

# ***INTRODUCTION***

# **MONITORING OF ENVIRONMENT**

## 1. INTRODUCTION

### 1. MONITORING OF ENVIRONMENT

In the recent years, the effects of natural or man made catastrophes have emphasized the need for developing a "global monitoring approach" to consider environmental problems and to understand the complexity underlying therein (Goward et al., 1987). The newly developed technique of "Remote Sensing" has enabled the earth scientists to obtain, process and display spatial information in a timely and cost effective way. Its synoptic viewing and repetitive coverage can enable early detection of any environmental disturbances and thereby aid in planning mitigative measures. Remote sensing techniques particularly, those based on space borne sensors, play a major role in providing comprehensive, reliable and upto date information on the character, distribution, productivity and utilisation of natural resources, besides facilitating periodic monitoring of the earth resources. Resultantly, one of the spin-offs of this spaceborne remote sensing technology is our vastly improved knowledge about our own planet/Earth and its resources. h,

#### 1.1 REMOTE SENSING

##### 1.1.1 Historical Perspective

The idea of remote sensing dates back to 300 B.C. in India, the proof of which 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 narrate them to the king of

Hastinapur. Again another such incident is that the exact aerial description of the sea-coast and trees around, made earlier by Kalidas in his book "Raghuvansha" as the Pushpak Viman flies from Columbo to Ayodhya has been confirmed by Prof. Pisharoty during his flight from Columbo to Madras recently (Pisharoty, 1988). Yet another interesting form of remote sensing has been referred by the ancient Greeks and Romans as *Duex ex Machina* in their play, to provide the ultimate solution to their problems.

The practical exploitation of this technique started in the 19th Century and since then it played a great role in mapping and resource inventories. 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. However, these surveys were laborious and time consuming due to the unlimited resources of the earth. With the birth of photography in 1839, the vistas for the survey of natural resources became wider. The first known aerial photograph was taken in 1858 by a Parisian photographer named Gaspard Felix Tournachon (Thomas and Kiefer, 1987). The earliest existing photograph was taken from a balloon over Boston in 1860 by James Wallace Black. The use of kites for obtaining aerial photographs was also tried and were replaced by aircraft since 1903 for aerial photography after the invention of aeroplanes. Followed by this in 1909, the first continuous scanning pictures were produced. In fact, remote sensing from rockets gave the first impetus to this technology covering a large area at a time with the advantage of better heights. In 1891 Ludwig Rohrman of Germany was granted the patent for a rocket propelled camera

system that could be recovered by a parachute for obtaining bird's eye photographic view. Another German, Alfred Maul added the concept of gyrostabilisation to rocket camera system and in 1912, he successfully launched a 41 kg payload containing a 200 x 250 mm format camera to a height of 790 m. Thereafter the developments of infrared film during the world war II in 1939 for the detection of camouflage military installations and convoys set-off a chain of other activities resulting in the development of new and more sensitive sensors as an offshoot of the military reconnaissance activities. From 1946 to 1950, spaceborne remote sensing evolved photographs from the rockets. Though they were of inferior quality they demonstrated the potential value of remote sensing.

The era of the satellite began with the launching of the U.S.A meteorological satellite called as Television and Infrared Observation Satellite (TIROS-1) in April 1960 (Thomas and Kiefer, 1987). The coarse and indistinct images of the Earth's surface obtained from it were improved in the satellite that succeeded, with the use of refined sensors, to give distinct features in the images. With this the exciting future for remote sensing from space became more apparent in U.S.A. During sixties the use of varieties of remote sensing aircrafts and satellite-borne sensors were investigated. Parallel to sensor technology a wide range of photographic emulsions were developed regularly. Experiments using data from both thermal infrared and microwave sensors on board aircrafts and satellites were developed later. The launching of highly developed and advanced Earth Resource

Satellites (ERS) enabled considerable studies in the field of satellite remote sensing.

The Earth Satellite missions provided breath-taking views of the Earth in all its glory and variety of structures and features as never seen before. The enormous information on the Earth resources available from the imagery obtained during different missions had inspired the launching of satellites specifically dedicated to the observations of the Earth resources during the seventies. The first such mission was the Earth Resources Technology Satellite, later renamed as Landsat-1 in 1972 (Fischer et al., 1976; Fredon and Gordon, 1983). This satellite carrying sensors, capable of providing synoptic views of the Earth's surface every 18 days, initiated the launch of other advanced satellites. It became the harbinger of many of the interpretation techniques presently used. The ultimate goal of remote sensing was to reach a stage of maturity, when reliable information could as a matter of routine be generated for the management of our fragile planet.

The ERS basically were categorised into two groups viz., the manned satellites, and the unmanned satellites (Paul, 1985). The manned satellites carried photographic and other sensors for the production of images of earth's surface. Images obtained from these could be visually interpreted with the aid of aerial photographic interpretation techniques. The manned satellites were Mercury (1961), Gemini-3rd series (1965), Apollo 6th series (1967), Skylab (1973), Space Shuttle (1981) etc. The unmanned satellites had a wide range of non-photographic sensors for the production of images of the earth surface. These images

were interpreted with the aid of aerial photographic interpretation and were also amenable to digital image processing techniques. The computer based image processors aided in the quantification of remotely sensed data, revolutionizing the space technology to a great extent. The unmanned satellites were grouped into four distinct groups viz., the first generation which included the Landsat series, the second generation of the French System Probatoire de 'l' Observation de la Terre "SPOT", the third generation of satellites carrying sensors to record thermal infrared wavelength like the Heat Capacity Mapping Mission Satellite (HCMMS), and the fourth generation of satellites which carry sensors that record microwave wavelength as Seasat, European Earth Resource Satellite and Radarsat.

#### **1.1.2 General Aspects**

##### **1.1.2.1 Definition**

Remote sensing in the broadest sense is the measurement or acquisition of information of some property of an object or phenomenon, by a recording device that is not in physical or intimate contact with the object or phenomenon under study. In short, remote sensing is the acquisition of information about objects, area and phenomenon on the earth surface without physical contact (Colwell, 1984).

##### **1.1.2.2 Principle**

The distance sensing of objects through non-contact methods involves the use of Electro Magnetic Radiations (EMR), emitted by the objects. A perfect black body, radiates energy

proportional to the fourth power of its absolute temperature in degrees Kelvin. Incoming solar energy peaks at about 480 nm and is negligible above 3  $\mu\text{m}$  while outgoing emitted radiation peaks near 10  $\mu\text{m}$  and is negligible below 3  $\mu\text{m}$ . These radiations which are reflected and emitted by objects are recorded by the sensors on the Earth Observation Satellites. The reflection or emission patterns normally referred to as its spectral signature by any object is very much dependent on the wavelength of the energy involved and is also specific to the object depending primarily on the atomic or molecular composition of the object. The whole edifice of remote sensing is based on this unique spectral signature of objects.

