mod dense forest, not frequently visited by tourists, Presence of Historical monument	Require High prioritization of conservation, development of Ecotourism activities like Rock climbing, Check dem should be constructed. Ideal for check dem construction
9	Moderately sustainable	Open forest area adjacent to village, yet not enchroached	Restoration Activity at priority basis
10	Moderately sustainable	degraded forest with scrub, adjacent to village, yet not enchroachment observed	Ideal place for Afforestation
11	Sustainable	Scrub, adjacent to village, observed enchroachment	can be saved for further development through afforestation activities or can be developed as a preservation plot etc.
12	Moderately sustainable	Forest with moderate diversity, easily approachable, close to Historical monument, moderate tourist pressure	Moderate tourist activities can be allowed
13	Moderately sustainable	very small forest area with scrub, adjacent to state highway	It can be saved from further transformstion into less sustainable through afforestation. Strict prohibition on the entry into this area to save further deforestation.
14	Less sustainable	Previously under forest as an open scrub, currently under agriculture	It should be retained as agriculture land but measures should be taken to prevent its further expansion.
15	Less sustainable	currently under agriculture	It should be retained as agriculture land but measures should be taken to prevent its further expansion.
16	Less sustainable	currently under agriculture	Agro-forestry can be planned Plantation of sp. O f Dalbergia, Melia, Casurina etc. can be adviced.
17	Less sustainable	currently under degraded land, gentle slope	Afforestation of fodder cum fuelwood species is (Leucaenea, Sesbania, Acacia, Albizia etc.) required,
18	Less sustainable	currently under agriculture, enchroachment, slope of the hill	Plantation of species to prevent soil erosion
19	Less sustainable	currently under open forest; enchroachment	required high conservation on priority basis, chances to be converted into non forest area.

Sustainable land management is basically “the adoption of land use systems that, through appropriate management practices, enables land users to maximize the economic and social benefits from the land while maintaining or enhancing the ecological support functions of the land resources". It is crucial in minimizing land degradation, rehabilitating degraded areas and ensuring the optimal use of land resources for the benefit of present and future generations. The Plan generated for Champaner has been designed in such a manner that it fulfills the above requirements. Moreover it should also be based on four common principles of sustainability as given below:

- Land-user-driven and participatory approaches
- Integrated use of natural resources at ecosystem and farming systems levels
- Multilevel and multistakeholder involvement; and
- Targeted policy and institutional support, including development of incentive mechanisms for SLM adoption and income generation at the local level

The areas therefore identified based on their sustainability should be managed accordingly. **Table 28** gives a precise plan in terms of the changes required in different plots to escalate them to a higher level of sustainability if they are at a lower level or maintain the higher level of sustainability for the posterity.

Its application requires collaboration and partnership at all levels – land users, technical experts and policy-makers – to ensure that the causes of the degradation and corrective measures are properly identified, and that the policy and regulatory environment enables the adoption of the most appropriate management measures but bringing out the above change.

ESD plan is considered an imperative for sustainable development and plays a key role in harmonizing the complementary, yet historically conflicting goals of production and environment. Thus one of the most important aspects of ESD is this critical merger of specific resource and environment through twin objectives:

i) Maintaining long term productivity of the ecosystem functions (land, water, biodiversity)

ii) Increasing productivity (quality, quantity and diversity) of goods and services, and particularly safe and healthy food.

iii) To operationalize the sustained combination of these twin ESD plan , it is impertative to understand drivers and causes of forest degradation and to take into account issues of current and emerging risks.

ESD plans are based on a holistic approach to achieve productive and healthy ecosystems by integrating social, economic, physical and biological needs and values. As it contributes to sustainable and rural development it should be given greater attention both at national and community level programmes.