1. Introduction

1.1 THE PRESENT ENVIRONMENT

One of the most critical issues which the world today faces is related to Environment. Environmental issue can therefore, be considered as a global concept. In the recent years anthropogenic activities resulting into the propagation of unsustainable life styles by the rich and the inability to meet the genuine needs of the poor for fuel, fodder, and water have highly contributed to the environmental degradation. They have broken the vital links between the biological and physiological processes, which sustains the ecological system. They are also gradually destroying the biological capitals like air, water, vegetation and other vital conditions of the environment. Thus, the demographic activities and pressures have damaged beyond recall the earth's richest and most fecund biomes reducing to minimal level the biological capacity of huge area of our planet.

The vegetation specifically in the form of forest cover constitutes the major biological investment of the earth system since its contribution and influence reach all other subsystems. Thus, forest forms a permanent vegetational cover exerting maximum influence on the environment and so its study becomes an urgent need of the present world.

1.1.1 Forest ecosystem

Forest is one of the most versatile, renewable resource consisting of natural plant communities with dominance of phenerophytes. It serves as a sink for green house gases to sustain the ecological balance and also provides five F'S i.e., Fuel, Fodder, Food, Fruits and Fertilizers for the benefit of mankind. The several ecological functions like stabilizing the soil, nutrient conservation, global cycling of carbon dioxide and water supplies moderation are done by forest. Hence, if forest is left unmanaged, the vegetational cover will come to wilderness. Unfortunately, being aware of all the above facts instead of preserving this most valuable and greatest natural heritage, it is squandered in the name of progress and development. It is subjected to pressures which are beyond its carrying capacity of the system. This can be clearly noted while studying the trends of forest cover.

1.1.2 Trends in Forest cover

Nearly 10,000 years ago, the earth boasted of a rich mantle of forest and open woodland covering some 6.2 billion hectares (Postel and 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 (Brewbaker, 1984), and to 4147 million hectares in 1994 (Dwivedi, 1994). Thus, despite growing recognition of the importance of forest to the economic and ecological health of the nations, deforestation is going on at a rapid rate as can be seen from the deforestation statistics of the developing countries (Fig.1). This has also been confirmed from the data regarding land area covered by forest in different countries of the world (Table 1). The developing countries show almost 6% less forest cover when compared to the developed countries. The table also shows that about 32% of world's land area is covered with forest. According to Brewbaker (1984), there is going to exist only 18% of forest cover by 2000 A.D., if the present deforestation trend continues. Added to this calamity is the increasing demand for fuel and fodder due to human and livestock population explosion.

The fuelwood requirement estimated for the present day population of our country itself is 150 million tonnes/year, which is likely to be 200 million tonnes/year by 2000 A.D. (Roy *et al.*, 1992). The fodder requirement in 1985 was about 746 million tonnes/year (National Dairy Research Institute report, 1985) and

ANNUAL DEFORESTATION IN DEVELOPING COUNTRIES (1981 - 85)

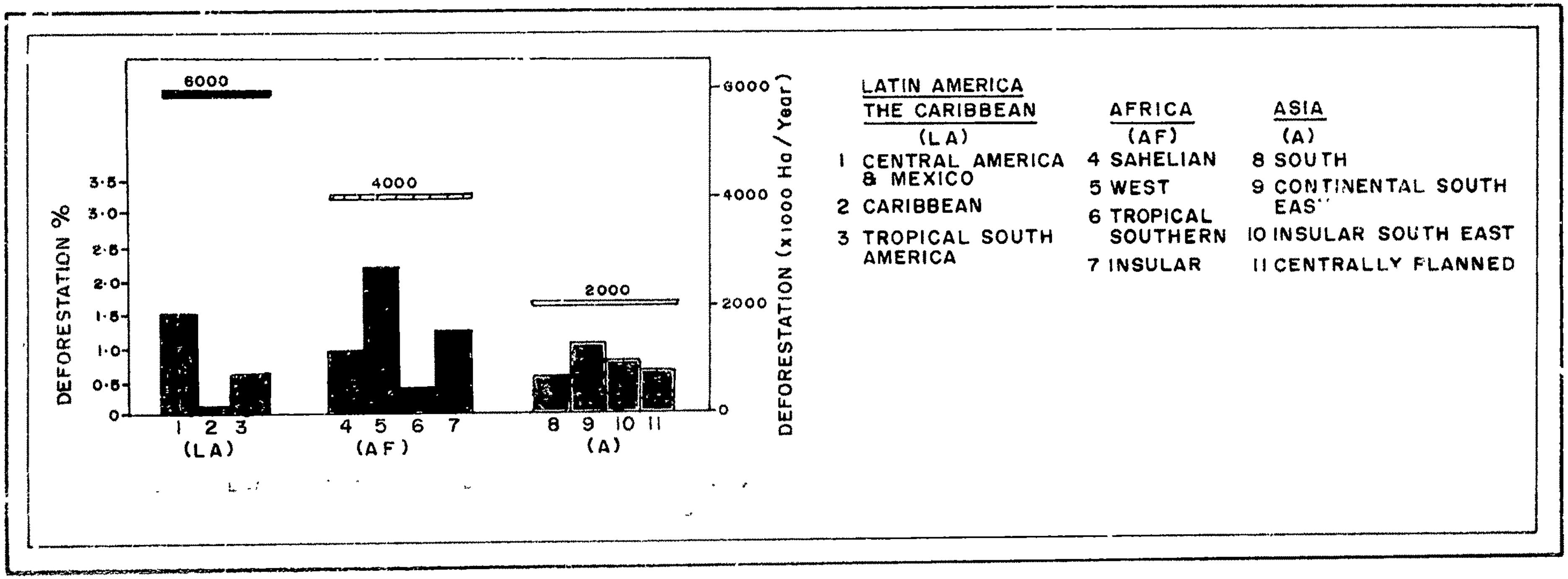


FIG. 1

(SOURCE : Rao U. R. , 1992)