#### 1.1.2.3 Requirements

Any study in remote sensing is basically dependent on three components, firstly, the EMR i.e. Electro-Magnetic Radiation, secondly, the Sensors recording this EMR and thirdly, the Platforms carrying this sensors.

##### 1.1.2.3.1 Electromagnetic Radiations

The Electromagnetic radiations travelling at a velocity of  $3 \times 10^8 \text{ ms}^{-1}$  form the basis in remote sensing technology. These radiations represent a high speed communication link between the sensor and the remotely located phenomena. Changes in the amount and properties of the EMR upon detection become a valuable source for data interpreting the important properties of the phenomena with which they interact (Suits, 1983). Though other types of force fields (such as sound waves) may also be used in place of EMR, the majority of the remotely sensed data



collected for geographic application are from the sensors that record electromagnetic energy (Jensen, 1983). The wavelengths of electromagnetic radiation that have been proved to be of particular value in environmental remote sensing are reflected radiations in visible, near infrared and middle infrared wave bands and emitted radiation in middle and thermal infrared wave bands from the natural resources and reflected radiations in microwave bands from artificial sources. Thus, 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 electromagnetic spectrum.

#### **1.1.2.3.2 Sensors**

The sensors are of two types, active sensors and passive sensors. Active sensors create their own radiations to illuminate the target, whereas passive sensors rely on naturally occurring radiations. The various sensors that are in use are the Photographic Camera, the Vidicon Television Camera, the Optical Scanner, the Microwave Radiometer and the Microwave Radar.

##### **i. The Photographic Camera**

The detecting medium used in this is a film similar to that used in the normal photography, except that it images the objects in specific bands of interest.

##### **ii. The Vidicon Television Camera**

The television type camera, generally favoured for orbital remote sensing is based on the Return Beam Vidicon tube (RBV). The RBV system consists of three television like cameras

aiming to view the same 185 x 185 km ground area simultaneously. RBV system do not contain film, but instead their images are exposed by a shutter device and stored on a photosensitive surface within each camera. This surface is then studied in rostral form by an internal electron beam to produce a video signal just as in a conventional television camera. Each RBV is referred to a subscene. The four subscenes comprise one Landsat MSS Scene. The other salient features are as described in Table 1 (Hord, 1986).

### iii. The Optical Scanner

It records sequentially the area elements 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 described below :

#### a. Multi Spectral Scanner (MSS)

The Landsat series are loaded with the multi spectral scanners. In MSS incoming energy is separated in several spectral components that are sensed independently by an array of detectors. The detectors of MSS capture energy from four spectral wave bands viz., 4,5,6 and 7 (Table 1). This band designation apply to Landsat 1,2 and 3 while for Landsat 4 and 5, the four MSS bands are designated as 1,2,3 and 4. The design of the component is such that each Instantaneous Field of View (IFOV) is 79.3 x 79.3 m, which is due to overlap direction arising from the sampling procedure is effectively reduced to 79.3 x 59.6 m. (Slater 1979, 1980).

Table 1. Description of different sensors

Sensors	Resolution m	Band No.	Wavelength μm	Colour	Application
1. OPTICAL SCANNER					
a. Multi-Spectral Scanner (MSS)	79/82	4	0.5-0.6	Green	Characteristics of water bodies
	79/82	5	0.6-0.7	Red	Distinguish topographic and man-made features
	79/82	6	0.7-0.8	Near Infrared	Detection of vegetation stress
	79/82	7	0.8-1.1	Near Infrared	Detection between land and water
b. Thematic Mapper (TM)					
30	1	0.45-0.52	Blue	Mapping of coastal water Difference between soil and vegetation and coniferous and deciduous forests	
30	2	0.52-0.66	Green	Healthy vegetation	
30	3	0.63-0.69	Red	Chlorophyll absorption and species differentiation.	

30	4	0.76-0.9	Near In- frared	Biomass survey
30	5	1.55-1.75	"	Vegetation Moisture measurement, Snow cloud differentiation
120	6	10.4-12.5	Thermal Infrared	Plant heat stress measurement; other thermal mapping
30	7	2.08-2.35	Mid In- frared	Hydrothermal mapping
2. RETURN BEAM				
80	1	0.475-0.575	Green	Characteristics of water bodies
80	2	0.58-0.68	Red	Distinction between topo- graphic and man-made features.
80	3	0.69-0.83	Near In- frared	Detection of vegetational stress.

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b. Thematic Mapper (TM)

Landsat 4 and 5 has been equipped with TM with an improved resolution and an extended spectral range in the visible and reflected infrared region (Table 1). The development of the Thematic Mapper carried by Landsat 4 and 5 represent the peak of evolution in the optical scanner technology (Thompson, 1979).

c. Push Broom Scanner

SPOT-1 carried two identical push broom scanners called as High Resolution Visible Scanners. These scanners are used to record in panchromatic or multispectral mode (Begni, 1982). The 10 m resolution from 0.51 to 0.7  $\mu\text{m}$  could be used for planimetric studies and 20 m multispectral mode from 0.51 to 0.59  $\mu\text{m}$ , 0.61 to 0.68  $\mu\text{m}$  and 0.79 to 0.84  $\mu\text{m}$  could be used for environmental studies (Chevral et al., 1981; Short, 1982). In case of Push Broom Scanner the across track data collection is effected mechanically, 'viewing' the entire swath simultaneously. There is no moving part in the sensor, which improves its reliability. Further in this mode of operation each line of the image is electronically scanned by a linear array of detectors located in the focal plane of optical system and successive lines of image are produced by satellite movement. This method maximises the exposure time for each ground point and ensures photogrammetric quality and geometric fidelity along the line scan axis. Each detector array provides data in a single spectral band. Thus the push broom scanner is a new generation of multispectral sensor (Wharton et al., 1981).

**c. Linear Imaging Self Scanning Sensors (LISS)**

These are employed on IRS-1A. There are two sensors LISS-I and LISS-II (Table 2a,2b). Each sensor has 2048 detectors arranged in the form of Linear arrays which are based on the push broom concept.

**e. Very High Resolution Radiometer (VHRR)**

It is employed on INSAT-1 for meteorological earth observations. It operates in the visible ( $0.55-0.75 \mu\text{m}$ ) and infrared ( $10.5-12.5 \mu\text{m}$ ) wavelength region with a spatial resolution of  $2.75 \times 2.75 \text{ km}$  and  $11 \times 11 \text{ km}$  respectively (Hord, 1986).

**f. Advanced Very High Resolution Radiometer (AVHRR)**

The AVHRR carried by NOAA satellites has four spectral channels, two visible and two infrared, with a capability to acquire data in the morning and afternoon, of a day at each location (Hord, 1986).

