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Mapping and characterisation of saline soils in Gohana, Haryana for subsurface drainage

R.C. Sharma

Central Soil Salinity Research Institute, Karnal 132001, India

Abstract

Saline soils of Gohana drainage project in Haryana were mapped and characterised using visual interpretation of SPOT satellite false colour composite image with ground survey and laboratory analysis. Morphologically the saline soils showed similarity in soil depth, colour, texture, structure and distribution of pores and roots. The soils had variable degree of salinity with dominance of neutral salts of sodium chlorides and sodium sulphates. The area has shallow water table and saline ground water. The saline soils with sandy loam textures, stable structures and absence of impervious layers are unlikely to cave in during the laying of subsurface drainage and salt leaching under saturated conditions. Adequate hydraulic conductivity in the range of 0.45 to 1.27 m/day would be able to release sufficient salts during the leaching process. Out of 4945 ha project area, 1330 ha were saline. The salt load in 1m soil depth of project area was 7.5 million ton. In order to restore the productivity of saline soils, installation of subsurface drainage system is recommended. The drainage system shall not only drain away excess salts from the root zone but also prevent further salinization due to upward salt fluxes from shallow water tables prevailing in the area.

Additional keywords : Remote sensing, semi-arid irrigated agriculture, drainage.

Introduction

Development of modern irrigation system has led to secondary salinisation and water logging of many crop lands in the arid and semi arid regions. Large scale water logging and secondary soil salinization have been reported in the Western Jamuna Canal Command in Haryana. The rehabilitational programme of salinised soils is achieved through the installation of subsurface drainage system. One of the major requirements for installation of subsurface drainage system is to collect detailed information about the extent, location and characteristics of soil salinity. The present study was conducted to map and characterise soil salinity of Gohana Drainage Project in Sonipat district of Haryana.

Study area

Gohana drainage project is located between 76° 40' to 76° 45' E and 29° 0' to 29° 5' N across the Jawahar Lal Nehru Feeder (JLN) of the Western Jamuna Canal

(WJC) in Sonipat district of Haryana. The landform constitutes the bottom part of the basin with an almost flat topography restricting surface drainage. Deep percolation losses from the irrigated fields and seepage from the canals have led to an increase in the water table of the area which fluctuates between 1-5 m from the surface. Climatically, the area is semi-arid with an average annual rainfall of 545 mm and average evapotranspiration of 1650 mm. The mean minimum and maximum temperature fluctuates between 5°C and 45°C. Wheat, rice sugarcane and forages are the main crops.

Materials and methods

To identify, delineate, diagnose and characterise saline soils, three tier approach of image interpretation, ground truth collection by pedon study and laboratory analysis of soil and water samples was adopted (Sharma and Bhargava 1988). Base map of the study area was prepared using Survey of India toposheets. False colour composite transparency of SPOT satellite for dry period was visually interpreted for identification and delineation of saline soils by enlarging to 1:25,000 scale on PROCOM. Area measurement of salinity classes was done with electronic planimeter. Five sites representing severity of salinity were studied for soil morphology and horizon-wise soil samples were collected for laboratory analysis. Twenty one ground water samples from five villages were collected for quality appraisal. The soil and water samples were analysed using the standard procedures (Richards 1954). Auger hole method of van Bear (1958) was used to measure hydraulic conductivity of the soil.

Results and discussion

Image interpretation: Taking advantage of good contrast of surface salt encrustation and soil barrenness with healthy wheat biomass, SPOT satellite image of February was visually interpreted (Verma *et al.* 1994; Sharma *et al.* 2000). Tone was found to be the most suitable photo element to identify and delineate saline soils appearing as smooth white irregular patches. The analytical data of surface soil samples from pedons and grid samples was incorporated in the interpreted map to establish salinity delineation. The final map with extent and distribution of saline soils was prepared (Fig. 1).

