SALT AFFECTED SOILS OF ETAH DISTRICT (U. P.): EXTENT, CHARACTERISTICS AND AGRICULTURAL EVALUATION

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CERTIFICATE

This is to certify that this thesis entitled **SALT AFFECTED SOILS OF ETAH DISTRICT (U.P.): EXTENT, CHARACTERISTICS AND AGRICULTURAL EVALUATION** submitted by Miss Madhurama Sethi for the award of degree of **DOCTOR OF PHILOSOPHY** has not been submitted for any degree of this or any other university. This is her own work.

We recommend this thesis be placed before the examiners for evaluation.

(Prof. A. Ahmed) May 10, 1993
Supervisor

10-5-93
(Prof. G.K. Chaddha)
Chairperson

DEDICATED TO

MY FATHER

AND

MY MOTHER

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CHAPTER I

INTRODUCTION

Man's increasing pressure on land dictates the need for research that will lead to better and more rapid methods for delineating soils for detailed studies of their physical and chemical parameters as well as for characterizing and mapping soil boundaries.

Salt affected soils although existing on the surface of the earth, represent a zone of physical, chemical and biological alteration of the underlying geologic material. Many processes have been active in their formation and alteration especially those of erosion and subsequent sedimentation. It is this balance between erosion and sedimentation in concert with climate and conditioned by time that greatly influence the occurrence and properties of these soils.

On all continents there exist vast areas of salt-affected soils. Worldwide, the extent is estimated at 954.8 m.ha. (Szabolcs, 1989). In India they cover an area of 7 m.ha. In a dominantly agricultural economy these represent a vital potential for reclamation and an increased source of land for agriculture to meet the needs of a burgeoning population.

1.1 Statement of the Problem

Although on going research has helped to identify the problems of salt-affected soils, an exact data inventory does not exist of their extent, characteristics and their agricultural potential.

The area under salt-affected lands demarcated by the revenue authorities can at best be taken as estimates (Aggarwal et. al., 1976). This is because there is no firm basis to categorize these soils at village level by officials who maintain land records as to what constitutes saline and alkaline lands. Salty lands lying uncultivated are collectively classified in the village records as culturable wastelands. In the absence of correct statistics no total assessment of the extent and magnitude is possible. Moreover even if the records for lands affected by alkalinity are separately maintained, this will not include large tracts which are on the verge of saline/alkaline conditions, where crop yields are low and plant growth perceptibly retarded.

Salt affected soils are known by different names, such as 'thur', 'reh', 'kallar', 'bari','usar' and 'karl'. The term 'usar' is derived from the sanskrit word 'ushtara' which means barren or sterile. Besides their presence in the soil itself salts are introduced into the complex by canal water. They are recognized by the presence of extensive white or grayish white ash coloured fluffy deposits on the surface. They occur in the vicinity of rivers or streams or near canals with obstructed natural drainage in arid, semi-arid and sub humid areas.

The problem is particularly acute in the semi arid tracts of the Indo Gangetic plain where alone 40 % of the total affected areas is encountered. The salts are deleterious to plant health and are extremely poor in fertility.

As salt-affected soil occur in patches it would be necessary to conduct research and classify these lands with respect to the whole agricultural mileu existing in the region. A basic survey to highlight the location of these salt-affected soils and their limitations requires an interpretation of remotely sensed data and a synthesis of investigations into soils, drainage climate, topography vegetation and so on.

No study of land degradation would however, be complete without assessing how these lands are being used, present practices, capability, suitability and the possibilities for sustained production.

Etah district in Uttar Pradesh has long been known to suffer from salt affliction. Although some surveys have been carried out the problem of extent and type of salt-affected soils needs furthers research to counter the gravity of on going degradation.

1.2 Objectives

As the information on salt-affected soils is extremely sparse a study on the salt-affected soils of Etah District has been conducted with the following objectives:

1. To map and delineate salt-affected soils in Etah District through visual and digital data using IRS-1A satellite data.

2. To carry out necessary ground truth and chemical analysis for corroboration.
3. To study the geomorphology and occurrence of salt- affected soils and
4. To evaluate these soils for agricultural productivity potential and examine the socio-economic factors influencing reclamation.

1.3. Research Questions

The study of salt-affected soils in Etah district was done considering the following questions.

- Can salt - affected soils be mapped and identified by their spectral signatures on remotely sensed data and areas located ?
- Can a suitable categorization of these soils be done based on severity of the problem ?
- Whether the ground truth and chemical analysis corroborate with the satellite data interpretation and establish if the soils are saline/sodic ?
- Whether geomorphology and drainage have influenced the occurrence and formation of these soils ?
- Have salt-affected soils influenced the present land cover and land use?
- Into what capability - suitability classes can salt - affected soils be categorised and their agricultural potential ?

- Whether socio-economic factors influence reclamation and if reclaimed what benefits would accrue to the farming community?

1.4 Data Base

The data base for the study was collected from different sources listed below:

- February and March 1989 IRS-1A data hard copies of LISS II on 1:250,000 scale from NRSA used for visual interpretation.
- February and March 1989 computer compatible tapes of IRS-1A of LISS I acquired from NRSA were used for digital analysis.
- Survey of India topographical sheets on both 1:50,000 and 1:250,000 were used for preparation of base maps.
- Ground truth was established though field work and soil samples collected from over 85% of the total district.
- Laboratory chemical analysis of the soils samples was carried out to define sodicity and fertility levels.
- State soil survey reports old geological records were consulted.
- Revenue records from Etah District were used to study landuse cropping patterns and so on.

1.5 Methodology

IRS-1A LISS-II data in the form of false colour composite on Band 2 (.52um -.59µm) Band 3 (.62µm -.68µm) and Band 4 (.77µm -.86µm) were visually interpreted for delineating salt-affected soils. A first level map was generated and the soils categorized. The aerial extent was calculated using the digital planimeter. IRS-1A, LISS-I, CCTS were used for digital analysis based on spectral difference on individual bands. Enhancement and other techniques in the form of algorithms were used to improve the quality of data for interpretation.

Administrative boundaries were superimposed using topographical sheets and geometric errors were removed by the use of GCP'S (ground control points). As the information to be processed on a single tape is too large it was conducted by dividing the digital data into data sets. Geomorphic units were examined on both visual and digital data.

The salt-affected soils were categorized according to their severity and the extent calculated on the computer to produce a final map.

Soil samples from 0-15 cm were collected from areas under different levels of severity and processed for chemical analysis. pH, ECe, ESP, CO_3, HCO_3 P, K were estimated in the laboratory to collate with the remotely sensed data. Mechanical analysis for silt, sand and clay fraction was also done using the hydrometer method. The fertility status has been discussed .

The process of formation and occurrence of salt-affected soils have been examined in detail. Land use and cropping patterns in the district and the socio-economic factors influencing the reclamation of these soils have also been investigated. Land evaluation as regards capability and suitability parameters was done according to the framework laid down by the FAO.

1.6 The Study Area

Etah district, covers an area of 444,600 hectares. It is divided administratively into 4 tehsils i.e. Jalesar, Etah, Kasganj and, Aliganj and 15 blocks. It is located between north latitudes 27° 18' and 28° 02' and 78° 11' and 78° 59' east longitudes (Fig. 1.1).

1.6.1 Physiography

The district forms a part of the vast Indo-gangetic plain formed by the rivers of Ganga, Yamuna and numerous other smaller streams. The slope of the land is imperceptible and nearly level and its direction is north west to south east.

Three major physiographical units that can be identified are, i) the khader or the younger alluvium that lies in the neighbourhood of streams, ii) The bangar or the older alluvium which occupies elevated areas beyond the reach of rivers made up of coarser materials and iii) old paleo - channels that are essentially low lying and subject to frequent inundation and waterlogging.

Much of the plain is underlain by nodules and concretions of irregular shape composed of impure calcareous matter called

MAP

kanker that have been segregated through the agency of underground water are present as a zone of calcareous material found to exist through much of the vast expanse of the Indo-gangetic plains.

1.6.2 Drainage

The northern boundary of the district conforms to the bed of the river Ganga. The old bed or the Burhi ganga still has some flow in it, clearly evident on the remotely sensed images. The Kali nadi drains the district northeast to southwest and forms the southern boundary of Etah. Two other rivers the Isan and Sirsa drain the south eastern portion. The district is criss crossed by a major and minor canal network. (Fig.1.2).

1.6.3 Geology

The area is made up mainly of alluvium brought down by the rivers and laid down in the Quatenary era during pleistocene times. The enormous thickness of the alluvium is a strong indication of its having been deposited in a great depression that is, in a syncline forming an aggradational plain (Singh, 1971). The alluvium is extremely thick as well as extensive and blankets and conceals the structural relationship that exists between the peninsula and the extra peninsula. Although the nature of the plain is not known, .PN12 much speculation has been going on about the exact tectonic origin of the depression and its subsurface geology. Various views have been expressed by

MAP

Suess (1893), Burrard (1915), Cowie (1921), Hayden (1913), Oldham (1917, 1923), Pascoe (1964) and Wadia (1938, 1966) regarding this depression.

The plains concealing the Ganga basin are the most extensive and can be divided into three parts. (Ramachandran, 1973).

1. The western U.P. shelf and the frontal deep the Sarada depression.
2. The eastern U.P. and Bihar shelf and the frontal deep Gandak depression.
3. The Purnia-Kishanganj shelf and the frontal deep.

Etah lies in the region of the western U.P. shelf which itself is divided into two subdivisions i.e. the Roorkee - Moradabad shelf and Hardwar deep on the west and the Bareilly, Lucknow shelf on the east.

The Bareilly, Lucknow shelf is made up of an unconformity at a relatively shallow depth in the southern portions near the peninsula. It slopes towards the north gently at first and then becomes deeper and deeper as the Siwalik foothills are approached. It has been established from deep well data that the formations are of the Vindhyan period. A structural well drilled at Kasganj in Etah to a depth of 1250 m encountered below the alluvium upper Siwaliks, Vindhyan limestones and shales with anhydrite.

1.6.4 Geomorphology

The Etah plain is largely alluvial in nature and forms a part of the Ganga Yamuna doab. It can be divided into three major geomorphological units:

1. Active flood plain
2. Recent flood plain
3. Old flood plain

1.6.5 Climate

The climate of Etah district is sub-humid to semi-arid. The mean annual precipitation and mean annual temperature are 692 mm and 27°C respectively. The temperature regime of the area may be recognised as hyperthermic. The detailed meteorological data on temperature are recorded from Agra as Etah has no meteorological observatory. The climatic conditions are reported to be similar. The climate conforms to the general monsoonic climate of the country. It is characterized by cool winter and hot dry summers. January is the coldest month with the mean maximum and minimum temperature occasionally dropping down to about the freezing point and frost occurs during these periods. After February, there is a continuous increase in temperature. May is generally the hottest month. The mean maximum and minimum temperatures are about 41°C and 27°C respectively. The summer season is intensively hot with maximum temperature sometimes rising upto 46°C. Hot dry dust laden winds blow in summer.

The ombrothermic diagram for the area indicates that the period from June to September is wet, whereas the remaining eight months constitute the dry period (Fig. 1.3).

The relative humidity of the area is highest during the monsoon and low in the remaining period (25% or less). Water evaporation from the surface varies generally from 73 to 392 mm. Being lowest (74mm) in December and highest (392 mm) in April. The maximum and minimum wind velocity is 39 and 8.7 km/hr respectively.

1.7 Significance of the study

In studies carried out so far there have been estimates that indicate the presence of large tracts of potentially arable land, but they do not permit any conclusions with regard to their location, extent and levels of agricultural productivity. In our country the search for alternate lands takes on an even greater significance.

We do know however that salt- affected and other degraded lands can be harnessed, reclaimed and brought under the plough, but little is known about the location and extent of these critical areas, their arable potential, their capability and suitability and the technology and level of investment that could bring maximum returns through increased inputs.

Etah district forms a part of the vast expanse of the Gangetic plains of Uttar Pradesh. In this study an attempt has

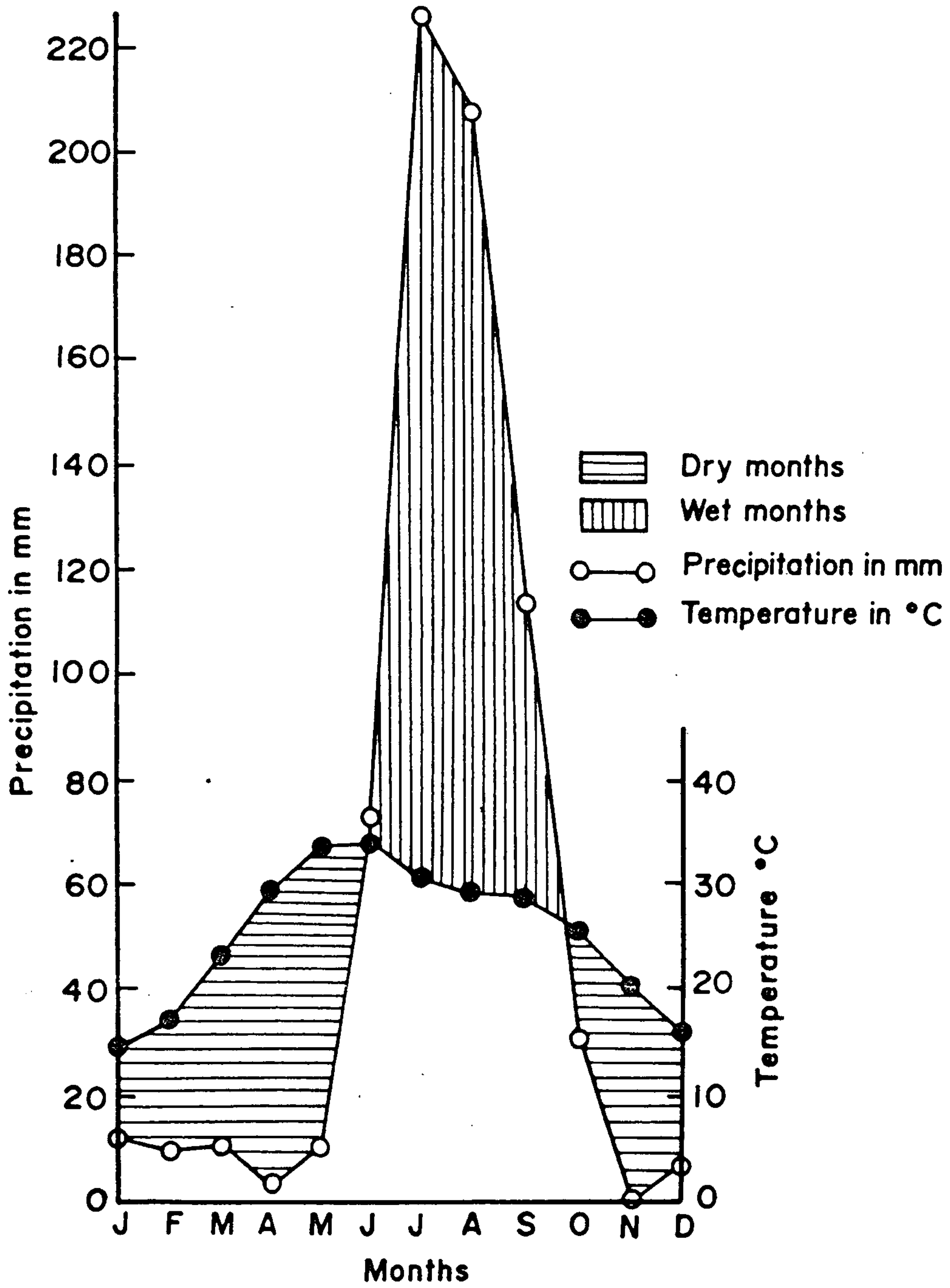


Fig. 1·3 Ombrothermic diagram

been made towards assessing the status of these lands according to the severity and putting them into meaningful categories for agriculture productivity. Satellite imagery has been used for conducting the analysis and factors influencing their nature and extent have also been investigated.

Salt -affected soils in three tahsils of the district were surveyed by the AIS & LUS in 1967, using traditional methods. In the study no categorisation of the soils was done and areas covered on the ground were very limited. The only other work carried out in the district was to assess the waterlogged soils by Singh et al. in 1988.

The present work is an attempt to contribute to the knowledge of salt- affected soils in an area which typifies the conditions existing in the Gangetic plain. At the same time it is an attempt to develop and use techniques that could evaluate these soils at a regional level.

CHAPTER II

AN OVERVIEW OF LITERATURE

The theoretical and practical research that is being done on salt - affected soils is essential to the explanation of the process of salinisation and alkalisation that have rendered vast expanses of the globe unfit for agriculture. The increasing demands for food and raw materials make this explanation and development of the system for optimal utilization of these territories imperative.

Considerable understanding of the problems of salt - affected soils has been achieved. Research into their nature and occurance and factors influencing their presence is continuing. A complete understanding of their physico-chemical characteristics and information on their area and extent is still to be achieved.

2.1 Nature and Processes of Salt Formation

The main source of all salts in the soils are primary minerals in the exposed layer of the earths crust. During the process of chemical weathering which involves hydration, hydrolysis, solution, oxidation, carbonation and other processes the salt constituents are gradually released and made soluble. The released salts are transported away from their source of origin through surface or ground water streams. The salts in the ground water streams are gradually concentrated as the water with dissolved salts moves from the more humid to less humid and relatively arid areas. The predominant ions near the site of weathering in the presence of carbon dioxide will be carbonates and hydrogen carbonates of calcium, magnesium, potassium and sodium. Concentrations at this stage are low. As the water with dissolved solutes moves from more humid to the arid regions, the salts are concentrated and the concentration may become high enough to result in precipitation of salts of low solubility. Apart from the precipitation the chemical constituents of water may undergo further changes through the process of exchange adsorption differential probability etc. and the net result of these processes invariably is to increase the concentration in respect of chloride and sodium ions in the underground waters and soils (Abrol et al., 1989). Processes closely related to geochemical, geological climatological and biological factors in the environment influence the formation of salt - affected soils (Szabolcs, 1979). The pedogenic processes in arid and semi arid regions are largely governed by a combined action of climate, underground water and its migration and of water soluble salts which may be of different origins. A combination of these factors is usually involved in the formation of saline and alkali soils.

2.1.1 Geological Factors

Geologic materials are highly variable in their elemental composition. The geologic formations through which the drainage water passes significantly influence the composition and total concentration of salts.

Salts released through weathering in the arid regions with limited rainfall are usually deposited at some depths in the soil profile, the depth depending on such factors as the water retention capacity of the soil, seasonal, annual and maximum rainfall etc. (Yaalon, 1965). Salt affected soils generally occur in regions that receive salts from other areas with water as the primary carrier.

The intimate relationship of geology is reflected in the nature of soluble salts in weathered crusts of rocks of the parent materials from which the soils originated. Thus weathering products from acid magmatic rocks like granites and gneiss are least mineralized whereas those from basic magmatic rocks (basalt, dibase etc.) are highly mineralized. The arid and semi arid climates where precipitation is usually less than evaporation, associated with certain elements of topography and ground water hydrology are often responsible for the accumulation in situ or transport and deposit in other places of salts and manifestations of saline and alkali characters in the soil (Agarwal et al., 1952).

Pure water is not particularly effective at causing chemical changes in rock forming minerals. Most natural water however contains dissolved carbon dioxide gas which it has picked up either from the atmosphere or from the soil, where plant and animal respiration causes the CO_2 to concentrate. Dissolved in water, carbon dioxide forms a weak solution of carbonic acid.

Most igneous and sedimentary rocks are composed largely of silcrete and calcrete minerals (quartz, feldspar, mica etc.) or hydrous silicates and calcretes (the clay group). The carbonate group of minerals which form the limestones are the only major non silicate rock forming minerals. In general terms, these minerals in the presence of carbonic acid gradually break down. The products of that breakdown often include both a soluble component which is then carried away by the water and an insoluble residue which is left at the point of weathering until transported by some surface agency. It should be noted incidentally that organic acids derived directly from the decomposition of plants may also play a role in chemical weathering (FAO/UNESCO, 1973).

As far as temperature is concerned in most chemical reactions rates increase with temperature. With the result that weathering generally proceeds far more quickly in tropical humid areas than in temperate humid zones. Exceptions exist however, limestone is found to increase in solubility at lower temperatures (Weyman D and V, 1983).

While it is evident that rock weathering is the primary source of all kinds of soluble salts usually found in soils, contemporary weathering and soil forming processes can be regarded as of major significance in the salinization of soils (Sokolovosky, 1941).

The sources of secondary deposits are shales, sandstones, glacial and wind borne materials and unconsolidated alluvium of various geological ages (Kelley, 1951). These have undoubtedly originated from the weathering of igneous rocks in various geologic periods. With the decomposition and production of salts and their subsequent conversion into the present sedimentary deposits. The drainage from these secondary products has been recognised as the most important source of salts in the soils.

Medlicott (1880) Center (1880) and Voelker (1897) were among the first to attribute the origin of soils in India to the decomposition of rocks through the agencies of water and atmospheric gases. Subsequently Leather (1897) summarized the origin of salts in the soils of India in four possible ways.

1. From a subsoil bed of salts for which no positive evidence exists.
2. Brought down by rivers after dissolution from the weathering of rocks and deposit along with alluvium
3. From the soil itself by further decomposition of soil minerals.
4. Distribution through canal water.

The formation of sodium carbonate in soil can also be ascribed to the release of sodium through base exchange reactions which gets hydrolysed and subsequently carbonated. These facts became known only through the chemical researches of Geodriz (1912) and Glinka (1927).

2.1.2 Climatic Factors

Where rainfall is sparse humidity is insufficient and irregular and so the soil forming processes range from rather intensive at times to virtual cessation at others. The climate governs the dynamics and migration of both mineral and organic elements in the soils. The weathering processes are limited by the shortage of water which also prevents the leaching and transport of the weathering products. In dry periods the soluble substances form efflorescence in patches on the surface of the soil.

In regions where the soils are not enriched even secondarily with sodium compounds Ca and Mg dominate among the cations and the dry climate leads to certain geochemical processes which cause soluble products to accumulate in both soils and waters (Szabolcs, 1979).

Aggarwal et al. (1952) state that saline soils are essentially but not exclusively parts of arid, semiarid zone. The fact that the occurrence of reh (salt efflorescence) in India occurs in well marked meteorological areas in the north western tracts like Punjab and Haryana, parts of Uttar Pradesh and Rajasthan was recognised by the early workers. The occurrence of such soils in the southern states is chiefly confined to the mid central tract which also has an arid and semi arid climate. Sen (1958) analysed the influence of climatic factors in the salinization of Indian soils.

Rainfall seems to have a greater effect than annual temperature in determining the salinity/alkalinity of the soils. Soluble salts will accumulate wherever evaporation exceeds total precipitation in arid zone. It reaches 1,500 - 3,000 mm per year which often exceeds the total precipitation received even for a number of years.

2.1.3 Hydrological Factors

Salt accumulation is further associated with certain types of relief connected geomorphologically to low lands and their component parts viz. flood plains, deltas, coastal terraces and lakes and hydrologically to regions of high water tables. At such places surface runoff is negligible and drainage water evaporates leaving the salts on the surface. This process of evaporation also brings up salts from the lower horizons if the moisture regime is connected with ground water. In fact this is the most important means of salt accumulation found in the contemporary salinization of soils. Kelly (1951) expressed the view that alkali soils are rarely residual in nature i.e. they have seldom been formed in situ by the residual weathering of primary rocks. Water is the chief transporting agent of salts and its subsequent evaporation gives rise to localization of salts in soil. Since these processes are accentuated in situations where soil materials are also transported, Kelley (1951) concluded that a large percentage of alkali soils in the world are alluvial in nature. It has been found that the magnitude of salinization is greater if the water table remains close to the surface for a long period.

Kovda (1965) has called attention also to the action of ground water in the soil forming processes in the arid and semi arid regions.

Ground water is always mineralized to some degree. In an arid climate the soluble elements it contains. Rise through the soil as result of capillary action, enrich the soil surfaces and form efflorescence which are grey or white where there is accumulation of sodium chloride or sodium sulphate or of magnesium or calcium salts, or black or dark brown where sodium carbonate coloured by dissolved humus accumulates in the top soil horizons (Abrol and Bhumbla, 1971). These efflorescences appear right at the soil surface, in the upper part of the soil horizon or in the case of highly saline alkali soils just below the powdery horizons.

The main elements, combinations of which give rise to the formation of salt - affected soils are Ca, Mg, Na, K, Cl, N, B and I. Geodriz (1912), in the USSR and Hilgard (1907), Harris (1920) and Kelly (1951) in USA took the view that weathering processes are mainly responsible for the appearance and accumulation of these salts.

The above mentioned factors have led to the contemporary, formations and accumulation of salt deposits in soils. The influence of geomorphological, hydrological and topographical conditions along with climate have set up the formation of salts.

It is extremely important to mention a general law, mainly the tendency of areas of contemporary salt accumulation in soil to occur in large stretches and to be concentrated on the left banks of rivers, of the vast ancient alluvial plains within the limits of their first, second and third terraces. This phenomena has been observed for example along the valleys of the Dnieper, Don, Volga, Saryu Darya, Amu Darya the Hawang Ho and the Ganges, amongst other rivers at various sections of their course. This tendency is a general one and also observed in other continents and of course under other conditions but salinity alkalinity is never as high as on the left bank river regions (FAO/UNESCO, 1973).

2.2 Geographic Distribution

Ample geographical data have been accumulated the world over showing that salt - affected soils are extremely widespread throughout the various continents of the world in USA, USSR, Australia, India, Pakistan and so on. In view of the high toxicity of such soils and their very unfavourable physical properties imparted by salts to both soils and soil forming sediments alkaline saline soils have a very low fertility and can only with difficulty be used for farming.

2.2.1 India

A map by Bhumbla et al. (1975) prepared at the Central Soil Salinity Research Institute, Karnal shows salt -affected soils occurring in India and their distribution in various states. Salt- affected soils occur in the states of Uttar Pradesh, Gujarat, West Bengal, Rajasthan, Punjab, Maharashtra, Haryana, Orissa, Mysore, Madhya Pradesh, Delhi, Kerala, Bihar and Tamil Nadu. The total extent is estimated at 7 million ha. These saline-alkali soils occur usually in association with normal zonal soils of the arid and semi arid regions. They are found in belts or as patches. At most places their pattern is variable and salinity-alkalinity conditions change even at relatively short distances. It is for this reason that field mapping of salt infested soils is a difficult task.

The grouping of salt - affected soils in India according to their occurrence is as follows:

	m.ha
Alluvial Indo Gangetic Plain	2.8
Medium and deep black soil	1.4
Coastal and deltaic alluvium	1.4
Coastal arid areas	0.7
Desert and semi desert areas	0.8

2.2.2 Uttar Pradesh

Aggarwal, Yadav and Gupta (1976) reported that the area under saline alkali soils in Uttar Pradesh was first assessed by the 'usar' land reclamation committee in 1938-39 constituted by the Uttar Pradesh government and was found to be 1.84 million ha. In a subsequent survey the figure was put at 1.28 million ha. U.P. has the largest salt - affected area found in any single state in India. The saline and alkali lands are mostly localized in the semi arid heart of the state and in the region lying south west of the Ganges. The districts worst hit by ravages of salt infestation are Mainpuri, Aligarh, Etah, Farrukhabad, Etawah, Agra, Mathura, Meerut, Kanpur, Unnao, Fatehpur, Allahabad, Rae Bareli, Lucknow, Hardoi, Faizabad, Pratapgarh and Sultanpur. There is also a stretch of low lying tract extending to the subhumid parts of the state comprising the district of Azamgarh western part of Ballia, Ghazipur and Bhadoi tehsil of Varanasi district. These soils are collectively known as **usar** and sometimes**Reh** or**Kallar**. The most common feature of such lands is the appearance at the surface of exclusive quantities of white, greyish white or ash coloured salt encrustations during dry periods. The land presents a sterile and barren look with a hard rock like surface, devoid of any vegetation. Some vegetation may occur in patches with poor or impeded drainage with muddy water stagnating over long periods during the rains. The surface is often impermeable to water and there may be a hard 'kanker' layer or clay pan at some depth in the profile.

2.3 Salt Formation in the Indo Gangetic Plain

The soils in the north western part of the country are chiefly 'sodic' (alkali). These have a preponderance of bicarbonates and carbonates of sodium (Bhargava et al., 1976). In its present shape the alluvial plain is largely Pleistocene except for the old channels and existing river flood plains,wherein continue the processes of fluvatile deposition. Underlying the alluvium are the unconsolidated Siwaliks and older tertiary sediments of the Himalayan piedmont below which lie more consolidated older formations such as Gondwana and the cretaceous (Pascoe, 1965).

The sodic soils begin to appear in Haryana occupying parts of the soil scape of the Pleistocene age, south of the Siwaliks where the alluvium attains a gentle slope (Bhargava et al., 1981). The sodic soils occur within a rainfall zone of 600-900 with rainfall exceeding evaporative demands for a certain duration. In Uttar Pradesh such soils not only occur in areas west of the 81°E longitude as reported by Raychaudhari and Govindrajan (1971) but also extend further east of the meridian. The radial centripetal drainage pattern in Haryana state and a sub parallel in Uttar Pradesh reflect a very gently sloping nature of the plain and their geomorphic setting favours the discharge of runoff water from other upstream catchments into flat shallow basins or depressions which these sodic soils occupy. The prevailing high temperatures facilitate evaporation of surface runoff.

These soils contain Quartz, feldspars (orthoclase, microcline, palagioclase) muscovite, biotite, chloritised biotite, tourmaline, zircon, hornblende and their sand fractions (Goswami, 1979). These minerals especially sodium and potassium feldspars release large quantities of calcium, potassium, magnesium and sodium carbonates on weathering through the action of water in general and of carbonic acid in particular (Kovda, 1965). Calcium and Magnesium deposited on the surface as bicarbonates are the first to get precipitated as carbonates as the process of drying begins and soil solution gets increasingly concentrated with sodium (Bhumbla, 1972; Szabolcs, 1969). The lime concretions of finer size distributed in the upper 1m depth result from this kind of pedogenic release of calcium and magnesium. The spread of sodic soils in localised depressions in parts of the Indo-gangetic alluvial plains with conspicuous accumulation of salts capable of alkaline hydrolysis highlights the role played by the operating continental cycles in their evolution under the monsoonic semi arid and sub tropical climate. The weathering of sodium and potassium aluminosilicate minerals particularly those like feldspars and feldspathoids in the piedmont zone close to the Siwalik hills (Bhargava et al., 1980) and in the plains also takes place through hydrolysis. In the existing geomorphic situations the relief features always favour a quick runoff from the Siwalik hills and the piedmont zone towards the plain. Consequently parts of the alluvial plains receive repeated floodings. These observations of Bhargava et al. (1981) are in close agreement with those of Kovda (1965) who reported that constant weathering of aluminosilicate minerals in drainage basins produces a steady supply of bicarbonates and carbonates of alkali which migrate with the subterranean and surface waters and accumulate in undrained areas under arid climatic conditions to form alkaline soils.

It is evident that sodic soils occurring in parts of Indo-gangetic alluvial plains have mainly originated from the process of sodiumization beginning at the surface. Sodiumization of deeper horizons remains relatively low and is most likely brought about by the illuviation of sodium saturated and highly deflocculated clay particles as well as limited leaching of alkali salt solutions. Repeated cycles of wetting and drying facilitates maximum accumulation of salts on the surface. While the presence of a salt horizon or a saline ground water table is essential in a typical solonetez profile which comprises of an illuvial, A horizon lying over an eluvial columnar structure or a blocky B, horizon followed by a carbonate B_2 horizon underlain finally by a salt horizon (Kovda, 1973)

The phenomenon whereby salts simply accumulate in the soil is closely related to the formation of alkali soils in different cycles and is linked geomorphologically to lowland or component parts of lowlands, flood plains, deltas, troughs, low river terraces and lake coastal terraces. From the hydrogeological point of view the processes are related to regions with high water tables (within the limits of capillary and film capillary rise of solutions). Hydrologically salt accumulation processes occur particularly in regions where runoff is slight or virtually absent.

In a study Bhargava and Sharma (1982) explained that the low lying areas as the oxbow lakes, old channels etc. remain submerged continuously from June to October and even beyond, receiving runoff water and lacking any outlet. Such prolonged and uninterrupted waterlogging with water with low degree of mineralization leads to fresh water recharge of underground water. In such circumstances the relief forms receive the salt influx from elevated relief forms as well as from subterranean hydrological currents resulting in salt formation.