**iv. 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 a large aperture directional antennae. The advantage of this radiometry is that the windows remain clear even in the presence of clouds (Barrett and Curtis, 1976).

**v. Microwave Radar**

Radar system provides its own illumination and records the radar return from the ground. The type of imaging radar

Table 2a. Salient features of IRS-1A satellite

	No. of LISS Sensors	
	LISS I Low Resolution	LISS II Medium Resolution
No. of spectral bands	4	4
IFOV	80	40
Geometric resolution from 904 km altitudes (m)	73	36.5
Swath width (km)	148	75 Composite-145
Quantification bits	7	7

Table 2b. Details of spectral bands

No.	Wavelength ( $\mu\text{m}$ )	Application
1.	0.44-0.50	Sensitivity to sedimentation, Discriminability to rock types
2.	0.52-0.58	Sensitivity to sedimentation
3.	0.62-0.69	Sensitivity to chlorophyll
4.	0.77-0.86	Sensitivity to plant biomass

generally considered for earth observations is the side looking radar (Barrett and Curtis, 1976).

#### 1.1.2.3.3 Platforms

There are three types of platforms used viz., ground-borne, airborne and spaceborne. (Indian Space Research Organisation, NNRMS, 1988).

- i. Groundborne Platform include two devices viz., Cherry arm configuration of the remote sensing van and tripod. These have the capability of viewing the object from different angles.
- ii. Airborne Platform 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, while aircrafts like U-2 and Rockell and X-15 are used in foreign countries.
- iii. Spaceborne Platforms are the panel studied observatories in the space, and are also termed as satellites. The mode can be geostationary permitting continuous sensing of portion of the earth or sun synchronous with polar orbit covering the entire earth at the same equator crossing time.

#### 1.1.2.4 Remote Sensing Resolution Consideration

Resolution plays a vital role in remote sensing. Resolution or resolving power is a measure of the ability of an optical system to distinguish between signals that are spatially near or spectrally similar (Swain and Davis, 1978). The ability to measure a biophysical variable using remote sensing, takes into consideration four types of resolution.



- i. Spectral resolution refers to the dimension and number of specific wavelength intervals in the electro-magnetic spectrum to which a sensor is sensitive.
- ii. Spatial resolution is a measure of the smallest angular or linear separation between two objects that can be resolved by the sensor.
- iii. Temporal resolution refers to 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.
- iv. Radiometric resolution defines the sensitivity of the detector to differences in signal strength as it records the radiant flux reflected or emitted from the terrain. It defines the number of just discriminable signal levels. It is generally believed that improvement in resolution increases the probability that phenomena may be remotely sensed more accurately (Everett and Simonett, 1976).

#### 1.1.3 Data Acquisition, Transmission and Interpretation

The data from the objects on the Earth are received in the form of signals by photographic sensors like conventional cameras or by the non-photographic sensors such as scanners, microwave detectors etc. In the former case the detection of electro-magnetic radiations can be performed photographically or the developed photograph gives the record of its detected signals. Thus, the film acts both as the detecting and the

recording medium. Then this information is interpreted by visual photo-interpretation techniques. In case of non-photographic sensor the energy reflected from each ground resolution cell after passing through a set of lenses and filters has been sensed by the sensors which converts the pictorial records on magnetic tapes. The data recorded on these tapes are in the form of row and columns. The individual elements of this matrix are referred to as pixels or picture elements. Each pixel has four values one of each band and its intensity is represented by the Digital Number (DN). The DN's constituting a digital image are recorded over numerical ranges such as 0 to 63, 0 to 127, 0 to 255, 0 to 511, or 0 to 1023. These ranges represent the set of integers that can be recorded using 6,7,8,9 and 10 bit binary computer coding sales, where bit is the binary digit i.e.  $2^6 = 64$ ,  $2^7 = 128$  upto  $2^{10} = 1024$ . In such numerical formats the image data can be readily analysed with the aid of a computer. The MSS records the reflected radiant flux in 6 bits and then expands the data in three of the bands to 7 bits where the values range from 0-127 (Lansing and Cline, 1975; Slater, 1980). The TM records the reflected radiant flux in 8 bits, where the values range from 0-255. The LISS sensors record the data in 7 bits and the values range from 0-128. The digital data can also be converted into an image form by photographing the screen display or by using a specialized film recorder. The data obtained thus can also be visually interpreted.

#### 1.1.4 Remote Sensing in India

Optimum and effective management of natural resources is the essential ingredient for a developing nation like India. Recognising the potential opportunities and benefits of satellite based remote sensing, Indian Space Research Organisation (ISRO) has conducted a variety of extensive and intensive nature of activities in the last decade, including aerial flights and experimental satellite missions. Starting with Aryabhata, launched in April 1975, ISRO has drawn ambitious programmes for the utilisation of satellite technology for development. Bhaskara-1 launched by Soviet rocket in June 1979 has been equipped with TV cameras on board for earth observation. More than 1000 pictures have been received before its mission ended in August 1981. Bhaskara-II an another improved version has been launched in November 1981, to continue the above studies (Basu, 1988). Besides several Joint Experiment Programme (JEP) such as Salyut-7 Joint Indo-Soviet Experiment have also been carried out operationalising the remote sensing system for the country. During April 3-11, 1984, Squ.Ldr. Rakesh Sharma as the Indian Researcher cosmonaut has conducted photographic operations using the hand held cameras, MKF-6M and Kate-140 in Salyut-7 space station at an altitude of 240 km Kate-140 camera is a Soviet cartographic camera with a focal length of 140 mm with single band panchromatic black and white imagery on aerial film rolls. Single frame of Kate-140 has an area of approximately 335 x 335 km on the ground with spatial resolution of 30m. MKF-6 M camera has provided a focal length of 125 + 0.5 mm and a ground resolution of 30 to 40 m. The data obtained from this space

flight is called as TERRA DATA (Jadhav, 1989). The establishment of National Natural Resources Management System (NNRMS) has been a great stride in the operational use of Remote Sensing technology in the history of India's Resource Management and has given birth to a series of Indian Remote Sensing Satellites (IRS). IRS-1A mission has been the first step in such an operational resources management for the country. IRS-1A satellite launched in March 17, 1988, has a repetitive cycles of 22 days, orbit inclination of  $99.028^\circ$ , altitude of 904 km (circular), local time of equatorial crossing 10 a.m. and period 103.2 minutes (Jayaraman, 1988). Other salient features are as described in Table 2a and 2b.

