Satellite image analysis of salinity areas through GPS, Remote sensing and GIS

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Abstract

Soil salinity and waterlogging are two of the main constraints present in irrigated agricultural lands. The Covering 577.86 sq km area of south west Punjab (Bhatinda and Muktsar districts) a part of the vast Trans-Gangetic Plain region of the Indo-Gangetic alluvial plain. A reconnaissance survey of the study area was done using satellite images (FCC). Satellite image of IRS 1D LISS III of March & May 2000 were used for visual interpretation of salinity areas. In total, the ground truth was collected from 24 villages, 120 samples were taken from different salt affected areas and non-salt affected areas under different classes were estimated by computer /or planimenteric measurements to complete land use statistics. Sand dunes distributed in all over the area, it is permanent and prominent feature. It was identified on the image as bright white with medium to coarse texture. The area under sand dunes is 3.61% (20.87sq.km). The area mapped in the classes of moderate and severe salt affected soil was 1.72 % and 7.90% of the total area. The area under waterlogged area is 2.88% (16.63 sqkm) of the total area.

In the IRS 1D image of March, the salt affected lands, crops appear to wither away and there is a heavy loss of yield. Salt tolerant grasses and weeds cover the waterlogged areas It is emphasized that waterlogging, salinity and secondary salinity in the villages of Muktsar and Bhatinda have reached a critical situation. In the up coming days the environmental crisis will only escalate only to be faced by the poor farmers. In the future multi-temporal satellite images should be used for continuous monitoring of the waterlogging and salinity dynamics in the region. Integrated analysis of spatial and non-spatial data parameters in Geographical Information System (GIS) environment must be made use of for any kind of decision making. The districts of Bhatinda and Muktsar have been identified to the intensive area study site for this research work.

Keywords: GPS, GIS, FCC, IRS, Salinity & Secondary salinity

Introduction

Salt – affected soils are widespread over the world especially in arid, semi arid and some sub- humid regions. Soil salinity and waterlogging are two of the main constraints present in irrigated agricultural lands. In India, the problem of salinity and alkalinity increases every year as a result of secondary salinisation. In India about 8.6 mha (Pathak 2000) of land area is affected by soil salinity. Salt affected soils occur in the states of Uttar Pradesh, Gujarat, West Bengal, Rajasthan, Punjab, Maharashtra, Haryana, Orissa, Delhi, Kerala and Tamil nadu. Almost 2.8 million hectares of salt-affected soils are present within the Indo-Gangetic alluvial plain occupying parts of Punjab, Haryana, Uttar Pardesh, Delhi, Bihar and Rajasthan states (Abrol *et al*. 1971).

The salt affected soils were primarily located in the irrigated areas of the old alluvial plains and zones of low rainfall, shallow water table depth and hot and dry moisture regions (Mandal and Sharma, 2005). Due to waterlogging and subsequent salinization the fertile productive land is gradually becoming unproductive. Remote sensing and GIS are powerful tools, which could be effectively used to study the dynamic behavior of waterlogged areas. Application of remote sensing technology in mapping and monitoring degraded lands, especially salt – affected soils, has shown great promise of enhanced speed, accuracy and cost effectiveness (Dwivedi, 1998). The visual interpretation of Indian Remote Sensing data (IRS LISS II) on 1:50,000 scale followed by ground survey identified waterlogged and salt infestation in IGNP, Rajasthan. Such data also indicated seasonal dynamics of waterlogging and soil salinisation in irrigated areas (Mandal and Sharma, 2011). A wide variety of satellite remote sensing data from Landsat – TM, SPOT, IRS 1C & 1D are now available to earth resource scientists for generating information on natural resources**.** In combination with the Geographical Information System (GIS), computer software used for handling of large and voluminous data integration of wide variety of data in more efficient fashion is possible. Both remote sensing and the geographical information system are being widely used for generating, storing, analyzing and retrieving the geographical data and in the study of salinity related phenomena. The districts of Bhatinda and Muktsar have been identified to the intensive area study site for this research work.

