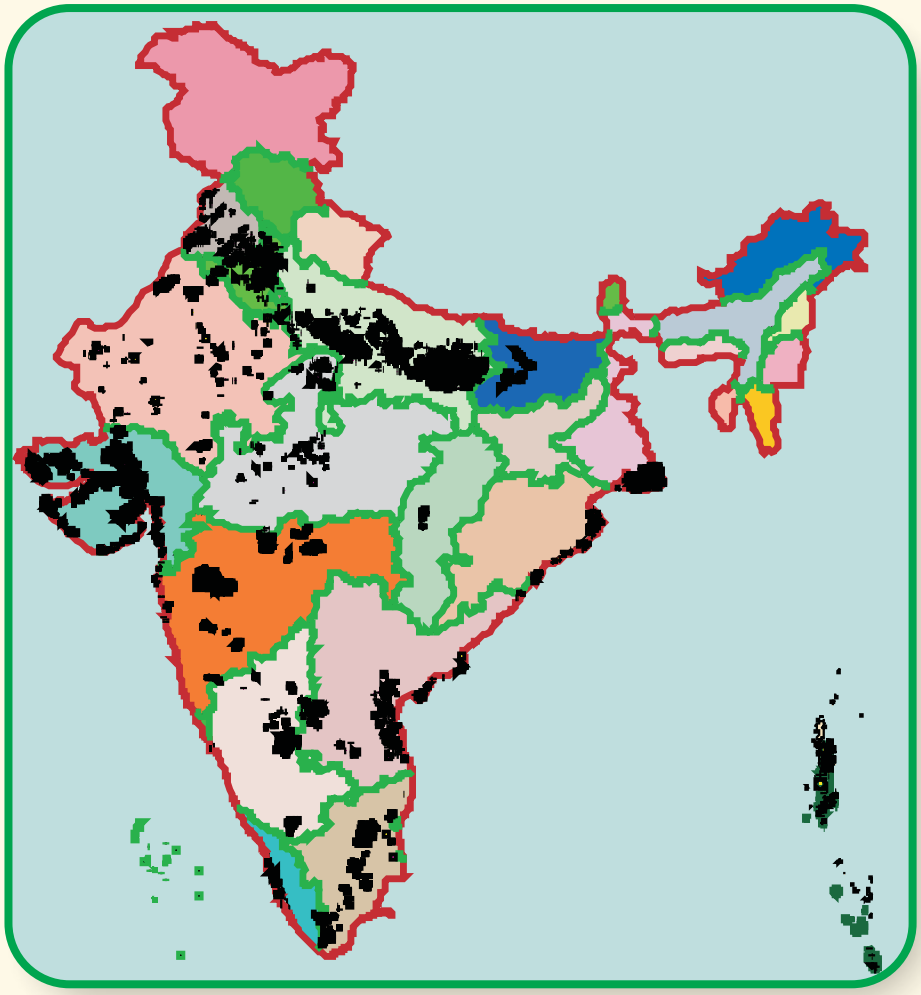
Technical Bulletin : CSSRI/Karnal/2/2010

COMPUTERIZED DATABASE ON SALT AFFECTED SOILS IN INDIA



A. K. Mandal
R. C. Sharma
Gurbachan Singh
J. C. Dagar

Central Soil Salinity Research Institute
KARNAL-132 001, HARYANA
2010

Citation :

A. K. Mandal, Sharma, R. C., Singh, Gurbachan and Dagar, J. C. (2010) Computerized Database on Salt Affected Soil in India. CSSRI Publ. No. 2/2010, Karnal, pp- 15.

Technical

Randhir Singh, Sh. Vijay Kumar Sehgal, Sh. Naresh, Parsha,

Published by :

Director Central Soil Salinity Research Institute
Karnal - 132001 (Haryana) India
Phone: 0184-2290501, Fax: 0184-2290480
E-mail: director@cssri.ernet.in. Website: www.cssri.org

Printed at :

Azad Hind Stores (P) Ltd.
S.C.O. 34, Sector 17-E, Chandigarh
Tel.: 0172-2704511-514; Fax : 0172-2704513
E-mail : ahsprinters@gmail.com

Technical Bulletin : CSSRI/Karnal/2/2010

COMPUTERIZED DATABASE ON SALT AFFECTED SOILS IN INDIA

A. K. Mandal
R. C. Sharma
Gurbachan Singh
J. C. Dagar

Central Soil Salinity Research Institute
KARNAL-132 001, HARYANA

2010

CONTENTS

ACKNOWLEDGEMENTS

The authors are thankful to the National Remote Sensing Centre, Hyderabad for providing the Salt Affected Soils maps for fifteen states in India. Special thanks are due to Dr. C. D. Thatte and Dr. S. K Gupta, Ex-Chairman and Member, Research Advisory Committee (RAC), Dr. N. K. Tyagi, Ex-Director and Member ASRB, Dr. Anand Swarup, Ex-Head, Soil and Crop Management Division and Head, SSAC, IARI, New Delhi and Dr. M. Sethi Principal Scientist, CSSRI, Karnal for necessary facilities and constant encouragement for initiating the work. The authors also thank Dr. Deepak Sarkar, Director, Dr. A. K. Maji, Head, Remote Sensing Application, Dr. G. P. Obi Reddy, Senior Scientist, GIS Section and Sh. Sunil Meshram, GIS laboratory, NBSS&LUP, Nagpur and Director, HSMITC, Haryana for necessary supporting documents and facilities to compile information. The technical support from Sh. Parshottom Lal, Sh. Naresh Kumar and Sh. Madan Poswal of CSSRI Karnal is also acknowledged

EXECUTIVE SUMMARY

Computerized database on salt affected soils is developed using Geographic Information System (GIS). These maps on 1:250,000 scale are geo-referenced and digitized. A relational database is developed in GIS linking polygons of salt affected soils and soil characteristics. State-wise estimate of salt affected soils are prepared from State maps for fourteen states and one Union territory (Andaman & Nicobar Islands). A total area of 6.7 Mha of salt affected soils is estimated at the country scale. These soils are variable in nature and distributed in nine physiographic units (A, B, C, D, F, G and H). Fifteen categories of soils were identified. These were merged to two categories i.e. saline and sodic for management purposes. Out of 6.7 Mha, saline and sodic soils covered 2.9 Mha and 3.7 Mha respectively. The spatial distribution of sodic soils showed common occurrence in the arid and semiarid regions and the saline soils in the coastal region intercepted by the frequent ingression of saline sea water. Significant area of sodic soils are distributed in the Gangetic plain in Uttar Pradesh, Punjab, Haryana and Bihar, the arid plains of Gujarat and Rajasthan and the peninsular plain of Madhya Pradesh, Maharashtra, Andhra Pradesh, Tamil Nadu and Karnataka. Saline soils are distributed in the coastal, deltaic plains and mangrove regions in Gujarat, Maharashtra, Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, Orissa, West Bengal and the Andaman and Nicobar Islands. The inland saline soils are predominantly found in Gujarat and Rajasthan. The regional databases were prepared for agro-climatic zones. These database also allow superimposition of related datasets such as climate, geology etc. useful for reclamation and management.

COMPUTERIZED DATABASE ON SALT AFFECTED SOILS IN INDIA

Introduction

Resource inventories of salt affected soils contain voluminous information on soil and physiography embedded with administrative/ political boundary, irrigation/drainage, settlements and infrastructure. Such data in the analogue form is difficult to apprehend and handle by the users of varied interest and background. Computerized information technology such as Geographic Information System (GIS) facilitates systematic storage, easy retrieval and analysis with multiple datasets for thematic output vital for planning management of natural resources. Digital database on soil salinity (which is dynamic in nature) can easily be interacted with any other datasets to infer and prepare location specific salinity/ alkalinity reclamation and management plans. An attempt has been made to develop a computerized database of salt affected soils in India using GIS. The methodology and outputs are elaborated in this publication.

Global and national scenario of salt affected soils

The FAO-UNESCO Soil Map of the World is an important soil information prepared at global scale (FAO 1996) while GLASOD, SOTER, WISE, and ISIS are some useful global databases developed for specific purposes (Oldeman and Van Englen 1993, Batjes 1996, King *et al.* 1994 and Stolbovoi *et al*. 2001). The Land and Plant Nutrition Management Services of FAO (www.fao.org/AG/AGLL/SPUSH) under Global network on the integrated soil management for sustainable use of salt affected soils created databases on the distribution and extent of salt affected soils useful at regional scale. Similarly national databases of some other countries on suitable scales are also available to support natural resource management, for example SSURGO, STATSGO and NATSGO in USA (Lytle 1993); CanSIS, NCDB and AAFC of Canada (Coote and MacDonald 2000) and ASRIS in Australia (Johnston *et al*. 2003).

Based on the soil map of the World, the regional estimate of the saline and sodic soils is 397 and 434 million hectares that constitutes about 15% of the of global land area (FAO 1997). These are distributed essentially in the Asia and the Pacific, Australia (8%), Europe (3.6%) and Latin America (2.5 %). Besides, Oldeman *et al*. (1991) also reported nearly 77 M ha of the Global land areas as salt affected due to human induced salinization while Tanji (1995) concurred that saline seep in dryland agriculture and secondary salinization in irrigated agriculture occupied 19.5% of the total area. In India, several estimates ranging from 7.0 to 26.0 M ha were reported by various agencies that were inconclusive for example, MOA (1994) reported 6.3 Mha, NCA (1976) 7.16 Mha, SPWD (1993) 7.17 Mha, NRSA (1993) 3.90 Mha, NBSS&LUP (1994) 6.20 Mha, Massoud (1974) 23.2 Mha, Abrol and Bhumbla (1971) 7.0 Mha.

The National Remote Sensing Agency (NRSA), Hydearabad, has prepared state-wise salt affected soils maps of India jointly with CSSRI, Karnal, NBSS & LUP, Nagpur, CAZRI, Jodhpur (ICAR)

and State agencies such as State Agricultural Universities and State Remote Sensing Application Centers. Integration of LANDSAT data and ground truth was used to prepare salt affected soils maps overlaying the administrative and political boundaries, infrastructure, irrigation / drainage and settlements. The map legend showed codes and description of physiographic units and soil characteristics describing nature, degree and extent of salinity/ sodicity. Using map scale of 1:250,000 voluminous data on the distribution and extent of salt affected soils in India was produced on 112 map sheets (Fig. 1).

GIS is an important tool to store and retrieve voluminous data useful for management of natural resources. Mandal and Sharma (2001) successfully integrated GIS overlay of topology with the spatial and nonspatial soil attribute to aid in the management of soil salinity in irrigated agriculture. Using ILWIS, GIS software, Mandal and Sharma (2005, 2006) worked upon the analogue maps of salt affected soils to accomplish digitization and prepare relational databases of soils attributes comprising of 14 states and one Union Territory in India. Thus geo-referencing of maps helped in superimposing various point and linear data layers to generate several thematic maps that are specific to a particular zone or region.

Data, Software and Equipments Used

The following tools were used to prepare computerized database of salt affected soils in India

- **Salt Affected Soils** maps on 1:250,000 scale
- The Survey of India maps on suitable scale
- Software ILWIS (*Integrated Land and Water Information System)*
- A Cal Comp (A_0 size) digitizer for geo-referencing and map digitization
- A Pentium (IV) computer with MS Office for entry, editing and data analysis.
- A scanner for scanning input data such as maps and figures
- A Printer for drawing printing outputs of maps, figures etc.