2.4 Classification and Physico Chemical Characteristics of Salt Affected Soils

Two main groups of soils have been distinguished (a) soils affected by neutral sodium salts, mainly sodium chloride (NaCl) and sodium sulphate (Na_2SO_4) (b) soils affected by sodium salts capable of alkaline hydrolysis mainly sodium bicarbonate ($NaHCO_3$), sodium carbonate (Na_2CO_3) and sodium silicate (Na_2SiO_3) (Richards, USDA Handbook 60, 1960).

Soils belonging to the first group are referred to as saline and the second group as alkali soils. These two main types differ not only in their chemical character but also in their geographical, physical, chemical and biological properties as well.

In field conditions, salt - affected soils can be recognised by the spotty growth of crops. Barren spots are often an indication of salinity and concentration of salts in the soil (FAO, 1988). The planning commission (1963) classified saline/ alkali soils into 1. Saline 2. Saline alkaline 3. and alkali.

Saline soils have an accumulation of neutral salts namely chlorides and sulphates of sodium, magnesium, calcium and potassium. The soils have an electrical conductivity of more than 4 dS/m at 25°C, pH of less than 8.5 and exchangeable sodium percentage (ESP) of less than 15.

Alkali soils contain sufficient exchangeable sodium to interfere with crop growth but do not contain appreciable quantities of soluble salts. The ESP is more than 15 and the electrical conductivity (EC) is less than 4 dS/m. The pH values generally range from 8.3 to 10.5.

Saline alkali soils result from a combined process of salinization and alkalisation. As long as excess salts are present the appearance is generally similar to alkali soils (USDA, Handbook 60).

The terms Saline-alkali soils is applicable to soils that possess characteristics of both. Other sub-categories also exist. Our concern is with both saline alkali and alkali soils. The general characteristics and basic principles involved in the identification, reclamation and management of salt - affected soils are the same throughout the world. However, differences from place to place in soil characteristics, climate, water availability, farm management capability, financial resources, available inputs and economic incentives lead to differences in method, extent and rapidity in soil reclamation. Although technical literature abounds with sound information, nevertheless there are far too many partial or complete failures of efforts. These failures are due to lack of proper identification and subsequent use of incorrect methods (FAO 1988).

A rapid and accurate assessment of the extent of salt - affected lands can be made through mapping using the remote sensing technique.

2.5 Mapping and Use of Remotely Sensed Data

As we still do not have an accurate cadastre on the exact location, extent and distribution of salt - affected soils, mapping and territorial evaluation is essential. The preparation of large scale and reconnaissance maps of these soils is indispensable in estimating size and distribution of salt - affected areas. Maps aid the methods and strategies of combat against salinity and alkalinity as well as investigation and dissemination of all kinds of research on salt - affected soils.

Remotely sensed LANDSAT/TM SPOT, IRS-IA/LISS-I and LISS-II data provide for adequate and accurate analysis of existence and spread of salinity, geomorphic features, drainage and landuse. Salt affected areas can only be mapped through remotely-sensed data because of their non continuous occurrence and existence with normal soils.

A purposeful land survey programme should not only provide accurate information but should also be upto date, space remote sensing particularly in the area of land and soil studies lags far behind in operationalisation though substantial research and development effort has been devoted in recent years. Studies reported so far show with considerable evidence that although field work cannot be fully eliminated, multispectral analysis is a valuable tool for delineation (Weismullur et al., 1979; Imhoff, 1980; Hovarth et.al., 1984).

Use of thematic mapper data with spatial resolution of 30 meters has shown encouraging results in soil and landuse mapping though the experiments conducted are mostly based on visual approach.

Remote sensing techniques have shown a great promise in studying land degradation problems by providing a quick inventory and pictorial representation of the affected areas as also portraying reclamation and conservation efforts. Presently satellite data owing to the intrinsic merits of wide synopticity and multi temporality are almost indispensable for macro level studies on change detection (Anuta and Bauer, 1973).

Manchanda and Khanna (1981) conducted research into the study of salinity and landscape relationships in parts of Haryana state. Using aerial photographs they identified six major landforms and found that the elements of landscape controlled the distribution of salts within each landscape. Through subsequent field check soil samples were analysed for pH and electrical conductivity confirming the aerial photo interpretation analysis.

While monitoring study of degraded lands of Thane district Maharashtra, Khire et al. (1988) found land currently lying under utilised or unidentified due to various reasons. The mapping of degraded lands was done on LANDSAT TM data on 1:50,000 scale of the period Oct. 1985 to March, 1986. False colour composite of band 2,3,4 were used for mapping. The LANDSAT FCC's were found to be extremely useful in delineating and classification of degraded lands. The classification followed was as suggested by the NWDB. After ground checks final maps showing degraded lands were transferred from the imagery to 1:50,000 scale topographical sheets. A similar study on wastelands was conducted using remotely-senseddata by Moghe and Kalra,(1988).

Gill et al. (1988) used TM FCC enlarged prints on the scale 1:50,000 and 1:1 m FCC transparencies using a combination of Bands 2, 3 and 4 covering the wave lengths 0.52 - 0.60, 0.63 - 0.69 and 0.76 - 0.90 micrometers. They carried out collection of collateral data as toposheets on 1:50,000 scales and revenue maps. Of the 13 fold classification of the NWDB, only 4-5 categories were identified on the basis of preliminary interpretation of tone, texture, shape, size, association etc. Categories having a doubtful and confusing signature were ground checked and the units rectified accordingly. Land affected by salinity/alkalinity was one of the categories/identified occupying 50 sq. km of the area and covering 23.20% of the total wastelands.

The study demonstrated that satellite remote sensing could be used operationally in mapping wastelands at 1.50 scale showing type, extent and location. It also proved to be economically viable in providing accurate baseline information.

Ahuja and Goyal (1987) carried out a visual interpretation of LANDSAT thematic mapper FCC data on 1:50,000 scale approximately corresponding to the season October to March, 1986 for the delineation of wasteland in Hisar district of Haryana state. After the interpretation in conjunction with ground truth, wastelands maps were finally prepared and suitable remedial measures and proper landuse planning was suggested for each category. The wastelands identified were sand, salts, degraded pasture, grazing lands, non forest plantation, degraded forest and forest. Two pedons representing the sandy and salt - affected wastelands were studied physico chemically.

Dutt et al. (1986) used LANDSAT/FCC data on 1:50,000 scales for identifying the wasteland categories such as gullied/ ravinous lands, undulating upland, salt - affected lands etc.

in 2000 km covering parts of Bangalore district. Standard image interpretation techniques which are based on photo elements such as tone, texture, pattern, association, location, shape and size were used. Interpreted details were finalized on basis of adequate ground truth. The details were transferred to a base map of 1:50,000 scale using the optical reflecting projector (ORP). The overall interpretation accuracy was found to be 76.7%.

The wasteland image interpretation key using satellite LANDSAT remotely-sensed data described salt - affected soils as below:

Wasteland class	Band5	Band7	FCC combination 4,5,7	Size
Salt affected	White to light grey	Light grey	White to light blue	small

Shape	Texture	Pattern	Location	Associ.	Season
Irregular	Fine to mottled	Scattered and non-contiguous	Inland plains valleys coastal low lands desert plains	Associated with irrig. agri. land crop area tidal marshes	Jan. to March

Salinity if due to capillary action in dry climates	Or under irrigated conditions due to unimpeded drainage of near brackish waters areas

Aerial photographs were used for a study of landforms, landuse and land units of a part of the Krishna district in A.P.

(Pudhuvi Raju and Vaidhyanadan, 1977). Major landforms were identified as hilly and flat uplands, piedmont deposits, rolling plains etc. Six classes of landuse and nine types of land units were also demarcated. Identifying fractures, fault lines and old river basins would aid in ground water drilling.

Geomorphological and landuse map of Gujarat prepared from LANDSAT by Murthy and Pofali (1984) was related to the climatic environment of the area for planned exploitation of natural resources.

With the objective of mapping water-logged lands their aerial extent and categorization for judicious use Singh et al. (1988) used multidate LANDSAT imagery for analysis in Etah district of U.P. Four different categories were identified for management and to check engulfing of cultivable area.

A multistage approach of information extraction involving LANDSAT TM imagery, aerial photographs on 1:50,000 scale and cadastral records were used to know the nature and extent of wastelands in some villages of Sultanpur district of Uttar Pradesh. The study has shown that an accurate reliable and updated information can be obtained using this approach (Singh and Mishra, 1988). Realising the utility of satellite data for preparing an inventory of large areas a project was taken up by RSAC (U.P.) at the instance of the NWDB under which mapping of problem lands has been carried out in twenty districts of the state. In the project LANDSAT TM imagery on 1:50,000 scale had been used for delineating classes and village location boundaries were plotted (Narayan, 1987; RSAC-UP, 1988).

Singh and Dwivedi (1986) examined the utility of LANDSAT imagery as an integral part of the data base for small scale mapping. A soil map of parts of Bundelkhand region and its adjoining areas in Uttar Pradesh covering an area of 41000 km^2 was prepared following a collative approach that used visual interpretation of LANDSAT imagery in conjunction with lithological, topographical and other collateral data and information from field work. The soil map was found to be better than the conventional map in terms of soil landscape boundary delineation. The study demonstrated the usefulness of LANDSAT imagery for small scale soil mapping. An overall accuracy of 93.3 percent with respect to soil landscape boundary delineation has been achieved.

A more recent work of Singh and Dwivedi (1989) was carried out on delineation of salt - affected soils through digital analysis of LANDSAT, MSS data. CCTs (computer compatible tapes) were used for an area 60243 km^2 in Uttar Pradesh. Data was analysed on the interactive multispectral data analysis system (MDAS). It involved the display of data on the moving window of the system, selection of spectrally homogeneous areas for which ground data were available, assigning a colour to each class. A total of 54 training sets representing different classes were fed into the system and both salt - affected and non salt - affected soils were classified using all data points (pixels) in the scene.

Based on the spectral response of these soils and subsequent correlation, two categories of salt - affected soils requiring different management practices, namely, typic Natrustalf and an association of Typic Natraqualfs and Aquic Natrustalfs could be delineated. Besides the salt - affected soils, other categories such as normal soils, forests, water bodies, river sand, gullies and ravines were also mapped.

By virtue of providing a synoptic view of a fairly large area in narrow and discrete bands of the electro magnetic spectrum every 8 days. LANDSAT data (both MSS and TM) enable resource scientists to map and monitor natural resources at regular intervals in a timely and cost effective manner with acceptable accuracy. Digital analysis of LANDSAT data has been used for separating out different levels of soil salinity/ alkalinity in the U.S.A. (Wiersma and Horton, 1976) Canada (Sommerfeldt et al., 1985), Iraq (Al Mahawili, 1983) and in India (Singh et al., 1977; NRSA, 1979 & 1981; Venkataratnam, 1980 & 1983).

Mothi Kumar and Bhagwat (1986) carried out delineation and mapping of salt - affected lands in Pariej village of Kheda district (Gujarat) using LANDSAT TM data on 1:50,000 scale. They superimposed the village boundary from cadastral map on saline land to enable the identification of saline lands at plot level under various categories. The ground truth verification includes the saline soil analysis and correlate the information with satellite data.

2.6 Land Evaluation

No study of degraded lands is complete however without an enquiry into the evaluation in terms of capability and suitability parameters. 'Land' is a wider concept than either soil or terrain hence it is land which is employed as the basis for evaluation. While carrying out the intricate process of evaluating land, classification for planning land use must be based on natural characteristics. The initial exercise is to map and study the existing land use which would be essentially subdivisions of rural land use such as agriculture grassland and forestry.

The FAO framework for land evaluation (1976) was proceeded by a background document (FAO, 1975), and the proceedings of two meetings of International expert consultants (Brinkman, 1978; Brinkman and Smythe, 1973; FAO, 1975; Smythe, 1970, 1971 & 1974; Higgins, 1975; Purneel, 1978), and reports on various pilot studies eg. in Malawi (Young and Goldsmith, 1977), Sri Lanka (Desaunnettes, 1960; Sompala, 1974), Mauritius (Arlidge and Wong, 1975), The Sudan (Van der Kevie, 1976) and Brazil, Surinam and Kenya(FAO,1976) illustrate the frame work towards its final form.

Klingbiel and Montgomery (1961) presented the definitive descriptions of the classes of the U.S.D.A. land capability classification. The most widely used system for evaluating agricultural land capability classification is that developed by the U.S.D.A. during the 1930's. Initially there were nine classes but it became established at eight (Norton, 1939; Hockensmith and Steele, 1974). By convention roman numerals are used to designate the classes. With class I the best land and class VIII the poorest. During the 1940's increasing attention was given to problems other than soil erosion and the new more general class descriptions emphasized the degree of limitations to the use of the land. Land capability subclasses indicating the kind of limitation. The rationalization and clarification of the subclasses was done by Hedge and Klingbiel (1957).

The classification for capability consists of broad grouping of soils based on their limitations and is designed to emphasize the hazards in different kind of soils. It serves as a guide to assess the suitability of the land for cultivation, grazing and forest. Some lands are good for cultivated crops others for pasture. The capability study is designed to prevent declining yields and emphasize the effort that would be required to obtain sustained yields.

The grouping of soils into capability classes is done on the basis of their capability to produce crops and pasture plants without deterioration over a long period of time. The criteria used in assessing a land unit are the physical land properties and the degree of limitation as a function of the severity with which crop growth is inhibited. It is mainly based on:

1. The inherent soil characteristics
2. The external land features
3. The environmental factors that limit land use

The factors that determine the capability of the soil are:

1. Depth of soil
2. Texture and structure of soil
3. Permeability
4. Relief
5. Extent of erosion
6. Presence of salts, alkali and other unfavourable chemical factors like pH.
7. Susceptibility to climate
8. Severity of climate.

The capability classification as put forward by the 'Framework' consists of three categories:

1. Capability classes
2. Capability sub-classes
3. Capability units.

(Framework of Land Evaluation, FAO Bulletin 32, 1976).

CHAPTER III

ANALYTICAL PROCEDURES & TECHNIQUES

To study the extent and characteristics and to carry out the agricultural evaluation of the salt - affected soils of Etah district the following materials and procedures have been employed. The occurance of salt - affected soils in distanced patches necessitates the use of a technique that would provide both synopticity as well as accuracy. The IRS-IA data provides adequately for the analysis of such soils. Details of the satellite itself, interpretation techniques, survey methods. chemical analysis techniques and agricultural evaluation criterion used are as follows.

3.1 IRS IA Satellite

The Indian Remote Sensing Statellite IA (IRS-IA) is the first of the satellites to be launched for providing remotely sensed date on a continuous basis. IRS-IA was successfully launched on March 17, 1988 from the Baikonour Cosmodrome in the Soviet Union using a VOSTOK launcher. The large number of images generated since have been used to evaluate their application potential for natural resources inventory.

The IRS-IA is a three axis stablized polar sun synchronous satellite. The space craft platform essentially consists of the main structure, thermal control system, power system, telemetry, tracking and command (T.T.C. system) as well as the attitude and orbit control system. The main frame of the spacecraft is in the shape of a parallelopipe.

Spacecraft Specifications

Spacecraft	:	Body stablized
Weight	:	Passive semiactive using heats and temperature contour 20 + 5 deg C for imaging sensors.
Solar assay	:	8.5 sq. m deployable and suntracking 620 watts at end of life.
Battery	:	Two nickle-Cd batteries of 40'A 4 capacity each
Attitude and orbit	:	Infrared horizon, star, sun sensors and gyros reaction wheels magnetic torques, hydrazine thrusters
Telemetry, tracking and command	:	S-band, two way doppler X-band beacon.

Orbit details

Orbit	:	Circular sun synchronous
Altitude	:	904 Kms (circular) local time of equatorial crossing 10 AM
Semi-major axis	:	7282.3 Kms
Inclination	:	99.028 degrees
Eccentricity	:	0.002
Period	:	103.192 minutes
Orbits/day	:	14

Data Format

1.	:	BIP band interleaved by pixel
2.	:	BIL Band interleaved by line
3.	:	BSQ Band sequential

Spectral Bands

1.	:	0.45 - 0.52 micrometer	
2.	:	0.52 - 0.59 "	
3.	:	0.62 - 0.68 "	
4.	:	0.77 - 0.86 "	
Quantization	:	128 grey levels	
Band to band registration	:	+ 0.25 pixels	
Swath	:	148 Km LISS I	
		146.5 Km LISS II	
Data rate	:	5.2 Mbps LISS I (bytes/sec.) 2 x 10.4 MB_{ps} LISS II	
Sensor	:	Linear image scanning system (LISS)	
No. of LISS cameras	:	LRC (one) Low resolution Camera	MRC (two) medium resolution Camera
No. of spectral bands	:	4	4
IFOV (m rad)	:	80	40
Geometric resolution from 904 km. alt.	:	72.5 metres	36.25 metres

The satellite employs the push broom or linear array scanner which is technologically one step ahead of the optical mechanical scanner of the MSS or TM type. Whereas the across track data collection is affected mechanically by a rotating or oscilllting scanner of the MSS or TM kind. In case of the push broom scanner there is an array of detectors (for each band) 'viewing' the entire swath simultaneously, Thus there is no moving part in the sensor of the latter which improves its realibility. The scanner exists in both SPOT and IRS.

The linear imaging self scanning sensors (LISS) have 2048 detectors each arranged in the form of linear arrays. LISS-I is a single low resolution camera giving a swath width of 148 km and a spatial resolution of 72.5 metres. LISS-II has two cameras aligned in parallel to give the same swath width but at an improved spatial resolution of 36.25 metres. Four similar spectral bands have been chosen for both the cameras in the wavelength 0.45 to 0.86um.

3.1.1 Data Characteristics

The data is available in digital form and is normally on computer compatible tapes which can be used on standard tape drive limits.

Each data point is called a pixel (picture element) and has a density value called grey value or grey level for each band. These value are also referred to as 'digital number' values.

The spatially ordered nature of images leads naturally to data storage format thus each line of image pixels is usually stored as a record. So a record constituting an image is called a file. Multispectral images are stored in one of the following formats BIL, BIP AND BSQ.

Storage Media

Digital data is stored on a magnetic mylar tape coated with a thin film of iron oxide or on metallic disks. magnetic tape and disk media can be read or written and rewritten many times over.

Spectral bands and their widths

The choice of spectral bands is critically dependent on the applications envisaged. Agricultural application are considered to be the first priority of the IRS-IA. Hence spectral bands are chosen for optimised vegetation mapping. (American society of photgrammetry, 1983) Spectral indices derived using data in the near infrared and red regions are highly correlated to some of the plant parametres like leaf area index, green biomass etc. The region 52 um to 59 μm is useful for the study of coastal environments since the penetration of light into the water column is higher at shorter wavelengths. The spectral region of 0.62 to 0.68 μm is characterised by high reflectance of vegetation compared to blue and red regions. This region is also found useful for turbidity assessment and bathymetric evalution. Discrimination of rocks and soils on the basis of their iron content is a possibility in this spectral region.

Spatial Resolution

Identification of crops under Indian conditions necessitates a resolution of 30-70 mts. However, the volume of data becomes too large if one considers 30m data only. For certain applications like land cover mapping, regional geological mapping, 70 mt. resolution is adequate. Hence two independent camera systems operating at 72.5 and 36.25m spatial resolutions have been chosen. Data with 72.5 spatial resolutions also enables continuity of data services to the users accustomed to LANDSAT, MSS class of imagery.

Repetition Cycle

The repetition cycle of 22 days for IRS-IA based on the trade off between orbit choice considerations and payload swath represents a compromise between the needs of dynamic resources applications such as agriculture and hydrology and those relating to 80 other dynamic applications such as geology, landuse and water exploration.

Orbit Selection

Commensurate with the constant illumination needs of the earths observation the orbit is sun synchronous. The major consideration in choice of attitude is greater geographical coverage from a single ground station, low drag effects, less frequent orbit correction requirement with the attendant savings in the on board fuel and possibility of orbit determination with better accuracies in view of reduced atmospheric modelling errors leads to the choice of orbits with altitudes of above 800 km.

It is to be emphasized that for an operational satellite with close tolerance requirements on orbit parameters. An orbit of 904 km altitude appears optimum considering the additional needs such as percentage overlap between contiguous strips of imagery, recurrence, swath and repitivity for the payload observations. Further from this altitude the low resolution camera provides a minimum image overlap of 10% between passes on successive days and has a repetivity of coverage for a particular scene of 22 days.

3.1.2 Data Products

The data is converted into a variety of data products such as high density digital tapes (HDDT) 70 mm film microfische, 240 mm black and white as well as colour prints, computer compatible tapes (CCT's) and false colour composites (FCC) in four different levels of processing. At level 1 browse products are generated in the form of HDDT and film negatives for all the bands of all the cameras after eliminating, the cloud areas through quick look data.

Band 1: (0.45 - 0.52 μm)

The spectral region 0.45 - 0.52 μm is characterised by absorption due to chlorophyll concentrations. However the signal to noise ratio considerations are required a minimum of 0.06 μm/bandwidth. Extending the region on the lower side beyond 45 of the spectral region is unadvisable because scattering effects due to Rayleigh's scattering become more pronounced at lower wavelenghts. This region is also important from coastal environment studies, since the penetration of light into the water column is higher at shorter wavelengths. This would enable studies related to sedimentation and in special cases aid bathymetry.

Band 2 (0.52 - 0.59 µm)

This spectral region is characterised by higher reflectance of vegetation. This band is of advantage for green vegetation applications although this region is not highly correlated in a mixed line/dead canopy situation. However, in conjunction with measurements in the red region this band is useful. Extending this spectral band beyond 0.59 um is not advisable since it reduces the regression significance. This band is on the long wavelength side of the broad attention minimum of water, thus giving access to turbidity assessment and bathymetric evaluation in the first 10-20m depth in clear water. This region is also known to be useful for discrimination of rocks and soils.

Band 3: (0.62 - 0.68 µm)

This region is characterised by a strong chlorophyll content. Atmospheric transmittance under good visibility conditions can be as high as 90% except around 0.90um which has been avoided by limiting the band to 0.68µm. Inclusion of 0.60 -

0.62 um region decreases the regression significance. It has been shown that the geology and soils of areas can be inferred from the images of this band on the basis of their vegetational mapping. In addition sedimentation studies near the coast are also possible.

Band 4.(0.77 - 0.86 µm)

Band 4 corresponds to the steep increase of the transition zone from low reflectance in the 0.66 µm region to high flat reflectance pattern in the 0.74 - 1.3 µm region in the case of vegetation. This region (0.70 - 0.74 µm) is noisy, useful for studies suggesting shoulder portion of the crop spectrum. Earth rotation and radiometric defects and annotated product are available with a nominal turn around time of 3 days. Standard products (used in this thesis) are generated at level 2, that are corrected for scene and platform related geometric defects the turn around time for this product is 7 days. At level 3 precision products are generated with a turn around time of 3 weeks having refined registration using ground control points. Special product at level 4 use standard product on CCT as inputs and are generated for specialized user needs for specific applications.

Standard products are also adjusted for map projection schemes and are available as black and white and colour photographic products, transparency form and also digitally in the form of computer compatible tapes.

False colour composites of Band 2,3,4 of IRS-IA, LISS-II of Etah were acquired from NRSA data centre for visual analysis.

	Path	Row	Subscene
LISS II	27	48	A_1
			A_2
			B_2
LISS II	28	48	A_2

Feb. - March imageries are most effective for identification of salt - affected lands and their classifictions. Standard image interpretation techniques based on photo elements such as tone, texture, pattern, association, location, shape and size were used for the identification of salinity. Ground control points were identified on the topographical sheets and transferred on the overlays to provide control for mapping.

The base map was prepared from Survey of India topographical sheets No. 54 1 & M on 1 : 250,000 scales. Salt affected soils classified into three major categories after wihich the boundaries were transferred into the overlays. The area calculations were done using the curvimeter 360I.

3.1.3 Digital Analysis

Computer compatible tapes of the same dates as the imageries i.e. Feb. - March data were acquired of LISS 1 data for digital analysis.

The computer used to conduct the study is the scientific micro system, SMS 1000 (Model 40) from Logetronics it is hardware/software package designed primarily for processing of Remote Sensing data. The hardware consists of a console terminal, a tape drive. Fixed and floppy disk drives, display processor colour printer, Dunn film recorder and an image scanner. The software tasks of the system are solicited through the views 100 image processing software package developed by Spatial Data system. Inc. The views 100 package has been designed to be means driven and consists of language programs as FORTRAN IV, 'C' etc. using the R1-II SJ (Version 5.0) operating system the programs are intended to provide standard image analysis algorithms for image display, data transfer from tape to disc, image file back on to magnetic tape and other related tasks. A set of image analysis routines include spatial filtering, image enhancement, image mathematics, statistical analysis and data classification.

Software

1. Operating system RT-II SJ Version 5.0
2. Compilers
3. FORTRAN IV Version 2.6
4. 'C' Compiler
5. MACRO Assembler version 0.5 - 0.16

VIEWS 100, image processing package had the following functional capabilities :

- Tape processing: transfer of digital satellite data from tape to disk.
- Scanner processing : Digitization of analog data through video digitizing image scanner and its display on video display unit.
- Image transfer: Transfer of disk to VDU.
- Image enhancement: Various numerical operations related to spectral filtering viz: histogram equalization, histogram normalization, psudeo-colour enhancement with interactive histogram slicing, histogram contrast stretching and psuedo colour contrast stretching interactively controlled by a joystick.
- Image classification: Unsupervised classification and supervised classification using maximum likelihood and parallelopiped classifiers.
- Image Mathematics: Numerical operations related to spatial filtering techniques including band ratioing, smoothening and edge enhancements, radiometric and geometric correction of data.
- Display utilities: Display of annotation, fascimile, missing scane lines etc. Examination of pixel grey values and display of polygon statistics.

- General utilities : Include printing of directory and discription of image files stored on disk.

- Rapid field verification was conducted and some training sets for digital analysis built up. A series of 3 training sets were identified based on visual image characteristies for verification and necessary modifications. The selection was done on the basis of spectrally homogeneous training sets of known composition assigning a seperate colour to each group of training sets by examining spectral values. Whereas the visual image interpretation techniques were based on spatial pattern recognition, the spectral pattern recognition procedure was used for computer aided analysis. Two types of classification exist, the unsupervised and the supervised. Unsupervised classifications are spectral classes whereas supervised classification provides information on thematic classes based on spectral values of the training set identified. The classification carried out is unsupervised and part supervised.

Using the windowing technique where to begin analysis a section of 512 lines x 620 pixels is chosen. The windowing procedure consists of a simple utility program or sub-routine that accepts as input the digital image contained by that rectangle. The upper left corner of the rectangle in the output has coordinates (1.1). The pixels outside the rectangle are simply discarded. This simple operation deserves special mention to emphasize that digital images contain a lot of data. Without proper editing early in the processing sequence a great deal of processing effort is removed.

Once these windows were identified the digital enhancement techniques were applied prior to interpretation and classification. These are intended to improve the interpretibility of an image increasing the appparent contrast between the features in the scene (Lilles and Keifer, 1979). The data are simply transformed to a more expressive and interpretable form. It is only after being transformed and displayed that interpretation begins.

The interpretation procedure is an activity utilizes the complimentary ability of the mind and the computer. The spatial attributes were exmined visually and the spectral differences were left to the computer.

3.1.4 Contrast Enhancement

Image display and recording drives typicallly operate over a range of 256 grey levels (0-225). Sensor data in a single image rarely extend over this entire range. Hence the intent of contrast stretching is to expand this narrow area over a wider range of grey values.

The result is an output image that emphasized contrasts between features.

3.1.5 Linear Contrast Stretch

If we consider an image with an output level it can vary from 0-255. A histogram of gray levels recorded in one spectral band over a scene on the output device displays 256 grey levels (0-255) and the histogram shows scene brightness values occurring only in the limited range of 60 - 128. If we used this we would not be using the full dynamic range of possible levels 128 to 255 would not be utilized reducing the ability to discriminate radiometric detail. The DN value of the lower half are assigned to black or 0 the upper are assigned to white or 255 the remaining DN values are distributed linearly within these extremes. These are particularly useful for delineating classes. In all cases the stretch carried out was uniform i.e. 95%. Subtle variations that were imperceptible in the input data bcecame more distinguishable.

Linear stretch is applied to each pixel using the algorithm:

$$DN = \frac{DN - Min}{MAX - MIN} \times 255$$

where DN - digital numbers (grey value) are assigned to pixel in the output image

DN - original digital number of pixel in input image

MIN - Min value of input image to be assigned a value of 0 in the output image.

MAX - Max value of input image to be assigned a value of 255 in output image.

The major drawback was that in this process as many display levels were assigned to the rarely occuring values. Half of the pixels having image values in the range of 60 to 108.The bulk of the image data (128 to 255). Although better than the direct display the linear stretch would still not provide the most expressive display of data.

The non linear or histogram equalized stretch was applied to further improve the data. In this approach, image values are assigned to the display levels on the basis of their frequency of occurance. More display values are assigned to the frequently occuring portion of the historgram. The image value range of 109 to 128 is now stretched over a large portion of the display levels (39 to 255). A smaller portion is reserved for the infrequently occuring image values of 60-108.

3.1.6 Density Slicing

Density slicing is an enhancement technique whereby the grey values distributed along the X axis of an image histogram are divided into a series of specified intervals or 'slices'. All of the grey values falling within a given interval in the input image are then displayed as a single grey value in the output image. Consequently if six different slices are established the output image contains only six different grey levels. This technique emphasizes surface grey scale differences that may have been imperceptible earlier.

After establishing the first window in the data the whole scene was divided into a series of windows. Each section was histogram stretched in both bands 2 and 3 and sliced. Using the digitiser the district boundaries were superimposed on each section and drawn using the joystick paintbrush in order to eliminate the area not required for analysis. The images were than psudocoloured to aid analysis and photographs taken on the Dunn camera as the final output. FCC's of the all three bands were generated of each section on the computer and the areas under severe, severe to moderate and moderate salt infestation taken down in total number of pixels under DN values assigned to salt - affected soils.

3.1.7 Flow Chart For Digital Analysis

```
CCT
 |
IMAGE
TRANSFER ------------------------- ORIG DN
TRAINING                           VALUE
   |
DISPLAY
IMAGE
   |
WINDOWING
   |
SUPERVISED/UNSUPERVISED ---------- PATTERN
CLASSIFICATION                     RECOGNITION
   |                               GRAY VALUES
   |
TRAINING SET
   |
ENHANCEMENT
   |
HISTOSLICING
   |
HISTO
STRETCH
```

3.2 Geomorhological, Drainage Mapping

Geomorphic units were delineated and the areas under the major units have been numbered for representation in the legend. A map of surface drainage showing the canal and river network was also generated using the LISS-II imagery through visual interpretation.

3.3 Survey and Ground Truth

In order to keep uniformity in season and dates of coverage. A field survey for ground truth was conducted between late December and early January when the Rabi crops had been sown. Five transects were taken up for survey in the salt - affected areas.

- Etah - Aliganj
- Etah - Sakit
- Etah - Badshapur Loya
- Etah - Kasganj
- Etah - Jalesar

72 soil samples (0-15 cms) from different sites were collected along these transects. Data sets were numbered S1, T1, Q1, Z1 using the first letter of a village covered during traversing.

3.4 Chemical Analysis

The soil samples were air dried, ground and sieved through

2 mm sieve for analysis. The soils were than analysed to study their chemical properties i.e. pH, electrical conductivity, organic matter, phosphorous, potassium, sodium, carbonate, bicarbonate calcium plus magnesium and exchangeable sodium pecentage. Soil extracts were made by filtering soil suspension in water for analysis of carbonate, bicarbonate, calcium and magnesium.

pH

pH was determined in saturated soil paste according to USDA Handbook No. 60 using glass electrode pH meter.

Electrical Conductivity (EC_e)

Electrical conductivity (EC) was determined in the extract of the saturation paste using sloubridge conductivity meter.

Exchangeable Sodium Percentage

Exchangeable sodium percentage was determined according to USDA Handbook No. 60.

Organic Carbon

1 gm of the soil sample was used for determining the organic carbon by rapid titration method of Walkley & Black (1934).

