Agropedology, 1999, **9**, 30-40

Soil degradation assessment through remote sensing and its impact on fertility status of soils of western Rajasthan

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Abstract

Present investigation deals with the identification and mapping of an area affected by various soil degradation processes in Sikar district of western Rajasthan of India. Soil degradation processes were identified by using IRS-1A subscene of 1991 and ground truth verification. The kind, extent and degree of degradations were mapped. Wind erosion and water erosion were major degradation processes. Nearly 56% of the area needs urgent attention to arrest the processes of soil degradation.

Impact of degradation on physical and chemical properties of soils were evaluated. The soils degraded due to wind erosion, water erosion and salinization contained lower amounts of available P, available K and organic carbon in comparison to the soils of non-degraded sites.

Additional keywords: Soil degradation, wind erosion, water erosion, salinization.

Introduction

The increasing human and animal population in arid Rajasthan is discernible in declining land-man ratio, which in turn has led to the extension of cultivation on marginal lands and decline in fallow lands.. The increased demand for food, fodder and fuel have forced intensive cultivation of croplands, use of poor quality water and over-exploitation of common grazing land resulting in degradation of soil resources through wind erosion, water erosion and salinisation. These degradation processes are site specific and differ in type, intensity and coverage of affected area. Therefore to map these degraded areas, remote sensing techniques have been found valuable in improving the accuracy and speed of the work by minimizing the time on field work. Based on the tonal characteristics on the IRS images, it has been possible to assess the extent and distribution of degraded areas affected by various degradation processes. Remote sensing technology has been used very successfully by many authors for mapping degraded lands (Teotia *et al.* 1980; Sehgal and Sharma 1988; Raina *et al.* 1983 and Raina 1994).

In this paper, remote sensing techniques have been applied for identification of the extent and degree of soil degradation in Sikar district of western Rajasthan. The effect of degradation processes on physical and chemical properties of soils has also been reported.

Materials and methods

The study area covering 7732 sq km is located in the north western part of Rajasthan between 27°07'10" and 28°12'10" N latitudes and 74°40'55" and 76°05'33"E longitudes. The climate of the Sikar district is arid to semiarid with average temperature of 40°C in summer and 6°C in winter,, mean annual rainfall of 453.6 mm, the annual evapotranspiration ranges from 1500 to 2000 mm.

The common trees found in the district are *Prosopis cineraria, Tecomella undulata, Acacia senegal, Acacia nilotica, Zizyphus nummularia, Azadirachta indica, Capparis decidua* and *Salvadora oleoides*. Forest areas on hills have *Anogeissus pendula* and *Boswellia serrata.*

Criteria for mapping soil degradation

The criteria laidout by Oldeman *et al* (1990) with slight modification (Raina *et al.* 1993) was adopted for identifying the degraded area due to different types of degradation processes and their degree of degradation (Table 1). The degree to which a soil has been degraded was estimated in relation to changes in agricultural suitability in case of cultivated soils and its biotic potential for pasture and forests.

Table 1. Criteria for assessing soil degradation

Area degraded due to different processes	Assessment factor	Degree of degradation			
		Slight	Moderate	Severe	Very Severe
Area subjected to wind erosion (W)	Surface features	Thick sand deposition along fence line	Thick sand deposition along fence lines and on fields; sandy hummocks	Degraded dunes very thick sand sheets, all devoid of vegetation	Degraded dunes and barchan dunes
	Percentage of area covered with vegetation	30-70%	10-30%	0-10%	Nil
Area subjected to water erosion (V)	Surface features	Shallow soil, gravels and stone cover 10% or less area	Occasional rock outcrops, soil eroded/deposited in patches, 40-50 cm deep soil buried pediments with rills	Undulating rocky area with pocket of soil 20-40 cm depth pediments with rills and gullies	Boulders and rock exposure cover 50% or more. Formation of network of wide gullies
	Type of water erosion	Slight surface runoff and sheet erosion	Moderate surface runoff, sheet erosion moderate to severe	Rapid surface runoff, gully erosion	Very rapid surface runoff, gully erosion
	Subsoil exposed per cent of area	Less than 5	5-10	10-15	15 and above

