

**Delineation, Characterization and Mapping
of Salt Affected Soils of Sheopur District of
Madhya Pradesh using Remote Sensing
and GIS Techniques**

THESIS

Submitted to the

**JAWAHARLAL NEHRU KRISHI VISHWA VIDYALAYA,
JABALPUR**

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By

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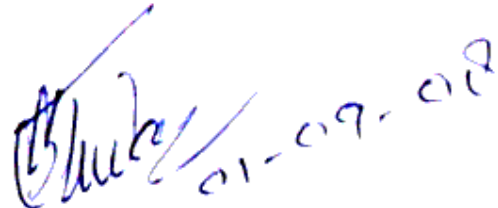
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CERTIFICATE - I

*This is to certify that the thesis entitled “Delineation, Characterization and Mapping of Salt Affected Soils of Sheopur District of Madhya Pradesh using Remote Sensing and GIS Techniques” submitted in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE (Soil Science and Agricultural Chemistry)** of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur is a record of the bonafide research work carried out by Mr. Dharmendra Singh Yadav, I.D. No.AP/IN/-178/02, under my guidance and supervision. The subject of the thesis has been approved by the Student’s Advisory Committee and the Director of Instruction.*

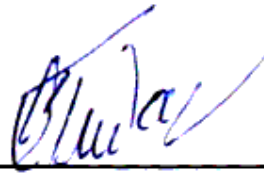
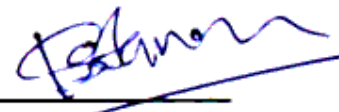
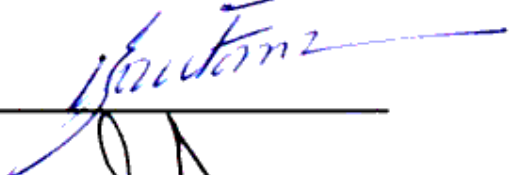

No part of the thesis has been submitted for any other degree or diploma (Certificate awarded etc.) or has been published/ published part has been fully acknowledged. All the assistance and help received during the course of the investigations has been acknowledged by him.


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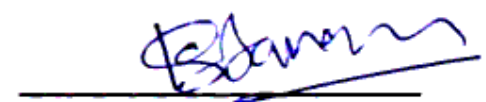
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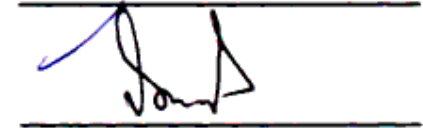
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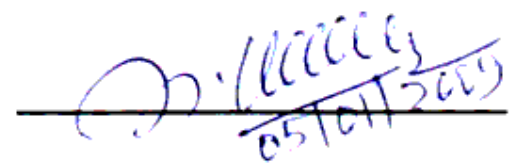
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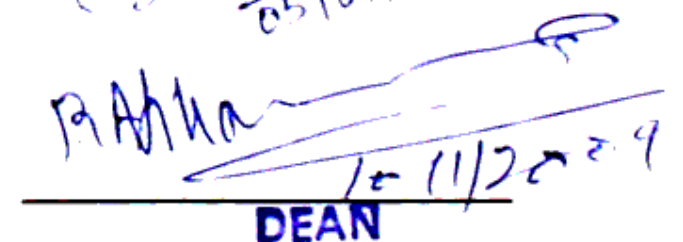
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(Dharmendra Singh Yadav)

ABBREVIATION

S.NO.	Legends	Description
1	C.D.	Critical difference
2	Ca	Calcium
3	CEC	Cation exchange capacity
4	cm	Centimeter
5	d.f.	Degree of freedom
6	dSm ⁻¹	Desi siemen per meter
7	EC	Electrical conductivity
8	ESP	Exchangeable sodium percentage
9	<i>et al.</i>	Alied (and other)
10	g	Gram
11	i.e.(viz.)	That is (in reference to)
12	K	Potassium
13	Kg	Kilogram
14	l	Liter
15	m	Meter
16	m.e.	Milli equivalent
17	Mg	Magnesium
18	mgkg ⁻¹	Milligram per kilogram
19	mm	Millimeter
20	N	Nitrogen
21	Na	Sodium
22	NS	Non significant
23	P	Phosphorus
24	S	Sulphur
25	%	Percent
26	**	significant

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CHAPTER – I

INTRODUCTION

CHAPTER – I

INTRODUCTION

Soil is the one of most important fundamental components of the terrestrial ecosystem. It is recognized as one of the most valuable life supporting natural resources on whose proper use depends the supply of food, fibre and wood etc.

Soil degradation is one of the main problems of many countries faced by them. Soil Salinization/ alkalization is one of the most serious forms of land degradation affecting approximately 10% of the total land surface of the globe. The problem occurs in varying intensities in more than 120 countries, extending to all the continents. The salt affected soils are more prominently witnessed in the arid and semi-arid areas, though many coastal areas in the humid climate are also affected due to the ingress of seawater.

The process of salinization of soils is inextricably woven with the terrestrial hydrological cycles. For the formation of salt affected soils, there must be movement of water to transport and redistribute soluble salts in the landscape. The process is enhanced in the irrigated regions of arid and semi-arid tracts through rise of water table and reckless use & ill management of irrigation water. Salt affected soils are occurring in un-irrigated regions originate through natural geologic processes with topographical situation of the landscape and impeded drainage. Salt affected soils present diverse problems and differ largely from normal soils in respect of morphological features, physical and chemical characteristics. They show wide variations from place to place and have been distinguished into several categories, the important ones being the saline and the sodic soils. Systematic studies on the characterization and classification of salt affected soils is of prime importance before undertaking any reclamation measures.

Soil salinization initially results in loss of soil productivity, but with increase in salinity, it leads to mortality of all vegetation, causing barrenness of soils, loss of habitat coupled with reduced biodiversity. Presence of salts

results in alterations of physical, chemical, mineralogical and biological properties of soils.

Out of an estimated area of 173.64 M ha of total degraded land in India, approximately 7 M ha are affected by soil salinity/ sodicity, though some workers have put this figure as high as 26.1 M ha (Yadav, 1986). The area under salt affected soils was estimated to be 7 M ha by Abrol and Bhumbra (1971). However, during the last decade several agencies have given divergent estimates of extent of salt affected soils. For example, the National Commission on Agriculture, indicated their extent as 7.16 M ha; the National Remote Sensing Agency as 3.9 M ha; the National Wasteland Development Board as 1.5 M ha; the National Bureau of Soil Survey and Land Use Planning as 6.02 M ha, whereas, Singh (1992), estimated the extent of these soils as 9.8 Mha. The data from various sources were critically evaluated at Central Soil Salinity Research Institute, Karnal (1996), and figure has now been updated to 7.4 M ha.

An area of more than 2.42 lakh ha is estimated to exist in Madhya Pradesh out of which about 2.0 lakh ha is in Chambal command area of the state. Salt-affected soils have their aerial extent in 23 districts spread over two physiographic landscapes i.e. black soil region and the alluvial soils of the Chambal. High water table in irrigation commands like Chambal, Tawa and Barna has been encountered inflicting a wide spread secondary salinisation (Tyagi and Minhas, 1998).

Reliable database on the extent of soils affected with salinity is important for devising meaningful strategies for their reclamation. It is hoped that in addition to precise estimates of the affected areas, the prediction of areas potentially prone to salinization and water logging will be possible accurately and rapidly with the use of tools like remote sensing. Therefore the present study “**Delineation, Characterization and Mapping of Salt Affected Soils of Sheopur District of Madhya Pradesh using Remote Sensing and GIS Techniques**” was undertaken with the following objectives:

1. Determination of Physico-chemical properties of the salt affected soils of Sheopur district.

2. To find out the nature and extent of saline and alkali soils of Sheopur district.
3. Use of satellite data in identification of saline and alkali soil and their extent.
4. Preparation of maps showing the magnitude of salinity/sodicity using Remote Sensing and GIS Techniques.

CHAPTER – II

REVIEW OF LITERATURE

CHAPTER – II

REVIEW OF LITERATURE

This chapter basically deals with the findings of the research work conducted in India and abroad related to the formation, delineation, characterization and mapping of salt affected soils in India and Abroad. The literature pertaining to the present study “**Delineation, Characterization and Mapping of Salt Affected Soils of Sheopur District of Madhya Pradesh using Remote Sensing and GIS Techniques**” is reviewed under the following heads:

- 2.1 Formation of salt affected soils
- 2.2 Extent of salt affected soils
- 2.3 Morphological characteristics
- 2.4 Physico-chemical properties
- 2.5 Image Processing/ mapping
- 2.6 Micronutrients status

2.1. Formation of salt affected soils

Salinization, alkalinization, desalinization, degradation and regradation are the stages to the formation of salt affected soils considered by De Sigmond (1932).

Desai and Sen (1953) and Agarwal and Yadav (1954) postulated that the weathering of the crystalline rocks forming the continents is considered to be the main source of the easily soluble salts in soil. Constant weathering of alumino-silicate minerals in drainage basins produces a steady supply of alkali bicarbonates and carbonates. These migrate with the sub terranean and surface waters and accumulate in un-drained areas having arid climatic conditions to form alkaline soils.

Richards (1954) mentioned weathering of primary minerals as a source of soluble salts. Saline soil occurs mostly near the coastal areas where water

act as a carrier of salts. Water also acts as source of salts when used for irrigation.

Agarwal *et al.* (1957) reported that salinity and alkalinity problems have taken place in several countries on consequent to the introduction of canal irrigation. The occurrence of salt affected soils in Uttar Pradesh is reported from very ancient times. The adverse effect of canal irrigation on development of soil salinity and reduction of crop productivity was brought to the notice of the Government as early as 1876 by an indigo planter, Mr. David Roberts, who had applied to the Board of revenue for relief. This led to the constitution of Reh Committee in 1877 to investigate into the causes of development of soil salinity.

Kovda (1961) mentioned that continental, marine, delta, artesian and anthropogenic cycles are responsible for salt accumulation in the soil.

Stace *et al.* (1968) following the classical ideas of Gedrviz viewed the solonchak, solonetz and soloth or salad as idealized stages in a sequence of genesis involving salt accumulation (Solonchak), followed by progressive leaching of salts, deflocculation by colloids and downward translocation of clay to form solonetz and finally hydrolysis of sodic clay subsoil, ending with the fully developed soloth.

High residual sodium carbonate (RSC) of underground water which rises to within one metre of the surface during monsoon season is responsible for direct alkalization of the salt affected soils of Punjab (Sharma *et al.*, 1974).

Bhumbla (1977) mentioned alternate wetting and drying as one of the contributory cause for salinity and alkalinity development.

Kaushik and Shukla (1977) observed that parent material, climate, topography, ground water and human influences are the main factors responsible for genesis of salt affected soils.

Abrol and Bhumbla (1978) revealed that in the Indo-Gangetic alluvial plains, sodic soils are dominant in area with a mean annual rainfall ranging from 550 to 900 mm, whereas, saline soils tend to form in areas with annual rainfall of < 550 mm. He also noticed that the formation of sodic soil is accentuated by the introduction of irrigation in the following manner.

- Irrigation with ground water of high sodium content results in the accumulation of sodium salts in subsurface horizon.
- Network of canals, minors and distributaries in an area cause impeded surface drainage resulting in accumulation of products of weathering.
- Rise of ground water table restricts leaching encouraging the processes leading to alkalization of the soil.

Bhargava *et al.* (1981) in a study on the characteristics and genesis of some sodic soils in the Indo-Gangetic alluvial plains of Haryana and Uttar Pradesh observed that sodic soils appeared on the soilscape surface in the *Pleistocene* age. These soils generally occupy micro depressions of about 20 to 30 cm depth. Release of salts in the *Siwalik* zone and the plains through alkali hydrolysis during the weathering of alumino-silicate minerals and their repeated convergence into micro depressions lead to the genesis of sodic soils at the surface, where good quality ground water occur in the sub stream. Weathering of mica present in these soils yields finer constituents of clay which preferentially move downwards in highly deep flocculated form and give rise to an illuvial B horizon.

India has now the second highest total net area under irrigation next to China, accounting for about 25% of the world's irrigation (Joshi and Agnihotri, 1984). However, faulty management of irrigation water has resulted in wide spread occurrence of the twin problem of water logging and soil salinity in several irrigation projects, particularly in the arid and semi arid areas.

Manchanda (1984) attributed the origin of primary salts in parts of North West India mainly to river shifting, tectonics and hydrology of the area considering the specific characteristics like absence of columnar/ prismatic structure and non-saline underground water and presence of low salt content in the present river water. It was further postulated that the old courses of *Sutlej* got interlocked in the levels complex resulting in salt accumulation, while in river *Yamuna* the course the salts were washed down due to flushing and coarse texture of the material.

The incidence of salinity in the high water table area of south west Punjab largely in districts of Faridkot and Ferozpur, where ground waters are

saline, is increasing (Sehgal *et al.*, 1986). It has been observed that during the last decade, groundwater has been rising at the rate of 0.5 to 1.5 m per year.

2.2. Extent of salt affected soils

Pre irrigation survey report of Chambal command area (Tamboli, 1958) established the occurrence of salt affected soils.

These problem soils were encountered in Mehgaon and Gohad Tehsil of Bhind District. and Jora, Sabalgarh, Seopur-kalan tehsil of Morena district (Anonymous, 1974) and comprise nearly 14.5% (40,600 ha) of the cultivable command area (280000 ha) proposed for irrigation. The acreage under salt affected soils is increasing in the Chambal command area of Madhya Pradesh. The water table even in summer in this area is reported to lie in between 0.5 to 1.5 m.

Szaboles (1977) stated that nearly 95.2 million hectares of land is affected by salinity and sodicity in the world, of which 7 million hectares land is affected in India alone (Yadav, 1976).

Dubey and Sharma (1990) delineated 20,330 ha of salt affected area during reconnaissance soil survey of Eastern part of Mehsana district of Gujarat, comprising Kadi, Kalol, Mehsana, Sidhpur and Kheralu talukas. Natrargids followed by Camborthids occupied a major part of the area.

Sidhu *et al.* (1991) mapped the extent of salt affected soils in Punjab using LANDSAT - MSS data and observed a decrease in salt affected soil area of from 0.699 Mha in 1972 to 0.488 Mha in 1984.

Singh (1994) observed an increase of 22% in cultivation due to reclamation within the salt affected soils in Kanpur district of U.P.

Sharma *et al.* (1995) reported that the extent of salt affected soils in Punjab has decreased from 2,32,585 ha in 1988 to 1,52,537 ha in the year 1996. The area of severely salt affected soils has decreased from 35,697 ha in 1988 to 22,374 ha in the year 1996, and that of moderately to severely salt affected soils from 1,44,868 ha in 1988 to 38,355 ha in 1996. However, the area of slightly to moderately salt affected soils has increased from 51,783 ha

to 91,828 ha because some area of other two categories after reclamation has come under this category.