Soil characteristics: The morphological characteristics of all the five pedons showed similarity in all the saline soils in soil depth, colour, texture, structure, distribution of pores and roots. Presence of red and yellow mottles and concentric nodules of hydrated iron and manganese oxides in the subsurface layers indicate influence of fluctuating water tables. Moist soil colours were yellowish brown in the surface and brown in the subsurface. Soil texture was sandy loam in the surface and sandy loam to occasionally sandy clay loam in the subsurface. Soil structure grades from weak subangular blocky in the surface to moderate subangular blocky and massive in the subsoil. Predominantly illitic clay minerals have given rise to stable soil aggregates (Sharma and Bhargava 1993). The soils have good sub-surface porosity for ideal water transmission characteristics. There was build up of clay in the subhorizons of some soils but without any evidence of clay skins. The soils were calcareous. In most of the cases, the soils have 5-10 percent calcretes at around 1 m soil depth. An impervious 10-15 cm thick petrocalcic layer at 90 cm soil depth was found in soil profile 5.

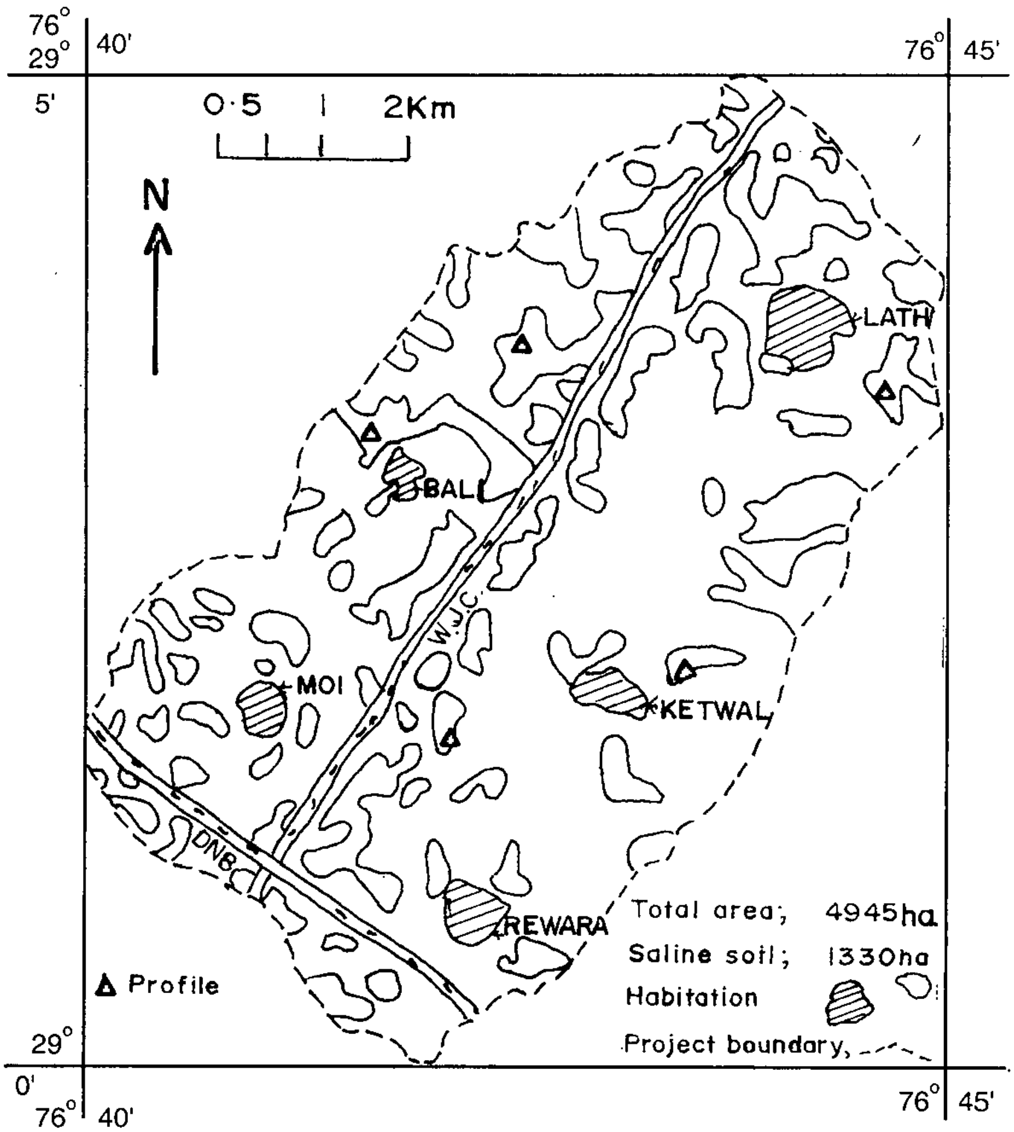

Fig. 1. Saline soil in Gohana drainage project district Sonipat, Haryana

Ionic composition of soluble salts and some other soil characteristics of saline soils are given in table-1. The soils were neutral in the surface with pH ranging between 7.0 to 8.2 and neutral to slightly alkaline in the substratum. The neutral soil pH is due to low amount of exchangeable sodium percentage (ESP) and dominance of neutral soluble salts. The higher pH value of subsoil layers in soil profile 4 is due to the presence of high amount of ESP and the presence of relatively high proportion

Table 1. pH, ESP and soluble ions of saline soils

Depth (cm)	pHs	ECe dSm^{-1}	ESP	SAR	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+
					me/L						
Profile -1, Village Ketwal											
0-15	8.1	31.0	5.6	46.7	-	0.5	315	86	51	35	306
15-45	8.3	11.9	7.5	30.3	0.5	0.5	117	31	16	9	107
45-73	8.2	2.8	8.0	12.3	0.5	1.5	10	6	4	3	23
73-100	8.4	6.8	10.4	16.9	0.5	2.5	56	18	11	8	52
100-125	8.4	7.0	10.5	30.2	0.5	2.5	78	17	9	5	80
Profile - 2, Village Ketwal											
0-16	8.2	9.7	8.0	28.5	-	1.5	86	32	12	8	90