Phosphorus

2.5 gm of seived sample was used for estimation of available phosphorus by Olsen's method (Olsen et al., 1954).

Pottasium

Available pottasium (Exchangeable + Water soluble) was determined in ammonium acetate extract of 5 g soil sample by Flame Photometer (USDA Handbook No.60)

Calcium & Magnesium

Calcium and Magnesium were determined in soil extracts by titration with Ethylenediaminetetra-acetate (Versenate) (USDA Handbook No.60).

Carbonate, Bicarbonate & Chloride

Carbonate and bicarbonate contents were determined in the soil extract by titration against standard sulphuric acid and chloride by standard silver nitrate titration method (USDA Handbook No.60).

Sulphate

Sulphate was determined by the turbidometric method, using Barium chloride precipitation (Massoumi and Cornfield, 1963).

3.5 Mechanical Analysis

Mechanical analysis consists mainly of two distinct operations, namely dispersion of the soil and grading the dispersed particles into a sized groups using the Boyucos (1936) hydrometer for determining sand, silt and clay fractions.

3.6 Process and Occurrence of Salt - affected Soils

The process and occurrence of salt - affected soils was studied using geological maps and through study of geochemistry of substances.

3.7 Land evaluation

Land evaluation was carried out using all information gathered through Remote Sensing data, ground with and direct observations. Maps and other information were also used for evaluation. The procedures laid down in FAO Bulletin 32 were followed and landuse was studied using secondary data obtained from the statistical magazine, Etah.

3.8 Socio Economics of Reclamation

Socio economic data, cropping and land use data used were extracted from revenue data at block level. Information on the economics of reclamation were gathered from tehsil office headquarters in Etah and CSSRI, Karnal.

CHAPTER IV

RESULTS AND DISCUSSIONS

IRS-1A data have been used to detect and assess the salt-affected soils of Etah district through a combination of visual and computer- aided techniques. The effort has been to integrate information on geomorphology, processes of formation and land cover to achieve a better understanding of their distribution, characteristics and agricultural useage.

4.1 Geomorphology

The Etah plain is largely alluvial in nature and forms a part of the Ganga Yamuna doab. It can be divided into three major geomorphological units:

1. Active flood plain
2. Recent flood plain
3. Old flood plain

(Fig 4.1)

Active flood plains

The active flood plain covers the northern part of the district. The river Ganga meanders through a wide bed north east to south west. The bed is covered with sand and fine materials and the river has formed a number of river islands and elongated channel bars. Recent levees occur alongside the river.

Recent Flood Plain

The recent flood plain is easily identified in the band 2 images of the IRS data. It stretches parallel south of the river

MAP

Ganga north-east to south-west and extends a little south of the Burhi Ganga. The Burhi Ganga forms the old bed of the river Ganga. It is a relict river with little flow. Large oxbow lakes have been formed by the river. Even though the peripheries of the lakes have become drier the soil moisture is still high. Elongated old levees are present all along the river and can be identified easily by their different tone on the images suggesting fine deposited materials at an elevation. The recent flood plain or the 'Khader' is in itself largely made up of fine materials and the soils are not so developed.

The Kali nadi traverses much of the district. On the satellite image the river appears to flow without any formation of a flood plain. In actual fact the river flows through a moderately deep channel and has built up levees at a height of 2 meters approximately and of considerable width along its channel. The river flows through the recent into the old flood plain.

Old Flood Plain

The old flood plain or 'Bangar' covers most of Etah district. Paleochannels of old non perennial rivers are spread over the surface of the old flood plain along with relict old oxbow lakes. Salt-affected lands locally known as 'Usar' are widespread and much better developed.

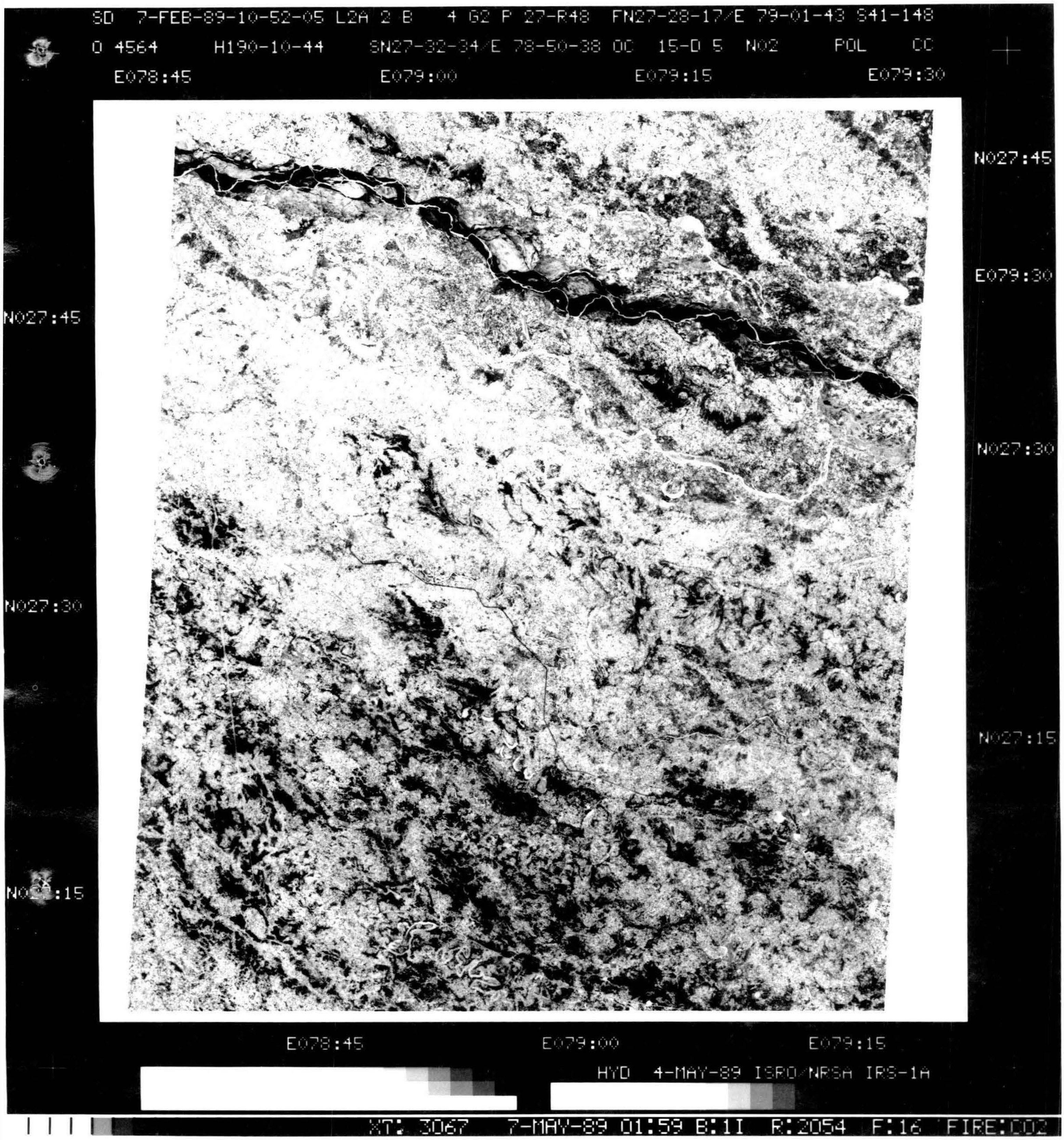
4. 2 IRS-IA Image Interpretation and Analysis

Both the visual and computer classification on remotely sensed data are necessary in the interpretive process that aid in the study of soil materials. All soils have their special identification signatures in the visible and near infrared wavelengths of the EMS that can be distinguished from each other for the study of their delineation, location, extent, characteristics and evaluation.

Spectral response patterns are known to vary due to natural variations, systemic seasonal variations and atmospheric haze. Hence, time is an important factor for the study of salt-affected soils on remotely sensed images. January - March satellite images were found to be most suitable for the study and appraisal of these soils. During this period the monsoon has receded and the salts rise to the surface through capillary action. The presence of salt-affected soils is emphasized by the barreness that contrasts sharply with the greeniness of growing crops on the images during this season.

4.2.1 Visual Interpretation

On the standard FCC path Row 27/48 and 28/49 (of LISS II Bands 2, 3 and 4) with resolution of 36.2 mts x 36.2 mtrs were used to georeference the image. A series of ground control points identified on the topographical sheets were superimposed. An overlay of the base map of Etah provided the necessary administrative details and area not in the district was excluded.



FCC Reproduced in Black and White

Using the visual interpretation keys of shape, size, colour, contexture, pattern and location through the processes of elimination, and recognition three major stratifications of salt-affected soils could be carried out. River sand in the active flood plain of the river Ganga had the same tone and texture as the barren white salt-affected area and hence had to be removed to aid correct analysis.

Severely salt-affected lands were found to be non-contiguous and smooth white in colour indicating barrenness and severity of salt infestation on the image. Severe to moderately severe salt-affected soils were identified by their white to bluish grey colour and slightly mottled texture with a red tinge indicating poor vegetal cover. The soils of this category were found to occur very close to the outer boundaries of the severely salt-affected areas.

The moderately salt-affected areas had a mottled appearance on the image, were blue gray in colour with red indicative of low crop cover and moderate salinity. Areas of slight salinity were not identified.

The categories were numbered (1) for severely salt-affected soils (2) for severe to moderately affected salt-affected soils and (3) for moderately salt-affected soils (Table 4.1).

Table 4.1: Categorization of salt-affected using visual interpretation.

Category Wasteland class	FCC	Shape	Texture	Pattern	Colour
1. Severely affected salt-affected lands	2,3,4	Irregular	Smooth even	Scattered non-contiguous	White
2. Severe to moderate salt affected lands	2,3,4	Irregular	Even to mottled	Scattered non-contiguous	White-Blue grey sparsely mottled red and blue.
3. Moderately salt-affected lands	2,3,4	Irregular	Mottled	Scattered	White to Blue grey mottled red

Location	Association	Crop cover	Season
Wide spread in old in flood plain	Virgin soils	No cover	January-March
Old flood plain	associated with with capillary action and irrigated	Sparse cover	
Old flood plain	land	Poor vegetal cover	

The curvimeter 360 I a digital planimeter was used to calculate the area under these three categories after mapping.

Over the district 32.2 % of the total area was found to be salt-affected. Severely salt-affected soils covered 57.6%, severe to moderately affected salt-affected soils 19.1% and moderately affected 23.3% of the total area under salt-affected soils. On the image these soils were found to be non-homogeneous and varying in shape and size. Their occurrence was scattered and they were interspersed with normal soils.

Using the visual interpretation integrative key based on image recognition of features, logical search and close scrutiny a thematic map with high levels of accuracy indicated direct information of the soil surface and the status, categorization and extent of salt-affected soils in the district (Fig 4.2).

4.2.2 Digital Analysis

To examine the accuracy of the visually interpreted image and to make a comparison, digital analysis, using numerical information extraction techniques was carried out in order to recognise and delineate the salt-affected soils from the large quantity of data on the computer compatible tape (CCT). The scenes of path and row 27/48 and 28/48 of February-March data LISS I (72.5 x 72.5 mts. resolution) corresponding with the dates of coverage on the hard copies were used for the analysis.

4.2.2.1 Multispectral Characteristics & Classification

Using the information extraction process of multispectral classification the spectral signatures were studied and pixels

MAP

assigned to categories with similar signatures. In the unsupervised method no training data have been employed but instead statistical techniques have been used to group the data sets into their perceived natural spectral classes mainly the maximum likelihood and parallelepiped algorithms. Unsupervised classification is also referred to as cluster analysis. It locates a number of cluster centres in the multidimensional (multiband) measurement space and eratively repositions them until they attain their maximum spectral separability. the unsupervised class does not utilize analyst special training data, rather the unsupervised classifications involves algorithms that examine a large number of unknown pixels and divides them into a number of classes based on natural groupings present in the image values. The basic premise is that values within a given cover type should be close together in the measurement space, whereas data in different classes should be comparatively well-separated.

The classes that result from unsupervised classification are spectral classes. Because they are based on natural groupings of the image values the identity of the spectral classes was not initially known. In the unsupervised approach it was important to first determine spectrally separable classes and then define their informational utility. The unsupervised classification approach has been used for spectral classification aided by ground check (part supervised). Registration from topographical sheets and selection of the initial point is an important aspect to the start of any analysis for classification. While working with a sub scene, or window, within the CCT, exact location of the desired window required careful location and calculation. First the exact study area was demarcated on the IRS imagery and the x and y distance identified and related to the pixel reference system. 'Badhshahpur Loya' was singled out for initial analyses in order to build clusters of similar signatures. Digital number values were examined to build up the interpretation keys through the full spectrum of DN values (grey levels) to delineate salt-affected soils.

4.2.2.2 Spectral Characteristics

Data in IRS are recorded on 4 different bands in four distinct parts of the spectrum. Since both soils and vegetation reflect differently in different parts of the electromagnetic spectrum the use of 'Bands' increases the chances for the study of unique signatures for identification of vegetation and soils.

To study these signature the original images were found to be limited in their capability for salinity assessment. Data were enhanced by contrast stretching and histogram slicing.

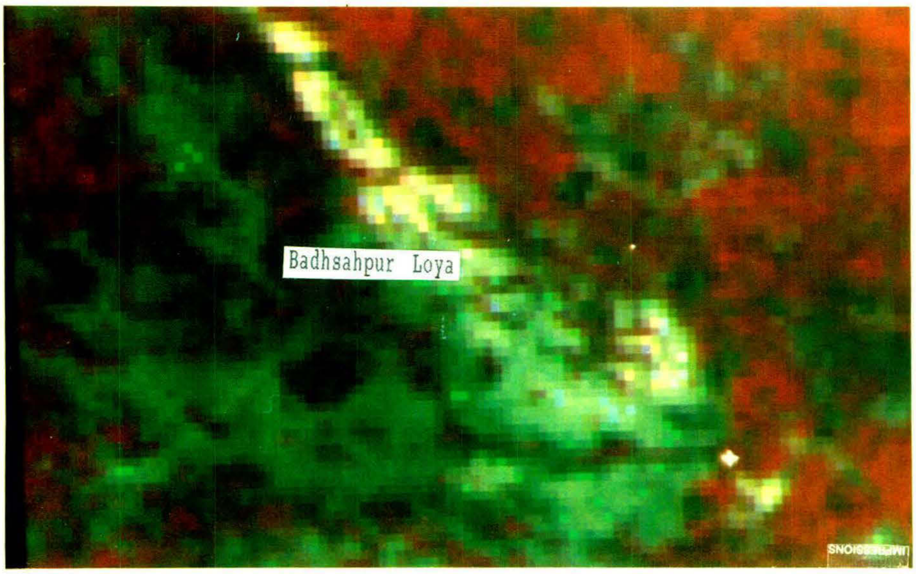
4.2.2.3 Enhancement

Band 2, 3 and 4 were enhanced independently of each other. Objects on the ground with similar spectral features may not be distinguishable on the IRS image as fine tonal differences cannot be resolved with the human eye. The process of contrast enhancement and stretching transforms the pixel values such that they stretch across the entire dynamic range of the electronic display device. With enhancement. The resulting images were clearer enabling distinct categorization of salt-affected classes into severe, severe to moderate and moderate. Due to the change of original values of data on application of computer techniques new values were assigned to the new data set thereby improving quality. To assess the accuracy of satellite data for identifying salt-affected soils and their extent, the three different bands (2.3 and 4) were generated in order to assess the band would be most useful for classification.

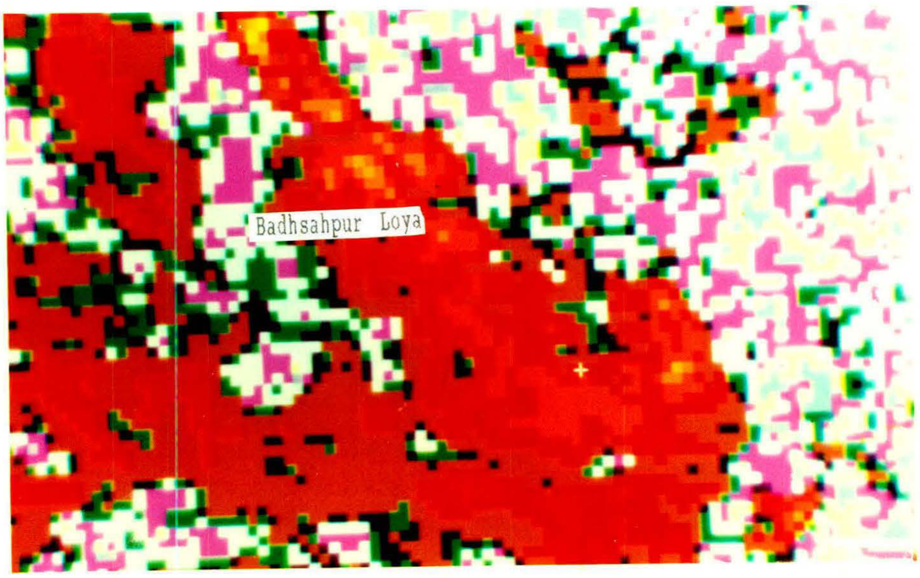
4.2.2.4 Windowing

On the computer generated false colour composite (FCC) of the window on village 'Badhshahpur Loya' and the area around it no significant categories of salt-affected soils were identifiable. Only barren salt-affected soils appeared clearly. The window was enhanced in all bands individually. The transformation of pixel values after being colour coded changed the quality of interpretability dramatically.

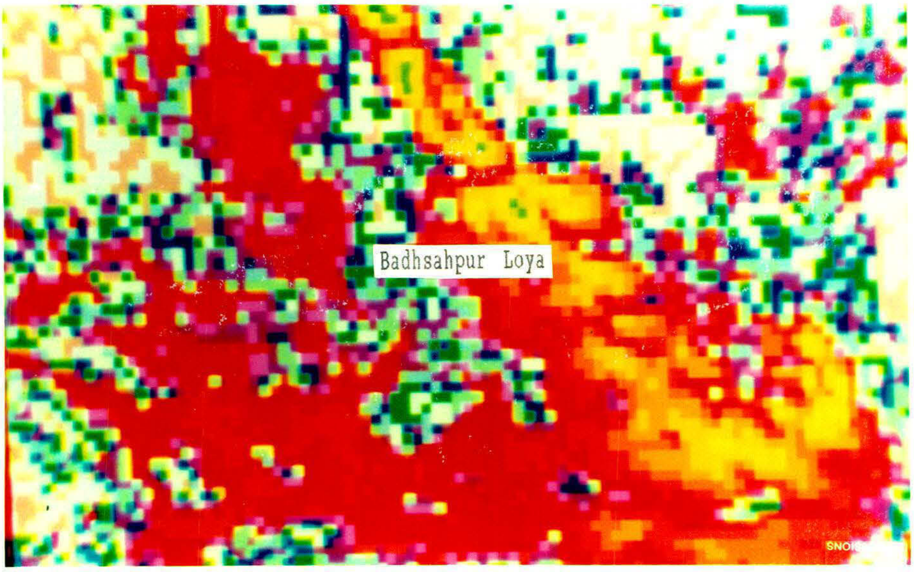
On band 2 (blue -.52 to .59 μm) all the three categories of salt-affected soils could be deciphered. However because the DN (Digital number) values club together the lines of demarcation between the severe, severe to moderate and moderate class merge together resulting in loss of detail (Fig.4.3a and 4.3b). On band



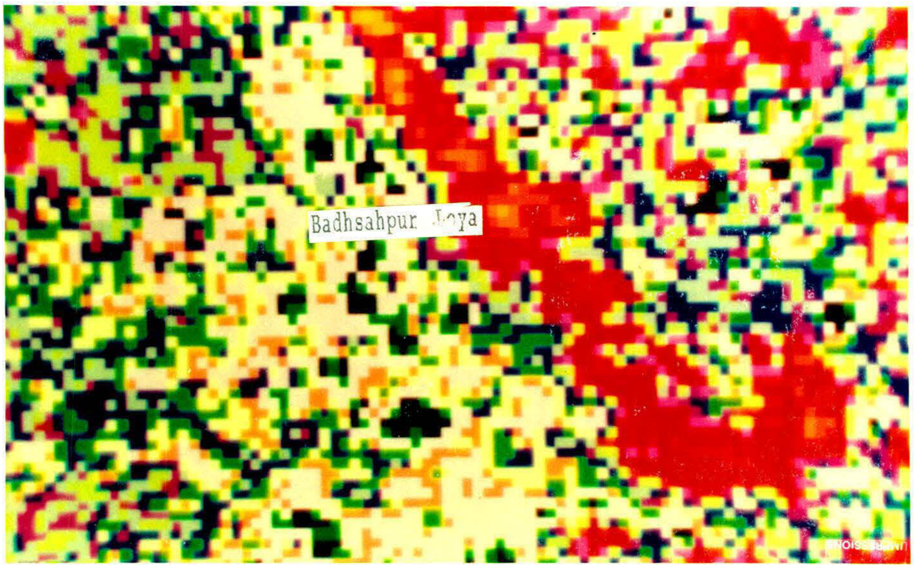
Badshahpur Loya FCC



Badshahpur Loya Band 2

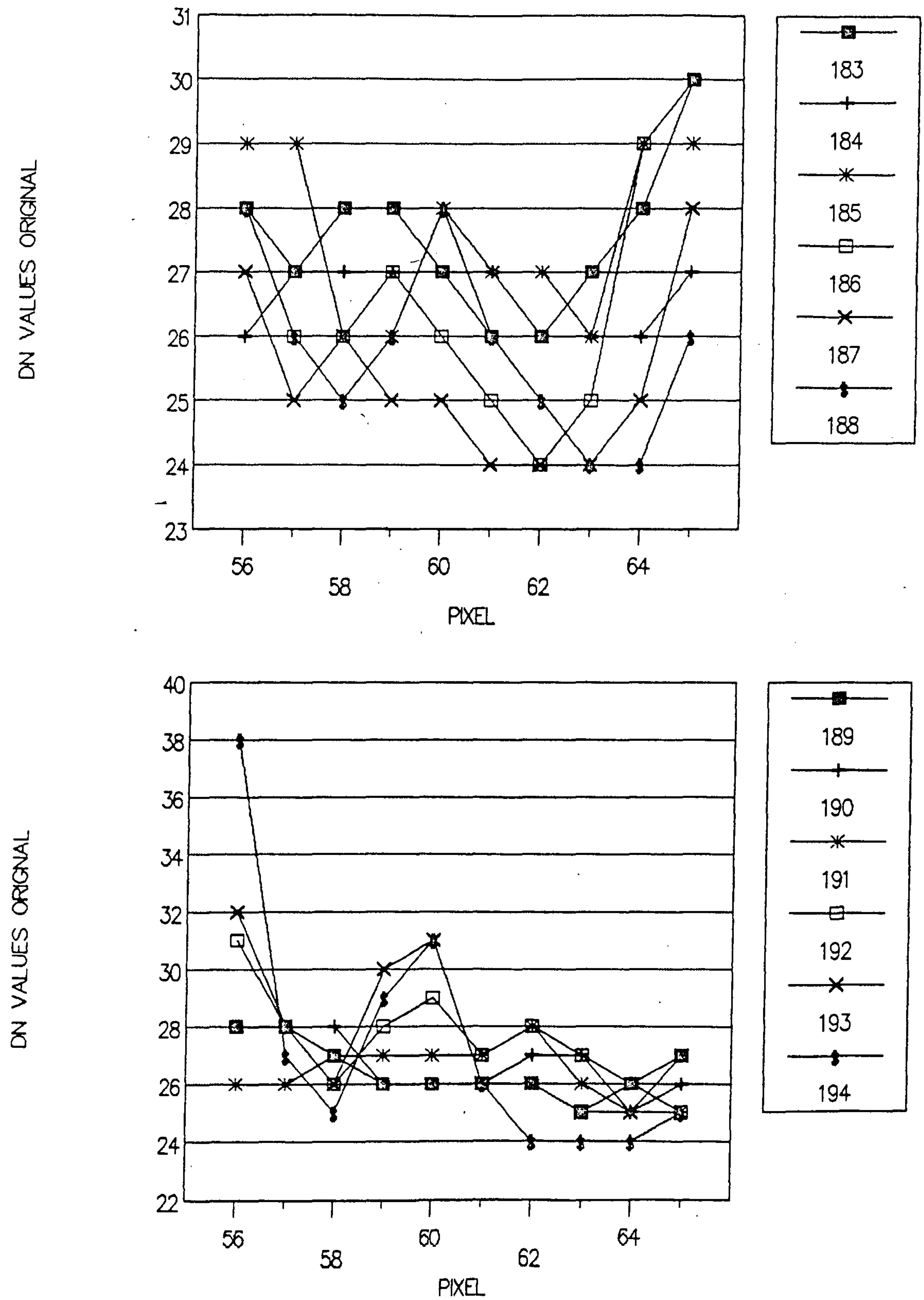


Badshahpur Loya Band 3



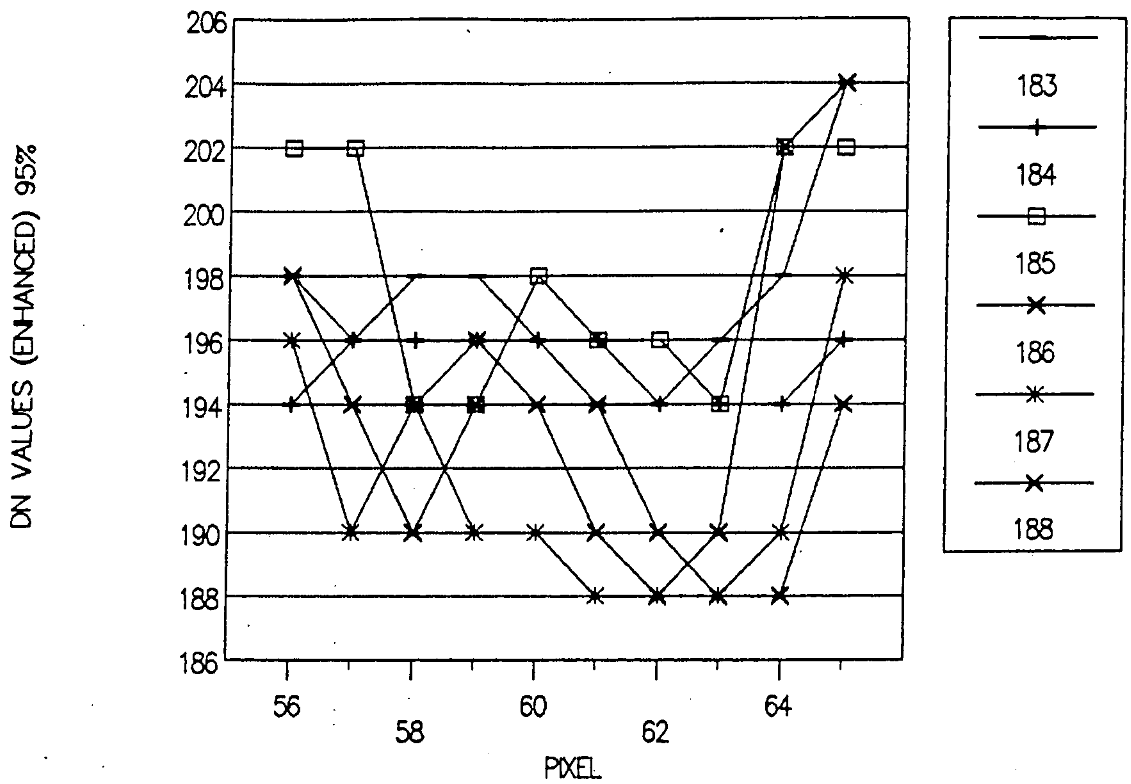
Badshahpur Loya Band 4

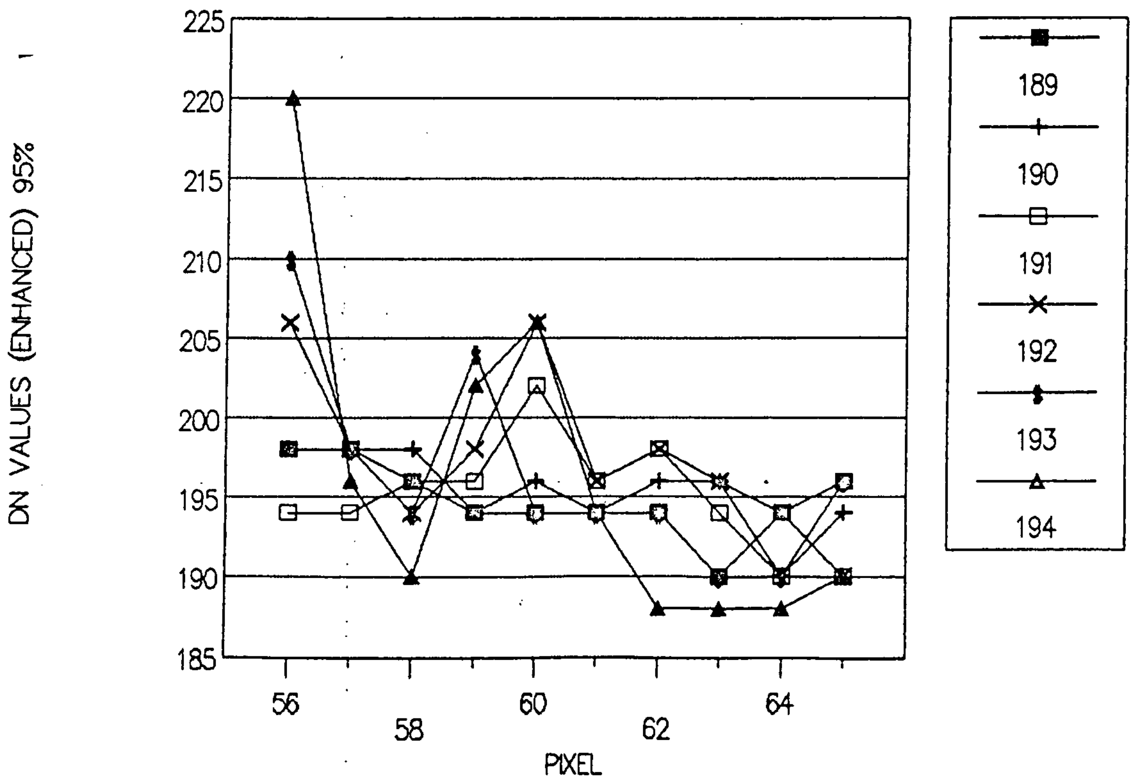
BAND 2



Fig·4·3 a Original value spectral response patterns Band 2

BAND 2





Fig·4·3·b Enhanced value spectral response patterns Band 2

2 the colour and spectral classes were combined to define the categories.

BAND 2 (.52 - .59 μm)

Colour/tone	Spectral values	Category
Yellow to light orange	219-238	Severe
Dark orange	196-218	Severe to moderate
Cyan to Pink	176-195	Moderate

On band 3 (green - .62 to .68 μm) the three classes of salt-affected soils were identified clearly. The DN values picked up singly and in a wider range bought about a clear distinction between severe, severe to moderate and moderate. A sample of graphs of 10 pixels and 20 lines exhibits clearly that the original DN values restrict interpretation on both band 2 and 3. However when enhanced the change in DN improve interpretability. (Fig. 4.4a and 4.4b).

