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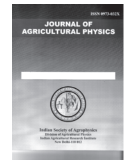

Research Article

Soil Properties under Different Land Use Systems in Parts of Chambal Region of Rajasthan

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ABSTRACT

A study examined the dynamics of soil physical and chemical properties under different land use systems in parts of Chambal region of Rajasthan. Soils were sampled at surface (0-15cm) layer under (i) irrigated sorghum/soybean-wheat rotation for over 20 years, (ii) ten-years-old *Leucaena leucocephala* plantation, (iii) grasslands for >15 years with dominant spp of *Hetropogan contortus* and *Dichanthium annulatum*, (iv) over 20-years-old undisturbed forest of *Prosospis juliflora* and shrubs and (v) twelve-years-old *Acacia senegal* plantation. Correlation matrix of 14 soil attributes representing soil physical and chemical properties resulted in a significant correlation ($P<0.05$) in 30 out of the 91 soil attribute pairs. Clear relationships among textural component, mean weight diameter (MWD), and soil organic carbon (SOC) were recorded, indicating role of SOC in aggregate formation under different land use systems. Further, among land use systems, grass land showed larger MWD followed by *Leucaena leucocephala* and mixed forest lands. The SOC, available nitrogen (Av-N), available phosphorous (Av-P), available potassium (Av-P) and cation exchange capacity (CEC) were higher in natural vegetation compared to other land cover. Therefore, trees along with grasses should be encouraged in ravenous land of Chambal region to maintain soil nutrient status for ecological sustainability in line with the changing landscape in the area.

Key words: Land use system, Soil properties, Ravine land, Chambal

Introduction

Soil productivity and sustainability depends on dynamic equilibrium among its physical, chemical and biological properties. These properties are continuously influenced by land uses with profound influence on soil properties and thus, help in restoration of soil quality (Deekor, 2012). Therefore, knowledge on the impacts of land use on soil property is indispensable for sustainable agricultural production (Fesha *et al*., 2002). Several researchers have studied the effect of land use on soil properties that provides an opportunity to evaluate sustainability of land use systems. Lal (1996) and Shepherd *et al*. (2000) examined that land use changes in tropical ecosystems could

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Table 1. Land use history and physiography of sampling sites

Land use	Details	Physiography	Initial soil properties
A. Table landscape			
1.	Irrigated cropping of sorghum/ soybean-wheat rotation for over 20 years with regular use of recommended doses of N, P through DAP and urea and occasional use of FYM	Gently sloping (up to 1 % slope), moderately well drained table lands in the immediate vicinity of ravines	Texture: Clay loam to clay Clay: 29.5 to 45.5% pH: 7.0-7.7 EC: 0.06 to 0.18 dS m^{-1} WHC: 37-48% SOC:0.33-0.45% CEC: 21.3-27.7 cmol(p^+)kg^{-1} Drainage: Slow to moderate
2.	Ten-year-old *Leucaena leucocephala* plantation		
3.	Grasslands for over fifteen years with dominant spp of *Hetropogan contortus* and *Dichanthium annulatum*		
B. Ravine landscape			
4.	Ravines under mixed forest over 20 years	Ravine land with 6 to 9m deep 'V' shaped and more than 18 m wide gully network is under influence of back flow from Chambal river	pH: 7.2-8.0 EC: 0.2-11.4 dS m^{-1} Clay: 16.9-27.4% SOC:0.20-0.24% Texture: Silty clay loam to clay loam Drainage: Moderate to good
5.	Ravines under *Acacia senegal* plantation over 12 years		

cause significant modifications in soil properties. Schipper and Sparling (2000) suggested that land use change modifications are biologically and chemically more rapid than are physically; forest ecosystems are important both ecologically and economically.

Conversion of native forests and pristine soils to cultivation is usually accompanied by decline in SOC and deterioration of soil structure. Offiong *et al*. (2009) reported that the levels of SOC, total N and CEC were substantially higher in soils of the undisturbed secondary forest than in soils adjoining the road. Similarly, several studies reported on impacts of land use on soil properties under arable lands in India (Joshi, 2002; Suma *et al*., 2011).