#### 1.1.5 Advantages and Limitations

Inventorying of natural resources has been carried out by several agencies through conventional ground based methods of survey to suit their specific purposes and needs. Such information suffers from defects such as inadequacy of data, lack of standard format, untimeliness and high subjectivity (Narayan, 1989). In such situation, a comprehensive approach that involves an optimum blend of modern survey techniques and traditional methods in combination with fast processing and analysis of data will be of immense value in taking timely and appropriate decisions. Remote sensing technology as methods of survey are gaining a momentum over the other non-conventional methods of survey. It exhibits several advantages like synoptic viewing of large area to the extent of  $34,000 \text{ km}^2$  ( $185 \times 185 \text{ km}$ ) coverage on a single Landsat imagery within a very short period. Further, it

is also relatively fast and economical for gross estimates compared to any other methods of surveying. Now the access to data is at every 8 days interval with two such satellites orbiting regularly or every day in the case NOAA. Moreover, it provides reliable, near real time and unbiased base line information. Despite the advantages it has limitations in the form of limited spatial (ground) resolution of the imagery i.e. only 1:1 million with the result the minimum mapping unit is 1 km<sup>2</sup> and non-availability of stereoscopic coverage.

#### 1.1.6 Applications

One of the unique features of remotely sensed data is that the same data can be used by various earth resources disciplines such as agriculture, forestry, geology or hydrology making it multidisciplinary with the great advantage of understanding their interrelationships. The data have been found to be useful in crop inventories and monitoring, study of land-use, search for minerals, hydro-carbons, and ground water, flood mapping, snow-melt modelling, soil mapping studies in archaeology, oceanography, environmental pollution and soil degradation etc. Thus space monitoring have permitted us to identify origin and the character of forces destructive to the environment with a minimal loss of time to trace and map spread of anthropogenic activity to estimate intensity and extent of ecological shifts and to study their interaction with the surrounding landscape. In this way it has entered the total monitoring information system as one of its sub-system.

## 1.2 IMPACT OF SALINITY ON SOIL AND VEGETATION

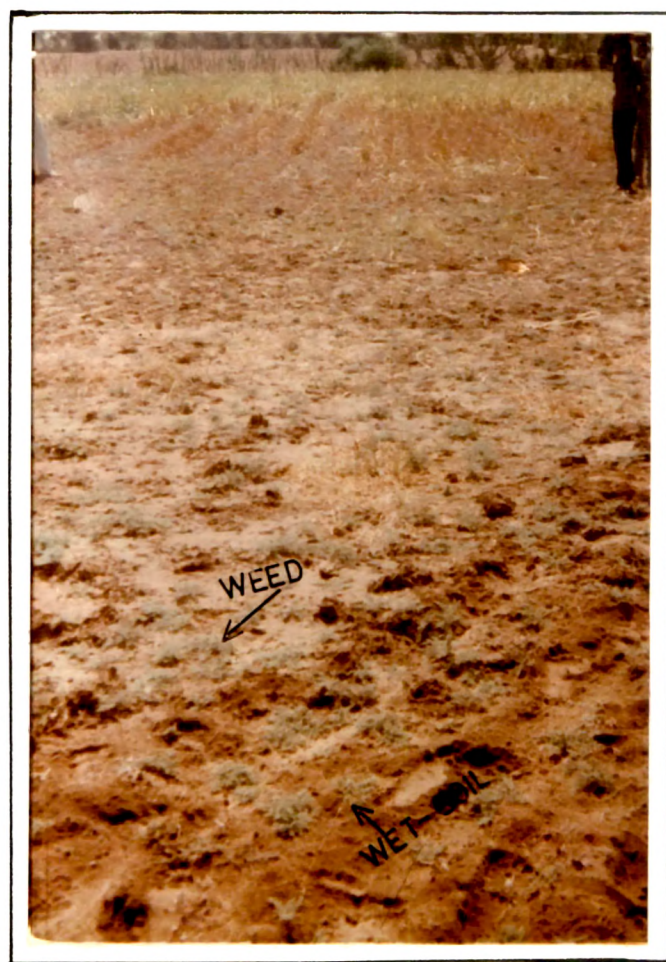
### 1.2.1 Soil Factor

Soil is a substance of essentially universal occurrence. In simple terms the soil is defined as a system consisting of three phases viz., solid, liquid, and gas, which are interlinked and interrelated with each other. Soil is also considered as the 'mantle of the earth crust' that supports vegetation and so it forms an integral part of the natural environment related to and affected by various environmental factors. Soil forms the most important parameter which can create imbalance in the ecosystem. Its common place occurrence has resulted into the failure of full appreciation of the impact it has made on every day life. Moreover, in the recent years the soils which need to be protected from damage through utmost care, are unfortunately undergoing deterioration. In addition to the damage created through the factors like sea-water ingress, desertification, fire, earthquakes, etc. the craze for exploiting the soil resources for a maximum production under irrigated agriculture has resulted in the emergence of problems of salinity, waterlogging and alkalinity in turn depriving the precious cultivable lands of their fertility. The damage thus caused to one of the vital ecological component has made it imperative to think of different aspects of amelioration to arrest further degradation for which a regular, quick monitoring of the area in question is necessary.

### 1.2.1.1 Salinity Status in India

Saline and alkaline lands have been known to occur in India since a century, more prominently in the Indus and Gangetic plains in the north. History records that in the early eighteenth century much of the wetlands have been covered with forest providing both forage and firewood to the local inhabitants. The increasing population in the years that followed, has ultimately resulted in their denudation, creating an ecological imbalance with excessive surface evaporation from the wet soil as seen in Plate 1 ultimately resulting in the formation of saline and alkali soils. The introduction of canal irrigation in parts of Meerut, Aligarh and Kolivadi valley has aggravated the degradation of cultivable lands owing to the appearance of saline efflorescence as evident in Plate 2. This has led to the formation of the historical Indian Reh Committee in 1877, which investigated into the causes of the deterioration of lands by Reh (an Indian terminology meaning salt efflorescence), presumed to be first employed in scientific literature by an Indian Geologist (Agrawal and Gupta, 1968). Thus the saline soils are locally termed as reh, rehala, namkin or khar. The common outwardly feature of this type of soil is the presence of extensive white, grayish-white or ash coloured fluffy deposition of salts on the surface of the land either in patches, scattered irregularly or otherwise in flocks.