BAND 3 (.62 - .68 μm)

Colour/Tone	DN values	Category
Yellow to orange green	214 - 238	Severe
Cyan	185 - 214	Severe to moderate
Pink	156 - 184	Moderate

BAND 3

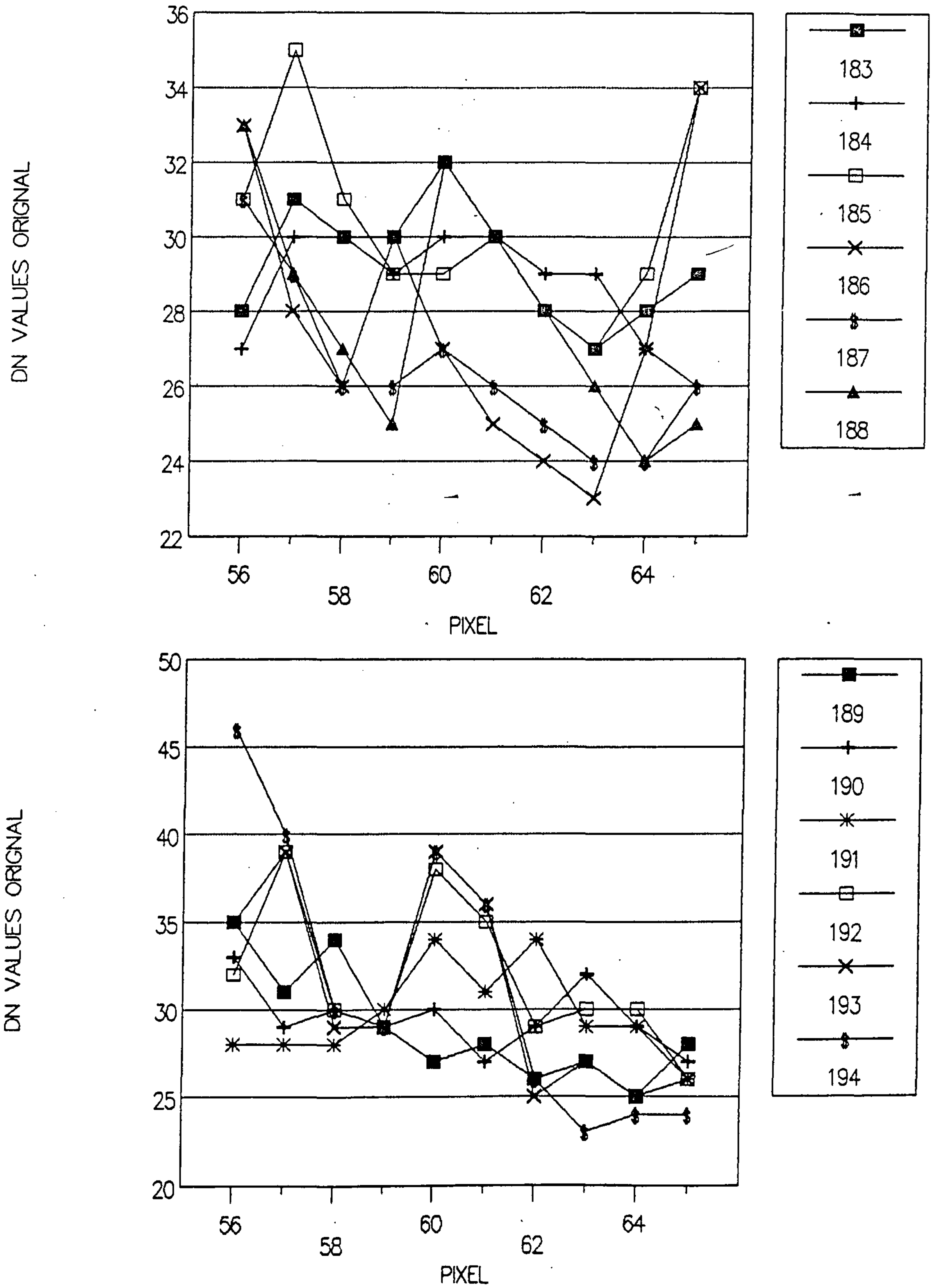
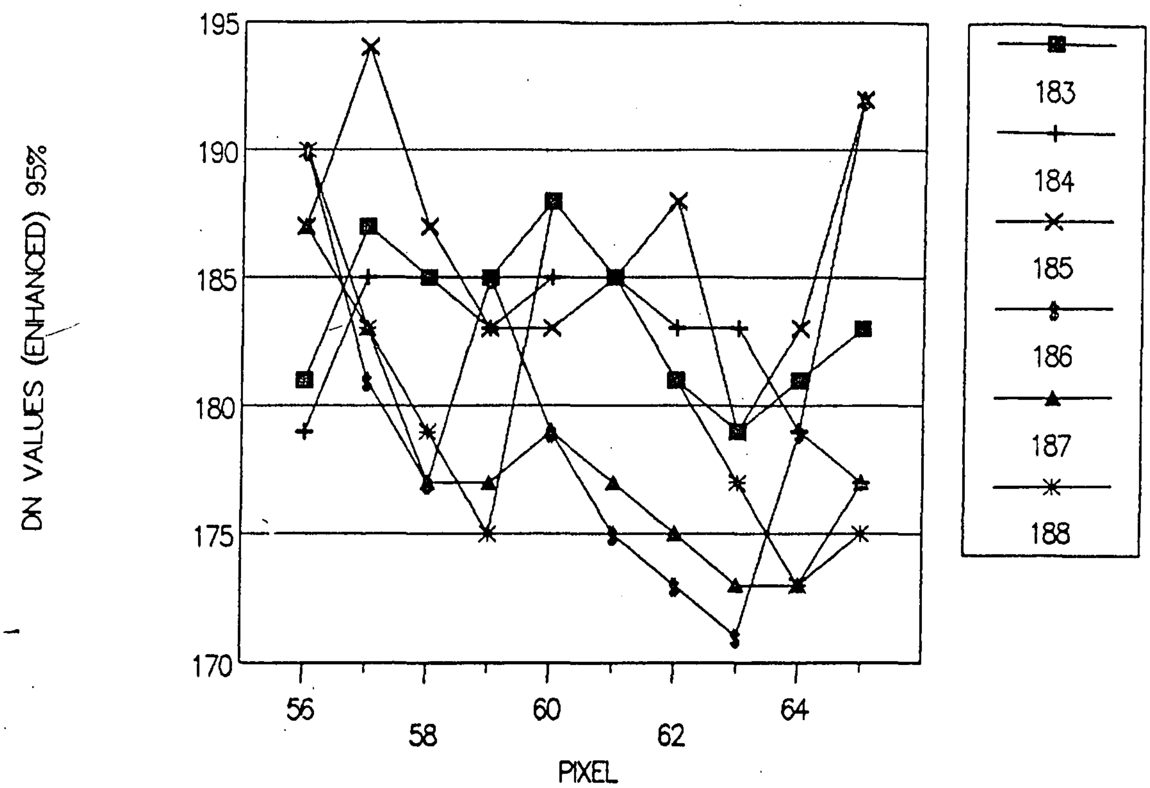


Fig. 4.4 a Original value spectral response patterns Band 3

BAND 3



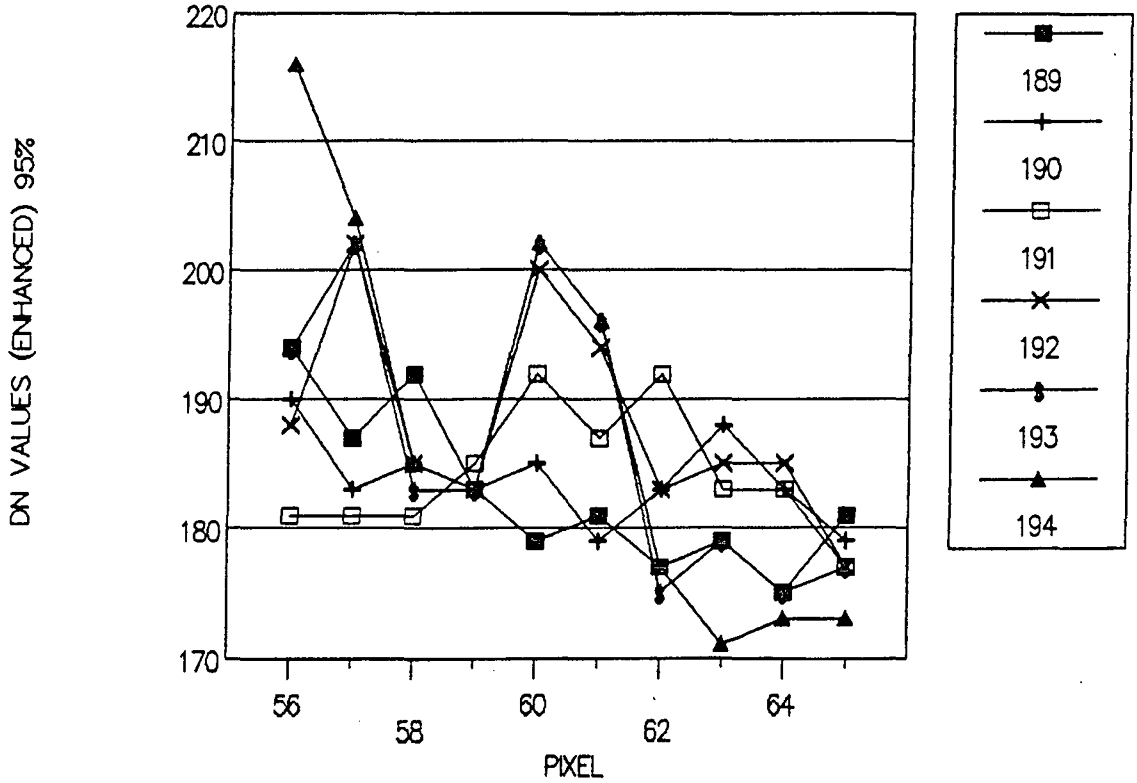


Fig 4·4 b Enhanced value spectral response patterns Band 3

On band 4 (.77 to .86, μm) only severe salinity showed up clearly. The other details were lost. The spectral values of the severe category were exaggerated to a value of 242. Band 4 because of its limited value for demarcation of salt-affected soils was not used any further for comparative analysis, but its use in FCC generation was necessary because as it images water bodies and wet areas comparatively better as it lies in the near Infra-red region. Other information as location of roads and railways appear in greater clarity than either bands 2 or 3, therefore its use is essential for locational mapping and registration of ground control points water bodies, roads, railways etc.

Two other window sites were also scrutinized to study the DN values. Ground truth of the 3 sites was carried out to study the pH of the soils in relation to salinity/alkalinity levels before the rest of the data were digitally processed. Considering the large quantity of data available on the two LISS I computer compatible tapes covering Etah district and also the fact that only 620 pixels and 512 lines can be covered by the graphic screen there arose the necessity of dividing the data on the two computer compatible tapes into 5 segments.

4.2.2.5 Data Set Studies

Each data set required registration. Ground control points from the topographical sheets of each segment were collated and the boundaries transferred on to the compiler screen in order to eliminate areas not in the district. On all 3 bands i.e. band 2 (blue), band 3 (green) and band 4 (red), the boundaries were superimposed individually to generate the FCC.

The spectral values were screened in segments through the full image. All 5 data sets were enhanced and histogram sliced and contrast stretched for computation of the areas under different classes of salt-affected soils.

While conducting the analysis it was found that whenever a new image was generated the colour routine changed. For this reason mosaicing of the images to form a map was not possible. This does not however, detract from the scientific content of the images generated since the reflectance values remain unchanged.

Data Set 1

Band 2 (Blue .52 μm to .59 μm) The first data set generated from CCT was that of North Etah. The image with original DN values gave poor results viz-a-vis salt status classification. The initial black and white (FCC) image generated in grey levels bore little clarity except that river and river sands in the active flood plain could be deciphered (photo S1). The subsequent false colour composites when colour coded improved the quality of data vastly (photo S2). On close examination of the DN values it was found that river sands and barren soils gave off the same spectral values. To avoid computer confusion that would lead to misclassification the complete active flood plain

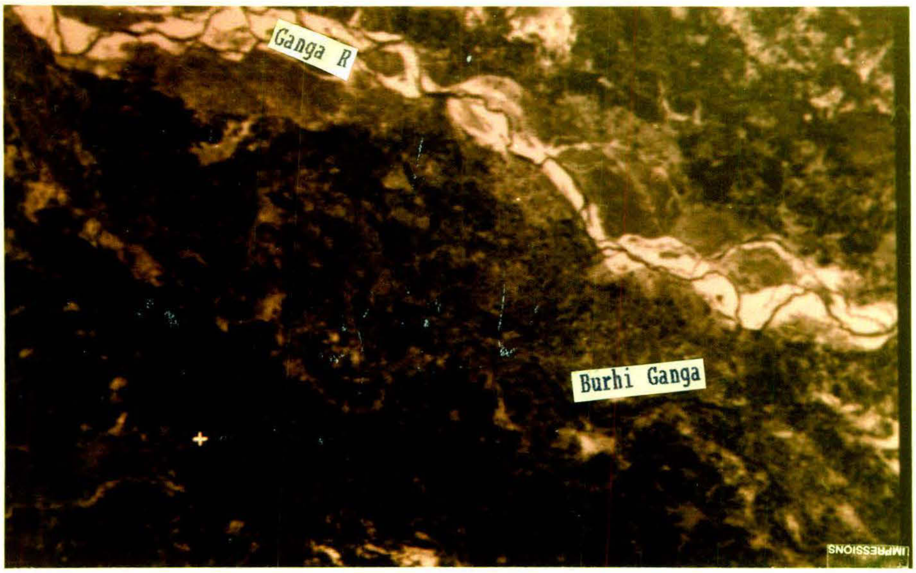


PHOTO S 1 North Etah (Black & White Band 2)

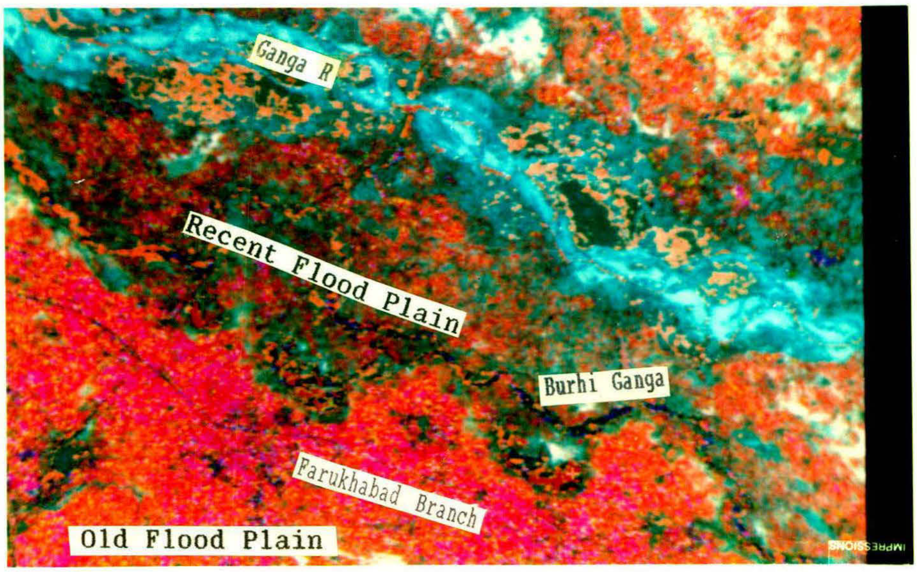


PHOTO S 2 North Etah (Band 2)

was blocked out (photo S3). On a contrast stretched image the rivers, oxbow lakes, canals and towns, showed up in a greater detail but salt-affected soils were indecipherable (photo S4). However, when the image was histogram stretched and sliced the demarcation of salt-affected soils into severely affected, severely to moderately affected and moderately affected could be carried out (photo S5). The region in the recent and active flood plain showed up little or no soils affected by salt.

Data Set Classification Index

DATA SET 1 (North Etah)	Severe	Severe to Moderate	Moderate		Severe	Severe to Moderate	Moderate
Photo S1 B&W Band 2	White	White mottled grey	Light grey	Photo S6 (B&W) Band 3	White	White mottled grey	Light grey
Photo S2 & S3 (FCC)	White	White mottled blue & red	Red mottled white & blue	Photo S7 (Cont stretch Band 3)	INDECIPHERABLE ONLY GEOMORPHIC UNITS		
Photo S4(Cont. stretch) Band 2	INDECIPHERABLE GEOMORPHIC UNITS			Photo S8 (Enhanced & Hist. Sliced) Band 3	Pink	Light pink to grey	Dark grey
Photo S5 Enhanced & Sliced) Band 2	Light pink	Light pink to grey	Dark pink				

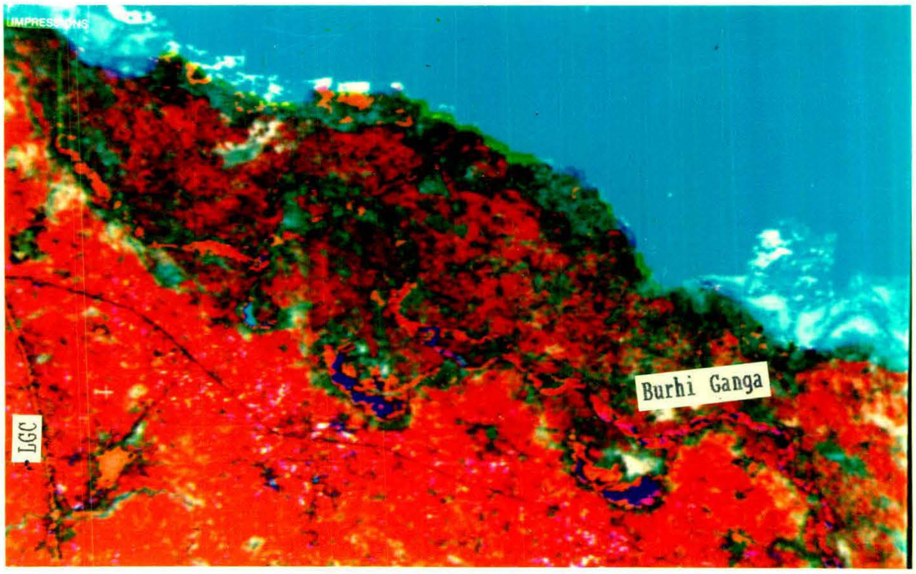


PHOTO S 3 N Etah (FCC)

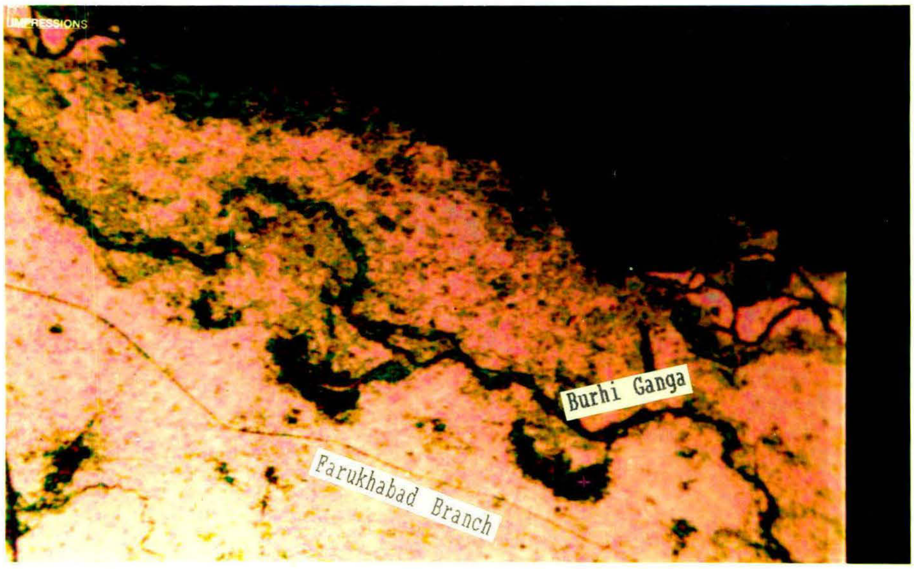


PHOTO S 4 N Etah (FCC)

Band 3 (Green .62 µm - 68 µm)

On band 3, the black and white image gave similar results as on band 2(S6). In grey levels the image interpretability was poor. On the contrast stretched image (S7) salt-affected soils were indecipherable. However, on histogram stretching and slicing the three categories could be clearly demarcated as in band 2 (S8). The DN values occurred closer together than in band 2 where the DN values are spaced apart and include spectral values of features closely related with salt-affected soils. The DN value range in band 2 (blue) and band 3 (green) for demarcation were the same as in those of 'Badhshahpur Loya' and the 2 other windows.

Band	DN Values	Categories
Band 2	219-238	Severe
	190-218	Moderate to severe
	176-189	Moderate
Band 3	214-238	Severe
	185-213	Moderate to severe
	156-184	Moderate

Slightly salt-affected soils were not decipherable.

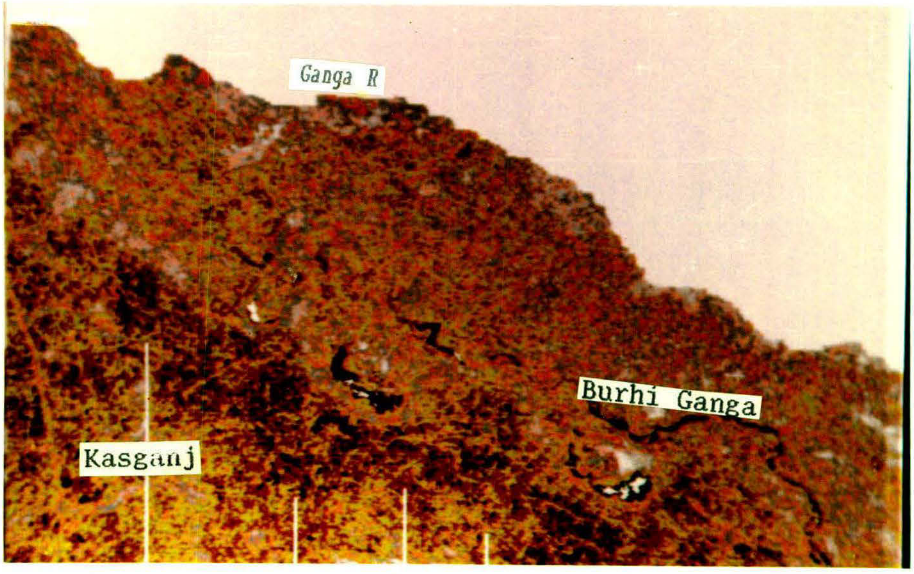


PHOTO S 5 N Etah (Band 2 Enhanced & Hist Sliced)

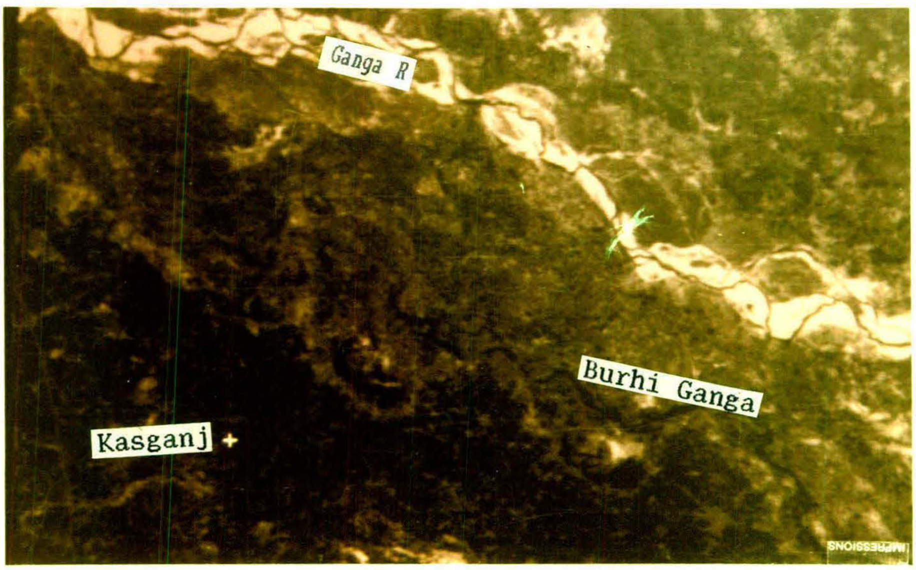


PHOTO S 6 N Etah (Black & White Band 3)

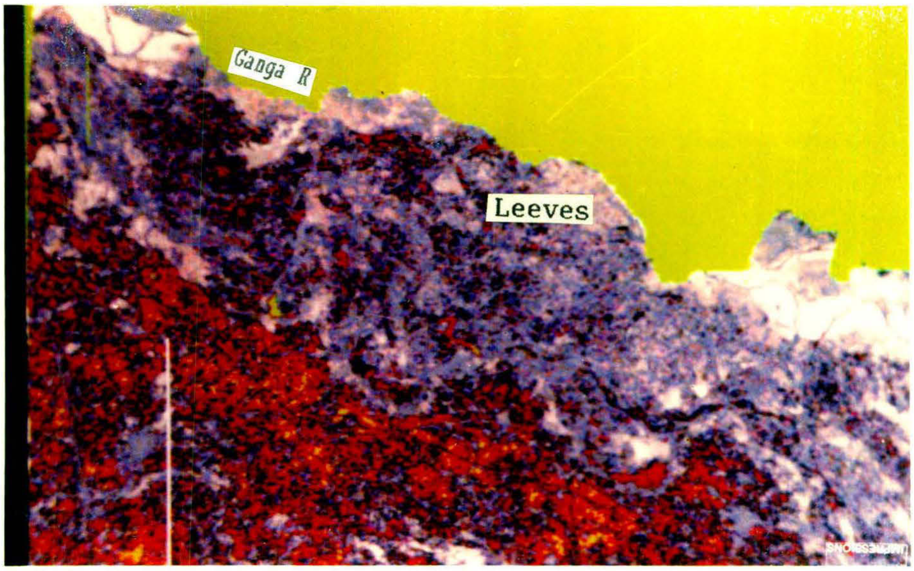


PHOTO S 7 N Etah (Cont Stretched Band 3)

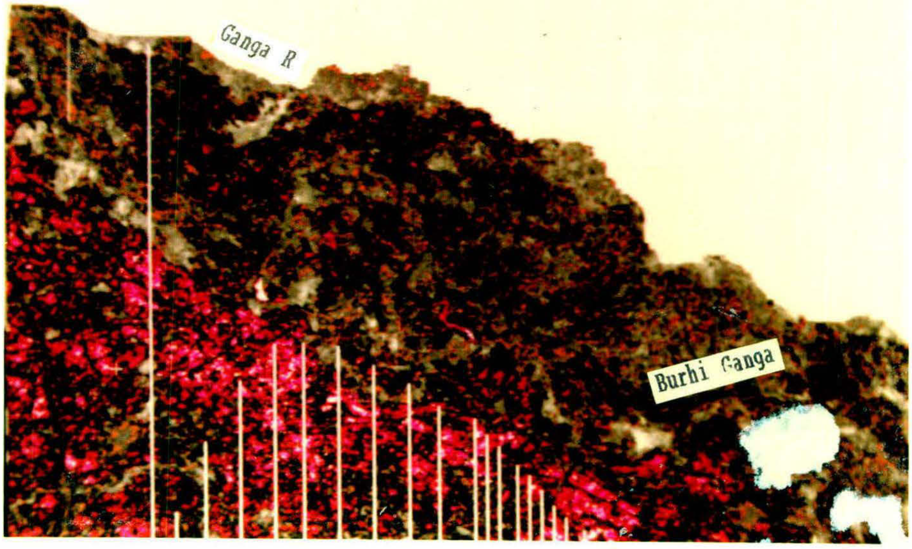


PHOTO S 8 N Etah (Enhanced & Hist Sliced Band 3)

Data Set 2

Band 2 (Blue)

The second image generated was of south central Etah covering Etah, Sakit and Jalesar blocks lying east of the western Yamuna canal, the region has widespread sodicity that occurs in patches. On the FCC (photo T1) severely affected areas gave off high reflectance values. The severe to moderate and moderate categories although discernible did not give off the required levels of accuracy in order to separate them. On being further histogram sliced (T2) on band 2, salt-affected soils of the second and third category became clearer. The three classes of salt-affected soils became distinct. The DN values were similar to those in the earlier image of North Etah.

Data Set Classification Index

DATA SET 2 (Etah)	Severe	Severe to Moderate	Moderate
photo T1 (FCC)	White	White mottled blue & red	Red mottled with blue blue & white
Photo T2 (Enhanced & Hist. Sliced) Band 2	Light Pink	Pink	Dark Pink
Photo T3 (Cont. Stretch) Band 3	Orange	Pink	Blue
Photo T4 (Enhanced & Hist. Sliced Band 3	Brick red	Light grey	Dark grey

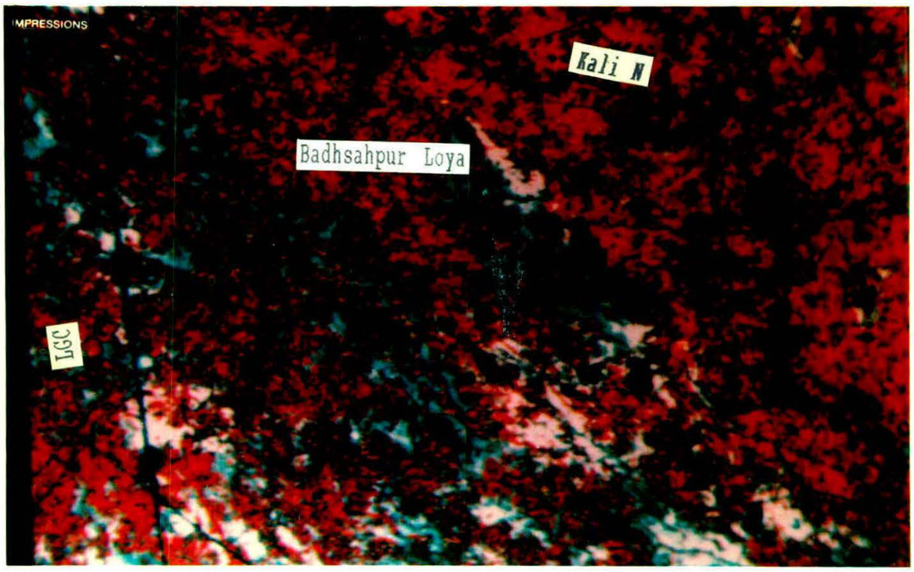


PHOTO T 1 Etah (FCC)

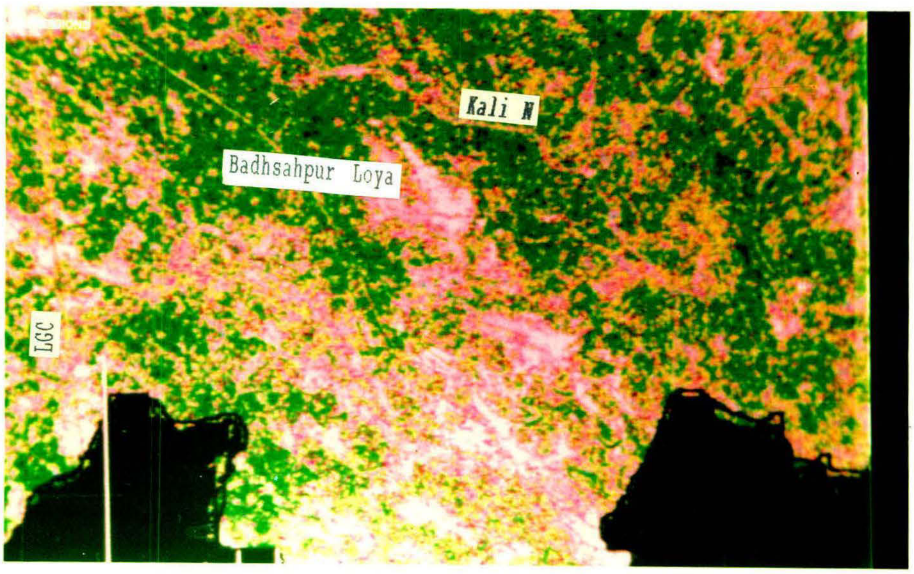


PHOTO T 2 Etah (Enhanced & Hist Sliced Band 2)

Band 3 (Green)

While conducting the analysis on band 3 (data set 2) on the contrast enhanced image barren soils could be identified clearly but again the DN values of the latter 2 categories proved difficult to identify due to loss of detail caused by the mixing up of closely occurring values. Through stretching and enhancement(T3), data on the image could be divided into 3 categories for computation (photo T4)

Data Set 3

The third data set generated was of the region lying east of data set 2 covering mainly Aliganj block. The false colour composite was generated after reading on the data in all three bands (photo Q1) and the boundary superimposed (photo Q2). Band 2 was subsequently enhanced histogram stretched and sliced(Q3). The barrenness of the soils in the region were found to increase eastwards. The DN values were highest in severely affected areas.

On band 3 the same procedures were applied and the total number of affected pixels noted. The band was suitably enhanced and histogram stretched to categorize levels of affliction (Q4).