The Chambal regions of Rajasthan are widely known for ravines and are glaring examples for soil degradation due to water erosion. However, only scattered information are available on the ravinous and adjoining table lands. Under these landscapes, soil undergoes various changes due to accelerated erosion processes. Land use-induced erosion affects soil physical and chemical properties especially soil aggregates, SOC and nutrient availability (Foster *et al*., 2003; Han *et al*., 2010). However, information on effect of land use systems on soil properties in the Chambal region is too scanty to recommend optimal and sustainable utilizations of land resources. With this background, the present study was taken-up to evaluate the impact of land uses on soil aggregates, SOC and a few other soil properties in the Chambal region.

Materials and Methods

Study site and soil

Soil samples were collected from area under (i) irrigated sorghum/soybean-wheat rotation for over 20 years with recommended dose of fertilizers (ii) ten-years-old *Leucaena leucocephala* plantation, (iii) grasslands for >15 years with dominant spp of *Hetropogan contortus* and *Dichanthium annulatum*, (iv) over 20-years-old undisturbed forest of *Prosospis juliflora* and shrubs and (v) twelve-years-old *Acacia senegal* plantation at the research farm of the Central Soil and Water Conservation Research and Training Institute (CSWCRTI) Research Centre, Kota, which is located in Kota district of Rajasthan (25° 13' 29'' to 25° 14' 18'' N latitude, 75° 52' 18'' to 75° 52' 44'' E longitude). Details of land use history and physiography of sampling site of different land uses are presented in Table 1. The climate of the region is characterized as hot semi-arid with mean annual rainfall of 748 mm. Soils are predominantly fine textured (>35% clay) and belong to the hyperthermic family of Typic Chromusterts (locally known as Kota series). The water holding capacity, pH, EC, SOC and CEC of sampling sites varied from 37-48%, 7.0-7.7, 0.06-0.18 dS m^{-1}, 0.33-0.45% and 21.3-27.7 c mol (p+) kg^{-1}, respectively.

Soil morphology

Soils of the study area have wide variation in texture (silty clay loam to clay loam), structure (granular to strong, coarse sub-angular blocky) and drainage conditions (slow to moderate drainage). The degree of erosion varied from e_1 (nil or slight erosion; up to 25% of A-horizon is lost; under table lands) to e_{3-} e_4 (severe to very severe erosion; A-horizon is completely lost and 50% of B-horizon is exposed; under ravine lands). Details of soil morphological characteristics are explained in Table 2.

Laboratory analysis

Soil was sampled at 0-15 cm depths under all land use systems. Soil samples were air-dried and ground to pass through 2 mm sieve. Samples were analyzed for texture (Gee and Bauder, 1986), MWD of aggregates (Yoder apparatus; van Bavel, 1953), pH and EC (soil: water ratio of 1:2.5), SOC (Walkley and Black, 1934), Av-N (Kjeldahl method; Subbaiah and Asija, 1956), Av-P (Olsen *et al.*,1954), Av-K (ammonium acetate extraction; Hanway and Heidel, 1952), exchangeable Na, Ca, Mg (Thomas, 1982) and CEC (Chapman, 1965).

Data analysis

Data were analyzed using SAS version 9.3 for averages, one-way analysis of variance (ANOVA) and Pearson's correlation. The one-way ANOVA was performed to determine variability of soil properties among the land uses, while Pearson's correlation was employed to determine the nature of association between soil variables to understand possible factors that affected their buildup in the soil.

Table 2. Morphological characteristics of soils (0-15 cm) of different land use system and landscapes

Sl. No	Soil colour		Structure	Texture	Erosion	Gravel (%)
	Wet	Dry				
Land use 1: Irrigated cropping						
1	10YR 4/4	10YR 3/3	sbk	cl	e_1^{*}	2.6
Land use 2: *Leuceana leucocephala* plantation						
2	10YR 3/3	10YR 3/3	sbk	cl	e_1	2.0
Land use 3: Grasslands						
3	10YR 3/3	10YR 3/3	gr	cl	e_1	4.3
Land use 4: Ravines under mixed forest						
4	10YR 4/4	10YR 3/3	abk	sicl	$e_{3-}e_4^{**}$	2.5
Land use 5: Ravine under *Acacia senegal*						
5	10YR 5/3	10YR 5/2	abk	sicl	$e_{3-}e_4$	2.2

