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Identification and Mapping Saline-Alkali Wastelands in Jodhpur District, Western Rajasthan Using Remote Sensing Techniques

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Abstract Application of remote sensing techniques in conjunction with ground truth for the identification, classification and mapping of natural and man-induced saline-alkali wastelands and their gensis and also morpholgical and physico-chemical characteristics of soils occurring under different geomorphic settings in Jodhpur district of western Rajasthan has been discussed in this paper. These wastelands appear in whitish grey to yellowish grey, whitish grey to dull red and milky white to dull white and light blue tones on LANDSAT TM false colour composites whereas on LANDSAT black and white products, they exhibit white to grey and dark grey tone. The genesis of natural saline-alkali wasteland is associated with the saline depressions, natural drainage channels and low lying areas and the man induced wastelands associated with older and younger alluvial plains and burried pediment had resulted due to use of canal and saline ground water for irrigation and rise of ground water table.

Key words Mapping, Natural and man induced saline-alkali wastelands, Remote sensing technique.

In the western Rajasthan, the saline-alkali wastelands occur under different geomorphic settings. The identification, classification and mapping of such wastelands by using modern methods is of paramount importance for their reclamation and proper management. Remote sensing techniques using LANDSAT black and white and false colour composite images in conjunction with ground truth have been proved to be useful, economic and faster in the identification and mapping of different types of wastelands (Kolarkar *et al.* 1980, Singh 1987, Singh *et al.* 1988). In this paper, an attempt has been made to identify, classify and to map the saline-alkali wasterlands and also to study their genesis, morphological and physico chemical characteristics of soils, in Jodhpur district of western Rajasthan using satellite remote sensing techniques in conjunction with ground truth.

The Environment

The study areas covering 22850 km^2 is located between latitudes 26°99' to 27°29' N and longitudes 71°59' to 73°46' E with Thornthwaite aridity index varying from 70 to 87. The average annual rainfall over the past 85 years is 307 mm varying over a range of 65 to 846 mm, 90% of which is received with relatively high intensity between June and September. The area lies in a belt having an average minimum temperature of 19°C, averge maximum of 33°C and annual evaporation of 3102 mm.

Topographically the district is characterised by vast alluvial plains in south and southeast having loamy sand to sandy loam and silty clay loam soils with high incidence of salinity and alkalinity; steeply rising hills in the southeast, undulating topography in the centre and sand dunes and interdunal plains in the north and southwest. Saline natural depressions (Ranns) occur throughout the district. The Luni river and its tributaries form drainage system of the district (Anonymous 1982).

Materials and Methods

LANDSAT TM False Colour Composites (FCCs) generated by a combination of bands 2, 3 and 4 on 1:50,000 scale; Survey of India topographical maps of 1:50,000 scale and published maps, reports etc. were used as basic materials to conduct this study. LANDSAT MSS black and white image and TM FCCs of October 1986 and January 1987 were used for the identification, classification and