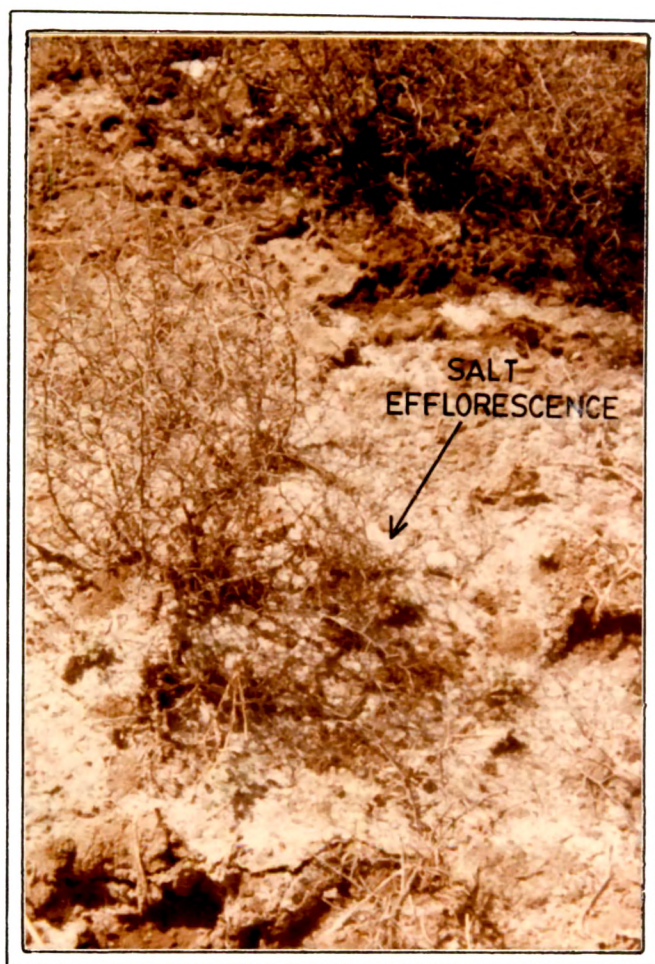
According to the latest statistics, the country is having some 264 million ha of land which does not have any potential for biotic production (after excluding areas which are intrinsically unfit for production on account of being



**PLATE 1**

Wet soil seen before evaporation with the emergence  
salt tolerant weed Cressa cretica L.



**PLATE 2**

Soil surface showing white salt efflorescence formed after evaporation of water.

perpetually snow bound or rocky etc.) and 175 million ha of degraded cultivable lands, of which an area of 13 million ha is degraded on account of waterlogging and/or salinization (Vohra, 1988). Earlier workers, Govindrajan and Gopal Rao (1978) have computed about 7 million ha of saline and alkaline soils to be present in India while recently Desale et al., (1989) have reported more than 8 million ha of saline and alkaline lands in India, mainly distributed in northern states viz., Uttar Pradesh, Haryana, Rajasthan and Gujarat. Other compact areas of saline soils are located in the central parts of Deccan of the Indian Peninsular (Patnaik, 1967; Ray Chaudhari, 1964). However, the recent survey conducted, by NRSA, Hyderabad using satellite images of 1980-82 has indicated that only an area of 39032.5 km<sup>2</sup> of land has been affected by salinity against the 70,000 km<sup>2</sup> reported in 1978. Gujarat has the maximum saline affected land about 20,602 km<sup>2</sup>, amounting to 52.8 per cent of the total area of the nation while Uttar Pradesh ranks second having 12,823 km<sup>2</sup> (National Remote Sensing Agency 1985-86).

#### 1.2.2 Classification and Grouping System of Salt Affected Soils

The term salt affected soils conveys a very limited information to soil scientists, engineers or any other users. Hence numerous classifications and soil grouping systems have been used for the purposes of definition, characterization, problem identification and amelioration of salt affected soils. After scanning the literature one finds that terms like saline, alkaline, and saline alkaline have often been used to describe

salt affected soils eventhough, nomenclature in East Europe, Russia, Canada and few other countries employ terms like Solonchak, Solonetz, Soda Solonchak, etc. Bulk of the scientific community in India uses the well known definitions of USDA (USSL staff, 1954). These definitions are based on pH (pH of saturated paste), E<sub>Ce</sub> (Electrolyte Conductivity of saturation extract of soil expressed as dSm<sup>-1</sup>) and ESP (Exchangeable Sodium Percentage) of the soil. The classification is given below :

#### **Saline Soil**

These soils are non-alkali soils containing appreciable quantities of soluble salts in such quantities, that they interfere with the growth of most crop plants. The electrical conductivity of the saturation extract is greater than 4 dSm<sup>-1</sup> (at 25°C) and the exchangeable sodium percentage is less than 15. The pH reading of the saturated soil paste is usually less than 8.5.

#### **Saline Alkali Soil**

These are the soils containing appreciable quantities of soluble salts. The exchangeable sodium percentage is greater than 15 and the electrical conductivity of the saturation extract is greater than 4 dSm<sup>-1</sup> (at 25°C). The pH of the saturated soil is 8.5 or less.

#### **Non-Saline Alkali Soil**

These soils contain sufficient exchangeable sodium to interfere with the growth of most crop plants and does not contain appreciable quantities of other soluble salts and so the ESP is greater than 15. The E<sub>Ce</sub> is less than 4 dSm<sup>-1</sup> (at 25°C).

The pH reading of the saturated soil paste is usually greater than 8.5.

However, Bhargava et al., (1976) have grouped salt affected soils occurring in India into the following two categories.

#### **Alkali Soils**

These are soils with pH more than 8.5, ESP of 15 or more and preponderance of carbonates and bicarbonates of sodium. E<sub>Ce</sub> is less than 4 dSm<sup>-1</sup> at 25°C.

#### **Saline Soils**

These are soils having pH less than 8.5, ESP less than 15 and preponderance of chloride and sulphate of sodium, calcium and magnesium (except gypsum). E<sub>Ce</sub> is more than 4 dSm<sup>-1</sup> at 25°C.

#### **1.2.3 Crop Response to Salinity**

Salinity has reduced the yield of irrigated crop throughout the world. It has severely decreased the agricultural productivity on dryland soil in many semi-arid and arid regions. Researchers have recognised salinity related problems such as reduction in emergence, rate of growth and yields due to salinity (Ayers, 1953; Jacobson and Adam, 1958; Kaddah and Fakahry, 1961; Malliwal and Paliwal, 1967 and 1969). Paralleled with the reduction in agricultural production, increased solutes in sediment loads in streams and rivers have been observed in Australia and North America. In general, accumulation of soluble salts in the root zone is one of the most serious problems associated with agriculture of the arid regions exposing the crop to various stresses connected with cell osmoticum, nutrition and

injury of the general metabolism (Bernstain, 1964). The osmotic stress occurs in the roots when salts of sodium and calcium accumulate around the root and lower the water potential of soil below that of the cells creating water shortage inside the plant system. This is otherwise called as physiological drought to differentiate it from physical drought as both created shortage of water in the system. The accumulation has often found to be rich in cation like sodium and to a lesser extent calcium and anions like chloride and sulphate. As a result most of the research work in the laboratory has been focused on the effect of NaCl. The nutritional or deficiency stress is created mainly because of the difficulty in the uptake of essential minerals as a result of competition with the toxic ions leading to an accumulation of toxic salt that results in the primary salt injury (Aleshin et al., 1987). Primary salt injury brings about disturbance in the varying metabolic activities and injurious changes in the lipoprotein membranes. Despite the nature of injury the expression of salinity damage manifests itself as growth or yield decrement, leaf damage, tillers reduction etc., ultimately restricting severely the economic yield. High levels of substrate salinity produces die-back of the whole twig or distinct leaf damages like cupping, yellowing, bronzing, necrosis, premature abscission, and premature fall and in some species increased leaf thickness or succulence due to enlarged mesophyll cells or thickened cell walls (Robinson, 1971).