Padole *et al.* (2000) observed that about 0.54 Mha out of 30 Mha reported to be salt affected is in Purna valley of Maharashtra. The soils of the area are mainly developed in the alluvium of weathered basalt under the active influence of climate and topography.

Saxena *et al.* (2000) reported that nearly 3.42 Mha of land is affected by the problems of salinity and sodicity, whereas 4.81 Mha area reported to have water logging problem in the Indo-Gangetic alluvial plain.

Moharana and Singh (2001) observed that there are evidences of land degradation which have occurred due to environmental hazards caused by natural as well as human (biotic) interferences, during a study carried out in 697.1 sq km area in Balotra-Pachpadra region of Western Rajasthan. The morphological characteristics of the landforms in this area indicate complex process in the development of salt affected soils. In the north of Pachpadra, surface features indicate long-term effect of natural hazards like wind & water erosion and salinity but in the south near Balotra area, the degradation process is indicative of man's role in the form of waste water disposal by textile industries. Such inter-play of both these factors has affected the natural resources like land, water and the soil. Based on the synoptic image (satellite data) and the ground truth analysis, the degraded landforms identified are hills, pediments, alluvial plains, flood plains, saline depressions, buried stream courses and the river bed. Soil investigations comprising of their physico-chemical characteristics indicate the dominance of natural salinity (sodium-chloride-sulphate type) and the prevalence of blown sand activity in the north but in the south the salinity/ alkalinity situation has been aggravated by addition of effluent water in the land. Such situations have changed the quality of land in the region.

Raghuwanshi (2003) reported that nearly 25,127 ha area was affected by the problem of salinity and sodicity in Bhind district of Madhya Pradesh using remote sensing & GIS techniques and the ground truth analysis. These soils were spread over three tehsils viz. Gohad, Mehgaon and Lahar.

Mehrjardi *et al.* (2008) results showed high correlation between ETM+ band 3 and salt concentration expressed by the exponential equation: $y = 0.001e^{0.058x}$ and correlation coefficient $R=0.58$. Thus, applying this equation to Landsat band 3, a soil salinity map was prepared. Ten soil samples for investigation of map accuracy was applied. The obtained soil samples and other more ten soil samples which basically had high similarity in spectral reflectance and geomorphological characteristics were used to examine the produced soil salinity map and to assess its accuracy. According to results the produced soil salinity map had an overall accuracy equal to 87% and Kappa index equal to 47% indicating an acceptable accuracy for this classification.

2.3. Morphological characteristics

The results of a preliminary investigation (Shah and Trivedi, 1954 and Agrawal *et al.*, 1979) on profiles samples collected from Santalpur revealed the sandy nature and presence of a large amount of gravels in these soils.

A typical solonetz profile comprises of a columnar to prismatic or blocky B₁ horizon (Kovda *et al.* 1973) but could not be observed in the salt affected soils of India (Bhargava and Abrol, 1978; Gandhi, 1978; Bhargava *et al.*, 1981 and Vinayak *et al.*, 1981).

Thamasson and Bullock (1975) reported that the pattern of mottling depends upon the drainage condition of the soil. In poorly drained soils, where drying takes place slowly, the precipitation of soluble Fe and Mn may lead to coarse pattern of mottling, whereas rapid precipitation results in lime diffuse mottles.

Bhargava, (1977) stated that fluctuating shallow ground water table is a characteristic feature of many salt affected soils which modifies colour and morphological characteristics. The prominent modification caused by fluctuating ground water table is change in the dominant matrix colour to grey. However, the extent of grey colour development depends on the availability of reducible iron and manganese (Mckeague, 1965 and Baratt, 1983).

Bhargava and Abrol (1978) observed platy structure in the upper few cm followed by sub angular/ angular blocky structure ultimately turning

massive in the calcic horizon usually about one metre deep in the sodic soils of Indo-Gangetic plains. The platy structure is formed due to surface flooding and accumulation of water containing silt and salts in the localized depressions supporting severely salt affected soils. The subsequent evaporation of water leaves a thin crust of salt rich silty material and repeated flooding result in the formation of platy structure (Vinayak *et al.*, 1981).

Sandy loam texture in epipedon and clay loam or clay texture in B horizon of sodic soils of Indo-Gangetic plains. On the other hand, uniform sandy loam or a coarser soils fabric or a sandy loam gradation within the saline profile has also been reported (Bhargava and Abrol, 1978).

Eswaran and Sys (1979) mentioned translocation of clay as the process of formation of argillic horizons. The media for translocation is water and an ample supply is necessary. In the absence of water, as in many orthids, clay is not translocated. There are, however, Aridisols with an argillic horizon-Aargids and the common assumption is that the argillic horizon in these soils is relict. They also suggested that soils with alternating wet and dry conditions have better developed argillic horizons than those, which are continuously wet or dry.

Sharma *et al.* (1979) observed high content of sand at the surface which gradually decreased with depth in flat plains due to translocation of finer particles especially during monsoon period when the soil gets dispersed as a result of beating action of rain drops (Sidhu *et al.*, 1976). Abtahi *et al.* (1979) observed that the distribution of clay with depth is erratic in profiles influenced by ground water and it is only when the soil is no more influenced by saline ground water that a distinct clay bridge appears.

Soil colour forms an important soil physical characteristic. It provides information for soil compositions i.e. mineralogy, organic matter, sesquioxides, soil moisture etc. It is one of the most important characteristics used for horizon differentiation. It is an index for other physical, chemical and biological properties of soils (Buol *et al.*, 1980).

Textural lamellae having more clay than horizons above or below appear in many sandy soils as stated by Torrent *et al.* (1980). These lamellae are considered to have formed by clay translocation (Soil Taxonomy, 1975).

Smeck *et al.* (1981) mentioned that many horizons considered to be Bt horizons in the field had very little illuvial clay as estimated by micro morphological studies despite the fact that many of these horizons have either a marked accumulation of clay relative to the A horizons or have a higher fine to total clay ratio than the C horizons, suggesting clay accumulation. They suggested the following five hypotheses for clay accumulation in B horizons: (i) clay concentration as a result of carbonate leaching from the solum, (ii) clay illuviation, (iii) in situ formation of clay size particles, (iv) disintegration of coarse grained materials, (v) stratification of parent materials.

Manchanda *et al.* (1983) In a micro morphological study of four typical soils of Haryana observed that mere increase in clay and shining ped faces are not enough to qualify for argillic horizon and micro morphological studies are necessary to confirm their presence.

Wilding and Rehasse (1985) noticed that periodic oxidation results in the formation of nodules and mottles of iron and manganese. Accumulation of iron and manganese in the subsoil is either by oxidation and immobilization in the oxidized sub soil and subsequent oxidation during drying cycle (Mitsuchi, 1975). This leads to the formation of nodules as oxygen diffuses rapidly into the ped interiors during drying cycles of the reduced soil.

Kaistha and Gupta (1993) based on reconnaissance soil survey of the subhumid temperate highlands in the Central Himalayas of Himachal Pradesh, two typical pedons were selected for determining their morphological, physico-chemical and mineralogical characteristics. Both the pedons did not show much horizon differentiation. The soils formed on steep slopes over granite/ gneiss parent material, having mixed vegetation (coniferous and deciduous), had ochric intergrading to mollic epipedon. Contrary to this, the soils on mild slopes over similar parent materials and under potato cultivation had mollic epipedon underlain by cambic sub-surface

horizon. The soils have been classified as Mollic Udorthents and Fluventic Hapludolls.

Bhattacharya *et al.* (1994) studied the morphological and analytical characteristics of two representative saline-sodic Vertisols in the humid/subhumid region of coastal plains of Gujarat. An attempt has also been made to classify such soils bringing the important soil characteristics viz., calcareousness, salinity and sodicity at higher category level in the light of recent modification suggested by the International Committee on Management of Vertisols as has been accepted in Soil Taxonomy.

Sidhu *et al.* (1994) and Sawhney *et al.* (1996) reported that the soils of seasonal rivulets and sand dunes/ bars exhibit A-C profiles indicating weak pedogenic development. Textures of these soils vary from sandy to loamy sand and are single grained or weakly developed sub-angular blocky in structure. Consistence varies from loose to firm.

Bhaskar and Nagaraju (1998) studied the pedological characteristics of some salt-affected soils occurring in piedmont slopes and in basin floors of sedimentary rock formations in Chitravati river basin of Andhra Pradesh. The soils of piedmont slopes have brown to light grey matrix with sub angular to angular blocky aggregates in B horizon; whereas soils of basin floors have greyish brown to very dark grey matrix with angular to prismatic structure. The textural change in soils of piedmont slopes shows high degree of variability in vertical distribution of sand and silt contents and yielded high sand/silt ratio. The degree of sodicity in these soils is due to the presence of sodium carbonate and bicarbonate and resulted in high pH conditions. The soils on piedmont slopes were classified as Vertic Ustropepts and Fluventic Ustropepts and soils on basin floors as Sodic Haplusterts.

Raghuwanshi (2003) reported that clear smooth boundary especially in the surface horizon occurs in P3, P4, P7, P8, P9, P10, P11, P12 and P13. In the middle horizons abrupt, irregular boundary was encountered specially in soils having vertic properties. These pedon were P1, P2, P5 and P6. The lower horizons of these pedons had clear, smooth boundary. This was due to development of "Natric" horizon coupled with inversions of these layers.

2.4. Physico-chemical characteristics

The amount of *Kankar* increased with the percentage of sodium carbonate and bicarbonate in soil due to exchange of calcium with sodium resulting in precipitation of calcium carbonate (Kanwar and Sehgal, 1962).

Wilding *et al.* (1963) mentioned that the lime concretions were formed before or during inception of *Natric* horizon. They proposed that CaCO_3 concretions were formed subsequent to the development of the *Natric* horizon due to diffusion of Ca from Ca-rich zones deeper within the profile and diffusion of CO_2 from the atmosphere up to the natric horizon and precipitation as a result of high pH values in the natric horizon.

Karale *et al.* (1969) reported high CEC value for sand and silt fractions of basaltic soils, in a study of soil genesis in relation to parent material and climate.

Dhir and Jain (1982) reported that lime enrichment has taken place in the genesis of calcic layer in soils of arid Rajasthan, which is a part of aggradations process of the late *Pleistocene* plains under a more moist climate than that of present day.

Cation exchange capacity is an important characteristic of the soils and clays (Kapoor and Cheema, 1982). It is well-known that there are two components of CEC, one has been termed as the permanent charge component of the CEC caused by isomorphous substitutions within the silicate lattice, and the other has been referred to as a measure of the pH dependent CEC.

Krishnamurti *et al.* (1982) stated that cation exchange capacity of soil clays varies with pH, and the pH-dependent charge has both an organic and inorganic component.

Gupta (1986) studied the statistical parameters of the alkali soils. The mean values, SD and coefficient of variations for the samples in respect of four groups of samples indicate increased spatial variation in respect of pH in the reclaimed than in the un-reclaimed field. The variation in EC reduced with

reclamation in both the soil depths. The large variation in EC of un-reclaimed fields is probably due to salt movement during many wetting and drying cycles over a period of years.

Sharma and Jha (1989) mentioned that sodicity and high pH resulted in breakdown of minerals and release of silica contents and its redistribution to greater depths on the basis of a comparative study of two salt affected and associated normal cultivated soils.

Bhogal *et al.* (1993) revealed that the deficiency of Zn is widespread in aquic ustifluvents and Udifluvents of Bihar followed by B. Available Zn, Cu, Fe, Mn and B were found to be significantly and negatively correlated with pH and positively with organic carbon. The step-down multiple regression equation indicated that the availability of Zn and Cu was predominantly controlled by both pH and organic carbon, whereas Fe and Mn by pH, organic carbon, available P_2O_5 and K_2O and that of B by pH, organic carbon and EC of the soils.

Sahu and Das (1993) studied four pedons formed on a toposequence in the coastal area of Astaranga block of Puri district. The pedon nearer to the creek and not protected by embankment was highly saline, salt content decreasing downwards with depth with fluvial characteristics, and are classified as Fluvaquents. The pedons away from the creek and protected by embankment are less saline with cambic horizon development and are classified as Haplaquents.

Representative soil profiles having relevance to irrigability from Majalgaon canal command area were studied for their physical and chemical properties (Bharambe *et al.* 1999). The soils were mostly Vertisols with high clay content, available water capacity between 0.21 and 0.27 $m\ m^{-1}$, infiltration rate between 5.0 and 10.0 $\times 10^{-6}\ m\ s^{-1}$ and slow to moderately slow drainability. These soils were neutral to alkaline in reaction, calcareous in nature, with low to medium fertility status of available N, P and K, high cation exchange capacity, dominated by exchangeable Ca followed by Mg, sufficient in DTPA extractable Fe, Mn, Cu and marginal to sufficient in available Zn

content. The data were also discussed with regard to management of these soils for irrigated agriculture.

In the *Haldi Ghati* region of Rajasthan with identical climate and vegetation, land physiographic position induced marked differences in soil properties like soil colour, horizon thickness, calcareousness, texture, soil pH, CEC and exchangeable bases (Sharma *et al.* 1999). Typic Ustorthents (side slopes), Typic Ustochrepts (food slopes, gently sloping plain and nearly level alluvial plain) and Typic Ustifluvents (flood plain) subgroups were identified in the area. Typic Ustochrepts in three physiographic positions indicated major differences in textural distribution.

Gupta *et al.* (2000) studied the morphological, physico-chemical and mineralogical properties of eleven typical salt affected pedons of Jammu district, Jammu and Kashmir State vis-à-vis their genesis and taxonomic classification. The pH values of saturation extract decreased and those of E_{Ce} increased with soil depth. The decrease in pH indicated lack of dispersion and downward movement of Na-clay in lower horizons while increased values of E_{Ce} showed leaching of ions (Cl^- , SO_4^{2-} , HCO_3^- , CO_3^{2-} , Na^+ , Ca^{2+} , Mg^{2+} , K^+) and subsequent deposition in lower horizons. Maximum content of Na^+ followed by Ca^{2+} and Mg^{2+} in all the pedons (except pedons 10 and 11) as attributed to seasonal movement of salts as well as local topographical situations and impeded drainage. In these soils translocation and deposition of clay in subsurface horizons of 5, 6 and 8 pedons evidenced textural B horizon development but did not qualify for an argillic horizon. The pH (8.5 to 9.7) decreased and EC increased with soil depth. The amount of free CaCO_3 ranged from 1.2 to 4.0 per cent, which generally increased with depth. Low (0.011 to 0.056 %) was due to poor and scanty vegetation and rapid oxidation of organic matter owing to high temperature in the study area. Cation exchange capacity varied from 5.3 to 12.8 cmol (p+) kg^{-1} . In surface horizons of pedons 1, 4, 5, 7 and 9 exchangeable Na was dominant, whereas, in subsurface horizons exchangeable Ca^{2+} was predominant throughout the depth whereas exchangeable Ca^{2+} , was found to be dominant in pedons 3, 6, 10 and 11. Exchangeable sodium percentage (ESP) was in the range of 5.8 to 45.9, which mostly declined with depth.