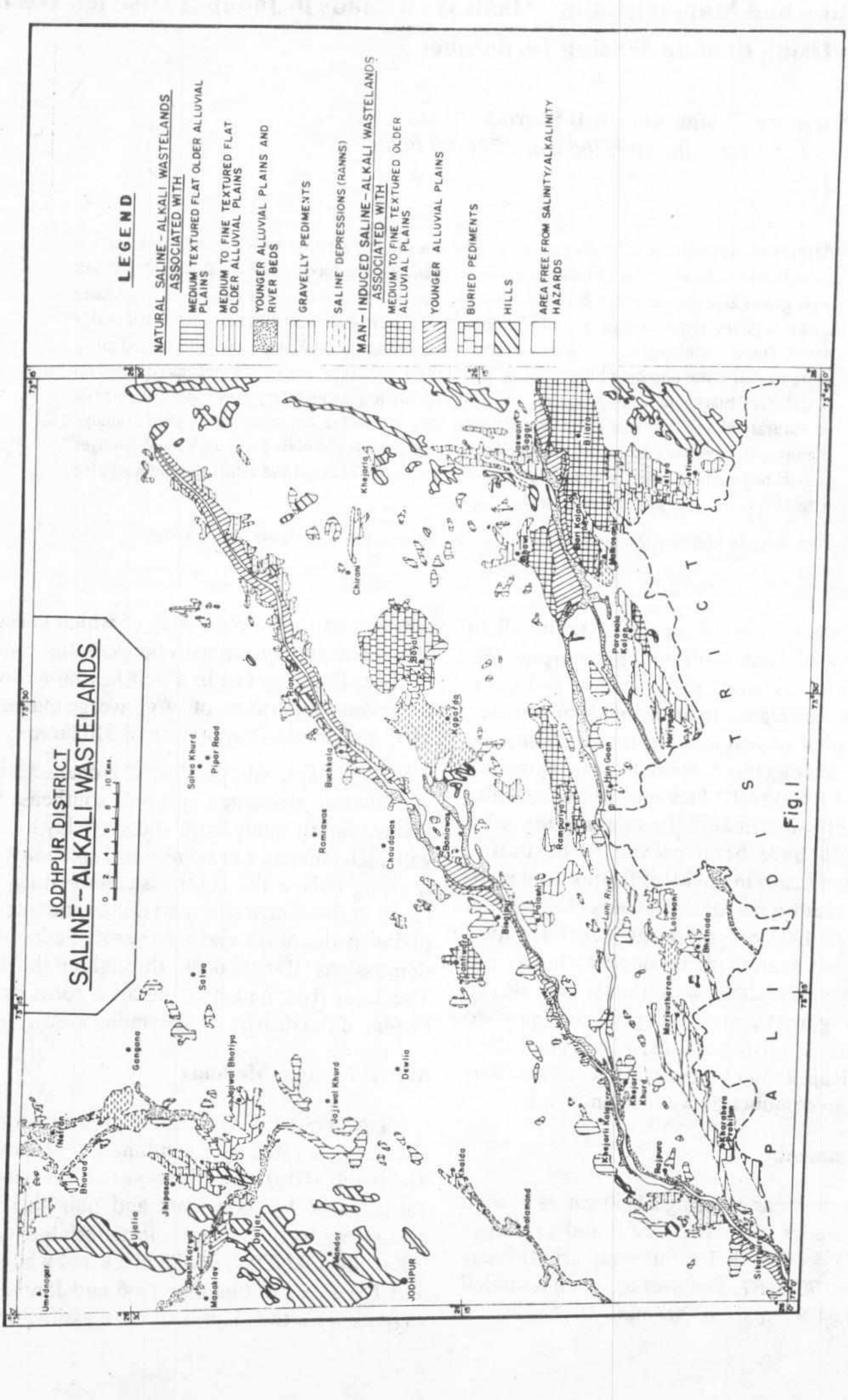

Fig 1 Saline-alkali watelands associated with different landforms

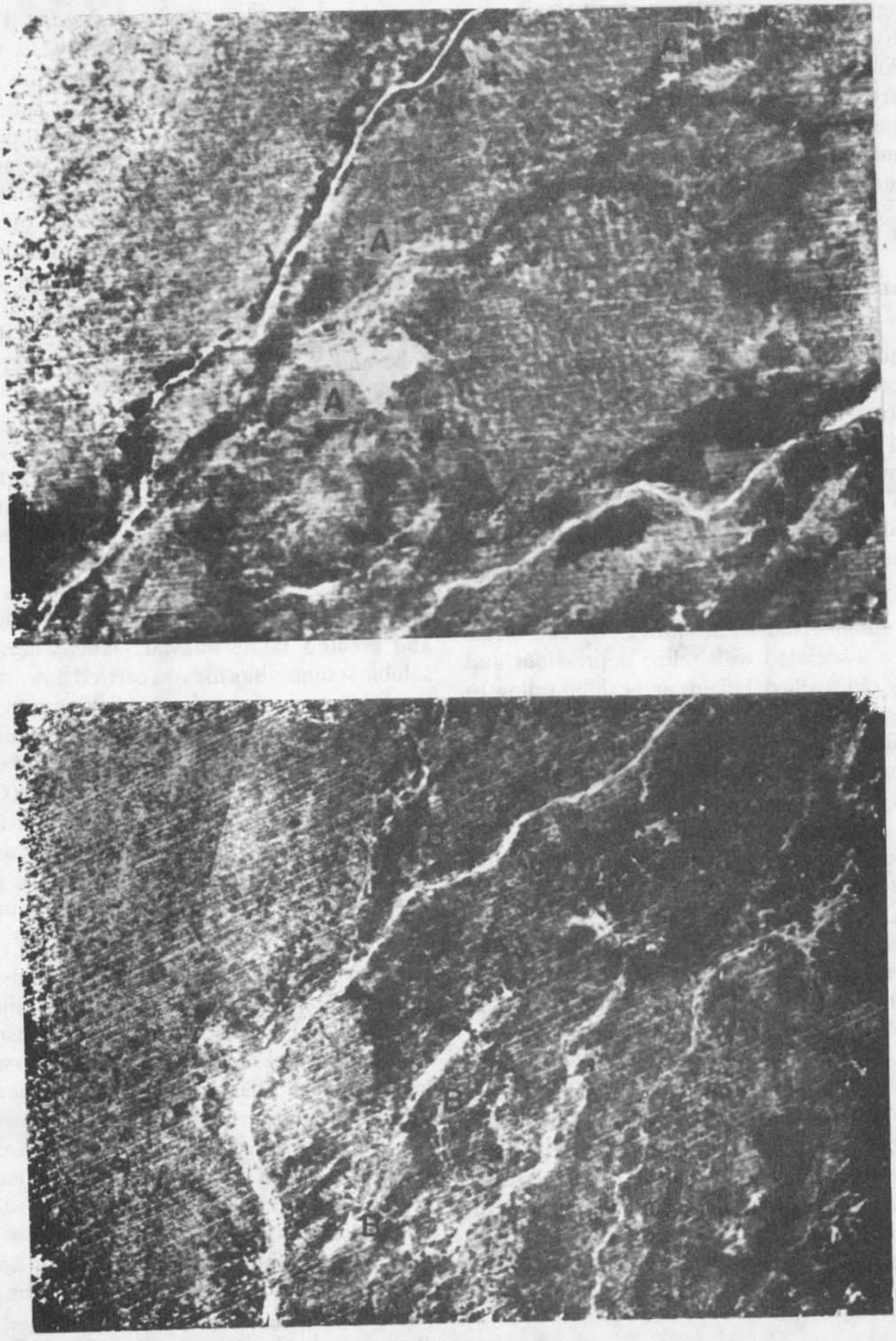

Fig 2 Segment of LANDSAT MSS band 5 image E-2725-04441 of wet season showing (A) areas affected by natural salinity (white to dark grey tone), and (B) areas affected by man-induced salinity.

mapping of the saline-alkali wastelands. During the field survey, the saline-alkali wastelands identified and delineated in the laboratory were verified and necessary corrections in boundaries were made in case of any discrepancy. The soil samples of the wastelands collected were analysed as per standard procedures.

