CHAPTER - 1
INTRODUCTION

1.0 INTRODUCTION

Nature is endowed with a high capacity of absorbing any kind of environmental shock, but man's activities in the recent past have crossed the threshold of this inbuilt absorbing capacity, and the results are before us in the form of accelerated climatic changes, degradation of our water systems, deterioration of air quality and conversion of large fertile areas into ecological deserts and wastelands. At this juncture, it is imperative to prepare long-term strategies for a sustainable and secure global environmental action plan.

Thus, to regulate the effective functioning of the global ecosystem, the earth's lungs are to be maintained and here begins the role of the forest. Forests are the most efficient core system enabling our earth to survive and function. Yet, of all the world's natural resources, forests are perhaps the most neglected and are being depleted at an alarming rate. The reason being that when nature follows the process of regeneration, which is continuous and gradual, sudden human intervention further decelerates this slow process. Such changes on all the components of the forest ecosystems results in a severe ecological backlash. Conservation of the forest ecosystem therefore requires immediate attention.

1.1 FOREST ECOSYSTEM

The word 'forest' is derived from the Latin word *foris*, meaning outdoor area, or outside the village boundary. Etymologically, it is "a large, uncultivated tract of land covered with trees and underwood" (Anon. 1943). Generally, 'forest' refers to an area occupied by different kinds of trees, shrubs, herbs and grasses and maintained for the production of wood and non-wood products.

The technical definition of a forest, given in the Indian Forest Records, 1936 reads as " an area set aside for the production of timber and other forest produce or maintained under woody vegetation for certain indirect benefits which it provides e.g. climate or protective" (Anon. 1966). Ecologically, it is defined as "a plant community predominantly of trees and other woody vegetation usually with a closed canopy" (Anon. 1953). Legally, 'forest' is an area of land proclaimed to be a forest under forest law.

The World Forest Inventory of FAO (1960) gives the following definition of 'forest'. "All lands bearing vegetative associations dominated by trees of any size, exploited or not, capable of producing wood or of exerting an influence on the local climate or on the water regime, or providing shelter for livestock and wildlife".

1.2 FOREST CLASSIFICATION

Forests have been classified on the basis of:

- age,
- method of regeneration,
- composition,
- ownership and legal,
- management,
- growing stock,
- density

1.2.1 Age

Forests are classified into even-aged forests and uneven-aged forests.

(a) Even-aged forest: It is also called a regular forest consisting of trees of approximately the same age.

(b) Uneven-aged forest: This is also called an irregular forest where trees vary widely in age.

1.2.2 Method of Regeneration

Forests are identified as high forest, coppice forest, natural and man-made forest based on their mode of regeneration.

(a) High forest: Forest regenerated from seeds.

(c) Coppice forest: Forest regenerated through coppice or some other vegetative parts of the tree.

(d) Natural forest: Forest regenerated naturally.

(e) Man-made forest: Forest raised artificially by human efforts.

1.2.3 Composition

Forests are classified into pure forests and mixed forests based on their composition.

(a) Pure forest: Pure forests are composed almost entirely of one species, usually to the extent of not less than 50%.

(b) Mixed forest: Mixed forests are defined as forests composed of trees of two or more species intermingled in the same canopy. The species composing the mixture are usually distinguished on the basis of economic importance as:

- Principal species : species first in importance either by frequency, volume or silvicultural value.
- Accessory species : species which assist in the growth of principal species.
- Auxiliary species : species, which are of inferior quality or size with relatively little silvicultural value or importance, associated with principal species. These are also called secondary species.

1.2.4 Ownership & Legal

On the basis of ownership, forests may be government forest, private forest and forests owned by corporations, panchayats, societies and other bodies (Anon. 1961). On the basis of legal status, government forests are further classified into: reserved forest, protected forest and village forest.

- Reserved forest : forest with complete protection, constituted according to the provisions in the Indian Forest Act.
- Protected forest : forest area subjected to a limited degree of protection constituted under the provisions of the Indian Forest Act.
- Village forest : forest assigned to a village community under the provisions of the Indian Forest Act.

1.2.5 Management

On the basis of management, forests are classified into protection forest, production forest and social forests.

(a) Protection forest: Protection forests are those which are managed primarily for ameliorating climate, checking soil erosion and floods, conserving soil and water, regulating stream flow and increasing water yields and exerting other beneficial influences.

(b) Production forest: Production forests are those which are managed primarily for their produce.

(c) Social forest: Social forests are also, in fact, production forests where produce is to be utilized by a neighboring society.

1.2.6 Growing Stock

Forests may be classified into a) normal forest and b) abnormal forest.

a) Normal forest: It is an ideal forest with regard to growing stock, age-class distribution and increment can be continued indefinitely without endangering future yields. Such forests serve as a standard for comparison and are rarely found in nature.

b) Abnormal forest: It is one which is not normal. Growing stock, age class distribution of stems, increment, etc., are usually more in deficit than in the normal forest.

1.2.7 Density

Density wise classifications of forest given by different workers are listed in Table 1.

1.3 IMPORTANCE OF FORESTS

Forests are the planet's largest and most important terrestrial ecosystem. The economic value of forests and their local economic and ecological importance are universally significant for their planetary functions. Forests contribute to the fundamental ecological process, which keeps the planet in a state of quasi-equilibrium (Costanza et al 1997). Forests have, apart from humans themselves, the greatest influence on the structure and functioning of the human habitat. Forests are fundamental to the maintenance of a habitable biosphere, they conserve biodiversity and shield the earth's landscape from abrupt change. Besides providing environmental and material services, they are a source of spiritual, aesthetic and symbolic values for many.