Methodology

The methodology includes geo-referencing and digitization of map coordinates with appropriate projection, datum and ellipsoid information to relate with the real world coordinates (Fig. 2). Digitization facilitates conversion of analogue data such as spatial or map features and non-spatial or attribute (soil characteristics) information to digital format suitable for easy access, quick retrieval and spatial analysis in multiple layers. The spatial data includes the map features for administrative and political boundaries, infrastructure, settlements, irrigation / drainage in the Survey of India topomaps and the polygons of salt affected soils in salt affected soils maps on 1:250,000 scale. The non-spatial data include physico-chemical properties such as soil reaction (pH), the electrical conductance (ECe) and exchangeable sodium percentage (ESP) required for soil characterization and legend development. Georeferenced maps and attribute data are linked to develop a relational database for retrieval of the geographic location and soil attributes suitable for planning and management of salt affected soils (Fig. 2).

Such data superimposed with related datasets like climate, water table depth, water quality and landform produce integrated database suitable for regional scale management of salt affected soils in Haryana (Fig. 3). At the country scale, agro-climatic zones (Ghosh 1991), rainfall/ temperature (NBSS&LUP 2002) and geology or parent materials (GSI 1948) data are also used for digital analysis to know spatial association with salt affected soils. Detail techniques are described below:

Geo-referencing and digitization of maps for salt affected soils

Geo-referencing of maps is an important activity prior to digitization. A digital file was created entering the boundary coordinates for the study area. The analogue map was fixed on a digitizer attached to the ILWIS software and a Pentium (IV) computer. The latitude/ longitude coordinates of the analogue map were transformed to a metric coordinate using Universal Transverse Mercator (UTM) projection with ellipsoid and datum information suitable for universal application. The maps were geo-referenced using *Map Referencing* technique. For this, the corner coordinates (*tic points*) of the analogue maps were entered into the map referencing dialogue box and digitized to maximum of four *tic points* that calculates the *Affine Transformation Coefficient (sigma value). Such process* establishes a spatial relation between the map and digitizers coordinates and the sigma value that assesses the accuracy of geo-referencing. The features such as administrative and political boundaries (country/state/district), irrigation / drainage (canal/ river), infrastructure (road/ railway), settlements (state/district capitals) were digitized using the Survey of India topomaps and stored as separate theme layers. The aerial coverage of salt affected soils units were digitized from the salt affected soils maps and stored as polygons of the salt affected soils. The codes and description of the map legends were stored in a *domain* file and linked with the map file. The color of the legend were stored in a *representation* file and linked with the domain items. The physico-chemical characteristics of salt affected soils were stored in an attribute table as shown in Fig. 2

Development of State/Regional/Country map

The thematic layers such as state/district boundaries, roads / railways, canal/river and state/district HQs were superimposed in GIS to develop a basemap. Overlaying thematic layers of the salt affected soil polygon and the basemap, the State map of salt affected soils was prepared. Using such methodology, the salt affected soil maps of fourteen states and one union territory (A&N) were prepared. The geo-referenced maps were integrated in GIS and a composite map of salt affected soils in India was prepared. The state maps were also used for development of regional database such as the Indo-Gangetic Plain, the Central and Western arid and semiarid region and the peninsular plain of India for regional planning. These were annotated for legends, texts, coordinates, gridlines and scale.

Development of attribute database : Map legends and soil characteristics

The terrain and chemical characteristics of soils were entered in an attribute table (Table 1). The chemical characteristics of soils such as pHs, ECe and ESP values were entered in columns with suitable domain describing nature of soils as saline, sodic and saline-sodic; degree of salinity/ sodicity as slight, moderate and strong and the extent of area as <1/3, 1/3-2/3 and >2/3 as

Table 1 : Description of map legend

Physiography		Nature of salt affected soils		Degree of salinity / sodicity		Extent of area in mapping unit	
Code	Description	Code	Description	Code	Description	Description	Color
A	Alluvial plain	s	Saline	1	Slight	<1/3	Yellow
B	Aeofluvial/ Aeolian/ Arid Plain	n	Sodic	2	Moderate	1/3-2/3	Orange
C	Deltaic Plain	sn	Saline-Sodic	3	Strong	>2/3	Magenta
D	Coastal Plain		Normal				
F	Peninsular Plain						
G	Mud Flats/ Mangrove Swamps						

described in the map legends (Fig. 1). These were coded as 's' for *saline*, 'n' for *sodic* and 'sn' for *saline-sodic* and numbered as '1' for *slight*, '2' for *moderate* and '3' for *strong* and represented by *yellow*, *orang*e and *magenta* color for the extent of area as <1/3, 1/3-2/3 and >2/3, respectively.

The ranges of ECe (4.0-8.0, 8.1-30.0 and >30 dS m-1), pH (8.5-9.0, 9.1-9.8 and >9.0) and ESP (<15, 15-40, >40) values (Table 2) were used to define slight, moderate and strong categories using USDA approach (Richards 1954). The codes A to G were used to define physiographic units such as 'A' for *alluvial*, 'B' for *aeofluvial /aeolian / arid*, 'C' for *deltaic,* 'D' for *coastal,* 'F' for *peninsular,* 'G' for *mud flats/ mangrove swamps and* '*H*' *for others units.* Thus fifteen categories of soils were identified (Table 3). It included three categories of saline soil (s1, s2 and s3), three for sodic soil (n1, n2 and n3) and nine for saline-sodic soils (s1n1, s1n2, s1n3, s2n1, s2n2, s2n3, s3n1, s3n2 and s3n3). Keeping in view the scale limitation and soil management aspects, these categories were merged and two categories of salt affected soils such as saline and sodic were identified. The attribute table containing soil physico-chemical properties were linked with the geo-referenced map features to generate a relational database.

Table 2 : Keys to the degree of salinity/sodicity

Degrees	Salinity	Sodicity	
	ECe (dS m^{-1})	pHs	ESP
Slight	4.0-8.0	8.5-9.0	< 15
Moderate	8.1-30.0	9.1-9.8	15-40
Strong	> 30	> 9.8	>40

Interactive database with agro-climatic, rainfall, temperature, geology maps etc.

The agro-climatic (Ghosh 1991), rainfall, temperature (NBSS&LUP 2002) and the geology / parent material zones (GSI 1958) were geo-referenced and digitized using ILWIS.GIS. These maps with similar geo-references were superimposed with salt affected soil map to develop interactive database to show spatial association with salt affected soils of India. Similarly, the rainfall, landform, water table depth, water quality maps of Haryana were digitized using the NBSS&LUP maps (Sachdeva *et al.*1995) and HSMITC (2001) data.

Fig. 3. in full Portrait format

Extent and Distribution of Salt Affected Soils

At state, regional and country scale

The salt affected soils are distributed in fourteen states and the Andaman & Nicobar Islands (Fig. 4). An extensive area is occurring in the Indo-Gangetic Plain (IGP) of Uttar Pradesh, Bihar, Haryana, Punjab and West Bengal. It also occupied significant area in the arid and semiarid

Table 3 : Description of soil characteristics

Code	Categories of SAS	ECe ($dS\ m^{-1}$)	Salinity Classes	pH Range	ESP Range	Sodicity Classes
s1	Slightly Saline	4.0-8.0	Slight	Low	Traces	Low
s2	Moderately Saline	8.1-30.0	Moderate	Low	Traces	Low
s3	Strongly Saline	>30.0	Strong	Low	Traces	Low
n1	Slightly Sodic	Low	Low	8.5-9.0	<15	Slight
n2	Moderately Sodic	Low	Low	9.1-9.8	15-40	Moderate
n3	Strongly Sodic	Low	Low	>9.8	>40	Strong
s1n1	Slightly Saline, Slightly Sodic	4.0-8.0	Slight	8.5-9.0	< 15	Slight
s1n2	Slightly Saline, Moderately Sodic	4.0-8.0	Slight	9.1-9.8	15-40	Moderate
s1n3	Slightly Saline, Strongly Sodic	4.0-8.0	Slight	>9.8	>40	Strong
s2n1	Moderately Saline, Slightly Sodic	8.1-30.0	Moderate	8.5-9.0	<15	Slight
s2n2	Moderately Saline, Moderately Sodic	8.1-30.0	Moderate	9.1-9.8	15-40	Moderate
s2n3	Moderately Saline, Strongly Sodic	8.1-30.0	Moderate	>9.8	>40	Strong
s3n1	Strongly saline, Slightly sodic	>30.00	Strong	8.5-9.0	<15	Slight
s3n2	Strongly saline, Moderately sodic	>30.0	Strong	9.1-9.8	15-40	Moderate
s3n3	Strongly saline, Strongly sodic	>30.0	Strong	>9.8	>40	Strong

regions of Gujarat, Rajasthan, Madhya Pradesh and Maharashtra and the peninsular region of Maharashtra, Karnataka, Tamil Nadu, Andhra Pradesh and Orissa. Sizeable area is distributed in east and west coast of Andhra Pradesh, Orissa, Tamil Nadu, Kerala, Karnataka, Maharashtra, Gujarat and the Islands of Andaman & Nicobar. Substantial area is also occurring in various canal commands such as Sharda Sahayak in Uttar Pradesh, Tungabhadra in Karnataka; the IGNP (Indira Gandhi Nahar Pariyojona), Chambal and Tawa in Rajasthan and Madhya Pradesh, Mahi and Ukai command area in Gujarat. State-wise estimate are presented in Table 4. The areas under saline and sodic soils are also estimated to assess nature, severity of degradation and management needs.

Fig. 4. in Portrait full page

Saline Soils

Out of 6727468 ha, the saline soils have occupied 2956809 ha (44%) and distributed in twelve states and one UT (Table 4). These are inland and coastal saline soils located in the arid/ semiarid regions associated with poor quality ground water and coastal areas with frequent inundation of saline seawater (Fig. 5). About 1.75 Mha is under inland salinity and 1.2 Mha is distributed in the east and west coast of India. Significant area is located in Gujarat, Andhra Pradesh, West Bengal, Orissa, Tamil Nadu and Andaman and Nicobar islands. In Gujarat, extensive area is found in Kachchh, Banaskantha, Jamnagar, Bhavnagar, Rajkot and Surendranagar districts. These are slight (44%), moderate (26%) and strongly (18%) saline in nature. In the East Coast, these soils are located in the East and West Godavari, Krishna and Srikakulam districts of Andhra Pradesh; Midnapur and 24-Parganas districts in West Bengal and Kendrapara, Puri, Bhadrak, Baleswar,

Table 4 : State-wise extent and distribution of salt affected soils in India

Sl. No.	State	Saline Soils (ha)	Sodic Soils (ha)	Total (ha)
1	Andhra Pradesh	77598	196609	274207
2	Andaman & Nicobar	77000	0	77000
3	Bihar	47301	105852	153153
4	Gujarat	1680570	541430	2222000
5	Haryana	49157	183399	232556
6	Karnataka	1893	148136	150029
7	Kerala	20000	0	20000
8	Maharashtra	184089	422670	606759
9	Madhya Pradesh	0	139720	139720
10	Orissa	147138	0	147138
11	Punjab	0	151717	151717
12	Rajasthan	195571	179371	374942
13	Tamil Nadu	13231	354784	368015
14	Uttar Pradesh	21989	1346971	1368960
15	West Bengal	441272	0	441272
Total		2956809	3770659	6727468

Ganjam and Jagatsinghapur districts in Orissa. These are strongly (27%) saline in Andhra Pradesh, slight, moderate and strongly saline in West Bengal and Orissa respectively. In the island areas, these are strongly saline and located in the South and Middle Andaman and North Andaman and Mayabandar.