Results and Discussion

Identification, distribution and mapping of wastelands :

Natural and man-induced saline-alkali wastelands occurring under different geomorphic setting in the study areas were identified, delineated and mapped from LANDSAT MSS black and white images and TM FCC in conjunction with ground truth. The genetic, morphological and physico chemical characteristics of soils also enabled to separate these two types of wastelands from each other (Fig.1)

Natural saline-alkali wastelands : By and large, these are associated with saline depressions and low lying older alluvial plains and exhibit yellow to whitish grey tone on LANDSAT TM false colour composites. They are of semi-circular to circular and elongated in shape. Due to the high density of *Prosopis juliflora, Capparis decidua, Zizyphus nummularia* and *Salvadora persica*, these wastelands also appeared as random specks of whitish grey and dull red tone on above LANDSAT products. These saline-alkali wastelands in association with rocky/gravelly and burried pediments occur in pockets and appear in dull white to whitish grey tone with specks of red spot on LANDSAT TM false colour composites. Such wastelands associated with younger alluvial plains and river beds could be easily and quickly identified and mapped due to grey to white tone with dull red specks, their location and pattern. They are of elongated shape and constitute highly saline loam to clay loam soils. Whereas due to surface salt crust, mottled texture and higher spectral reflectance they exhibit white to whitish grey tone with dark grey specks on LANDSAT MSS band 5 black and white image (Fig. 2).

man-induced saline-alkali wastelands : These are associated with canal and saline wells water irrigated older and younger alluvial plains and burried pediments appear in whitish to dull red tone on LANDSAT TM FCCs. The whitish tone of these wastelands is due to high spectral reflectance from surface salt crust and dull red tone is caused by chlorophyll content of poor growth of standing crops in fields. They occur in discontinuous dull red patches and in elongated shape under different geomorphic settings. These wastelands associated with above landforms appear in white to dark grey tone and mottled texture on LANDSAT band 5 black and white image (Fig 2).

Gensis of wastelands :

During the Pleistocene period alternate dry and wet phases have played a significant role in the formation of saline depressions (Ranns), saline alluvial plains and associated natural saline-alkali wastelands. Calcium sulphate being less soluble was deposited in the upstream of drainage basin and created saline alluvial plains wheras more soluble sodium chloride was carried downstream to the confluence of the rivers resulting into the formation of saline depressions. Due to capillary action, evaportion and upward movement of salts, the saline-alkali wasterlands came into being (Ghose *et al.* 1982). The whole profile of the alluvial sediments is highly charged with soluble salts and maximum concentration is found at surface through capillary action and high temperature during the period of May and June (Dhir *et al.* 1979).

Man-induced saline-alkali wastelands largely under younger and older alluvial plains have developed due to human activity like construction of canal and tanks along the burried course of the prior drainage channels and use of saline wells water for irrigation in the area. Faulty method of irrigation has caused the severe saline-alkali problem due to rise of ground water in the medium to fine textured alluvial plains with burried salinity in the substrata. In these areas, salts were moved with upward trend due to capillary action and high temperature gradient and resulting in the formation of thick salty crust layer at surface and saline-alkali wastelands (Dhir *et al.* 1979, Ghose *et al.* 1982).