Species and cultivars differ in their ability to tolerate saline substrate. The salt loving plants, halophytes have evolved themselves to survive in sea-water and among the

glycophytes, the forages generally exhibit greater tolerance than the cereals. Among the crops 6000 ppm of NaCl salinity has been found to be critical with the exception of cultivars like rice and cotton that can tolerate upto 8000 ppm. Rice and Oat cultivars differ in their capacity to tolerate salinity during germination (Pearson et al., 1966; Panchaksharaiah and Mahadevappa, 1971 and Verma and Yadava, 1986) as against wheat cultivars that are generally affected at germination stage (Malliwai and Paliwal, 1967 and 1969). Kaddah and Fakahry (1961) reported that some rice cultivars were particularly sensitive to salinity at the seedling growth (Iyengar et al., 1977). In some cases the growth was highly inhibited even at  $EC_e$  of  $8 \text{ dSm}^{-1}$  of the root medium (Ogra and Baijal, 1978). Cultivars of castor also differ in their capacity to tolerate salinity at different stages of growth (Abd El Rehman et al., 1974). The salinity effect can be distinct or more evident at a particular stage in some crops. According to Malek et al., (1961) salinity affects the growth of rice at preflowering stage. Thus soil salinity affects adversely the growth of different plants resulting in a decrease in the productivity of the agricultural ecosystem as a whole making it necessary for immediate, genuine and extensive experimentation to decide the specific reclamative methods to suit a particular saline system, mainly because of the complexity of the saline tolerance mechanism operating in different species and also in response to the varying climatic and edaphic factors.

### 1.3 Relevance of Remote Sensing to Salinity and Vegetational Mapping and Monitoring

The advent of remote sensing has made technological breakthrough in gathering information on the stressed lands, wastelands and other natural resources. The manifestation of white encrustation on the surface of saline soils forms the basis for many a successful attempt on the use of remote sensing in this field. Increasing demand on food, fodder, fuel and fibre by the exploding population of the biosphere has necessitated the adaptations of scientific measures for increasing land productivity. This has created a great pressure on the natural resources like soils and crops making it imperative for an early detection of the degradation followed by a quick and reliable mapping of salt affected agricultural lands to implement plans to prevent further degradations parallel with the reclamation and utilisation programmes.

Considerable work has been done in soil resource mapping at semidetained and reconnaissance level using aerial photointerpretation techniques in India and abroad (Hilwig and Karale, 1970; Srinivasan, 1972; Ahuja and Manchanda, 1980; Karale and Das, 1986 and Everitt et al., 1977). Spaceborne multispectral data by virtue of its synoptic and repetitive coverage in the narrow and discrete bands of the electromagnetic spectrum holds very good promise for delineating, mapping and monitoring salt affected soils in a time and cost effective manner with reasonable and acceptable accuracy (Colwell, 1974b; Dwivedi et al., 1987; Everitt et al., 1981; Hooda et al., 1989; National Remote Sensing Agency, 1981; Richardson et al., 1976 and Singh et

al., 1977). Similarly, the utility of remote sensing in vegetational studies has become quite significant. The photosynthetically active green vegetation as such has spectral reflectances which are quite distinct from most other objects on the earth's surface. It displays an unique reflectance spectrum, with low reflectance in the visible (0.4 to 0.7  $\mu\text{m}$ ) spectral region and high reflectance in the near infrared (0.7 to 1.3  $\mu\text{m}$ ) spectral region. Thus, crop canopy having different growth conditions have different spectral responses in different bands of electromagnetic spectrum. This forms the basis of plant stress monitoring by remote sensing technique. In vegetation monitoring, using the ratios of different bands mainly red and infrared, different vegetation indices are generated viz. Greenness Vegetation Index (GVI), Yellowness Vegetation Index (YVI), the transformed vegetation index and so on (Kauth and Thomas, 1976; Rouse et al., 1973). Thus the use of photographic infrared (IR) and red linear combinations for monitoring vegetation biomass and physiological status have become common in the remote sensing community. The IR/Red ratio is considered to be effective in normalizing the effect of soil background variations and is useful for estimating biomass (Colwell, 1973 and 1974a; Carneggie et al., 1974; Johnson, 1976 and Maxwell, 1976). Thus the vegetational differentiation which is a difficult and complex task requiring more subtle analysis has been made easier using remote sensing technique.



#### 1.4 SIGNIFICANCE AND OBJECTIVE OF THE STUDY

As per the Agricultural Census of 1970-71, out of an area of nearly 1.86 crore ha of land in Gujarat State, about 96 lakh hectares were under cultivation. Out of these 96 lakh ha, approximately 13 lakh ha received irrigation through various sources. The irrigated area through canals was nearly 3 lakh ha. There has been a rapid progress in the construction of various major, medium and minor irrigation schemes in the state and as per the assumption made by the National Commission on Agriculture (1976), nearly 26 lakh ha of land in Gujarat State is likely to be brought under canal irrigation by the end of this century (Bapat, 1988). However, the recent study conducted by Nayak and others (1987) using visible image interpretation quantifies the increase in saline affected area in Kheda district of Gujarat from 926.58 km<sup>2</sup> in 1975 to 1049.61 km<sup>2</sup> in the year 1986, revealing an increase of 13 per cent. Such an increase though in qualitative terms has been reported in the Mahi Command Area by earlier workers (Kalubarme et al., 1983). They have attributed the cause of salinity in this area to inadequate drainage, poor outfall conditions, improper conveyance of water through unlined canals, field to field irrigation leading to stagnation of water, blocking of underground drainage and raising of heavy perennial crops in the command area. Therefore, while considering the preventive measures for soil degradation alongwith an efficient soil and water management, a careful selection of crops to be cultivated and other phytosociological survey in the command area is of vital importance. Also, reliable temporal monitoring of saline affected lands and the status of crop productivity

therein, is required which could be extremely useful in chalking out suitable remedial measures in these once fertile cultivable fields. Looking at the gravity of the problem, the present study has been undertaken.