2.5. Image processing

A Reconnaissance soil survey of a part of the Chambal command Bhind district was conducted using the ariel photographs of 1: 50,000 scale and Landsat imagery (FCC) in the scale of 1:2,50,000 (Jadhav and Sharma,1984) for the important land use of the area consider the agro climatic condition topography and the soil problems.

Manchanda (1984) utilized the remote sensing technique in the study of distribution of salt affected soils in North-West India. The LANDSAT - MSS data in conjugation with ground check were used to know the distribution and origin of salts in the area.

Sah *et al.* (1995) carried out a study to develop a methodology to classify the salt-affected soils using remote sensing and GIS. Taking salt crust as a criterion, LANDSAT - TM with bands other than two and six was found effective, to a greater extent, in classifying the extremely and moderately saline area. Integration of GIS was found effective in classifying low and potential saline areas as well as in correcting some of such area misclassified as extremely or moderately. The confirmation of resulted six salinity classes with field check, existing map and soil analysis proved it as reliable one. However, similar pattern of soil salinity was obtained from the study compared to the existing map of 1989 prepared from LANDSAT - MSS at scale 1:250,000, the classification results showed more details. The study concluded that integration of GIS with digital image processing of TM was very effective for classifying and monitoring of saline soils.

Manual methods of soil data handling are slow and inefficient in managing large volumes of information (Nair *et al.*, 1996). Computer based data management overcome some of the difficulties and provide for storage, retrieval and processing of basic data.

Satellite based remote sensing data has emerged as a vital tool in soil survey and generation of information, which helps to evolve the optimum land use plan for sustainable development of an area. A wide spectrum of satellite remote sensing data from LANDSAT, TM, SPOT, IRS-IA, IRS-IB and IRS-IC are now available to the earth resource scientists for preparation of soil and

land users. Mapping of soil through remote sensing data has been attempted by several workers and many other have also reported the utility of the technology for evaluation the land for agricultural land use planning Ahmed *et al.* (2000)

The survey and characterization of salt affected soils of Bhind, Datia, Gwalior and Morena districts of M.P. was done by the AICRP on Management of Salt Affected Soil and Use of Saline Water in Agriculture, J. N. Krishi Vidyalaya, College of Agriculture, Indore using Remote Sensing and GIS Techniques during 2002, 2005, 2006 & 2007 respectively. The area delineated as salt affected soils was 25,127, 9245, 28,613 and 22,592 ha in Bhind, Datia, Gwalior and Morena districts of M.P. respectively (Annonymus, 2002, 2005, 2006 and 2007).

2.6. Micronutrients

Kuhad *et al.*(1986) revealed that DTPA extractable Zn, Cu, Fe and Mn range between 0.29 and 0.94, 1.50 and 2.50, 2.68 and 13.40 and 3.67 and 12.01 ppm, respectively. The highest levels of available Zn, Cu, Fe and Mn were in surface soils. Clay is significantly and positively correlated only with available Cu.

Sakal *et al.* (1988) noticed that four micronutrient cations were found to be wide spread in old alluvial soils of Bihar. Available Zn, Cu, Fe and Mn were significantly and negatively correlated with pH. Available Zn and Cu showed a significant negative correlation with soil salinity.

Singh *et al.* (1988) reported that the mean content of available Zn in all the profile samples was 0.27 ppm, the variation being 0.12 to 0.94 ppm. The amounts of DTPA extractable MN in all the profiles and horizons ranged from 0.66 to 12.0 ppm.

Nipunage *et al.* (1996) observed that the available Fe, Mn, Zn and Cu ranged from 2.9 to 10.1, 4.1 to 46.5, 0.1 to 0.5 and 1.0 to 4.7 mg kg⁻¹, respectively in Inceptisol soil series of Maharashtra. In general these micronutrient cations decreased with depth. The surface and subsurface samples of Inceptisol soil series were sufficient in available Fe, Mn and Cu.

The higher content of these cations in the surface layer may be due to variable intensity of pedogenic processes. The total Fe, Mn, Zn and Cu content ranged from 6.4 to 14.40 per cent, 800 to 2880 ppm, 48 to 240 ppm and 140 to 520 ppm, respectively. Soil pH and EC showed significantly negative correlation with total Mn and available Mn and Zn. Similarly CaCO_3 showed negative correlation with total Mn and Zn and available Fe and Mn

Sharma (1998) reported that available micronutrient status of Bhind district, M.P. Ginochi village recorded highest available micronutrient and sufficiency of DTPA extractable zinc, copper, manganese and iron. Available micronutrient decreased with increase in depth.

Singh (2001) reported that the total stock of micronutrients in most of the Indian soils range between 0.4-27 per cent Fe, 37-11500 mg Mn, 2-1600 mg Zn, 2-960 mg Cu, 3-630 mg B and 0.1-11.6 mg Mo kg^{-1} soil (20, 47, 59,62) but amount of plant usable micronutrient pools is rather low to moderate depending upon soil properties, cropping pattern being followed and environmental conditions (29, 37, 42). Analysis of 2.52 lakhs surface soil samples revealed that DTPA extractable micronutrient cation content in Indian soils ranged between 0.2-6.9 mg Zn kg^{-1} , 0.1-8.2 mg Cu kg^{-1} , 0.8-196 mg Fe kg^{-1} , 0.2-118 mg Mn kg^{-1} soil with a mean of 0.87, 2.1, 19, 21 mg kg^{-1} soil (43, 48, 55). Frequency distribution of 14300 surface soil samples revealed that 24, 23 and 15 per cent soils of Indo-Gangetic alluvial plains had DTPA. Zn 0.2-0.4, 0.4-0.6 and 0.6-0.8 mg kg^{-1} soil, respectively. Mean available zinc content of alluvial soils is about 0.90 mg kg^{-1} soil. Available B, Mo and Co content in soils ranged from 0.08-2.6, 0.07-7.67 and 0.1-5 mg kg^{-1} soil respectively.

CHAPTER – III

MATERIAL AND METHODS

CHAPTER - III

MATERIAL AND METHODS

This chapter deals with the materials and the methods used for the study entitled “**Delineation, Characterization and Mapping of Salt Affected Soils of Sheopur District of Madhya Pradesh using Remote Sensing and GIS Techniques**”. A study was undertaken under All India Coordinated Research Project on Management of Salt Affected Soils and Use of Saline Water in Agriculture, College of Agriculture, Indore, Madhya Pradesh. The details of which are presented in the following manner:

3.1. General description of the area

The Sheopur district is located between 25°16'53.5" N - 26°13'37.1" N latitude and 76°27'49.4" E - 77° 40'21.2" E longitudes. The area is mainly drained by river Chambal and its tributaries from South-West to North-East direction. The district constitutes three tehsils viz. Sheopur, Karahal and Vijaypur (Fig. 3.1).

3.2. Geology

Geologically the region forms part of the Archaean shield of the Deccan Peninsula, which consists of the well – foliated highly, contorted and faulted gneissic basement complex. Since then it has been presumed to be the imprints of all the major geological events in some form or the other though the main formations outcropping in the region are confined only to the Dharwarians (Aravallis) and the Vindhyan, separated by the “Great Boundary Fault”.

The Aravalli system is largely composed of argillaceous deposits, metamorphosed from shales through slates and phyllites to mica schist. On the southeastern fringe of the region, which escaped intense metamorphism, the Gwalior and Bijawars are found probably on a relatively elongated granitic

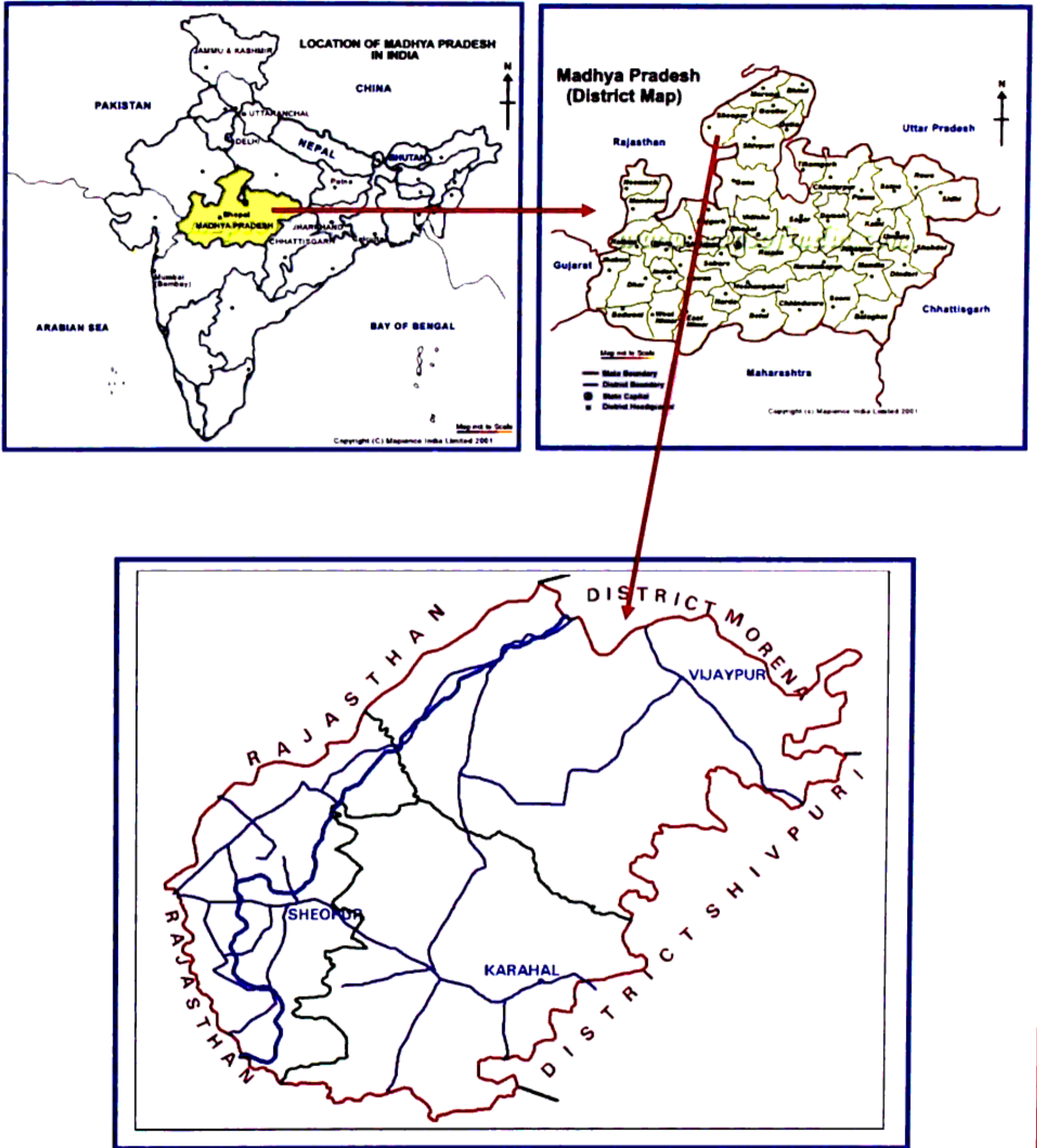


Fig 3.1: Location of Sheopur district of M. P. in India

platform whose "junction with the Bundelkhand granite marks one of the oldest shorelines recognizable in India and is equaled only by that discernible in "Mewar". The *Gwalior series* distinguished into the Lower (*Par series*) and upper (*Morar series*) consists mostly of sandstones, quartzites siliceous limestones and dolomites.

The most typical development of the Vindhyan occurs south of the Chambal in Madhya Bharat area. The junction of the upper Vindhyan with the older rocks of the Aravallis at their north-west extremity reveals an extremely long fault of great throw, which has brought the undisturbed, almost horizontal strata of the Vindhyan sandstone in contact with the highly folded and foliated schists of the Aravallis. The great fault, which has a throw of 1,500 m, is roughly parallel with the course of the Chambal.

3.3. Topography

The area has a varied topography which is the result of its geological history as well as the exogenetic forces that have gone into its making. The denudational chronology of the regional landscape from pre-cambrian to sub-recent period, peneplanation, warping, intrusion and deformation, have produced many relict features which are represented by the outliers of the Aravallis as well as the Vindhyan scarp lands.

The region presents an amalgam of lowland and upland topography. The 150 m contour encloses a small portion at Bhind, Morena and sheopur districts particularly along the river valleys. The dominance of the lowland is highlighted by the 300 m contour, which takes long sweeps including the Chambal-Sindh basin.

3.4. Physiography

Physiographically the area belongs to Northern Plains. The major soil types are deep alluvium derived with medium available water capacity. The Longest growing period ranges between 90 to 120 days. Major crops of the area are millets, wheat, pulses, mustard and maize. The district has a total

geographical area of about 383832 ha. Only 59% area is covered under the gross irrigated area of the reported net sown area (152316 ha.). Canal irrigation is the major source of irrigation which accounts for 42.94% of the total irrigated area.

3.5. Climate and agro-ecology

The area comes under the Agro-Ecological Region 4 characterized by hot semi-arid climate with alluvium derived soils. The average rainfall of Sheopur district is 620 mm per year. The maximum temperature rises up to 49°C in summer while the minimum temperature is recorded 2°C in winter.

3.6. Base maps

1. Geocoded cloud free digital data of RESOURCESAT –1 (LISS III).
2. Topographical sheets from Survey of India, and
3. Published geographical, soil and ground water maps and reports, wasteland maps, meteorological reports and other ancillary information.

3.7. Approach

Digital satellite data were procured from the NRSA, Hyderabad. Visual interpretation of satellite digital data through Remote Sensing Software and collected data like topographical maps and published maps/ reports were used for identification and delineating salt affected soils of the area and subsequently for assessing the magnitude of salinity/ sodicity. Geographical position of the identified points was recorded using RS software and soil samples were also collected from identified points for ground truthing. During the traversing of the area, soil samples were also collected from other locations showing salinity/ alkalinity problem. The geographical position of the sampling points was recorded with the help of GPS. The ERDAS Imagine version 8.7 software was used for analysis and interpretation of digital data. Two pedons were also excavated and examined in the salt affected area and

collected soil samples from different horizons after morphological examination for detailed laboratory analysis. The samples were analysed for salinity/alkalinity parameters as per the methods laid down by Richard (1954). According to salinity and alkalinity hazards, the soils were classified in to 9 categories comprises of 3 levels of salinity viz. salinity {(slight (EC_e 4-8 dS/m), moderate (EC_e 8-15 dS/m) and high ($EC_e >15$ dS/m))} and 3 levels of alkalinity {(Slight (ESP 15-25), Moderate (ESP 25-40) and High, (ESP > 40)). On the basis of degree of salinity and alkalinity, the soils were classified and map of the district was generated using Remote Sensing as well as GIS Techniques.

3.8. Laboratory methods

Collected soil samples were brought to the laboratory, air-dried and ground in a wooden pestle mortar. The ground samples were passed through a 2 mm sieve and stored in polythene bags for further analysis.