Study area

Punjab is a part of the vast alluvial expanse popularly known as Indo Gangetic plains. The plain is nearly 300 km in length from north to south and about 280 km broad. The study area lies in Eco region 2 (M9E1), between geo-coordinates 30° 00` to 30° 15` N & 76° 30` to 76° 45` E. Covering 577.86 sq km area of south west Punjab (Bhatinda and Muktsar districts) a part of the vast Trans-Gangetic Plain region of the Indo-Gangetic alluvial plain (Fig.1). The southwestern parts of Punjab and Haryana having sandy soil, which also coincides with low rainfall (Panigrahy *et al.* 2010).

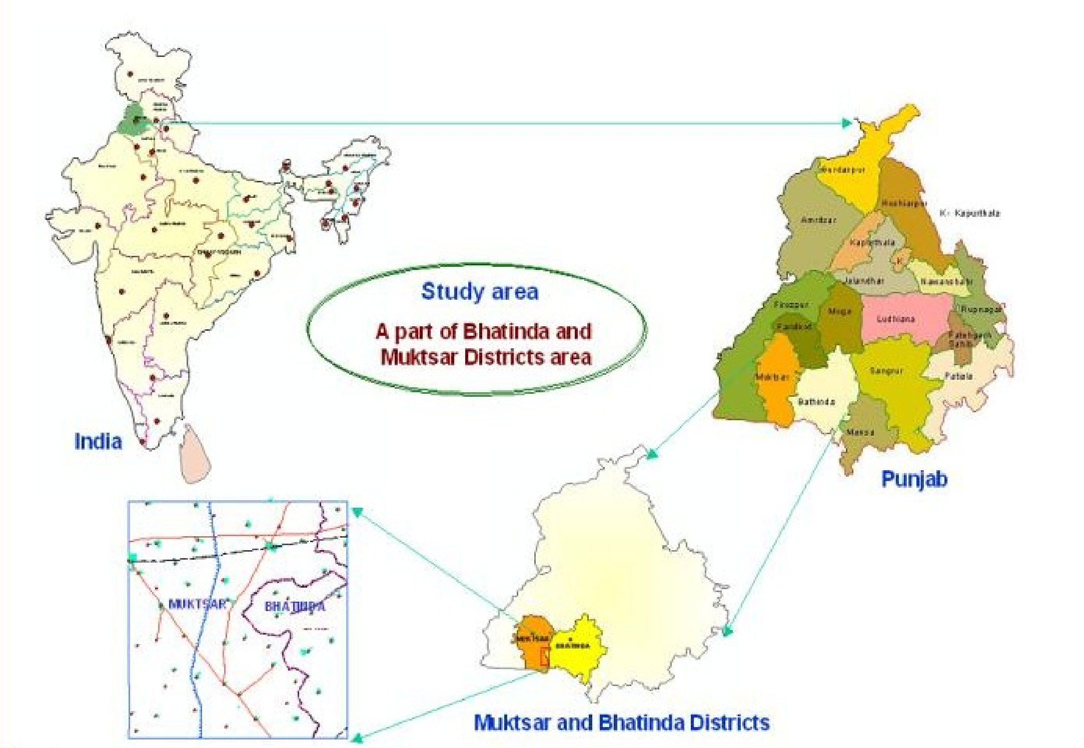

Fig.1

Materials and Methods

(i) Remote sensing data:

For the purpose following multi-spectral and multi-date IRS 1D images of the study area, were procured from the National Data Center (NDC), Balanagar, National Remote Sensing Agency (NRSA) Hyderabad.