#### 1.5 THE OBJECTIVES OF THE STUDY

- i. To select the proper season (summer/winter) and suitable data products viz., Landsat TM/MSS and TERRA (Kate-140) to study salinity development in the study area.
- ii. To detect and classify saline affected lands of Khambhat taluka by visual image interpretation of multirate, multispectral and multiseasonal satellite data to assess the degradation since 1975.
- iii. To overlay the saline degradation pattern on the cadastral maps of some villages and to assess the utility of TM data, for microlevel studies on the ownership plot basis.
- iv. To assess the vegetational changes in correlation with the different levels of salinity by visual image interpretation and digital analysis of the satellite data products.
- v. To identify the potentialities of IRS-1A LISS II data for salinity and vegetational studies and develop suitable techniques for Soil Brightness Index and Vegetational Index.
- vi. Further to survey the site of study for learning the changes in the agricultural pattern, the soil, the

distribution of vegetation etc.

- vii. To correlate the different classes of salinity identified with the chemical compositions of soils.
- viii. To investigate the degradation in crop productivity from the affected field.
- ix. To screen different rice cultivars under laboratory conditions to test their tolerance to salinity and to transfer the knowhow to the farmers as a measure towards better farming in the stressed lands.
- x. To attempt field trials using the different saline tolerant rice cultivars to regreen saline lands as a bio-reclamative attempt.

Thus the main objective of this study was to fully tap the potentialities of this newly developed and advanced remote sensing technique in detecting the saline land and vegetational status in the degraded lands of Khambhat taluka and also to suggest possible ways to improve the crop/vegetation stand in the affected lands.

#### 1.6 DESCRIPTION OF THE STUDY AREA

Khambhat taluka lies in the south of Kheda district, between 22°-15' and 22°-38' north latitudes and 72°-25' and 72°-45' east longitudes covering an area of 110,960 ha (Fig. 1). It has in all 101 villages. The distribution of area under different land use for this taluka is as given in Table 3. The climate of this taluka is subtropical with a cold dry winter and a hot dry summer. The average temperature for the years 1975 to 1988 ranged between 15 to 45°C (Fig. 2) (Soil Survey Division, Vadodara, 1985 and District Agricultural Office, Khambhat, personal

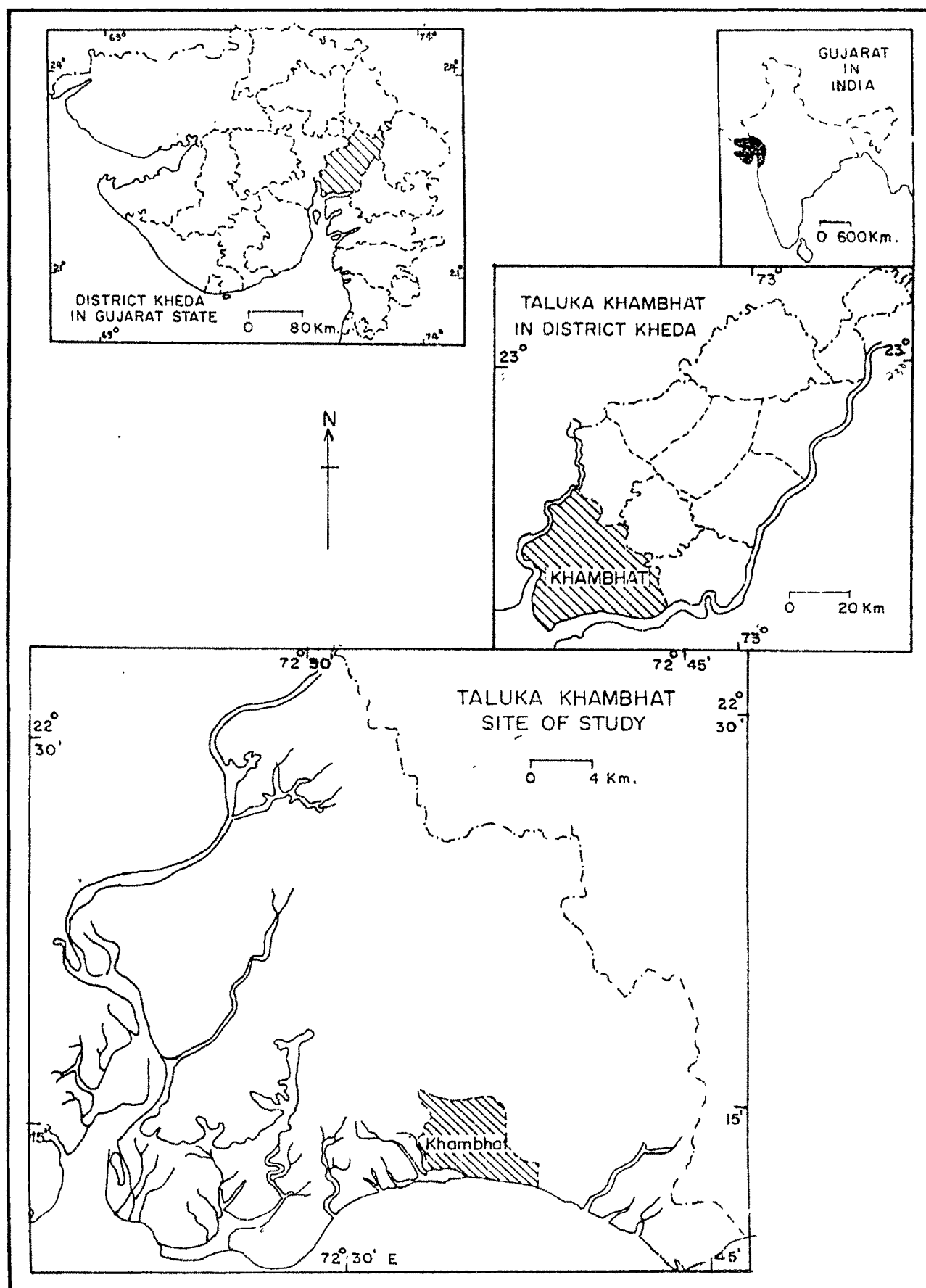


FIG.1. SITE OF STUDY

Table 3. Statement showing the distribution of area under different landuse for Khambhat taluka (Soil Survey Division, Vadodara, 1985)

Landuse	Area (ha)
Geographical	57,540
Culturable	24,426
Culturable waste	2,995
Unculturable	33,114
Net cropping	21,431
Double cropped	3,275
Gross cropped	24,706