3.8.1. Mechanical analysis of soil

Particle size analysis for sand, silt and clay was done by the Bouyoucos Hydrometer method (Bouyoucos, 1927).

3.8.2. Calcium carbonate (alkaline earth carbonate)

Estimation of $CaCO_3$ was done as per the procedure of Piper (1950), which involves the dissolution of carbonates in presence of standard hydrochloric acid and back titration of the excess acid with standard alkali.

3.8.3. Saturation percentage

After preparing the saturated soil paste, a portion of the paste was transferred to a tarred soil can with lid and dried in an oven at $105^\circ C$ for 24 hrs and reweighed to record the saturation percentage.

3.8.4. pH of the saturation paste (pHs)

The pHs was recorded in the saturated paste (Richards, 1954).

3.8.5. Saturation extracts analysis

The saturated soil paste was transferred to a washed filtering flask fitted with a Buchner funnel and filter paper (What man No.40), connected to a vacuum pump. The extraction of the water held at saturation point was completed within 4 to 5 hr. The extract was collected in a double Stoppard polythene bottles for further analysis.

(a) Electrical conductance of the saturation extract (ECe)

The electrical conductance of the saturation extract was determined on electrical conductivity meter. The temperature correction was made on the basis of solution temperature and reported at 25°C (Richards, 1954).

(b) Water soluble cations

The water soluble Ca^{2+} and Mg^{2+} were determined by Versenate titration (using EDTA) and Na^+ and K^+ by flame photometer (Richards, 1954).

(c) Water soluble anions

The carbonates, HCO_3^- and Cl^- in the saturation extract were estimated as per the methods of Richards (1954) and SO_4^{2-} by Versenate titration using EBT as an internal indicator (Jackson, 1967).

(c) Sodium adsorption ration (SAR)

SAR was calculated by taking concentration of Ca^{2+} , Mg^{2+} and Na^+ in soil samples (Richards, 1954)

$$\text{SAR} = \text{Na}^+ / \overline{(\text{Ca}^{2+} + \text{Mg}^{2+})/2}$$

(The values of Ca, Mg and Na are in me L^{-1})

3.8.6. Exchangeable cations

(a) Calcium and Magnesium

The exchangeable Ca^{2+} and Mg^{2+} was determined by displacement with 1N sodium acetate of pH 8.2. The soil sample extracted and leachate was analysed for Ca^{2+} and Mg^{2+} as per the method of Richard (1954). The water soluble Ca^{2+} and Mg^{2+} content was deducted from the obtained value and reported as exchangeable Ca^{2+} and Mg^{2+} .

(b) Sodium and Potassium

Exchangeable Na^+ and K^+ was analysed by extracting the soil with 1N neutral (pH 7.0) ammonium acetate. The leachate was analysed on flame photometer for Na^+ and K^+ (Richards, 1954). The water soluble Na^+ and K^+ was deducted from the obtained value and reported as exchangeable Na^+ and K^+ .

3.8.7. Cation exchange capacity (CEC)

The cation exchange capacity of the soil was determined by the procedure of Bower *et al.* (1952), which makes use of 1N sodium acetate of pH 8.2. All the cations of the exchangeable sites were replaced by saturating the sample with excess sodium followed by washing with ethanol to remove excess amount of sodium from the soil. The sodium held at exchange sites were replaced by washing with 1N neutral (pH 7.0) ammonium acetate. The replaced sodium was determined by flame photometer (Richards, 1954).

3.8.8. Exchangeable Sodium Percentage (ESP)

ESP was calculated by using relationship given by Richards (1954)

$$\text{ESP} = (\text{Exchangeable Na}^+ / \text{CEC}) \times 100$$

(The values of Na and CEC were in $\text{cmol (p}^+) \text{ kg}^{-1}$)

3.8.9. Micronutrients analysis

The micronutrient cations viz. Zn, Cu, Fe and Mn were analysed by the method described by Lindsay and Norvell (1978) using DTPA (Diethylene triamine pentaacetic acid) as extractant from the soils. The content of micronutrients in the extract was measured with an Atomic Absorption Spectrophotometer.

3.10. Analysis of satellite data

Various steps involved in the analysis of satellite data are presented in Figure 3.2. After geometric correction and linear contrast stretch, the image was visually interpreted in individual bands and various band combinations, and by applying filtration, Principal Component Analysis (PCA) and band rationing, supervised classification was employed with maximum likelihood and minimum distance methods including the bands 1, 2, 3 and 4 (Sah *et al.*, 1995).

3.11. Correlation study

The coefficient of correlation was worked out for different parameters as per the method suggested by Panse and Sukhatme (1978).

$$r = \frac{\Sigma xy - (\Sigma x \Sigma y)/N}{\sqrt{[\Sigma x^2 - (\Sigma x)^2/N] \times [\Sigma y^2 - (\Sigma y)^2/N]}}$$

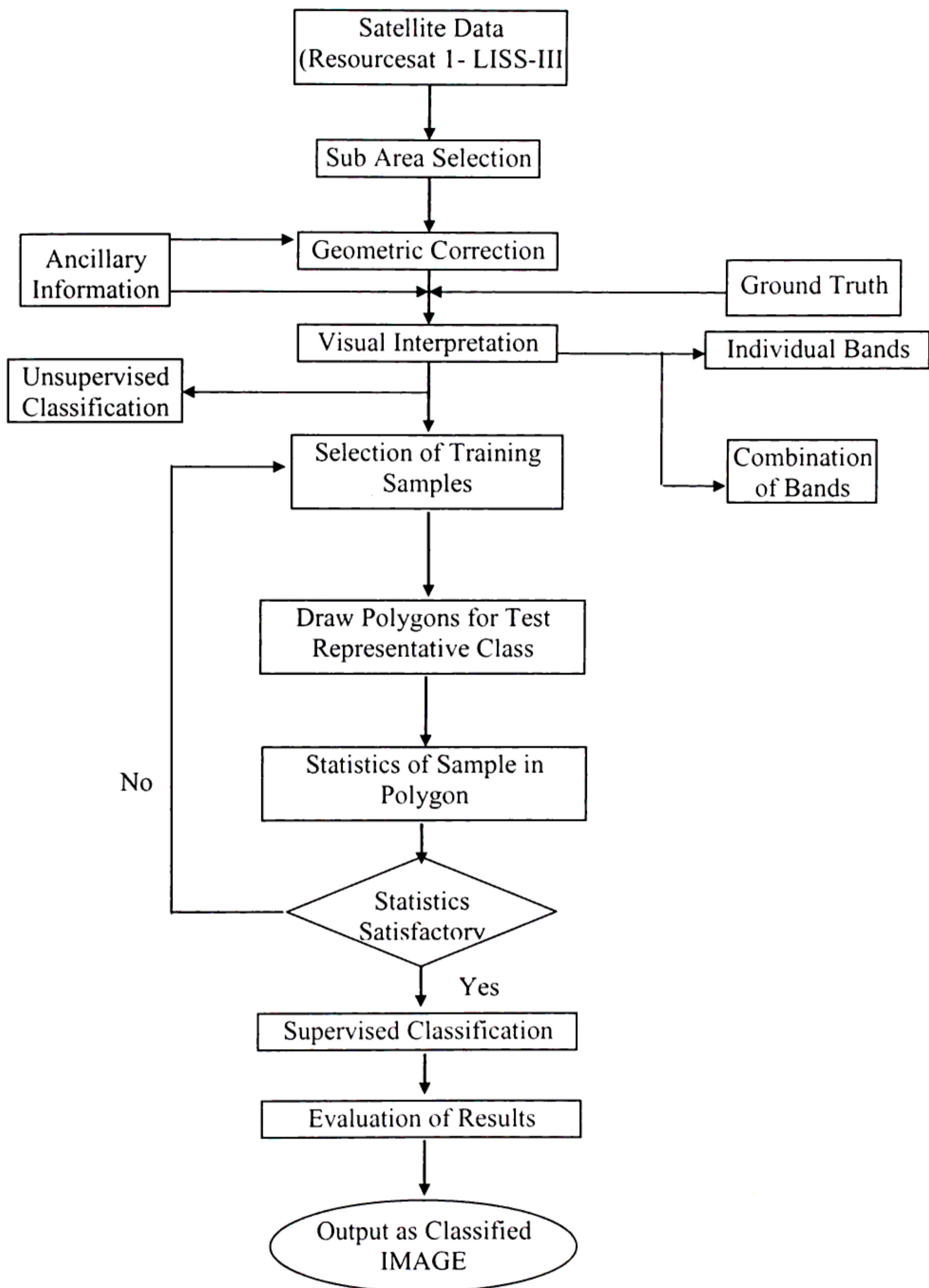


Fig.3.2 Flow Chart Showing Various Steps Involved in Image Classification

CHAPTER – IV

RESULTS

CHAPTER – IV

RESULTS

This chapter deals with the study of results on Sheopur district related to thesis entitled “**Delineation, Characterization and Mapping of Salt Affected Soils of Sheopur District of Madhya Pradesh using Remote Sensing and GIS Techniques**”. The experimental findings are presented here under different headings.

4.1. Physico-chemical properties of surface soils

The salt affected soils are mostly located in Sheopur and Vijaypur tehsils of Sheopur district. Twenty seven soil samples (0-15 cm) were collected during reconnaissance survey of the area. The precise location (Longitude and Latitude) was recorded using Geo-Positioning System. Two soil pedons were excavated and examined in the affected area and soil samples collected from different horizons after morphological examination were used for detailed laboratory analysis.

The data on mechanical composition and particle size distribution of surface soil representing Sheopur and Vijaypur tehsils of Sheopur district were presented in table 4.1.2. The texture of surface soil graded in to loam, silty loam and clay loam. Most of the samples are dominated by silt particles. Out of 27 samples, 19 samples are representing the loam category.

Twenty seven surface soil samples were collected from different villages of Sheopur and Vijaypur tehsils of Sheopur district (Table 4.1.3). Eighteen out of 27 samples were characterized as alkali (Table 4.1.1). The reaction of soil (pHs) in the surface layer is alkaline. pH of the saturation extract ranged from 7.9 to 8.6. Most of the samples depicted higher pHs i.e. > 8.0. The electrical conductivity of saturation extract (EC_e) is an important property to judge the behaviour of soil in respect of salinity/ alkalinity. Nine soil samples of Sheopur district showed $EC > 4 \text{ dSm}^{-1}$ was classified as saline-

alkali. Among different cations, Na was the dominant one in all the soil samples and ranged from 2.2 to 227.7 me L⁻¹. This shows that the soils are saturated with Na followed by Ca and Mg. The SAR values ranged between 1.2 and 59.5 (mmol L⁻¹)^½.

The data pertaining to exchangeable cations, CEC and ESP (Table 4.1.4) revealed that Na was the dominant cation followed by Ca, Mg and K. Exchangeable Ca, Mg and Na ranged from 10.5 to 24.5, 4.5 to 9.5 and 6.5 to 28.1 cmol (p⁺) kg⁻¹ respectively. Cation exchange capacity (CEC) ranged from 23.5 to 48.9 cmol (p⁺) kg⁻¹, whereas, exchangeable sodium percentage (ESP) varied from 19.8 to 61.6 respectively. One samples from Sheopur and twelve samples from Vijaypur tehsils belonged to ESP greater than 50.

Micronutrients status of surface soils

The data pertaining to DTPA extractable micronutrients viz., Fe²⁺, Cu²⁺, Zn²⁺ and Mn²⁺ were depicted in table 4.1.5. The data revealed that the content of Fe²⁺, Cu²⁺, Zn²⁺ and Mn²⁺ ranges between 2.19 - 3.87, 1.79 – 1.92, 0.61 – 2.23 and 1.26 – 31.92 mg kg⁻¹ respectively. The Fe²⁺ content was below the critical limit of 5.0 mg kg⁻¹ in all the samples. The content of Cu and Zn was above the critical limits (Cu – 0.2 and Zn – 0.6 mg kg⁻¹) in all the samples collected from salt affected areas of the district. Manganese content was below the critical level of 2.0 mg kg⁻¹ in only 5 samples, whereas the content of Mn was very high i.e. > 10.0 mg kg⁻¹ in 3 samples belonging to villages Daurad, Hurlpur and Iklod.

Table 4.1.1. Classification of surface soil samples on the basis of chemical analysis collected from Sheopur district of M.P.

S.N.	Village	Location	Crops grown	Irrigation	Texture*	Salinity / Alkalinity
Sheopur tehsil						
01	Pandola	25°31'32.2"N, 76°38'59.4"E	Barseem, Wheat, Mustard	Canal	cl	Alkali
02	Bichhudi Babdi	25°27'49.4"N, 76°36'43.4"E	Wheat, Mustard	Canal	cl	Alkali
03	Badauda	25°28'40.3"N, 76°40'43.5"E	Wheat, Mustard	Canal	l	Alkali
04	Modla	25°31'16.9"N, 76°39'11.2"E	Wheat, Mustard	Canal	l	Saline alkali
05	Modla	25°31'25.7"N, 76°39'02.1"E	Wheat, Mustard	Canal	l	Saline alkali
06	Pandola	25°32'56.9"N, 76°38'52.2"E	Wheat, Tomato, Pea	Canal	sil	Alkali
07	Dhoti	25°40'06.4"N, 76°34'39.6"E	Wheat, Mustard	Canal	l	Saline alkali
Vijaypur tehsil						
08	Bojpaiya	26°06'35.3"N, 77°18'33.4"E	Wheat, Mustard	Canal	l	Saline alkali
09	Mada	26°05'45.6"N, 77°19'00.3"E	Wheat, Mustard	Canal	l	Alkali
10	Khitarpal	26°04'36.0"N, 77°19'32.0"E	Wheat, Mustard	Tube Well	l	Alkali
11	Sunbai	26°05'35.9"N, 77°22'43.4"E	Garlic, Gram, Wheat, Mustard	Tube Well	l	Alkali
12	Andhpur	26°05'43.4"N, 77°22'47.8"E	Wheat, Mustard	Tube Well	l	Alkali
13	Daurad	26°06'15.6"N, 77°23'26.6"E	Wheat, Mustard	Tube Well	l	Alkali
14	Daurad	26°06'20.1"N, 77°23'31.0"E	Wheat, Mustard	Tube Well	l	Saline alkali
15	Barakala	26°07'16.6"N, 77°24'00.5"E	Wheat, Gram	Tube Well	l	Saline alkali
16	Daurad	26°06'04.7"N, 77°23'10.5"E	Wheat, Mustard	Tube Well	cl	Alkali
17	Daurad	26°05'58.4"N, 77°23'04.9"E	Wheat, Mustard	Tube Well	cl	Alkali
18	Hurlpur	26°02'46.9"N, 77°19'36.0"E	Wheat, Mustard	Tube Well	l	Alkali
19	Hurlpur	26°02'41.5"N, 77°20'00.3"E	Wheat, Mustard	Well	l	Saline alkali
20	Hurlpur	26°02'40.6"N, 77°20'01.0"E	Wheat, Mustard	Well	cl	Saline alkali
21	Hurlpur	26°02'40.5"N, 77°20'04.7"E	Wheat, Mustard	Well	cl	Saline alkali
22	Hurlpur	26°02'09.9"N, 77°19'24.8"E	Barseem, Mustard	Tube Well	cl	Alkali
23	Iklod	26°01'42.3"N, 77°19'19.2"E	Wheat, Mustard	Tube Well	l	Alkali
24	Iklod	26°01'56.6"N, 77°19'22.3"E	Mustard	Tube Well	l	Alkali
25	Iklod	26°01'32.8"N, 77°19'21.4"E	Wheat, Sugarcane, Mustard	Tube Well	l	Alkali
26	Hurlpur	26°02'31.4"N, 77°19'29.2"E	Mustard	Tube Well	l	Alkali
27	Vijaypur	26°03'57.5"N, 77°21'05.0"E	Mustard	Tube Well	l	Alkali

* l - loam; cl - clay loam; sil - silt loam;

Table 4.1.2. Mechanical analysis of surface soil samples collected from Sheopur district of M.P.

