Chapter 1
Introduction

...man is a bundle of relations, a knot of roots, whose flower and fruitage is the world..."

1.0 Sustainable development:

Forest has always been a necessary resource to the human civilization because it is directly related to the growth and development of the society. It plays a dominant role in moulding and shaping the life of the citizens. It is comprised of diverse complexes of soil, water, air and associated plant and animal life, i.e. biodiversity, involving the total ecosystem. Our forests are the product of thousands of years of evolution and adaptation to change. Being one of the most diverse natural ecosystems, forest and the life they support have an intrinsic value. Our future depends on the preservation and improvement of this natural resource (**Husain, 2003**).

Forests are lost at an unprecedented rate despite of all the above fact. This, in turn, is seriously eroding the capacity of our planet to sustain life on earth. The year 2011 was declared the International Year of Forests by the United Nations to raise awareness and strengthen sustainable management, conservation and development of all types of forests for the benefit of current and future generations. Over the last two decades of the 20th century, rapid deforestation has taken its toll. Approximately, 15 million hectares of forests are lost annually, largely in the tropics. It is also clear that the structural integrity of much of the forest cover that remains has deteriorated and the negative impacts of deforestation are getting noticed internationally. Being the heritage of our children, forest must be managed for the future. As trustees we have to assemble present needs without compromising on the future generation's ability to meet their needs. Being concerned with the deteriorating situation of forests, the world communities have joined their hands to find out a solution by deliberating on the subject in various conventions like Rio-de Janeiro and the latest Doha round of talks. These communities have realized that the management of this resource becomes complicated

since needs of the people exceed over their demands. This situation has lead to that point where sustainable resource management is a prerequisite. Sustainable use of any resource requires to be bound by nature's laws and at the same time adhere to carrying capacity levels of that habitat. This can happen only by following the saying of the Great Indian leader Mahatma Gandhiji saying that "the resource should be used for sufficing the needs and not the greed". At the same time this greed has raised a few challenges related to forests against the world communities, which need to be addressed like,

1) How to meet the future demand for wood and non-wood products without degrading the forest resource base?

2) How to protect forest environment with anticipated increase in world population?

3) How to maintain forest resources with different forest types worldwide?

Answering these questions requires implementation of rapid and urgent actions related to forests and their issues.

1.1. Radical and Urgent Actions addressing forest

The first global policy on Sustainable Forest Management (SFM) after the Rio Summit in 1992 was one such radical step towards the sustainable management. This policy was designed to understand this resource completely or holistically and SFM was a goal for international and national policy makers. As such there was no specific way in which this sustainability could be assessed as it was very vague and complex concept. But this concept added to the clarity as it encompassed three dimensions of welfare, i.e. economic, social & environment involving a number of complex synergies and tradeoffs between them. To manage forest resource sustainably, besides these three dimensions,

knowledge of few additional components is also essential like Forest and its associated factors like its ecology, change dynamics & its status at different level. These components are explained separately.

1.2. Forest

The word "forest" comes from Middle English and old French *forest* which means “vast expanse covered by trees". It was first introduced in English as the word for wild land set aside for hunting. The exact origin of Medieval Latin *foresta* is obscure. Some authorities claimed that the word is derived from the late Latin phrase *forestam silvam*, meaning "the outer wood"; others claimed that the term is the latinisation of the Frankish word *forhist.* In India, Forest Survey of India (FSI) defines a forest as ‘all the lands, more than one hectare in area, with a tree canopy density of more than 10%’.

1.2.1. Forest Ecology and Ecosystem

Ecology is the science that studies ecosystems and it takes into consideration five different aspects viz; a) Stucture, b) Function c) Complexity d) Interactions between ecosystem components & e) Change over time. In this context forest ecology is the study of forest ecosystems where trees and other vegetation determine the ecological character. As a science, it describes and provides an understanding of the differences between forest ecosystems in different habitat along with the changes in any one forest over time.

A forest ecosystem is one of the major ecological unit that exists as "home" for native and introduced communities of classified organisms. It is typically associated with land masses covered with trees which are classified by foresters into forest cover types. It always tend to move towards maturity or into a climax forest which is termed

as forest succession. It increases the diversity up to the point of old age where the system slowly collapses. When an ecosystem is exploited and its components begin to die naturally, then the maturity of the forest ecosystem declines.

External disturbance factors like anthropogenic activities and resource exploitation initiate continuous changes in the forest ecosystem and these changes are also determined by the internal ecosystem processes like forest succession and climax. These changes are vital for the maintenance of many aspects of biological diversity and also for the long term sustainability of the ecosystem and involve the understanding of change dynamics.

1.2.2. Forest change dynamics

Any vegetation changes if it is left to its own natural condition. This fact is also implied to the forest vegetation also which shows changes with time. In reality, the change is always occurring due to several different factors viz. reduction in growth, increase in mortality and impact of various biotic and abiotic factors like fire, wind, snow, insects which reduces the number of living trees.

Such factors also contribute to the changes in forest vegetation exhibiting dynamics over a period of time. Understanding of such dynamics also helps in unraveling the physical and biological processes underlying them.

A simplified model of forest change dynamics has been given by FAO, **(FAO, 2010)** (**Figure 1)** wherein two classes are shown: Forests and other lands. This model states that a reduction in forest area can happen through either of the two processes: i.e. deforestation and natural disasters. Deforestation is by far the most important factor and it implies that forest areas

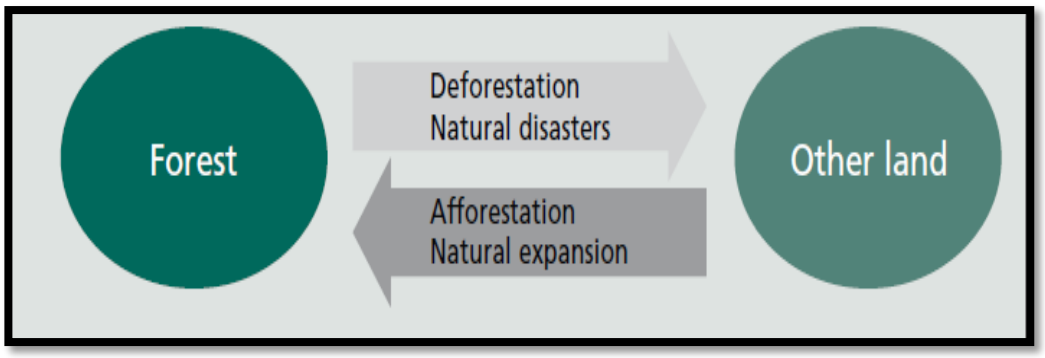

Figure 1: Forest Change Dynamics

are cleared by people and the land is converted to another use, such as agriculture or infrastructure. Natural disasters may also destroy forests, and when area is incapable of natural regeneration, and lack of replantation acivity, it too gets converted to other land. On the other hand, an increase in forest area can also happen in two ways: either through afforestation or through natural expansion of forests. In the later case a forest which is cut down, get replanted (regeneration) or grows back on its own within a relatively short period (natural regeneration) and hence there is no change in forest area. Such changes also change the land use pattern and needs proper planning.