Area degraded due to different processes	Assessment factor	Degree of degradation			
		Slight	Moderate	Severe	Very Severe
	Soil thickness (cm)	60	40-60	10-40 in pockets gravelly strata without soil	Less than 10 gravelly strata
	Percentage of area covered with vegetation/ crops	More than 50	50-25	25-10	Less than 10
Areas subjected to salinisation and alkalinisation (S)	Surface features	Slight saline water irrigated areas	Moderately saline water irrigated areas, naturally saline areas amendable to reclamation	Low lying area having high salinity/alkal-inity	Rann area
	Salt layer location in soil profiles	Substrata salinity below 80 cm	Salts present in sub-surface soil 30-60 cm	Salts present in 30 cm layer	Salts in upper layer
	Morphologic al features of salinisation	Manifestations of salts not visible	Few, small spots of salts in the upper dry part of profile	Frequent small spots of salts	Salt crust on surface
	Profile salinity (electrical conductivity, dS m^{-1} in 1:2 soil water suspension	1-5	5-8	8-12	12 and above
Applicable for all types of degradation processes	Agricultural suitability	The terrain has somewhat reduced agricultural suitability. Restoration to full productivity is possible by modification of the management system. Original biotic functions are still largely intact.	The terrain has greatly reduced agricultural suitability but still suitable for use in local farming system. Major improvements are required to restore productivity. Original biotic functions are largely destroyed.	The terrain is non reclaimable at farm level. Major engineering works are required for terrain restoration. Original biotic functions are largely destroyed.	The terrain is unreclaima-ble and beyond restoration. Original biotic functions are fully destroyed.

Mapping present status of soil degradation

Soil degradation assessment of Sikar district was carried out by using (1:50,000 scale) satellite imagery. False colour composite (bands 2,3,4) IRS-1A Geocoded Path 31, and row 48 of March 1991 was used for the study. Satellite imageries were interpreted visually in conjunction with Survey of India topographical maps of the same scale, based on the tonal characteristics. Tentative

units showing different degradation processes were demarcated. These units were verified through groundtruth. At several sites, the texture, calcareousness, colour and soil depth were recorded (Soil Survey Staff 1975). The soil samples collected from degraded and non-degraded sites were analysed for soil pH and electrical conductivity in soil: water suspension (1:2), organic carbon, available phosphorus and available potassium by methods described by Jackson (1967).

Results and discussion

The kind and degree of soil degradation in Sikar district of western Rajasthan is presented in figure 1. Causative factors identified were high population of both human (1.84 million, density 238 persons/km^2) and animal (1.76 million) as per 1991 census, which forced the people for (a) cultivation of marginal lands (dune slopes, shallow soils) (b) use of poor quality water for irrigation and (c) indiscriminate cutting of trees and overgrazing in pasture lands. Mainly three types of soil degradation processes were identified in the study area.

(1) Area subjected to wind erosion (W); (2) Area subjected to water erosion (V); (3) Area subjected to salinization and alkalinization (S).

The salient features of each degradation class are discussed below.

Area degraded due to wind erosion (W)

Soil degradation due to wind erosion resulted in the formation of sand sheet, hummocks and barchan dunes as depositional and exposure of plant roots and substrata as erosional features. Total area degraded due to wind erosion/deposit hazards was 4585 km^2 (59.3%). The characteristics of different intensities of soil degradation due to wind erosion/deposition are discussed below.

Slightly degraded soils (W1): Soils of this area are deep to very deep, pale brown to light yellowish brown fine sand to loamy sand and are classified as Typic Torripsamments/coarse-loamy Haplocambids. Such areas occur in Ranoli, Shishu in Sikar tahsil and Govindpura, Sarwari and Mandha village in Danta Ramgarh tahsil. On IRS images, this unit is recognised by its pale brown with red tinge due to rabi crop. Soils degraded due to slight degradation occupy 1229 km^2 (15.9%) area.

Moderately degraded soils (W2) : These are very deep, fine sandy soils of hummocky plain, classified as coarse-loamy Haplocambids and Typic Torripsamments. Such degradation is common in the villages Renu, Bairas, Palsana, Abhawas, Bidsar, Bhagowa, Bajayawas and Karar. On satellite imagery, this unit is recognised by its pale brown small strips with very less reddish tinge due to rabi crops. Moderately degraded soils occupy 1817.7 km^2 (23.5%) area.