S. No.	Name of Village	Location	Clay (%)	Silt (%)	Sand (%)	CaCO ₃ (%)	Texture
Sheopur tehsil							
1	Pandola	25°31'32.2"N, 76°38'59.4"E	21.4	48.6	30.1	6	cl
2	Bichhudi Babdi	25°27'49.4"N, 76°36'43.4"E	25.4	42.6	32.1	12	cl
3	Badauda	25°28'40.3"N, 76°40'43.5"E	44.4	33.6	22.1	10	l
4	Modla	25°31'16.9"N, 76°39'11.2"E	41.4	42.6	16.1	16	l
5	Modla	25°31'25.7"N, 76°39'02.1"E	37.4	48.6	14.1	12	l
6	Pandola	25°32'56.9"N, 76°38'52.2"E	34.8	53.3	11.9	14	sil
7	Dhoti	25°40'06.4"N, 76°34'39.6"E	40.8	41.3	17.9	12	l
Vijaypur tehsil							
8	Bojpaiya	26°06'35.3"N, 77°18'33.4"E	38.8	41.3	19.9	10	l
9	Mada	26°05'45.6"N, 77°19'00.3"E	32.8	45.3	21.9	18	l
10	Khitarpal	26°04'36.0"N, 77°19'32.0"E	36.8	43.3	19.9	6	l
11	Sunbai	26°05'35.9"N, 77°22'43.4"E	38.8	42.7	18.5	14	l
12	Andhpur	26°05'43.4"N, 77°22'47.8"E	32.8	40.7	26.5	2	l
13	Daurad	26°06'15.6"N, 77°23'26.6"E	34.8	40.7	24.5	8	l
14	Daurad	26°06'20.1"N, 77°23'31.0"E	31.8	41.7	26.5	2	l
15	Barakala	26°07'16.6"N, 77°24'00.5"E	36.8	38.7	24.5	6	l
16	Daurad	26°06'04.7"N, 77°23'10.5"E	33.2	38.3	28.5	4	cl
17	Daurad	26°05'58.4"N, 77°23'04.9"E	31.2	37.3	31.5	2	cl
18	Hurlpur	26°02'46.9"N, 77°19'36.0"E	44.2	39.3	16.5	8	l
19	Hurlpur	26°02'41.5"N, 77°20'00.3"E	38.2	36.3	25.5	6	l
20	Hurlpur	26°02'40.6"N, 77°20'01.0"E	36.2	33.3	30.5	6	cl
21	Hurlpur	26°02'40.5"N, 77°20'04.7"E	34.0	35.3	30.7	10	cl
22	Hurlpur	26°02'09.9"N, 77°19'24.8"E	31.0	35.3	33.7	6	cl
23	Iklod	26°01'42.3"N, 77°19'19.2"E	45.0	33.3	21.7	4	l
24	Iklod	26°01'56.6"N, 77°19'22.3"E	45.0	31.3	23.7	8	l
25	Iklod	26°01'32.8"N, 77°19'21.4"E	45.0	37.3	17.7	4	l
26	Hurlpur	26°02'31.4"N, 77°19'29.2"E	41.0	39.3	19.7	12	l
27	Vijaypur	26°03'57.5"N, 77°21'05.0"E	43.0	32.3	24.7	16	l

Table 4.1.3. Chemical analysis of saturation extract of Surface Soil Samples collected from Sheopur district of M.P.

S. No.	Village/Tehsil	pHs	ECe (dS m ⁻¹)	Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺	CO ₃ ²⁻	HCO ₃ ⁻	Cl ⁻	SO ₄ ²⁻	SAR	Saturation (%)
Sheopur tehsil													
1	Pandola	8.6	2.6	1.6	0.8	23.2	0.21	0.8	4.0	14.0	7.0	21.2	48.5
2	Bichhudi Babdi	7.9	1.7	5.2	2.8	8.0	0.84	0.6	5.2	7.6	3.4	4.0	51.2
3	Badauda	8.3	1.3	4.0	2.0	6.8	0.23	0.4	4.0	6.8	1.8	3.9	50.9
4	Modla	8.5	19.2	15.4	8.6	206.1	0.29	0.6	4.8	180.0	45.0	59.5	49.2
5	Modla	8.1	22.2	27.7	10.2	227.7	0.82	0.4	3.0	202.4	60.6	52.3	50.1
6	Pandola	8.4	1.5	4.4	1.8	7.5	0.80	1.0	5.0	7.0	1.5	4.3	52.6
7	Dhoti	8.3	6.6	26.0	10.0	36.0	0.32	0.4	4.4	53.2	14.3	8.5	54.2
Vijaypur tehsil													
8	Bojpaiya	8.5	7.8	5.0	2.4	77.9	0.33	0.4	4.4	61.2	19.6	40.5	50.1
9	Mada	8.5	0.9	3.4	1.6	3.7	0.14	0.4	4.8	2.8	0.9	2.3	49.2
10	Khitarpal	8.6	0.9	4.6	2.2	2.2	0.50	0.4	4.8	3.0	1.3	1.2	48.4
11	Sunbai	8.3	0.9	4.0	2.0	2.4	0.32	0.6	4.2	3.6	0.3	1.4	50.1
12	Andhpur	8.2	1.1	5.2	2.4	3.1	0.22	0.6	5.2	4.8	0.3	1.6	51.3
13	Daurad	8.6	1.3	6.2	2.8	3.6	0.61	1.0	8.0	3.0	1.2	1.7	52.6
14	Daurad	8.2	5.1	12.0	5.0	39.2	0.30	0.4	4.0	42.0	10.1	13.5	53.8
15	Barakala	8.0	5.2	22.0	8.0	26.6	0.42	0.4	3.2	44.0	9.4	6.9	50.9
16	Daurad	8.3	1.3	6.6	3.0	3.2	0.27	0.6	6.8	3.4	2.3	1.5	51.4
17	Daurad	8.0	1.4	6.8	2.8	4.5	0.27	0.2	2.4	6.8	5.0	2.1	49.8
18	Hurlpur	8.4	1.4	5.0	2.2	5.9	1.02	0.8	6.4	3.6	3.3	3.1	54.3
19	Hurlpur	8.5	7.6	16.4	6.8	105.2	0.64	0.8	8.0	98.4	21.8	30.9	56.9
20	Hurlpur	8.2	8.5	16.0	6.4	78.7	1.07	0.2	5.2	81.4	15.3	23.5	53.4
21	Hurlpur	8.2	10.3	14.8	6.2	102.3	0.30	0.2	4.0	96.8	22.6	31.6	54.5
22	Hurlpur	8.3	1.2	4.2	1.8	6.0	0.23	0.2	6.0	2.8	3.2	3.4	52.2
23	Ikod	7.9	1.2	5.2	2.2	4.5	0.40	0.4	6.0	3.0	2.9	2.4	51.8
24	Ikod	8.2	2.9	2.8	1.2	24.2	0.42	0.6	12.0	10.0	6.0	17.1	52.3
25	Ikod	8.0	3.0	10.0	4.4	14.6	1.00	1.0	7.6	16.0	5.4	5.4	56.4
26	Hurlpur	8.1	1.2	4.6	1.8	5.6	0.17	0.6	5.0	3.4	3.2	3.1	53.4
27	Vijaypur	8.2	2.1	5.4	2.2	12.9	0.33	0.2	3.6	10.8	6.2	6.6	53.2

Table 4.1.4. Exchangeable Cations, CEC and ESP of Surface Soil Samples collect from Sheopur district of M.P.

S. No.	Name of Village	Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺	CEC	ESP
		(c mol (p ⁺) kg ⁻¹)					
1	Pandola	22.5	8.5	12.7	1.2	44.9	28.3
2	Bichhudi Babdi	22.5	9.0	8.4	0.9	40.8	20.6
3	Badauda	17.5	7.5	16.5	1.1	42.6	38.7
4	Modla	13.5	6.0	18.7	1.0	39.2	47.7
5	Modla	11.0	5.0	14.3	0.8	31.1	46.0
6	Pandola	10.5	4.5	20.2	0.7	35.9	56.3
7	Dhoti	24.5	9.5	8.6	0.9	43.5	19.8
8	Bojpaiya	11.5	6.0	21.7	1.2	40.4	53.7
9	Mada	15.5	7.0	17.5	1.0	41.0	42.7
10	Khitarpal	12.0	5.5	16.9	1.4	35.8	47.2
11	Sunbai	13.5	6.5	17.1	0.9	38.0	45.0
12	Andhpur	16.0	7.0	21.8	0.8	45.6	47.8
13	Daurad	12.5	5.5	21.2	0.7	39.9	53.1
14	Daurad	12.0	5.5	22.0	0.9	40.4	54.5
15	Barakala	14.5	6.5	19.4	1.0	41.4	46.9
16	Daurad	11.5	5.5	23.6	1.3	41.9	56.3
17	Daurad	11.5	4.5	28.1	1.5	45.6	61.6
18	Hurlpur	11.3	5.0	6.5	0.8	23.5	27.4
19	Hurlpur	13.5	6.5	19.0	1.4	40.4	47.0
20	Hurlpur	15.0	5.5	26.6	1.1	48.2	55.2
21	Hurlpur	14.5	6.5	25.3	0.8	47.1	53.7
22	Hurlpur	16.0	7.0	25.0	0.9	48.9	51.1
23	Iklod	12.0	4.5	21.8	1.0	39.3	55.5
24	Iklod	11.5	7.0	22.3	0.7	41.5	53.7
25	Iklod	12.5	5.5	17.7	1.1	36.8	48.1
26	Hurlpur	11.5	5.0	20.8	1.0	38.3	54.3
27	Vijaypur	12.5	5.5	24.2	0.9	43.1	56.1

Table 4.1.5. Micronutrients status in surface soils of Sheopur district

S. No.	Name of Village	Micronutrient content (mg kg ⁻¹)			
		Fe ²⁺	Cu ²⁺	Zn ²⁺	Mn ²⁺
1	Pandola	3.53	1.61	1.38	1.93
2	Bichhudi Babdi	3.48	1.58	1.14	1.26
3	Badauda	3.29	1.32	1.18	2.92
4	Modla	2.34	1.05	1.37	8.51
5	Modla	2.43	1.26	0.97	4.38
6	Pandola	2.28	1.92	1.42	2.48
7	Dhoti	3.20	1.83	2.01	2.47
8	Bojpaiya	2.35	0.92	1.19	3.39
9	Mada	3.18	1.07	2.23	2.43
10	Khitarpal	2.19	1.28	1.27	8.06
11	Sunbai	2.79	1.03	1.03	2.28
12	Andhpur	2.78	0.93	1.28	2.14
13	Daurad	2.59	0.98	0.86	2.43
14	Daurad	2.63	1.00	1.12	9.77
15	Barakala	2.53	0.86	0.99	2.03
16	Daurad	3.02	0.99	1.12	2.89
17	Daurad	3.22	0.79	1.02	26.34
18	Huripur	2.54	1.90	1.27	31.92
19	Huripur	3.07	1.17	1.71	2.22
20	Huripur	2.98	1.16	1.21	5.13
21	Huripur	3.04	1.14	1.06	2.16
22	Huripur	3.04	1.38	0.61	1.84
23	Iklod	2.60	0.81	0.94	15.44
24	Iklod	3.50	1.42	0.93	2.20
25	Iklod	2.79	1.38	1.00	1.83
26	Huripur	2.60	1.47	1.11	2.05
27	Vijaypur	3.87	1.58	1.53	1.98

Critical limit – Fe - 5.0 mg kg⁻¹ Cu- 0.2 mg kg⁻¹ Zn- 0.6 mg kg⁻¹ Mn- 2.0 mg kg⁻¹

4.2 Morphology, characterization and classification of pedons

PEDON 1

Location - 25°31'17.0"N, 76°39'11.1"E

Date: 09.01.2008

Village - Modla;

Tehsil - Sheopur;

District - Sheopur

Mapping Unit - I-d5- B1e2;

Drainage - Poorly drained;

Slope - 1-3 %;

Erosion –Slight;

Water table - More than 10 m;

Vegetation – *Acacia nilotica*, *Prosopis juliflora*, *Azadirachta indica*, Kush grass, Khajoor, Karil, Akauwa

Crops grown - Mustard, Wheat;

Present land use – Fallow

Classification: Coarse loamy, mixed, hyperthermic family of Typic Natrargids.

Macromorphology:

Horizon	Depth (cm)	Description
A1	0-11	Light gray (10 YR 7/2) dry; sandy clay; light brownish gray (10 YR 6/2) moist; weak, fine, massive structure; loose, friable, sticky and plastic; violent effervescent with dil. HCl; very fine and few roots; fine, common tubular pores; moderately permeable; clear, smooth boundary.
AB	11-30	Brown (10 YR 5/3) dry; silty clay; dark brown (10 YR 4/3) moist; moderate, medium, sub angular blocky structure; hard, firm, slightly sticky and slightly plastic; violent effervescent with dil. HCl; very fine and few roots; 1-2 mm size lime concretions about 3 % by volume; common, very fine tubular pores; moderately permeable; clear, wavy boundary
Bt1	30-66	Brown (10 YR 5/3) dry; silty clay; dark brown (10 YR 4/3) moist; moderate, medium, sub angular blocky structure; hard, firm, slightly sticky and plastic; violent effervescent with dil. HCl; 1-4 mm size lime concretions about 10 % by volume; few, very fine tubular pores; moderately permeable; clear, smooth boundary

Bt2	66-102	Brown (10 YR 5/3) dry; silty clay; dark brown (10 YR 4/3) moist; moderate, medium, sub angular blocky structure; very hard, very firm, very sticky and very plastic; violent effervescent with dil. HCl; 1-3 mm size lime concretions about 5 % by volume; few, very fine tubular pores; moderately permeable; clear, smooth boundary.
Bt21	102-127	Brown (10 YR 5/3) dry; silty clay; dark brown (10 YR 4/3) moist; moderate, medium, sub angular blocky structure; hard, firm, sticky and very plastic; violent effervescent with dil. HCl; 1-2 mm size lime concretions about 3 % by volume; few, very fine pores; moderately permeable; clear, smooth boundary.
Bt22	127-142+	Yellowish brown (10 YR 5/4) dry; silty clay; dark yellow brown (10 YR 4/4) moist; moderate, medium, sub angular blocky structure; hard, firm, sticky and plastic; violent effervescent with dil. HCl; 1-2 mm size lime concretions about 1-2 % by volume, common; very fine pores; moderately permeable; clear, smooth boundary.