*e_1:- No erosion or slight erosion, upto 25% of A horizon is lost

**e_3– e_4:- Severe to very severe erosion (A horizon is lost and 50% B horizon is exposed)

Results and Discussion

Relation between physical and chemical soil properties

Correlation matrix of 14 soil attributes representing various soil physical and chemical properties under different land use systems revealed significant correlation in 30 attribute-pairs out of ninety-one pairs (Table 3). The MWD had positive correlation with SOC (r= 0.72), Av-N (r=0.76) and Av-P (r=0.58). The high correlation between MWD and SOC indicated that formation of aggregates is highly influenced by SOC. Humic acid and inorganics play important role in stabilization of clay microstructure (<2 μm diameter), whereas micro- and macro-aggregates are stabilized by bacteria, fungi, microbial derived substances, plant roots and their exudates, which are directly and/or indirectly influenced by amount of organic matter present in the soil (Aparicio and Costa, 2007). Significant correlation between MWD and Av-N could be explained by higher correlation between SOC and Av-N (r=0.85). Higher correlation between SOC and N was reported (Cao *et al*., 2012; Rashidi and Seilsepour, 2009). Soil pH was negatively correlated with Av-P (r=-0.70) and Av-N (r=-0.68), indicating that at higher pH, these nutrients are less available to crop. Fernàndez and Hoeft (2012) has critically discussed the availability of plant nutrients under varying pH and suggested that nutrients in soils are strongly affected by soil pH due to reacting with soil colloids and other nutrients.

The CEC showed significant positive correlations with clay content and SOC, but was negatively correlated with Av-K. Clay particle and organic matter tend to adsorb cations as Al^{3+}> Ca^{2+}>Mg^{2+}>K^{+}=NH_4^{+}>Na^{+} (Na+ is the least strongly adsorbed), that may be the reason of negative correlation between CEC and Av-K.

Calcium content in soil showed significant and positive correlations with silt content and pH and is negatively correlated with clay content and Av-P. Calcium-silt correlation might be due to mineral composition of parent material that should be investigated further. Positive correlation between Ca and pH is due to higher solubility and greater potential of hydrolysis of $CaCO_3$ at higher pH. Similar result was presented by Taddese and Abegaz (2003), who emphasized the availability of Ca^{++} at various range of pH. Negative correlation between Ca and Av-P could be attributed to P-fixation by Ca at higher pH in form of dibasic calcium phosphate dihydrate, octo-calcium phosphate and hydroxy apatite (Mahdi *et al*., 2011). This result is further corroborated by finding of Tariq and Mott (2006).

Effect on soil particle distribution

There were significant soil textural variations among the land use systems. In the present study, sandy loam, clay loam and loam texture was observed under cropped area, natural vegetation and ravinous land, respectively (Table 4). In cropped area, use of heavy tillage implement led to deposition of clay in sub-surface layer and this could result in reduced porosity and drainage, and increase water retention. Similar results were reported by others under continuous cropping and intensive land use (Agoume and Birang, 2009; Kauffmann *et al*., 1998; Subbulakshmi *et al*., 2009). Further, clay content is significantly affected under ravinous land compared with adjacent table land. This change in particle size distribution is thus attributed to extensive erosion from the area, which leads to translocation of clay from one place to another (Hillel, 1998).

Effect on aggregate stability

Land use system is one of the key factors influencing soil aggregates stability. This was attributed to positive impact of the vegetation on soil health due to addition of organic matter through leaf litter. Furthermore, different types of vegetation cover under different land uses enhance infiltration and offer favourable microclimate (Mohanty *et al*., 2012). In the present investigation, MWD of aggregates showed significant variations under different land use systems (Table 4). Grass land showed larger MWD followed by *Leucaena leucocephala* and mixed forest area. In table land, cropped area showed small MWD whereas in ravinous land,

Table 3. Pearson's correlation matrix of soil properties (n=42)