Table 1 *Morphological characteristics of saline-alkali wastelands*

Association of saline-alkali wastelands and their location	Extent (km^2)	Geomorpholgy	Soil
		Natural saline-alkali wastelands	
Medium textured flat older alluvial plain (Lolasani, J-1)	87.9 (0.77)*	Nearly level topography with less than 1% slope and medium textured sediments underlain by *kankar* pan at varying depth	Greyish brown to dark greyish brown, sandy loam to loam, calcareous
Medium to fine textured flat older alluvial plain (Between Kharabera Prohitan-Morisuthara, J-2)	71.2 (0.31)	Flat land with less than 1% slope and medium to fine textured sediment underlain by *kankar* pan	Light brownish grey to dark greyish brown, loam, clay loam and silty clay loam, highly calcareous.
Younger alluvial plain and river bed (Rajpura, J-3)	86.5 (0.38)	Nearly level to gently sloping plain with coarse to medium textured sediments with loose prorous gravel/pebbles substrata.	Brown to yellowish brown, loamy sand to sandy loam, slightly calcareous
Rocky/gravelly pediments (Karwar Basani, J-4)	67.0 (0.29)	Gravelly flat surfaces with rock fragments	Pale brown to light brownish grey, gravelly loamy sand to gravelly sandy loam, calcareous
Saline depression rann (Kaparda, J-5)	30.7 (0.13)	Circular to semi-circular almost level slope, wet and dry, fine sediments.	Grey to greyish brown, loam to clay loam, silty clay loam and clay strongly calcareous.
		Man-induced saline-alkali wastelands	
Medium to fine textured flat older alluvial plain (Malkosani, J-6)	177.5 (0.77)	Nearly flat topography with medium to fine textured sediments underlain by *kankar* pan.	Greyish brown to dark greyish brown, loam to clay loam, strongly calcareous
Younger alluvial plain and river bed (between Lamba and Bhawi, J-7)	75.2 (0.33)	Flat to slightly undulating and light to medium textured younger alluvial plains	Brown to dark yellowish brown, sand to sandy loam, moderate calcareous
Burried pediment (Jelwa, J-8)	28.3 (0.12)	Nearly flat with rock outcrops and gravelly sandy surface deposit	Yellowish brown to light brownish grey, gravelly sandy loam to loam, strongly calcareous

* Figures in parenthesis indicate the percentage of the total area of the district.

Morphological and physico-chemical characteristics of the soils.

Morphologically, natural saline-alkali wastelands are characterised by almost level slope, surface salt crust and highly saline loam to clay loam and silty clay-loam soils of brownish grey to greyish brown and dark brown colour (Table 1). The dominent soluble salts of wastelands are sodium chloride followed by calcium and magnesium sulphate. The ECe ranges from 1.32 to 152.4 dS m^{-1} and pH value from 8.1 to 8.8. The SAR and ESP values range from 3 to 1442 and 9 to 86 respectively (Table 2).

The dominent morphological characteristics of the man induced saline alkali wastelands are almost level slope, impeded drainage conditions, highly saline, loam to clay loam soils of brown to greyish brown colour underlain by *Kankar* pan and weathered rocky strata at 30 to 180 cm depth (Table 1).

The physico-chemical characteristics of soils of these wastelands revealed that they had sodium chlorides, sodium-calcium chloride and sodium chloride-sulphate type salinity. The dominant cation are Na, Mg, K and anion Cl, SO_4, HCO_3. The pH ranges from 8.0 to 9.9. The electrical conductivity of saturation extract ranges from 31.32 to 168.63 dSm^{-1} and SAR, ESP value ranges from 17 to 261 and 24 to 79, respectively (Table 2).

Table 2 *Physico-chemical characteristics of the soils of saline-alkali wastelands*

Profile No.	Soil depth (cm)	Organic carbon (%)	pH 1 : 2	ECe dSm^{-1}	Cation me L^{-1} Na	K	Ca	Mg	Anion me L^{-1} Cl	HCO_3	SO_4	SAR	ESP
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Natural Saline-Alkali wastelands													
J – 1	0-10	0.25	8.6	1.3	6.5	0.1	5.2	3.7	7.5	8.0	0.1	3	9
	10-30	0.38	8.7	2.6	16.3	0.1	3.0	6.0	15.0	10.8	0.1	7	21
	30-100	0.12	8.8	5.8	47.8	0.1	5.2	2.8	15.0	9.0	1.5	23	25
	100-120	0.12	8.2	8.2	69.5	0.5	5.0	7.0	62.5	19.0	0.2	28	26
J – 2	0-2	0.39	7.7	152.5	1391.0	43.5	87.5	32.5	1260.0	4.0	290.0	170	49
	2-12	0.47	8.0	99.8	913.0	37.0	36.5	31.5	7000.0	4.5	390.5	156	47
	12-28	0.32	8.1	63.4	606.8	27.0	27.0	11.0	330.0	5.0	336.5	139	45
	28-70	0.21	8.7	18.1	146.0	10.0	3.0	0.1	90.0	6.0	64.5	97	39
	70-120	0.21	8.5	6.0	48.0	9.0	2.0	0.5	40.0	5.0	14.3	43	29
J – 3	0-30	0.34	8.3	2.1	17.4	0.2	2.2	2.0	10.0	9.0	2.7	12	22
	30-60	0.28	8.7	4.7	47.7	0.2	2.2	2.0	35.0	7.0	4.0	29	26
	60-90	0.29	8.6	13.9	121.7	0.2	10.5	5.0	125.0	5.0	7.7	44	29
	90-120	0.25	8.8	27.3	221.7	0.3	32.0	16.0	250.0	10.0	10.0	45	30
J – 4	0-5	0.12	8.1	59.8	5888.2	20.5	27.2	8.2	4000.0	886.0	1475.0	1442	86
	5-15	0.07	8.4	19.8	1883.6	6.6	34.5	16.0	1500.0	378.0	184.2	394	65
	15-30	0.06	8.8	9.4	839.1	3.3	5.1	12.1	750.0	111.5	154.6	40	29