In the inland plains, saline soils are identified in Gujarat (17%), Rajasthan (6.6%), Maharashtra (5.9%), Karnataka (0.06%), Haryana (1.6%) and Bihar (1.6%) states. These soils are mostly occurring in the arid and semiarid areas of Rajasthan located in Jalor, Bhilwara, Ajmer, Churu, Barmer and Pali district. In Haryana these are common in Jind, Hisar, Sirsa, Rohtak and Jhajjar districts. In Gujarat, these soils are distributed in Surendranagar, Ahamadabad, Jamnagar, Rajkot and Amreli districts. These are also found in West Maharashtra primarily confined in Pune, Thane, Sangli, Satara and Rayagad districts and in Saran district of Bihar.

Fig. 5 in Portrait full page

Fig.6 in Portrait full page

Sodic soils

Sodic soils have occupied 3770659 ha covering 66% of the total area (Table 3). These soils are essentially located in the Indo-Gangetic Plain, arid and semiarid region in Western and Central India and the Peninsular Region in the Southern India (Figure 6). State-wise extent and distribution showed that significant area is located in Uttar Pradesh, Gujarat, Maharashtra, Tamil Nadu, Andhra Pradesh, Haryana, Rajasthan, Punjab, Karnataka, Madhya Pradesh and Bihar. In the Indo-Gangetic Plain, these soils have occupied 1787759 ha covering 47% of the total area in Uttar Pradesh, Haryana, Punjab and Bihar states (Fig. 7). In Uttar Pradesh, these are distributed significantly in the Upper-, Middle- and Lower Gangetic Plain region covering Mainpuri, Azamgarh, Etawah, Raebareli, Hardoi, Sultanpur, Jaunpur, Pratapgarh, Etah and Unnao districts. In Punjab, considerable area is found in the Trans-Gangetic Plain region of Ferozpur, Sangrur, Amritsar, Faridkot, Mansa and Patiala districts. In Haryana, sodic soils are commonly occurring in the Central Haryana covering Panipat, Sonepat, Kaithal, Karnal, Jind and Kurukshetra districts. Overlaying irrigation network layer on salt affected soils, a large area under salt infestation is found around the irrigated region of WesternYamuna and Bhakra canals in Haryana, Sirhind and Rajasthan Feeder canals in Punjab, Ganga and Sharda Sahayak canals in Uttar Pradesh and Gandak and Kosi canal commands in Bihar. Further, superimposition of water quality maps with salt affected soils showed substantial areas under salinity/ sodicity underlain by saline/ sodic ground water. The soils are moderately and strongly sodic in Uttar Pradesh, slight and moderately sodic in Haryana, Punjab and Bihar.

Significant area (35%) of sodic soils is found in the arid and semiarid regions covering Gujarat, Rajasthan, Madhya Pradesh and Maharashtra states (Fig. 8). In Gujarat, these are found in the Mehsana, Ahamadabad, Surendranagar, Banaskantha and Junagadh districts. These are strongly (18%) and moderately (5%) saline in nature. In Rajasthan, slightly (41%) and moderately (6%) sodic soils are found in Chhitorgarh, Udaipur, Hanumangarh, Ganganagar and Jaisalmer district in central and northern part. Slightly (69%) sodic soils are found in Western Maharashtra and

Vidarbaha region covering Ahmadnagar, Jalgaon, Akola, Solapur, Buldana, Amravati, Nasik, Kolhapur and Aurangabad districts. In Madhya Pradesh, slightly (79%) sodic soils are occurring in Gwalior, Bhind, Morena, Vidisha and Ujjain districts.

In the Peninsular region, sodic soils have occupied extensive areas (18%) in Tamil Nadu, Andhra Pradesh and Karnataka States (Figure 9). These are essentially found in the central Tamil Nadu covering Ramanathapuram, Cuddalore, Kanchipuram, Tirunelveli, Thanjavur, Pudukottai, Madurai and Tiruchirapalli districts. These soils are slightly (59%), moderately (32%) and strongly (4%) sodic in nature. Sodic soils are also found in Karnataka covering Chitradurga, Bellary, Raichur, and Mysore districts. These soils are slight (71%) and moderately (24%) sodic in character. Sodic soils are also distributed in the scarce rainfall zone of Rayalseema and Southern Zone of Andhra Pradesh covering Nalgonda, Anantpur, Krishna, Prakasam, East Godavari, Kurnool, Chittoor and Guntur districts. These are slight (41%), moderate (22%) and strongly (7%) sodic in nature.

Fig. 7 in full/half Portrait format whichever is suitable

Fig. 8 in full/half Portrait format whichever is suitable

Fig. 9 in full / half Portrait format whichever is suitable

Interactive Databases

Regional scale database in Haryana

The salt affected soils map of Haryana in digital format was superimposed to develop interactive databases with rainfall, landform, water table depth and water quality data useful for management of salt affected soils. Interaction of soils and rainfall data in Haryana has shown that 74% area is lying in the average annual rainfall zone of 400-600 mm, while 15% and 9% occur in the 600-800 mm and 300-400 mm zone, respectively. Similarly, digital interaction with landform zones indicate that 60% area lies in the old alluvial plain, 25% in the old alluvial plain with sand dune and 10% in the recent alluvial plain. Apart from this, the salt affected soils are also found in active alluvial plain (1.5%), Aravalli pediments (1.2%), Fluvio-aeolian plains (1%) and aeofluvial plain (0.6%). Interaction of salt affected soils with water tabled depth data revealed the existence in 66% of the total area in the water table depth of 3-10 m bgl while 30% lies in the 10-20 m bgl. The water quality zones also showed that 39% and 21% area lie in the saline and marginal ground water zone while 40% lies in the fresh ground water zone. Thus, spatial association of salt affected soils with related data revealed that rainfall, parent material and ground water are involved simultaneously in the distribution of salt affected soils in Haryana. Such studies also facilitate in locating and characterizing areas for site specific management options or alternate land uses in salinity affected areas and suitable technology for its reclamation.

Physiographic regions

The salt affected soils are distributed in major physiographic units including the Great Plain, Peninsular Plain and Coastal plain in India (Fig. 10). Significant area exists in the alluvial (38%),

peninsular (19%), aeofluvial/aeolian/arid (9%), coastal, deltaic and mud flats/ mangrove swamps (19%) and others (15%) regions (Table 5). In the alluvial plain, salt affected soils are distributed in Uttar Pradesh (53%), Gujarat (20%), Haryana (9%), Bihar (6%), Punjab (6%) and Karnataka (6%) States. These are sodic (76%) and saline (24%) in nature. In the Peninsular Plain (F), sodic (86%) and saline (14%) soils are distributed in Maharashtra (47%), Tamil Nadu (27%), Andhra Pradesh (15%) and Madhya Pradesh (11%). In the aeofluvial/aeolian/arid plains, saline soils are dominating that occupied 75% area in Gujarat (46%) and Rajasthan (54%).

In coastal region, saline soils are found in the coastal plain (D) of Gujarat (65%), Orissa (12%), Andhra Pradesh (8%), Kerala (3%), Tamil Nadu (2%), Maharashtra (1%), and Andaman and Nicobar (1.8%) islands. These are also located in the deltaic plain (C) of Orissa (28%) and West Bengal (72%) and in the mud flats/ mangrove swamps (G) of West Bengal (74%), Andaman and Nicobar (14%), Andhra Pradesh (6%) and Orissa (5.5%). Sodic soils are dominant in the alluvial plain of Uttar Pradesh (52%), Haryana (7%), Punjab (6%), Karnataka (5.7%) and Bihar (4%) State. These are also found in the arid plains of Rajasthan (23%) and Gujarat (2%); in the peninsular plains of Maharashtra (33%), Tamil Nadu (27%), Andhra Pradesh (15%) and Madhya Pradesh (11%) and in the coastal plain of Gujarat (5%), Andhra Pradesh (0.6%), Tamil Nadu (0.5%) and Karnataka (<0.1%). Thus alluvial, peninsular and coastal plains are prominent physiographic regions that showed substantial salt accumulation through river channels, sea water intrusion and presence of salt forming parent materials.

Fig.10 in full page Portrait

Table 5 : Distribution of salt affected soils in Physiographic regions

Sl. No	Name of the State	Physiographic Units							Total Area (ha)
		Alluvial Plain (A)	Aeofluvial/ aeolian/ arid Plain (B)	Deltaic Plain (C)	Coastal Plain (D)	Mud flats/ Mangrove Swamps (G)	Peninsular Plain (F)	Others (H)	
1.	AP	------	------	---	56423	25111	192673	----	274207
2.	A & N Islands	--------	-------	------	12366	64634	------	-----	77000
3.	Bihar	153153	-------	---	------	-----	-----	-----	153153
4.	Gujarat	510951	285574	---	462315	------	------	963160	2222000
5.	Haryana	232556	------	---	------	------	------	------	232556
6.	Karnataka	148922	-----	---	586	-----	521	-------	150029
7.	Kerala	------	------	---	20000	------	------	------	20000
8.	Maharashtra	------	------	---	6713	283	599763	----	606759
9.	M. P	------	------	---	-----	------	139720	------	139720
10.	Orissa	------	------	43023	79543	24572	------	------	147138
11.	Punjab	151717	------	------	------	------	------	------	151717
12.	Rajasthan	------	338128	------	------	------	------	36814	374942
13.	Tamil Nadu	------	-------	-------	16805	-------	351210	------	368015
14	U P	1368960	-------	------	------	-------	-------	-------	1368960
15.	W. Bengal	-------	------	109613	-------	331659	-------	-------	441272
Total		2566259	623702	152636	654751	446259	1283887	999974	6727468

Agro-climates

The climate and soil types showed an important role in the development of salt affected soils. Based on the climate, soil types and physiographic features, the Agro-climatic Zones (ACZ) and Regions (ACR) were delineated by the ICAR under NARP and further implemented by the Planning Commission of India for agricultural development (Ghosh 1991, Basu and Guha 1996). These maps were geo-referenced and superimposed the salt affected soils maps in GIS to prepare the regional database useful for planning salinity management. The salt affected soils are distributed in 13 regions and the zone-wise estimate of salt affected soils was prepared in GIS (Table 6). Higher extent is found in the Upper Gangetic Plain Region (12.6%) located along the course of river Ganges in the northern and central Uttar Pradesh. Considerable area is located in the Trans-Gangetic Plain Region (11.3%) along the Ganges and its tributaries in Punjab and Haryana States. Significant area is also found in the Middle Gangetic Plain Region (7%) at Uttar Pradesh and Bihar. In Lower (9.3%) Gangetic Plain Region, the salt affected soils are distributed along the Gangetic delta in West Bengal. Due to the influence of sea water inundation, a significant area is found in the East Coast Plain and Hills Region (13.7%) covering Orissa, Andhra Pradesh and Tamil Nadu states. Important area is also found in the Gujarat Plain and Hills Region (14.2%). Considerable area is found in Southern Plateau and Hills Region (7.9%) located in Andhra Pradesh, Tamil Nadu and Karnataka states.