	Sand (%)	Silt (%)	Clay (%)	MWD	pH	EC	SOC	Av- N	Av- P	Av- K	Na	Ca	Mg	CEC
Sand (%)	1.00													
Silt (%)	-0.72**	1.00												
Clay (%)	0.66**	-0.99**	1.00											
MWD	-0.33	-0.13	0.17	1.00										
pH	-0.06	0.55*	0.59*	-0.38	1.00									
EC	0.17	0.33	-0.38	-0.68**	0.64**	1.00								
SOC	-0.71**	0.55*	-0.52*	0.72**	-0.13	-0.02	1.00							
Av-N	0.17	-0.53*	0.55*	0.54*	-0.68**	-0.87**	0.85**	1.00						
Av-P	-0.41	-0.05	0.10	0.58*	-0.70**	-0.72**	0.45	0.50	1.00					
Av-K	-0.13	.424	-0.44	0.14	0.40	0.06	.200	0.04	0.01	1.00				
Na	0.34	-.246	0.22	-0.32	-0.09	-0.14	-1.07	0.18	0.14	0.27	1.00			
Ca	-0.16	0.66**	-0.70**	-0.31	0.91**	0.47	-0.11	-0.55*	-0.52*	0.48	-0.08	1.00		
Mg	0.28	0.18	-0.23	-0.09	0.46	0.16	-0.07	0.05	-0.40	0.73**	0.30	.426	1.00	
CEC	0.73**	-0.77**	0.75**	-0.33	-0.37	0.11	-0.47	0.12	-0.16	-.605*	0.15	-.487	-0.35	1.00

*Difference between means is significant at 5% alpha level (2-tailed)
**Difference between means is significant at 1% alpha level (1-tailed)

Table 4. Physical properties of soils under different land use systems

Soil properties	Cropped area	*Leucaena leucocephala*	Grassland area	Ravine under MF	Ravine under AS
Sand (%)	45.60[a] (0.11)	44.36[b] (0.11)	43.48[c] (0.06)	42.27[d] (0.24)	44.15[b] (0.25)
Silt (%)	12.06[d] (0.26)	16.80[c] (0.22)	17.23[c] (0.38)	37.43[a] (0.20)	32.96[b] (0.22)
Clay (%)	42.34[a] (0.20)	38.84b (0.17)	39.29[b] (0.36)	20.30[d] (0.36)	22.89[c] (0.18)
Texture class	Sandy loam	Clay loam	Clay loam	Loam	Loam
MWD (mm)	1.17[b] (0.06)	1.42[b] (0.09)	3.42[a] (0.60)	1.34[b] (0.12)	0.62[b] (0.02)

Values in parenthesis indicate standard errors
Different alphabet along row indicates significant effect

Table 5. Chemical properties of soils under different land use systems

Soil properties	Cropped area	*Leucaena leucocephala*	Grassland area	Ravine under MF	Ravine under AS
pH	7.78[a] (0.012)	7.04[c] (0.062)	7.32[b] (0.012)	7.81[a](0.167)	8.01[a] (0.044)
EC (dS m^{-1})	0.48[a] (0.009)	0.32[b] (0.058)	0.26[b] (0.015)	0.45[a] (0.035	0.44[a] (0.025
SOC (%)	0.48[b] (0.01)	0.69[a] (0.07)	0.76[ab] (0.01)	0.63[a] (0.03)	0.45[ab] (0.11)
Av-N (kg ha^{-1})	277.33[c] (3.71)	365.00[ab] (5.51)	390.33[a] (1.67)	291.67[c] (1.33)	222.0[bc] (8.62)
Av-P (kg ha^{-1})	14.45[c] (0.33)	23.86[a] (0.87)	23.82[a] (0.95)	20.09[b] (0.80)	17.37b[c] (1.50)
Av-K (kg ha^{-1})	403.33[a] (5.90)	421.00[b] (17.62)	473.00[b] (41.74)	430.00[b] (8.66)	563.00[b] (10.54)
Na [c mol (p+)kg^{-1}]	3.37[ab] (0.20)	3.91[a] (0.09)	3.08[ab] (0.40)	2.97b (0.39)	3.51a[b] (0.06)
Ca [c mol (p+)kg^{-1}]	26.37[bc] (3.23)	12.24[d] (2.09)	19.17[cd] (1.49)	32.13[ab] (2.37	37.97[a] (3.77)
Mg [c mol (p+)kg^{-1}]	7.73[b] (0.34)	7.14[b] (0.03)	6.80[bc](0.30)	4.50[c] (1.20)	14.90[a] (1.23)
CEC [c mol (p+)kg^{-1}]	31.20[a] (0.72)	24.92[a] (0.57)	18.34[b] (1.37)	15.44[b] (1.41)	12.96[b] (0.58)