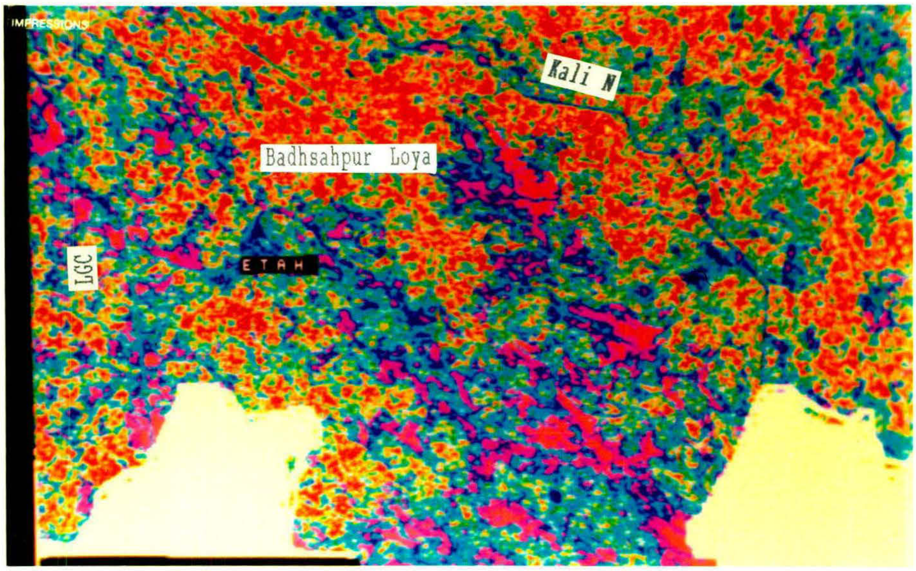


PHOTO T 3 Etah (Cont Stretch Band 3)

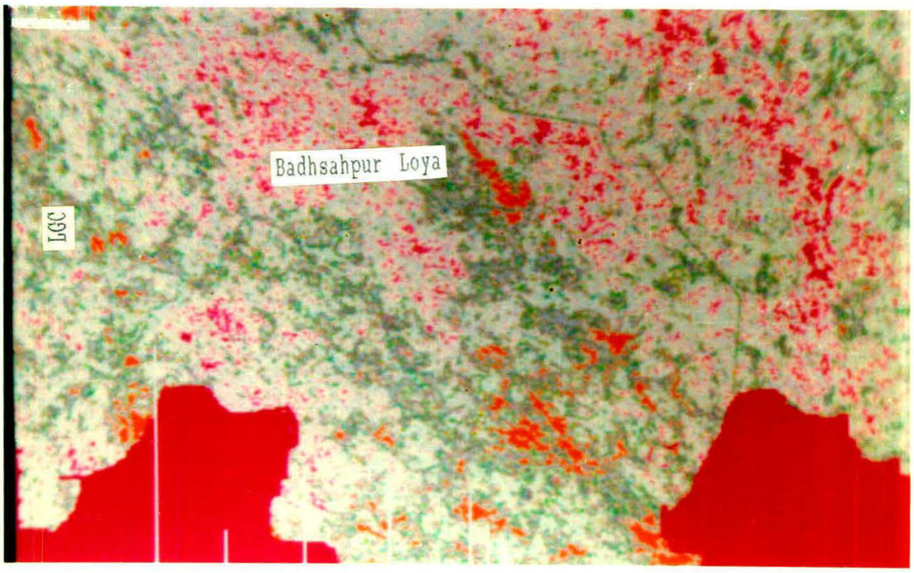


PHOTO T 4 Etah (Enhanced Hist Sliced Band 3)

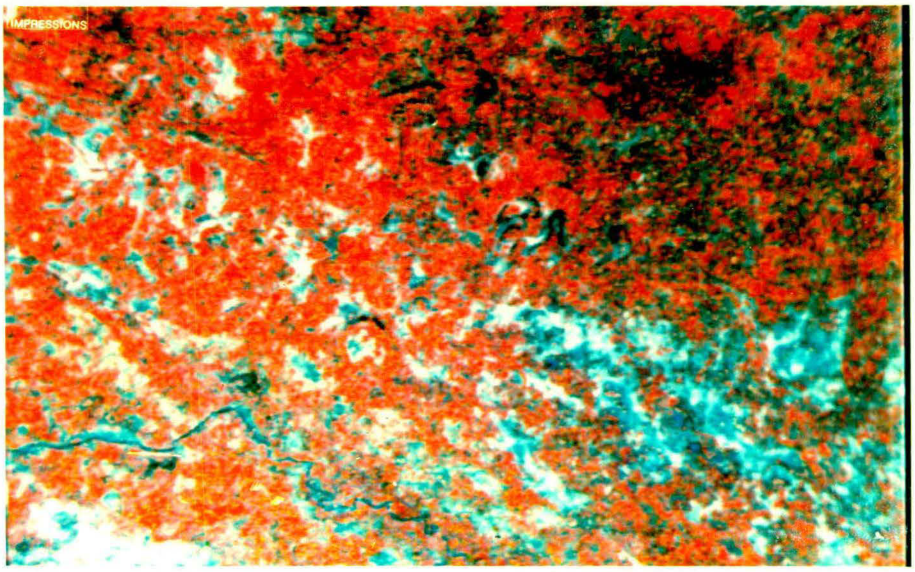
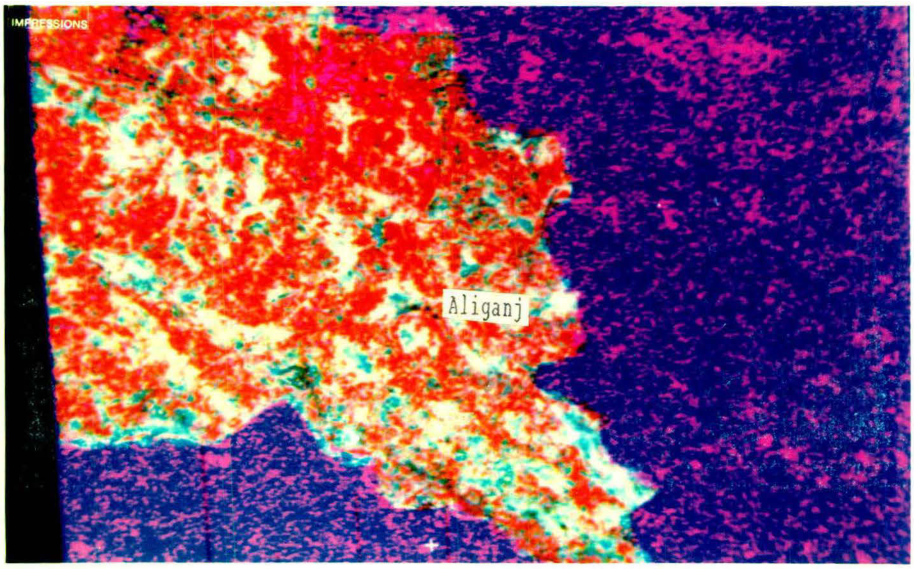
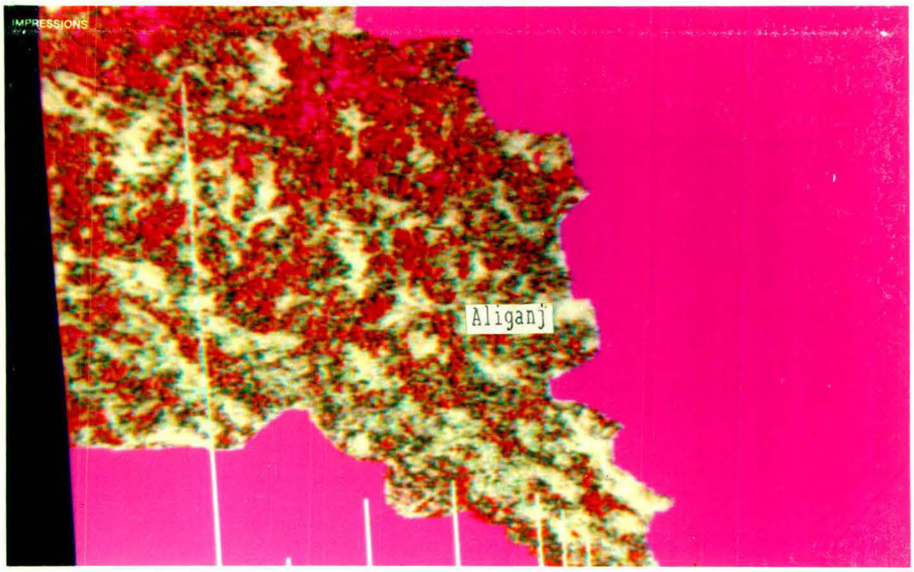


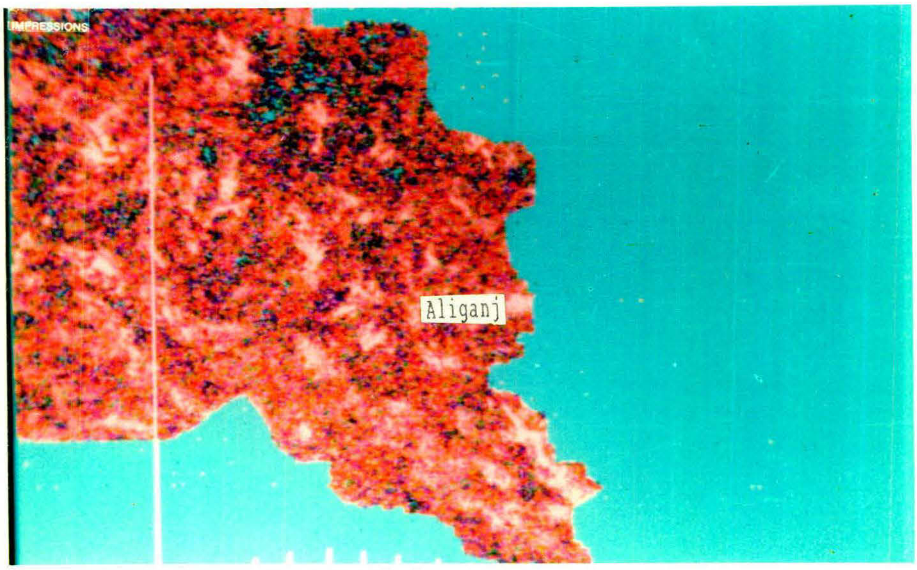
PHOTO Q1, E, SE Etah (FCC)



Q 2, E, SE Etah FCC with Boundary



Q 3,E, SE Etah (Enhanced & Hist Sliced Band 2)



Q 4,E, SE Etah (Enhanced & Hist Sliced Band 3)

Data set Calssification Index

DATA SET 3 (East, South-East Etah)	Severe	Severe to Moderate	Moderate
Photo Q1 FCC	White	White mottled blue & red	Red mottled blue & white
Photo Q2 FCC with Boundary	White	White mottled blue & red	Red mottled blue & red
Photo Q3 (Enhanced & Hist. Sliced) Band 2	White	White mottled with grey	Grey
Photo Q4 (Enhanced & Hist. Sliced) Band 3	White	White mottled with blue	Purple mottled blue

Data Set 4

This data set covered most of Jalesar block on the western portion of the district and was the most severely salt-affected (Photo Z1,Z2,Z3). Barren severely affected areas were found to cover large areas while category 2 and 3 were comparatively not so widespread. The similar procedures of enhancement and stretching were applied as before on both band 2 (Z4) and band 3 (Z5, Z6).

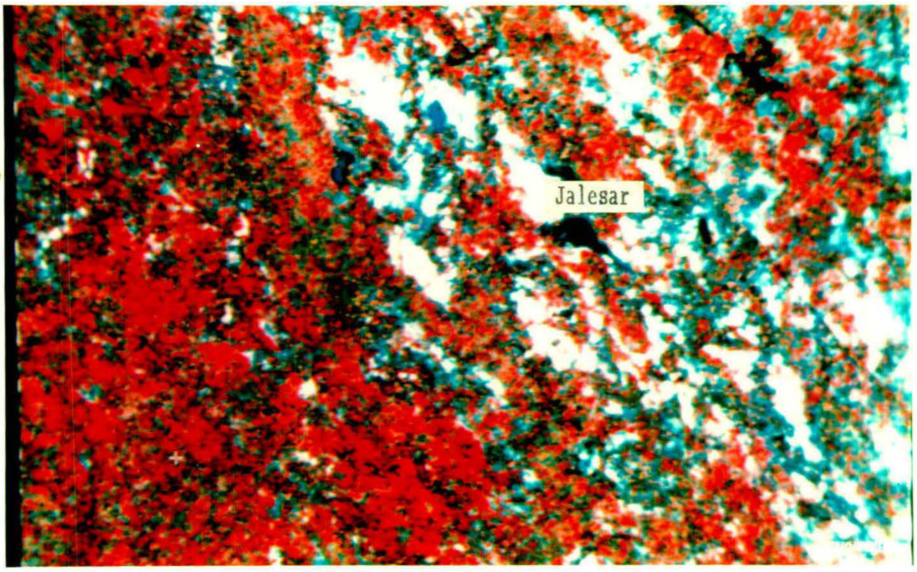


PHOTO Z 1 West Etah (FCC)

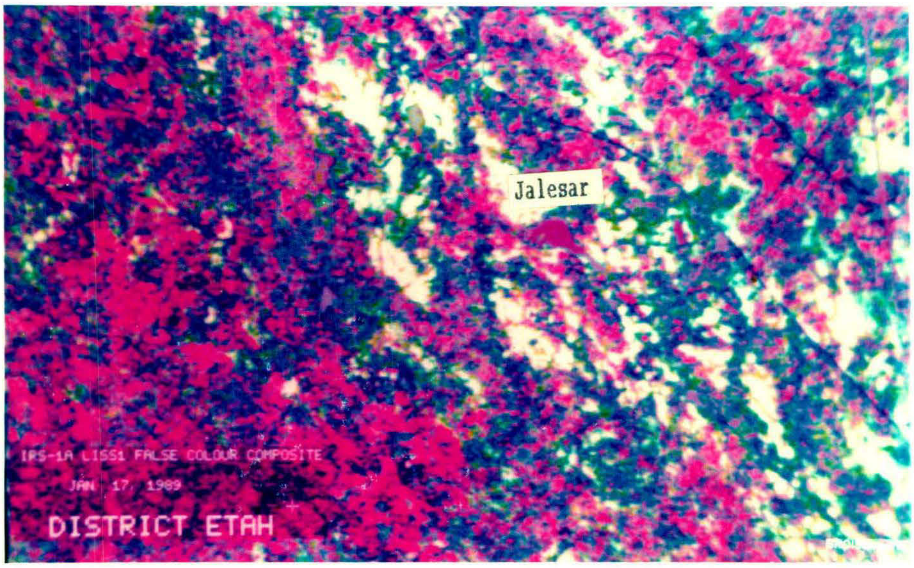


PHOTO Z 2 West Etah (Colour coded FCC)

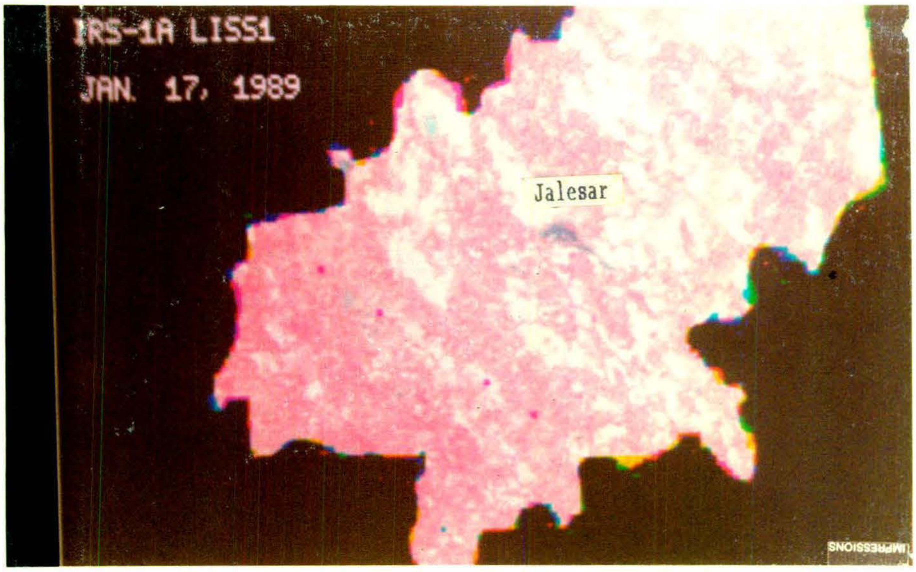


PHOTO West Etah (FCC with Boundary)

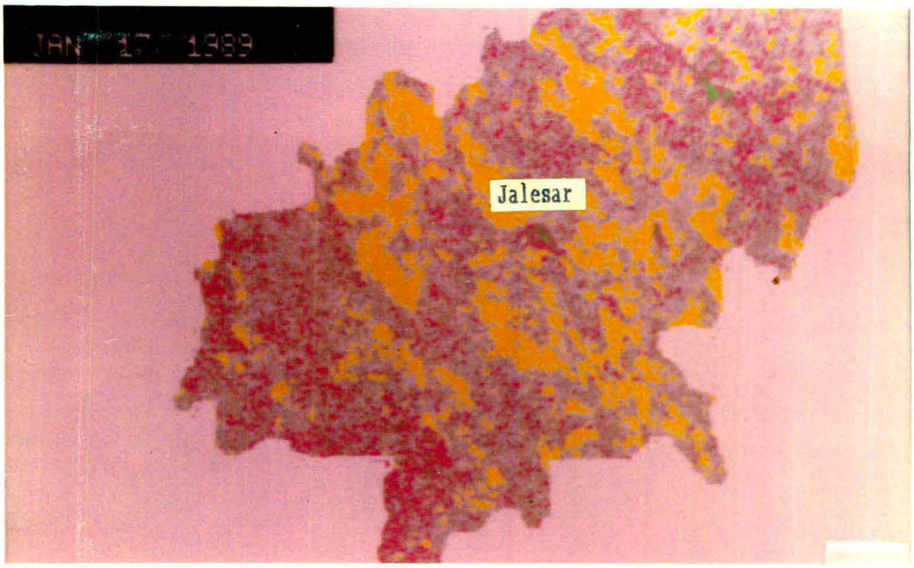


PHOTO West Etah (Enhanced Hist Sliced Band 2)

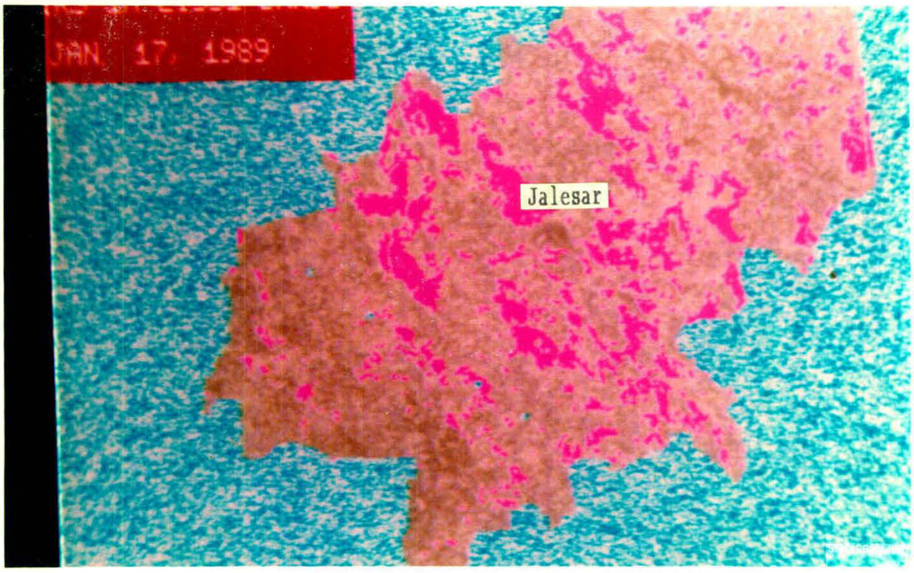


PHOTO Z 5 West Etah (Enhanced Hist Sliced Band 3)

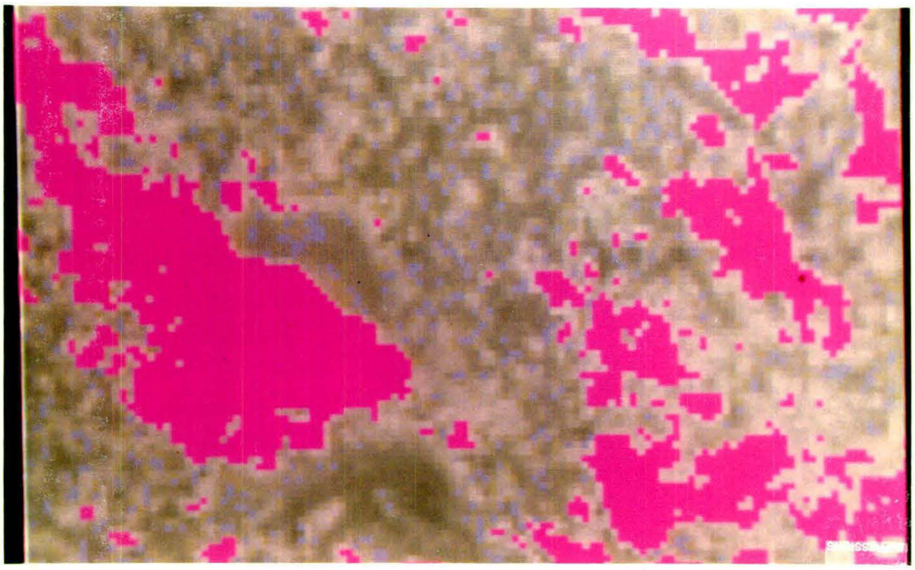


PHOTO Z 6 West Etah (Zoomed, From 25)

Data set Calssification Index

DATA SET 4 (South-West Etah)	Severe	Severe to Moderate	Moderate
Photo Z1 FCC	White	White mottled blue & red	Red mottled blue & white
Photo Z2 (Colour coded) FCC	White	White mottled green	Green mottled yellow
Photo Z3 FCC with boundary	White	White mottled blue & red	Red mottled blue & white
Photo Z4 (Enhanced & Hist. Sliced) Band 2	Yellow	Pinkish grey	Light pink
Photo Z5 (Enhanced & Hist. Sliced) Band 3.	Bright pink	Pinkish grey	Pink
Photo Z6 Zoomed from Z5	Bright pink	Pinkish grey	Pink

Data Set 5 & Data Set 6

Data set 4 was of south Etah covering the southern tip of the district and data set 5 was a thin fine strip east of the western Yamuna canal. Salt affected soils were classified according to the severity of the problem on both data sets.

On completion of generation of the 5 data sets the pixels for each category on band 2 and band 3 were compiled individually on LISS-I for area calculations under different categories.

4.3 Area and Extent of Salt Affected Soils

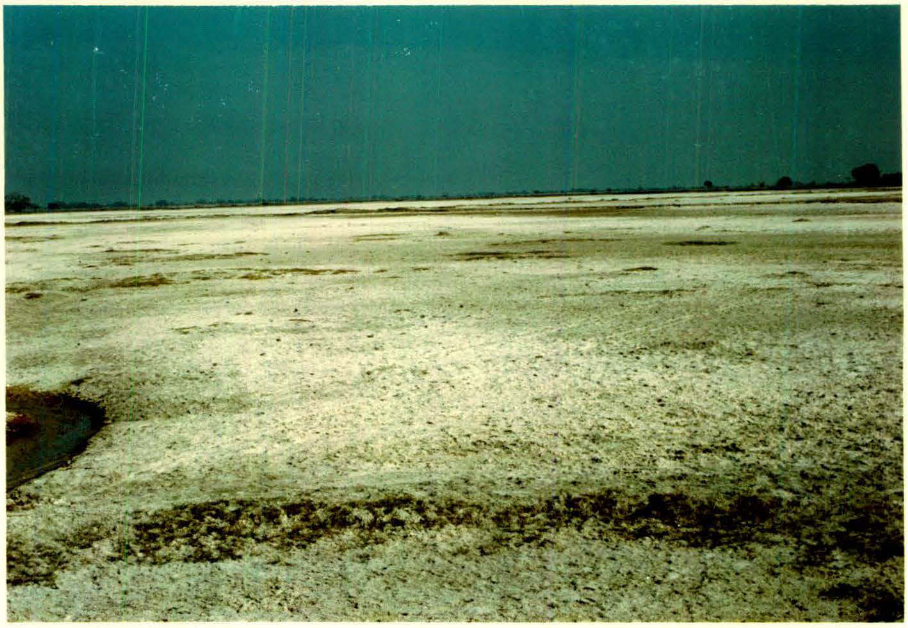
Band 2 (.52 - .59μm)

Severely salt-affected soils on band 2 covered 1059.19 sq. km i.e. 62.5% of the area in the district is under salt-affected soils. Moderate to severely affected areas covered 214.98 sq. km or 12.8% and moderately salt-affected areas were found over 421.7 sq. km or 24.8% of the total area under salt-affected soils. 38.14% of the total district was found to be affected by the salt hazard in this band.

Band 3 (.62 - .68μm)

On band 3, salt-affected soils were found over 42% of the total area of the district. Of this 1063.3 sq. km or 56.6% were under the severe category, 351.9 sq. km i.e. 18.8% were found under the severe to moderate category and 451.36 sq. km or 24.6% were under the moderately salt-affected area (Fig 4.2).

In a comparison between the area interpreted visually on the FCC on LISS-II images and the FCC generated on LISS-I the latter showed up a 4% greater area under salt-affected soils. The reason is attributed to the computer's capability to decipher larger numbers of grey levels that are translated into colours on the images than the human eye.



Salt Affected Soils

Salt Affected Soils with Waterlogging

Although the barren severely affected areas are easily distinguishable visually, the mixing up of colours of the other two categories may have caused visual confusion. The enhancement and stretching of the digital data considerably increased the accuracy and quality aiding in designation and categorization.

The area results obtained in the individual bands exceeded those of the visually interpreted false colour composite (Table 4.2 and Fig 4.5).

Table4.2: Nature of the band used and degree of precision in estimating different type of alkali soils.

Degree of alkalinity	Visual	Band 2	Band 3
	Percent of area under salt-affected soils	Percent of area under salt-affected soils	Percent of area under salt-affected soils
Severe	57.6	62.5	56.6
Severe to Moderate	19.1	12.7	18.8
Moderate	23.3	24.8	24.6
Percent of Total area	32.2	38.1	42.0
Total area of district	444,600 hectares		

Salt affected soils were found to cover a much larger area under band 3. The categorization of these soils into 3 categories was best conducted on this band and with maximum accuracy. The

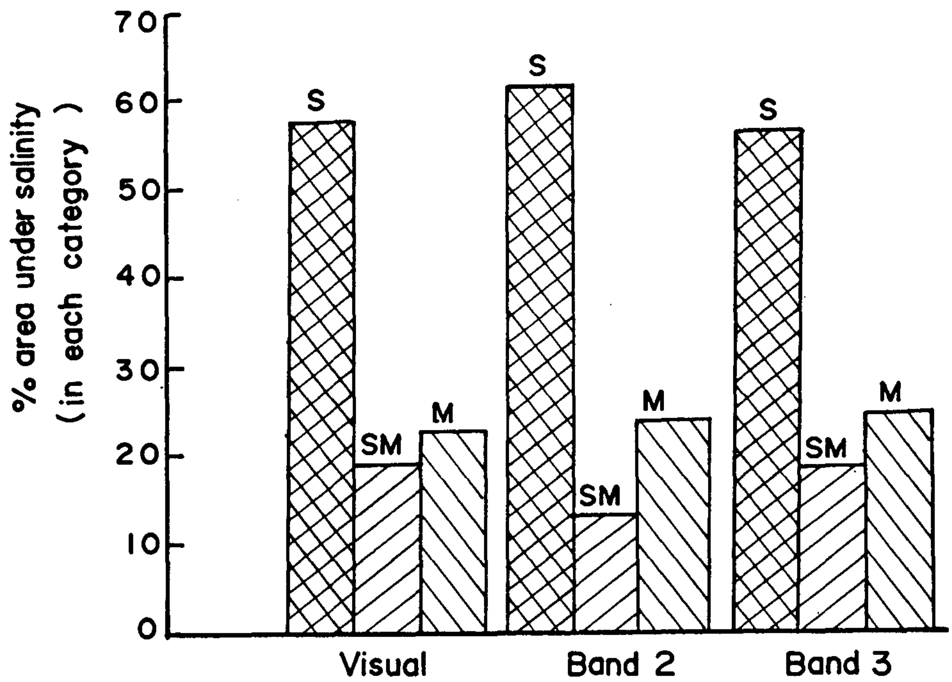


Fig.4·5 Area under different categories of salt affected soils using visual and digital techniques sequentially closely occurring values decreased the possibility of erroneous categorization (Fig. 4.4a, 4.4b) and proved most appropriate for sodicity assessment. There is a high reflectance given off by spongy mesophyll cells within the leaves of plants. During the growing season their chlorophyll content contrasts sharply with the and contrasts with the barrenness aiding in categorization and accurate assessment of the spread and location of salt-affected soils.

On band 2 in comparison the widely occurring DN values increased the possibility of features with closely occurring values with salt-affected soils to be banded together lowering the ability to classify and separate the degrees of severity. Although this band is useful for soil studies it was more difficult to distinguish the individual classes.

The original values in both cases gave poor interpretability but through image transformation the new values assigned to the classification levels highlighted salt-affected soils in both bands 2 and 3.

On band 4 in the near infrared region of the electromagnetic spectrum water bodies and moist soils were clearly identified. Only severely salt-affected soils appeared clearly and the study of other classes exhibited poor results in the statistical estimates of each spectral class. However, in combination with green and blue in the false colour composite the results were close to those of the visually interpreted data.

Between the visually interpreted data and band 2 the area under salt-affected soils was 5.8% greater while it was 9.8% more in band 3. Band 3 proved most accurate for categorization of these soils. Singh and Diwedi (1989) in their study of Mean DN values on LANDSAT MSS Spectral Bands also found that salt-affected areas could be spectrally separable into different classes.

Even though the accuracy of visual interpretation is high, to assist and improve the evaluation, comparable data on the CCT removes ambiguities that arise during visual interpretation mainly that similar patterns and colours occurring may not be visually decipherable. Digital analysis concentrates on every 'pixel' (72.5m x 72.5 m) whereas visual interpretations are of larger areas. When performing a digital analysis the computer analyses the algorithms, evaluates reflectance values and fits values into one of several categories using spectral separability. However, the digital approach is somewhat limited in its 'intelligence' for it is necessary in ensure that the raw data is as free of confusion as possible using visual techniques. Initially visual interpretation and the computed algorithms are both necessary to classification of salt-affected soils till such time that the computer is essentially trained.

Misclassifications may occur in both processes but the overall accuracy level for interpretation was found to be close to 88 percent.

MAP

Table:4.3 pHs and ESP of the soil as differentiated from the satellite data using DN values 156-184.

MODERATELY SALT AFFECTED SOILS

Satellite Data DN Value	Sample No.	pHs	ESP
	04	8.8	54
	12	8.4	50
156-184	19	8.8	44
(MODERATE)	29	8.7	53
	34	8.9	58
	51	8.4	48
	52	8.7	54
	64	8.4	46
	65	8.7	50

Category - II (Severe to Moderately affected on image)

The DN values in the severe to moderate category delineated on the IRS - IA image ranged between 185-214. Twentytwo of the ground samples had a higher pHs ranging between 9.2 and 9.8 and a mean value of 9.64. This high pHs is indicative of higher levels of alkalinity. ESP of these soil samples ranged between 56-72 (Table 4.4).

Category-1 (Severely affected)

Severely salt-affected soils on the image had a DN value range of between 215-238. 37 soil samples in this category had a pHs range of between 9.9 to 10.7 indicating very high levels of alkalinity. The ESP range for these samples was also comparatively high going up to 90 with a mean value of 73-90 (Table 4.5 and 4.6).