Table 1 : Distribution of the world's forest land. (Million hectares)

Region	Total land area	Forest Type Closed	Forest Type Open	Total	Per cent of total land area forested
N. America	1835	469	215	684	37
Europe	472	153	21	174	37
Former USSR	2227	792	128	920	41
Others	950	72	70	142	15
Developed countries Subtotal	5484	1486	434	1920	35
Africa	2966	218	500	718	24
S.America	2054	692	250	942	46
Asia	2573	469	98	567	22
Developing Countries Subtotal	7593	1379	848	2227	29
World total	13077	2865	1282	4147	32

(Source Dwivedi, 1994)

Projected fodder requirement for 2001 A.D. is 1072 million tonnes/year (Committee of Animal Feeds and Fodder report, 1974). This over exploitation of forest resources will contribute to irrecoverable and detrimental effects like changes in the climatic conditions, soil erosion, desertification, decrease in biodiversity and several other biological backlashes.

To avoid such a situation there is a need for adoption of a holistic approach for achieving eco-friendly sustainable development. This sustainable development of the world to meet the growing demand of the rapidly increasing population without causing imbalance in the global green house effect and thus, preserving the climatic and ecological balance of the globe demands rational, practical and immediate attention towards monitoring and management of our forest through appropriate measures. Conservation and management of existing natural forests relies not only on regeneration of species and appropriate silvicultural practices but also stresses on intensive efforts towards increasing the forest wealth through social forestry and agro-forestry programmes.

The revised National Forest Policy (1988) and the Rio Earth Summit (1992) have also emphasized for greater efforts to increase the green gold through various afforestation programmes such as social forestry, farm forestry, agro-forestry etc. to recoup the ecosystem.

1.1.3. What is social forestry ?

The term social forestry was coined by Westoby during his lecture at 9th Commonwealth Forestry Conference held in New Delhi in 1968 (Muthuraman, 1994). According to Westoby, social forestry is " a forestry that aims at the flow of protection and recreation of benefits for the community". Social forestry is also defined in various ways by several professionals and academicians. According to the National Commission of Agriculture (1976), " It is a tree raising programme to supply firewood, small timber and minor forest produces to the rural population".

Whereas some foresters put it as afforestation of all available lands outside the reserve forest areas with the purpose of meeting the requirements of ecological and environmental security, the basic five F's, socio-economic development of the rural poor, preventing soil erosion and adding recreational and aesthetic values to the urban areas. In short, it is a tree planting programme of any organisation on any available vacant/waste land. These lands can be canal banks, road and rail sides, village common lands, degraded lands, marginal and sub-marginal agricultural lands, industrial complexes, urban areas, Shanti vanas, school forest, fore-shore land etc. to fulfill the day-to-day needs of rural population. Thus it is closely linked with environmental amelioration and socio-economic upliftment the latter resulting in considerable improvement in the quality of life in rural and urban centres of human habitation.

1.1.4 Wastelands

Specifically, a wasteland can be defined as a land lying unused, uncultivated and sparsely inhabitated. The appendage `waste' gives the impression of being `useless' or `Non-usable'. While some categories of land like iceberg, shifting sands, sand dunes may be `waste' in the real sense of the term, there are others which do produce some material but perhaps not of the desired quality or quantity (Sen *et al.*, 1988). This factor has lead to the conception of culturable waste and non-culturable waste, which forms the basic divisions of the wastelands of India. In short, culturable wasteland is a land "which is capable or has the potential for the development of agriculture, pasture and afforestation ", but it is not being used to its optimum level due to certain constraints like salinity, alkalinity, soil erosion, waterlogging, etc., whereas non-culturable wasteland "is a land which is barren and rocky cannot be put to any productive use such as agriculture and forest cover", e.g. snow covered or glacial areas and barren or rock out crops (Anon., 1985).

For the identification of above wastelands it is essential to understand especially their location, nature and extent for taking suitable afforestation measures. Although several agencies have estimated the total extent of wastelands differently, recent National Remote Sensing Agency (NRSA) of the Department of Space, India explained the detailed wasteland mapping of 146 critically affected districts of 18 states. The total area falling under different wastelands in India was estimated to be 53.3 million hectares which is 16.21 per cent of its total geographical area. The detailed extent of different wasteland categories of our country is shown in fig. 2. To develop these lands for productive use, Government of India passed a resolution to afforest 5 million hectares of wastelands annually through National Wastelands Development Board (NWDB). The main objectives of such afforestation activities and specifically social forestry plantation are production, rural development and ecological improvement (Tewari, 1991).