The understanding of the forest change dynamics and its role in the land use planning and management along with the understanding of different issues and crisis related to forest at the regional, national, state and local level.

1.2.3. Forest Issues and Crisis: Regional, National, State and local level

1.2.3.1. Regional: Asia:

Asia is the world's largest continent and has a wide diversity of forest ecosystems. At the region's geographic extremes, these ecosystems include extensive boreal forests in Siberia, moist tropical forests in South-East Asia, subtropical forests in the mountains of southern Asia, and juniper forests in the Arabian Peninsula. Asia is also home to more than half of the world's human population and, as in other regions,

population growth and development has been accompanied by widespread deforestation (**FAO, 2012**). The forests of southern Asia were cleared to provide cropland to support a rapidly expanding human population. Shifting cultivation was the primary driver of forest clearing until the late eighteenth and early nineteenth centuries and during this time period nearly 40 million hectares of forest was cleared, mostly for commercial agriculture **(Williams, 2002).** According to the **FAO Report, 2010** in Asia the forest land has been covered by an area of approximately 512 million hectares. These resources are highly concentrated, within five countries – China, Indonesia, India, Myanmar and Malaysia – accounting for 81 percent of forested land. **(Plate 1)** Between 2005 and 2010, this region reportedly has increased its net forest cover by around 21 million hectares, with the growth mainly coming from countries like China and India**. (Plate 2)**

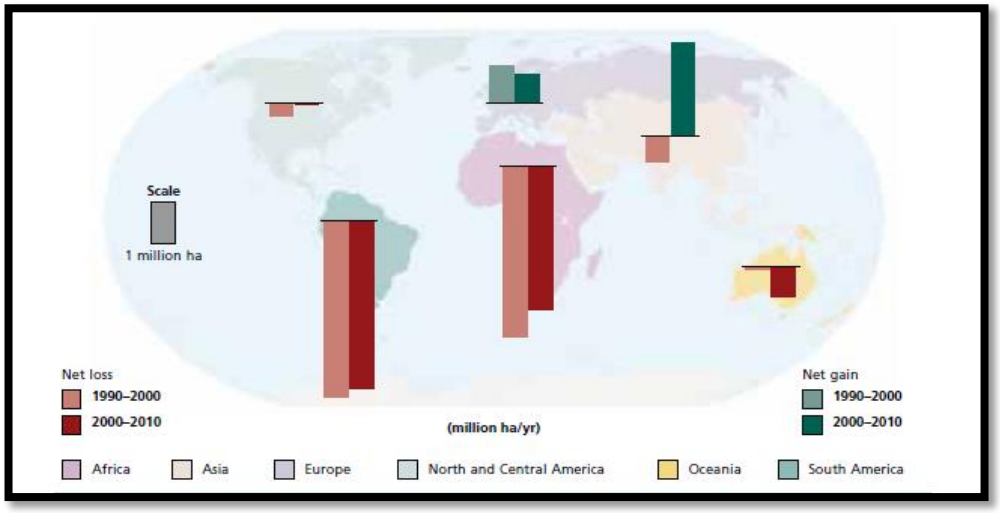

Plate 1. Annual change in forest area by region
(Source: Global forest resource assessment, 2010, pg.no-XVII)

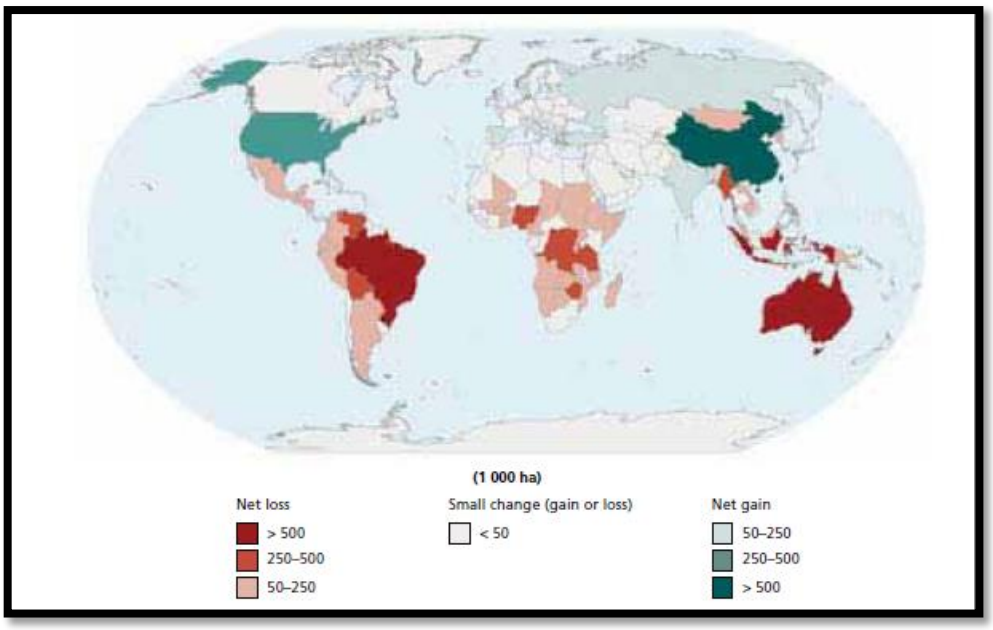

Plate 2. Annual change in forest area by country
(Source: Global forest resource assessment, 2010, pg.no-XVII)

In short, there has been mixed progress over the last 20 years at the regional level with large variations between countries and sub- regions.

1.2.3.2. National: India

India is a densely populated country with high pressure on land and forest resources. The total geographic area of the country is 32,87,240 km^2 (327.8 million ha) and the population is 1,210 million (census 2011) which gives population density of 382 persons per km^2 and 0.06 ha per capita forest. It is the 7^{th} largest country comprising 2.4 per cent of the World's geographic area, and 1.8 per cent of its forests, but supports 17.5 per cent of its population.