About 10.7% of salt affected soils is found in the Central Plateau and Hills Region of Madhya Pradesh and Maharashtra. Salt affected soils are occurring also in the Western Dry Region (4.2%) located in Rajasthan, aridity and poor quality ground water are common occurrence that accentuates salt development in this region (Fig. 11). Such data facilitate planning and decision making in broad reclamation and management options for salt affected regions.

Fig. 11 in full page portrait

Table 6 : Distribution of salt affected soils in Agro-climatic Zones

Zone No.	Name of the zone	Salt affected area	
		ha	%
3.	Lower Gangetic Plains Region	628400	9.3
4.	Middle Gangetic Plains Region	476018	7.0
5.	Upper Gangetic Plains Region	848340	12.6
6	Trans-Gangetic Plains Region	765470	11.3
7.	Eastern Plateau & Hills Region	17280	0.5
8.	Central Plateau and Hills Region	719370	10.7
9.	Western Plateau & Hills Region	441550	6.5
10.	Southern Plateau & Hills Region	535090	7.9
11.	East Coast Plains and Hills Region	925310	13.7
12.	West Coast Plains and Hills Region	58080	0.9
13.	Gujarat Plain and Hills Region	953910	14.2
14.	Western Dry Region	282010	4.2
15	Island Region	77000	1.2
	Total	6727468	

Rainfall and temperature

The map of salt affected soils was superimposed with the rainfall distribution map of India (NBSS& LUP 2002) to develop an interactive database (Fig. 12) that show spatial interaction of salt affected soils with rainfall (Table 7). Significant area (51%) of salt affected soils is found in the low (<300 mm) to moderately low (500-800 mm) rainfall regions. These are distributed in Gujarat (64%), Rajasthan (10%), Uttar Pradesh (8%), Punjab (4%), Haryana (0.6%), Maharashtra (5%) and Karnataka (1.5%) States. Saline soils are dominant in low rainfall region occurring prominently in Gujarat (47%), and Rajasthan (5.7%) while sodic soils are also found to some extent in Uttar Pradesh (7%), Gujarat (5%), Maharashtra (5%), Rajasthan (4%), Haryana (4%) and Punjab (3.8%) and Karnataka (0.2%). Severe aridity and deficit rainfall, absence of proper leaching and the presence of poor quality of ground water are typical characteristics of this region facilitating salt development in soil profiles.

The salt affected soils covered 3021982 ha (45%) in the moderate (800-1000 mm) and moderately high (1000-1500 mm) rainfall regions. These are distributed in Uttar Pradesh (35%) and Bihar (5.3%) in IGP and Tamil Nadu (12%), Maharashtra (11%), Andhra Pradesh (6%) and Madhya Pradesh (4.4%) in the peninsular region. Sodic soils are dominant immoderate rainfall zone and distributed in Tamil Nadu (11%), Maharashtra (6%), Madhya Pradesh (4%) and Andhra Pradesh (3%), while saline soils are found in the moderately high rainfall zone distributed in West Bengal (14%), Maharashtra (5%), Andhra Pradesh (2%) and Tamil Nadu (0.5%) especially located along the sea coast. The salt affected soils are also commonly found in the high (1500-2000 mm), very high (2000-3000 mm) and excessive (>3000 mm) rainfall zones especially located along the sea coast. State-wise distribution showed that these soils (4%) are distributed in Kerala (7%), Orissa (5%), West Bengal (6%) and Maharashtra (1%); and Andaman and Nicobar islands (26.5%). These soils are essentially saline in nature.

Fig.12 in full page in portrait

Table 7 : Distribution of salt affected soils in relation to ranges rainfall

Sl. No.	Degree of Rainfall	Salt affected soils (ha)	%
1	Very Low (<300 mm)	138754	2.0
2	Low (300-500 mm)	1296767	19.4
3	Moderately Low (500-800 mm)	1983516	29.4
4	Moderate (800-1000 mm)	1255559	18.6
5	Moderately High (1000-1500 mm)	1762854	26.2
6	High (1500-2000 mm)	157882	2.3
7	Very High (2000-3000 mm)	32652	0.6
8	Excessive (>3000 mm)	99484	1.5
	Total	6727468	100

Salt affected soils are distributed in various temperature zones (Fig 13) ranging from Mild Hyperthermic (20-22.5°C) to Megathermic (>27°C). A significant area (**75.7%)** is occurring in Strong Hyperthermic (25-27.5°C) region (Table 8). These are distributed in Gujarat (36%), Uttar Pradesh (26%), West Bengal (8.5%), Maharashtra (6.3%), Rajasthan (5.3%), Andhra Pradesh (4.2%), and Bihar (2.6%). A considerable area (14.4%) is found in the Hyperthermic (22.5-25°C) region, distributed in Maharashtra (28%), Haryana (34%), Punjab (15%), Rajasthan (11%), Madhya Pradesh (8%) and Andhra Pradesh (6%). About 5.9% area is found in Mild Hyperthermic (20-22.5°C) region, distributed in Gujarat (94%) and Karnataka (6%). The SAS occupied 3.8% in the Megathermic zone (> 27.5°C) located in Tamil Nadu. The data showed that soil temperature is also an important factor operating parallel with other climatic parameters, and influence distribution of salt affected soils, higher in the Hyperthermic region.

Fig.13 in full page portrait

Geology/parent materials

Interactive databases were prepared to show spatial association of salt affected soils with geology / parent materials (GSI 1958), useful for salinity management (Fig 14). Salt affected soils were identified in seven geological formations ranging from Pleistocene and recent to cretaceous and Jurassic period (Table 9). Significant area (70%) is located in the Pleistocene and recent formations, distributed in the alluvial plain of Gujarat (32%), Uttar Pradesh (31%), West Bengal (10%), Rajasthan (7%), Bihar (4%) and Orissa (3.3%) states. Such data indicates sedimentary processes involved in accumulation of salts in large quantities with parent materials in the alluvial plains, primarily by transportation and deposition along the major rivers, originating from the Himalayas and Vindhyan ranges (Dhir 1998, Bhargava *et al.* 1981). These soils are sodic (38%) and saline (31%) in nature. The salt affected soils occupied 12.2% in the Deccan and Rajmahal trap region, covering coastal, aeolian/ aeofluvial/arid and peninsular plains of Gujarat (18.5%), Maharashtra (72%) and Madhya Pradesh (8%). These are also sodic (64%) and saline (36%) in nature. Due to volcanic origin of such parent materials, these soils are fine textured, develop cracks and fissures and contain adequate alkaline salts originating from the underlying basalts formation (Wadia 1966). About 9.7% is found in the Archaean Schist and gneisses formation mostly located in the peninsular, coastal and alluvial plains in Tamil Nadu (53%), Andhra Pradesh (25%) and Karnataka (17%) States (Wadia 1966). These are primarily sodic (9.5%) and

Table 8 Distribution of salt affected soils with respect to ranges of temperature

Sl. No.	Ranges of temperatures	Salt Affected Soils (ha)	%
1	Mild Hyperthermic (20-22.5°C)	403477	5.9
2	Hyperthermic (22.5-25°C)	972109	14.5
3	Strong Hyperthermic (25-27.5°C)	5094290	75.8
4	Megathermic (>27.5°C)	257592	3.8
	Total	6727468	100

Table 9 : Distribution of Salt affected soils in geological formations / parent materials

Sl. No.	Name of the geology / parent materials	Salt affected area (ha)			
		Saline	%	Sodic	%
1	Archaean Schist and Gneisses	8576	0.1	603766	9.5
2	Pleistocene and Recent	1962927	31.1	2449788	38.9
3	Dharwar Schist	0	0	86020	1.3
4	Lower Paleozoic	30706	0.5	67067	1.0
5	Deccan and Rajmahal trap	276746	4.4	493142	7.8
6	Tertiary	268016	4.3	22994	0.4
7	Cretaceous and Jurassic, Upper Gondwanas	38297	0.6	1343	0. 1

** The geology data for Orissa and Andaman and Nicobar islands is not available*

saline (0.13%). The salt affected soils are also found in the tertiary deposits (4.6%) along the coastal and river delta regions of Gujarat (62%), Andaman and Nicobar (26.4%) and Tamil Nadu (8.3%) states (Bhargava and Bhattacharjee 1982, Dhir 1998). These soils are mostly saline (4.2%) and sodic (0.36%) in nature. The salt affected soils are also found in the Lower Paleozoic formations (1.5%). It is distributed in the peninsular, coastal and alluvial plains of Andhra Pradesh (33%), Orissa (29%) and Rajasthan (29). These are commonly sodic (0.5%) and saline (1%) in nature. Similar association is also found with Dharwar Schist formation located in Karnataka (42%), Andhra Pradesh (30%) and Rajasthan (28%). These are mainly sodic (1.3%) in nature (Bhargava and Bhattacharjee 1982). Soils with Cretaceous and Jurassic formations are found near the Kachchh in Gujarat (85%) and West Rajasthan (15%). These are mostly located in the alluvial, aeofluvial/aeolian /arid and coastal plains, which is connected to the Jurassic Salt Range through the river course and marine currents (Wadia 1966). Such studies revealed the influence of different geological formations and parent materials on the nature, distribution and extent of salt affected soils in India.

Fig.14 in full page portrait

References

Basu DN and Guha GS. (1996). *Agro-climatic Regional Planning in India*. Concept Publishing Co., New Delhi, pp.330.

Batjes NH (*1996)*. The carbon and nitrogen in the soils of the world. *European Journal of Soil Science* **47:**151-163.

Bhargava GP and Bhattachrjee JC. (1982). Morphology, genesis and classification of salt affected soils. In: *Review of Soil Research in India* Part III International Congress of Soil Science, New Delhi, 507-528.

Bhargava GP, Pal DK, Kapoor BS and Goswami SC. (1981). Characteristics and genesis of some sodic soils in the Indo-Gangetic alluvial plains of Haryana and Uttar Pradesh. *Journal of the Indian Society of Soil Science* **29**(1): 61-70.

Coote DR and MacDonald KB. (2000). The Canadian Soil Database. In: Sumner, M (Ed.) *Handbook of Soil Science*, CRC Press, New York, H 41-51.

Dhir RP. (1998). Origin and accumulation of salts in soils and ground waters. In: Tyagi NK and Minhas PS (Eds.). *Agricultural Salinity Management in India*, CSSRI, Karnal, p. 41-60.

FAO (1996). *The Digitized Soils Map of the World Including Derived Soil Properties*, Food and Agricultural Organization, Rome.

FAO (1997). Production Yearbook, Food and Agricultural Organization, Rome, v. 48.

Ghosh SP. (1991). *Agroclimatic Zone Specific Research, Indian Perspective under NARP*, Indian Council of Agricultural Research (ICAR), New Delhi, pp. 1-539

GSI (1958). *Records of the Geological Survey of India*. Vol. **87** No. 4. Geological Survey of India, Calcutta.