Table:4.4 pHs and ESP of the soil as differentiated from the satellite data using DN values (184-214)

SEVERE TO MODERATE

Satellite Data DN Value	Sample No.	pHs	ESP
	01	9.3	60
	02	9.8	68
	09	9.8	69
185-214	10	9.7	72
(SEVERE TO	20	9.4	62
MODERATE)	21	9.7	68
	22	9.6	68
	23	9.8	70
	32	9.7	68
	39	9.3	59
	42	9.8	69
	44	9.8	72
	46	9.7	70
	58	9.8	71
	59	9.2	56
	61	9.7	72
	63	9.7	70
	67	9.7	69
	68	9.8	72
	71	9.4	62
	72	9.7	68

Table:4.5 pHs and ESP of the soil as differentiated from the satellite data under DN values (215-238)

SEVERELY AFFECTED

Satellite Data DN Value	Sample No.	pHs	ESP
	03	10.0	82
	05	10.5	88
	06	10.7	90
215-238	07	10.2	82
(SEVERE)	11	9.9	73
	13	10.6	85
	14	10.5	84
	15	10.3	80
	18	10.2	86
	24	10.6	86
	25	10.1	80
	26	10.2	78
	27	10.3	84
	28	10.3	83
	30	10.5	85
	31	10.3	82
	33	10.3	82
	35	10.5	85
	36	10.0	76
	37	10.0	77
	38	10.3	82
	40	10.3	82
	41	10.2	80
	43	10.5	88
	45	10.4	87
	48	10.1	78
	49	10.3	82
	50	10.6	90
	53	10.1	78
	54	10.2	78
	56	10.1	82
	57	10.1	80
	60	10.3	86
	62	10.2	85
	66	9.9	75
	69	10.1	88
	70	10.5	90

Table:4.6 Degree of alkalinity and their reflectance values for alkali soils of Etah.

DN Value	pHs		ESP			Degree of alkalinity
	Range	Mean	Range	Mean		
156-184	8.4-8.9	8.64	44-58	50.77	Category-III	Moderate
185-214	9.2-9.8	9.64	56-72	67.45	Category-II	Severe to moderate
215-238	9.9-10.7	10.27	73-90	80.57	Category-I	Severe

4.4.2 Saturation Extract Composition

The soil samples were further analysed for their salt and anionic content in the saturation extract. Alkali soils are characterized by high carbonate and bicarbonates of Sodium

Category-III

The electrical conductivity (ECe) a measure of salt concentration in this category ranged between 6.3 to 64.4 dS/m. The samples were found to have predominantly bicarbonate and carbonate ions. The former ranged from 7 to 230 meq/l and in the latter from nil to 280 meq/l. Chloride ions ranged from 0.1 to 109.1 meq/l and sulphate ions ranged from 0.05 to 36.4 meq/l (Table 4.7).

Table:4.7 Anionic composition of saturation extract of soils falling under DN value class (156-184).

DN Value	Sample number	ECe dS/m^{-1}	CO_3^{2-} meq/l	HCO_3^{-1} meq/l	CL^{-1} meq/l	SO_4 meq/l
156-184	04	12.6	0.0	40.0	48.4	16.1
	12	6.3	0.0	40.0	12.9	4.4
	19	10.9	0.0	45.0	36.0	12.0
	29	64.4	220.0	230.0	109.1	36.4
	34	14.3	16.0	7.0	6.7	22.5
	51	8.6	0.0	35.0	28.7	9.5
	52	14.5	0.0	85.0	33.8	11.2
	64	4.9	15.0	75.0	7.3	2.5
	65	10.3	400.0	460.0	51.1	17.2

Category-II

The ECe of the 22 samples in the severe to moderate category ranged between 10.5 to as high as 113.8. The carbonate and bicarbonates in these soils were found to be comparatively higher. Carbonate ranging from 1.0 meq/l and bicarbonate 15 meq/l to 450 meq/l. Chloride in these samples ranged from between 5.4 meq/l to 181 meq/l and sulphate from between 1.9 to 54 meq/l (Table 4.8).

Table:4.8 Anionic composition of saturation extract of different soils falling under DN value class 185 - 214

DN Value	Sample number	ECe dS/m^{-1}	CO_3^{2-} meq/l	HCO_3^{-1} meq/l	CL^{-1} meq/l	SO_4 meq/l
	01	10.5	1.0	35.5	38.5	12.3
	02	17.8	39.0	50.0	50.0	16.8
	09	57.5	390.0	110.0	42.2	14.1
	10	72.5	220.0	335.0	95.6	31.9
185-214	20	31.0	70.0	105.0	76.0	25.3
	21	115.0	560.0	450.0	78.8	26.2
	22	22.4	152.0	37.0	19.7	6.6
	23	55.2	232.0	75.0	137.8	46.0
	32	64.4	200.0	250.0	94.9	32.2
	39	41.4	240.0	42.0	74.0	25.0
	42	92.2	291.0	305.0	181.0	61.0
	44	77.0	440.0	110.0	123.8	41.2
	46	14.9	30.0	35.0	47.0	16.0
	47	13.8	68.0	20.0	28.0	9.5
	58	13.8	68.0	20.0	28.0	9.5
	59	14.3	60.0	40.0	24.2	8.1
	61	43.2	210.0	160.0	34.8	11.7
	63	113.8	480.0	370.0	162.0	54.0
	67	57.1	340.0	270.0	34.3	11.5
	68	3.7	22.0	15.0	5.4	1.9
	71	27.0	20.0	50.0	112.5	37.5
	72	16.6	40.0	75.0	28.7	9.6

Category-I

Of the 37 samples in the severely salt-affected category ECe ranged between 7.0 to very high i.e., 100.05 dS/m. Carbonates were also very high going up to 760 meq/l. Bicarbonates ranged between 5.0 meq/l to 460 meq/l. Chloride in these soils ranged between 5.6 to 259 meq/l and sulphate between 1.0 to 38 meq/l (Tables 4.9 and 4.10).

Table4.9: Anionic Composition of saturation extract of different soils falling in DN value class 215-238

DN Value	Sample number	ECe dS/m^{-1}	CO_3^{2-} meq/l	HCO_3^{-1} meq/l	CL^{-1} meq/l	SO_4 meq/l
	03	50.6	168.5	140.5	60.8	20.2
	05	43.1	200.0	205.0	14.6	4.9
	06	30.4	170.0	120.0	7.9	2.6
215-238	07	50.6	160.0	250.0	54.0	18.0
	11	87.4	380.0	410.0	47.3	15.7
	13	52.9	200.0	280.0	27.6	9.2
	14	78.2	490.0	260.0	18.0	6.0
	15	30.4	250.0	25.0	16.3	5.5
	18	47.7	310.0	150.0	9.6	3.2
	24	40.2	310.0	27.0	36.6	12.2
	25	40.2	260.0	42.0	56.3	18.7
	26	97.8	600.0	250.0	72.0	24.0
	27	100.1	760.0	164.0	43.0	14.4
	28	47.7	215.0	140.0	68.6	22.9
	30	29.5	160.0	100.0	19.7	6.5
	31	43.4	360.0	41.0	18.6	6.2
	33	52.9	480.0	47.0	1.5	0.5
	35	49.4	200.0	118.0	99.0	33.0
	36	77.0	220.0	260.0	163.0	55.0
	37	78.2	440.0	140.0	114.0	38.0
	38	92.0	480.0	394.0	259.0	8.6
	40	38.5	140.0	120.0	70.0	24.0
	41	29.3	180.0	55.0	32.6	12.0
	43	33.5	200.0	80.0	30.9	10.4
	45	92.0	620.0	135.0	93.0	31.0
	48	96.6	490.0	275.0	113.0	38.0
	49	20.7	140.0	60.0	3.9	135.0
	50	28.7	200.0	49.0	21.4	71.0
	53	57.5	320.0	40.0	120.9	40.1
	54	39.2	300.0	5.0	48.8	16.2
	56	38.9	200.0	50.0	78.2	25.0
	57	7.0	16.0	15.0	14.6	14.4
	60	45.4	235.0	150.0	38.8	13.1
	62	43.4	250.0	160.0	13.5	4.5
	66	26.6	400.0	460.0	51.1	17.2
	69	43.1	160.0	220.0	28.8	9.6
	70	17.2	92.0	70.0	5.6	1.9

Table 4.10: Range and mean values of Anionic composition of saturated extract of alkali soils in different reflectance value classes. a) ECe and Carbonate; b) Bicarbonate, Chloride, Sulphate

a)

DN Value	ECe		CO_3	
	Range	Mean	Range	Mean
156-184	4.0- 64.4	15.1	0.0-400	65.1
185-214	3.7-115.0	57.6	0.1-480	181.3
215-238	7.0-100.1	50.7	16.0-760	290.7

b)

DN Value	HCO_3 meq/l		Cl^{1-} meq/l		SO_4 meq/l	
	Range	Mean	Range	Mean	Range	Mean
156-184	7.0-460.0	105.7	0.1-109.1	30.419	0.1-36.4	13.2
184-214	15.0-450.0	129.0	5.4-181.0	66.877	1.9-61.0	21.9
214-238	5.0-460.0	148.9	1.5-259.0	53.309	0.5-135.0	20.7

4.4.3 Fertility Evaluation

The chemical parameters used for assessing fertility status were Olsen's P, organic carbon, available K and cation exchange capacity (CEC).

Category-III (Moderate)

Organic carbon in soils of this category varied from 0.15 to 0.67 representing low levels. Olsen's P and available K however were found to be ranging from medium to high levels indicating sufficient quantities of these nutrients. The soils were of medium texture and showed a wide variation from loam, silty clay and clay loam. The cation exchange capacity ranged from 6.7 - 10.4 the soils are illitic in nature (Table 4.11).

Table 4.11: Fertility status of soils falling under value class 156-184.

DN Value	Sample number	OC %	Olsen's P kg/ha	Available K kg/ha	CEC meq/100 gms	Texture
	04	0.15	14.00	168	10.1	Clay loam
156-184	12	0.17	7.73	117	10.1	Clay loam
	19	0.36	12.53	285	8.8	Silty clay
	29	0.34	77.00	548	6.8	Silty clay loam
	51	0.67	15.60	336	6.7	Loam
	52	0.42	13.40	268	8.6	Loam
	64	0.36	8.96	280	8.1	Loam
	65	0.48	18.08	319	8.3	Loam

Category - II (Severe to Moderate)

The organic carbon in this category was relatively lower and ranged from .13 to .69 but Olsen's P tends to be higher and present in larger quantities while available K is present in almost the same quantities. The texture showed a wide variation and tends to be heavier than category III soils which are medium textured. The CEC ranges between 6.8 to 12.7 that is not very different from the medium textured soils (Table4.12)

Table 4.13: Fertility Status of soils under DN value class 215-238.

DN Value	Sample number	OC %	Olsen's P kg/ha	Available K kg/ha	CEC meq/100 gms	Texture
	03	0.27	26.88	336	12.5	Clay
	05	0.23	29.12	224	10.9	Sandy clay/clay
	06	0.17	15.68	235	10.9	clay loam
	07	0.34	26.88	190	10.9	Clay loam
215-238	11	0.13	83.32	330	11.7	Clay loam
	13	0.25	55.69	397	13.6	Clay
	14	0.25	71.68	403	14.4	Clay
	15	0.23	11.94	218	10.8	Clay loam
	18	0.25	58.24	179	10.2	Clay loam
	24	0.21	21.48	330	12.0	Clay
	25	0.23	60.86	285	12.2	Clay
	26	0.24	93.01	344	11.5	Silty clay
	27	0.34	125.30	304	13.4	Clay
	28	0.36	37.60	392	12.8	Clay
	30	0.63	26.88	470	13.8	Clay loam
	31	0.38	42.36	496	13.8	Clay/Silty clay
	33	0.27	51.16	218	12.1	Clay
	35	0.36	51.91	492	12.1	Clay loam
	36	0.48	93.08	347	12.0	Clay
	37	0.25	69.04	436	15.4	Clay
	38	0.19	73.90	263	12.8	Clay
	40	0.19	22.40	414	13.9	Clay
	41	0.42	38.00	375	10.8	Clay
	43	0.17	38.00	296	13.4	Clay
	45	0.17	97.07	212	9.1	Clay
	48	0.40	89.06	660	8.0	Loam
	49	0.29	20.00	285	12.9	Clay
	50	0.25	28.61	330	12.8	Clay
	53	0.59	44.80	375	8.9	Silty loam
	54	0.19	35.80	431	8.0	Clay
	56	0.25	49.20	403	8.8	Clay loam/loam
	57	0.46	11.20	375	6.8	Loam
	60	0.19	44.17	218	8.8	Loam
	62	0.27	26.65	296	12.8	Silty loam
	66	0.38	20.16	285	11.8	Silty loam
	69	0.61	29.12	408	11.7	Clay
	70	0.29	8.96	291	12.1	Clay

Table4.14: Mean and range values of fertility parameters in Alkali soils of Etah District

DN Value	OC%		P (kg/ha)		K(kg/ha)		CEC (meq/100 gms)	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
176-189	0.15-0.67	0.37	7.73-77.0	21.42	117-548	301.44	6.7-10.4	8.66
190-218	0.13-0.63	0.31	8.96-116.8	44.03	100-682	303.81	6.8-12.7	9.28
219-238	0.13-0.63	0.30	8.96-125.3	46.73	179-660	339.00	6.8-15.4	11.63

The results clearly show that the degree of alkalinity can be easily described by the DN values as obtained from IRS-IA Band 3 data.

Further it has been observed that the CEC and Ece values increase with the increase in the severity of the problem of alkalinity while organic carbon decreased. The available K was maximum in soils of the severe category. This may be due to the heavier texture of the soil and or more release of K under high degree of sodicity. Further analysis of the data showed that irrespective of the category of the soil there appears to be very high correlation between the pHs and the ESP (Fig. 4.7) of the soil with r^2 value of 0.84. This relationship can be used easily to predict ESP of the soil from pHs data thus avoiding the cumbersome analysis of determining ESP (Abrol et al. 1980)

In alkali soils of Etah district the Olsen's extractable P increases with the severity of the alkalinity (Fig.4.8). This is

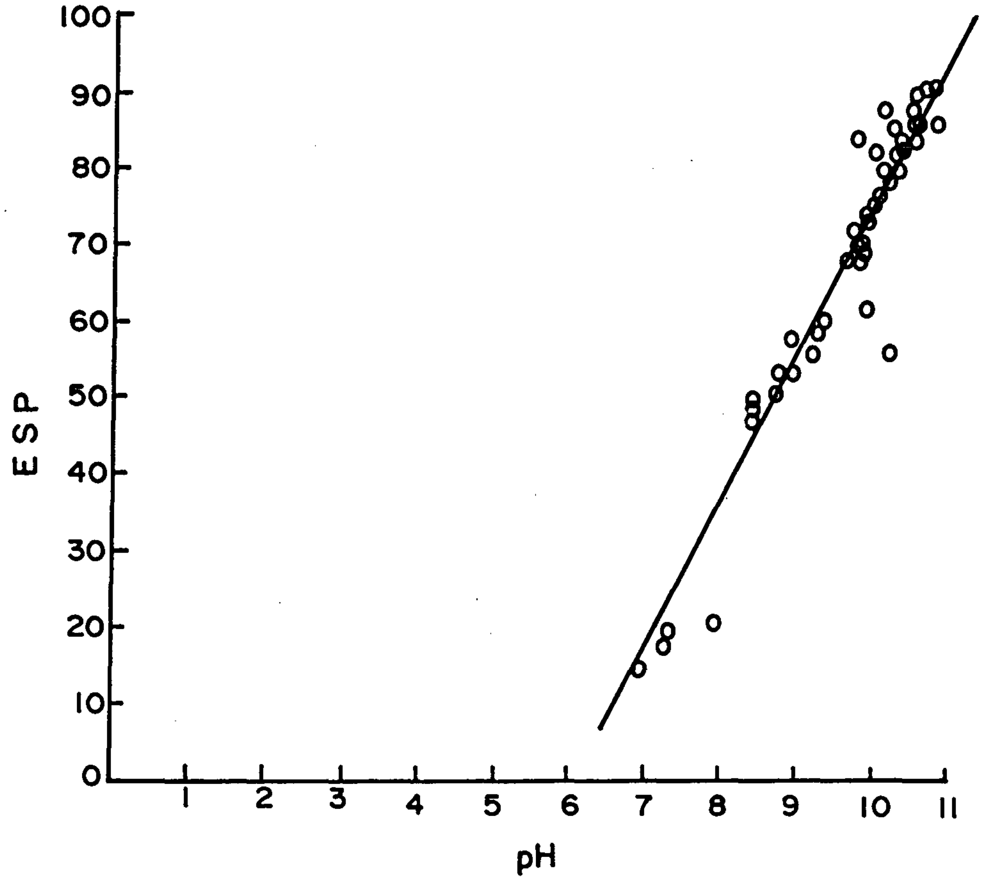


Fig. 4·7 Relationship between pH of the saturation paste and the exchangeable sodium percentage of Etah district

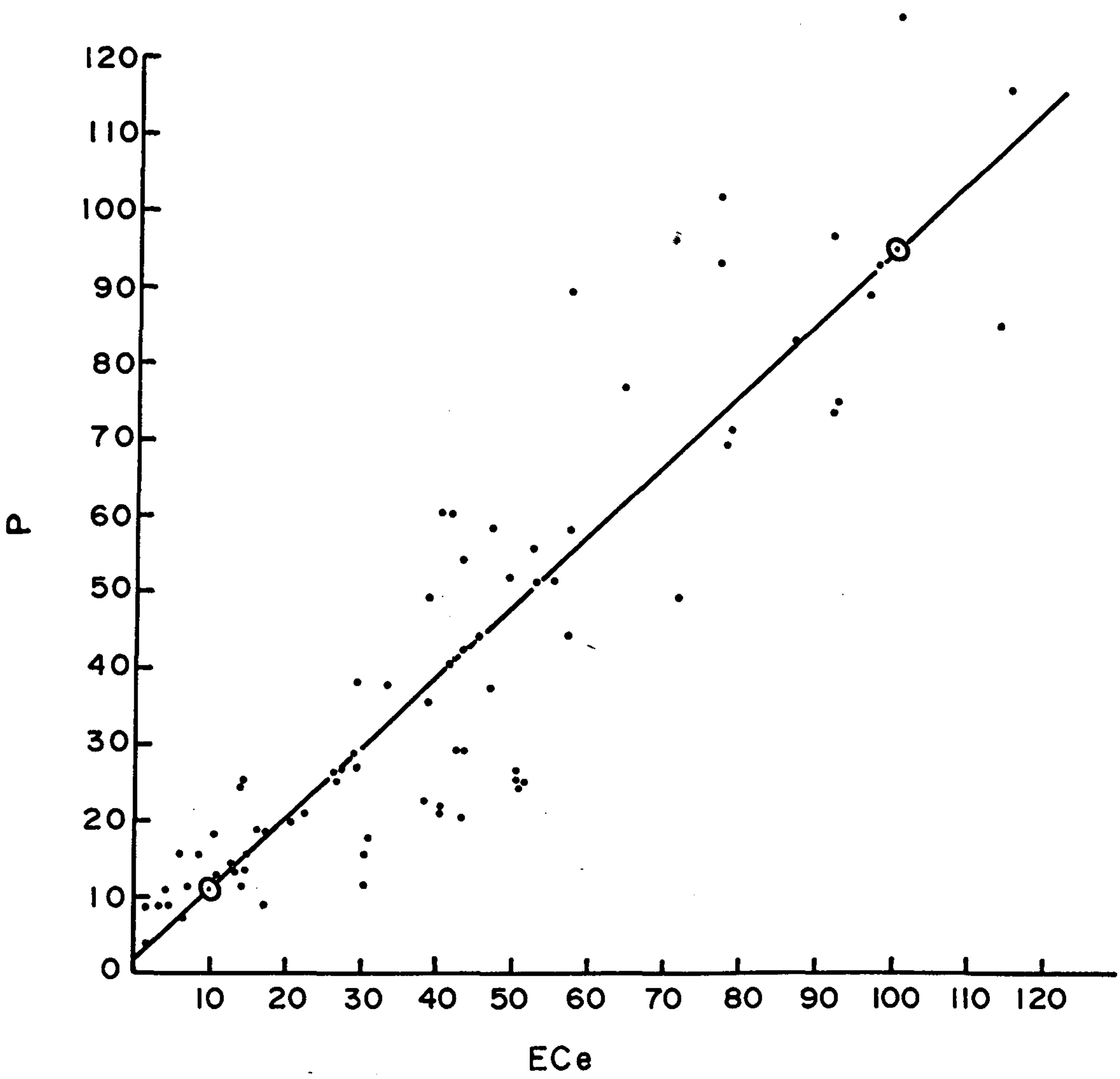


Fig.4·8 Olsen's extractable phosphorous as affected by ECe of the alkali soils due to the increase in carbonates and bicarbonates of Na which constitute the bulk of soluble salts in alkali soils. These in turn dissolve the insoluble P from the soil resulting in higher concentrations of Olsen's P. (Chhabra et. al., 1981) Based on these observations it can be concluded that alkali soils in Etah are rich in extractable K and P and low in organic carbon.

Alkali soils as mentioned before (Abrol et al 1981) have appreciable quantities of soluble salts generally absent. They are however rich in salts capable of alkaline hydrolysis e.g. Na_2CO_3 (sodium carbonate).

The pH of the saturated soil paste is more than 8.2 and ESP (Exchangeable Sodium Percentage) of more than 15 is the accepted unit indicating sodicity. An electrical conductivity of the saturation extract is generally less than 4 dS/m at 25°C but the presence of Na_2CO_3 causes the ECe to be high.

The exchangeable sodium percentage and pH show up a well defined relationship and pH serves as the approximate index of soil sodicity (alkali) status. Sodium is the dominant soluble cation. High pH causes precipitation of soluble Ca + Mg and their concentration is these soils is very low. Gypsum is nearly always absent.Beek and Breemen (1973) have stated that alkali soils have an unstable structure and the physical properties become increasingly worse with increasing pH.

4.4.4 Sakit Series (Benchmark soils of Etah district)

The salt affected soils of Etah have been broadly defined by the SAKIT benchmark series (Benchmark soils of India, NBSS&LUP 1982).

This series is a member of the fine sand loam to clay, mixed hyperthermic family of Typic Natrustalfs. These soils have a light brownish grey to light olive brown very alkaline A horizon variegated coloured dark brown to dark yellowish brown very strongly. Alkaline clay loam Bt horizons and yellowish brown to dark greyish brown mottled very strongly alkaline gravelly sandy clay loam to clay loam C horizons. They have developed in old alluvium and flat terraces in Etah at an elevation of 150 to 200 m above MSL.

Typifying Pedon Sakit Sandy loam, Alkaline waste

A11, 0-11 cm - light brownish grey (2.5 Y 6/2 D) very fine sandy loam, greyish brown (2.5 Y 5/2 M) moderate fine to medium platy structure; hard friable. strons strongly effervescent salt cutans common fine roots; pH 10.5; abrupt wavy boundary.

A12, 11 - 38 - Light olive (2.5 Y 5/4 M) sandy clay loam, weak to moderate medium subangular blocky structure, friable, slightly sticky and slightly plastic; strongly effervescent) few 1 to 2 mm size iron-manganese conceretions 1 to 2% by volume; salt cutans; few fine fibrous roots, common very fine discontinuous vertical tubular imped pores, pH 10.4 clear wavy boundary.

B21 t 38 - 48 cm variegated colours - dark brown (10 Y 3/3 M) and dark greyish brown (2.5 Y 4/2 M), clay loam, moderate medium columnar structure, firm, slightly sticky and slightly plastic, strongly effervescent 1 to 2 mm size iron manganese conceretions 1 to 2% by volume, salt cutans, few fine fibrous roots, many very fine discontinuous vertical tubular imped pores, pH 10.2 abrupt wavy boundary.

B22 t 48 - 69 variegated colours - dark yellowish brown (10 Y 4/4 M) and dark greyish brown (2.5 Y 4/2 M) clay loam strong medium columnar structure firm sticky and plastic, very strongly effervescent, 2 to 5 mm size, calcium carbonate.

Micromorphology

The fauna are responsible for most of the recent and former voids. The soil material is unstable when wet. High sodium saturation causes peptization releasing clay which moves down, fills the voids and forms cutans and infillings become finely graved. In the B21 t horizon the former fine to medium prismatic structure elements are embedded and infilled, often coarser grained, zones about 10 mm wide. Carbonates have accumulating throughout the B horizons. Associated with voids, some calcans and carbonate needles occur in the B21 t horizon. Carbonate and sesquioxide nodules are also present.

Range in Characteristics

The thickness of the solum is 85 to 100 cm. The estimated MAST is 27°C and MWST is 17.5°C. The moisture regime is hypothermic.

The horizon is 30 to 40 cm thick. Its colour is in hue 2.5 Y value 5 to 6 and chroma 2 - 4. The texture varies from sandy loam to clay loam. Salt encrustations at the surface and salt cutans in lower part of the A horizon are common. The Bt horizon is 50 to 60 cm thick. It has variegated colours in hues 10 YR and 2.5 Y, value 3 to 4 and chroma 2 to 4. Texture is dominantly clay loam. Clay cutans and distinct mottles are present. The Cca horizon which is more than 50 cm is of variegated colours and mottled.

Drainage And Permeability

Imperfectly drained with slow permeability.

Use And Vegetation

Mostly barren with salt loving grasses.

Distribution And Extent

Extensive in Etah and adjoining district of Uttar Pradesh.

Type Location

Village Ramgarh - Hasanpur Tehsil - Jalesar District Etah.

Series Proposed

AIS and LUS Regional Centre, Delhi, 1978.

Interpretation

Sakit soils are highly alkaline. They have drainage problems and are subject to stagnation during the monsoon. Groundwater rises to within 2 metres from the surface. These soils need to be brought under cultivation.

Interpretation Grouping

1. Land capability subclass IIIs
2. Irrigability subclass IIId
3. Productivity potential low

4.5 Occurrance and Formation of Salt Affected Soils in Etah District

The abundance of alkaline earths and of minerals in the alluvial deposits of the Gangetic plains are closely related with the geology of the Uttar Pradesh Himalayas from where the major rivers draining the plain emerge.

The Himalayan zone consists of mainly 3 stratigraphical zones: 1. Greater Himalayas composed of Fosiliferous sediments, 2. Central Himalayas composed of granites and other crystalline rocks, and 3. the outer Himalayas composed of sediments of the tertiary age (Singh, 1971).

The Greater Himalayan Zone is separated from the central Himalayas by a major thrust. Mainly crystalline the major rocks are quartzites, migmatites, gneiss, garnet, schists, diorite and amphibolites.

In the middle Himalayan zone, the main structural features are the Krol belt consisting of sandstones, limestone and quartzites along with shales. The Tal series contain fragmentary molluscs and corals of the system and the sedimentary belt of Deoban - Tejam, following the main thrust line are made up of crystalline rocks i.e. shales limestones and magnesite, topped with limestones and dolomites and thick sections of quartzite. The inner sedimentary zone (Deoban - Tejam belt) of the lower Himalayas is separated by a thrust sheet of a huge crystalline mass of metamorphosed rocks with a highly complex character . The Subathus extend into the middle Himalayas and consist of a similar mass of rocks (Fig 4.9).

The lower Himalayan zone is built entirely of Siwalik sediments constituting detrital clays and conglomerates. The quartzites, granites and limestones are metamorphosed sedimentaries extensively rich in alumino-silicate materials (Goldschimidt, 1958). Quartzite, dolerite, granite micas and amphibolites contain sodium, calcium feldspars (palagioclase). Sodium is also present along with calcium in carbonaceous sediments. Metamorphosed sedimentary rocks are rich in clays as illite, vermiculite and montmornollite that are present in the Himalayan system. (Wadhpole, 1970)

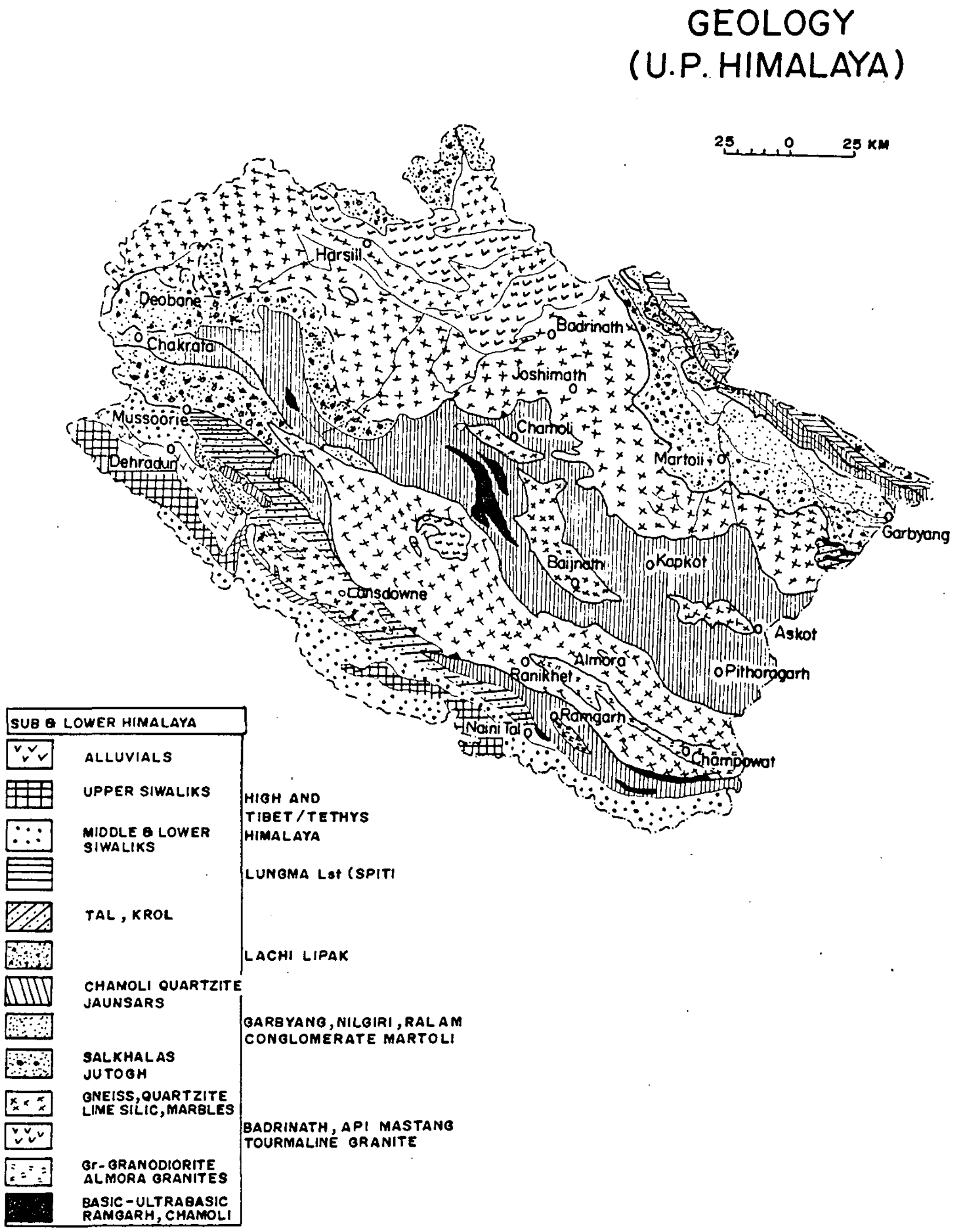

GEOLOGY
(U.P. HIMALAYA)
25 0 25 KM
Harsill
Deobane
Badrinath
Chakrata
Joshimath
Mussoorie
Chamoli
Dehradun
Martoli
Garbyang
Baijnath
Kapkot
Lansdowne
Askot
Almora
Ranikhet
Pithoragarh
Ramgarh
Naini Tal
Champawat
SUB & LOWER HIMALAYA
ALLUVIALS
UPPER SIWALIKS
MIDDLE & LOWER SIWALIKS
TAL, KROL
CHAMOLI QUARTZITE JAUNSARS
SALKHALAS JUTOGH
GNEISS, QUARTZITE LIME SILIC, MARBLES
Gr-GRANODIORITE ALMORA GRANITES
BASIC-ULTRABASIC RANGARH, CHAMOLI
HIGH AND TIBET/TETHYS HIMALAYA
LUNGMA Lst (SPITI
LACHI LIPAK
GARBYANG, NILGIRI, RALAM CONGLOMERATE MARTOLI
BADRINATH, API MASTANG TOURMALINE GRANITE

Fig. 4·9

Special mention of the high salt content in the Shali series must be made. These extend from the salt range in Pakistan to the UP Himalayas and contribute greatly to the presence of salts in the soils of the plains.