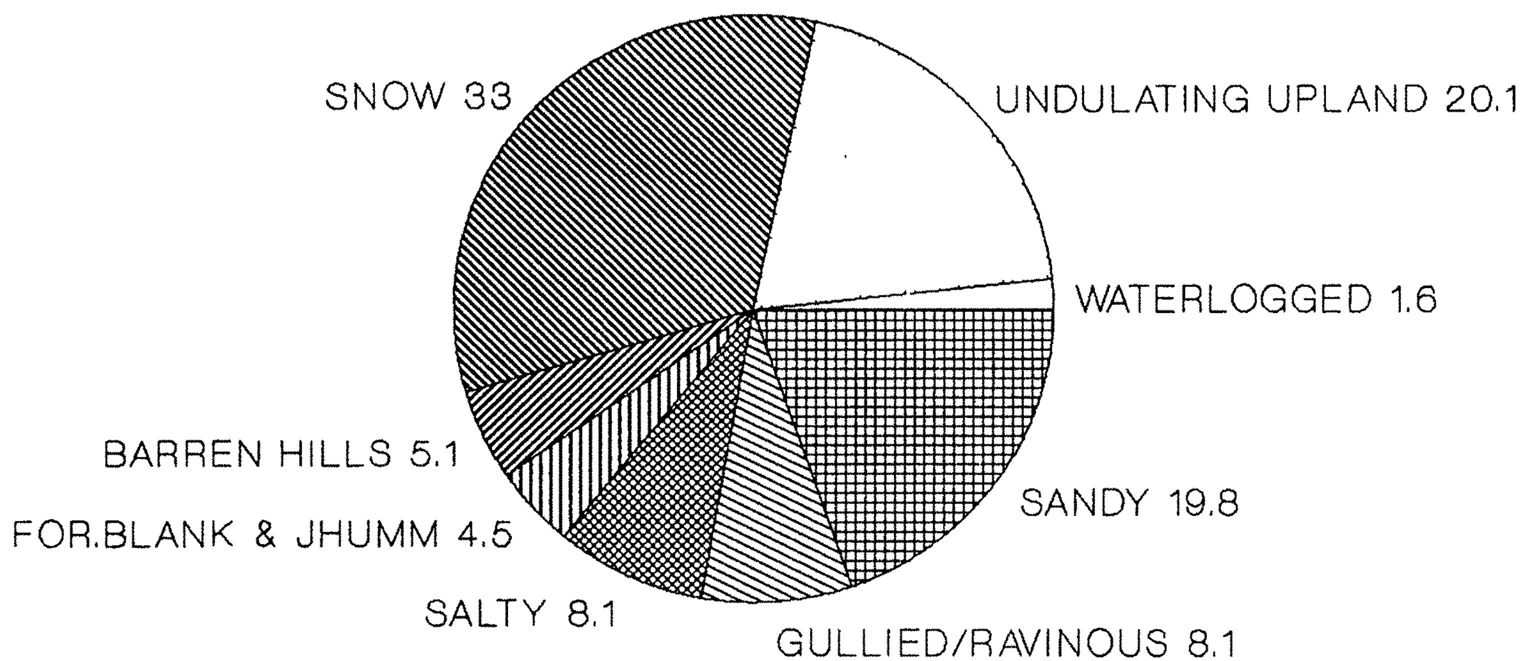
The production involves increase in

- production of raw materials for village level cottage industries based on the forest products
- production of small timber, fuelwood, and fodder for satisfying wholly or partly some of the basic needs of the rural population
- yield of crop through appropriate agro-forestry models
- yields of edible fruits, flowers, tubers and other minor forest products.

The rural development on the other hand stresses on

- increasing the income of the weaker sections of the village community
- creating additional gainful employment for the rural poor
- developing new assets which can form part of a village based cottage industry
- introducing sustained basis systems for common property resources managed by the village community which strengthens the benefits of storing mechanism and local decision making process and

TOTAL WASTELAND IN THE COUNTRY
AREA IN SQ.KMS (533003)



(VALUES IN %)

FIGURE : 2

(Source : Rao, 1994)

- helping and developing tribal intensive areas.

Finally the ecological development is mainly based on

- protecting and improving the soil
- reclaiming degraded land
- decreasing pressure on natural forest
- providing stability to environment.

Realising the importance of achieving the above goals, many of the countries have implemented these schemes. Several reports have also shown the success of this programme. For instance, the U.S. Agency for International Development (AID) has contracted with CARE and the PAN American Development foundation to encourage agro-forestry and tree farming in Haiti, USA. The project succeeded in planting more than 27 million seedlings between the year 1982 and 1986 (Winterbottom and Hazelwood, 1986). In Kenya, the green belt movement sponsored by National Council of Women of Kenya has involved more than 15,000 farmers and half million school children in establishing 670 community nurseries and planting more than 2 million trees (Sweeney, 1986).

The Chinese have successfully established trees on about 33 million hectares of land which has led to the increase of forest cover from 8.6 to 12.7 per cent of the nation land during 1948 to 1978. (China situation and outlook report, 1984) whereas in Britain, annual planting rate was 26000 hectares in 1970's and 21000 hectares in 1980's (Anon.,1992). As an outcome of all such activities, the rate of afforestation in tropical Africa, tropical America, and Asia is 0.4, 0.1 and 0.4 million hectares/year respectively (Rao, 1992).

1.1.5. Afforestation in India

It is universally accepted that India is underprivileged in forest management. The productivity of our forests is one of the lowest in the world, i.e. 0.8 cubic meter per hectare when compared to the world average of 2.1 cubic meters per hectare. Hence afforestation programmes have been launched to prevent the fast declining forest cover. As such plantation activity in India is almost several centuries old. Evidence of its existence in the country dates back to the era of Emperor Ashoka (B.C. 320) who emphasized the need for raising the roadside plantations. The occurrence of canalside plantation was also noted in the period of Mughal Emperor Akbar. Afterwards a Britisher named Mr. Conolly made a beginning in forestry development with the establishment of the Teak plantation in 1843 which is now popularly known as Nilambur Teak plantation. In 1911, the taungya system of raising agricultural crops in between planted trees gave a greater push to the afforestation activity in Bengal. However, afforestation till 1950 was not a regular and extensive activity and it remained confined to specific sites only. The second half of the century saw a radical change in the afforestation programme (Table 2).