HSMITC (2001). *Haryana Ground Water Quality Map*. Haryana State Minor Irrigation and Tubewell Corporation Limited, Government of Haryana, Chandigarh

Johnston RM, Barry SJ, Bleys E, Bui EN, Moran CJ, Simon DAP, Carlile P, McKenzie NJ, Henderson BL, Chapman G, Imoff M, Maschmidt D, Howe D, Grose C, Schoknecht N, Powell B and Grundy M. *(2003).* ASRIS: The database. *Australian Journal of Soil Research* **41:** 1021-1036.

King D, Daroussin J and Tavernier R. (1994). Development of a soil geographic database from the soil map of the European Communities. *Catena* **21:** 37-56.

Lytle DT. (1993). Digital soil databases for the United States. In: Goodchild MF, Parks BO and Steyaert LT. (Eds.) E*nvironmental Modeling with GIS*. Oxford University Press, New York, 386-391,

Mandal AK and Sharma RC. (2001). Mapping of waterlogged and salt affected soils in IGNP command area. *Journal of the Indian Society of Remote Sensing* **29(4)**: 229-235.

Mandal AK and Sharma RC. (2006). Computerized database of salt affected soils for Agro-climatic Regions in the Indo-Gangetic Plain in India using GIS. *Geocarto International* **21**(2): 47-57.

Mandal AK and Sharma RC. (2005). Computerized database on salt affected soils in Haryana State. *Journal of the Indian Society of Remote Sensing* **33**(3): 447-455.

NBSS & LUP (2002). *Soils of India*. NBSS Pub. No. 94, National Bureau of Soil Survey and Land use Planning, Nagpur, pp. 130

NRSA (1996). *Salt Affected Soils*. National Remote Sensing Agency. Department of Space Government of India, Hyderabad.

Oldeman LR and Van Enggelen VWP. *(1993).* A world soils and terrain digital database (SOTER) - An improved assessment of land resources. *Geoderma* **60:** 309-325.

Oldeman LR, Hakkeling RTA and Sombroek WG. (1991). Second Revised Edition of the World Map of the Status of Human Induced Soil Degradation. An exploratory note. International Soil Reference and Information Center (ISRIC), Wageningen. 35p.

Richards LA. (1954). *Diagnosis and improvement of Saline and Alkali soil*s. USDA Handbook No. 60, Washington, pp. 160

Sachdev CB, Lal T, Rana KPC, and Sehgal J. (1995). *Soils of Haryana for optimizing land use*. NBSS Publ. 44 (Soils of India Series 3), National Bureau of Soil Survey and Land Use Planning, Nagpur, India, 59p.

Stolbovoi V, Montanrella L, Medvedev V, Smeyan N, Shiskov L, Unguryan V, Dovrovaol Skii G, Jamgne M, King D, Rozov V and Savin I. (*2001).* Integration of data on the soils of Russia, Belarus, Moldova, and Ukraine into the soil geographic database of the European community. *Eurasian Soil Science,* **34:** 687-703

Tanji KK. (1995). Foreword. *In The Salinization of Land and Water Resources*: *Human causes, Extent, Management and Case Studies*. Centre for Resources and Environment Studies. The Australian National University, Pub. Cab International, Wallingford, Oxon.

Wadia DN. (1966). *Geology of India*. Third Edition, ELBS and Macmillan Co. Ltd. London

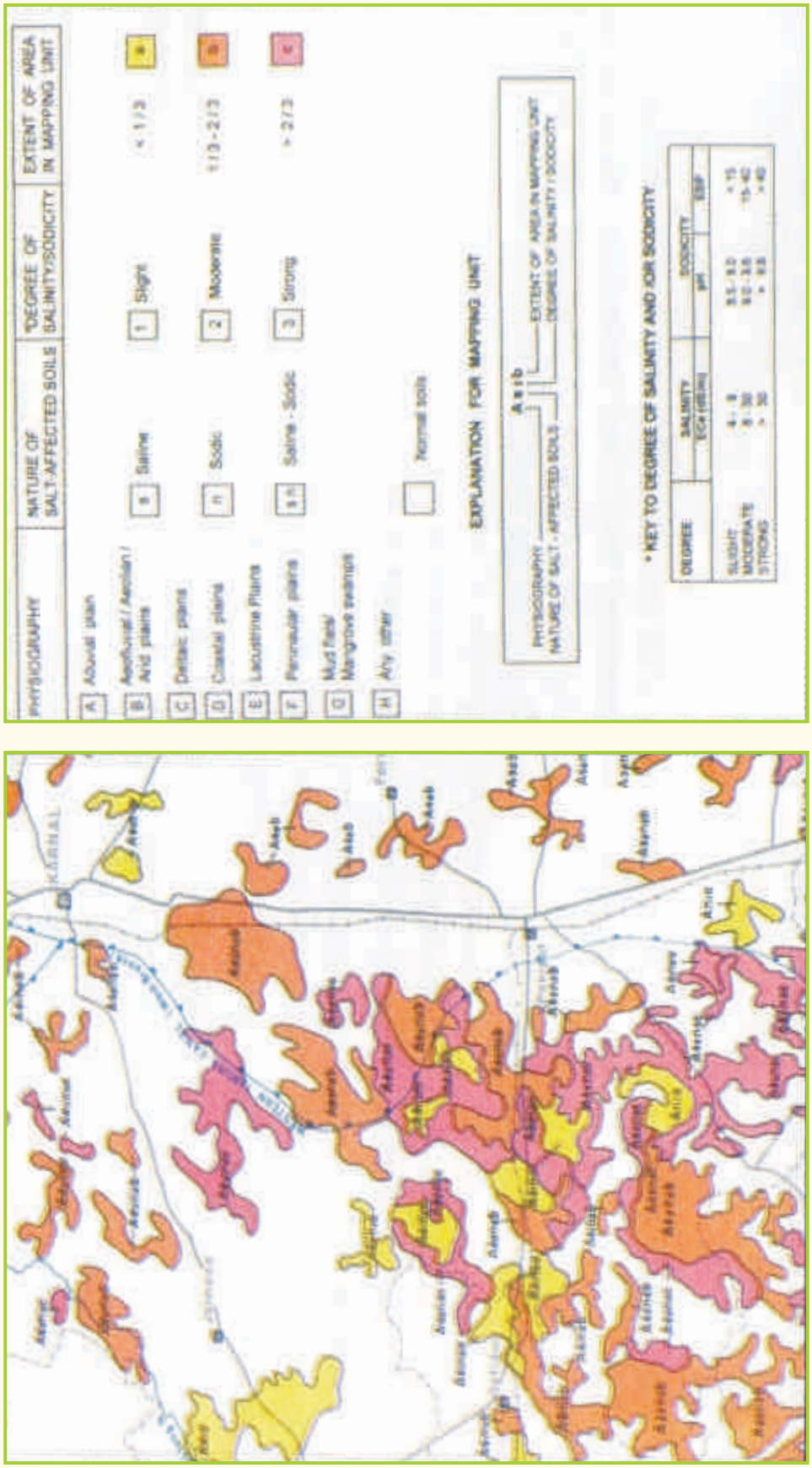


Fig. 1 : Salt affected soil map and description of legends (NRSA 1997)