It is clearly demonstrated by geological and mineralogical evidence that the residual hydrothermal solutions originating in the mountains are associated with magmatic and igneous magmatic rocks. They must have in many cases contained considerable amounts of sodium compounds or of sodium ions. These can be traced in the residual solutions formed in the deposits of hydrothermal sodium minerals such as albite or zeolites. Several types of metamorphism are associated with an increase in sodium content however the major chemical process involves a change in the coordination of aluminum from six as in mica and clay minerals to four as in the feldspar. These reactions result in the fixation of increasing amounts of sodium as in the series from quartz biotite -> sericite -> phyllites through phyllites and mica schists containing albite to oligoclase -> boitite gneiess and finally to gnieses containing both sodic palagioclase and pottasium feldspar.

This process of geneisification of rocks which were originally argillaceous sediments is found in connection with granite and quartzite intrusions contemporaneous with orogenic movements and with regional metamorphism. These have been described in the Alpine system and in the Himalayas (Goldschimidt, 1958).

Presently among geologists, the opinion is gaining ground that many so called granites or gneiss granites, especially in the Orogenic zones of the earth are really products of alkali transfer into metamorphosed sediments. The carbonate materials coming from the limestone and dolomites.

The weathering of these rocks is then the primary source of soluble salts entering natural waters, sediments and soils (Pendias K and Pendias, H 1985). The geochemistry of salts in any given place according to Szabolcs (1989) is determined by the mobility of the compounds formed and by the sequence of precipitation of the weathering products. The mobility of the rock forming elements depends on the following factors.

1. The stability of the crystalline network
2. The radius of ions formed during weathering
3. The change of the ions formed during weathering.

Translocation of weathering products any where over the earths surface and particularly in the Indo-gangetic plains under discussion depends upon their mobility and that elements and compounds weathered from these rocks must be mobile in order to accumulate in soils and waters.

Table:4.15 Relative mobility and average distribution of some elements and ions in rocks and water

Component of iron	Average composition of igneous rocks (%)	Average composition of the mineral residue of river waters (%)	Relative mobility of elements and compounds (%)
Si_o2	59.9	12.80	0.20
AL_2O_3	15.35	0.90	0.20
Fe_2O_3	7.29	0.40	0.04
Ca^{2+}	3,60	14.70	3.00
Mg^22	2.11	4.90	1.30
Na^+2	2.97	9.50	2.40
K^+	2.57	4.40	1.25
Cl^-	0.05	6.75	100.00
$SO_4{}^{2-}$	0.15	11.60	57.00
$CO_3{}^{2-}$	-	36.50	

(Szabolcs 1989)

Table 4.16 Average elemental composition of some igneous rocks

Elements	Ultrabasic rocks	Basaltic rocks	High Ca granitic rocks	Low Ca granitic rocks
Si	205	230	314	347
Al	20	78	82	72
Fe	94	86	30	14
Ca	25	76	25	5
Mg	204	46	9	2
Na	2	20	28	26
K	0.04	8	25	42
Ti	0.30	14	3.40	1.20
Mn	1.60	1.50	0.54	0.40
P	0.22	1.10	0.92	0.60

(Szabolcs, 1989)

Prevailing climatic regimes have caused the solubility of sodium carbonates and bicarbonates to a large degree depends on the temperature. (FAO/UNESCO, 1973) at temperatures of below 0° and below the solubility of soda and sodium bicarbonate (but not of sodium chloride) drops to as little as 3 to 5 g/l. At temperatures around 30° the solubility of soda is as high as that of sodium chloride that is approximately 350 g/l while at high temp. its solubility is nearly 500 g/l i.e. higher than that of sodium chloride (Fig.4.10). The behaviour of soda in relation to temperature is similar to that of sodium sulphate. The solubility

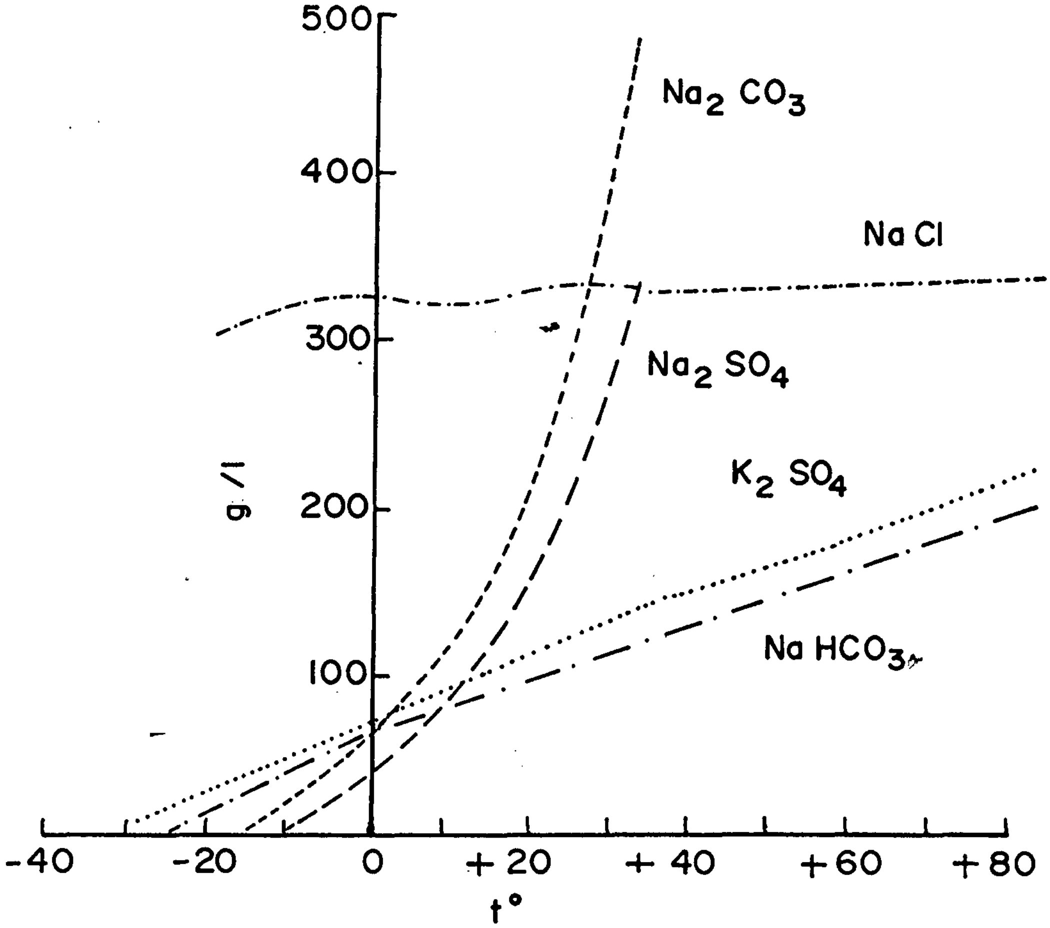


Fig.4.10 Salt solubility depending on temperature

of sodium bicarbonates is thought to vary more than soda. It means soda at atmospheric temperatures (below 15°C) will precipitate into deposits in soils together with sodium sulphate while chloride will be carried away by ground, subsoil and surface waters. It is thus to be expected that, in regions with a cold climate and severe climates, soils will be characterized mainly by accumulation of sulphates and carbonates of alkali.

A high soda concentration in solutions in its turn exercises a strong influence on the solubility and mobility of calcium carbonate (Fig.4.11). In the presence of sodium carbonate calcium carbonate is still a little soluble,(Da Costa, 1979) but the soda, even when the total alkalinity drops to 0.1 g/l, of HCO_3, virtually eliminates the calcium from the soil and solution. This explains why the ground waters, in regions of alkaline salt accumulation, contain practically no calcium despite the presence of calcium carbonate in rocks and soil horizons.

4.5.1 Geomorphic Processes.

The geomorphology of the landscape has also played the governing role in the distribution of materials in all types mentioned. Water is the main carrier both on the surface of the soil and underground that has transported the salts towards the places where they have accumulated.

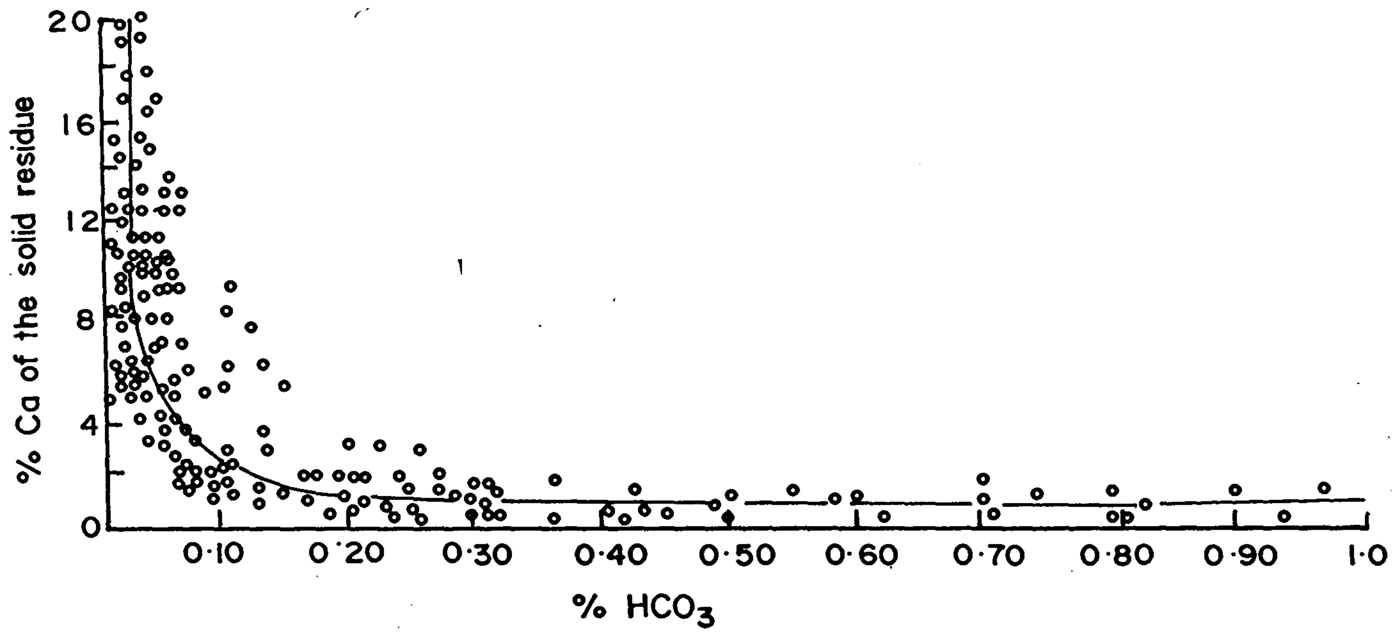


Fig.4·11 Relationship between content of water-soluble Ca and the total alkalinity

The initial weathering is taking place in the upper reaches of the mountains. Subsequently the weathered material have been washed down and therefore accumulated in river terraces and the alluvial plains.

In the northern hemisphere the salt accumulation has taken place most often in left terraces of the rivers rather than on right. The cause of this phenomenon is the shape of the terraces on the right and left sides of the rivers. The 'Ber' law states that the shape of the terraces along both sides of the rivers forms differently in consequence of the rotation of the globe. Valid as and when the rivers flow north-south. Often salt accumulation is concentrated in the middle courses of rivers aided by near flat topography and the semi arid climate as in Etah where the Ganga meanders widely and the shape of the right hand terraces as compared to the left is steeper.

In the first terrace i.e. the 'Khader' there is only slight salt accumulation while in the upper or second terrace the 'Bangar' salt accumulation is much greater. Topographically however salt accumulation has also occurred in micro depressions, the formation is closely dependent on the local salt and water movements resulting from the processes of periodic leaching and accumulation. Migrating solutions have sometimes concentrated in depressions and on the slightly elevated areas encircling the depressions.

Old paleochannels and oxbow lakes in Etah being low lying also have excessive salts. The constant wetting and drying cycles have caused them to form even on slightly raised areas. These soils have salt efflorescence above and usually a calcium carbonate layer present in the profile ranging between a depth of 1 to 3 meters.

4.5.2 Calcrete Formation and Processes

Composed dominantly but not exclusively of calcium carbonate and occurring in a state ranging from amorphous to highly indurated to nodular as a result of replacive or displacive introduction of vadose carbonates in the weathering profile these terrestrial materials are referred to by Watts (1977) as calcretes.

Calcrete types have been defined by Netterburg (1969, 1976) and later modified by Goudie(1973, 1983) and Van Zuidam (1975). They describe the 'nodular calcretes' as 'discrete' usually intact, very soft to very hard concentrations of carbonate cemented soil usually in a loose calcareous soil matrix. The nodule size may increase towards the top of the profile and the opposite happens too. Although the upward formation is restricted by the hard pan.

The glabules (Brewer and Sleeman, 1963) could be internally structureless or concentric concretions with a highly variable external morphology and are either small or large and form a layer of considerable geomorphic importance (Lattman 1977)

This occurrence and presence of 'calcrete' deposits over the district and right through the Indo-gangetic plains is caused both by nonpedogenic and pedogenic processes that have formed these duricrusts and the subsequent formation of nodular concretions through the process of authogenesis[1] (Aristarian, 1970).

In effect the non-pedogenic part of the process had been initiated by the Himalayan rivers wherein the fluvial process has involved the carrying and deposition within the channels and valleys (Lattman, 1973 & 1977) or deposition has been carried out by sheet floods in the geologic past (Breazeale and Smith, 1936). This is the non pedogenic process. The pedogenic deposition or 'per ascensum' process is indicative that downward moving soil waters have penetrated to a certain depth in the vadose zone and subsequently returned to the surface zones of these soils by capillary action bringing up solution and reprecipitating as a result of evaporation and other effects.

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1 Authogenesis is the process of chemical reorganisation within sediments when minerals in the sediments react with one another or with the fluid in the pore spaces. Sometimes new minerals may be formed by these reactions by grains of existing materials may be enlarged or otherwise altered. Hydrolysis reduction, hydration and dehydration are among the processes involved.(Encyclopedia Britannica, 1980)

The origin of alkali soils has involved the lateral transportation and redeposition of weathered fragments and their reformation by the in situ processes referred to by Goudie (1983) as the 'detrital model'.

4.5.3 Ion Chemistry of River Water & Influence on Present Salt formation

Slow weathering is an on-going process. In their study of major ion chemistry of the Ganga-Brahmaputra river systems. Sarin et. al. (1981) have studied the major ion composition of the Ganges during the lean period (post-monsoon). The sample data show up a low content of Na, K and Mg in the head water region of the Bhilangana in Tehri and Alaknanda at Bagwan. The Ganga at Varanasi has the highest Na, K and Mg content. The ion composition changes thereafter and lesser amounts are detected in the delta region in Bangladesh. The pH of the waters ranged between 7.2 and 8.4.

The authors further state that the major ion chemistry of the Ganga main channel is controlled by the composition of its tributaries. This is clearly discernible from the downstream variation in the upper and lower portions during lean flow mainly the significant increase in sodium content along the Ganga mainstream between Rishikhesh and Varanasi. Further downstream with the confluence of the highland rivers the sodium content decreases. During the lean period Cl + SO_4 are more significant in the anion balance chloride being more enhanced. This increase in sodium chloride and sulphate concentrations along the main channels indicate that during lean flow there is a significant contribution of major ions from soil salts/groundwater. Calcium and magnesium account for about 80% of the cations whereas bicarbonate accounts for 80% to 90% of the anions. The high concentrations of sodium and chloride in the Ganga and Yamuna in lower mid-stream is mainly due to contribution from soil salt.

The close to normal pH of the river waters is indicative that the weathering and translocation is no longer at its peak and has slowed down. In the geological history of Himalayas the young rivers at some point of time may have encountered large deposits of sodium and calcium carbonate that they carried down. The present process is somewhat reversed. More in situ formation of calcium carbonate is taking place through capillary action in salt-affected soils. The run-off from these and ground waters is causing increased amounts of Na, K and Mg to occur midstream within the river.

4.6 Landuse

The extensive alkalinity of these soils in Etah district has led to a comparatively low productivity. Crops are unable to grow. The area for cropping being restricted to available normal soils.

Table 4.17: **Landuse in Etah District.**

Landuse	Area in ha.	% age of total geographical area
Alkali lands	11553	2.5
Land under non-agriculture uses	40855	9.1
Barren land	39299	8.8
Permanent pastures	1058	0.2
Area under trees + bushes	3366	0.8
Current fallow	20267	4.5
Other fallow	28911	6.5
Forest	633	0.1
Net area sown	268668	67.5
Total geographical area	444600	100.0
Net irrigated area	246510	55.4

Satistical Magazine Etah 1986.

The revenue data on landuse show up 9.1% of the total geographical area in Etah is under non-agricultural uses. Barren lands cover 8.8% and alkali lands only 2.5%. Permanent pastures are spread over 23% of the area and .75% of the area is under trees and bushes. Current and other fallow lands cover 4.5 and 6.5% of the district respectively and forest cover is only 14%. (Fig.4.12).

The net sown area in the district is 67.48% of this 55.44% is under irrigation. Alkali lands cover only 2.5% of the district, in sharp contrast to the digital data on band 3 in

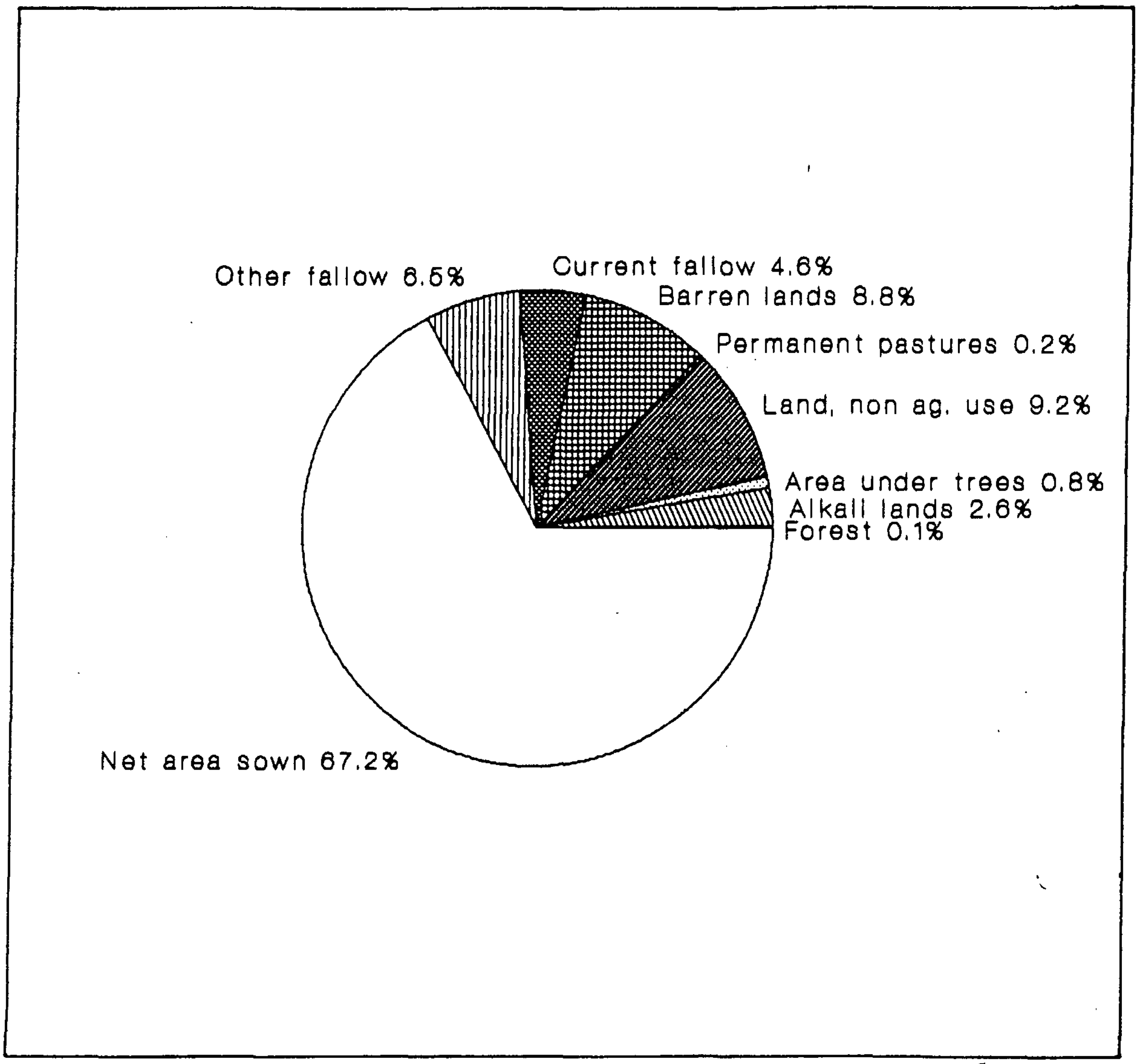


Fig.4.12 Land Use in Etah District

which the extent of alkali lands is close to 42% even if barren and alkali lands are put together the percent area is only 11.3% which is an underestimation of the area under alkali lands. The area last reported by the AIS & LUS (Report No.460, 1979) covering three tahsils was 24.7% under salt-affected soils. Another 6.7% was reported to be under water-logged conditions.

Cropping systems:

Major crops grown in Kharif in Etah are rice, maize, bajra and jowar. Other crops grown are urd, moong, sugarcane, cotton, til and groundnut.

In rabi the crops grown are wheat, barely, gram peas. masoor, arhar, tobacco, potato and other crops. Wheat emerges as the 1st ranking crop. Six blocks have 36% to 40% of their area under wheat. Five blocks have 31% to 35% area under wheat while four had only 25% to 30% area under wheat (Fig 4.13). Rice and bajra are second ranking crops (Fig 4.14). The major rice/bajra growing area lies to the south of the district . This is also the region with major alkalinity where other crops as maize cannot grow because of the extent and presence of salts. Cropping intensity is highest in Kasganj, above 200%. The region is free of alkali soils, Marhara and Sitalpur have a cropping intensity between 180% to 200% despite alkali soils. The lowest cropping intensity is found in the low wheat/bajra/maize growing areas east of the district (Fig 4.15).

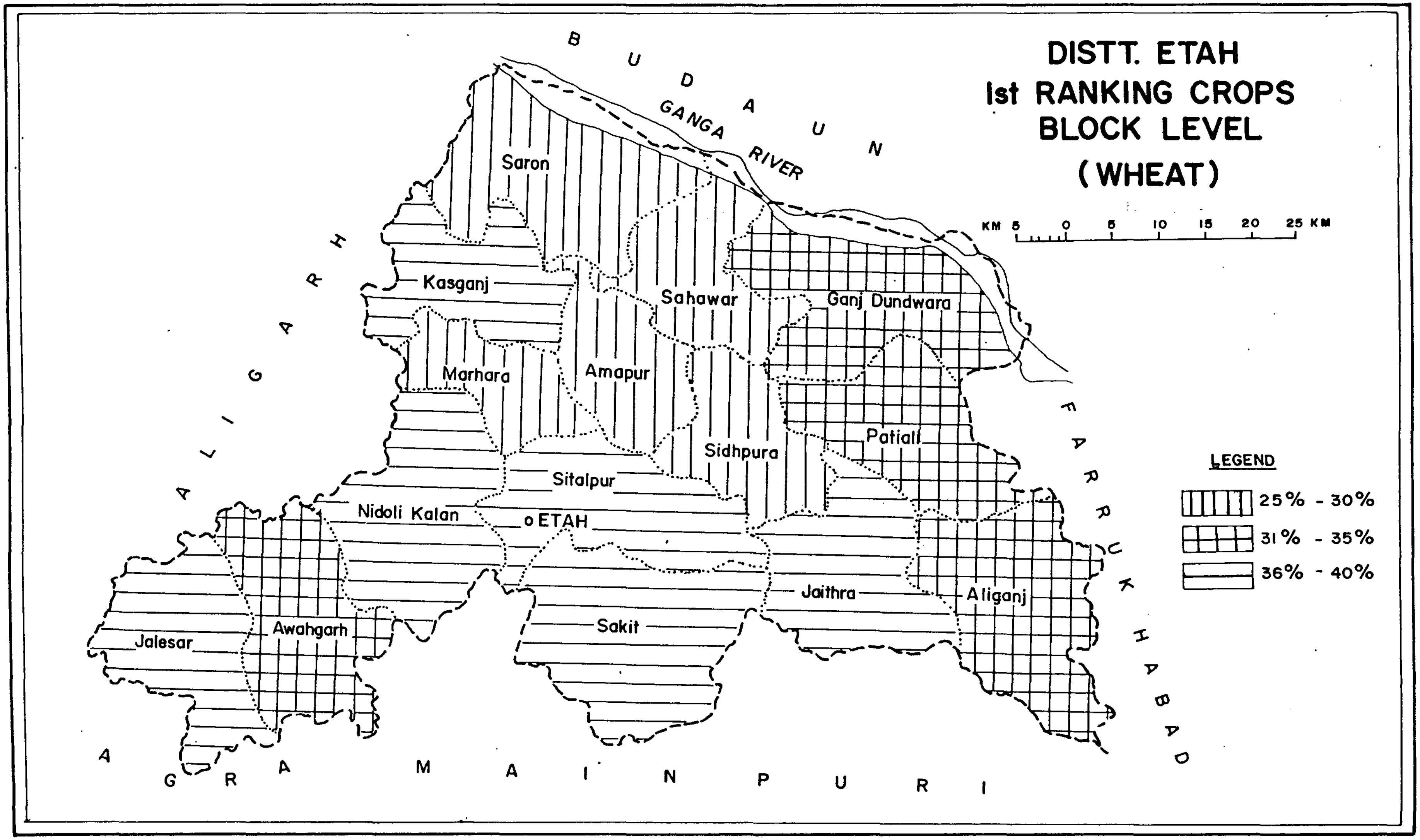
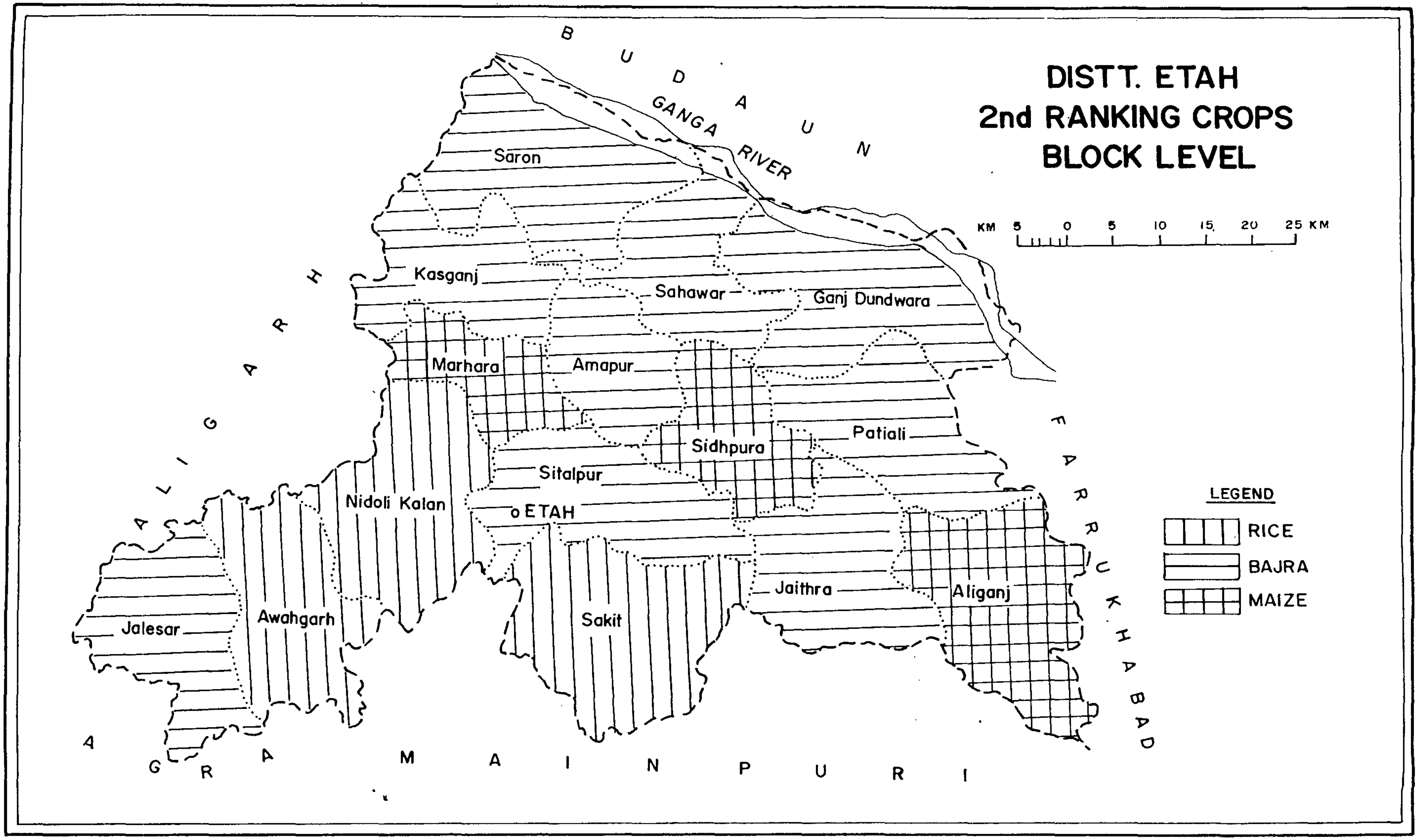
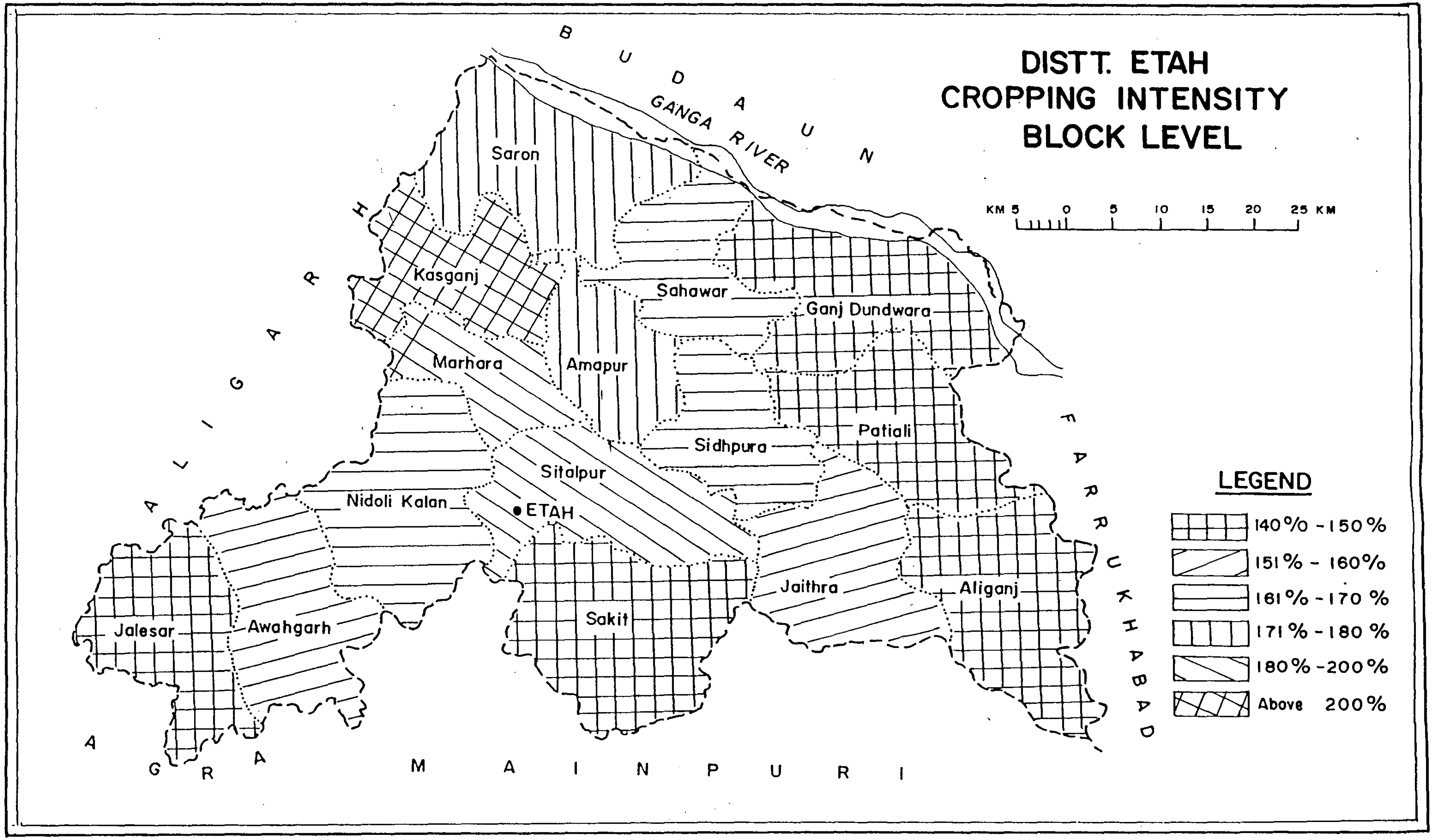

DISTT. ETAH
Ist RANKING CROPS
BLOCK LEVEL
(WHEAT)
KM 5 0 5 10 15 20 25 KM
LEGEND
25% - 30%
31% - 35%
36% - 40%
BUDAUN
GANGA RIVER
ALIGARH
FARRUKHABAD
AGRA
MAINPURI
Saron
Kasganj
Sahawar
Ganj Dundwara
Marhara
Amapur
Patiali
Sidhpura
Sitalpur
Nidoli Kalan
ETAH
Jaithra
Aliganj
Awahgarh
Jalesar
Sakit

Fig. 4·13



DISTT. ETAH
2nd RANKING CROPS
BLOCK LEVEL
KM 5 0 5 10 15 20 25 KM
BUDAUN
GANGA RIVER
ALIGARH
AGRA
MAINPURI
FARRUKHABAD
Saron
Kasganj
Sahawar
Ganj Dundwara
Marhara
Amapur
Sidhpura
Patiali
Sitalpur
Nidoli Kalan
o ETAH
Jalesar
Awahgarh
Sakit
Jaithra
Aliganj
LEGEND
RICE
BAJRA
MAIZE

Fig. 4·14



DISTT. ETAH
CROPPING INTENSITY
BLOCK LEVEL
KM 5 0 5 10 15 20 25 KM
BUDAUN
GANGA RIVER
ALIGARH
FARRUKHABAD
AGRA
MAINPURI
Saron
Kasganj
Sahawar
Ganj Dundwara
Marhara
Amapur
Patiali
Sidhpura
Sitalpur
Nidoli Kalan
ETAH
Jaithra
Aliganj
Sakit
Jalesar
Awahgarh
LEGEND
140% - 150%
151% - 160%
161% - 170%
171% - 180%
180% - 200%
Above 200%

Fig.4·15

The following crop rotations are followed:

Maize-wheat	1 year
Fallow-wheat	1 year
Bajra-gram or pea	1 year
Jowar-arhar	1 year mixed crop
Maize-wheat	1 year
Moong-wheat	1 year
Paddy-wheat	1 year
Sugarcane-ratoon	2 year

The farmers are familiar with the practice of green manuring wherein dhaincha (Sesbania), sanai, moong, etc. are used for the purpose. The use of fertilizers is common.