A planned economic development was started in 1951, with the introduction of first five year plan which included afforestation for soil conservation. Afforestation of important industrial economical species and afforestation of fast-growing species was introduced in the second five year plan (1956) and third five year plan (1961) respectively.

Despite all the noble objectives the social forestry programme has failed to make any significant impact in most states and reduce the gap between demand and supply. However states like Gujarat and Haryana met with some success (Gulati, 1990). The basic reasons for the success of this programme in these states were the

Table 2. Plantation established under different schemes in India from 1951 (in thousands hectares)

Scheme	51-55	56-65	66-70	71-75	76-80	81-85	Total
Industrial Plantations	76 (53)	435 (304)	534 (374)	545 (381)	607 (424)	687 (480)	2884 (2016)
Fuel wood Plantations	1 (1)	42 (25)	68 (41)	84 (50)	191 (115)	229 (137)	615 (369)
Environmental Plantations	27 (13)	190 (95)	142 (71)	119 (60)	121 (61)	145 (73)	744 (373)
Total	104 (67)	667 (424)	744 (486)	748 (491)	919 (600)	1061 (690)	4243 (2758)

Figures in brackets correspond to areas reduced by 30%,40% and 50% to account for an average survival/success rate of 70%,60% and 50% for industrial,fuelwood and environmental plantations respectively.

(Source : Aggrawal,1990)

presence of poor natural forest cover and good cooperation of the local inhabitants in the establishment of plantations. Whereas in other states the programme was not doing so well because of several constraints like lack of information about minor forest produce, lack of suitable infrastructure, erratic rainfall, less cooperation from local people, poor site condition, unsuitable species selection and limited fund to nurture them and finally lack of information on wastelands. The statistical data on different plantation schemes like industrial, fuelwood and environmental implemented all over India (Table 2) have also shown no encouraging results, since they give an average success/survival rate which can not be taken as a basis for better plantation planning. This indicates that the implementation of this programme is not only important but the monitoring of the progress of this plantation and identification of wasteland for planting them through regular visits has also become an essential aspect of proper planning and sustainable development. Monitoring of social forestry plantation is imperative for several reasons. Firstly, it provides reliable data on the operation of this plantation programmes which is altogether lacking (Aggarwal, 1990; Anon., 1991). Secondly, it provides the information on social forestry plantation which is absent even in the Survey of India (SOI) toposheets, a major source of reference regarding landscape of India (Anon., 1990). Such plantations change the magnitude of the forest area base due to which national and state forest inventory information become obsolete within few years.

Reinventory of all plantation areas through conventional methods would be far 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. Ironically, such need coincided with man's quantum leap into the space age. Astronauts looked down, and an array of sophisticated automated sensors and electronic eyes sweeped across the heaven documenting in a vertitable avalanche of data a whole range of parameters with which a many interlocking ecosystem and subsystem are routinely quantified. In short, the science of remote sensing emerged as a boon for the earth scientist making various facets of the earth discernible. Remote sensing technique has proved its potential in monitoring of natural resources due to its repetitiveness, synoptic view, near real time data acquisition, and cost effectiveness. So the use of Remote Sensing technique with optimum ground truth samples can aid in monitoring the plantation with reduced cost, time and efforts.

1.2 REMOTE SENSING

1.2.1. Historical perspective

The idea of remote sensing dates back to 300 B.C. in India. The proof of this is found in the great epic Mahabharata in the form of Divine eye, bestowed to Sanjay to witness happenings on the battle field "Kurukshetra", a couple of hundred kilometers away from the palace and narrafe them to the blind King of Hastinapur, Dhrutrashtra. Yet another interesting form of remote sensing has been referred to by the ancient Greeks and Romans as **Duex ex Machina** in their plays to provide the ultimate solution to their problems.

Earlier, when mapping was adopted for various purposes, features of the landscape were mapped from the saddle by the use of crude instruments and "Eye ball" sketching. With the birth of photography in 1839, the vistas for the survey of natural resources became wider. Thereafter, the development of infrared film during the world war-II in 1939 for the camouflage military installations played a major role.

The practical exploration of this technique started begining in the 20th century. In the early 1960, the term Remote Sensing was coined by the staff of the Geography branch Office of the Naval Research (ONR), USA. Since then, remote sensing played a paramount role in Natural Resource inventories.

The era of satellite began with the launching of the USA meteorological satellite called as Television and Infrared Observation Satellite (TIROS-1) in April 1960. This satellite provided breath taking views of the earth in all its glory and variety of structures and features as was never seen before. This inspired the launching of satellites specifically dedicated to the observations of the earth resources during the early seventies. The first such mission was Earth Resources Technology Satellite (ERTS), later renamed as Landsat-1 in 1972 (Fischer *et al.*, 1976). The successful launching of this satellite boosted other countries resulting into generation of System Probatoire de '1' Observation de la Terre (SPOT) of France, Indian Remote Sensing Satellite (IRS) of India 1988, European Remote Sensing Satellite (ERS) etc..

1.2.2 General aspects

The problem of adequate definition for remote sensing has remained unsolved although several definitions have been put forth by different scientists. Remote Sensing is considered as the collection of information about an object without being in physical contact with the object (Sabins, 1978). Whereas, according to Colwell (1984) Remote Sensing is the measurement or acquisition of information of some property of an object or phenomenon, under study.

1.2.3 Basic concept

The most widely used remote sensing techniques are mainly based on detection/sensing of electromagnetic radiation which are reflected/scattered or emitted by objects in the earth surface.

