Annals of Arid Zone 53(2): 77-85, 2014

Soil Degradation Assessment in Major Land Use Systems in Sikar District of Western Rajasthan

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Received: December 2013

Abstract: Study on assessment of soil degradation in major land use system namely rainfed and irrigated crop lands, grazing lands and forest lands in Sikar District of western Rajasthan was conducted to identify the kind of soil degradation, its intensity and effect on soil fertility. Extensive and intensive field survey was carried out with the help of Survey of India toposheets, IRS-1A satellite imagery (Path 31 and Row 49) False Color Composite (band 2, 3, 4) on 1:50,000 scale. Wind erosion/sand deposition is the main soil degradation process identified in all the three land use systems. On satellite images, slightly degraded soil appears as pale brown with dark magenta tone indicating crop/vegetation cover (W1); moderately degraded soils in pale brown with patches of medium magenta tone (W2) light tone indicating sand piling and severe degraded soils in light yellow with whitish tones indicating extensive occurrence of typical dune features. The wind erosion degraded nearly 82.02% rainfed crop lands, 27.83% grazing lands, 40.69% irrigated crop lands and 8.44% forest lands. Water erosion is the main soil degradation process in forest and grazing lands that degraded about 76.98% and 38.17% area, respectively. Slight soil degradation appeared in uniform dark magenta tone in rainfed crop lands with uniform light pale brown to medium grey tone, medium degradation indicated by whitish grey patches of shallow soils with few stream channels and severe degradation is represented uniformly by light brown tone, intercepted by a number of streams that appear light gray in color. Combined degradation due to wind and water erosion accounted for 16.38% of grazing and 13.86% of forest lands. Salinity and alkalinity hazards degraded 17.58% area of grazing land. Surface soil samples from degraded and non-degraded sites of rainfed crop lands, irrigated crop lands and grazing lands were analyzed for soil fertility. The results revealed that organic carbon, available phosphorus and potassium were high in non-degraded sites than the degraded sites.

Key words: Soil degradation, wind erosion, water erosion, satellite imagery.

Human needs often change the natural system from one that is stable to one that is degrading, dependent on the severity of the human interference. In Sikar District during last three decades there have been drastic changes in the land use system due to exploration of ground water for irrigation and use of tractor mounted equipments, farmers have started to cultivate marginal lands (dune slopes and shallow soil) with the use of poor quality ground water (saline/high RSC water) for irrigation. Besides this, overgrazing of pasture lands, indiscriminate cutting of trees for fodder, fuel and other requirements, brought significant deterioration in the soil resources. In India about 120.7 Mha area is reported to be suffering from various types of degradation processes. Singh *et al.* (1992) reported that 89.7% area of western Rajasthan is affected by different type of degradation processes, viz. wind erosion, water erosion and salinization. Thus soil degradation assessment is essential for suggesting measures for conservation of resources and restoration of the productivity of deteriorated soils in different land use systems.

The Central Arid Zone Research Institute (CAZRI) has been carrying out soil degradation mapping since the year 1991. Studies on soil degradation mapping on small scale using remote sensing techniques have been reported in several literatures (Saxena *et al.,* 1991; Raina *et al.,* 1993; Raina, 1999). However, soil degradation in major land use systems is still in dearth. Therefore, present study is an effort to estimate the area degraded and its intensity in different land use system in Sikar District of western Rajasthan, with a view to help in planning for restoration of soil productivity.

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Table 1. Criteria for assessing soil degradation