16-50	8.4	3.9	9.0	10.6	0.5	2.0	34	7	10	6	30
50-88	8.3	2.8	8.5	8.5	-	1.0	20	6	7	4	20
88-110	8.4	16.0	4.5	20.8	0.5	-	16	7	7	5	22
110-150	8.3	4.0	8.0	10.0	1.0	2.0	33	14	11	7	30
Profile - 3, Village Bali											
0-16	7.0	61.2	3.5	10.9	-	-	765	180	445	261	206
16-55	7.9	15.3	4.5	15.5	-	-	162	39	55	35	104
55-105	7.6	16.0	4.5	20.8	-	-	176	40	46	32	130
105-145	7.8	18.9	4.5	20.7	-	-	180	41	50	35	135
Profile - 4, Village Bali											
0-15	8.2	27.7	5.0	35.4	-	0.5	327	26	47	31	221
15-32	8.3	5.8	5.5	14.2	-	0.5	48	16	13	8	46
32-86	8.4	3.1	7.5	8.0	-	1.0	22	7	6	4	18
86-110	8.5	2.6	8.2	7.5	1.0	2.0	20	4	6	3	16
110-140	8.8	2.0	12.0	7.0	2.5	5.5	15	4	5	3	14
140-165	8.9	1.7	13.5	8.2	2.5	5.5	11	2	3	2	13
Profile - 5, Village Lath											
0-19	7.9	54.0	5.7	40.3	-	1.0	611	190	180	128	500
19-70	7.8	24.8	5.0	28.2	-	1.0	220	90	65	41	205
70-90	8.3	17.5	5.7	24.7	-	1.0	149	70	43	28	147
90-100	8.3	9.0	5.7	14.6	-	2.0	79	25	25	16	66

of sodium carbonate and bicarbonates. ESP of surface layers ranging between 3.5 to 8.6 for medium textured soils does not pose sodicity problem. However, build up of carbonates and bicarbonates to the extent of 8 me/1 in profile 4 indicate the setting in of alkalisation process below 1m soil depth.

The electrolyte concentration in root zone columns of soil range between ECe (dS/m) of 1.7 to 61.2. Due to annual evaporation deficit of 1100 mm there is a constant upward flux of electrolytes beginning post monsoon to the start of next monsoon season. Electrolyte concentration mainly consisting of neutral salts was found maximum in the surface layers. Chlorides and sulphates were the most abundant anions and bicarbonates were in minute quantities. Sodium was the most dominant cation followed by calcium and magnesium. Dominance of neutral salts would result in good physical conduction during and after leaching with good quality irrigation water. Presence of soluble sulphate may initially lead to corrosion of concrete tiles and metallic components of the drainage system but after the salt content decreases sulphate corrosivity shall decrease simultaneously. High values of SAR ranging from 7.0 to 46.7 may lead to sodification following salt leaching. Based on the characteristics of soils pHs, ECe, ESP and SAR the soils under the drainage project have been termed saline.