Values are in parenthesis indicate standard errors.
Different alphabet along row indicates significant effect.

soil under *Acacia senegal* showed small MWD. Larger diameter of MWD under grassland is attributed to their root system, which is more intense, dense. The extensive fibrous root systems help in producing larger aggregate by holding the small fractions together. Perennial grasses are generally associated with high microbial biomass and carbohydrate production which also stimulate micro-aggregation (Gale *et al*., 2000). Studies have shown potential values of grass in improving soil aggregates (*e.g.* Oku *et al.,* 2011). Soil under *Leucaena leucocephala* also showed larger MWD, followed by soil under mixed forest. *Leucaena leucocephala* and mixed forest are fast growing, N-fixing trees and through the decomposing litter over the period, provides a favourable environment for biological activity, which help in nutrient cycling and improvement in SOC and stability of aggregates. Similar results have been observed by Somasundaram *et al*. (2012) and Mohanty *et al*. (2012). Lower MWD in cropped area was attributed to lower SOC in that system. It is generally accepted that soil aggregate and organic carbon are interrelated (Six *et al.,* 2000).

Effect on soil chemical properties

Soil pH, EC, OC, Av-N, Av-P, Av-K, Ca, Mg and CEC were significantly affected by the land use systems (Table 5). The soil pH values were the highest in ravines under *Acacia senegal* and lowest in soil under *Leucaena leucocephala*. Variations in pH among land use systems reflect differences in uptake of exchangeable bases, N-fixation, production of litter high in organic acid content and the stimulation of mineral weathering (Finzi *et al.,* 1998; Githae *et al.,* 2011). The *Acacia* species contain psychoactive alkaloids.

Among alkaloides, phenethylamine is most common, which is strongly basic in nature. This could be possible reason for higher soil pH under *Acacia senegal*. The SOC and Av-N were high in grassed area followed by soil under *Leucaena leucocephala*. Higher SOC in this system resulted into high CEC, which further affected the availability of Na, Ca, and Mg. The higher SOC and N content in area with perennial grass might be due to higher organic matter inputs from above- and below-ground litter. The results are in agreement with Materechera (2010).

The soil EC showed significant variations among different land uses. It was higher under cropped area than other land use systems. It is due to inflow of soluble salts through irrigation water. Many workers advocated the use of good quality of irrigation water to control soil salinity in agricultural land (Ahmed *et al*., 2012).

The Av-P was highest under *Leucaena leucocephala* followed by grassland. It is well-established that availability of P is highly sensitive to change in soil pH. With increase in pH, P availability decreases as P gets tie-up with Ca and Mg; if soil pH decreases, P is coupled with Fe and Al. In our study, Av-P was higher in soils with pH near to neutral; and as pH increased, Av-P decreased. Our soil had high Av-K (403.3-563.0 kg ha^{-1}). Most of the Indian soils are rich in potassium (Naidu *et al*., 2011), due to presence of potassium containing minerals like illite, muscovite, gluconite, biotite, phlogopite, sanidine and orthoclase in Indian soil (Sekhon, 1999).

Conclusions

It is evident from the study that different land use systems have significant impact on soil physical environment and availability of nutrients in the soil. Soils under long periods of perennial natural vegetation and grasses led to positive changes in soil physical and chemical properties. This study indicates that soil properties like MWD, SOC are negatively affected in cultivated system possibly due to intensive tillage practices. The high quantities of SOC, Av-N, -P and -K and CEC in the natural vegetation signifies that these areas mimic the forest ecosystem and have substantial effect on soil nutrient built-up. Dense canopy cover helps in nutrient accretion in the soil by minimizing the loss through soil erosion and leaching. It also enhances production of litter and provides optimum temperature for bacteria, fungi, micro-fauna and other soil microbes that facilitate organic matter decomposition. The present study of quantifying soil properties under different land systems will contribute greatly in identifying and planning for necessary precautions required for sustainable environment.

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