Soil degradation processes	Assessment factor	Degree of degradation			
		Slight	Moderate	Severe	Very severe
Wind erosion	Surface features	Thick sand deposition along fence line	Thick sand deposition along fence line and on fields; Sandy hummocks	Degraded dunes, thick sand sheets; all devoid of vegetation	Degraded dunes and barkhan dunes
	Percentage of area covered with vegetation	30-70%	10-30%	0-10%	Nil
Water erosion	Surface features	Shallow soil, gravels and stones over 10% or less area	Occasional rock outcrops, soil eroded/ deposited in patches, soil 40-50% deep, buried pediments with rills	Undulating rocky area with pockets of soils 20-40 cm depth sediments with rills and gullies	Boulders and rock exposer cover 50% or more formation of network of wide gullies
	Type of water erosion	Slight surface run off and sheet erosion	Moderate surface run off, sheet erosion moderate to heavy	Moderate heavy surface runoff few gully erosion	Very heavy surface run off and gully erosion
	Sub-soil exposed per cent of area	< 5	5-10	10-15	>15
	Soil thickness (cm)	60	40-60	10-40 in pockets gravelly strata without soil	< 10 gravelly strata
	Percentage of area covered with vegetation/crop	> 50	25-50	10-25	< 10
Salinization/ alkalization	Assessment factor surface features	Slight saline water irrigated areas	Moderate saline water irrigated area, naturally saline areas amendable to reclamation	Lowlying area having high salinity/ alkalinity	Rann area
	Salt layer location in soil profile	Substrata salinity below 80 cm	Salts present in sub-surface soil 30-60 cm	Frequent small spots of salts	Salt crust on surface
	Morphological features of salinization	Manifestation of salts not visible	Few small spots of salts in the upper dry part of profile	---	---
	Profile salinity (EC dS m^{-1})	1-5	5-8	8-12	12 and above
All types of degradation	Agricultural suitability	The terrain has some what 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 bio tic functions are largely destroyed	The terrain is un-reclaimable and beyond restoration, original biotic functions are fully destroyed

Source: Oldeman *et al.* (1991); Sehgal (1996) and Raina *et al.* (1993).

Materials and Methods

Study area

The Sikar District, located in the north-eastern part of the arid Rajasthan covering 7732 km^2 area and lies between 27°07′10″ to 28°12′10″ N and 74°40′55″ to 76°05′33″ E. The climate is arid and characterized by scanty/ erratic rainfall, extreme temperature and high evaporation rates. The average annual rainfall is 453.6 mm varying from 377 mm in north to 502 mm in east. The mean maximum and minimum temperature during summer season are 40°C and 6°C, respectively. The annual evapo-transpiration ranged from 1500 to 2000 mm. Vegetation is largely dominated by the trees *Prosopis cineraria, Tecomella undulata, Acacia nilotica* and *Acacia senegal*. The common shrubs and herbs found in the study area are *Ziziphus nummularia, Capparis decidua.* Soils are deep to very deep mostly sandy to loamy sand and sandy loam. Fine loamy soils occur in patches (in and around 'Neem ka thana' and 'Khandela' towns). While, saline soils occur as natural saline depressions in Danta Ramgarh tehsil of the district.

Mapping Present Status of Soil Degradation in Different Landuse System

Criteria for mapping soil degradation

The criteria laidout by Oldeman *et al.* (1991) with slight modification by Raina *et al.* (1991, 1993) was adopted for identifying the area degraded due to different types and intensity of degradation process under different land use systems (Table 1). The degree to which soil has been degraded was estimated in relation to changes in agricultural suitability for cultivated land and biotic functions (overgrazing or cutting of trees for domestic uses) in case of pasture and forest soils. Causative factors for soil degradations were also identified.

Interpretation of remote sensing data and field studies: By using IRS-1A satellite imagery (Path 31 and Row 49) false color composite (band 2, 3, 4) on 1:50,000 scale soil degradation mapping was carried out in different land use system in Sikar District. Satellite imageries were interpreted in conjunction with Survey of India topo-maps on the same scale. Visual interpretation was carried out based on the tonal characteristics of different degradation

Table 2. Relationship between the kind and intensity of degradation process and the spectral characteristics on IRS imagery

Area degraded due to different processes	Degree of degradation process			
	Slight	Moderate	Severe	Very severe
Wind erosion (W)	Pale brown with dense red tinge due to kharif crop (W1)	Pale brown with dense reddish tinge (W2)	Pale brown with typical dune features (W3)	Light yellow and whitish tones with typical dune features
Water erosion (V)	Uniform medium and light pale brown tone (V1)	Whitish grey patches indicate areas of shallow soils with few stream channels (V2)	Uniformly light brown, intercepted by a number of streams that appear light gray (V3)	Not observed
Salinization/ alkalization S/A	Occasional fallow pockets, appear light brown; associated cultivated fields appear light pink (S1)	Medium grey and whitish patches in scattered form (S2)	White patches (S3)	Not observed
Combined effect of wind and water erosion (WV)	Whitish rills and pale brown hummocky area with less reddish tinge (W1V1)	Pale brown and whitish grey in tone (W2V2)	Very light brown tone of sand deposition and whitish stream courses (W3V3)	Not observed
Combined effect of water erosion and salinity VS)	Whitish grey patches in between reddish tinge (S1V2)	Whitish grey with red tinge due to vegetation interrupted. Bynum bar of streams (V2S2)	Not observed (V3S3)	Not observed
Combined effect of wind erosion and salinity (WS)	Not observed (W1S1)	Light brown patches (W2S2)	Not observed (W3S3)	Not observed