Data in table 2 indicate sandy loam soil textures in the surface and sandy loam to sandy clay loam in the subsurface layers. The cation exchange capacity (CEC) varying from 6.5 to 14.5 are compatible with clay content and indicates illitic type of clay minerals. Sandy loam soil textures with illitic clay minerals have given rise to stable soil aggregates. The soils do not have an impervious horizon or a pan of any kind within 2 m. depth. They also lack a sandy-skeletal textural class which cave in easily when saturated. The soils have good sub-surface porosity and ideal water transmission characteristics. Horizontal hydraulic conductivity of soils ranged between 0.45-1.27 m/day. Thus, the soils would be able to release sufficient salts during the leaching process. Calcium carbonate concretions were present to the extent of 5 to 9 per cent. However, 15 cm thick petrocalcic layer with 55 per cent calcium carbonate concretions in soil profile 5 has to be broken to effect salt leaching.

Soil classification :

Soils of the project area fall under '*ustic*' moisture regime and '*hyperthermic*' temperature class. The diagnostic horizons in the surface were ochric whereas in the subsurface these were cambic. The salt affected soils of drainage project Gohana have been classified as fine-loamy, mixed, hyperthermic Typic Haplustepts (saline phase).

Table 2. Physical and chemical characteristics of saline soils

Depth (cm)	$CaCO_3$ (%)	Lime nodules (%)	Sand	Silt	Clay	CEC [cmol(p+) kg^{-1}]	H.C. (m/day)
			<2mm %				
Profile - 1, Village Ketwal							
0-15	1.1	–	69.5	15.0	15.5	7.5	–
15-45	0.2	–	67.0	16.5	16.5	7.7	–
45-73	1.0	–	58.0	18.5	23.5	9.8	–
73-100	0.9	5.0	59.0	18.0	23.0	10.5	–
100-125	9.0	7.5	71.0	14.0	15.0	6.5	0.90
Profile - 2, Village Ketwal							
0-16	1.1	–	58.0	18.5	23.5	11.5	–
16-50	0.8	–	56.0	17.5	26.5	13.7	–
50-88	0.7	–	54.0	19.0	27.0	14.5	–
88-110	3.6	5.0	62.0	20.0	18.0	9.5	–
110-150	8.2	2.0	69.5	14.5	16.0	8.0	1.00
Profile - 3, Village Bali							
0-16	0.6	–	68.5	15.5	16.0	8.5	
16-55	0.2	–	66.0	16.0	18.0	9.5	–
55-105	0.2	–	69.5	15.5	15.0	7.0	–
105-145	0.5	–	70.0	14.0	16.0	7.0	1.27
Profile - 4, Village Bali							
0-15	0.6	–	67.0	16.0	17.0	8.5	–
15-2	0.1	–	65.5	15.5	19.0	10.0	–
32-86	1.8	–	64.0	17.5	18.5	10.0	–
86-110	0.2	–	63.5	18.0	18.5	10.5	–
110-140	7.2	5.0	62.5	14.5	23.0	13.5	–
140-165	11.0	9.0	61.0	14.0	24.0	14.0	0.45
Profile - 5, Village Lath							
0-19	0.3	–	64.0	17.5	18.5	10.0	–
19-70	0.2	–	62.0	18.0	20.0	11.5	–
70-90	4.0	10.0	59.0	21.5	19.5	11.0	–
90-105	21.6	55.0	56.5	24.5	19.0	12.0	–

Ground water quality : Mean chemical composition of ground water under saline and sodic conditions is given in table 3 The ground water was drawn from strata between 5 to 43 m depth. The water table in the project area was shallow and fluctuates between 0.5 to 2.0 m depth. The electrolyte concentration measured by EC was invariably greater than 5.0 dS/m. Predominant salts were chlorides of sodium, calcium and magnesium. Carbonates and bicarbonates were present in smaller amounts. SAR values were less. Some ground waters with low electrolyte concentration were found to have dominance of carbonates and bicarbonates than divalent ions. Such waters can not be used for irrigation without neutralising harmful effect of residual sodium carbonate by addition of calcium bearing amendments. Keeping in view the high SAR of the soil solutions, the available natural saline water of EC around 5 dS/m would be useful in keeping the soils stable and flocculated during the initial stages of leaching process.