Table 1 : Densitywise forest classification

Sr. No.	Source	Forest classification	Definition
1	Fosberg's (1967)	Closed forest	Tree crowns interlocked.
		Open forest	Tree or shrubs crowns are only partly interlocked and are often free standing.
		Sparse forest	Tree crowns widely spaced and stand apart.
2	NRSA (1982)	Closed forest	>30 % crown density.
		Open/Degraded forest	10-30 % crown density.
		Mangroves forest	Irrespective of crown closure with salt tolerant forest ecosystem.
		Non-forest	<10 % crown closure.
3	FSI (1999)	Dense forest	>40 % canopy density.
		Open forest	10-40 % canopy density.
		Scrub forest	< 10 % canopy density.
		Mangroves forest	Irrespective of crown closure with salt tolerant forest ecosystem.
		Non-forest	Land devoid of trees.

Forests contain at least two-thirds of the earth's terrestrial species. It is reported that 10% of the world's forest tree species are threatened with extinction (WCMC/IUCN/WWF, 1998). They help in stabilizing the landscapes and play a central role in the nutrient cycle of elements. They are the sinks of carbon dioxide and are a source of oxygen, the vital gas that makes the earth fit to support life. Forests, within their soils, contain 700 billion tons of carbon and each year they process 5-10 tons of carbon per hectare (Soni et al., 1992).

In terms of commercial wood production, forests occupy a central economic position, generating valuable export revenue for national development and improving their balance of payments. Thus

their economic importance continues to grow in the coming years. In terms of energy, in developing countries about two billion people still rely on traditional fuels as their principal source of energy. Biomass accounts for 15% of the world's total energy consumption and fuel wood accounts for 5% of total energy consumption.

Forests also play an important role in providing recreational and aesthetic beauty. People without forest-defined cultures also go to forests to enjoy their special aesthetic and recreational qualities.

1.4 FOREST HISTORY

Forests have occupied large tracts of land in India since time immemorial. There are passing references to forests in the 'Ramayan' and the 'Mahabharat'. The first mention of management of forests is found in Kautilya's 'Arthashastra', which describes this subject during the reign of Chandragupta Maurya in 300 B.C. A Superintendent of Forests was appointed during those days for the protection of forests. There were punishments for forest offences during those days. In those days, forests were classified on the basis of religion, land for grazing of royal elephants and hunting grounds for royals as well as for the public (Chaturvedi, 1992).

During the days of Ashoka, importance was given to the planting of trees along the roads and on camping sites. The Mughal Emperor, Akbar, had evinced interest in the planting of trees along canals. The specified species of timber values were proclaimed by local rulers as Royal trees; otherwise, forests were open to all to do what they liked. The step towards conservation began in the year 1900. A commission was appointed to enquire into the availability of teak in the Malabar forests and a ban was imposed on the felling of teak below 21 inches in girth.

During the British rule, a German, Dr. Brandis, was appointed to set up a forestry management in India. He then established the forest department under the Government of India on 1st November 1864 and became India's first Inspector General of Forests. The Indian Forest Act, 1865 also came into being as the first attempt on forest legislation by the British. During the period 1871-1900 preparation of working plans was done for the treatments of forests based on scientific considerations.

Presently, the locals cause destruction of forests. The locals, including tribals, have never contributed to the regeneration of forests but have used forest products. The forest rangers are often blamed for not being able to take care of the forests and many people are of the view that transferring forests to local control will improve the situation.

These forests were under no management at one time. Then they passed through a phase of consolidation and good management. They are now returning to the stage of no management due to the populist view that forests must meet the local needs even at the cost of total destruction. The forests are deteriorating very fast. Unregulated felling is on the increase with negligible amount of regeneration. Instances of protection of forests by local people are few and far between.

1.5 STATUS OF FORESTS

1.5.1 Global

About 10,000 years ago, the earth boasted of a rich mantle of forests and open woodland covering some 6.2 billion hectare. (Postel & Heise, 1988). Over the centuries, a combination of land clearing for crop production, commercial timber harvesting, cattle ranching and

fuel wood gathering have shrunk the forest cover to 7000 million hectares in 1900 (Brew Baker, 1994) and to 4,147 M ha. in 1994 (Dwivedi, 1994) (Table 2). The table shows that about 32% of the world's land area is covered with forests.

Table 2 : Distribution of world's forestland (M ha.)

Sr. No.	Region	Total Land Area	Closed Forest	Open Forest	Total	Percent of total Land area forested
1	N. America	1835	469	215	684	37
2	Europe	472	153	21	174	37
3	Former USSR	2227	792	128	920	41
4	Others	950	72	70	142	15
	Developed Countries Subtotal	5484	1486	434	1920	35
5	Africa	2966	218	500	718	24
6	S. America	2054	692	250	942	46
7	Asia	2573	469	98	567	22
	Developing Countries Subtotal	7593	1379	848	2227	29
	World Total	13077	2865	1282	4147	32
Source : Dwivedi, 1994						

The Food and Agricultural Organisation (FAO) of the United Nations assesses the forest cover of the world regularly. A comparative account of percent of forest cover and per capita availability in different regions and countries of the world, as per the FAO, is given in Table 3. It shows that per capita forest in India is very low as compared with the world's average.