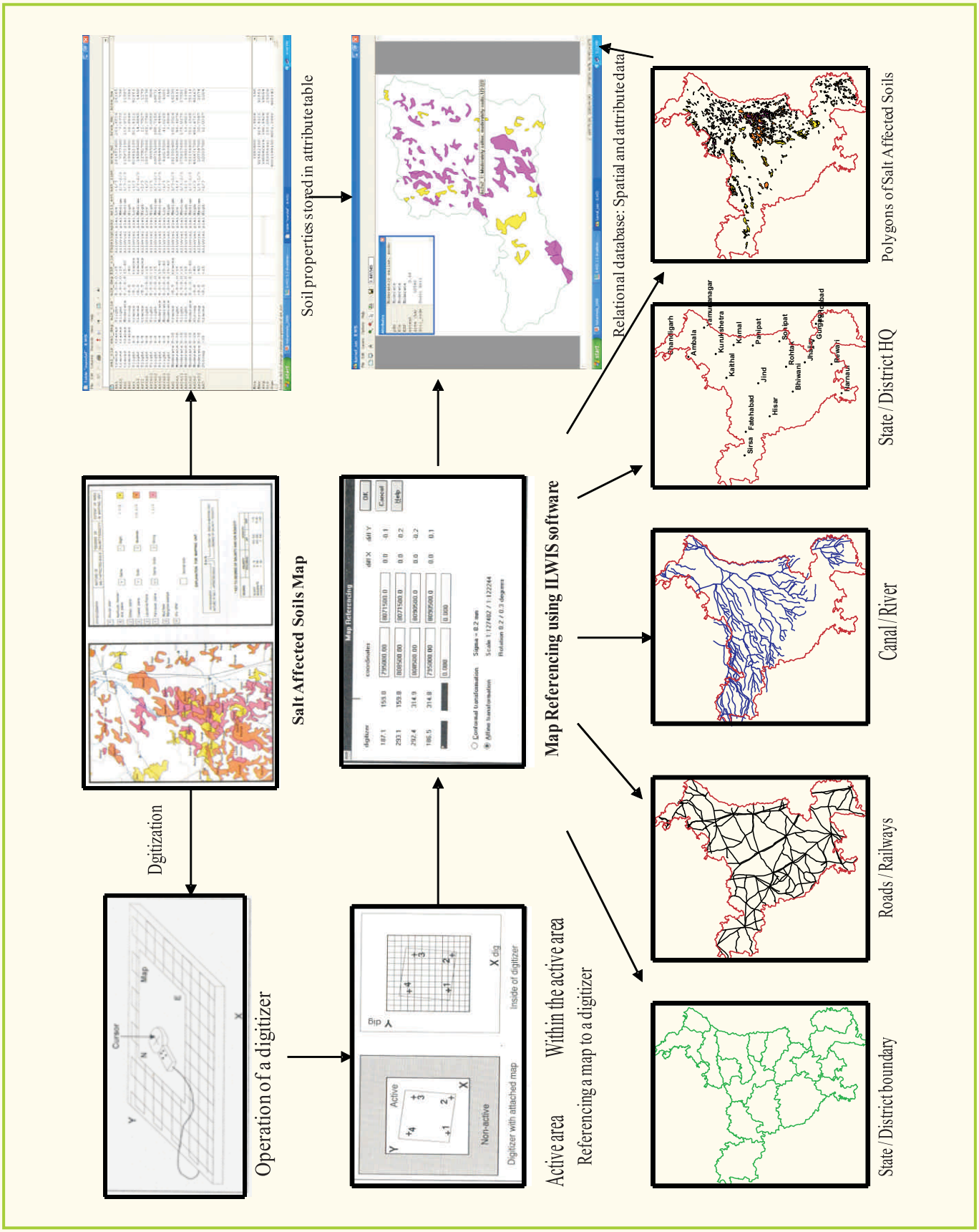


Fig. 2 : Methodology for digitization of salt affected soil maps

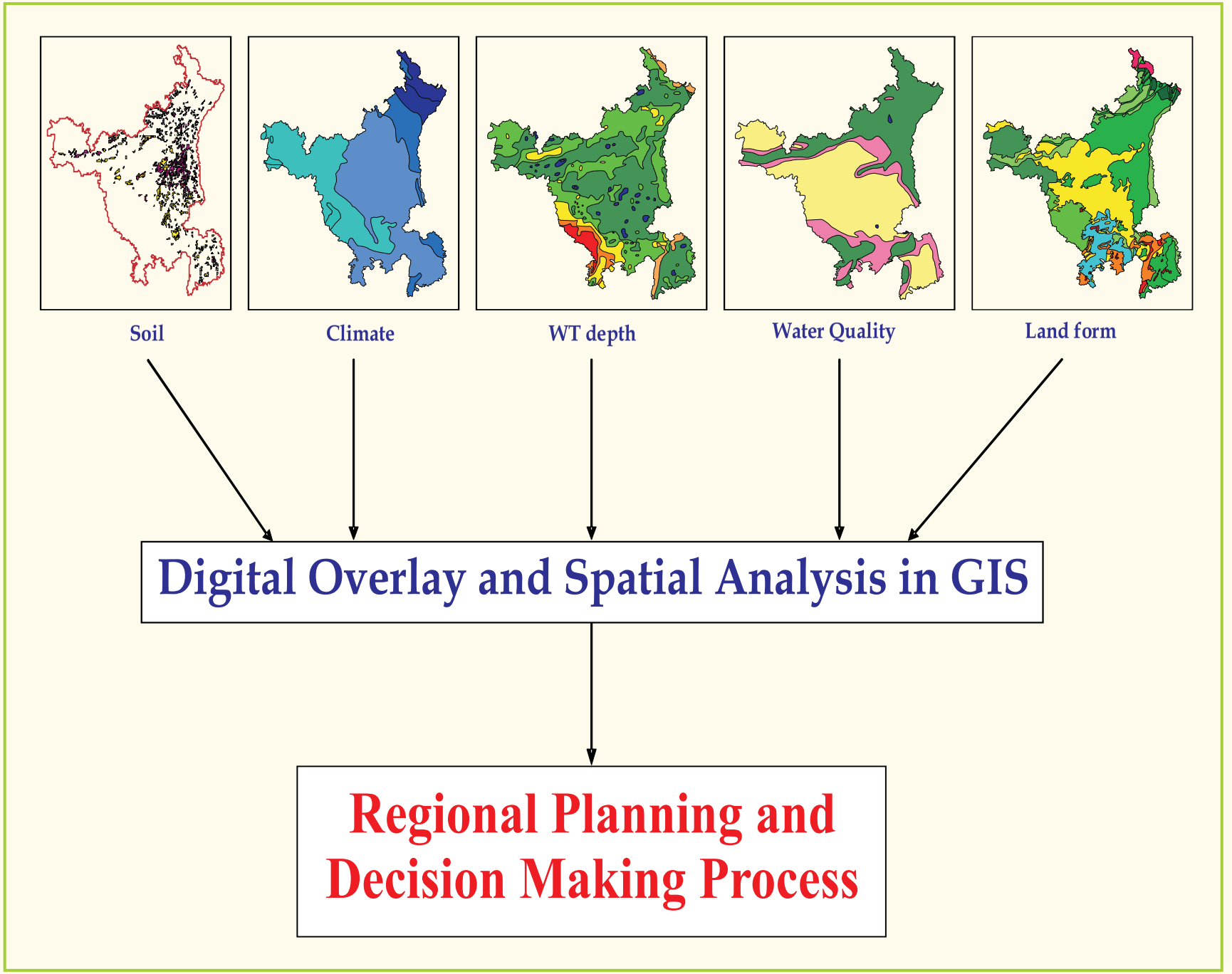


Fig. 3 : Management of natural resources using GIS

Fig. 4 : Salt Affected Soils in India

Fig. 5 : Saline soils in India

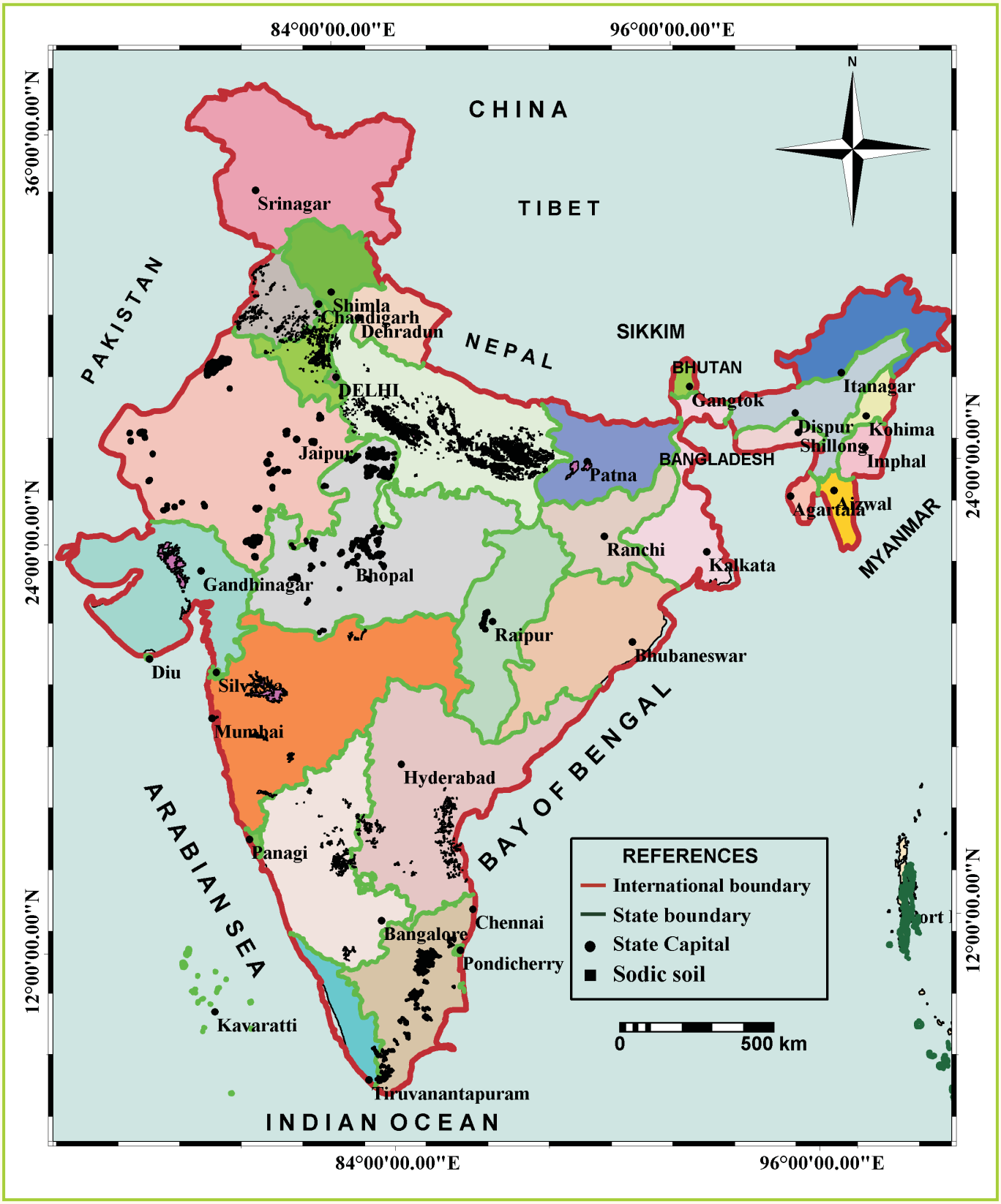
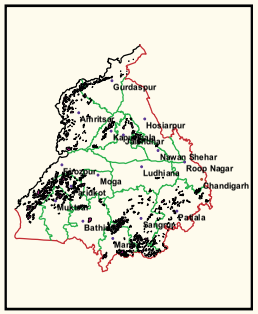
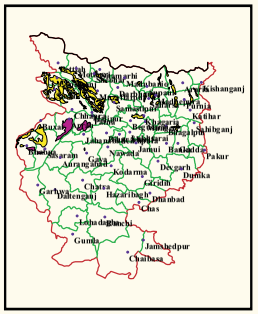
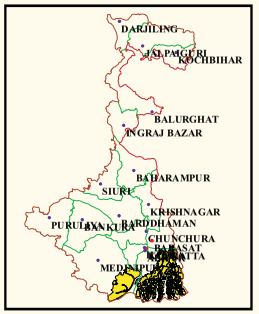
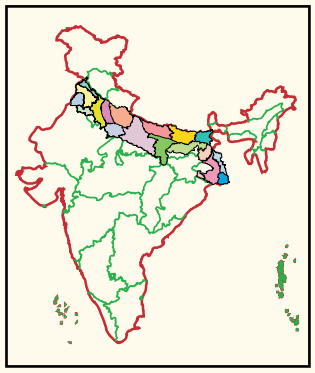