In the 1970s, India's annual rate of deforestation was estimated at 1.3 million hectares which was reversed with the introduction of National Forest Policy (NFP) in 1988. The NFP established a target that a minimum of one third of the country's total land area should be forested. As per the India State of Forest Report (ISFR) **(FSI,2011),** today total 23.81 percent (including 2.76% of tree cover) of land area has

been accounted for forest covering 78.29 m ha. land, while in 1990 it stood at 19 percent. Out of total tree cover (i.e. 21.85%) 2.54 %, 9.76%, 8.75%, and 1.28% is occupied by very dense, moderately dense, Open and Scrub forest cover, respectively **(Figure 2).** In terms of the forest productivity, it is very low (0.68 m3/ha/year) as compared to the world average productivity of 2.1 m3/ha/year **(Kumar et al., 2011).**

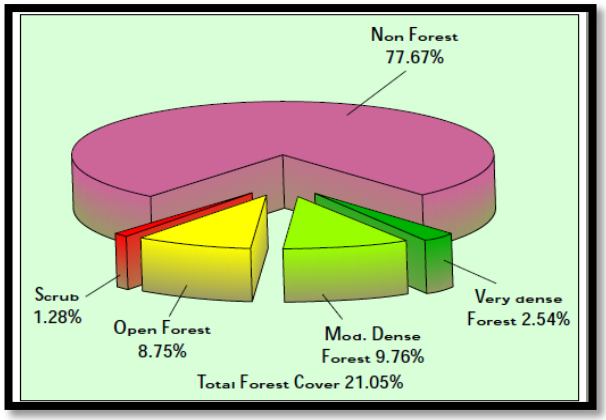

Figure 2. Forest Cover of India

(Source: State Forest Report, 2011)

1.2.3.3. State: Gujarat:

The natural vegetation of the state is restricted to areas which receive adequate rainfall and are at the same time agriculturally unproductive. Gujarat has about 14,619 km2 of land under forest which forms 7.46 % of the total geographical area. A large part of the forest cover which is economically exploitable is distributed in the districts of Dangs, Panchmahals, Bharuch, Surat, Valsad, Junagadh, Sabarkantha and Banaskantha. With increasing population, there is an increase in Reserved, Protected and unclassed forest categories since 2000-01 **(Figure 3)** but per capita availability of forest is becoming gradually decreased which is 0.0003 sq km in year 2011. As per the FSI report, **(FSI, 2013)** the forest of Gujarat is classified based on very dense (0.19%), Moderately dense (2.67%), Open (4.60%) and Scrub (0.76%) forest **(Figure 4).** .

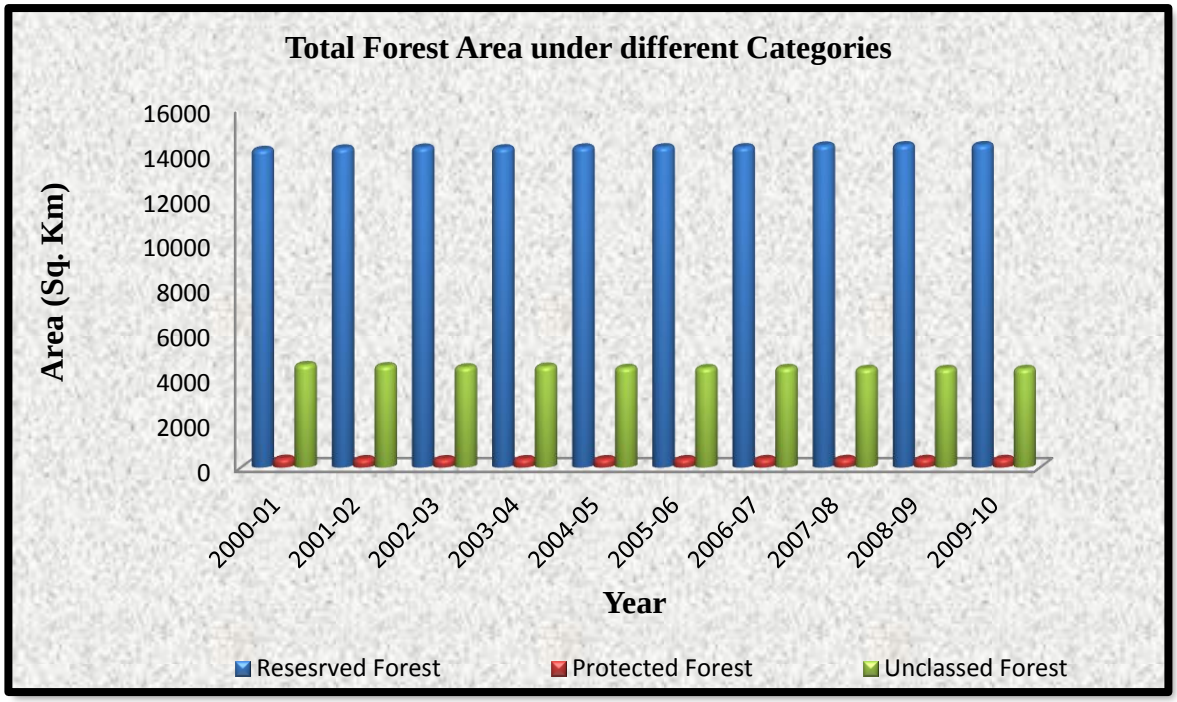

Figure 3. Different Category of Forest Area in the Gujarat State

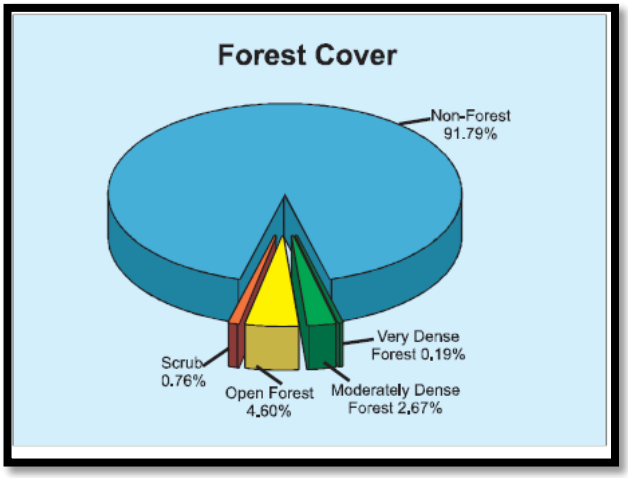

Figure 4. Forest cover of Gujarat

(Source: Gujarat state forest Report, 2011)

1.2.3.4. Local: District: Panchmahal ;Taluka : Halol ; Place : Pavagadh

The district Panchmahal is one of the districts on the eastern part of the Gujarat State. The total geographical area of the district is 4461 sq.km and out of this 565 sq.km area is covered by the forest (in 2007) which constitutes approx. 12.67% of the total geographic area. As compared with the year 2005, this forest has been decreased by 5

sq. km. According to the Working Plan of Panch mahal, the total forest area of the district was 110029.91 ha, out of which 107385.69 ha, 450.32 ha & 2193.90 ha area were declared as reserved forest, protected forest and unclassed forest respectively. This forest constituted 17% of the total geographic area of the district. In the district of Panchmahal, the per capita land is 0.250 ha and per capita forests is 0.065 ha. This district has only one forest division. i.e. Godhara Forest Division **(Plate 3)** and this division is further divided into 13 ranges, 45 rounds,160 beats and 627 villages.