The details of digital satellite data used in the study are given below:

Table 1. Details of digital satellite data

Satellite	Sensor	Path/ Row	Type	Period	To be used for
IRS ID	LISS III	93/50	Digital data	March 2000	Vegetation crop inventory & crop parameters
IRS ID	LISS III	93/50	Digital data	May 2000	Salinity & waterlogging

(ii) Ancillary data

The information of contour, administrative boundaries such as sand dunes, canals, important towns, villages and roads and highway were digitized to prepare the base map. The published soil survey reports, soil maps, atlas of Punjab, census report, water quality reports for the study area were collected and utilized during interpretation and field work.

Visual Interpretation techniques: it comprises of (i) Pre -field interpretation (ii) Field work (Ground truth) & (iii) Post -field work (Fig. 2).

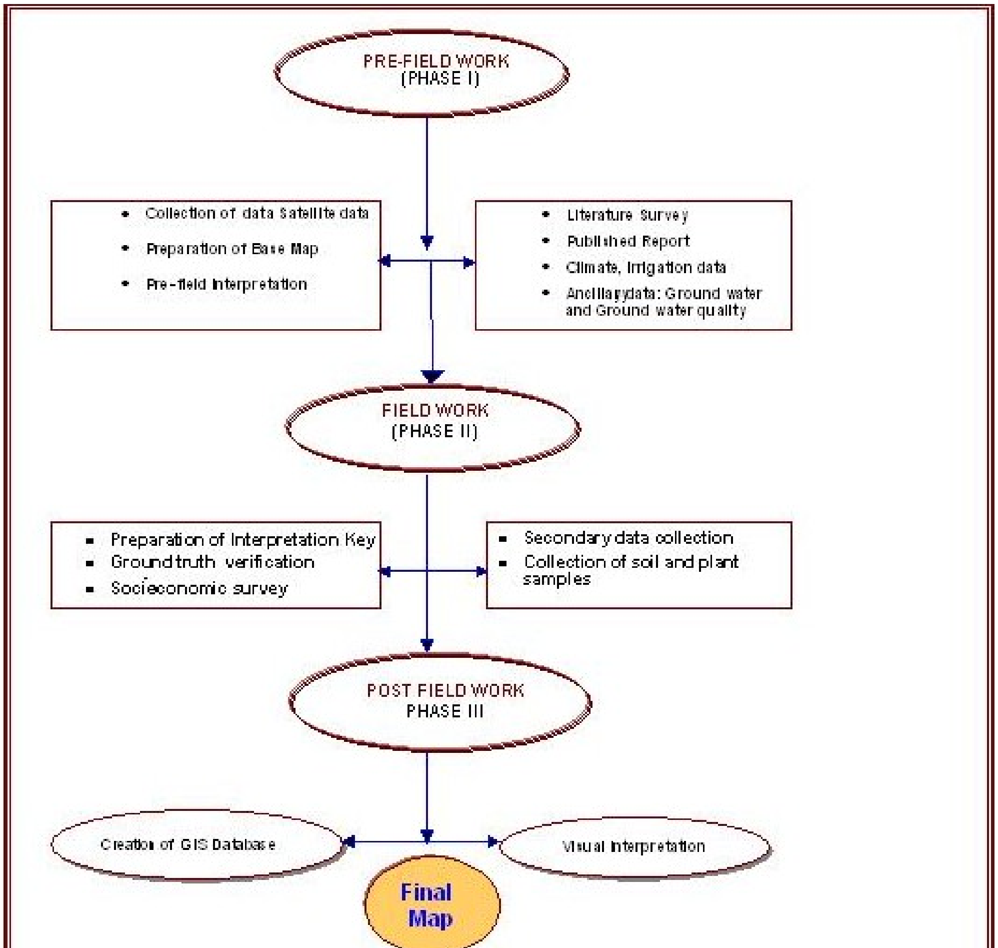

Fig. 2 Overview of the methodology used for data creation and visual analysis

(i) Pre- field interpretation

The enhanced false colour composite image of the study area was displayed on 1:50,000 scale on monitor. Standard FCC was visually interpreted for salt affected soils and waterlogged areas with the help of image elements like tone, texture, shape, size, pattern and association, etc. The salt affected soils usually appear in tones of bright white to dull white with medium to coarse texture on Standard FCC due to the presence of salts, on soil surface. The landforms associated with the occurrence of salt affected soils are also considered during interpretation. The obstructions to natural drainage like roads, railway lines, distributaries, etc. can easily be identified on the FCC images (Fig.3). The waterlogged/ pond areas appear on the FCC image in dark blue to a black tone with a smooth texture. Additional pre- and post- monsoon images were used to permanently identify waterlogged area. For this an interpretation key was developed. A tentative legend was also prepared.