1.5.2 India

Forests in India are not evenly distributed and are mostly in the mountainous regions. The Northern plains are completely devoid

Table 3 : Global Status of Forest Cover

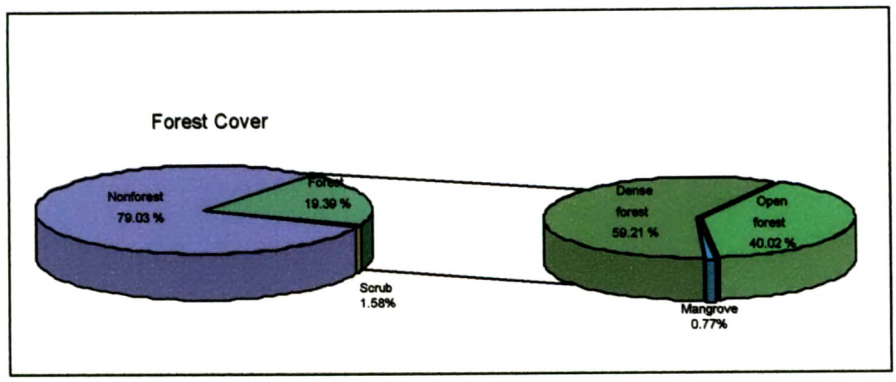
Sr. No.	Region/Country	Percentage of forest cover to land area (1995)	Per capita forest (ha)
1	World*	26.6	0.64
2	Asia*	16.4	0.1
3	Africa*	17.7	0.7
4	Europe*	41.3	1.3
5	China	14.3	0.1
6	Pakistan	2.3	0.01
7	Nepal	33.7	0.2
8	Bangladesh	7.8	0.02
9	Sri Lanka	27.8	0.1
10	Indonesia	60.6	0.6
11	Malaysia	47.1	0.8
12	Philippines	22.7	0.1
13	Japan	66.8	0.2
14	USA	23.2	0.8
15	India	15.7	0.06
Source: State of World Forests, FAO (1999)			
* Region			

of forests. Only mountain ranges e.g. the Himalayas, Western Ghats, Satpuras, Vindhyas etc. possess some area covered with forests.

Out of a total geographical area of 328.8 million hectares in India, approximately 63.7 million hectares of land have been classified as forests, which is 19.39% of the geographical area of the country. Dense forests, open forests and mangroves constitute 11.48 %, 7.76% and 0.15% respectively (Figure 1) of the geographic area. Statewise details of the forest cover in the three categories are given in Table 4.

The government owns about 95% of the forests of the country. The remaining 4% is owned by corporate bodies and 1% by private individuals. Government forests are classified into reserved, protected and unclassed forests under the provision of the India

Figure 1 : Forest Cover Status of India



Forests Act, 1927. Reserved forest is an area notified under the provisions of the Indian Forest Act or State Forest Acts having full degree of protection. In reserved forests, all activities are prohibited unless permitted. The protected forest is an area notified under the provisions of the Indian Forest Act or State Forest Acts having limited degree of protection. In protected forests, all activities are permitted unless prohibited. Unclassed forest is an area recorded as forest but not included in the reserved or protected forest category. Ownership status of such forests varies from state to state. Thus reserved forests, protected forests and unclassed forests constitute 54.44%, 29.18% and 16.38% of the forest area respectively. Statewise details of recorded forest area are furnished in Table 5.

1.5.3 Gujarat

Gujarat has a forest area of 19.6 million ha, which constitutes 5.96% of the geographical area of the country (FSI, 1999). It is situated on the western coast of the country and lies between latitude 20° 07′ & 24 ° 43' N and longitude 68 ° 10' & 74 ° 29' E. There are four forest types viz. Tropical Moist deciduous, Tropical Dry Deciduous, Tropical Thorn and Littoral and Swamp Forest. The forests are mostly

Table 4 : Extent of Dense forest, Open forest, Mangrove in State/UTs (sq. km.)