1.2.4 Electromagnetic Radiation (EMR)

Sun is the important source of EMR used in the conventional remote sensing. EMR spans a large spectrum of wavelength right from very short wavelength gamma rays ($10^{-6}\mu m$) to long radio waves (10^{6} m) (Fig.3). In remote sensing, the most useful regions are the visible, infra red and microwave regions. All the

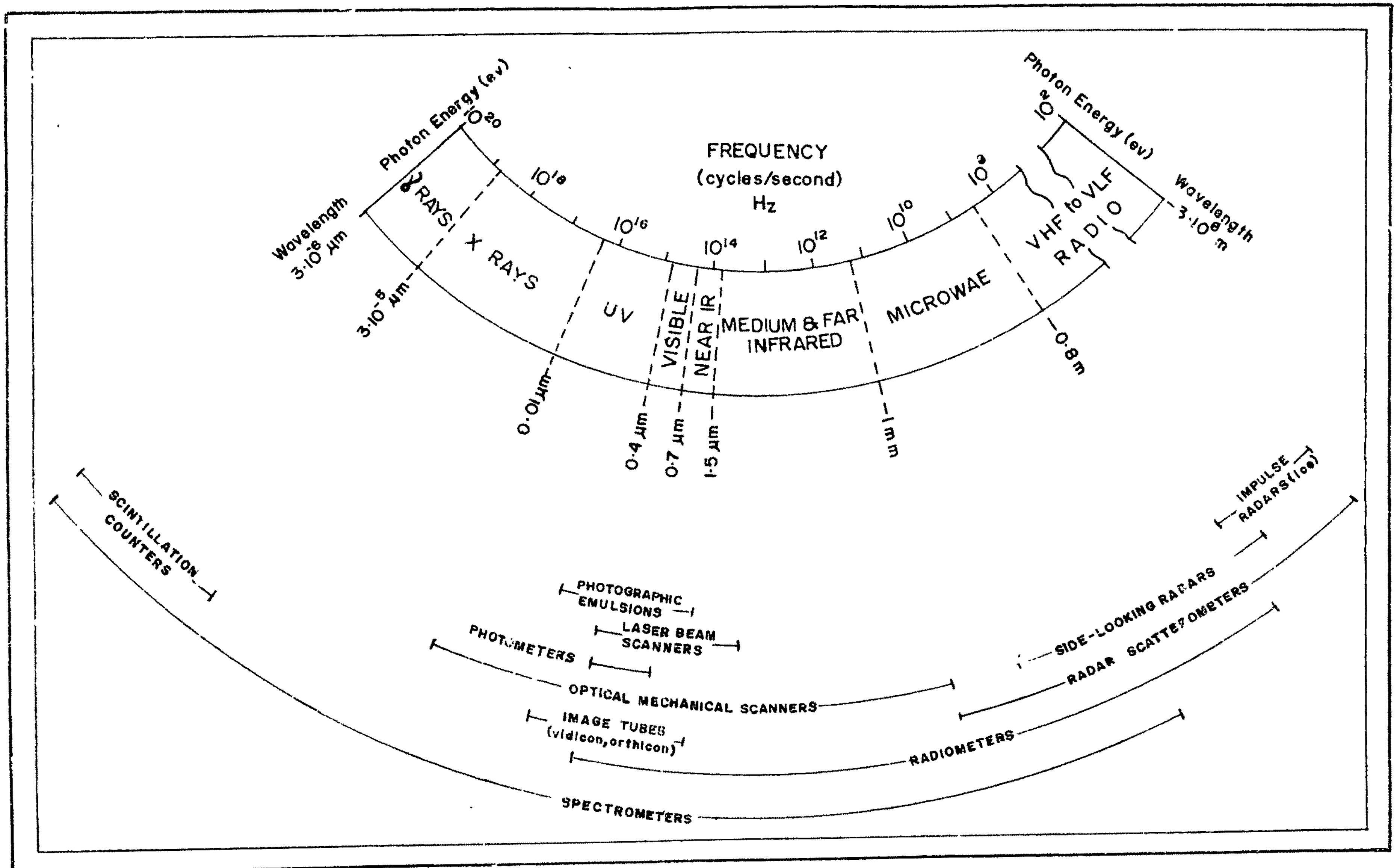


Fig. 3 The electromagnetic spectrum. (SOURCE: POGORZELSKI, 1976)

objects at temperatures above zero degree absolute emit EMR at different wave-lengths as per Planck's law.

$$w_\lambda = [(2\pi hc^2)/\lambda^5 * 1/e^{ch/\lambda kT} - 1]$$

where

λ = Wavelength, h = Planck's constant, c = speed of light k= Boltzmann constant and T = absolute temperature

In general, every object reflects/scatters a portion of EMR incident on it depending upon its physical properties which is known as "spectral signature". The detailed signature of vegetation and the variation in the land covers are depicted in fig. 4a and fig. 4b respectively.

This signature directly or indirectly leads to the identification of the object/its condition. The reflected portion of EMR is picked up by the sensor loaded in the satellite.

1.2.5 Sensors

Any device that receives electromagnetic radiation, converts it into a signal and presents it in the suitable form for obtaining environmental information is called sensor (Curran, 1985). There are two types of sensors viz., Active and Passive. One which create its own radiations to illuminate the target is called Active sensor while Passive sensor is the one which sense the natural radiation. The major sensor parameters which have bearing on optimum utilization of data include

i) Spatial resolution

The capacity of the sensor to discriminate the smallest object on the ground.

ii) Spectral resolution

The dimension and number of specific wavelength intervals in the EM spectrum to which a sensor is sensitive.