process on the imagery and tentative units were demarcated. The demarcated units were checked in the field (ground truth verification) with the help of FCC and, inappropriate land due to practices by human *viz.* cultivation on marginal lands (dune slopes, shallow soils etc.), over exploitation of grazing lands were co-related with the surface manifestations (Table 2).

The irrigated fields appeared in dark brown tone with standing crop and without crop the same area has typical medium grey tone which was different from rainfed fields that appeared in light tone on the FCC. At each site, terrain characteristics were observed, including degradation features, water erosion in terms of rills and gully formation and wind erosion in terms of sand sheeting, formation of hummocks and dunes. At several sites soil characteristics viz., texture, color, depth and underlying strata were recorded (Soil Survey Staff, 1975) by examining auger holes. Surface (0-30 cm) soil samples were collected from rainfed crop lands; irrigated crop lands and grazing lands of degraded and non-degraded sites. High RSC and saline water samples were collected from the wells of irrigated fields for subsequent laboratory analysis.

Laboratory studies: Collected soil samples were analysed for appraisal of salinity/ alkalinity and fertility status. The soil pH and electrical conductivity were determined in soil:water suspension (1:2), organic carbon, available P (olsen extractable-P) and available K (1N NH_4OAC extractable-K, pH 7.0) were determined as per the procedure outlined by Jackson (1973). Water samples were analyzed for their cation and anion contents as described by (Richard, 1954). Based on field observations and laboratory interpretation soil degradation map was prepared on 1:50,000 scale showing kind and degree of degradation and then reduced to 1:250,000 scale (Fig. 1).