Sr No	State/UT	Dense Forest	Open Forest	Mangrove	Total Forest Cover	Percentage of geographic area	Scrub
1	Andhra Pradesh	24,190.00	19,642.00	397.00	44,229.00	16.08	9,559.00
2	Arunachal Pradesh	57,756.00	11,091.00	0.00	68,847.00	82.21	104.00
3	Assam	14,517.00	9,171.00	0.00	23,688.00	30.20	324.00
4	Bihar	13,274.00	13,200.00	0.00	26,474.00	15.23	1,914.00
5	Delhi	35.00	53.00	0.00	88.00	5.93	3.00
6	Goa	995.00	251.00	5.00	1,251.00	33.79	16.00
7	Gujarat	6,430.00	5,504.00	1,031.00	12,965.00	6.61	2,948.00
8	Haryana	449.00	515.00	0.00	964.00	2.18	191.00
9	Himachal Pradesh	9,120.00	3,962.00	0.00	13,082.00	23.50	566.00
10	Jammu & Kashmir	11,019.00	9,422.00	0.00	20,441.00	9.20	3,089.00
11	Karnataka	24,832.00	7,632.00	3.00	32,467.00	16.93	4,489.00
12	Kerala	8,429.00	1,894.00	0.00	10,323.00	26.56	91.00
13	Madhya Pradesh	81,619.00	50,211.00	0.00	131,830.00	29.73	3,853.00
14	Maharashtra	26,613.00	19,951.00	108.00	46,672.00	15.17	7,160.00
15	Manipur	5,936.00	11,448.00	0.00	17,384.00	77.86	177.00
16	Meghalaya	5,925.00	9,708.00	0.00	15,633.00	69.70	261.00
17	Mizoram	3,786.00	14,552.00	0.00	18,338.00	86.99	125.00
18	Nagaland	5,137.00	9,027.00	0.00	14,164.00	85.43	14.00
19	Orissa	26,073.00	2,745.00	215.00	47,033.00	30.21	5,439.00
20	Punjab	517.00	895.00	0.00	1,412.00	2.80	107.00
21	Rajasthan	4,309.00	9,562.00	0.00	13,871.00	4.05	6,921.00
22	Sikkim	2,363.00	755.00	0.00	3,118.00	43.94	386.00
23	Tamil Nadu	8,659.00	8,398.00	21.00	17,078.00	13.13	2,836.00
24	Tripura	2,228.00	3,517.00	0.00	5,745.00	54.79	38.00
25	Uttar Pradesh	22,902.00	11,114.00	0.00	34,016.00	11.55	1,177.00
26	West Bengal	3,565.00	2,672.00	2,125.00	8,362.00	9.42	98.00
27	Andaman & Nicobar islands	6,515.00	125.00	966.00	7,606.00	92.21	0.00
28	Chandigarh	6.00	1.00	0.00	7.00	6.14	0.00
29	Dadra & Nagar Haveli	159.00	43.00	0.00	202.00	41.14	10.00
30	Daman & Diu	0.00	3.00	0.00	3.00	2.68	0.00
31	Lakshadweep	0.00	0.00	0.00	0.00	0.00	0.00
32	Pondicherry	0.00	0.00	0.00	0.00	0.00	0.00
	Total	377,358.00	237,064.00	4,871.00	637,293.00		51,896.00

Source: FSI, 1999

distributed in the southern part of the state, whereas the middle and eastern parts bear bamboo forests of inferior quality. The main forest formations in the state are of teak, bamboo and mangroves.

The forest cover of the state, based on satellite data of Oct.-Dec. 1996 is 12,965 sq. km., which is 6.61% of the geographical area (FSI, 1999). Forest cover details of dense, open and mangrove forests and scrub among the districts are depicted in Table 6.

Vadodara district has 7,794 sq. km. of the geographical area of the state. It constitutes 497 sq. km. i.e. 6.38% of the forest cover (FSI, 1999).

An inventory of the forest cover through conventional methods would be too expensive and time consuming. Thus, a technique to meet this information in a short time at a minimal cost and with a reasonable accuracy was needed. Such a need was fulfilled by the science of remote sensing which has a synoptic view and repetitive coverage, covering inaccessible areas. It is also economical in terms of cost and time. Thus, the use of remote sensing technique with ground sampling can aid in monitoring the forest ecosystem with repetitive, real time data at a lower cost and with less time and efforts.

1.6 REMOTE SENSING

1.6.1 Introduction

Remote sensing means acquiring information about a phenomenon, object or surface while at a distance from it. It is the science and art of obtaining information about an object, area or phenomenon through the analysis of data acquired by a device that

Table 5 : Distribution of Recorded Forest Area in State/ UTs (sq.km.)

Sr. No.	State/UT	Geographical area	Reserved Forest	Protected Forest	Unclassed Forest	Total forest area	Percentage of forest area
1	Andhra Pradesh	275,068.00	50,479.00	12,365.00	970.00	63,814.00	23.20
2	Arunachal Pradesh	83,743.00	15,321.00	8.00	36,211.00	51,540.00	61.54
3	Assam	78,438.00	18,242.00	3,934.00	8,532.00	30,708.00	39.15
4	Bihar	173,877.00	5,051.00	24,168.00	7.00	29,226.00	16.81
5	Delhi	1,483.00	78.00	7.00	0.00	85.00	2.83
6	Goa	3,702.00	165.00	0.00	1,259.00	1,424.00	38.46
7	Gujarat	196,024.00	13,819.00	997.00	4,577.00	19,393.00	9.89
8	Haryana	44,212.00	247.00	1,104.00	322.00	1,673.00	3.78
9	Himachal Pradesh	55,673.00	1,896.00	31,473.00	2,038.00	35,407.00	63.60
10	Jammu & Kashmir	222,235.00	20,182.00	0.00	0.00	20,182.00	9.08
11	Karnataka	191,791.00	28,611.00	3,932.00	6,181.00	38,724.00	20.19
12	Kerala	38,863.00	11,038.00	183.00	0.00	11,221.00	28.87
13	Madhya Pradesh	443,446.00	82,700.00	66,678.00	5,119.00	154,497.00	34.84
14	Maharashtra	307,690.00	48,373.00	9,350.00	6,119.00	63,842.00	20.75
15	Manipur	22,327.00	1,463.00	4,171.00	9,520.00	15,154.00	67.87
16	Meghalaya	22,492.00	981.00	12.00	8,503.00	9,496.00	42.34
17	Mizoram	21,081.00	7,127.00	3,568.00	5,240.00	15,935.00	75.59
18	Nagaland	16,579.00	86.00	507.00	8,036.00	8,629.00	52.04
19	Orissa	155,707.00	27,087.00	30,080.00	17.00	57,184.00	36.73
20	Punjab	50,362.00	44.00	1,107.00	1,750.00	2,901.00	5.76
21	Rajasthan	342,239.00	11,585.00	16,837.00	3,278.00	31,700.00	9.26
22	Sikkim	7,096.00	2,261.00	285.00	104.00	2,650.00	37.34
23	Tamil Nadu	130,058.00	19,486.00	2,528.00	614.00	22,628.00	17.40
24	Tripura	10,486.00	3,588.00	509.00	2,196.00	6,293.00	60.01
25	Uttar Pradesh	294,411.00	36,425.00	1,499.00	13,739.00	51,663.00	17.54
26	West Bengal	88,752.00	7,054.00	3,772.00	1,053.00	11,879.00	13.38
27	Andaman & Nicobar islands	8,249.00	2,929.00	4,242.00	0.00	7,171.00	86.93
28	Chandigarh	114.00	31.00	0.00	0.00	31.00	27.19
29	Dadra & Nagar Haveli	491.00	198.00	5.00	0.00	203.00	41.34
30	Daman & Diu	112.00	0.00	0.70	0.00	0.70	0.62
31	Lakshadweep	32.00	0.00	0.00	0.00	0.00	0.00
32	Pondicherry	493.00	0.00	0.00	0.00	0.00	0.00
	Total	3,287,326.00	416,547.00	223,321.70	125,385.00	765,253.00	23.28