A map showing preliminary interpreted units on FCC with base details was generated before going into the field.

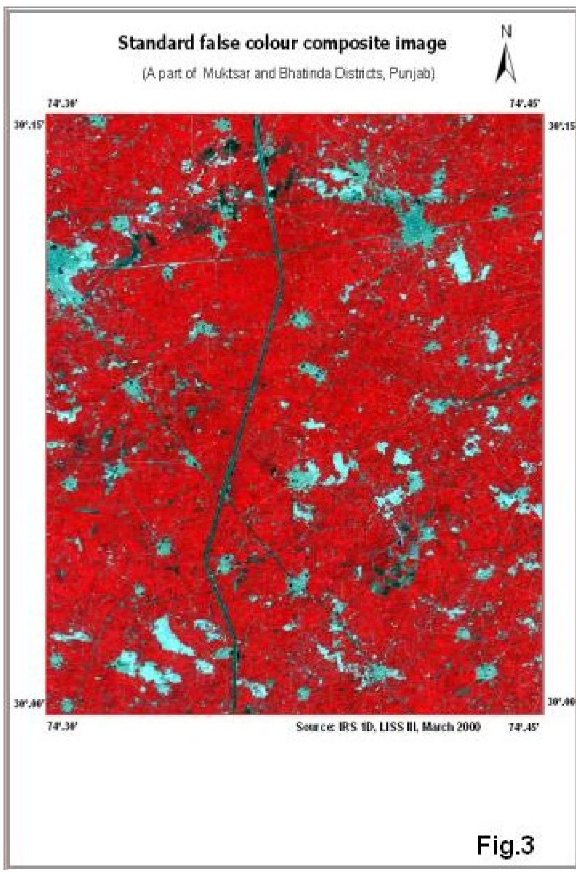

Fig.3

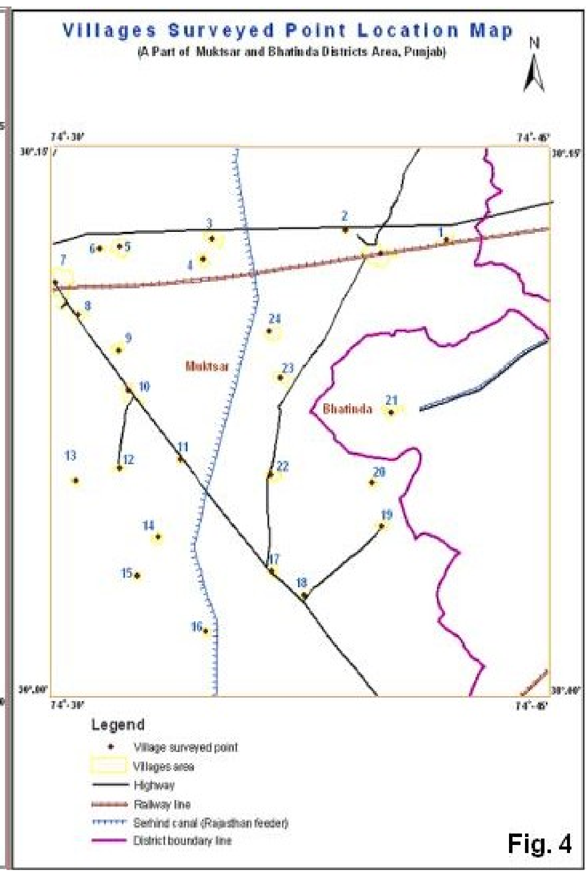

Fig. 4

(ii) Field – work (collection of ground truth information)

Initially rapid traverse of the study area was made to identify the sampling points in the area. Detailed field investigations were carried out in various physiographic units to observe the broad physiographic - soil relationship. The study area was surveyed three times in a year viz December- January, February- March and April – May.