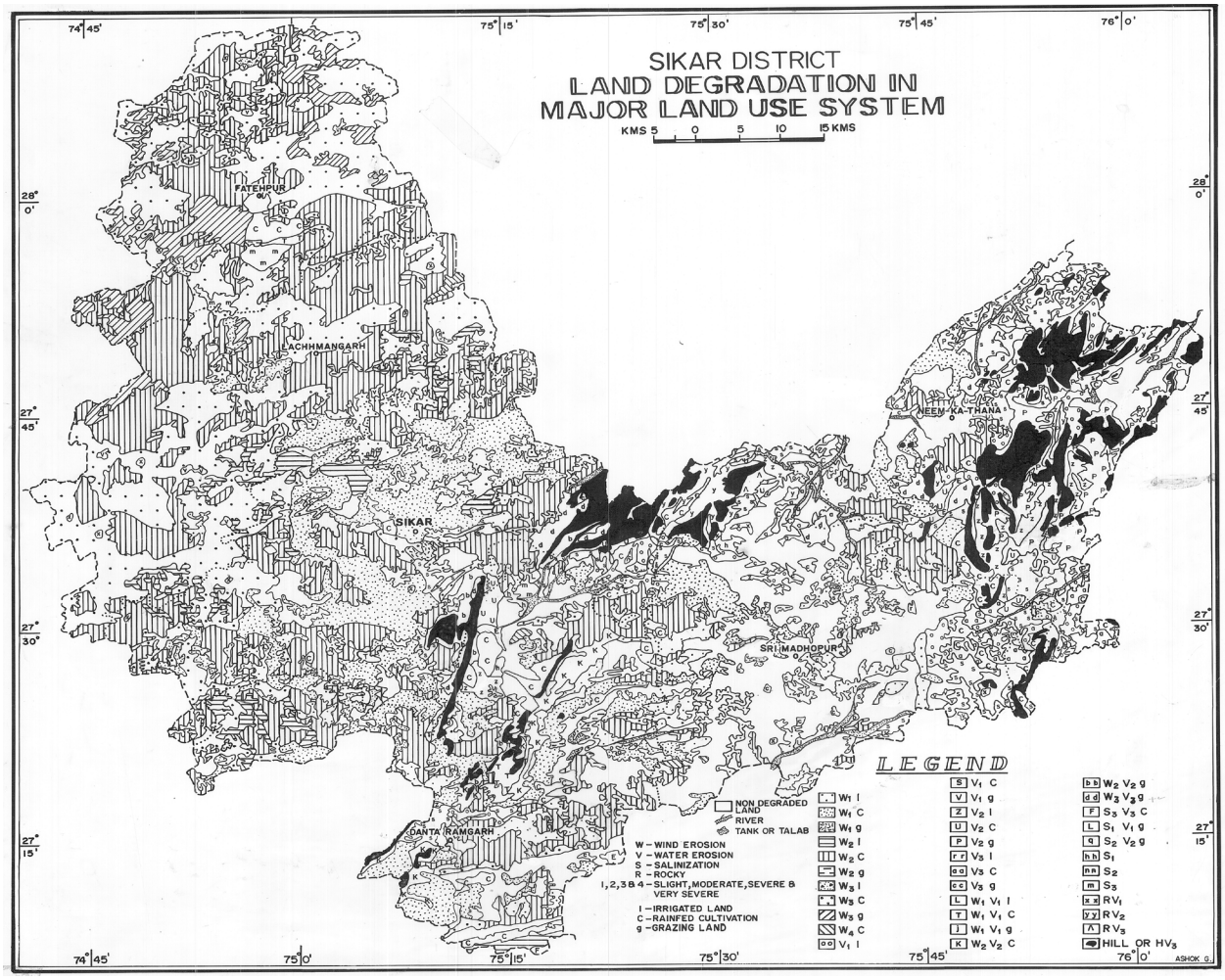

Fig. 1. Land degradation map of Sikar District.

Results and Discussion

The kinds and intensity of soil degradation process in different land use systems of Sikar District are presented in Fig. 1. Soil degradation assessment in major land use system is discussed below. Impact of degradation processes on soil fertility status and management strategies for optimizing agricultural production in different land use system is also discussed.

Degradation in rainfed croplands

Rainfed croplands cover 4500 km^2 area of Sikar District out of which 93.46% area has been affected due to different degradation processes (Table 3). In rainfed cultivated lands wind erosion/deposition is the major land degradation process followed by water erosion, salinization/alkalization and combined hazards. The brief description of these processes with their extent and intensity is discussed below.

Wind erosion/deposition: The results of degradation studies showed that about 82% of the rainfed area was under different stages of degradation. The slight degradation (19.65% of the total rainfed crop land area) was mostly in the form of sand sheets as a drift deposit on the soil surface. In moderately degraded area massive sand movements in the form of thick sand sheets of 100-500 cm and hummocks of 1-2 meters height occur in 36% area. Severely degraded areas include the dunes except upper flanks which were cultivated. Possibly due to this reasons these sandy soil became loose and in response to strong blowing winds resulted in thick sand piles and dunes. Out of total rainfed cultivated lands 26.34% is severely degraded on account of wind erosion.

Water erosion: Soil degradation due to water erosion was mostly observed in the cultivated fields of shallow soil depth (10-25 cm) near foot hills. The rainwater has dissected the cultivated fields to form rills and gullies. Slight water erosion is very common in the form of sheet wash resulting in the loss of top fertile soil. Total area degraded due to water erosion was 427.03 km^2 (9.49%) out of which 5.22% was slightly, 1.89% moderately and 2.38% severely degraded due to gully formation.

The area under degradation due to salinization/alkalization is only 12.55 km^2 (0.28%). Combined effects of wind erosion water erosion and salinization affected only 1.67% area of the total area of rainfed crop lands.

Degradation in irrigated croplands

Irrigated croplands are mainly degraded due to irrigation with poor quality water (high RSC and saline water) but it is not mappable due to its occurrence in patches. Other processes are wind and water erosion. Total area of irrigated land is 1577.11 km^2 out of which 884.30 km^2, (56.07%) area is degraded due to different degradation processes viz. wind erosion, water erosion and salinization (Table 4). The brief description of different degradation processes is given below.