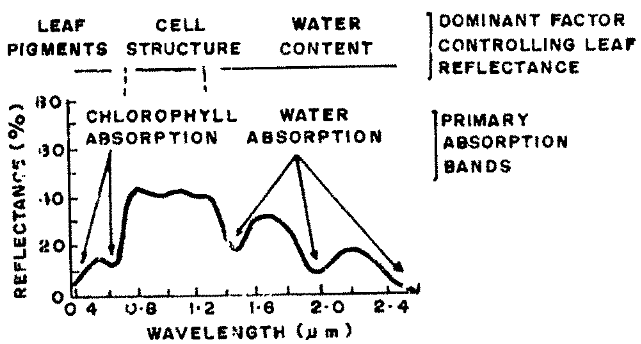


Fig 4a Typical vegetation reflectance spectrum (adapted from Deekshatulu, B L. and Bajpai, O. P 1982)

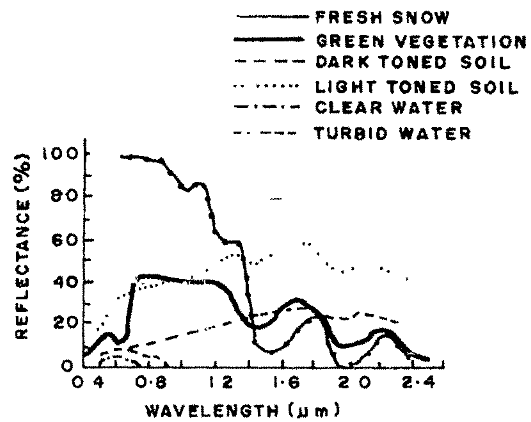


Fig 4b Comparison of reflectance spectra of a few land covars (adapted from George Joesph and Navai gund, R. R. 1991)

iii) Radiometric resolution

It indicates the sensitivity of the detector to make differences in signal strength as it records the radiant flux reflected or emitted from the terrain and

iv) Temporal resolution

It shows how often a given sensor obtains imagery of a particular area. Ideally the sensor obtains data repetitively to capture unique discriminating characteristics of the phenomena of interest.

Sensors used for remote sensing can broadly be classified as those operating in the optical infra red (OIR) region and those operating in the microwave region.

1.2.6 OIR Sensors

i) Photographic cameras

Photographic camera is the oldest and probably the most widely used image system. The detecting medium used in this is a film. Some of the limitations of photographic cameras are their limited spectral response (only upto 0.9 micron) dynamic range, non-amenability to digital processing and problems associated with reproducibility of the quality of the imagery.

ii) Television cameras (TVC)

TVC was the first imaging system used in space to get the imagery of the earth telemetered down as electrical signals. The TV cameras also have a limited spectral response depending on the material used for the photosensitive surface. TV cameras do not have the capacity to produce high resolution imagery and also have a limited dynamic range.

iii) Optical scanners

Optical scanners record sequentially the area element of the scene as narrow shivers and produce a complete image from these area elements through a process called scanning. A few such scanners are

a) MultiSpectral Scanner (MSS)

b) Thematic Mapper (TM)

c) Push Broom Scanner (PBS)

d) Linear Imaging Self Scanners (LISS)

e) Very High Resolution Radiometer (VHRR)

There is a practical limit in improving the spatial resolution using these optical mechanical scanners. Charge Coupled Device (CCD) are currently used to provide very high resolution imageries. The detailed information regarding all the above scanner is given in the table 3.

iv) OIR Active Sensors

The advancement of high power laser technology in the optical and IR region with active laser remote sensing is a promising new means of obtaining useful information about earth and its environment especially related to atmospheric constituents and phenomena. The laser system used for remote sensing is referred to as LIDAR (Light Detection and Ranging).

v) Microwave Remote Sensors

Microwave radiometer is a passive sensor used to measure the emitted energy in millimeter and centimeter wavelength bands. The advantage of this is that the windows remain clear even in the presence of clouds. While in the case of active microwave radiometer, it cannot produce fine resolution imagery from satellite altitudes. Side Looking Airborne Radar (SLAR) is the first active sensor used to

Table 3 : Description of different sensors used in different satellites

Sr. No.	Sensor	Satellite	Resolution (Metre)	Repetitive Cycle (Days)	Band Code	Spectral Range (microns)
1	MULTISPECTRAL SCANNER (MSS)	Landsat 1 USA,1972	79	18	4	0.5-0.6
					5	0.6-0.7
					6	0.7-0.8
					7	0.8-1.1
2	RETURN BEAM VIDICON (RBV)	Landsat 2 USA, 1975	80	18	1	0.47-0.57
					2	0.58-0.68
					3	0.69-0.83
3	THEMATIC MAPPER (TM)	Landsat 5 USA, 1984	30	16	1	0.42-0.52
					2	0.52-0.60
					3	0.63-0.69
					4	0.76-0.90
					5	0.55-1.75
					7	2.08-2.35
			120 (Only for Band 6)		6	10.40-12.50
4	PUSHBROOM (PB)	SPOT 2 France, 1986	10 (For PLA)	26	1	0.51-0.73
					1	0.50-0.59
					2	0.61-0.68
			20 (For MLA)		3	0.74-0.89
5	ADVANCED VERY HIGH RESOLUTION RADIOMETER (AVHRR)	NOAA USA	110 X 110	Twice Daily	1	0.55-0.68
					2	0.72-1.10
					3	3.55-3.93
					4	10.33-11.30
					5	11.50-12.50
6	LINEAR IMAGE SELF SCANNING SENSOR (LISS)	IRS 1 India, 1988	35.25 (For LISS-1)	22	1	0.45-0.52
					2	0.52-0.59
					3	0.62-0.68
					4	0.77-0.86
			72.5 (For LISS-II)			

produce imagery of the terrain. The recent Synthetic Aperture Radar (SAR) partially overcomes the problem of resolution of imagery.