Physico-chemical properties

The analytical data of the selected pedon is given in table 4.2.1. The texture of the soil ranges from loam to clay loam with clay content varying from 17.76 to 31.76 % with accumulation between 66 to 102 cm depths. The pedon was calcareous and saline-alkali in nature with E_{Ce} ranging from 1.9 to 15.7 dS m⁻¹. The E_{Ce} values indicate accumulation of salts on the surface. The dominant ionic species are sodium and chloride. The ESP varied from 31.3 to 82.2. The CEC values varied in between 35.6 to 41.5 cmol (+) kg⁻¹.

The textural composition revealed that the pedon belongs to coarse loamy family with mixed mineralogy. The overhead climate is hyperthermic. The soil ESP was very high at all the depths (Table 4.2.1). These features lead to its classification as a member of coarse loamy, mixed, hyperthermic family of Typic Natrargids.

The data on DTPA extractable micronutrients viz., Cu, Zn, Mn and Fe revealed that micronutrients content decreased with the soil depth indicating their higher concentration at the upper strata (Table 4.2.2). The copper content ranged between 1.28 and 2.59 mg kg⁻¹. The manganese varied from 0.16 to 0.48 mg kg⁻¹, iron ranged from 0.11 to 1.1 mg kg⁻¹ and the zinc from 0.96 to 1.81 mg kg⁻¹.

Table 4.2.1. Physico-chemical properties of of the soil (Pedon 1)

Depth (cm)	Sand	Silt	Clay	CaCO ₃	Textural Class	Saturation (%)	pHs	ECe (dSm ⁻¹)
	(%)							
0-11	43.52	38.72	17.76	24	l	48.4	10.0	15.7
11-30	33.52	44.72	21.76	26	l	50.1	10.1	12.0
30-66	23.52	52.72	23.76	28	l	52.4	9.4	5.1
66-102	23.52	44.72	31.76	36	cl	51.6	8.5	2.2
102-127	27.52	44.72	27.76	36	cl	54.3	7.9	2.0
127-142+	31.52	44.72	23.76	24	l	52.3	8.4	1.9

Depth (cm)	Water soluble ions (me L ⁻¹)								SAR	Exch. Cations			CEC	ESP
	Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺	CO ₃ ²⁻	HCO ₃ ⁻	Cl ⁻	SO ₄ ²⁻		Ca ²⁺	Mg ²⁺	Na ⁺		
	[cmol(+)kg ⁻¹]													
0-11	6.6	2.4	147.2	0.80	16.0	32.0	88.6	20.4	69.4	5.0	2.0	29.5	37.7	78.2
11-30	5.8	1.8	111.6	0.78	20.0	40.0	48.8	11.2	57.3	3.5	1.5	33.3	40.5	82.2
30-66	1.6	0.8	47.6	0.81	4.4	20.0	22.0	4.4	43.4	5.5	2.5	25.9	37.1	69.8
66-102	1.4	0.6	19.0	0.75	0.4	9.0	8.8	3.5	19.0	12.0	4.5	14.9	35.6	41.9
102-127	2.2	1.0	16.5	0.56	0.2	4.0	9.6	6.5	13.1	12.0	5.5	18.8	41.5	45.3
127-142+	1.8	0.6	15.9	0.31	0.4	6.4	6.8	5.0	14.5	14.5	6.5	12.4	39.6	31.3

Table 4.2.2. Micronutrients status of the soil (Pedon-1)

Horizon	Depth (cm)	Available micronutrients (mg kg ⁻¹)			
		Cu ²⁺	Fe ²⁺	Zn ²⁺	Mn ²⁺
A1	0-11	2.59	1.11	1.81	0.48
AB	11-30	2.40	1.01	1.60	0.27
Bt1	30-66	1.99	0.47	1.30	0.25
Bt2	66-102	1.65	0.22	1.24	0.22
Bt21	102-127	1.53	0.21	1.11	0.21
Bt22	127-142+	1.28	0.11	0.96	0.16

PEDON 2

Location - 26°02'40.6"N; 77°20'01.0"E

Date: 12.01.2008

Village - Hurlpur;

Tehsil - Vijaypur,

District - Sheopur

Mapping Unit - cl-d5- B2e2;

Drainage - Moderately drained;

Slope - 3-8 %;

Erosion – Moderate;

Water table - More than 10 m;

Vegetation – *Acacia nilotica*, *Prosopis juliflora*, *Azadirachta indica*, *Argimon maxicana*

Crops grown - Sorghum/ Mustard

Present land use – Fallow

Classification: Coarse loamy, mixed, hyperthermic family of Typic Natrargids

Macromorphology :

Horizon	Depth (cm)	Description
A1	0-8	Light gray (10 YR 7/2) dry; silty loam; light yellowish brown (10 YR 6/4) moist; weak, fine, sub angular blocky structure; very hard, firm, slightly sticky and slightly plastic; strong effervescent with dil. HCl; few, fine roots; fine, common tubular pores; fine many nodules (lime concretions), moderately permeable; clear, smooth boundary.

AB	8-17	Yellowish brown (10 YR 5/4) dry; silty loam; dark brown (10 YR 4/3) moist; strong, fine, sub angular blocky structure; very hard, very firm, slightly sticky and slightly plastic; strong effervescent with dil. HCl; medium, few very fine roots; very fine, few tubular pores; moderately permeable; clear, smooth boundary.
Bt1	17-36	Brown (10 YR 5/3) dry; silty loam; dark brown (10 YR 4/3) moist; moderate, fine, sub angular blocky structure; hard, firm, slightly sticky and slightly plastic; strong effervescent with dil. HCl; very fine, common tubular pores; moderately permeable; clear, smooth boundary.
Bt2	36-49	Light yellowish brown (10 YR 6/4) dry; silty loam; yellowish brown (10 YR 5/4) moist; moderate, fine, sub angular blocky structure; hard, firm, slightly sticky and slightly plastic; strong effervescent with dil. HCl; 2 to 3 mm size lime concretions about 4 % by volume; very fine, common tubular pores; slowly permeable; clear, smooth boundary.
Bt21	49-63	Light yellowish brown (10 YR 6/4) dry; silty loam; yellowish brown (10 YR 5/4) moist; moderate, fine, sub angular blocky structure; hard, friable, slightly sticky and slightly plastic; strong effervescent with dil. HCl; 2 to 5 mm size lime concretions about 6-7 % by volume; fine, very fine, common tubular pores; slowly permeable; clear, smooth boundary.
Bt22	63-91	Light yellowish brown (10 YR 6/4) dry; silty loam; yellowish brown (10 YR 5/4) moist; moderate, fine, sub angular blocky structure; hard, firm, very sticky and very plastic; strong effervescent with dil. HCl; 1-2 mm size lime concretions about 3 % by volume; fine common tubular pores; slowly permeable; clear, smooth boundary.
Bt23	91-111	Yellowish brown (10 YR 5/4) dry; silty loam; dark yellowish brown (10 YR 4/4) moist; strong, fine, sub angular blocky structure; very hard, firm, very sticky and very plastic; strong effervescent with dil. HCl; 1-2 mm size lime concretions about 1-2 % by volume; very fine common tubular pores; very slowly permeable; clear, smooth boundary.
Bt24	111-130+	Light yellowish brown (10 YR 6/4) dry; silty loam; yellowish brown (10 YR 5/4) moist; moderate, fine, sub angular blocky structure; hard, firm, slightly sticky and slightly plastic; strong effervescent with dil. HCl; very fine common tubular pores; very slowly permeable; clear, smooth boundary.

Physico-chemical properties

The analytical data of the selected pedon was given in table 4.2.3. The texture of the soil ranges from loam to clay loam with clay content varying from 11.76 to 27.76 % with accumulation between 49 to 63 cm. The pedon is saline-alkali in nature with E_{Ce} ranging from 4.5 to 10.2 dSm⁻¹. The E_{Ce} values indicate accumulation of salts on the surface. The dominant ionic species are sodium and chloride. ESP varies from 10.4 to 60.4. The CEC values are in accordance with the clay content and vary from 30.6 to 48.5.

The textural composition revealed that the pedon belong to coarse loamy family with mixed mineralogy. The overhead climate is hyperthermic. An exchangeable sodium percentage (ESP) of 15 percent or more in one or more horizons within 40 cm of its upper boundary representing the presence of Natric sub-surface horizon. The soil ESP is very high at all the depths except lowest horizon (111-130+ cm). These features lead to its classification as a member of coarse loamy, mixed, hyperthermic family of Typic Natrargids.

The data on DTPA extractable micronutrients viz., Cu²⁺, Zn²⁺, Mn²⁺ and Fe²⁺ revealed that micronutrients content decreased with the soil depth indicating their higher concentration at the upper strata (Table 4.2.4). The copper content ranged between 1.78 and 2.44 mg kg⁻¹. The manganese varied from 0.24 to 1.45 mg kg⁻¹, iron ranged from 0.09 to 0.78 mg kg⁻¹ and the zinc from 0.82 to 3.28 mg kg⁻¹.

Table 4.2.3. Physico-chemical properties of of the soil (Pedon 2)

Depth (cm)	Sand	Silt	Clay	CaCO ₃	Textural Class	Saturation (%)	pHs	ECe (dSm ⁻¹)
	(%)							
0-8	23.52	48.72	27.76	6	cl	51.4	8.3	10.2
8-17	27.52	46.72	25.76	8	I	53.2	8.9	4.8
17-36	35.52	42.72	21.76	12	I	56.4	8.5	4.9
36-49	43.52	44.72	11.76	12	I	55.4	8.6	5.0
49-63	33.52	42.72	23.76	22	I	54.5	8.4	5.5
63-91	29.52	44.72	25.76	6	I	53.2	7.9	5.5
91-111	27.52	46.72	25.76	24	I	54.6	8.0	5.4
111-130+	31.52	46.72	21.76	32	I	55.5	7.8	4.5

Depth (cm)	Water soluble ions (me L ⁻¹)								SAR	Exch. Cations			CEC	ESP
	Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺	CO ₃ ²⁻	HCO ₃ ⁻	Cl ⁻	SO ₄ ²⁻		Ca ²⁺	Mg ²⁺	Na ⁺		
	[cmol(+)kg ⁻¹]													
0-8	2.8	1.2	97.8	0.21	0.8	4.4	60.0	36.8	69.2	7.5	3.0	21.8	39.5	55.1
8-17	0.8	0.4	46.2	0.21	1.0	6.4	28.8	11.4	59.6	8.0	3.0	29.3	48.5	60.4
17-36	1.2	0.4	46.8	0.18	0.8	5.6	24.0	18.2	52.3	8.5	4.0	24.3	46.0	52.8
36-49	1.6	0.8	47.4	0.24	0.8	4.8	28.0	16.4	43.2	7.5	4.5	8.4	30.6	27.5
49-63	2.6	1.0	51.0	0.38	0.2	5.2	34.0	15.6	38.0	6.5	3.0	19.5	40.2	48.5
63-91	2.2	0.8	52.1	0.23	0.2	4.4	32.0	18.7	42.5	9.0	4.5	12.0	37.7	31.8
91-111	2.8	1.2	49.8	0.28	0.2	4.4	32.0	17.5	35.2	6.5	3.0	9.8	32.5	30.2
111-130+	3.0	1.0	41.2	0.15	0.2	3.2	26.0	16.0	29.2	11.5	4.5	3.5	33.7	10.4

Table 4.2.4. Micronutrients status of the soil (Pedon-2)

Horizon	Depth (cm)	Available micronutrients (mg kg ⁻¹)			
		Cu ²⁺	Fe ²⁺	Zn ²⁺	Mn ²⁺
A1	0-8	2.44	0.78	3.28	1.45
AB	8-17	2.43	0.76	2.13	1.24
Bt1	17-36	2.41	0.64	1.63	1.02
Bt2	36-49	2.32	0.51	1.41	0.44
Bt21	49-63	2.17	0.31	1.4	0.29
Bt22	63-91	1.97	0.21	1.18	0.27
Bt23	91-111	1.93	0.12	1.08	0.24
Bt24	111-130+	1.78	0.09	0.82	0.24

4.3 Genesis of salt affected soils of sheopur district

The morphology of the horizon samples from pedons examined in the salt affected area reveals light gray (10 YR 7/2) to brown (10YR 5/3) colour (Table 4.3.1). The texture varies from loam to clay loam. The structure ranges from weak, fine, massive to strong, fine, sub angular blocky. The porosity ranges from fine to very fine. The horizons boundaries were clear and smooth in most of the horizons. Most of the horizons are calcareous in nature with loose to very hard consistence under dry condition and from sticky to very sticky in moist condition. The effervescence with dil HCl (0.1 N) ranged from slight to violent effervescence. Concretion (calcium carbonate) persists in the range of 2-10 %. The soil forming factors viz., arid climate, geology, nearly level to flat topography in the plains and ravines along the riverbanks have resulted in deposition of salt and sodium in the area.

4.4 Classification of salt affected pedons of sheopur district

The salt affected soils belong to Aridisols order. The classification for different pedons is given in the table 4.4.1 and 4.4.2. Both the profiles were classified in to typic Natrargids.