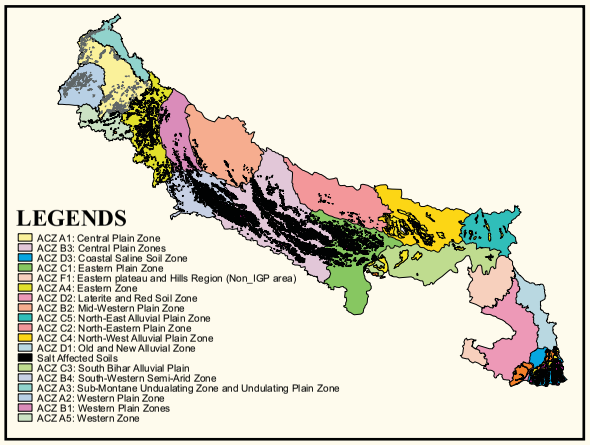
Fig. 6 : Sodic soils in India





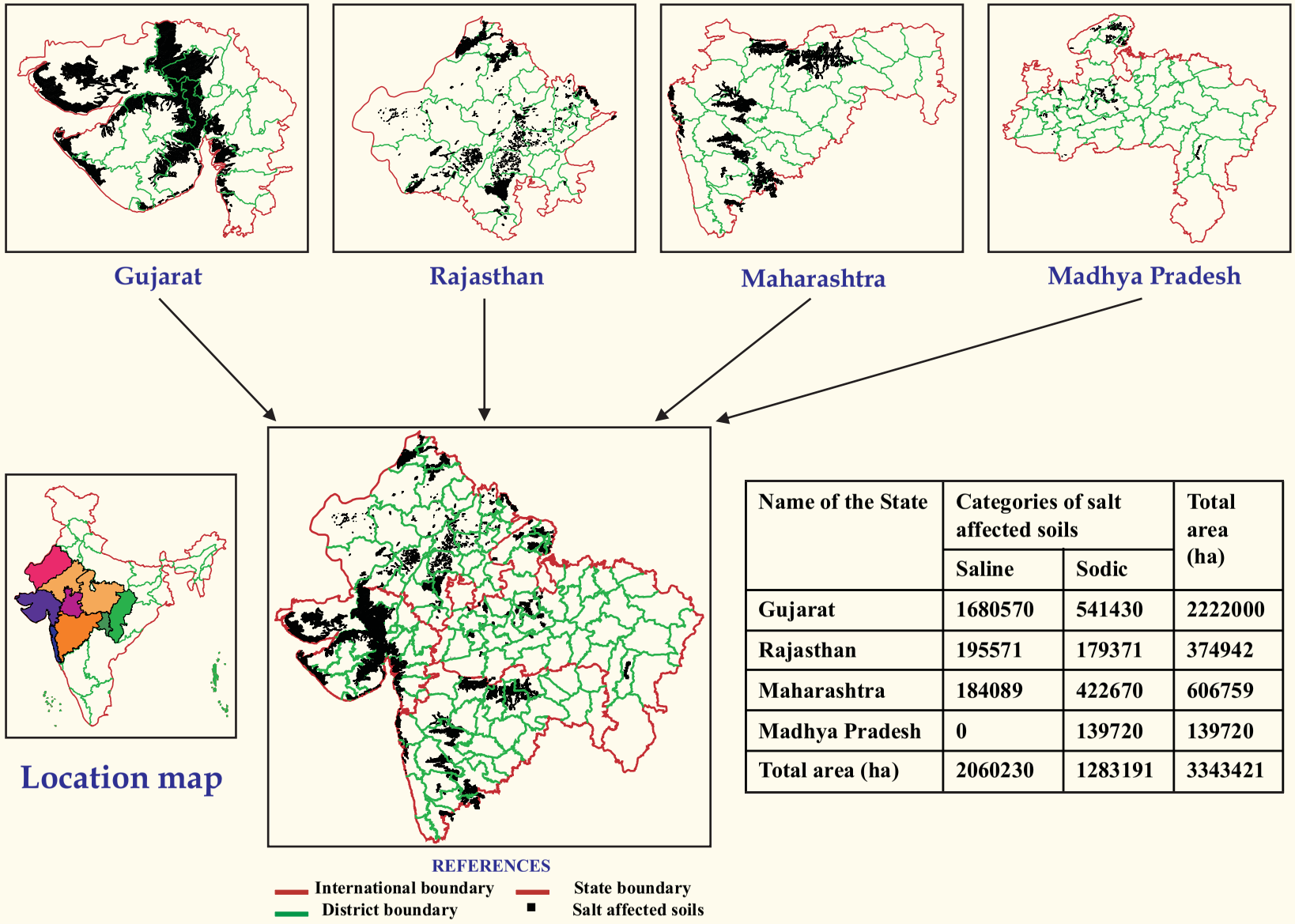






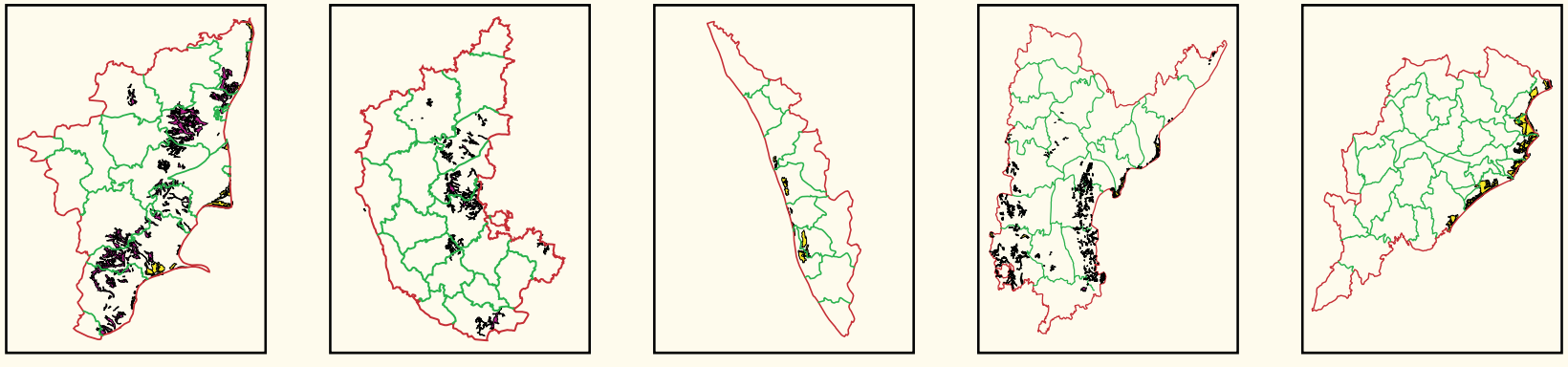
S N	Name of the State	Saline Soil (ha)	Sodic Soil (ha)	Total (ha)
1	Haryana	49157	183399	232556
2	Punjab	-------	151717	151717
3	Uttar Pradesh	21989	1346971	1368960
4	Bihar	47301	105852	153153
5	West Bengal	441272	--------	441272
	Total	559719	1787939	2347658

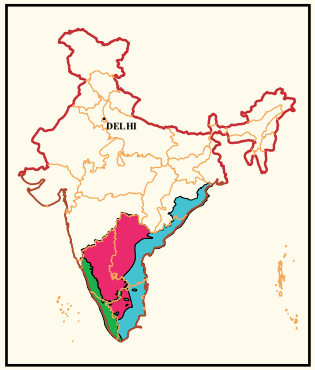
Fig. 7 : Salt affected soils in the Indo_Gangetic plain



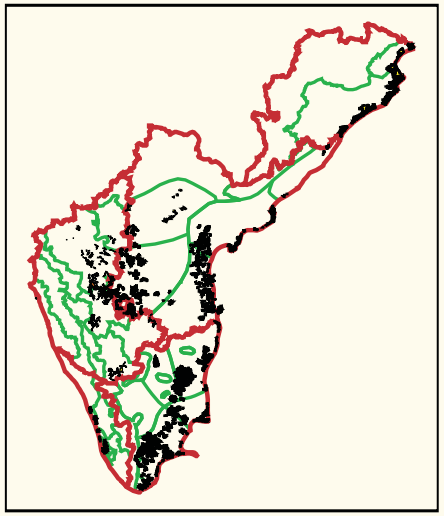
Name of the State	Categories of salt affected soils		Total area (ha)
	Saline	Sodic	
Gujarat	1680570	541430	2222000
Rajasthan	195571	179371	374942
Maharashtra	184089	422670	606759
Madhya Pradesh	0	139720	139720
Total area (ha)	2060230	1283191	3343421

Fig. 8 : Salt affected soils in arid and semiarid regions





Location of IGP



REFERENCES
Agroclimatic Zones
State boundary
Salt Affected Soils

S N	Name of the State	Categories of salt affected soils Saline Soil	%	Sodic Soil	%	Total area (ha)	%
1	A. Pradesh	77598	8	196609	20	274207	28
2	Tamil Nadu	13231	1	354784	37	368015	39
3	Karnataka	1893	0.2	148136	15	150029	16
4	Orissa	147138	15	------		147138	15
5	Kerala	20000	2	------		20000	2
Total area (ha)		259860	26	699529	73	959389	