Severely degraded soils (W3): This type of soil is commonly found in the dune and in highly hummocky area classified as Typic Torripsamments. Dune height is 20-50 meters. At few places, the fresh sand in the form of 10-50 cm thick sand

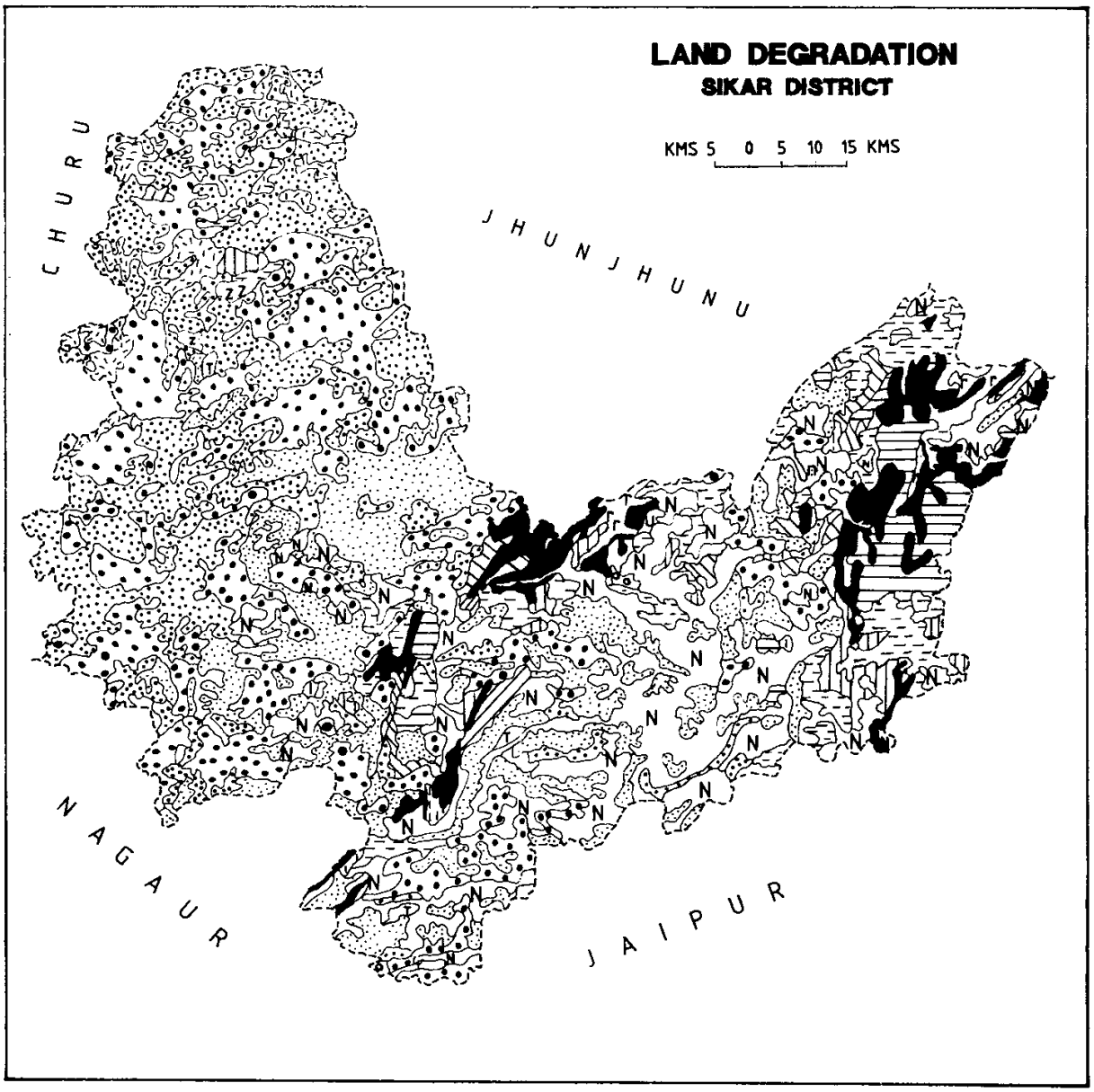

Fig. 1. Extent of land degradation in Sikar district.

sheets occur on the crest and flanks of these dunes. In village Thimoli, Tihay, Dinwa, Bibipura and Karanga, dunes of low to medium height have been levelled and are used for irrigated farming. In Raipura, Chomu, southern side of Bhuma Bara, south-east and south-west side of Chirasara village, very high dunes were identified. On satellite imagery, this unit was recognised by its pale brown, with typical duny features. The soils degraded due to severe wind erosion occupy 1360.9 km^2 (17.6%) area.