Table 3. Average composition of ground waters

No.of samples	Water depth (m)	EC (dS/m)	CO_3^{2-}	HCO_3^-	Cl^-	Na^+	Ca^{2+}	Mg^{2+}	RSC	SAR
			me/L							
					Saline waters					
16	6-38	5.8	0.2	6.5	32.5	30.6	11.0	15.7	-	8.3
					Sodic waters					
5	5-43	2.4	2.1	9.2	8.0	17.2	2.0	3.1	6.2	9.2

Table 4. Salt load in soils

Soil Profiles	Weighted ECe (dS/m)	Percent salts 1m soil depth	Average salt % in each profile	Total salts in 1ha m saline soil	Total salts in 1330 ha of saline soils - ton/ha m
1	11.0	0.26			
2	4.5	0.11			
3	23.3	0.56	1.83/5=0.37	$0.37 \times 15.2 \times 10^6$	$5.6 \times 10^6 \times 1330$
4	7.3	0.23		$=5.6 \times 10^6$ kg	=74,79,920 kg
5	27.5	0.67			(7.5 m ton/ha m)

Drainage requirements: Restricted surface drainage, high water table and poor quality ground water are mainly responsible for secondary soil salinisation of the project site. Minerals weathering under alternate dry and wet conditions of the region release significant quantities of salts into the soil solution (Bhargava *et al.* 1981). Weighted salt content up to 1m soil depth of 5 saline soil profiles was calculated from ECe values of different horizons (Table 4). Average salt content of saline soil amounted to 5600 ton/ha m. This was multiplied with total area of saline soils (1330 ha) to compute a salt load of 7.5 million tons/ha m in the project site. Prevailing shallow water table and exudational climate would further continue to add salts to the soil profile through upward capillary flux of salts. To restore agricultural productivity of these soils, it is necessary first to remove huge salt load from the root zone and secondly keep the saline water table below the critical water table depth of 1.5 m to prevent resalinisation process (Khosla *et al.* 1980). This could be achieved by installation of subsurface drainage system. Good horizontal hydraulic conductivity of soils ranging between 0.45–1.27 m/day would be able to provide adequate leaching to released salts. The salt leachate could be easily disposed off from the project area through the nearby existing Drain No. 8.

References

Bhargava, G. P., Pal, D. K., Kapoor, B. S., and Goswami, S.C. (1981). Characteristics and genesis of some sodic soils in the Indo-Gangetic Alluvial Plain of Haryana and U. P. *Journal of the Indian Society of Soil Science* **29,** 61-70.

Khosla, B. K., Gupta, R. K., and Chawla, K. L. (1980). Evaluating field hydraulic properties and soil salinisation under conditions of high water table. *Proc. Intern. Symp. Salt Affected Soils Karnal.* pp. 256-262.

Richards, L. A. (Ed) (1954). 'Diagnosis and Improvement of Saline and Alkali Soils'. USDA Agriculture Handbood No. 60. Washington, DC.

Sharma, R. C., and Bhargava, G. P. (1988). Landsat imagery for mapping saline soils and wetlands in north-west India. *International Journal of Remote Sensing* **9,** 39-44.

Sharma, R. C., and Bhargava, G. P. (1993). Remote sensing for assessing the distribution and characterisation of saline and alkali soils in Haryana. *Agropedology* **3,** 95-104.

Sharma, R. C., Saxena, R. K., and Verma K. S. (2000). Reconnaissance mapping and management of salt affected soils using satellite images. *International Journal of Remote Sensing* **21,** 3209-3218.

van Bear (1958). The Augehole Method. International Institute of Land Reclamation and Improvement. Bulletin No. 1 Wageningen. Netherland. p. 32.

Verma, K. S., Saxena, R. K., Barthwal, A. K., and Deshmukh, S. N. (1994). Remote sensing techniques for mapping salt affected soils. *International Journal of Remote Sensing* **15,** 1901-1914.

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