In total, the ground truth was collected from 24 villages, 120 samples were taken from salt affected areas and non-salt affected areas (Fig.4). The different villages surveyed were Giddarbaha, Thiri, Malaut Danewala, Abulkharana, Tappakhera, Adhnian, Mahuana, Sahnakhera, Pajawa, Lambi, Channu, Mann, Raikekalan, Lalbai, Tharajwala, Shekhu, Fakarsar and Jandwala Chakatarsinghwala, etc. Soil and plant samples were collected with their geographic location using GPS (Fig. 5a &5b). In Muktsar district, corresponding rise in water table is 0.2m per year and tube well density is 114 per 1000 ha (Sood *et al*., 2009).

A reconnaissance survey of the study area was done using satellite images (FCC). Salt affected lands and affected crops were identified on the ground and ascertained on the satellite

Fig. 5a Soil samples collection with GPS location point

Fig. 5b Salinity and waterlogged area

Fig. 5c Crop affected by salinity

Fig. 5d Salinity on the surface

image by characterizing image characteristics. Satellite image of IRS 1D LISS III of March & May 2000 were used for the purpose (Fig.5c&5d).

(iii) Post- field work

Modification of the Post-field work primarily involved preliminary interpreted the mapping units on the FCC of the satellite data in the light of field information and soil physico-chemical data. The tentative legends prepared during the pre- fieldwork were also finalized. A final map showing visual salt affected soils was prepared.

Results & Discussion

IRS –1D Image data have been used to detect and assess the salt affected land and waterlogged land and crop through a combination of visual and digital techniques. The effect has been to integrate the information on salt affected soil, waterlogging and crops using remote sensing to gain a better understanding of the current status and problems that are associated with these degraded lands. The methodology used for visual interpretation of multi-date satellite comprised the following five major steps.

(a) Selection and acquisition of data: Standard FCC imagery of IRS data of May and March 2000.

(b) Preliminary visual interpretation: IRS FCC's of May 2000, interpreted individually making use of the interpretation keys. The boundaries of salt affected/waterlogged/ land use/land cover classes plotted onto a transparent overlay.

(c) Ground data collection and verification: Following the previously drawn scheme and transverse plan, ground truth information collected as per specific proforma to cover at least 60 percent of the image as a reconnaissance, initially in areas where no mapping has been conducted before. Areas of doubtful preliminary interpretation were particularly verified.

(d) Final interpretation and modification: Based on the ground truth data the modifications were effected and classes as well as their boundaries refined.

(e) Area estimation: computer estimated Areas under different classes /or plan metric measurements to complete land use statistics.
The above mentioned detail is reiterated in order to provide a highlight for the results of the visual interpretation. The enhanced false colour composite images of the study area were displayed on 1:50,000 scale on a monitor. The FCC was visually interpreted for normal soil, moderate salt affected soil land; severe salt affected soil and waterlogged areas using visual interpretation keys based on tone, texture, pattern and association etc. Landforms associated with the occurrence of salt affected soils were considered during interpretation.