Very severely degraded soils (W4) : This type of degradation was identified in the areas infested by barchan dunes of 2 to 5 m height and reactivated stabilized dunes of 60 to 90 m height. Dunes near Bhagot and Lakhyawali Dhani are 70 m high. Unstabilized dunes were observed near Bajor and Mandha village. Oran lands of the villages Pipal Balodi, Dinwa and Abhawas, have barchan dunes of height 4-5 m. Soils in these areas are pale brown to light yellowish brown (10YR 6/3 – 10YR 6/4) fine sand classified as Typic Torripsamments. On satellite imagery, this class appears as pale yellow with typical dune pattern. This category of very severe degradation occupies 177.3 km^2 (2.3%) of the area.

Area degraded due to water erosion (V)

Water erosion is the main soil degradation process in the north and north-eastern part of the Sikar district and occur mostly in the pasture lands or in the vicinity of hills of Neem ka Thana, Sikar and Dange Ramgarh tahsil of Sikar district. Water erosion occurs in the form of sheet, rill and gullies and observed in 1445.1 km^2 (18.7%). The characteristics of different intensities of soil degradation due to water erosion are discussed below.

Slightly degraded soils (V1): During the rainy season, there is a loss of surface soil through runoff. Such type of degradation is common in the pasture lands. Along hill slopes, these lands are subjected to sheet flows. Such type of degradation occur in the villages Thimoli, Bibipura, Dantru, Kudan, Dhaka and Shanusar. The soils in these areas are loamy sand to clay loam, pale brown to dark brown (10YR 6/3, 10YR 4/3) and non-calcareous to strongly calcareous classified as coarse-loamy Haplocambids/ Haplogypsids. On satellite imagery, this class appears as medium brown with dark gray mottles. This category of slight degradation occupies 512.5 km^2 (6.62%) area.

Moderately degraded soils (V2): Areas of moderate degradation have shallow to moderate depth with very gentle slope (1-3%) and areal exposure of substrata. The degradation mostly occur in the pasture and cultivated lands in the adjoining areas of hills. The soils are dark brown to brown (10YR 3/3, 7.5YR 5/4), loamy sand to sandy loam and loam classified as fine-loamy Haplocambids. Such type of degradation occur in the villages Salidpura, Khandla, Barol and adjoining areas of Raghunath protected forest. On satellite imagery, this class appears as whitish, gray patches indicating areas of shallow soils with few stream channels. This category of degradation occupies 412.62 km^2 (5.34%) area.

Severely degraded soils (V3): This category of degradation occur around hills and rocky gravelly uplands. Areas of this unit appear barren, devoid of vegetation and are strewn with stones, rocks and gravel on the surface. The soils in pockets are brown to dark brown (7.5YR 5/4-3/2) and texture varies from gravelly sand to loamy sand and loam and are lithic/skeletal soils. This type of degradation mainly occurs in Neem ka Thana and Sikar tahsils of Sikar district. Near Chankari and Salwari, Kankar pan is exposed in cultivated field near large gullied area. In open scrub lands of Mau severely gullied 10-60 ft deep and 20-70 ft wide gullies were found. In the villages Gudi calan, Prithvipura, eastern side of Kochchor and in Samarthpura, this type of degradation is very common. On satellite imagery, this type of degradation appears uniformly light gray, intercepted by streams which appears whitish gray. This unit occupies about 520 km^2 (6.73%) of the total area.