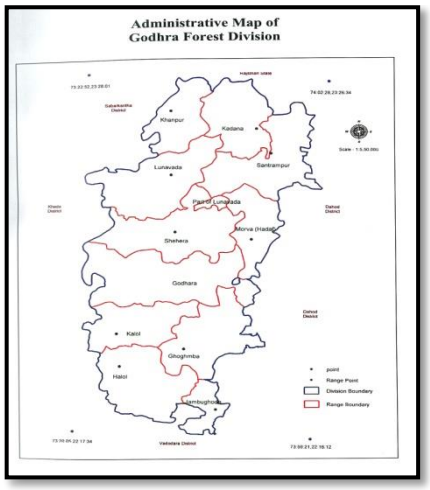

Plate 3. Administrative Map of Godhara Forest Division

1.2.4. Forest of Pavagadh:

Forest Area of Pavagadh falls under Halol Range of Godhara Division. Total 6356.98 Ha. area of Halol Range is covered under forest which is legally constituted as Reserve Forest. It is comprised of four rounds and fifteen Beats **(Table 1.)**

Table 1. Forest area under different rounds under the Halol Range

Sr.No.	Name of round	Reserved Forest area	Protected/Unclassed forests	Total forest area
1	Pavagadh	2099.63	0.72	2100.35
2	Dhankuva	1593.74	0	1593.74
3	Vav	1482.15	0	1482.15
4	Shivrajpur	1180.74	0	1180.74
	Total	**6356.26**	**0.72**	**6356.98**

1.2.4.1. Flora

In Pavagadh forests nearly 320 species of trees, herbs & shrubs have been identified as per the records of the forest officials of which some have medicinal value as well. Few of Important species are enlisted below in the **Table 2, Table 3, Table 4 & Table 5.**

Table 2. List of Important Trees species

LOCAL NAME	SCIENTIFIC NAME
Arduso	*Ailanthus excelsa*
Aledi	*Morinda tinctoria*
Amla	*Emblica officinalis*
Amli	*Tamarindus indica*
Aniyar	*Acacia leucophoea*
Ankal	*Analgium salvifolium*
Ashotri	*Bauhinia racemosa*
Baval	*Acacia nilotica indica*
Bahedo	*Terminalia bellerica*
Bhagaro	*Erythrina suberosa*
Bili	*Aegle marmelos*
Biyo	*Pterocarpus marsupium*
Bor	*Zizyphus mauritiana*
Charoli	*Buchanania larizan*
Asan	*Bridelia retusa*
Dhaman	*Grewia tiliaefolia*
Dhavdo	*Anogeissus latifolia*
Dudhi	*Wrightia tinctoria*
Gandobaval	*Proposis juliflora*
Garmalo	*Cassia fistula*
Ghatbor	*Zizyphus xylophyrus*
Gorad	*Acacia Senegal*
Gorasamli	*Pethecolobiam dulce*
Gugal	*Boswellia serrata*
Haldarvo	*Adina cordifolia*
Jambu	*Syzygium cumini*
Kadayo	*Sterculia urens*
Kakad	*Garuga pinnata*
Kanaji	*Holoptelea integrifolia*
Karanj	*Pongamia pennata*

Kashid	*Cassia siamea*
Khair	*Acacla katechu*
Khakhro	*Butea monosperma*
Kusum	*Schleichera oleosa*
Limdo	*Azadirachta indica*
Mahuda	*Madhuca indica*
Moina	*Lannea coromandalica*
Mokho	*Schrebera swieteenioides*
Nilgiri	*Eucalyptus spp. (Mysore hybrid)*
Rayan	*Manilkara hexandra*
Rohan	*Soymida febrifuga*
Sadad	*Terminalia crenulate*
Sag	*Tectona grandis*
Saragwo	*Moringa oleifera*
Sarasadi	*Albizzia odoratissima*
Shivam	*Gmelina arborea*
Simal	*Bombax ceiba*
Siras	*Albizzia lebbek*
Sisoo	*Dalbergia sisoo*
Sitafal	*Anona squamosa*
Tad	*Borassus flabellifer*
Tanach	*Ougeinia oogeinensis*
Umberdo	*Ficus racemosa*
Vad	*Ficus benghalensis*

Table 3. List of Important Shrubs and Herb species

LOCAL NAME	SCIENTIFIC NAME
Adusa	*Adhatoda vasica*
Ankado	*Calotropis gigentia*
Awar	*Cassia auriculata*
Dano	*Lantana camara*
Dhatura	*Datura inoxia*
Kuda	*Holarrhena antidysentirica*
Muradsing	*Helicteres isora*
Nagod, Nirgund	*Vitex nigundo*
Prijat	*Nytanthus arbortristis*
Puwad	*Cassia tora*
Thor	*Euphorbia nerifolia*

Table 4. List of Important Climbers

LOCAL NAME	SCIENTIFIC NAME
Asan	*Cocculus hirsutus*
Chanoti	*Abrus Precatorius*
Galo	*Tinospora cordifolia*
Karamdo	*Carissa conjesta*
Kuvech	*Mucuna pruriens*

Table 5. List of Grass species

LOCAL NAME	SCIENTIFIC NAME
Jinjavo	*Dichanthium annulatum*
Kakudu	*Saccharum spontaneum*
Pusha	*Cymbopogon citrates*
Shukli	*Hetropogon contortus*

1.2.4.2. Fauna:

In the areas of Pavagadh forests & surroundings animals like panther, Jungle cat, Civer Cat, Jacket Hyaena, Porcupine, common Fox, bluebull, pythons, common mongoose Indian civet, vulture, gamdems etc. are often seen. In the medieval times during 1832, the forest of Pavagadh was full of sandal wood trees & 73 clephants were caught during the reign of Jehangir. Thus today even one of the vallies is named as "Haathi – Khin".