1.2.7 Platforms

They are the vehicle or support from which a remote sensing system collects data (Richason *et al.*, 1983). The sensor systems need to be placed on suitable platforms. They can be stationary or mobile depending upon the needs of observation and constraints. Though aircraft, balloons, rockets and satellites have been used as platforms, the most extensively used platform is a satellite. Based on the orbit the satellite can be classified into (a) Geostationary, for example National Oceanic and Atmospheric Adminstration (NOAA), (USA), INSAT (INDIA) and (b) Sun-Synchronous for example SPOT (FRANCE), IRS (INDIA).

1.2.8 Data products generation

The data acquired by a sensor invariably suffers from a number of errors. These errors occur due to various reasons, such as scene surface characteristics, motion of the earth, imaging characteristics, stability and orbit characteristics of the platform and atmospheric effects. Preprocessing is carried out to correct these errors to the maximum extent so that the inherent quality of the original information of the scene is brought out in an optimal way. The output of the preprocessing is available in standardized formats, either in photographic products in the form of black and white or colour transparencies or prints of different bands or combination of bands or in the form of digital information provided in specific formats in computer compatible tapes (CCT).

1.2.9 Image interpretation

Generally, the two major methods of data analysis used for extracting resource related information from data products, either independently or in combination with some other collateral information, are visual interpretation and digital image processing.

Visual interpretation methods are usually used for extracting information on natural resources. This is mainly based on some of the image characteristics like size, shape, tone, shadow, texture etc.. The major drawbacks in this method are range of gray values recorded on a film or print is limited : the number of colour tone recognised by the human brain is quite large but still limited. The interpreter is likely to be subjective in discerning subtle differences in tones.

1.2.10 Digital analysis

This involves the manipulation and interpretation of digital images with the aid of computer. To classify a pixel into any particular class, several algorithms have been developed such as supervised, with the help of prior knowledge of the ground and unsupervised classification without ground truth information but by grouping the spectral properties of the pixels.

1.2.11 Relevance of Remote Sensing for forestry mapping and monitoring

The advent of remote sensing has made technological breakthrough in gathering information on natural resources specifically in the field of forestry. The use of aerial remote sensing for forest related application has been operationalised since long. In the past, aerial surveys were routinely conducted to detect crop damage by pests and to map forest cover (Heller and Wear, 1952).

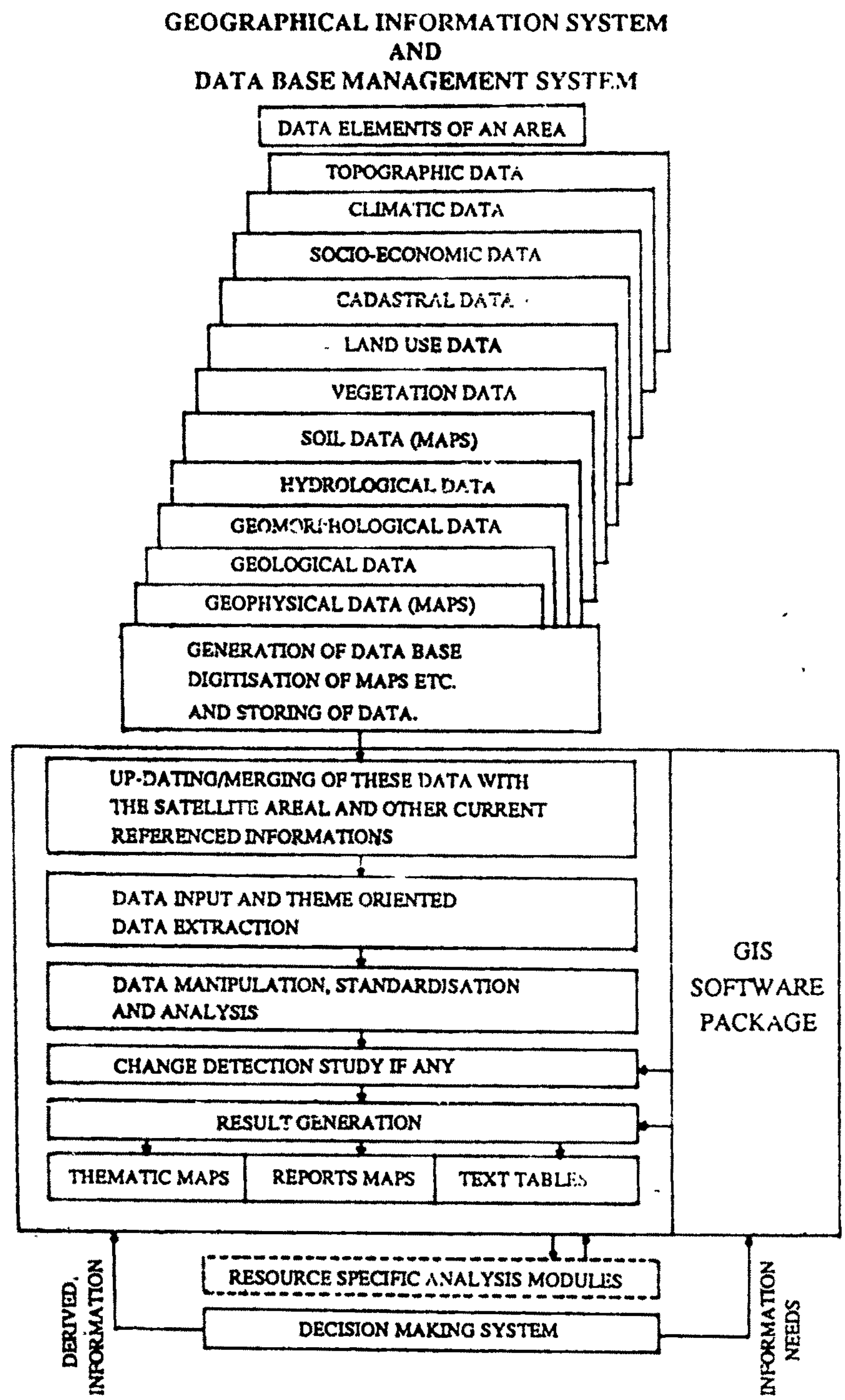
In India, forest aerial survey was conducted for coconut wilt disease in Kerala (Dakshnamurti *et al.*, 1971). The aerial remote sensing as such gives more accurate results than the satellite imageries but the high cost of data generation, lack of synoptic view, non-availability of repetitive coverage and complexity of data handling makes the satellite data to be more and better suitable for such studies (Prashad and Singh, 1984). Several workers have shown the potential of non photographic data for forest related studies. Beaubien and Jobin (1974) used digital technique for mapping of forest cover types. In India, Madhavan Unni (1977) carried out computer classification and delineation of plantation types using Landsat data in the two areas of tropical forests. Jadhav *et al.*, (1986) studied forest type status of Karnataka region by using digital visual mix methodology.