Area degraded due to natural and anthropogenic salinity/alkalinity

The soils affected by natural salinity/alkalinity generally occur in the lowlying areas of saline flat older alluvial plains, younger alluvial plains and saline depressions (rann). The soils of this area are variable in texture ranging from sandy loam to loam, clay loam and silty clay loam, grayish brown to dark grayish brown and strongly calcareous. The substrata is gravelly coated with lime and at places hard lime concretionary layers which restrict the infiltration of surface water resulting in the development of impeded drainage conditions and salinity/alkalinity problem. Anthropogenic salinity/alkalinity problem has developed due to the use of saline/sodic ground water for raising crops. This has also resulted in the rise of ground water table and development of secondary salinisation in cultivated lands.

Slightly degraded area: Slightly degraded area with salinity/alkalinity hazard (15.8 km^2, 0.28%) mainly occurs in cultivated and grazing lands near Aloda and Gonora villages. The EC and pH of these lands vary from 0.1 to 3.8 dS m^{-1} and 7.84 to 9.15, respectively. On satellite imagery, this class appears grayish white patch in the scattered form.

Moderately degraded area: The degradation of this type has affected 12.8 km^2 (0.16%) area and lies near Danta Ramgarh, Kankera, Chuwas, Rajanpura Bibipura and Aloda villages. The electrical conductivity of soils affected by this class ranges between 4 and 8 dS m^{-1} and pH between 7.6 and 10.0. On satellite imagery, this class appears as whitish patch in the scattered form.

Severely degraded area: In this class, naturally saline areas with high content of salts throughout the soil profile have been included. These areas were observed near Bai, Kailas, Khatu, Kochchor and Nemara villages. It covers 2.02 per cent area of the district. The electrical conductivity and pH of the soils affected by this type of hazard varies from 8.2 to 21.2 dS m^{-1} and 10.8, respectively. On satellite imagery, these lands appear as whitish patches.

Area degraded due to combined effect of wind erosion-water erosion and salinity

In these areas soil removal/deposition, formation of hummocks and dunes by wind erosion, and sheetwash, rill and gully formation by water erosion were observed. Total area degraded due to combined effect of wind and water erosion is 235.62 km^2 (3.18%). The area degraded due to combined effect of water and wind erosion, water erosion and salinity and wind erosion and salinity is presented in table 2. The area degraded due to combined effect of slight wind and water erosion occur in the adjoining area of village Bibipur, northeastern side of Rinau and western side of Dharmsala in Fatehpur tahsil. This type of area also occur in between Dantla and Bijaywas in Danta Ramgarh tahsil in Sikar district. Moderately degraded area occur in the villages Gauti, Khrol, Mandawa and Todi villages. Areas degraded with severe wind and water erosion hazards occur in the eastern side of Bhargaron ki Dhani, Jeeron ki Dhani, Bhageja and in between the villages of Kali khera and Thikari. In the areas degraded due to combined effect of salinity and water erosion, top soil has been removed due to sheet and rill erosion and high salinity restricts plant growth. This category includes pasture lands, saline and high RSC water irrigated fields mostly in the villages Banthla and Bai. Open scrub land of Bajor is degraded due to slight wind erosion and salinity hazard.

Table 2. Soil degradation by wind erosion/deposition, water erosion and salinization

Soil degradation processes	Water erosion Severity and extent of soil degradation (km^2)			Combined effect of slight wind erosion and salinisation (W1S1)
	Slight	Moderate	Severe	
Wind Erosion				
Slight	62.7 (0.81)	--	--	3.25 (0.042)
Moderate	--	95.8 (1.25)	--	
Severe	--	--	87.12 (1.13)	
Salinity				
Slight	21.4 (0.25)	--	--	
Moderate	--	29.05 (0.37)	--	

Effect of soil degradation on fertility status of soil

An attempt was made to correlate the interpreted satellite data with the soil physical and chemical characteristics (Tables 3, 4 and 5) and the results are discussed below.

Effect of wind erosion deposition on fertility status of soils: Results (Table 3) indicated that there is little variation in the pH and conductivity of the soils. Regarding fertility status, content of organic carbon, available potassium and phosphorus are more in nondegraded soils in comparison to degraded soils. The results are in conformity with Aggarwal and Gupta (1980) and Gupta et al. (1981) who reported cumulative nutrient removal from bare sandy plain whereas the pasture sandy soils remained free of erosion. The depletion of nutrients from cultivated field has been found much higher because the amount of soil removal from cultivated land is high.