1.3 Sustainable development of Forest

Sustainable development is a vague and complex concept covering all aspects of life at national and international levels and of government policies.

Development implies different meaning to different walks of life. The contemporary notion of development is like the more you eat or have, you will be better off; which is forcing the people to accumulate more physical stuffs. This trend is against

the theme of ***sustainable development***, which can be meeting even at minimum input or supply. As a part of the demands on forestry to meet present needs and our ethical responsibility toward future generations, the following definition of sustainable forest development was given by **Maini (1989)** stated that "Sustainable development of forest land and its multiple economic and environmental values involves maintaining indefinitely, without unacceptable impairment, the productive and renewal capacities as well as the species and ecological diversity of forest ecosystems**."** This can be acquired by maintaining their a) integrity, b) productive capacity, c) resiliency and d) biodiversity.

a) Integrity: It involves the sustenance of a wide range of ecological processes where plants, animals, micro-organisms, soil, water and air are constantly interacting. Through these processes, forests provide a number of essential functions for life on this planet. They maintain the chemical balance, stabilize the climate, recycle nutrients, break down pollutants, clean the air and water, and are vital to watershed protection, soil formation, carbon storage and the supply of food and habitat for wildlife.

b) Productive capacity: It is determined by a number of factors, such as the fertility of the soil, the climate and the presence of various plant and animal species.

c) Resiliency: Ecosystem resilience refers to the capacity of an ecosystem to recover from disturbance or withstand ongoing pressures**. (McCook et al, 2007).** It is a measure of how well an ecosystem can tolerate disturbance without collapsing into a different state that is controlled by a different set of processes. Resilience is about an ever changing system of disturbance and recovery. Forests must be managed sustainably so that their natural resilience allows the recovery process to begin immediately after a disruption. This is a key element of sustainable forest management.

d) Biodiversity: This includes the variety of different species, the genetic variability of each species and the variety of different ecosystems they form. Maintaining the unique and rich array of diverse plant and animal communities requires maintaining the health and diversity of the whole forest landscape, as well as designating specific areas to be protected because of their unique ecological value. **(Anon, 1992)**

1.3.1. Concept and History of Sustainable development

Sustainable development has been defined in literally hundreds of different ways over the last three decades, One of the most popular definitions, from the Brundtland Report *Our Common Future*, states that "'Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

The concept of Sustainable development has been introduced to the world in 1960s. Rachel Carson had first used this term in her book '***The Silent Spring***' and in consequent years publications like Paul Erlich's '***Population Bomb'*** and the Club of Rome's '***Limits to Growth*** 'frequently used this term with respect to global development issues.

In 1972, the United Nations Conference on the Human Environment held in Stockholm brought the industrialized and developing nations together to formulate the 'rights' of the human family to a healthy and productive environment.

In 1980, the International Union for the Conservation of Natural Resources (IUCN) published the World Conservation Strategy (WCS) which provided a precursor to the concept of sustainable development. The Strategy declared that conservation of

nature cannot be achieved without development to improve poverty and grief of hundreds of million of people and stressed the interdependence of conservation and development in which development depends on caring for the Earth. Unless the fertility and productivity of the planet are safeguarded, the human future is at risk.

At the 48th plenary of the General Assembly in 1982, the WCS initiative culminated with the approval of the World Charter for Nature in which the mankind was considered as a part of nature and that his life is depending upon uninterrupted functioning of the natural systems. In 1983, the World Commission on Environment and Development (WCED) was created and in 1984, WCED was constituted as an independent body by the United Nations General Assembly. In 1987, the Brundtland Report enhanced the understanding of global interdependence and the relationship between economics and the environment. The statement of the report stated that "the environment does not exist as a sphere separate from human actions, ambitions, and needs, and therefore it should not be considered in isolation from human concerns. The environment is where we all live; and development is what we all do in attempting to improve our lot within that abode. The two are inseparable." **(WCED 1987) .** Since then, thousands of initiatives have been taken at local, national, and global levels in an attempt to address different aspects of the sustainable development. Out of these thousands, few initiatives with their outcomes are highlighted as following:

The first UN Conference on Environment and Development (UNCED) was held in Rio de Janeiro in June, 1992 which adopted an agenda called as ***Agenda 21*** for environment and development in the 21st Century. This conference was a Programmer of Action for Sustainable Development and it contained the Rio Declaration on

Environment and Development. It recognized each nation's right to pursue social and economic progress and assigned each State the responsibility of adopting a model of sustainable development; and, the Statement of Forest Principles. During this Rio Declaration, agreements were also made on the Convention on Biological Diversity and Climate Change.

As a further step in year 2000, The **World Development Report (2000)**, emphasized the creation of sustainable improvements in the quality of life for all people as the principle goal of development policy.

On the similar line 2002, The World Summit on Sustainable Development (WSSD) was organized at Johannesburg and it stressed upon the plan of implementation & establishment of number of partenership intitiative related to sustainable management of forest resource, as it was considered to be one of the important resource.

1.3.2. Criteria and Indicator Approach for Sustainable Forest Management

SFM requires a specific framework which can be significant in developing certain Criteria and Indicators (C&I) for assessing it (**Table 6**). **Philis and Andriantiatsaholiniaina 2001** has emphasized a practical tool for assessing such sustainability in the form of C&I and in this context C & I has been assessed over past several years countries across the globe to develop C&I for SFM. E.g. Organization for Economic Co-Operation and Devalopment (OECD) countries has adopted different types of C& I based on different types of framework.

Table 6. Criteria & Indicators under different frameworks with their respective countries

Sr. No.	Countries	Framework	No of Criteria & Indicators
1	Sweden	Bruntland Report	4themes(30)
2	Austria	NSSD	48
3	European Commission	IEEP	11
4	Canada & Norway	Capital Approach	---
5	ITTO Initiative on criteria and indicators	-----	7(66)
6	Dry-zone Africa Process	----	7(47)
7	Montreal Process (non-legally binding)	-----	7(67)
8	Tarapoto Proposal	------	1 global, (7 global) 7 national(47 national,) 4 forest management unit (FMU) (22 FMU)
9	Regional initiative for dry forests in Asia	-----	8(49)

Further it was also analyzed at national level as well as Forest Management Level (FMU) and whether C&I should be separately develops for FMU. According to **Raison & Brown (2001)**, the application of C&I to improve SFM raises major challenges specifically its adaptation related to National or FMU level. In India, the C&I for SFM were initially designed by the National Task Force of Government of India under the leadership of Dr.Ram Prasad,Director, IIFM.(**Kotwal & Prasad,2001**)

These were redefined during the Bhopal –India (B&I) Process from the criteria earlier defined by ITTO.(**ITTO,1998)**

1.3.3. Criteria and Indicators of Bhopal- India Process:

Out of eight different criteria two criteria i.e. 1st & 5th were considered in the present study for developing sustainable plan of forest area of Pavagadh hill. With respect to 1st criteria all seven indicators have been considered for assessment where in case of 5th criteria only indicators were considered (**Table 7**).