Table 2. Visual interpretation keys based on FCC of IRS ID, LISS III image (15th May, 2000 standard FCC)

Sl. No.	Ground Features	Interpretation keys				
		Tone	**Texture**	**Shape/ size**	**Pattern**	**Association**
1	Salt affected soil	Dull white	Rough	Irregular	Dispersed	Weed /grass
2	Waterlogged area with weeds	Blackish red mixed tone	Smooth	Irregular	Dispersed	Salt tolerant weed
3	Normal soil	White gray, white tone	Smooth	Irregular	Regular	Irrigated land
4	Plantation /orchards	Bright red, red and dark red	Smooth	Fixed	Regular	Near road side
5	Sand dunes	Bright white tone	Medium to coarse	Uniform	Contiguous	Shrub/arid plantation
6	Settlement (Habitation)	Cyan, gray pinkish mixed tone	Mottled	Irregular	Clustered	Pond
7	Feeder (Rajasthan canal)	Dark black-bluish line	Smooth	Regular	Linear	Plantation & Un-mettle road
8	Railway line	Dark black with reddish mixed tone	Smooth	Regular	Linear	
9	Metalled road	Black tone	Smooth	Regular	Linear	

Normal soil on the FCC of May 2000 was detected in white gray tone with a smooth texture. Fields with moisture had a light to dark gray tone. Salt affected lands appeared in dull white surrounded by light blue tone indicating moisture and encrustation. The patches appeared irregular in shape with a rough texture. Waterlogged areas appeared in a dark grey red mixed tone associated with salty surfaces and the presence of salt tolerant weeds. Sand dunes were the dominant permanent natural feature clearly distinguished on the FCC as a bright white tone. Habitation (settlement) appeared in Cyan and gray pinkish mixed tone with mottled texture. Plantation /orchards appeared as bright red to dark red with smooth texture. Most of the plantations appeared close to the roads. The Rajasthan canal appeared as the most dominant linear feature in dark black-bluish (Fig.6 and Table. 2).

Kalra ***et al.*** studied on the basis of IRS LISS III FCC images the salt affected soils of Kotri and Taswaria villages appeared in bright white to light grey tone, smooth texture with white mottles. Ground characteristics of all features were identified during field checks. Collating visual interpretation and ground truth information and integrating visual interpretation keys, the geocoded image was visually interpreted. Some reclassification was necessary. A map showing the different land cover classes was prepared (Fig. 7 &Table 3).

Salt affected soils have distinct expression on the FCCs in bright to dull white tone appearing in patches within the background of normal soils supporting good vegetation (that appears as bright red / magenta tone) on 1:50,000 scale. The salt affected soils with poor crop growth appear in a dull red mottled tone. In general, the FCCs of February- March were found