55.44% of the total district is irrigated. The major irrigation being provided by tubewells and canals. Despite the wide canal network in the region 62.71% of the total irrigated area is irrigated by tubewells and 24.67% of the area is irrigated by canals. Irrigation intensity is highest in Sitalpur which has a high cropping intensity and is a major wheat, bajra growing area. Ganj Dundwara is the block with the lowest cropping intensity and the lowest area under irrigation (Fig. 4.16).

A correlation between cropping intensity and irrigation intensity shows up an r^2 value of .64. 98.9% of the total area under wheat is irrigated. 42.05% of the rice area and 4.6% of the area under Bajra are irrigated.

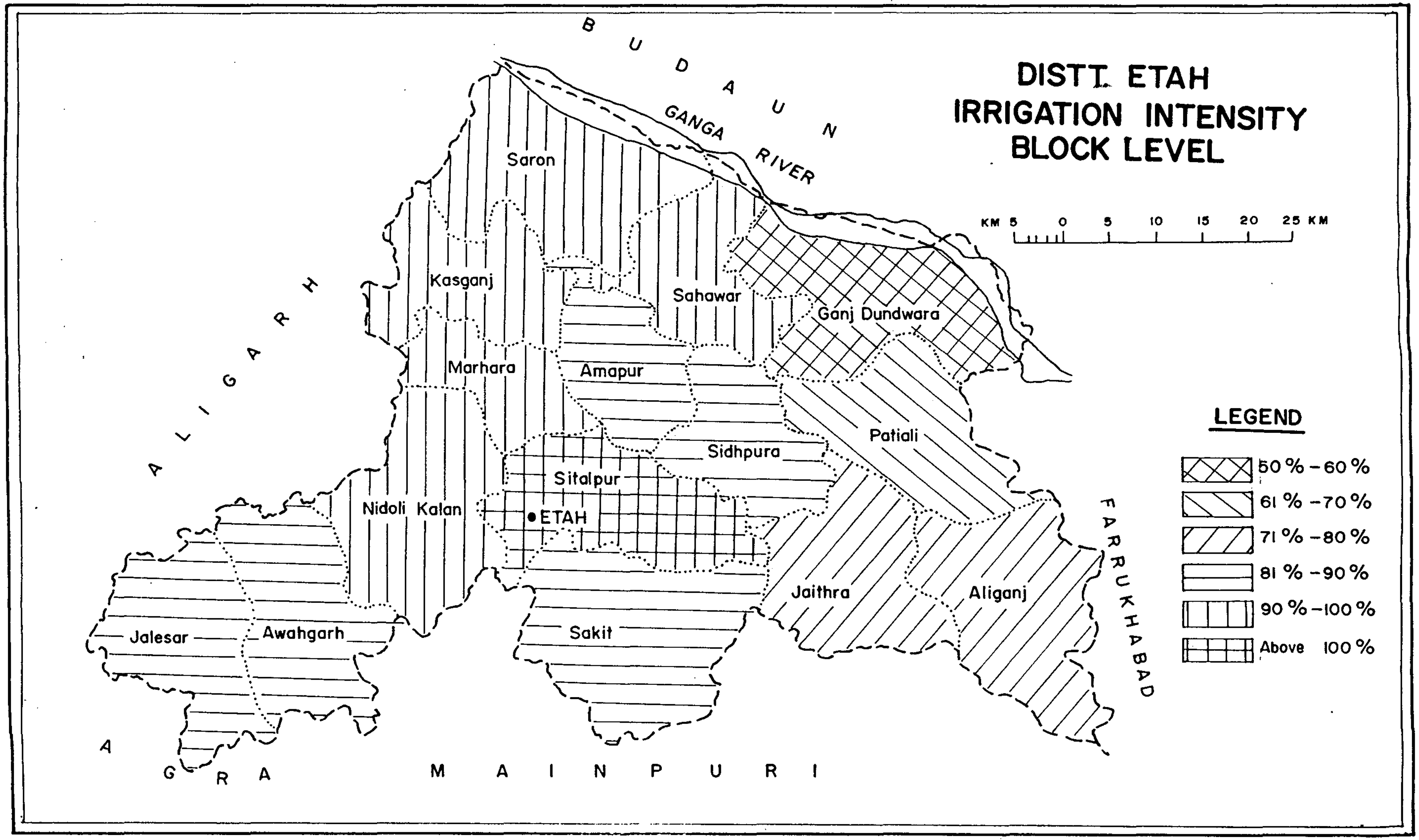

DISTT. ETAH
IRRIGATION INTENSITY
BLOCK LEVEL
KM 5 0 5 10 15 20 25 KM
B U D A U N
GANGA RIVER
A L I G A R H
A G R A
M A I N P U R I
F A R R U K H A B A D
Saron
Kasganj
Sahawar
Ganj Dundwara
Marhara
Amapur
Patiali
Sidhpura
Sitalpur
Nidoli Kalan
ETAH
Jaithra
Aliganj
Jalesar
Awahgarh
Sakit
LEGEND
50 % - 60 %
61 % - 70 %
71 % - 80 %
81 % - 90 %
90 % - 100 %
Above 100 %

Fig. 4·16

or improves the structure and tillage of the soil. To prevent puddling and to improve permeability, organic material application is necessary and the soils should not be worked on when wet. In irrigated areas part of these soils have limited use because of a high water, table, slow permeability and the hazard of salt accumulation. Each distinctive kind of soil in class IIII or IV has one or more alternative combinations of use and practices required for safe use but practical alternatives available to average farmers are less than those for soils in category I and II.

Within the classification system the severely affected salt-affected soils are class IV lands. These lands have very severe limitations that restrict the choice of plants and require very careful management or both. The restrictions in use for soils in class IV are greater than for those in class III. Located mainly in the old flood plain (Bangar) the texture of these soils ranges from sandy clay to clay. The pH range indicating severe alkalinity, is very high between 9.8 and 10.7. The soils are poorly drained and are often water logged. The surface run-off is high and turbid because of the clay and has a high EC and pH. The soils are very difficult to cultivate. Although high in phosphorus and potassium the organic carbon is very low resulting in poor overall fertility. Presently covered by some salt tolerant grasses the soils are barren and have limitations of a 'Kanker' layer between 1 m to 3 m. They are conditionally suitable (Class IV SC_s with application of amendments they can be reclaimed for cropping.

The salt-affected category II and III can be classified in land capability/suitability class III. Occurring in the old flood plain and the recent flood plain. The texture varies between sandy loam, loamy clay, loam to clay. The moderately affected alkali soils have a pH range of 8.4 to 8.9 and 9.2 to 9.8 respectively. They are imperfectly to ill drained. The surface run-off is moderate to high and low in organic matter and the water are turbid moderately alkaline to non-saline with medium to very high P and K. The low organic matter content being mainly responsible for their poor fertility. They are difficult to moderately difficult to cultivate, have salt tolerante grasses growing and a poor crop cover in the moderately alkali areas. The soils require major amendments as nitrogen, Zinc application for reclamation and should be cropped with salt tolerant crops. Improved agronomic practices would go a long way in increasing their productively which is extremely low. Presently these lands are almost unfit for cropping and are conditionally suitable class III Sc_s (Table 4.18).

Table 4.18: Charactersitics for Land Evaluation of Alkali Soils in Etah District

A.

Physiography (M & R)	Geomorphic unit (R)	Texture (DL)	Alkalinity pH Range (DL)	Drainage Class (OF)
1. Old flood plain Recent flood plain	2 and 3	Sacl, clay loamy clay	High 9.9-10.7	ill drained
2. Old flood plain	3	Sicl,Sacl, clay	Mod 9.2-9.8 High	ill drained
3. Old flood plain	3	loam to cl	Mod 8.2-8.9	Fairly ill drained

Run off	Soil fertility (DOF)	Climate Type	Ease of cultivation (DOF)	Land cover (DOF)
1. High run off Highly turbid High EC, High pH	very poor N High P, High K	Semi arid	Very difficult	Tolerant grasses
2. High run off Moderately turbid Alkaline	Very poor N High to Moderately High P, High K	Semi arid	Very to moderately difficult	Tolerant grasses
3. Mod to low runoff slightly turbid Non saline	Poor N Moderate P, High K	Semi arid	Moderately difficult	Tolerant grasses poor crop cover

B.

Input	Crop yeild	Salt affected Category	Capability (FAO)
1. Nitrogen + Zinc Fertilizers gypsum pyrite	Nil	I (Severe)	IV se
2. Nitrogen Zinc Fertilizers gypsum/pyrite	Nil	II (Severe to Mod)	III se
3. Nitrogen zinc fertilizers	Poor	III Mod	III se

c.

Management needed (for all three classes)	Suitability Class (FAO)
a) Reclamation	SC_s
b) Surface drainage	SC_s
c) Salt tolerant crops	SC_s
d) Improved agronomic practices	

METHOD OF ASSESSMENT

M	-	Maps
R	-	Remote sensing
DL	-	Direct Measurement in Laboratory
DOF	-	Direct Observation in Field

Sacl - Sandy clay
Sicl - Silty clay
cl - clay

The input needed to reclaim these soils is much less than that needed for reclamation and management of class IV lands. The water table at some places is as high as 3 feet and at others 40 to 60 feet in depth. The soil hydraulic conductivity is extremely poor. The suitability of these crops for agriculture is conditional and dependent on major inputs.

In both land capability classes the workability of the soils is a major limitation. Major amendments are needed in terms of gypsum application along with nitrogen fertilizer and zinc. Surface drainage is necessary to reclaim the soils. A package of management practices such as growing salt tolerant crops and trees that can stand salt stress are essential along with improved agronomic practices.

4.8 Socio-Economic Factors Influencing Reclamation

The limitations imposed on land by the natural environment determine its capability, suitability development. This is turn affects the productivity. A resource inventory is an essential pre-requisite for estimating monetary inputs and assessing gains accruing thus.

Technology for reclamation of alkali soils is already available and includes land grading, bunding, assured irrigation, soil test based application of amendments and fertilizers, planting of suitable varieties of rice and wheat, careful water and agronomic practices. If judiciously applied, this technology can help increase yields that are comparable to normal soils.

Joshi (1985), and Joshi and Singh (1990) have reported that 3.34 lakh ha of alkali land have been reclaimed by 1987-88. They further state that the investment on reclamation is determined by the soil type, pH of the soil, prevailing wages of labour, prices of input and amendments and subsidy policies of the government.

The major investment at first is on the amendment itself. In subsequent years the need ceases. Mainly gypsum in Punjab and Haryana and iron pyrites in Uttar Pradesh are effective in reclaiming these soils. The amount of application is dependent on the severity and is estimated in the laboratory. On an average 12-15 t/ha of gypsum is needed in a highly degraded soils and including application would cost Rs. 5,380 per ha.

In order to encourage the farmers to reclaim soils the government gives subsidises. The cost of amendment and its application to beneficiaries have been worked out by Joshi and Singh (1990) at Rs. 1,780 per ha with additional cost of Rs.260 per ha for irrigation with good quality waters. Based on these estimates, the cost of land leveling, bunding, leaching and amendment is about Rs. 7,660 per has without any subsidy and Rs. 4.060 per ha with 75 percent subsidy on the amendment. An additional investment of Rs. 13,000 for sinking a tubewell is required (including boring and purchase of a pump set).

The overhead expenditure may be excessive for the poor and marginal farmer resulting in land lying unreclaimed. The lands are either with the Panchayat and have been divided into Pattas and given to the landless who in any case do not have the means to reclaim these lands unless the total infrastructure and total subsidy is provided. There are lands gifted as Pattas in Etah which have remained as such for years.

The land holdings are extremely small and fragmented and if inherited the subdivisions are many. Also the scattered nature of these lands hinders the availability of assured irrigation and restricts the use of technology to overcome these constraints. Joshi et al (1991) emphasize the importance of demonstrations and creation of infrastructure.

Technology developed at CSSRI includes the following:

1. on farm development
2. creation of an irrigation infrastructure
3. amendment application
4. high yielding suitable crops of rice and wheat.

If applied the benefits to the farmers will increase and so will the credit worthiness of the land Joshi et al.(1985) have calculated the returns from reclamation of Alkali soils (Table 4.19).

Table:4.19 Returns from reclamation of Alkali soils

Level of subsidy on gypsum	Benefit cost ratio	Net present worth(Rs./ha)	Pay back period (year)
50 percent	1.15	3293	2-1/2*
75 percent	1.20	4403	2

* Value of net returns obtain in 3 years of reclamation.

The reclamation and management of alkali soils results in substantial increase in the value of land mainly because of its production potential and income generation. The value of alkali lands after reclamation increases by about Rs.10,000/- per ha. Reclamation of alkali soils generates production and considerable employment opportunities in rural areas (Table 4.20).

Table:4.20 Employment generation due to reclamation of alkali soils.

Item	Estimated demand for human labour (man days/ha)
Labour demand for reclamation	30
Paddy Production	94
Wheat Production	41
Total employment generation in the first year of reclamation	165
Employment generation in the subsequent years	135

After Joshi et al. (1985).

The most important benefit of reclamation however is the increased production of additional foodgrains. Joshi et al. (1985) have estimated that in the first year of reclamation itself a farmer can get nearly 4.5 t/ha of unhusked rice and about 1.5 to 2.0 t/ha of wheat. The yield in subsequent years increases after the third year of reclamation of former can obtain 5 t/ha of unhusked rice and 2.5 to 3.0 t/ha of wheat.

The intangible but important benefit that results from reclamation is the improved quality of the environment. Rainfall is efficiently utilized, reducing runoff and irrigation needs. Improvement in infiltration rate of the soils conserves rain water. The hazard of floods is controlled by reduction in peak runoff during periods of heavy rainfall.

With reclamation Barren salt-affected soils are transformed into improved landscapes that eventually result in improved flora, fauna and micro-climate of the region.

CHAPTER V

SUMMARY AND CONCLUSION

Effective agricultural management requires an accurate knowledge of the nature of problem soils, their location and how widespread the problem is. Traditional methods of survey are too inefficient to be applied in a region where the magnitude of the problem is large. It is necessary to use satellite based data. Initially the approach consists of using land based date in specific cases in conjunction with remotely sensed data. This provides the understanding that is necessary to interpret remotely sensed data for use in a routine manner.

[It is now possible to summarize the information generated during the course of this work] and draw conclusions. [The delineation of salt-affected soils has been described] The ground truth for corroboration with remotely sensed data that was established and used has been summarized. Geomorphology and occurrence of salt-affected soils has been presented. The present evaluation with regard to these soils in terms of agricultural productivity has been reviewed.

5.1 Nature and Extent of Salt - Affected Soils

Salt affected soils are diverse in nature and have diverse morphological, physical, chemical and biological properties, but the common feature is the presence of salts in the soils. Although information about the problems of their utilization have been identified, a detailed inventory on their extent, characteristics and agricultural potential does not exist. In

India where such soils are estimated to spread over 7 million ha. they present an additional source of land for agriculture if reclaimed properly. Alkali soils are deleterious to plant health. They have a pH of more than 8.4, an ESP of more than 15, and the electrical conductivity of the saturation extract is generally less than 4dS/M at 25°C. The presence of sodium carbonate is the main reason for the high ECe.

Uttar Pradesh has the largest area in the country lying waste because of alkaline conditions. Occurring mainly in the semiarid region, the salt-affected soils exist in wide belts or as patches with extremely variable alkaline conditions, making their estimation difficult.

The District of Etah in Uttar Pradesh covers an area of 444,600 hectares, of which salt-affected soils form an extensive part. These soils have been a serious setback to agriculture in the district. Geologically, Etah forms a part of the western U.P. shelf and sub section Lucknow Bareily shelf and is made up mainly of alluvium, upper Siwaliks, Vindhyan limestones and shales with anhydrite. Physiographically, the district forms a part of the Gangetic plains and has three major units. The old flood plain or the Bangar, the recent flood plain the khader and old channels that are essentially low lying and subject to waterlogging. The Ganga forms the northern boundary of the district. The Burhi Ganga, Isan and Sirsa are the other rivers flowing through. On the IRS-IA image, the three major geomorphic units identified are the active flood plain, recent flood plain and the old flood plain.

5.2 IRS-IA Image Interpretation and Analysis

The present second generation satellites with their improved resolution abilities go a long way in accomplishing the task of identification and characterization for increased agricultural production in salt-affected soils and significantly reduce the effort required for cumbersome survey and provide rapid information flow for speedy analysis.

Both the visual and digital classifications are necessary to the interpretive process that aid in the study of soil materials. All soils have their special identification signatures in the visible and near infrared wavelengths of the EMS that can be distinguished from each other for the study of their delineation.

Spectral response patterns vary due to natural variations, systemic seasonal variations and atmospheric haze, hence time is an important factor for the study of salt - affected soils on remotely sensed images. January to March data were found to be most suitable for the study and appraisal of these soils.

5.2.1 Visual Interpretation

Visual interpretation techniques using shape, size, colour and texture on the false colour composite of LISS-II images were extremely useful in the identification and delineation of salt-affected soils. It was possible to categorize the soils on the basis of the level of severity into severe, severe to moderate and moderate classes. Severely salt-affected lands appeared white in colour emphasizing the barreness of the soils. Severe to moderately affected soils had a white to blue grey colour with a mottled appearance indicating little to no vegetal cover. The moderately salt-affected soils were blue white to grey in colour and mottled with red indicating low crop cover. Areas of slightly salt-affected soils could not be identified on the images.

5.2.2 Digital Analysis

To determine the levels of accuracy of visually interpreted data computer compatible tapes of similar dates of IRS, IA, LISS- 1, (72.5 x 72.5 resolution) were utilized. Using numerical extraction techniques original and enhanced data were examined to test their efficacy for the study of spectral response patterns. It was found that original data gave very poor results but when the images were enhanced through the full range of the electronic display device salt-affected soils could be effectively divided into different classes. Ambiguous classifications vis a vis salt-affected soils could only be removed through the use of an unsupervised classification of fixed cluster analysis along with contrast stretching and histogram slicing using the maximum liklihood and parallelepiped algorithms. It is important that the spectral reflectance of a certain category occurs close together to form classes and that their DN values are similar. Partly supervised classification was conducted by using 3 windows in the C.C.T. Through the process of windowing small sections of the image were extracted for a close scrutiny of DN values and their corroboration on the ground in order to establish value class divisions with pH. The window on "Badhshahpur Loya" was used as the bench mark for the study of DN values of salt-affected soils.

On Band 2 (.52 to .59um), the DN values because of their wider occurrence club together and the fine lines of demarcation are lost. Low salt-affected levels could not be deciphered on the images. On Band 3 (.62 to .68um), the three classes of severe, severe to moderate and moderate were found to be easily distinguishable.

The DN values occur closer together hence the detail is picked up over the complete spectrum. The boundary lines between severe, severe to moderate and moderate become fine and sharp bringing about a clear distinction. However low salt levels were again not identified. A quick field check with a pH meter was done to collate the 'Badhshahpur Loya' Benchmark on the ground. The pH readings were found to collate well with the digital data. On Band 4, only severely salt-affected soils could be demarcated. The Band was however found to be useful in FCC generation.Water bodies and other thematic details such as roads and railways are imaged in greater clarity on band 4 These are essential for providing ground control to the images.

The full images were divided into 5 segments and each individual segment was enhanced, contrast stretched and histogram sliced.

Data set 1 was of North Etah

Data set 2 of Etah

Data set 3 of Aliganj

and Data set 4 of Jalesar

Data set 5 was of Sakit and

Data set 6 covered the region west of the lower Ganga canal.

The spectral value classes for salt-affected soil area demarcation, remained the same as the Benchmark of Badshahpur Loya.

On Band 2 the DN values were

219 - 238	Severe
190 - 218	Severe to moderate
176 - 189	Moderate

On Band 3 the DN values were

214 - 238	Severe
185 - 213	Severe to moderate
156 - 184	Moderate

The overall accuracy level for interpretation in Digital analysis was 88 percent.

On Band 2, severely affected soils covered 62.5 percent of the area. Severe to moderately affected areas covered 12.8

percent and moderately salt-affected soils covered 24.8 percent of the total area under salt-affected soils. 38.14 percent of the total district was found to be affected by salt.

On Band 3 in comparison 42 percent of the total district was found to be under salt-affected soils. Fifty six point six percent was under the severe category, 18.8 percent in the severe to moderate category and 24.6 percent under the moderate category.

In a comparison between the area visually interpreted on LISS-II images and the digital data on LISS-I the latter showed up a 9.8 percent greater area under salt-affected soils. The reason is attributed to the computers capability to decipher greater numbers of grey levels than the human eye.

5.3 Correlation Between Chemical Data and Remotely Sensed Data

DN values of band 3 were used to define and identify different categories of alkali soil based on pH and ESP. 72 samples from different sites were collected for collation 5 samples of which were of normal soils . The DN values of 156-184 indicated moderately salt-affected soils. The pHs of these samples ranged between 8.2 and 8.9 and had an ESP of between 44-58. The Ece ranged between 6.3 to 64.4 dS/m. The soil samples had a predominance of bicarbonate and carbonate ions with low organic carbon. However, Olsen's P and available K were of medium to high levels indicating sufficient quantities of these nutrients. The soils were medium textured with a CEC range of 6.7 - 10.4.

The DN values in the severe to moderate category delineated on Band-3 ranged between 185 - 213. The pHs of the soil samples was between 9.2 and 9.8 with an ESP range between 56-72. The Ece ranged between 10.5 to as high as 113.8 dS/m. The carbonate and bicarbonate content in these soils was much higher in comparison to the moderate category. Organic carbon was much lower in these soils representing very low levels of nitrogen. P is present in larger quantities while available K remains almost the same. The soil textureshows a wide variation but tends to be heavier.

Severely salt-affected soils were in the high DN value range of 214 - 238. The soils had an extremely high pHs ranging between 9.9 to 10.7 indicating extremely high levels of alkalinity. ESP was as high as 90. The Ece ranges of these samples was from 7.0 to as high as 100.05 dS/m. The carbonate content of these soils was high going upto 760 meq/l. Bicarbonates ranged between 5.0 meq/l to 460 meq/l chlorides and sulphate were also present in smaller quantities. Olsen's P and K were available in greater quantities. The soils were comparatively more heavy in texture.

It has been further observed that the CEC and Ece values increase with the increase in the severity of alkalinity. Available K was the maximum in soils of the severe category. This may be due to the heavier texture of the soil. Irrespective of the category there appears to be a very high correlation between pHs and ESP of the soil samples. Also P and K are available in sufficient quantities.

The 'Sakit' benchmark series established by the AIS and LUS is representative for the salt-affected soils in Etah district. Highly sodic they have drainage problems and a ground water rise within 2 meters. This series is a member of the fine sandy loam to clay, mixed hyperthermic family of Typic Natrustalfs.

The results of the chemical analysis and DN values clearly indicate that the degree of alkalinity could be easily described by DN values as obtained from IRS-IA Band 3 data. Ground truth however has an integral role to play in the complete understanding of the categorization of salt-affected salts.

The sodium content of the soils is closely correlated to the spectral signatures, therefore it is only through the use of such data that salt-affected soils can be identified in their entirety. However it would be presumptous to leave the categorization without ground check as other chemical parameters as ESP. CEC, Co_3, HCo_3 cannot be estimated from satellite data.

Once the process of delineation is complete from satellite data ground check in windows is necessary to build up detailed legends for alkali soils.

5.4 Formation and Occurrence

The formation and process that have led to the presence of alkali in the district and over the Gangetic plains is closely related to the geology of the Uttar Pradesh Himalayas. In the three stratigraphical zones are present fosiliferous sediments, granites, quartzites and amphibolities with a highly complex character containing sodium, calcium feldspars. Sodium is also present along with calcium in carbonaceous sediments. Geological and mineralogical evidence clearly demonstrate that residual hydrothermal solutions from igneous magmatic rocks contained considerable amounts of sodium compounds or sodium ions. The Shali series extending from the salt range in Pakistan to the U.P. Himalayas contribute greatly to the salt content in the plains.

Amongst geologists the opinion is gaining ground that gneiss - granites and granites in the orogenic zones of the earth are really products of Alkali transfer into metamorphosed sediments. The carbonate materials coming from limestone and dolomites.

The weathering of these rocks is the primary source of soluble salts entering natural waters, sediments and soils. The geochemistry of salts is governed by the mobility of compounds formed and the sequence of precipitation of weathering products.

Climate regimes influence the solubility of sodium carbonate and bicarbonates. Low temperatures cause the precipitation of sodium bicarbonate and carbonate at temperatures below 15°C. together with sodium sulphate in soils. Hence in regions of severe winters an accumulation of sulphates and carbonates of alkali occurs. The high soda content in turn influences the presence of calcium carbonate causing it to be virtually eliminated from the soil complex explaining why there is no calcium despite a layer of calcium carbonate below the soil.

The geomorphology of the landscape has also played a governing role in the process of salt formation. Water is the main carrier that has transported the salts to places where they have accumulated, on the left terraces of the river Ganga in contrast to the right which have formed differently and are steeper according to Ber's law.

Much of the salt accumulation is on the second terrace or the Bangar. The presence of salts in the Khader being only marginal. Salt accumulation has occurred in the micro depressions depending on the local salt and water movements. Migrating solutions have sometimes concentrated in depressions as well as slightly elevated areas encircling the depressions. Old paleochannels and oxbow lakes being low lying have salt deposition. Salt efflorescence is present on the surface of the alkali patches and a calcium carbonate kanker layer is present at a depth ranging between 3 meters and 1 meter.

The Kanker deposits occur in an amorphous to highly indurated to nodular forms as result of replacive or displacive introduction of vadose carbonates in the weathering profile and are referred to as clacretes. These are formed by a combination of nonpedogenic and pedogenic processes.

The nonpedogenic part of the process being initiated by the Himalayan rivers which have carried and deposited these materials in the geologic past. The pedogenic processes are presently on going, by which downward moving waters have penetrated in the vadose zone and are subsequently being brought to the surface through capillary action and reprecipitating and forming nodular concretions through the process of authogenesis. The Himalayan rivers are no longer carrying large quantities of salts. Infact the process is somewhat reversed and soil salts and ground waters are contributing to 80 to 90 percent of the anions in river waters.

The presence of large deposits of salts over the district have led to a general low productivity in terms of food grains. Alongside is the underestimation of the extent of alkali lands by the revenue authorities that report only 2.5 percent of the total geographical area under alkali soils. In contrast to 42 percent identified on Band 3 LISS-I, IRS - IA images.

The net sown area in the district was 67.5 percent of which 55.44 percent is under irrigation. Major crops grown in Kharif over the district are rice, maize, bajra and jowar.

Wheat, barley, gram and pea are grown under Rabi. Wheat is the major crop, with rice and Bajra as the other major crops. Cropping intensity was highest in Kasganj which is free of alkalinity, Marhara and Sitalpur also have a high cropping intensity despite the presence of alkali soils as the area is heavily irrigated and is a major wheat growing region. The intensity of irrigation is aiding the process of secondary salt deposition already in presence adding to the affliction.

5.5 Agricultural Evaluation and Limitations

The parameters used to identify and study salt-affected soils for land evaluation and management are brought together to assess the capability and suitability of these lands for increased agricultural output.

The severely affected lands are class IV lands with severe limitations. Because of their high alkalinity these soils are difficult to cultivate and are poorly drained. They are heavy textured with high ECe and pH. Although P and K are in sufficient quantities these soils are very low in organic carbon and have the severe limitation of Kanker deposits in the profile. The soils need heavy inputs in terms of fertilizers, pyrite and require corrective drainage measures to reclaim them.

The severe to moderate and moderate salt-affected soils have limitations which are less than class IV lands. Although poor in fertility they are easier to reclaim because of a lesser

ECe and pH. They are difficult to moderately difficult to cultivate and require inputs of fertilizer, pyrite and corrective drainage. When amended with necessary inputs these lands can yield good crops and be upgraded to class II lands. Presently classes of Alkali soils are conditionally suitable for agriculture.

Technology already exists for the reclamation of Alkali soils and includes land grading, bunding, assured irrigation etc. However the economics of investment on reclamation is determined by the soil type and the pH of the soil, prevailing wages of labour, prices of input, amendments and the subsidy policies of the government. The Major investment at first is on the amendment itself. Based on estimates the cost of land levelling, bunding, leaching and the amendment is about Rs. 7,600 ha without any subsidy and 4,060 per ha with 75 percent subsidy. Even at this level of subsidy the expenditure is excessive for the poor farmer to bear. Even if the land has been gifted to him this monetary input is often impossible. Fragmented land holdings and the scattered nature of the soils further hampers the reclamation processes and restricts the use of technology.

However this can be overcome by using a technology package developed at CSSRI, Karnal which includes on farm development, creation of an irrigation infrastructure, application of amendment, leaching and growing of suitable crops of high yielding rice and wheat.

The reclamation and management of alkali soils results in a substantial increase in the value of land mainly because of income generation. The value increasing by about Rs.10,000 per ha. Reclamation increases employment opportunities. The estimated demand for human labour per ha. in the first year being 165 mandays and 135 mandays in subsequent years.

The most important benefit occurring from reclamation is the production of additional food grains and the improvement in the quality of the environment.

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