Wind erosion/deposition: Out of 1577.11 km^2 area, 40.69% area of irrigated field is degraded due to sand deposition from the adjoining sand dunes and highly hummocky area through wind erosion resulting in the declining of germination percentage, injury in plants and deterioration in fertility status of soil resulting in low yield. Out of 40.69% total degraded

Table 3. Severity and extent of soil degradation in rainfed croplands (4500 km^2)

Soil degradation processes	Severity and extent of soil degradation			Total extent of land degradation (km^2)
	Slight	Moderate	Severe	
Wind erosion	884.50 (19.65)	1621.10 (36.00)	1185.50 (26.34)	3691.10 (82.02)
Water erosion	235.00 (5.22)	85.00 (1.89)	107.03 (2.38)	427.03 (9.49)
Salinity/Alkalinity	8.80 (0.20)	3.75 (0.08)	-	12.55 (0.28)
Combined effect of wind and water erosion	23.46 (0.52)	50.80 (1.13)	0.75 (0.02)	75.01 (1.67)
Total	1151.76 (25.59)	1760.65 (39.12)	1293.28 (28.74)	4205.69 (93.46)
Extent of area free from any hazard	294.30 (6.54)			

Figures in parenthesis shows percent area of land use.

Table 4. Severity and extent of soil degradation in irrigated croplands

Soil degradation processes	Severity and extent of soil degradation			Total extent of land degradation (km^2)
	None-Slight	Moderate	Severe	
Wind erosion	356.20 (22.58)	174.60 (11.07)	110.9 (7.03)	641.70 (40.69)
Water erosion	144.20 (9.14)	77.03 (4.88)	0.92 (0.058)	222.15 (14.08)
Salinity/Alkalinity	3.50 (0.22)	--	--	3.50 (0.22)
Combined effect of wind and water erosion	6.40 (0.40)	10.55 (0.67)	--	16.95 (1.07)
Total	510.30 (32.35)	262.18 (16.63)	111.82 (7.10)	884.30 (56.08)

Figures in parenthesis shows percent area of landuse.

area, 11.07% area is moderately and 7.03% area severely degraded due to wind erosion/ deposition.

Water erosion: It was mainly observed in the areas of shallow soil depth with sloppy terrain and also in the vicinity of hills. The gravels and pebbles are spectacular on the surface due to sheet and rill erosion. Total area degraded due to water erosion is 222.15 km^2, out of which 4.88% is moderately and 9.14% area is slightly degraded. However, the area degraded due to combined effect of wind and water erosion is only 1.07%.

Salinization/Alkalization: In Sikar District ground water is the main source of irrigation because 90% area is irrigated by wells. About 50-60% wells in Sikar District contain either high RSC or saline water. Irrigation with high RSC water leads to the development of sodicity, salinity, crusting and deterioration of physico-chemical properties of soil (Joshi, 1992; Joshi and Dhir, 1994). After 5-10 years of irrigation with sodic water, the soil becomes severely degraded and crop yields sharply declined. High RSC water mostly occurs in Fatehpur, Lachhmangarh and Neem ka Thana tehsils having pH varying from 8.0-8.8, EC (1.6-2.1 dS m^{-1}), RSC (4-20 me L^{-1}) and SAR (11.4-30.2). Continuous use of these waters for irrigation the soils turned in to the sodic soils.

Degradation in Grazing Land

Under this category, degradation in pasture lands, Orans and all type of waste lands used for grazing are considered and studied for kind and degree of degradation. When the degradation due to overgrazing sets in the landscape gets eroded and vegetation becomes sparse and nutritionally low grade (Raina, 1992). Total 937.28 km^2 area of grazing land has been degraded due to wind erosion/deposition, water erosion and salinization activities in different severity classes (Table 5).

Wind erosion/deposition: The grazing land was mostly covered with sand sheeting and hummocks. The total area degraded due to wind erosion/deposition was 27.83% out of which 17.11% area very severely and 6.36% area severely degraded. In very severely degraded areas (17.11% of the area) however there was irregular or uneven displacement of soil material resulting in the formation of barchan dunes.