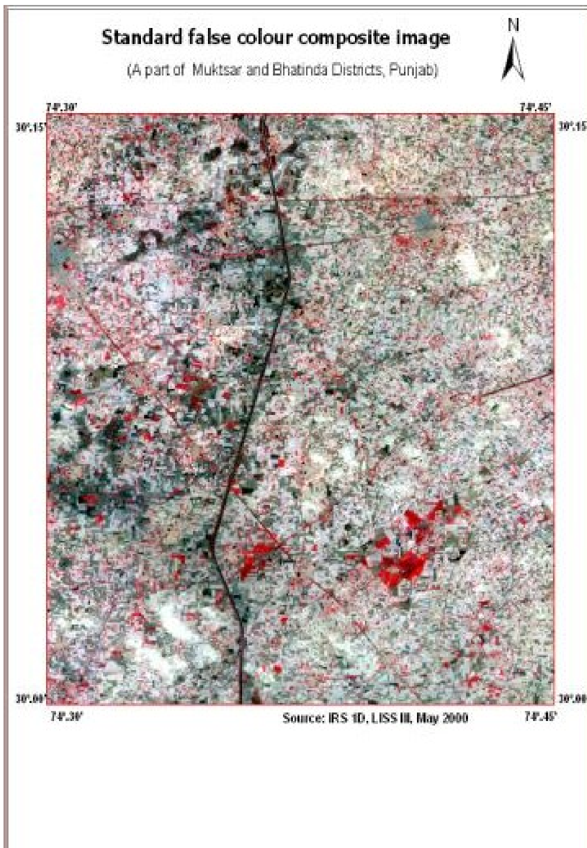

Fig.6

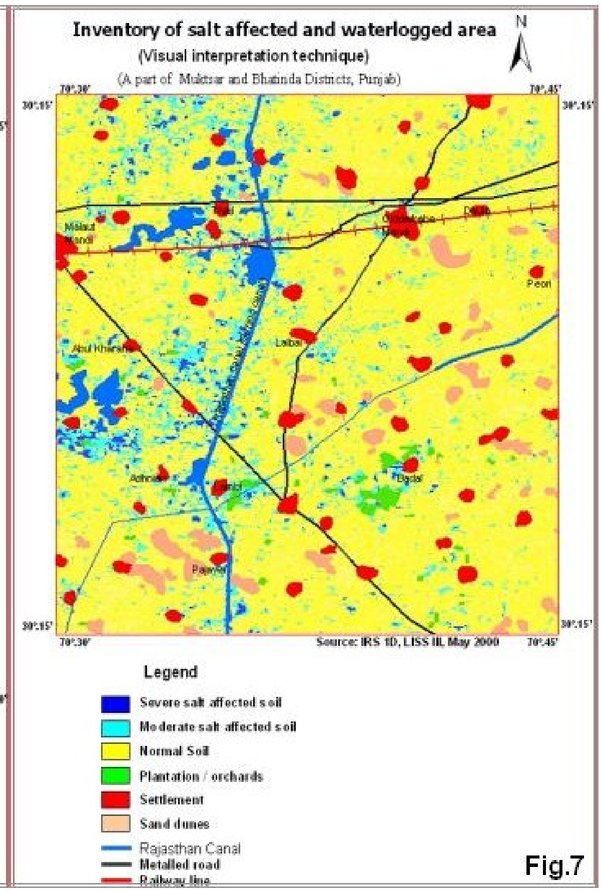

Fig.7

appropriate for mapping salt affected soils.

Table 3. The extent of salt affected land and various land use/ land covers classes (Based on visual interpretation)

Sl. No.	Land use/ land cover classes	Area (km^2)	Area (%)
1.	Severe salt affected soil	9.96	1.72
2.	Moderate salt affected soil	45.63	7.90
3.	Normal soil	446.24	77.22
4.	Waterlogged area	16.63	2.88
5.	Plantation/ orchards	8.27	1.43
6.	Settlement	24.41	4.22
7.	sand dunes	20.87	3.61
8.	Rajasthan canal	3.35	0.58
9.	Metalled road	1.73	0.32
10.	Railway line	0.76	0.13
	Total	**577.86**	100

The results of the visual interpretation are comparable to the NRSA mapped salt affected soils at 1:50,000 scale on a limited extent, using LANDSAT TM and IRS FCC imagery. The salt affected soil maps were prepared for Mainpuri and Unnao districts of Uttar Pradesh and for South Coastal districts of Andhra Pradesh.

Ground truth of salt affected areas

(i) Salt affected cropped areas

During the month of March, wheat crop reaches maximum vegetative growth. Continuous upward flux of water from September to March brings salts from soil substratum on to the surface. The satellite image for the month of March was most suitable for mapping crop affected by salinity. The FCC was visually interpreted for Normal crop, crop affected by moderate salinity and crop affected by severe salinity with the help of image elements like tone, texture, pattern and association etc . Salinity affects any morphological, physiological and biochemical process, including plant growth and nutrient uptake (Willenborg *et al*., 2004) while conducting the survey it was observed that wheat crop look like burn and plant growth was stunted. Water and salt stresses are of particular significance to irrigated crops (Fowden *et al*., 1993).

Crop affected by salinity was collated with soil salinity of soil samples taken during the field survey. The selection of the fields was based on "healthy" crop regions and crop affected by salinity (severe/ moderate salinity). The areas of healthy crops and crop affected by salinity (severe/ moderate salinity) were determined by the color spectrum of the LISS III image, Pseudo-natural colour composite of RGB for bands (2, 3 and 4). After the fieldwork, the salinity measurements associated to those of expected area according to satellite image was established.