The mapping and monitoring of forest resources have increased many fold in India after the launching of IRS satellite. Since then numerous studies have been carried out regarding mapping of forest type (Kachhwaha, 1990; Roy and Das, 1991). However, when compared to the studies on the mapping of natural forest cover, only a few attempts have been made to study the afforested areas using remote sensing techniques. Jadhav *et al.*, (1987) carried out visual interpretation of Landsat MSS data for monitoring of afforestation and deforestation in some blocks of U.P.

In 1987, Madhavan Unni and Murthy Naidu explained the transformation of vegetational cover due to tourism and commercial plantation programme (Eucalyptus and Wattle) at Kodaikanal in Tamilnadu. Landsat TM data was used to map the afforestation in North Scotland, (Wooding, 1986; Smith, 1988), and reforestation in British columbia (Bansal *et al.*, 1991).

Nichol and Collins (1988) evaluated the agroforestry production system in the Sudano Sahelian zone of West Africa using remote sensing data. Similar studies were carried out in mapping of afforestation for shelter belt (Gaunhua, 1990), and degraded land (Shiva, *et al.*, 1988; Jadhav *et al.*, 1989). Singh and Rajak, (1992) have used IRS and TM data respectively for afforestation site identification.

The need for environmentally benign and socially accountable development has put a heavy demand on the capabilities of planners. Therefore, planning and execution now require more accurate, reliable and timely information and better tools for management of such information. Thus, there is a need for an integrated holistic approach (Fig.5).



(SOURCE: SRIVASTAVA, V.K.,1992.)

FIG:5

Most of the data available today are collected by different agencies for different purposes and are often incompatible for the integration of above database for effective planning. Manual or conventional methods involve overlaying and retracing. These techniques are not adequate while handling large set of data or when repeated analysis is required or several alternative scenarios are to be generated which results in non-availability of information in time. In such circumstances computerised Geographical Information System (GIS) takes a big leap towards integration of geo-related information.

1.3.1 Geographical Information System (GIS)

It is a computer assisted system for the capture, storage, retrieval, analysis and display of spatial data, (Clarke, 1986). In detail, GIS is both a database system with specific capabilities for spatially referenced data, as well as set of operations for working with the data (Stars and Estes, 1990).

GIS is variously called as `Geo based information system', `Geo data system', Spatial information system' etc., Since Geography is binding element in all these systems it is suggested that all these systems fall under the generic term, Geographical Information System, in short GIS (Clarke, 1986).

GIS very eloquently integrates the digital thematic maps prepared from remotely sensed data and digital cartographic data. The significant feature of GIS technology is its `Modelling capacity'. Modelling is a powerful tool for analysing trends and identifying factors that affect them, or for displaying the possible consequences of planning decisions or projects that affect them for resource use and management.

1.3.2 Evolution

In 1936, Charks Colby presented a paper on challenges in geography in which he outlined quantitative approaches to map based problems. This has later le d to the under spinnings of GIS technology. However, the first generation GIS development started in 1960 and the commercialization of GIS began since 1970 and was followed by consolidation and integration in 1980. In India, customized GIS, for the Natural Resource Data Management System (NRDMS) was developed by Department of Science and Technology (DST). The current decade of 1990's will see the operationalisation of this technology on a large scale. Several agencies in India have started developing different packages for instance, GeospaceGIS, ISROGIS, GRAMS, NICGIS etc..

Since then, the GIS played a paramount role in natural resources management. Several models have been generated for different resource planning both in India and abroad. Using GIS considerable work has been done regarding forest planning and management (Martin, 1985; Reisinger and Davis, 1987; Hendrix and Price, 1988) and land capability and its suitability for different resources (XingHong and Hua 1992; Jere and Sridhar, 1993; Whitley *et al.*, 1993). Jadhav *et al.*, (1992) have also generated a model for Gir forest working plan revision using GIS technology in Gujarat.