Table 5. Severity and extent of soil degradation in grazing land

Soil degradation processes	Severity and extent of soil degradation				Total extent of land degradation (km^2)
	Slight	Moderate	Severe	Very severe	
Wind erosion	22.30 (2.38)	18.50 (1.97)	59.60 (6.36)	160.40 (17.11)	260.80 (27.83)
Water erosion	125.27 (13.37)	134.00 (14.30)	98.47 (10.50)	-	357.74 (38.17)
Salinity/Alkalinity	9.50 (1.01)	5.32 (0.57)	150.00 (16.0)	-	164.82 (17.58)
Combined effect of wind and water erosion	32.85 (3.50)	34.45 (3.67)	86.37 (9.21)	-	153.67 (16.38)
Total	189.92 (20.26)	192.27 (20.56)	394.44 (42.08)	160.40 (17.10)	937.28 (100.00)

Figures in parenthesis shows percent area of land use.

Water erosion: Water erosion in grazing land occurs in the form of sheet, rill and gullies. Severely degraded areas were mostly around hills and rocky/gravelly uplands. Open scrub lands were severely gullied (10-60 ft deep and 20-70 ft wide gullies). Moderately degraded areas were observed in the villages Khandela, Barol and adjoining area of Raghunath protected forest. Slightly degraded areas are nearly shallow and sloppy occuring mostly along the lower smooth hill slopes. Total area of grazing land degraded due to water erosion is 38.17% out of which 13.37 and 14.30% was slightly and moderately degraded while 10.50% area was severely degraded.

Salinization/Alkalization: Under this category land mainly remains dry with salt encrustation. The electrical conductivity and pH of the severely degraded soils varied from 8.2 to 21.2 dS m^{-1} and 8.2-10.8, respectively. Total 17.58% of grazing lands were degraded due to salinity and alkalinity out of which 16% was severely degraded.

Combined effect of wind and water erosion: Total area of grazing land degraded due to wind and water erosion in combination was 16.38%, out of which 9.21% area is severely degraded due to dissected dunes and gully formation.

Degradation in Forest Land

Forest land constitute 568.48 km^2 (7.35%) area of the district and occur mainly over the Aravalli hill ranges existing dominantly in Neem ka thana and northern part of Sri Madhopur and eastern part of the Sikar tehsils. Among these, Raghunath Garh, Harshnath, Ganwari, etc. are protected forest areas. In western and north western parts of the district, the Fatehpur Bir and Devipura forest is also in degraded condition.

Forest lands have been degraded due to cutting of trees and shrubs, unrestricted grazing and mismanagement which resulted in wind erosion, water erosion and a combination of both. Out of 568.48 km^2 forest land about 77% area is degraded due to water erosion, 13.86% due to combined effect of wind and water erosion and 8.44% area due to wind erosion/ deposition activities (Table 6).

Water erosion: Total area degraded due to water erosion is 437.93 km^2 out of which 313.57 km^2 is severely, 116.34 km^2 is moderately and 8.02 km^2 is slightly degraded.

Combined effect of wind and water erosion: Total combined area degraded due to wind and water erosion is 78.80 km^2 (13.86% of the forest land), out of which 38.37 km^2 (6.75% of forest land) is severely, 12.69 km^2 (2.23% of forest land) is moderately and 27.75 km^2 (4.89% of forest land) is slightly degraded.

Wind erosion: Total area degraded due to wind erosion is 48.00 km^2, (8.44%) out of that 2.1% severely, 4.4% moderately and 1.9% is slightly degraded

Non Degraded Lands

The Non-degraded land cover 294.3 km^2 area of rainfed land and 692.81 km^2 area of irrigated land which mostly occur in Sri Madhopur and Danta Ramgarh tehsil followed by Neem ka thana and Sikar tehsil.