Table 4.3.1. Brief Morphological Features of Pedons

Horizon	Depth (cm)	Colour		Texture	Structure	Consistency	Porosity		Boundary		CaCO ₃ (%)	Effev. With 0.1N HCl	Nodulea		Taxonomical Class
		Dry	Moist				S	Q	D	T			S	Q	
Pedon -1															
A1	0-11	10YR7/2	10YR6/2	l	1,f,m	l, fr, s, p	f	c	c	s	24	ev	-	-	Coarse loamy, mixed, hyperthermic family of Typic Natrargids
AB	11-30	10YR5/3	10YR4/3	l	2,m,sbk	h,fi,ss,sp	vf	c	c	w	26	ev	m	m	
Bt1	30-66	10YR5/3	10YR4/3	l	2,m,sbk	h,fi,s,sp	vf	f	c	s	28	ev	f	c	
Bt2	66-102	10YR5/3	10YR4/3	cl	2,m,sbk	vh,vfi,vs,vp	vf	f	c	s	36	ev	f	c	
Bt21	102-127	10YR5/3	10YR4/3	cl	2,m,sbk	h,fi,s,vp	vf	f	c	s	36	ev	f	f	
Bt22	127-142	10YR5/4	10YR4/4	l	2,m,sbk	h,fi,s,p	vf	c	c	s	24	ev	f	f	
Pedon -2															
A1	0-8	10YR7/2	10YR6/4	cl	1,f,sbk	vh,fi,ss,sp	f	c	c	s	6	es	f	m	Coarse loamy, mixed, hyperthermic family of Typic Natrargids
AB	8-17	10YR5/4	10YR4/3	l	3,f,sbk	vh,vfi,ss,sp	vf	f	c	s	8	e	-	-	
Bt1	17-36	10YR5/3	10YR4/3	l	2,f,sbk	h,fi,ss,sp	vf	c	c	s	12	es	-	-	
Bt2	36-49	10YR6/4	10YR5/4	l	2,f,sbk	h,fi,ss,sp	vf	c	c	s	12	ev	m	m	
Bt21	49-63	10YR6/4	10YR5/4	l	2,f,sbk	h,fr,ss,sp	vf	c	c	s	22	ev	m	c	
Bt22	63-91	10YR6/4	10YR5/4	l	2,f,sbk	h,fi,vs,vp	f	c	c	s	6	ev	f	c	
Bt23	91-111	10YR5/4	10YR4/4	l	3,f,sbk	vh,fi,vs,vp	vf	c	c	s	24	ev	f	f	
Bt24	111-130	10YR6/4	10YR5/4	l	2,f,sbk	h,fi,ss,sp	vf	c	c	s	32	es	-	-	

Texture: cl - clay loam ; l - loam;

Structure: 1,f,m - weak, fine, massive; 2,m,sbk - moderate, medium, subangular blocky; 1,f,sbk- weak, fine, sub angular blocky; 2,f,sbk- moderate, fine, subangular blocky; 3,f,sbk- strong, fine, subangular blocky;

Consistency: **Dry** (l- loose, h- hard, vh- very hard) **Moist** (fr-friable, fi- firm, vfi- very firm) **Wet (stickness-** ss- slightly sticky; s-sticky; vs- very sticky **Palsticity-** sp- slightly plastic; p- plastic; vp- very plastic)

Porosity/ Nodulea/ Roots: **S** – Size (vf - very fine, f – fine, m – medium, c – coarse), **Q** - quantity (f – few, c – common, m – many)

Boundary : **D** – Distinctness (a – abrupt, c – clear, g – gradual, d – diffused), **T** - topography (s – smooth, w – wavy, i – irregular, b – broken)

Effervescence/ Reaction : e- slight; es- strong; ev - violent.

Table. 4.4.1. Taxonomic Classification at a glance (Soil Taxonomy, 1998)

	Pedon	
	P-1	P-2
Order	Aridisol	Aridisol
Sub-order	Argid	Argid
Great group	Natrargids	Natrargids
Sub-group	Typic	Typic
Family	coarse loamy, mixed, hyperthermic family of Typic Natrargids	coarse loamy, mixed, hyperthermic family of Typic Natrargids

Table 4.4.2. Classification of salt affected pedons of Sheopur

Pedon No.	Classification
P-1	coarse loamy, mixed, hyperthermic family of Typic Natrargids
P-2	coarse loamy, mixed, hyperthermic family of Typic Natrargids

4.5 Nature and extent of salt affected soils of sheopur district:

The classification of salt affected soils of Sheopur district was done on the basis of data of soil analysis, features identified showing salinity/ sodicity problem on digital satellite data of Resourcesat-1 LISS-III through visual interpretation of the digital image using Remote Sensing Software (ERDAS IMAGINE 8.7) and ground truth. The maps were developed through digitization of the area identified on LISS III image in GIS environment. The villages were identified by overlaying the respective geographical maps (scanned and rectified using ERDAS software) over maps generated. List of identified villages and extent of problem in district/ tehsil is presented in table 4.5.1. Most of the salt affected area come under the category of slightly saline and moderately alkali (7788 ha) followed by slightly saline and slightly alkali (7761 ha), slightly saline and highly alkali (3641 ha), moderately saline and highly alkali (123) and highly saline and highly alkali (234). The total area of salt affected soils in Sheopur district is 19547 ha (Table 4.5.2). The villages were categorized under different levels of salinity and sodicity on the basis of ground truthing and analytical data (Fig. 4.1).

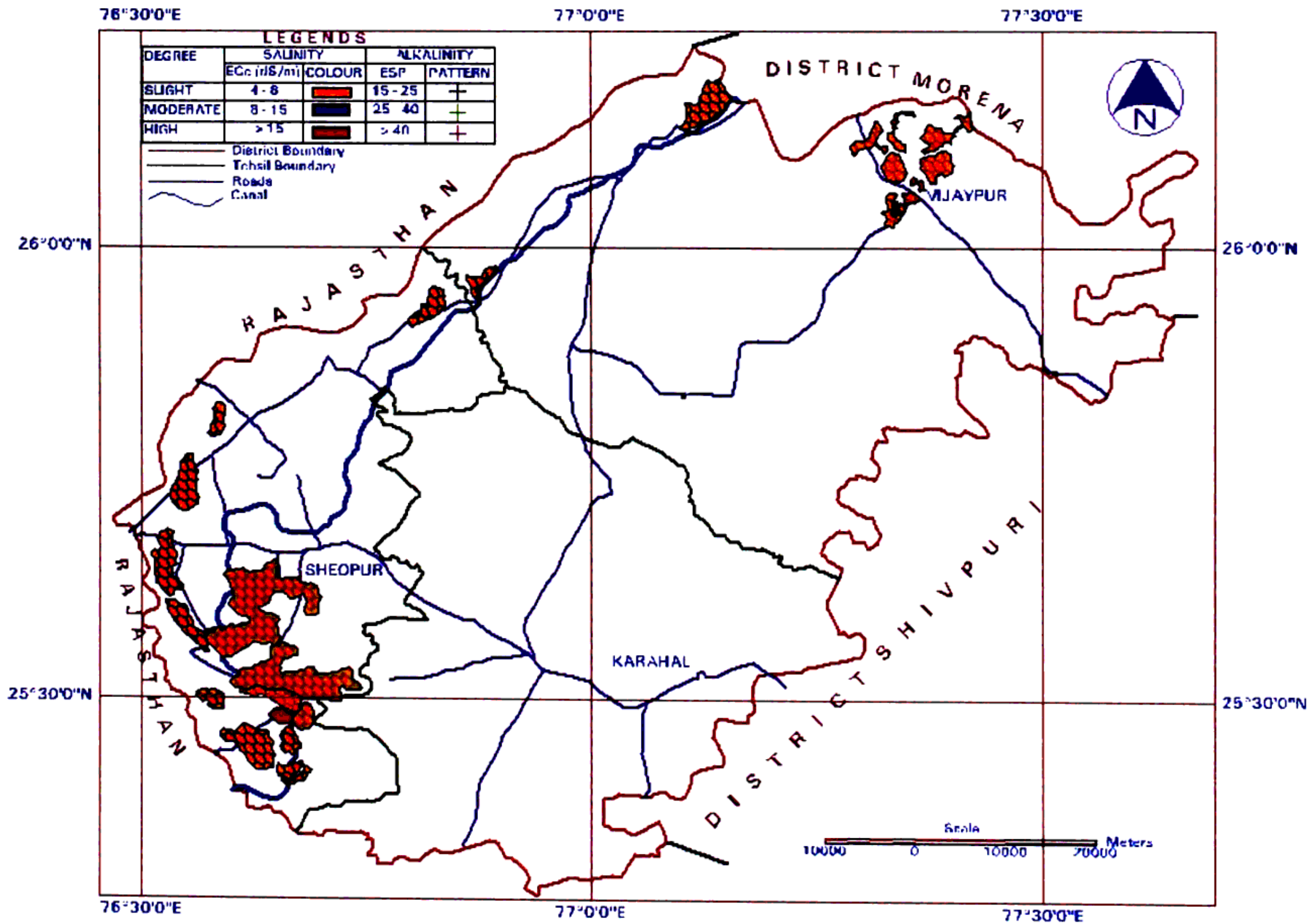


Fig 4.1. DISTRIBUTION OF SALT AFFECTED SOILS IN SHEOPUR DISTRICT OF M.P.
 (BASED ON RESOURCESAT-1 LISS-III DIGITAL DATA OF APRIL 2003)

Table 4.5.1. Distribution of salt affected soils in different tehsils and affected villages of Sheopur district

Category	Tehsil	Area (ha)	Name of villages
Slightly saline and slightly alkali (EC 4-8 dS/m and ESP 15-25)	Sheopur	6117	Panadi, Nimodaveer, Guda, Amalda, Patpuda, Sankulki, Nanavada, Gurnavada, Diwadi, Utanwad, Veerakhedali, Vahravada, Vasond, Sarangpur, Bavadibichhu, Lalitpura, Dharpura, Kudayatha, Adotpura, Thikariapali, Boraddev, Mitvadia, Makdawadakhurd, Vanadi. Nayagaon, Halgaondakhurd, Kaloni, Prempura, Hathvari, Adwad, Viththalpur, Chheetakhedali, Makhanakhed, Jwad, Chukjwad, Pahadalya, Vehrod, Dalarnakalan, Vadaudaram, Seesvali, Kaririya, Vanwada, Mudalawada, Lahchauda, Bagadia, Vagdari, Khojipura, Viloni
	Vijaypur	1644	Balawani, Tarrakhurd, Nitawas, Panchon, Smarda, Beerpur, Seekheda, Guhar
Slightly saline and moderately alkali (EC 4-8 dS/m and ESP 25-40)	Sheopur	7788	Badauda, Pipalda, Khanpura, Khedli, Radeb, Mekhadahedi, Saraswali, Vilaidi, Mudla, Galmanya, Luhad, Luhadikheda, Pandoli, Bamorijat, Karnyakhedali, Pandola, Masoondar, Narayanpura, Vadikheda, Hirnikheda, Tulsef, Koodh, Dukalyakheda, Vijaypur, Ramgavadi, Kilorach, Daulatpura, Pipaldi, Pachipura, Rigni, Kamapur, Kishorpura, Kundhaveli, Chaudpur, Ajapura, Bamorihala
Slightly saline and highly alkali (EC 4-8 dS/m and ESP > 40)	Sheopur	616	Muganapura, Galmanya, Badauda, Mudla
	Vijaypur	3025	Ahiri, Oopacha, Itbai, Madha, Bojpaiya, Khitarpal, Ranavad, Bagrod, Maisaai, Andhpur, Daurad, Barakala, Dongarpur, Gohara, Vichpuri, Bhevra, Sunbai, Bardula, Arushtha, Laxamanpura, Ladpura, Barkheda, Vijaypur, Hurlpur, Iklod
Moderately saline and highly alkali (EC 8-15 dS/m and ESP > 40)	Vijaypur	123	Ladpura, Barkheda
Highly saline and highly alkali (EC > 15 dS/m and ESP > 40)	Sheopur	234	Muganapura, Indrapuri, Badauda, Udayata
Total		19547	



Table 4.5.2. Area of salt affected soils in different categories of Sheopur district

S.No.	Category	Area (Hectares)
1	Slightly saline and slightly alkali (EC 4-8 dS/m and ESP 15-25)	7761
2	Slightly saline and moderately alkali (EC 4-8 dS/m and ESP 25-40)	7788
3	Slightly saline and highly alkali (EC 4-8 dS/m and ESP > 40)	3641
4	Moderately saline and slightly alkali (EC 8-15 dS/m and ESP 15-25)	0
5	Moderately saline and moderately alkali (EC 8-15 dS/m and ESP 25-40)	0
6	Moderately saline and highly alkali (EC 8-15 dS/m and ESP > 40)	123
7	Highly saline and slightly alkali (EC > 15 dS/m and ESP 15-25)	0
8	Highly saline and moderately alkali (EC > 15 dS/m and ESP 25- 40)	0
9	Highly saline and highly alkali (EC > 15 dS/m and ESP > 40)	234
	Total	19547

CHAPTER – V

DISCUSSION

CHAPTER- V

DISCUSSION

This chapter of thesis deals with interpretation of results and computed values of various relationship obtained from data recorded during the course of study on “**Delineation, Characterization and Mapping of Salt Affected Soils of Sheopur District of Madhya Pradesh using Remote Sensing and GIS Techniques**”. The interpretations have been made in light of findings and possible reasons described by other workers noticed during similar studies. The various parameters have been discussed under different subsequent headings.

5.1. Physico-chemical properties of surface soils

The salt affected soils are mostly located in Sheopur and Vijaypur tehsils of Sheopur district. The texture of surface soil graded in to loam, silty loam and clay loam. Most of the samples are dominated by silt particles. Out of 27 samples, 19 samples are representing the loam category.

Eighteen out of 27 samples collected from salt affected area of the district were characterized as alkali. The reaction of soil (pHs) in the surface layer is alkaline. The soil reaction (pHs) ranged from 7.9 to 8.6. Most of the samples depicted higher pHs i.e. > 8.0. The electrical conductivity of saturation extract (EC_e) is an important property to judge the behaviour of soil in respect of salinity/alkalinity. Nine soil samples of Sheopur district showed EC_e > 4 dSm⁻¹ was classified as saline-alkali (Richards, 1954). Among different cations, Na was the dominant one in all the soil samples and ranged from 2.2 to 227.7 me L⁻¹. This shows that the soils are saturated with Na followed by Ca and Mg. Gupta *et al.* (2000) also reported similar findings for soils of Jammu district of Jammu and Kashmir. The SAR values ranged between 1.2 and 59.5 (mmol L⁻¹)^{1/2}.

Among the exchangeable cations, Ca was the dominant one followed by Mg, Na and K. Exchangeable Ca, Mg and Na ranged from 105 to 24.5, 4.5 to 9.5 and 6.5 to 28.1 cmol (p⁺) kg⁻¹ respectively. Similar results were observed by Gupta *et al.* (2000). Cation exchange capacity (CEC) ranged from 23.5 to 48.9 cmol (p⁺) kg⁻¹, whereas, exchangeable sodium percentage (ESP) varied from

19.8 to 61.6 respectively. One samples from Sheopur and twelve samples from Vijaypur tehsils belonged to ESP greater than 50.

The content of Fe^{2+} , Cu^{2+} , Zn^{2+} and Mn^{2+} ranges between between 2.19 - 3.87, 1.79 – 1.92, 0.61 – 2.23 and 1.26 – 31.92 (mg kg^{-1}) respectively. The Fe content was below the critical limit of 5.0 mg/kg in all the samples. The content of Cu and Zn was above the critical limits (Cu – 0.2 and Zn – 0.6 mg kg^{-1}) in all the samples collected from salt affected areas of the district. Manganese content was below the critical level of 2.0 mg kg^{-1} in only 5 samples, whereas the content of Mn was very high i.e. > 10.0 mg kg^{-1} in 3 samples belonging to villages Daurad, Hurlpur and Iklod.

5.2. Morphology, characterization and classification of pedons

5.2.1. Soil colour

The morphology of the horizon samples from pedons examined in the salt affected area reveal light gray (10YR 7/2) to brown (10YR 5/3) colour in dry condition. Soil colour forms an important soil physical characteristic. It provides information for soil compositions i.e. mineralogy, organic matter, sesquioxides, soil moisture etc. It is one of the most important characteristics used for horizon differentiation. It is an index for other physical, chemical and biological properties of soils (Buol *et al.*, 1980).