contd......2

1	2	3	4	5	6	7	8	9	10	11	12	13	14
J – 5	0-20	0.18	8.3	116.1	4391.0	44.8	28.3	569.0	4500.0	45.6	428.6	283	81
	20-55	0.16	9.2	69.1	652.1	1.08	14.6	30.2	600.0	5.0	23.5	137	67
	55-110	0.12	9.2	23.4	221.7	0.8	6.7	7.7	220.0	3.2	13.5	102	52
	110-140	0.02	9.2	27.6	260.8	0.9	9.6	8.0	260.0	2.8	16.7	67	66
	140-190	0.03	9.8	33.7	308.0	3.3	11.9	15.0	310.0	2.6	29.6	84	55
Man-induced saline-alkali wastelands													
J – 6	0-15	0.31	9.0	89.4	869.5	8.9	56.0	38.5	865.0	4.2	103.7	126	65
	15-25	0.22	8.6	168.6	1169.5	14.7	44.0	37.5	1580.0	3.7	2327.0	261	79
	25-40	0.11	8.9	39.1	186.9	3.0	4.0	17.0	175.0	3.5	31.5	59	45
	40-65	0.06	8.9	16.0	160.8	3.3	6.0	4.0	140.0	5.0	28.1	80	51
	65-110	0.05	8.7	68.2	534.7	6.4	17.0	32.0	533.0	3.0	153.1	108	61
J – 7	0-24	0.10	9.1	63.2	17.3	0.5	43.6	1.6	11.0	7.5	1.4	8	20
	24-45	0.28	9.7	24.9	21.2	0.3	1.5	0.9	8.0	14.5	1.4	19	24
	45-65	0.21	9.8	31.2	29.3	0.2	0.9	0.7	8.0	17.5	5.7	14	25
	65-75	0.11	9.8	34.4	28.3	0.1	4.7	1.0	10.0	18.5	5.6	17	23
J – 8	0-15	0.11	8.0	129.6	1243.4	17.3	44.0	51.0	1230.0	2.5	123.2	180	50
	15-25	0.09	8.0	25.5	243.4	3.4	4.5	8.0	195.0	2.5	62.8	97	39
	25-40	0.05	7.9	69.9	695.6	6.9	13.5	18.5	605.0	3.0	226.5	194	49

Conclusions

LANDSAT black and white images and TM false colour composites have been found useful tool for the identification, classification and mapping of natural and man induced saline- alkali wastelands. The natural and man-induced wastelands due to distinct variations in their form, size. pattern and spatial and spectral characteristics could be easily separated and mapped from LANDSAT MSS black and white and TM false colour composite images. The difficulty however, was faced to separate these wastelands from eroded rocky surfaces and riverine sand due to similar spectral reflectance and tonal and textural characteristics. Based on the ground truth and size, form, pattern and location, these wastelands could be separately mapped.

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