Fig. 9 : Salt affected soils in the peninsular region

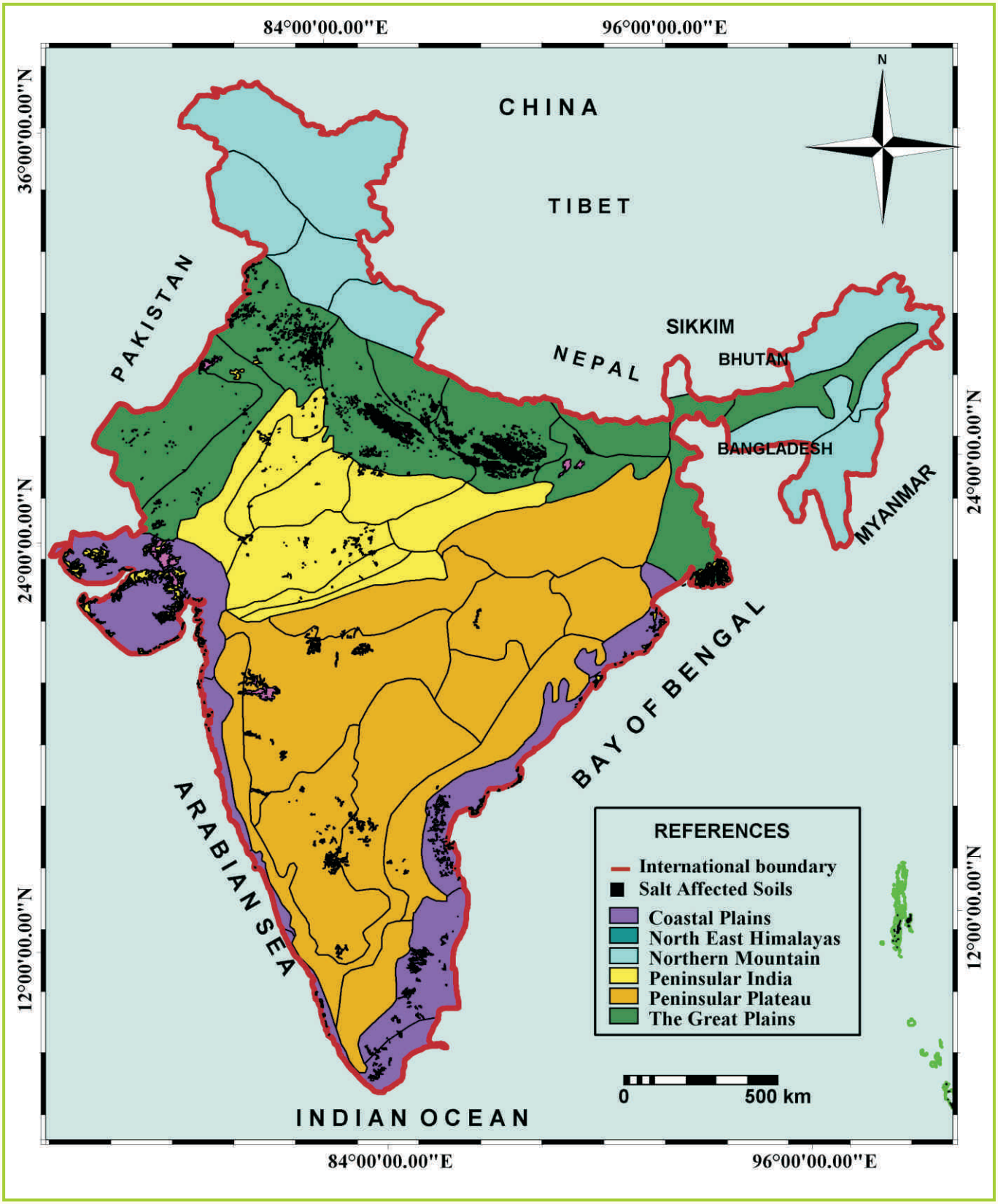


Fig. 10 : Salt affected soils with physiographic regions

Fig. 11 : Salt affected soils with Agroclimatic Zones

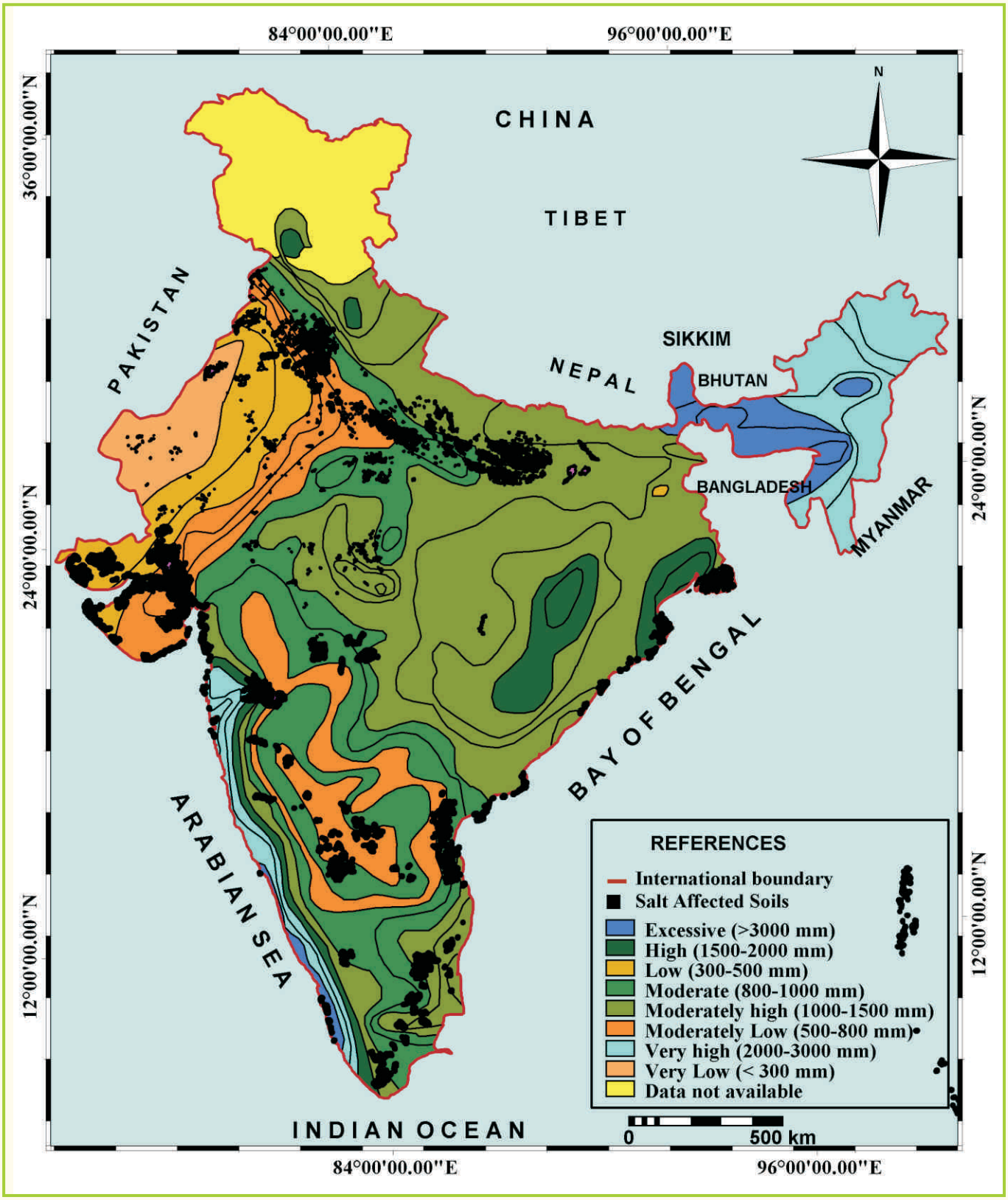


Fig. 12 : Salt affected soils with Rainfall data

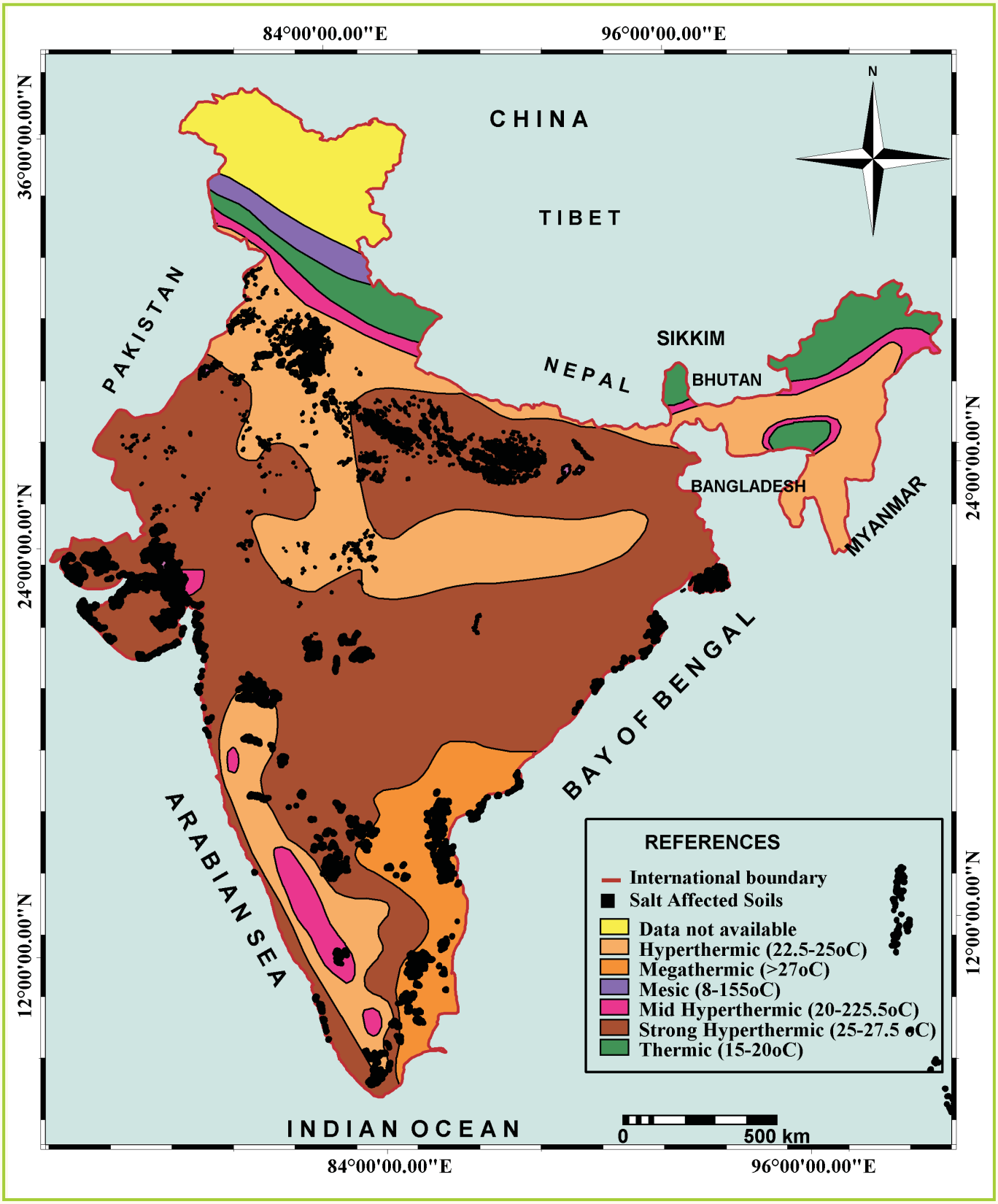


Fig. 13 : Salt affected soils with Temperature data

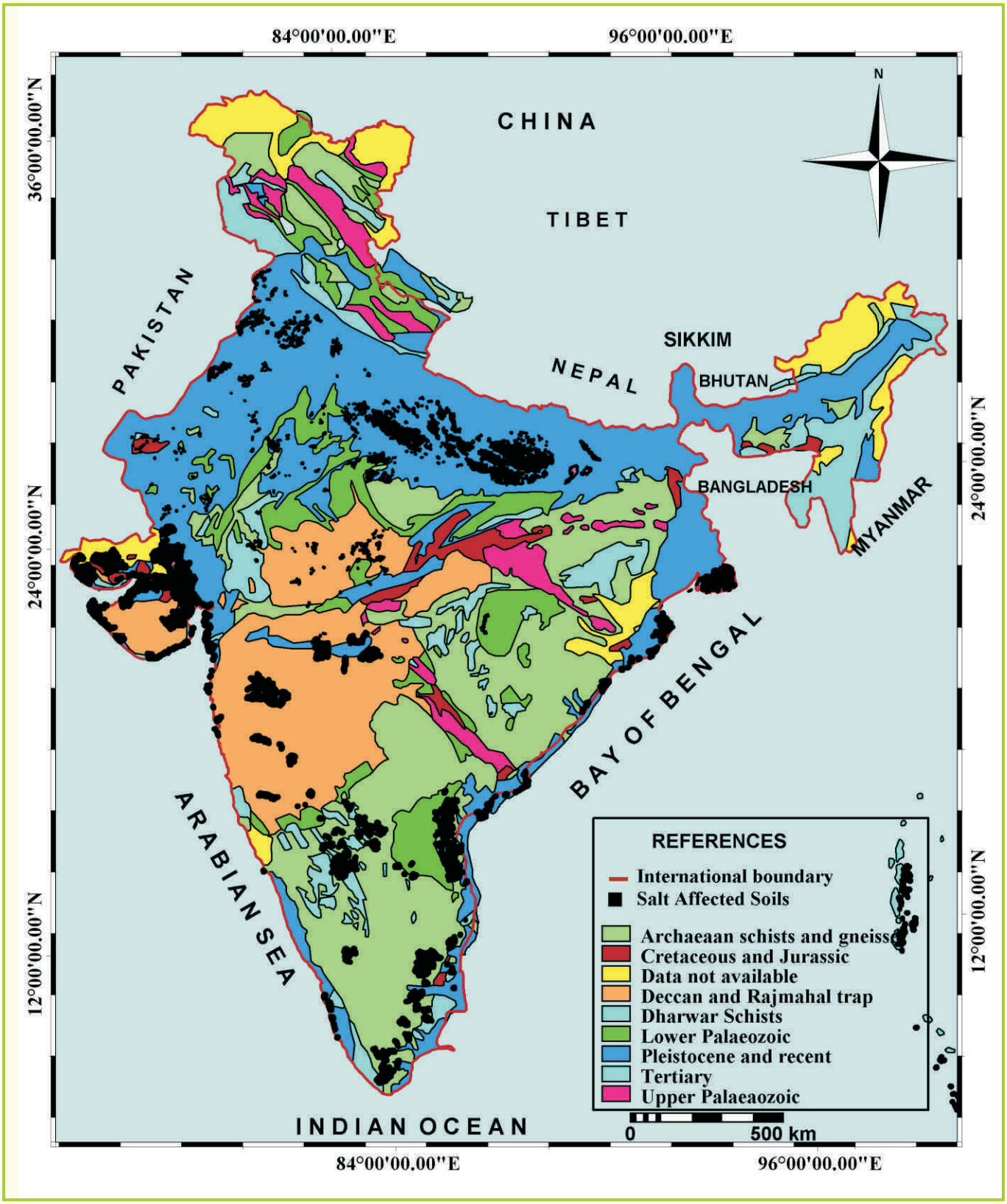


Fig. 14 : Salt affected soils with geology / parent materials