Table 7. Criteria and indicators of Bhopal-India Process

Sr. No.	Criterion	Indicators
1	Increase in the extent of forest and tree cover	• Area of Forests • Area under open and dense forests • Trees outside forests • Per capita forest area and trees outside forests • Diversion of forestland to non-forestry purposes • Encroachment, submergence, mining • Plantations
2	Maintenance, conservation and enhancement of biodiversity	• Variety of plant species • Variety of animal and bird species • Pure patches of certain species (specific habitats) • Waterbodies/waterholes
3	Maintenance and enhancement of ecosystem function and vitality	• Malformed, dried and deformed trees • Incidents of fire • Regeneration status • Incidence of pests • Incidence of weeds • Incidence of diseases • All age class trees
4	Conservation and maintenance of soil and water resources	• Number of gullies • Duration of streamflow in and around forest area • Decaying leaf litter • Water level in wells • Exposed roots and uprooted trees • Soil and water conservation measures • Perception about water availability

5	Maintenance and enhancement of forest resource productivity	• Production of fuelwood • Production of timber and poles • Basal area • Stem density • Number of NWFP yielding trees per hectare • Number of other species per hectare • Total NWFP production • Use of quality seeds in plantations
6	Optimization of forest resource utilisation	• Per household consumption of timber, poles • Per household consumption of fuelwood • Availability and utilisation of grass and fuelwood • Efforts to increase efficiency of fuelwood • Level of sustainable harvest of NWFP • Value addition
7	Maintenance and enhancement of social, cultural and spiritual benefits	• Year of formation • Number of meetings per year • Average attendance in meetings • Average women attendance in meetings • Agenda and minutes • Fund available with JFMC • Proportion of household income from forests • Trees, plants and patches protected for cultural reasons • Application of indigenous knowledge in management and use
8	Adequacy of Policy, legal and institutional framework	• Financial transparency • Capacity building • Conflict resolution mechanism • Adequacy of rules and regulations • Efforts to reduce pressure on forests • Mechanism for protection, management and benefit sharing • Empowerment of JFMC for the above • Powers of Forest Officials devolved to J

Assessment of both the criteria required a holistic approach taking into account the precarious environmental conditions. Moreover, to manage any resource effectively and sustainably the understanding of three components is also required viz., information, policies, and participation of the stake holders in concern with that resource. Such

information can be acquired only when answers of the specific questions related to that resource viz.

- ✓ How much of that resource is present?
- ✓ What is the extent of its spatial distribution? and
- ✓ Whether it is being used judiciously and sustainably or not?

It was very clear that the utility of advance integrated techniques of Remote Sensing –Geographical Information System (RS-GIS) has the potential of achieving this goal. Therefore the present study has exploited the potentials of this techniques for assessing these indicators.

1.4. Role of remote sensing and GIS

Remote sensing proves to be an effective tool in providing relevant, reliable and timely information **(Marble et al., 1983; Gugan et al., 1993).** This tool when integrated with GIS provides an additional benefit in terms of designing and developing different management strategies. Several studies have been carried out worldwide, which have demonstrated the capability of remote sensing and GIS in development and planning **(Smith et al., 1980; Hellden et al 1982; Trotter, 1991; SAC, 1992; Welsh et al., 1992; Kushwaha et al., 1993).** In similar studies remote sensing data becomes vital in terms of economic performance and data acquisition. On the other hand GIS proves its importance for planning from local to global scales (**Beinat and Nijkamp, 1998**). By interfacing remote sensing with GIS, different management scenarios have been generated, which helped the planners in assessment the feasibility of various alternatives before selecting the one that would be most suitable for a given area(**Nellis et al,1990**). **Kushwaha et al.(1996)** have demonstrated the method for integrated

sustainable rural development planning using remotely sensed data and GIS in Pathri Rao sub water shed area. **Skidmore et al, 1997** have shown the role of RS –GIS as a policy tools by generating policy, providing information and ensuring participation for sustainable land management.

1.5. Generation of different land-use themes & thematic maps of forest Cover

In recent year resource assessment using advance technology of spatial data assessment has made the thematic map generation very essential. This map emphasizes a special theme or special topic which can be related to average distribution of rainfall in an area or population density or any such variable covering a large geographic area. It is different from a natural map because it directly connects a specific variable with a specific geographic location. It uses qualitative analytical method to show and analyze the day to day information. Preparations of thematic maps serve two primary purposes.

- Acquisition of specific information about particular locations and about spatial patterns.
- Comparison of different patterns on two or more maps.

The sources of thematic map data are important as they require not only enormous but also accurate, recent and reliable data in a wide range of subjects depending upon the user's interest. **(Cammack, 2005)**. Based on the number of subjects or themes thematic maps can be univariate, bivariate or multivariate maps.

- Univariate : It deals with only one type of data and therefore looks at the occurrence of one type of event. This process would be good for mapping a location's rainfall.

- Bivariate: It shows the distribution of two data sets and models their correlations such as rainfall amounts relative to elevation.

- Multivariate: It takes into consideration two or more data sets like rainfall, elevation and the amount of vegetation relative to both etc.

Thematic mapping has a long history in cartography as well as in the computers. Thematic maps did not develop as a map type until the mid-17th Century because at that time accurate base maps were not there. In 1686 Edmond Halley, an astronomer from England developed a star chart and later in that same year, he published the first meteorological chart using base maps. In 1701, he also published the first chart to show lines of magnetic variation which was considered as a thematic map that later became useful in navigation. In addition to these the first map of Paris was developed using isolines and this was believed to be the first use of isolines to display a theme that did not have to do with physical geography**. (Briney,2009)**

1.5.1. Methods of generating Thematic Maps:

Thematic maps can be generated in many different ways. In general there are five techniques that are used most often.

1. **Chloropleth map :** This is a first and most commonly used map which displays quantitative data as a color and can show density, percent, average value or quantity of an event within a geographic area. Sequential colors on these maps represent increasing or decreasing positive or negative data values.

2. **Proportional or graduated symbol map:** These are the another type of map and they represent data associated with point locations such as cities. Here the data is displayed in the form of proportionally sized symbols to show differences in occurrences. Circles are most often used with these maps but squares and other geometric shapes are suitable as well.