Table 6 : Districtwise forest cover (sq. km.) (1999)

Sr. No.	District (T-Tribal)	Geographical Area	Dense forest	Open forest	Mangrove	Total	Change compared to 1997	Scrub
1	Ahmedabad	8,707.00	3.00	50.00	0.00	53.00	0.00	94.00
2	Amreli	6,760.00	107.00	84.00	0.00	191.00	0.00	53.00
3	Banaskantha-T	12,703.00	433.00	314.00	0.00	747.00	1.00	256.00
4	Bharuch	9,038.00	730.00	456.00	6.00	1,192.00	-34.00	135.00
5	Bhavnagar	11,155.00	29.00	91.00	25.00	145.00	4.00	152.00
6	Gandhinagar	649.00	3.00	10.00	0.00	13.00	4.00	2.00
7	Jamnagar	14,125.00	25.00	173.00	140.00	338.00	61.00	67.00
8	Junagarh	10,607.00	1,158.00	494.00	1.00	1,653.00	45.00	47.00
9	Kheda	7,194.00	0.00	41.00	0.00	41.00	1.00	38.00
10	Kachchh	45,652.00	251.00	1,035.00	854.00	2,140.00	294.00	739.00
11	Mehasana	9,027.00	0.00	32.00	0.00	32.00	0.00	98.00
12	Panchmahal-T	8,866.00	396.00	610.00	0.00	1,006.00	-3.00	473.00
13	Rajkot	11,203.00	6.00	81.00	0.00	87.00	7.00	60.00
14	Sabarkantha-T	7,390.00	370.00	304.00	0.00	674.00	-1.00	291.00
15	Surat-T	7,657.00	907.00	380.00	4.00	1,291.00	-4.00	46.00
16	Surendranagar	10,489.00	15.00	76.00	0.00	91.00	20.00	201.00
17	The Dangs - T	1,764.00	1,008.00	496.00	0.00	1,504.00	-4.00	4.00
18	Vadodara -T	7,794.00	205.00	292.00	0.00	497.00	-2.00	169.00
19	Valsad -T	5,244.00	784.00	485.00	1.00	1,270.00	-2.00	23.00
		196,024.00	6,430.00	5,504.00	1,031.00	12,965.00	387.00	2,948.00

is not in contact with the object, area or phenomenon under investigation (Lillesand & Kiefer, 1994).

1.6.2 Principle

The distance sensing of objects through non-contact methods involves the use of electromagnetic radiation (EMR) emitted by the objects. Incoming solar energy peaks at about 10 μm and is negligible below 3 μm. The whole remote sensing is based on this unique spectral signature of objects. Detection and discrimination of objects or surface features means detecting of radiant energy reflected or emitted by objects or surface material. Different objects return different amount and kind of energy in different bands of the

electromagnetic radiation incident upon them. The reflection depends on the property of the object (structural, chemical & physical) and also surface roughness, angle of incident, intensity and wavelength of radiant energy.

1.6.3 Requirements

Any study in remote sensing is basically dependent on three components: firstly, the EMR, secondly, sensors recording the EMR and thirdly, platforms carrying the sensors.

Electromagnetic Radiation

The electromagnetic radiations travelling at a velocity of $3x10^{8}ms^{-1}$ form the basis in remote sensing technology. These radiations represent a high speed communication link between the sensor and remotely located objects. Although human eyes are sensitive only to the visible light, the remote sensing techniques have extended the human viewing capability to other segments of the spectrum.

1.6.4 Stages in Remote Sensing

- Emission of electromagnetic radiation, or EMR (sun/self emission)
- Interactions with the atmosphere
- Interaction of EMR with the earth's surface
- Transmission of energy from the surface to the remote sensor
- Data processing, output and analysis

1.6.4.1 Emission of electromagnetic radiation, or EMR (sun/self-emission)

Electromagnetic radiation is composed of many discrete units called photon/quanta. The source of electromagnetic radiation is solar energy. It is termed as electromagnetic spectrum, which ranges between 10^{-11}cm – 10^{2}cm (Table 7). Each particle on the earth's surface emits the energy within the range of electromagnetic spectrum. The remote sensing senses these radiations providing us with the information.