Impact of Degradation on Fertility Status of Soil

An attempt was made to co-relate the interpreted satellite data with soil fertility status (Table 7) and the results are discussed below. Results revealed that there was a notable depletion in organic carbon, available phosphorus and potassium status in the surface

Table 6. Severity and extent of soil degradation in Forest land (568.48 km^2)

Soil degradation processes	Severity and extent of soil degradation			Total extent of land degradation (km^2)
	Slight	Moderate	Severe	
Wind erosion	11.00 (1.93)	25.00 (4.40)	12.00 (2.11)	48.00 (8.44)
Water erosion	8.02 (1.41)	116.34 (20.46)	313.57 (55.16)	437.93 (76.98)
Salinity/Alkalinity	-	3.75 (0.66)	-	3.75 (0.66)
Combined effect of wind and water erosion	27.75 (4.89)	12.69 (2.23)	38.37 (6.75)	78.80 (13.86)
Total	46.77 (8.23)	157.78 (27.75)	363.94 (64.02)	568.48 (100.00)

Figures in parenthesis shows percent area of land use.

Table 7. Impact of soil degradation on fertility status in major land use system of Sikar District

Land use	Degraded/non-degraded	Soil parameters		
		Organic carbon (%)	Available phosphorus (kg ha^{-1})	Available potassium (kg ha^{-1})
Rainfed	D	0.015-0.198 (0.10)	1.57-17.25 (5.8)	67.5-382.5 (165)
	ND	0.091-0.395 (0.14)	3.92-62.72 (9.8)	101.3-821.3 (230)
Irrigated	D	0.03-0.258 (0.15)	3.92-32.26 (7.2)	57.5-562.5 (197)
	ND	0.105-0.684 (0.22)	6.27-72.58 (12)	112.5-866.3 (300)
Grazing/OS	D	0.03-0.334 (0.12)	2.35-29.57 (5.28)	90-821.3 (270)
	ND	0.098-0.502 (0.163)	4.7-54.88 (9)	101.3-1024 (355)
Forest	D	0.015-0.213 (0.137)	3.13-18.82 (11)	101.3-450 (255)
	ND	0.091-0.437 (0.21)	4.7-42.34 (15)	135-662 (330)

Figures in parenthesis shows mean value; D- Degraded, ND-Non-degraded.

soil (0-30 cm depths) of different land-use system. The decrease in organic carbon content in all the land use system ranged from (26.4-34.8%) and maximum decrease (34.8%) was found in forest land soil followed by irrigated and rainfed 31.8 and 28.6%. Minimum 26.4% decrease was found in grazing land soil. In case of available phosphorus maximum decrease (41.3%) was found in grazing land soil followed by rainfed and irrigated (40.8 and 40%) and minimum percent decrease was observed in forest land soil. In case of potassium, maximum (34.3%) decrease was found in irrigated soil followed by rainfed and grazing land soil (28.3 and 23.9%) and minimum decrease (22.7%) was found in forest land soil over the non-degraded soils of Sikar District. This could partly due to more wind erosion from degraded lands. Daniel and Langham (1936) reported 24.5-46% loss of organic carbon due to sand drift. Gupta *et al*. (1981) reported nutrient loss due to wind erosion from flat sandy plains compared to pasture lands in western Rajasthan. Raina and Joshi (1991) also reported nutrient loss due to wind and water erosion.

Conclusion

The study revealed that wind erosion/sand deposition is the main soil degradation process identified in all the three landuse systems. The wind erosion degraded nearly 80.02% rainfed cultivated, 27.83% grazing and 40.69% irrigated and 8.44% forest land. Water erosion is the main soil degradation process in forest and grazing land that degraded about 76.98% and 38.17% area, respectively. The satellite FCC images were very useful in delineating the moderate and severely degraded soils under different land use. Combined degradation due to wind and water erosion accounted for 16.38% of grazing and 13.86% of forest land. Salinity and alkalinity hazards degraded 17.58% area of grazing land.

It can be concluded that wind erosion is a serious problem affecting productive agricultural lands and requiring immediate attention for control. In Sikar District, cultivation on sand dune is a common practice. There is prime need to improve permanent vegetation cover on marginal lands for ecological balance. Grazing and forest lands are in highly degraded state. Plantation of shrubs and trees is essentially recommended for protecting the soil from further degradation.

Acknowledgements

We express our sincere gratitude to Dr. M.M. Roy, Director, Central Arid Zone Research Institute, Jodhpur and Dr. Amal Kar, Head of Divison of Natural resources and Environment for providing necessary facilities.

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Printed in June 2015