3. **Isarithmic or contour map :** It uses isolines to depict continuous values like precipitation levels. These maps can also display three-dimensional values like elevation on topographic maps. Generally data for isarithmic maps is gathered via measureable points (e.g. - weather stations) or is collected by an area (e.g. - tons of corn per acre by county). Isarithmic maps also follow the basic rule that there is a high and low side in relation to the isoline. For example in elevation if the isoline is 500 feet (152 m) then one side must be higher than 500 feet and other side must be lower.

4. **Dot map:** It is another type of thematic map and uses dots to show the presence of a theme and display a spatial pattern. On these maps, a dot can represent one unit or several, depending on what is being depicted with in the map.

5. **Dasymetric map :** This map is a complex variation of the choropleth map and it uses statistics and extra information to combine areas with similar values instead of using the administrative boundaries common in a simple choropleth map.

Despite of all these facts it should also be clear that they are only good at the degree to which they represent the theme. Thematic maps are able to visualize an area in terms of its demographic, ecological, economic and environmental dimensions which are the basic components of the sustainable development. It also shapes up a person's ability to understand a scenario in the context of space. Information in the form of figures and text are translated into a picture from which the data can be added or removed as per the requirement. To be precise it provides an evolving platform from which decisions can be made over time.

1.5.2. Consideration for thematic Mapping

Cartographers take into consideration several important things while designing a thematic map which are as follows:

A. **Map's Audience:** This determines the reference points to be included in the base map according to the requirement of the users along with the map's theme. e.g. A political scientist would consider political boundaries as a reference point, while a biologist would be more interested in contours showing elevation.

B. **Sources of a thematic Map:** It takes into consideration accurate, recent, and reliable sources of information in a wide range of subjects from environmental features to demographic data.

C. **Usage of thematic maps:** It is important to consider the way in which the obtained data is used. Only based on the utility of the data it can be grouped into univariate, bivariate or multivariate type of thematic map.

To achieve the goals of sustainable development, timely information on the nature, extent, spatial distribution of the natural resources is a pre-requisite. This can be achieved or served by generating thematic maps of different resources. **(Rao, 2000)**. Among these resources, Forests have acquired increasing importance for their role not only in meeting the material requirements but also for their ecological and environmental functions. Therefore, to sustain this resource for the present as well as future generation it is very much essential to adopt the criteria and Indicators adopted by different agencies for sustainable development of this resource. e.g. Green Growth **(OECD, 2012**), forest ecosystem service approach (**FAO,2009)** etc.

1.5.3. Thematic Maps for sustainable forest management

Sustainable forest management encompasses all the three components of sustainability, viz. ecological, economic and socio-cultural well-being. In a country like India, whose forests are rich and diverse, collection and compilation of information on different forest parameters is a daunting task. It is almost axiomatic that accurate, reliable, and up-to date information is essential for wise and efficient decision making. To be more effective, there is an urgent need to embrace rapid and cost-effective mapping techniques like thematic mapping as they are constantly updated for sound and sustainable planning and development. Thematic maps of total forest cover, growing

stock, annual increment, species composition, biodiversity, non-timber forest products etc. can be generated for such purposes.

- Accurate estimates of the extent of forest, and ideally a range of forest types, are required for a complete understanding of forests and their sustainable use which is a task full of uncertainty and difficulties.
- Moreover, the uncertainties associated with biomass are a larger limit to understanding the role of tropical forests in the carbon cycle than those associated with forest area change. **(Houghton et al. 2000).** Remote sensing has considerable potential as a source of biomass data.
- The greatest threat to biodiversity is land cover change-induced habitat destruction **(Chapin et al. 2000)**, reinforcing the need for accurate maps of forest extent and change.

1.5.3.1. Thematic Maps: Conventional v/s non-conventional methods

Achieving resource sustainability based on these criteria require the generation of thematic maps. These maps can be generated using both conventional and non conventional technique. Spatial Maps generated using non-conventional techniques have many advantages when compared to Conventional Maps such as given below:

- Non conventional technique i.e. multi-sensor/multi-resolution capability of satellite technology enables the users to get temporal imagery which aid in carrying out multi-level/ scale mapping. Such kind of repetitive coverage is required during monitoring of many forest activities.
- The synoptic view of the satellite data provides large area coverage and it is cost effective also.

- Conventional Map represents the terrain features in a symbol format and since it is made manually, the chances of occurrence of errors are always high and therefore cannot be reliable.
- On the other hand the remote sensing image represents replica of earth surface features and level of details varies with the spatial/spectral properties of the satellite data.
- Spatial Information can be integrated with other data formats such as vector shape file, GPS inputs and others in GIS environment.

During the last few decades, the world mapping activity has been experiencing a gradual transition from conventional graphical mapping to numerical, computer mapping. In the past, under the conventional method monoscopic aerial photographs were used which could not remove the inherent object displacement. They required intensive field studies. Softcopy mapping has revolutionized these procedures, where different thematic layers are generated using computers and such spatial and non spatial data are integrated in GIS environment using criteria based decision rules. Digital photogrammetry is also rapidly evolving field. In India recently SOI India has taken up a major task of generation of digital database by converting the existing toposheets (1:250,000; 1:50,000 & 1:25,000 scales) (**Raju, 2003).** Since the year 2005 onwards the remote sensing technology has been widely used for the assessment of different forest parameters which is briefly enlisted in **Table 8.**

Table: 8. Assessment of different forest parameters using remote sensing technology by different research workers

Sr. No.	Forest Parameters	Name of Research scientist	Year of Research publication
1.	Forest stock maps	Bebarta	2008
		Mahto	2001
2.	Forest fire detection	Hussain et al	2008
		Jaiswal et al	2002
3.	Forest type map	Roy and Ravan	1996
		Shrivastav & Anitha	2010
4.	Biodiversity Conservation	Wang et al	2010
		Debinska & Brussard	1994
		Turner et al.	2003
5.	Identification of priority areas for plant conservation	Balaguru et al	2006
6.	Assessment of Land use –Land change for biodiversity conservation	Flamenco-Sandoval et al	2007

These all parameters have been assessed individually using conventional and non conventional techniques but they have not been interlinked and applied to forest area in context of their sustainable development.

1.5.4. Role of Forest survey of India (FSI)

Forest Survey of India (FSI), the premier national organization for forest resource assessment carrying out forest and tree cover assessment. It assesses forest cover of the country using high resolution remote sensing data (i.e. (IRS- LISS III & IRS P6 Resourcesat- LISS III) and publishes biennial report in the form of 'State of Forest Report' (SFR). With this improved spatial resolution and scale of interpretation, FSI can asses the forest cover up to 1 ha. This type of advance technique has enabled FSI to map these forest cover more precisely in terms of classes like very dense forest, moderately dense forest, open forest and scrub.