Table 7 : Electromagnetic Spectrum

Division	Wavelength
Gamma rays	10^{-11} cm $< \lambda <$ 10^{-8} cm
X-rays	10^{-8} cm $< \lambda <$ 10^{-6} cm
Ultraviolet light	10^{-6} cm $< \lambda <$ $4 \xi 10^{-5}$ cm
Visible light	4×10^{-5} cm $< \lambda <$ 7.6×10^{-5} cm
Infra-red light	8×10^{-5} cm $< \lambda <$ 10^{-1} cm
Microwaves	10^{-1} cm $< \lambda <$ 10^{2} cm
Radiowaves	10^{2} cm $< \lambda$

1.6.4.2 Interactions with the atmosphere

Atmospheric effect affects the satellite data products. These are caused by the interaction of the electromagnetic radiation emitted by the objects with the different atmospheric constituents such as aerosol. These electromagnetic radiations therefore get slightly modified from its original form. Scattering, absorption and refraction are the different processes related to the interaction of EMR with the atmosphere.

1.6.4.3 Interaction of EMR with the earth's surface

Radiation incident upon the earth's surface is reflected, refracted or absorbed by the earth's surface. The reflections vary based on the type of the surface and each reflection is therefore unique. It is considered to be the spectral signature of that object.

1.6.4.4 Transmission of energy from the surface to the remote sensor

The sensors placed on the platforms take up the energy coming from the surface. Platforms are of three types, viz. ground borne, air borne and space borne.

Ground borne :

It includes two devices, viz. cherry arm configuration of the remote sensing van and tripod. These have the capability of viewing the object from different angles.

Air borne :

It can be further classified into balloon-based and aircraft-based platform. In India, four types of aircrafts are used as remote sensing platforms, viz. the Dakota, Avro, Cessna and Canberra. Some foreign countries use aircrafts like U-3, Rockell and X-15.

Space borne :

This comprises the panel-studded observatories in space which are also termed as satellites. In India, the satellite for natural resources is the IRS series (Table 8). The mode can be geostationary, permitting continuous sensing of a portion of the earth or it can be sun synchronous with polar orbit covering the entire earth at the same equator crossing time.

Table 8 : Specification of IRS Series Satellites

Satellites	Year	Sensors	Spectral Bands (m)	Nominal Spectral Location	Spectral Resolution (m)	Swath Width (km)	Repeatitive Coverage (days, at equator)
IRS - 1A/1B	1988, 1991	LISS I	0.45-0.52	Blue	72.5	148	22
		LISS II	0.52-0.59	Green	36.25	146	
			0.62-0.68	Red			
			0.77-0.86	Near Infrared (IR)			
IRS -1C/1D	1995, 1997	LISS III	0.52-0.59	Green	23.5	142	24
			0.62-0.68	Red	23.5	142	
			0.77-0.86	Near Infrared (IR)	23.5	142	
			1.55-1.70	Mid IR (Short wave IR - SWIR)	70	148	
		Panchromatic	0.50-0.75	Panchromatic	5.8	70	5
		WiFS	0.62-0.68	Red	188	774	5
			0.77-0.86	Near Infrared (IR)	188	774	

1.6.4.4.1 Sensors

'Sensor' is a device used to gather information with the help of electromagnetic radiation, which is converted into signals and then into usable information. Sensors are of two types: active or passive depending on the source of energy.

Active sensors use their own energy. A passive sensor uses the solar electromagnetic energy. The types of sensors operating are listed in Table 9.

1.6.4.4.2 Sensor operation

Sensor operations can be grouped into two categories depending upon the mechanism used by the sensor to view each pixel.

i) Electromechanical, also called Across track scanning: the sensor oscillates from side to side to form an image.

ii) Linear array or Along track scanning: an array of detectors is used to simultaneously sense the pixel values along a line.

1.6.4.5 Data processing, output and analysis

The information from the sensor is received by the ground station on high-density digital tapes, which gets processed through high-speed interactive computers, into interpretable formats. The output of the data is in the magnetic tape or CD. Another type of output is an image form by using a photographic film and then analysis is done.

1.7 GEOGRAPHICAL INFORMATION SYSTEM

1.7.1 Definition

Geographical or spatial data represent phenomena from the real world in terms of (a) their position with respect to a known co-ordinate system, (b) their attributes that are unrelated to position (such as colour, cost, pH, incidence of disease) and (c) their spatial interrelation with each other which tells about their linkage together. This data can be analysed, processed, stored and retrieved using the powerful GIS system for generating logical conclusion. This important system of GIS has been looked at from three different angles by different workers. Burrough, (1986) and Parker, (1988) gave a tool-based definition which looks upon GIS as an information technology which stores, analyses and displays both spatial and non-spatial data. Smith et al, (1987) considered GIS as a database system in which most of the data are spatially indexed and upon which a set of procedures are operated in order to answer queries about spatial