*differentiate*

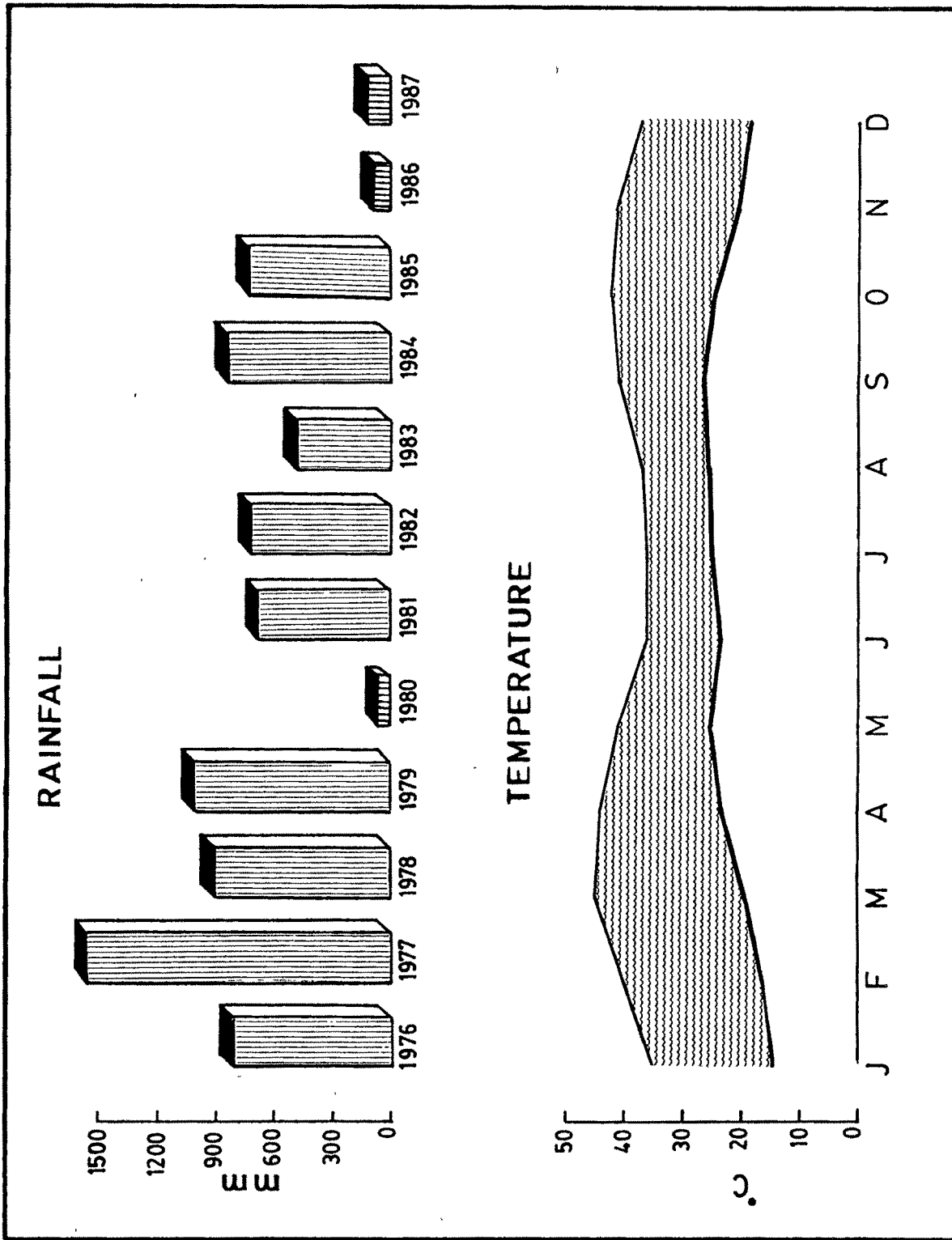


FIG. 2. MEAN ANNUAL RAINFALL AND MONTHLY TEMPERATURE IN KHAMBHAT TALUKA FROM 1976 TO 1987.

communication). The monsoon generally sets in during the later part of June and lasts upto the end of September. Though the rainfall in the district is normally more than the state average, it is on the whole inadequate, less compared to other areas of the district and not evenly distributed. The year-wise rainfall of this taluka from 1975 to 1985 shows the rainfall to be ranging between 633 mm and 1537 mm with the exception of 1980 (Fig. 2) (Soil Survey Division, Vadodara and District Agricultural Office, Khambhat, personal communication). The two years that followed, is considered as drought years due to the negligible amount of rainfall during the period.

The physiographic position of this area is midland to lowland. Therefore, the topography of this area is uneven. Major part of this area at the north is low lying while the remaining part at the south is flat and slightly elevated. The soil is very deep, moderate to imperfectly drained, calcareous, moderately fine to fine textured, occurring on nearly level to flat land. The depth of the effective soil is about 90 cm. while the texture of the soil is clay loam to clay and at places silty clay.

This taluka is fairly and adequately served with irrigation facilities from Mahi Right Bank Canal (MRBC). In 1959 with the construction of a pick up weir at Vanakbori, the area under the command of MRBC was brought under canal irrigation. Afterwards in 1976 the construction of Kadana reservoir supplemented the irrigation further, making canal water available the year round. The MRBC up to 1981-82 had a potential of 3,55,955 ha in the command. An area of 2,28,177 ha from seven

talukas was irrigated as against the potential of 3,55,955 ha. Thus the irrigation intensity achieved during 1981-82 was worked out to be 64.08 per cent (Kalubarme et al., 1983). MRBC forms a part of the alluvial basin in Central Gujarat. The thickness of the alluvium is comparatively less in the eastern portion, becoming more towards the Gulf of Khambhat.

The main crops grown here are rice (Oryza sativa L.), Bajra (Pennisetum typhoides (Burm.f.) Stapf & Hubb.), Juwar<sup>a</sup> (Sorghum vulgare Pers.), Kodri (Paspalum scrobiculatum L. var. longifolium (Roxb.) Dom.), oil seeds, Rajko, fodder grass etc. in the Kharif season and wheat (Triticum aestivum L.) pulses, vegetables, spices and Rajgiro (Amaranthus hybridus L. subsp. cruentus (L.) Thell. var.) in the rabi season. Cotton (Gossypium arboreum L.), tobacco (Nicotiana tabacum L.) Tuber (Cajanus cajan L.) and fruit trees are grown as two seasonal or perennial crops (Soil Survey Division, Vadodara/1985). In the fifties this taluka has been identified to produce a two seasonal crop, the best cotton or wheat, also known as best Bhal wheat, during Rabi season. The introduction of canal irrigation has slowly changed the situation as cultivable lands became waterlogged and the crops have been replaced to the changing edaphic factors. The choice of rice, requiring heavy irrigation has damaged the once fertile lands further, bringing to surface the saline efflorescence to such an extent that some cultivable fertile lands lie barren now and their owners are labourers in other fields or moved away looking for fresher pasture elsewhere (personal communications).