Table: 9. Forest cover Mapping over the years by FSI

Cycle of Assessment	Year	Data Period	Sensor	Resolution	Scale	Minimum mappable area (ha)	Mode of interpre-tation
I	1987	1981-83	LANDSAT-MSS	80 m	1:1 million	400	Visual
II	1989	1985-87	LANDSAT-TM	30 m	1:250,000	25	Visual
III	1991	1987-89	LANDSAT-TM	30 m	1:250,000	25	Visual
IV	1993	1989-91	LANDSAT-TM	30 m	1:250,000	25	Visual
V	1995	1991-93	IRS-1B LISSII	36.25 m	1:250,000	25	Visual & Digital
VI	1997	1993-95	IRS-1B LISSII	36.25 m	1:250,000	25	Visual & Digital
VII	1999	1996-98	IRS-1C/1D LISS III	23.5 m	1:250,000	25	Visual & Digital
VIII	2001	2000	IRS-1C/1D LISS III	23.5 m	1:50,000	1	Digital
IX	2003	2002	IRS-1D LISS III	23.5 m	1:50,000	1	Digital
X	2005	2004	IRS-1D LISS III	23.5 m	1:50,000	1	Digital
XI	2009	2006	IRS-P6-LISS III	23.5 m	1:50,000	1	Digital
XII	2011	2008-09	IRS-P6-LISS III & IRS-P6 AWiFS	23.5 m 56 m	1:50,000	1	Digital

From the above **Table 9** it is clear that as the resolution of satellite data and the scale of interpretation have improved, the gap between data period and assessment year has also

reduced with the introduction of digital image processing (DIP) which ultimately resulted in high accuracy. **(FSI, 2011)**

1.6. Identification of Ecologically Sensitive Area

The concept of an ecologically sensitive area (ESA) is appealing and consequently; it is among the most widely used terms with no explicitly accepted definition. In fact, ESA is often considered synonymous to: environmentally sensitive areas (**Saxena et al., 2007; Hemkumara, 2009; Macdonald, 2000; Steiner et al., 2000; Capuzucca & Federal, 2001**) environmentally sensitive zones (**Anon,2008**) ecologically sensitive ecosystem(**Lin et al., 2008**), ecologically sensitive sites, etc., depending upon the context and the area or location of conservation interest.

"An ecological sensitive area (ESA) is a bio-climatic unit (as demarcated by entire landscapes) in the forest area wherein human impacts have locally caused irreversible changes in the structure of biological communities (as evident in number/ composition of species and their relative abundances) and their natural habitats.

1.6.2. Concept of ESA

The concept of 'Ecologically Sensitive Areas' is very different from that a protected area like a national park which is supposed to be entirely free from human interference. Ecologically Sensitive Areas' are areas under human use and all human activities prudently regulated under the Environment (Protection) Act, 1986. ESAs are not at all meant to stop development but to ensure that development is environment friendly and people oriented, as well as serve to preserve the ecological heritage on a long term basis. There are no set regulations instead, the regulations are worked out with due respect to local context.

Considering this fact, identifying ecologically sensitive area is the most practical means for providing an appropriate level of protection to the natural values of areas and for management practices. There is a proverb that "Prevention is better than cure "which is appropriate for any type of ecosystem management. For forest ecosystem prevention of degradation is better and cheaper than the cure. Thus apart from long term economic losses due to unsustainable development, conserving the diversified areas will become financially unviable and with respect to this, ESA play a vital role by identifying such diversified areas of the forest ecosystem. It is inevitable that land use changes will occur in the future, such changes should be planned to help ensure that complementary goals are achieved. This can be done by including concerns for forest conservation in the form of ESA, as a major component in land use planning and management strategies. Humans have long relied upon the biosphere for resources such as food, water and energy. Demand for these resources with a changing climate is likely to increase with a rising population which ultimately leads to changes in land-use patterns. Today these changes encompass the greatest environmental concerns of human populations like climate change, biodiversity loss and the pollution of water, soils and air. Sustaining the essential resources, monitoring and mediating the negative consequences of this land use have therefore become a major priority of researchers and policymakers around the world. Assessment and mapping of spatial land productivity variations has become essentials to understand the land use properly.

1.6.2. Significance of Land Use Change for identification of ESA

Land use relates to the human activity or economic function associated with a specific piece of land (**Jenson, 1996**). 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 (**CARA, 2006**). The term land cover originally referred to the kind and state of vegetation, but it has broadened in subsequent usage to include human structures such as buildings or pavement and other aspects of the natural environment, such as soil type, biodiversity, and surface and groundwater (**Meyer 1995**). Land cover categories generally include cropland, forests, wetlands, pasture, roads, and urban areas. Land use is distinct from land cover despite the two terms often being used interchangeably. Changes in Land use patterns are affected by human intervention and natural phenomena such as agricultural demand and trade, population growth and consumption patterns, urbanization and economic development, science and technology, and some other factors. (**Brar, 2013**) As a result, information about land use is essential for any kind of natural resource management and action planning. Timely and precise information about land use change detection of earth's surface is extremely important for understanding relationships and interactions between human and natural phenomena for better management of decision making (**Lu *et al.*, 2004**). Accurate and up-to-date information about LULC is continually in demand for sustainable development of resources where it is served as one of the major input criteria.

Sustainable development is a process which involves people, institution, natural resources and the environment. It is an attempt to provide the best outcomes for the human and natural environments both now and into the indefinite future (**Munier 2005**).

1.7. Ecologically sustainable development plan

The mankind's desire to achieve his development objectives through heavy reliance on natural resources and the implications this might have on the environment could potentially leave adverse footprints for future generations. This has affected the carrying capacity of the ecosystems throughout the world and created an ecological imbalance. The need to prevent this situation is more critical than ever. That is why the time is ripe to renew the call for development that is both sustainable and ecologically friendly for entire ecosystem as a whole in order to reverse some of the negative environmental and social trends. This concept is recognized as Ecologically sustainable development. It can be defined as using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased.

In this context advance technology like remote sensing and GIS represent an important tool permitting a better knowledge of past, present and long term consequences of human activities in virgin ecosystem.

1.8. Objectives:

1) **To generate a different land use themes and Thematic Maps of Forest Cover using Satellite Data**
2) **To identify ecologically sensitive Area.**
3) **To prepare Ecologically Sustainable Development Plan**
4) **Recommendations and suggestions**