5.2.2. Soil boundary

The layer between two adjoining horizon is termed as soil boundary. Clear smooth boundary was observed in most of the horizons in both the pedons. Clear and wavy boundary was noticed in pedon-1 between surface (0-11 cm) and subsurface horizon (11-30 cm). This was due to development of "Natric" horizon coupled with inversions of these layers. Similar observations were recorded by Raghuwanshi (2003) in the Bhind district of M.P.

5.2.3. Soil texture

The texture in the area varies from loam to clay loam. Most of the horizons are calcareous in nature with slightly hard to very hard consistence under dry condition and from slightly sticky to very sticky in moist condition.

Raghuwanshi (2003) also reported similar results for the salt affected soils of Bhind district of M.P.

5.2.4. Lithological discontinuity

The depth distribution pattern of sand, silt and clay was non-uniform in all profiles which indicated that the profiles were developed on stratified materials. The results are in line with the findings of Wang and Arnold (1973) ; Eswaran (1979), Dubey (1982) and Raghuwanshi (2003) who used particle size distribution to establish uniformity / discontinuity.

Sand/ silt ratio greater than 0.2 indicates lithological discontinuity (Table 5.1) and stratification (Smith and Wilding, 1972; Anand et al, 1977; Sharma et al., 1979, Smeck et al., 1981 and Dubey, 1982). The sand/ silt and (sand+silt)/ clay ratio in the present study indicated lithological discontinuity due to imprints of different fluvientic cycles of past owing to that the flood water containing sediments and salts gets deposited.

Table 5.1. Sand/silt and (sand+silt)/clay ratios in different pedons

Horizon	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Sand / Silt	(Sand+Silt)/ Clay
Pedon 1 - Pandola						
A1	0-11	43.52	38.72	17.76	1.12	4.63
AB	11-30	33.52	44.72	21.76	0.75	3.60
Bt1	30-66	23.52	52.72	23.76	0.45	3.21
Bt2	66-102	23.52	44.72	31.76	0.53	2.15
Bt21	102-127	27.52	44.72	27.76	0.62	2.60
Bt22	127-142+	31.52	44.72	23.76	0.70	3.21
Pedon 2 - Hurlpur						
A1	0-8	23.52	48.72	27.76	0.48	2.60
AB	8-17	27.52	46.72	25.76	0.59	2.88
Bt1	17-36	35.52	42.72	21.76	0.83	3.60
Bt2	36-49	43.52	44.72	11.76	0.97	7.50
Bt21	49-63	33.52	42.72	23.76	0.78	3.21
Bt22	63-91	29.52	44.72	25.76	0.66	2.88
Bt23	91-111	27.52	46.72	25.76	0.59	2.88
Bt24	111-130+	31.52	46.72	21.76	0.67	3.60

5.2.5. Soil structure

The structure ranges from weak, fine, massive to strong, fine, sub angular blocky. Similar observations were also reported by Subbaiah and Manickam (1992) and Singh (1999) in Chambal Plains of Rajasthan. The alkaline environment resulted in dispersion of clay particles which resulted in structure degradation.

5.2.6. Lime concretions

Mostly nodular with irregular shape lime (CaCO_3) was encountered in both the pedons. Its size ranged from 2 to 5 mm and its content ranged from 2 to 10 per cent. Shiva Rau and Kasinathan (1954) mentioned that the illuviation of calcium carbonate and occurrence of lime concentration could occur under high temperature coupled with precipitation below 1200 mm per annum.

5.2.7. Salinity alkalinity

Richards (1954) categorized the salt affected soils into saline, saline-alkali and alkali soils on the basis of pHs, salt concentration (ECe of saturation extract) and exchangeable sodium percentage (ESP). On the basis of these criteria, the two types of soils were encountered in the present study. Both the pedons under study had $\text{ESP} > 15$ and ECe more than 4.0 dSm^{-1} . Hence they qualified for saline-alkali category.

5.2.8. Micronutrients

On considering the critical limits (Lindsay & Norvell, 1978) Zn ($< 0.6 \text{ mg kg}^{-1}$), Cu ($< 0.2 \text{ mg kg}^{-1}$), Fe ($< 5.0 \text{ mg kg}^{-1}$), Mn ($< 2.0 \text{ mg kg}^{-1}$) the data obtained in the present study indicate that the salt affected soils are either low or approaching the critical limits of deficiency. The content of Fe^{2+} , Cu^{2+} , Zn^{2+} and Mn^{2+} ranged between 0.09 - 1.10, 1.28 - 2.59, .082 - 3.28 and 0.16 - 1.45 mgkg^{-1} respectively on considering both the pedons together. Similar observation were recorded by Sharma and Jha (1989) in salt affected soils of Bihar, where these soils contained less DTPA extractable Fe and Mn as compared to their normal counterparts.

In black soils (Inceptisols) of Maharashtra, Nipunage, *et. al.* (1996) observed that the available Mn, Zn, Cu and Fe ranged from 4.1 to 46.5, 0.1 to 0.5, 1.0 to 4.7 and 2.9 to 10.1 mg kg⁻¹, respectively. These micronutrient cations decreased with depth. The higher content of these cations in the surface layer may be due to variable intensity of pedogenic processes.

5.3. Relationship of soil properties with micronutrients

5.3.1. pH of the saturation paste (pHs)

Significant and positive relationship between soil pHs and Cu was noticed in case of pedons (Table 5.2). However, non significant relationship between pHs and DTPA extractable Fe, Cu, Zn & Mn was noticed in case of surface samples. Bhogal *et al.* (1993) reported that the availability of Zn and Cu was predominantly controlled by both pH and organic carbon.

5.3.2. Electrical conductivity of saturation extract

ECe with iron and copper had highly significant positive correlation (at 1% level) amongst both the pedons of the area (Table 5.2). However, DTPA extractable Fe, Cu, Zn & Mn have non significant relationship with ECe in case of surface samples. In Vertic and Typic Natrargids, the ECe revealed highly significant relationship with available Copper and significant relationship with available Zinc (Raghuwanshi, 2003).

5.3.3. Lime content (CaCO₃ %)

Highly negative relationship was found between lime content with manganese in both pedons (Typic Natrargids) and significant positive correlation was seen between lime with DTPA extractable Zn in case of surface samples (Table 5.2). In Vertic and Typic Natrargids, lime showed negative correlation with available copper and manganese (Raghuwanshi, 2003).

5.3.4. Sand, Silt and clay content

Significant positive relationship was observed in case of surface samples in between Fe and sand & silt. In pedons (Typic Natrargids) the relationship was found to be non-significant with sand, silt and clay.

5.3.5. Sodium Adsorption Ratio (SAR) and Exchangeable Sodium Percentage (ESP)

The SAR showed significant positive correlation with DTPA extractable Fe, Cu and Mn in case of pedons only. ESP indicated significant and negative relationship with available copper and zinc in case of surface samples, whereas, in case of pedons significant positive correlation was noticed with Cu (Table 5.2). Similar were the observation recorded by (Raghuwanshi, 2003)

5.3.6. Cation exchange capacity

The CEC indicated significant and negative relationship with available Mn in surface samples, whereas, in case of pedons it was positive and significant. Significantly positive relationship exist between CEC and iron in case of surface samples only (Table 5.2). The CEC indicated significant and negative relationship with available iron in Typic Natrargids of Bhind district of M.P. (Raghuwanshi, 2003)

Table 5.2. Correlation Coefficient

Soil Properties	Micronutrients			
	Fe ²⁺	Cu ²⁺	Zn ²⁺	Mn ²⁺
Surface samples				
pHs	-0.320	0.093	0.101	-0.221
ECe	-0.256	0.023	0.036	-0.166
CaCO ₃	0.079	0.368	0.466*	-0.291
Sand	0.571**	-0.292	-0.247	-0.078
Silt	-0.408*	0.246	0.286	-0.100
Clay	-0.198	0.070	-0.011	0.164
SAR	-0.208	-0.130	0.039	-0.105
ESP	-0.239	-0.543**	-0.385*	-0.001
CEC	0.521**	-0.318	-0.025	-0.429*
Critical value of r at 5% - 0.381 at 1% - 0.487				
Pedons				
pHs	0.241	0.565*	-0.225	-0.249
ECe	0.763**	0.922**	-0.072	0.348
CaCO ₃	-0.453	-0.258	-0.073	-0.681**
Sand	0.073	0.339	0.170	-0.079
Silt	0.361	-0.159	0.006	0.050
Clay	-0.338	-0.355	-0.235	0.074
SAR	0.743**	0.827**	-0.026	0.612*
ESP	0.421	0.771**	-0.206	0.239
CEC	0.185	0.348	0.091	0.616*
Critical value of r at 5% - 0.532 at 1% - 0.661				

*Significant at 5% level ** Significant at 1% level

CHAPTER – VI

SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FURTHER WORK

CHAPTER-VI

SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FURTHER WORK

The results of investigation “**Delineation, Characterization and Mapping of Salt Affected Soils of Sheopur District of Madhya Pradesh using Remote Sensing and GIS Techniques**” carried out can be summarized as following:

1. The salt affected soils are mostly located in Sheopur and Vijaypur tehsils of the district as identified with the help of visual interpretation of the digital data as well as ground truthing.
2. The area of Salt Affected Soils in Sheopur district is 19,547 ha (5.1 % of the total geographical area and 12.8 % of the net sown area of the district).
3. The area under different categories of salinity and alkalinity was Slightly Saline-Slight Alkali is 7761 ha affecting 55 villages; the slightly saline and moderately alkali category occupies 7781 ha in 35 villages. The slightly saline and highly alkali soils were encountered in 29 villages infesting 3641 ha. An area of 123 ha was found to be under moderately saline and highly alkali class in 2 villages. Highly saline and highly alkali soils occupied 234 ha in 4 villages.
4. Salinity/ alkalinity problem exist in the area as evidenced by analysis of surface samples. The pH of saturation extract varied from 7.8 to 8.6, the EC_e had wide range between 0.9 and 22.2 dSm⁻¹ and the SAR from 1.2 to 59.5 (mmol L⁻¹)^{1/2}. The texture varied from loam to clay loam.
5. Among different cations, Na was the dominant one in all the soil samples and ranged from 2.2 to 227.7 me L⁻¹. This shows that the soils are saturated with Na followed by Ca and Mg.

6. Exchangeable Sodium was the dominant cation followed by Ca, Mg and K. Exchangeable Ca, Mg and Na ranged from 10.5 to 24.5, 4.5 to 9.5 and 6.5 to 28.1 cmol (p⁺) kg⁻¹ respectively.
7. Cation exchange capacity (CEC) ranged from 23.5 to 48.9 cmol (p⁺) kg⁻¹, whereas, exchangeable sodium percentage (ESP) varied from 19.8 to 61.6. One samples from Sheopur and twelve samples from Vijaypur tehsils belonged to ESP greater than 50.
8. The DTPA extractable micronutrients content (viz., Fe, Cu, Zn and Mn) ranges between 2.19 - 3.87, 1.79 – 1.92, 0.61 – 2.23 and 1.26 – 31.92 mg kg⁻¹ respectively. The Fe content was below the critical limit of 5.0 mg kg⁻¹ in all the samples. The content of Cu and Zn was above the critical limits (Cu – 0.2 and Zn – 0.6 mg kg⁻¹) in all the samples collected from salt affected areas of the district. Manganese content was below the critical level of 2.0 mg kg⁻¹ in only 5 samples, whereas the content of Mn was very high i.e. > 10.0 mg kg⁻¹ in 3 samples belonging to villages Daurad, Hurlpur and Iklod.
9. The morphological examination of the typical pedons (2) revealed light gray (10 YR 7/2) to brown (10YR 5.3) colour. The structure ranges from weak, fine, massive to strong, fine, sub angular blocky. All pedons showed slightly hard to very hard consistence under dry condition, which changed from from slightly sticky to very sticky in moist condition.
10. The sand/silt and sand+silt /clay ratio indicate lithological discontinuity in pedons indicating the imprints of different fluventic cycles of past.
11. In general, the pH of saturation extract varied from 7.9 to 10.1; the ECe between 1.9 and 15.7 dSm⁻¹ and the SAR from 29.2 to 69.4 (mmol L⁻¹)^{1/2}. The ESP had a range from 10.4 to 82.2 and CaCO₃ % ranged from 6.0 to 36.0 per cent. The sand varied from 23.5 to 53.5 %; the silt from 38.7 to 52.7 % and the clay from 11.8 to 31.8 %. The cation exchange capacity of these soils varied from 30.6 to 48.5 cmol(p⁺) kg⁻¹.

12. The content of Fe, Cu, Zn and Mn ranged between 0.09 - 1.10, 1.28 - 2.59, .082 - 3.28 and 0.16 - 1.45 mg/kg respectively on considering both the pedons together
13. The salt affected soils belong to Aridisols order. Both the pedons were classified as Typic Natrargids.
14. The map showing salt affected soils of the district was generated at 1:200,000 scale using Remote sensing and GIS technique.

Conclusions:

1. The salt affected soils are mostly located in Sheopur and Vijaypur tehsils of the district. The area of Salt Affected Soils in Sheopur district is 19,547 ha. The soils were either alkali or saline alkali in nature. The texture varied from loam to clay loam.
2. Cation exchange capacity (CEC) ranged from 23.5 to 48.9 cmol (p⁺) kg⁻¹, and ESP varied from 19.8 to 61.6. Exchangeable Na was the dominant cation followed by Ca, Mg and K.
3. The DTPA extractable Fe content was below the critical limit of 5.0 mg kg⁻¹ in all the samples.
4. The sand/silt and sand+silt /clay ratio indicate lithological discontinuity in pedons indicating the imprints of different fluventic cycles of past.
5. The pHs and ECe varied from 7.9 to 10.1 and 1.9 and 15.7 dSm⁻¹ respectively. The ESP ranged between 10.4 - 82.2 taking both the pedons together.
6. The content of Fe and Mn was below the critical limit, whereas, the content of Cu and Zn was above the critical limit on considering both the pedons together
7. The salt affected soils belong to Aridisols order. Both the pedons were classified as Typic Natrargids.

Suggestions for further work

1. Mineralogical and total elemental composition of salt affected soils of sheopur district should be studied.
2. The similar study of salt affected soils should be performed in other districts of M.P.

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VITA

VITA

The author of this thesis ***Dharmendra Singh Yadav S/o Mr. Radhe Shyam Yadav*** was born on 10th June 1982 at Kirathpur village of Morena district of Madhya Pradesh. He completed primary education at native place. He passed high school examination of M.P. Board, Bhopal from S.K.H.S. school Jalalpur, Morena in year 1998 and higher secondary school examination of M.P. Board, Morena from Convent Higher Secondary School Morena with first division (68.2%) in year of 2001.

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He is now submitting the thesis after completing the course with 6.55 OGPA out of 10.00-point scale.