Table 3. Effect of wind erosion on physical and chemical properties of soils

Parameters	Nondegraded	Slightly degraded W1	Moderately degraded W2	Severely degraded W3
pH	7.42-8.4	8.05-9.0	7.6-8.4	8.1-8.4
Conductivity dS m^{-1}	0.111-0.832	0.74-0.192	0.13-0.754	0.088-0.85
% organic carbon	0.211-0.28	0.13-0.24	0.076-0.033	0.039-0.120
Available K kg ha^{-1}	201.25-450.00	90-326	106-371	45.0-213
Available P kg ha^{-1}	12-28	6-14	10-30	3-8

Effect of water erosion on fertility status of soils: The fertility status of soils affected by water erosion (Table 4) indicate that the loss of all the nutrients was more in degraded soils. In the rainy season, runoff water from adjoining area removes fertile top soil. The results were in agreement with those of Gopinathan *et al.* (1988).

Table 4. Effect of soil erosion on physical and chemical properties of soils

Parameters	Nondegraded	Slightly degraded V1	Moderately degraded V2	Severely degraded V3
pH	7.42-8.4	7.7-8.3	7.8-8.4	8.3-9.2
Conductivity dS m^{-1}	0.11-0.83	0.09-0.23	0.08-0.16	0.08-0.48
% organic carbon	0.21-0.65	0.08-0.19	0.07-0.27	0.05-0.16
Available K kg ha^{-1}	201.2-866.2	157-292	61-196	67-393
Available P kg ha^{-1}	12-28	12-28	4-14	3-7

Effect of salinity alkalinity on fertility status of soils: Physical and chemical characteristics and fertility status of degraded and nondegraded soils are given in table 5. The pH of the normal and salt affected soils was in the alkaline range, varying from 7.4 to 8.4 in nondegraded soils and from 7.6 to 10.07 in degraded soils. The electrical conductivity increased with intensity of degradation e.g. slight (1.38 – 3.8 dS m^{-1}), moderate (4-7.5 dS m^{-1}) and severe (8.2 – 11.2 dS m^{-1}), which may adversely affect the uptake of nutrients.

Table 5. Effect of salinisation/alkalinisation on physical and chemical properties of soils

Parameters	Nondegraded	Slightly degraded S1	Moderately degraded S2	Severely degraded S3
pH	7.4-8.4	8.4-10.0	8.4-9.0	7.6-8.8
Conductivity dS m^{-1}	0.11-0.83	1.38-3.8	4-7.5	8.2-11.2
% organic carbon	0.21-0.65	0.20-35	0.19-0.38	0.20-0.39
Available K kg ha^{-1}	201-866	101-347	200-400	216-380
Available P kg ha^{-1}	12-28	12-18	10-18	4-18

The soil data indicated that there is not much variation in organic carbon content of moderately and severely degraded soils (0.19 to 0.39%) although organic carbon in non-degraded soil was more (0.21 to 0.65). This is apparent from the results that high salinity does not have an adverse effect on the available K which ranged from 201 to 866 kg ha^{-1} in non-degraded soils and 101 to 400 kg ha^{-1} in degraded soils. Higher amount of potassium in degraded soils might be attributed to the grazing animals (Raina and Joshi 1991). The value of available phosphorus in non-degraded soil ranges from 12-28 kg ha^{-1} although in degraded soil it ranged from 12-18 kg ha^{-1} and decreased as intensity of degradation increased. Thus the impact of soil degradation processes such as wind erosion/deposition, water erosion and salinization on the fertility status of soil indicated the loss of potassium, phosphorus and organic carbon. Raina (1992) has also reported loss of organic carbon, nitrogen and phosphorus due to soil degradation in the sandy soils of arid Rajasthan.

Conclusions

The results of the present study indicated that satellite remote sensing data is a valuable tool for mapping degraded lands. In Sikar district, nearly 56% area needs immediate attention to arrest the processes of soil degradation. Soils degraded due to different degradation processes have low amount of available P, K and organic carbon than the soils of non-degraded sites.

Acknowledgement

The author is grateful to Dr. A.S. Faroda, Director of Central Arid Zone Research Institute, Jodhpur for providing the facilities. Technical help rendered by Shri Mohar Singh and Ashok Gehlot is acknowledged.

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Received : October, 1997; Accepted : June, 1999