Table 9 : Types of Sensors

Sr. No.	Sensors	Sensors Types	Description
1	Photographic camera		A film similar to normal photography.
2	Vidicon Television camera		Television type camera generally formed for orbital remote sensing is based on return beam vidicon tube. The RBV system consists of three television-like cameras to view the same 185x185 km. ground area simultaneously.
3	Optical scanner		It records sequentially the area elements of the scene as narrow shivers, through a process called scanning.
		Multispectral Scanner	Landsat series are loaded with multispectral scanner. The design of the component is such that each instantaneous field of view is 99.3x79.3 m., which due to overlap arising from sampling procedure is effectively reduced to 79.3x59.6 m.
		Thematic mapper	Landsat 4&5 has been equipped with an improved resolution and an extended spectral range in the visible and reflected infrared region.
		Push Broom Scanner	SPOT-1 carried two identical push broom scanners called high-resolution visible scanners. These scanners are used to record in panchromatic or multispectral mode. The 10m. resolution from 0.51-0.7 μm could be used for planimetric studies and 20m. multispectral mode for environmental studies
		Linear Imaging Self Scanning Sensors (LISS)	IRS series carry LISS sensors. There are three sensors: LISS I, LISS II and LISS III. Each sensor has 2048 detectors arranged in the form of linear arrays, which are based on the broom concept.
		Very High Resolution Radiometer (VHRR)	It is employed on INSAT for meteorological earth observations. It operates in visible, IR wavelength region with a spatial resolution of 2.75x2.75 km. and 11m.x11m. resolution.
		Advanced Very High Resolution Radiometer (AVHRR)	The AVHRR carried by NOAA satellite has four spectral channels, two visible and two IR with a capability to acquire data in the morning and afternoon of a day at each location.
4	Microwave Radiometer		The microwave radiometer operating in millimeter and centimeter wavelength bands is a passive radiometer, which intercepts the earth's electromagnetic waves by means of large aperture directional antennae. The advantage of this radiometry is that the windows remain clear even in the presence of clouds.
5	Microwave Radar		Radar system provides its own illumination and records the radar return from the ground. The type of imaging radar generally considered for earth observations is the side-looking radar.

entities in the database. Cowen, in 1988, gave a different view on GIS considering it as a decision support system involving the integration of spatially referenced data in a problem-solving environment. GIS can therefore be considered as an information system, which processes data about the physical and cultural world and uses these to do research in order to solve practical problems.

1.7.2 History of GIS

GIS history dates back to 1960 and is computer based. Hundred years or so earlier, manual procedures were used. The initial developments originated in North America with different organizations such as the US Bureau of the Census, US Geological Survey, Environmental Systems Research Institute and others. In the 1970s, a sound and stable data structure to store and analyze map data became dominant. This led to the introduction of topology in GIS. Topology and related graph theory proved to be effective and efficient tools to provide logically consistent two-dimensional data representations. Another significant breakthrough occurred with the introduction and spread of personal computers in the 1980s. It was possible to execute programs that previously could only run on mainframe computers. Relational database technology became the standard. Research on spatial data structures, indexing methods and spatial databases made tremendous progress. The 1990s was characterized as a period of the object orientation in system and database design, recognition of geoinformatics as a professional activity and spatial information theory as the theoretical basis for GIS.

In India, the major developments have happened in the last decade with significant contribution coming from the Department of

Space emphasizing the GIS applications for Natural Resources Management. Notable among them are Natural Resource Information System (NRIS), Integrated Mission for Sustainable Development (IMSD) and Biodiversity Characterisation at National Level. India has realized the importance of GIS for many applications like natural resource management, infrastructure development, facility management, business/market applications, etc. and has taken up many GIS based projects according to the user organization requirements.

1.7.3 Elements of GIS

GIS has been divided into four elements: hardware, software, data and liveware (Table 10).

1.7.4 Data Models

The conversion of real world geographical variation into discrete objects is done through data models. The linking of the real world domain of geographic data and complete representation of this feature is done through data models.

Basically, data models are of two types: raster and vector. A **raster data model** is comprised of a collection of grid cells. In this type, for representation of geographic data, sets of cells with definite co-ordinates are used; each cell is independently addressed with the value of an attribute. **Vector data model** uses line segments or points represented by their explicit x, y co-ordinates to identify locations. Connecting line segments whose area is defined by a set of line segments form different discrete objects.

Table 10 : Elements of GIS

Sr.No.	Elements of GIS	Details
1	Hardware	**Types of Computer Platforms** - Modest Personal Computers - High performance workstations - Minicomputers - Mainframe computers **Input Devices** - Scanners - Digitizers - Tape drivers - CD - Keyboard - Graphic Monitor **Output Devices** - Plotter - Printers
2	Software	Input Modules Editing MRP Manipulation/ Analysis Modules Modeling Capability
3	Data	Attribute Data Spatial Data Remote Sensing Data Global Database
4	Liveware	People responsible for digitizing & implementing GIS Trained personnel

1.7.5 Data Structures

The organization of data structures inside the information is done through number of ways. It affects data storage, volume and processing efficiency. In addition to spatial information, many GIS software have specialized capabilities for storing and manipulating attribute data in addition to spatial information. There are three basic data structures, viz.

- **Relational :** It organizes the data in terms of two-dimensional tables.
- **Hierarchical :** It stores the data in a way that a hierarchy is maintained among the data items.
- **Network data structure :** It is similar to the hierarchy structure with the exception that in this structure a node may have more than one parent.

1.7.6 GIS Analysis

For effective utilization of natural resources or sustainable development, GIS perform a variety of spatial analysis including overlaying combinations of features and recording resultant conditions, analyzing flows or other characteristics of network proximity analysis and defining districts in terms of spatial criteria. It turns out to be a very effective tool for the decision-making process.