(ii) Salt affected soils

Using the visually interpreted data it was easy to identify the different classes defined on the image. The whole area was covered in transects: North South, East West, North East, North West, South West and South East.

A work plan for a field survey was designed according to the features noticeable on the satellite image. During the field visit, special attention was given to GPS readings (geographic location) and field impressions. The selection of the fields was based on "healthy" soil regions, salt-affected soils, partly salt affected fields and salinity and waterlogged areas. These identified units were geo-registered with GPS readings. The areas of healthy crops and poor crops were determined by the color spectrum of the LISS III image, Pseudo-natural colour composite of RGB for bands (2, 3 and 4). After the fieldwork, the salinity measurements were associated with the satellite image was established.

Singh, *et al.* (1998) found that water tables rise and salinity comes to the surface in south western districts of Punjab, every year after the in the month of May. High water tables and waterlogged conditions were found extensively prevalent during ground truth.

Salinity appears in patches associated with waterlogged fields and have a mixed spectral response of red tone. During ground verification, salt accumulation was also found to be associated with salt grass and salt tolerant wild vegetation. The area mapped in the classes of moderate and severe salt affected soil was 1.72 % and 7.90% of the total area.

(iii) Waterlogged areas

Waterlogging has occurred because of the accumulation of irrigation water, seepage of canal water in low-lying areas. Ground truth verification of some areas under irrigation, show a light to dark grey tone intermixed with reddish mottles in the images, were found to posses shallow water table depth ranging from 0.5 -1.5 m. Prominent waterlogging was identified on the image as blue to black mixed tone. The area under waterlogged area is 2.88% (16.63 km^2) of the total area.

(iv) Sand dunes

Sand dunes distributed in all over the area, it is permanent and prominent feature. It was identified on the image as bright white with medium to coarse texture. The area under sand dunes is 3.61% (20.87 km^2).

Conclusion

Soil salinity has been brought about by natural or human-induced processes and is a major environmental hazard. Crop growth reduction due to salinity is generally related to the soil in osmotic potential of the root zone. High soil salinity can also cause nutrient imbalances, resulting in the accumulation of toxic elements in plants. With the major objectives to map salt affected soils and secondary salinization of soils using satellite remote sensing data through visual interpretation and digital techniques and to characterize spectral characteristics of crop (wheat) influenced by salinity/ secondary salinization this research work was commenced. Using IRS 1D images of March and May 2000 studies were conducted to assess the effects of secondary salinization on cereal crops. Recent advances in remote sensing technology have opened new vistas in inventory, characterization and monitoring of degraded lands. Remote sensing and GIS have been effectively used to study the dynamic behavior of salinity and waterlogging in this study. Satellite imagery and false colour composites were visually interpreted to identify salt affected lands and locate their geographic position using the Global positioning system. Ground truth was carried out to confirm the visual interpretation using both the hard copy and the soft copy on the computer. Using the interpreted image as a base, soil and plant samples were collected with their geographic location using GPS. In total, ground truth was collected at 24 villages.

In south west Punjab areas affected by waterlogging due to seepage of water from canal and salinity due to salts on the surface appeared as a white salt encrustation. Due to irregular irrigation, seepage and high water requirement of crops the arid environment has turned into salt affected/ secondary salinized and waterlogged area. In the salt affected lands, crops appear to wither away and there is a heavy loss of yield. Salt tolerant grasses and weeds cover the waterlogged areas. It is emphasized that waterlogging, salinity and secondary salinity in the villages of Muktsar and Bhatinda have reached a critical situation. In the up coming days the environmental crisis will only escalate only to be faced by the poor farmers. In the future multi-temporal satellite images should be used for continuous monitoring of the waterlogging and salinity dynamics in the region. Integrated analysis of spatial and non-spatial data parameters in Geographical Information System (GIS) environment must be made use of for any kind of decision making.

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