1.8 REMOTE SENSING AND GIS FOR FORESTRY MAPPING AND MONITORING

An integrated approach using Remote sensing and GIS can solve several issues related to forests. The extent of forest cover changes over a certain span of time can be monitored. Strategies for restoration, protection and conservation can be studied. The role of the forest ecosystem in terms of climate and other abiotic components can be emphasized. The damage due to diseases and fire can be analysed and timely, imperative measures can be suggested.

The advent of remote sensing has made a technological breakthrough in gathering information on natural resources specifically in the field of forestry. The use of aerial remote sensing

for forest related study has been operationalised since long. In India, from 1970-1978, series of aerial surveys, essentially using multiband aerial photography and concerning interpretation of colour IR photographs were undertaken by ISRO.

In India, aerial photo interpretation was conducted for coconut wilt disease in Kerala (Dakshnamurti et al. 1971). Heller & Wear (1952) reported that the aerial surveys were routinely conducted to detect crop damage by pests and to map forest cover. The study on forest and land use survey has been done in the economically backward district of Panchmahals and land use survey in the Idukki district of Kerala. Tomar and Maslekar (1974) did land use and forest type classification using aerial photo interpretation.

The era of multispectral photography began after extensive use of black and white aerial photography. Colwell (1960) explained in detail the use and limitations of multispectral remote sensing. Rhode (1972) gave an account of multispectral sensing of forest tree species.

The aerial remote sensing gave more accurate results than the satellite imageries but it has a high cost of data generation, lack of synoptic view, non-availability of repetitive coverage and complexity of data handling in comparison to satellite data. The potential of satellite imagery for forest related studies has been shown by several workers. Heath (1974) has given an account of Earth Resources Technology Satellite and its potential in Forestry.

Porwal and Roy (1992) did a comparative study of satellite imagery and aerial photography for forestry studies. Beaubien and Jobin, (1974) used digital technique for mapping of forest damage and cover types of Anticosti Island. Aldrich (1975) used space imagery for detecting disturbances in a forest environment. In India,

Madhavan Unni (1977) carried out computer classification and delineation of plantation types using digital visual mix methodology. Jadhav, R.N. (1984) also prepared compartment level maps of north and south Dangs division using Salyut-7 data.

The mapping and the monitoring of forest resources have increased considerably in India after the launching of the IRS satellite. Since then, numerous studies have been carried out regarding mapping of forest type (Porwal & Pant (1989), Jadhav et al (1986 & 1997), Roy et al (1995), Kachhwaha, (1990) and Roy & Das, (1991)). Agarwal (1991) had taken up study for preparation of forest stock maps for Gora range of Rajpipla forest division in Gujarat using satellite remote sensing data.

Remote sensing has proved to be a very effective means for developing an integrated GIS, which could meet the challenges of managing forests. Synergistic approach of remote sensing and GIS benefit in a way that remote sensing provides both detection and monitoring abilities as well as a philosophical approach and GIS has analytical capabilities which give the best results. The data available through different agencies are often incompatible and too large. In such cases, the conventional method seems to be inaccurate and time consuming. In such circumstances, computerized GIS takes a big leap by integrating geo-related information.

Climate and terrain has a significant role to play in the development of forest cover. GIS can be used to establish a relationship between these parameters. Several studies have been carried out on the holistic approach of remote sensing and GIS.

Several models have been generated for different resource planning both in India and abroad. Considerable works have been done using GIS, regarding forest planning and management (Martin

1985, Reisinger & Davis, 1987, Hendrix & Price, 1988) and land capability and its suitability for different resources (Xing Hong & Hua 1992; Jere & Sridhar, 1993; Whitley et al., 1993). Jadhav et al (1992) also generated a model for the Gir forest working plan revision using GIS technology in Gujarat. A study on forest fire prone area mapping of Gir protected area was carried out by Jadhav et al. in 1999. A status report for fire studies in tropical forests has been prepared by Roy & Gregoire, (1999). Rangnath et al (2000) prepared a status report showing the use of modern technology and information system for suitable forest management. The forest cover monitoring using RS & GIS, in Dhaulkand range, Uttar Pradesh, was done by Das et al (1990). Pathak (1997) suggested GIS principles and applications in forestry studies.

Numbers of studies have been carried out on the forest cover, using remote sensing and GIS technique, which have profound use in forest monitoring. The present study was attempted to study the status of the forest cover of the Vadodara district. Forest cover in this district is very low; no detailed analysis in this forest area has been done so far. The working plans are also decades old and in many areas there are no working plans. Thus, looking at the gaps in this field, the present study was designed with the following objectives:

1.9 OBJECTIVES

i. To select a proper season and suitable satellite data products for forest cover studies based on the phenological pattern of the vegetation therein.

ii. To delineate forest cover using the visual interpretation technique and generate a precise classification of the forest in this area.

iii. To attempt different digital analysis for enhancing the forest features and achieve further categorization of forest classes.

iv. To carry out detailed ground studies to understand the soil properties and vegetational distribution in each class delineated.

v. To estimate change in forest cover from 1970 to 1989 and from 1989-1999 using multitemporal IRS LISS data.

vi. To collect different attribute data linked to forest resource in this area and having impact on this resource.

vii. To generate a villagewise database regarding the forest cover area and fuel wood consumption.

viii. To integrate the spatial and non-spatial information generated in a GIS mode for making suggestions to the existing working plan.