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Erodibility Studies under Different Land Uses in North-West Himalayas

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ABSTRACT

Soil profiles developed under different land uses viz. cultivation, orchard and forest were studied for their erodibility characteristics. Results revealed that Organic carbon, clay, CEC, water stable aggregates (WSA), mean weight diameter (MWD) were the dominating factors influencing the dispersion and erosion ratios. Forest soils were found to have low dispersion and erosion ratio followed by orchard and cultivated land use. There results were also supported by the findings of runoff plot studies, where forest soils were found to be more stable followed by orchard and cultivated lands. The runoff (13.5, 8.85 and 5.75% of the total rainfall) and soil loss (32.11, 20.0 and 11.68 t ha^{-1}) were observed under cultivated, orchard and forest land use, respectively. Maximum loss of available NP&K (58.48, 16.46 and 10.62 kg ha, respectively) was also recorded under cultivated land use.

Key words: Dispersion ratio, Erodibolity, Erosion ratio, Mean weight diameter, Runoff, Water stable aggregates

Introduction

Soil is an important natural resource for all land based activities to meet the requirements of food, fuel, fodder, fiber etc. of mankind and to manage this resource on sustained basis is one of the vital issues under present scenario, when the pressure on soil is increasing day by day. It is estimated that our of 329.0 m ha of total geographical area of India, about 146.82 m ha land suffers from soil erosion and land degradation (NBSS&LUP, 2005). It includes water erosion (93.68 m ha), wind erosion (9.48 m ha), waterlogging/flooding (14.30 m ha), salinity/ alkalinity (5.94 m ha), soil acidity (16.04 m ha) and complex problem (7.38 m ha). About 5334 million tones of the soil is eroded annually along with large quantities of nutrients (Dhruvanarayanana and Ram Babu, 1983). The soil erosion is not only causing the loss of production base, but it is also resulting into shallowing the soil profiles, formation and extension of gullies and disappearance of natural water resources. This situation needs immediate attention for conservation and sound management of soil and water resources which can be achieved by formulating and implementing an effective soil and water conservation programme for which the knowledge of soil properties, its erosion behavior and quantitative assessment of soil and nutrient loss is important. The present investigations were, therefore, taken up to study the erodibility characteristics and soil and nutrient losses under different land uses.

Materials and Methods

The study was undertaken in mid-hill region of Himachal Pradesh situated at 30°55’ to 31°06’N latitude and 77°06’ to 77°13’E longitude. The salient characteristics of profile sites and runoff plots are presented in Table 1. The climate of the study area is sub-temperate sub-humid with mean annual temperature 20 °C and annual rainfall of 100 mm. The study of erodibility characteristics of the soil was carried out in eight locations under three lands uses viz. cultivation, orchard and forest. Organic carbon (OC), cation exchange capacity (CEC) and bulk density were determined as per standard methods. Particle size analysis was done by International pipette method. Dispersion and erosion ratios were

Table 1. Salient characteristics of the studied soil profiles

Location	%slope and aspect	Approx. elevation (m, amsl)	Dominant land use	Dominant textural class	Parent material
Nauni	10, S	1220	Cultivation	gsil	Ferromagnesium shales & dolomitic limestone
Nauni	12, S	1250	Orchard	gsil	Ferromagnesium shales
Lavighat	30, N	1450	Cultivation	gl	Shales & limestone
Rundan Ghonron	40, NE	1500	Cultivation	slc	Shales & red sandstone
Mukrari	5-10, NE	930	Cultivation	sil, sicl	Alluvium
Majhat	12-25, N	1000	Forest	gsil	Shales & limestone
Kandaghat	10-15, NE	1500	Orchard	gsil	Sedimentary rocks
Ranno	15-25, NE	1200	Forest	gsil	Shales &red sandstone

determined as per the procedure outlined by Middleton (1930). Stability of soil was assessed by determining the water stable aggregates (>0.25 mm and <0.25 mm) following the procedure given by Yoder, 1936. The mean weight diameter (MWD) was calculated with the help of procedure outlined by Van Bavel (1949).

The study of rainfall-runoff-soil loss and nutrient loss was also carried out under cultivation, orchard and forest lands uses in 10×10 m plots under 2 percent slope, contributing runoff water to a graduated container placed below the V notch. The cultivated land was under tomato and pea cultivation and recommended cultural practices were followed for growing these crops. Under orchard land use, the experiment was laid out in 10 years old apricot orchard having 8×8 m spacing. The orchard was equipped with drip irrigation system and basins were maintained weed free. The canopy coverage of the plant was about 40 percent. Under forest land use, there were 10 years' old 12 to 14 trees of chir (*Pinus roxburghii*) in each plot having more than 40 percent canopy. Runoff and soil loss data were determined by installing 'V' notches permanently on the lower end of the plots, where total runoff volume was determined from 100 ml runoff sample by drying it at temperature of 105°C. Runoff samples were also analyzed for the loss of available N, P and K.

Results and discussion

The bulk density had a wide range both in surface (0.96-1.15 g cm^{-3}) and sub-surface (1.01-1.54 g cm^{-3}) horizons and increased with profile depth (Table 2). Under cultivated land use bulk density was found to be comparatively higher in surface (0.96-1.15 g cm^{-3}) and sub-surface (1.01-1.54 g cm^{-3}) horizons and lowest in forest soils i.e. 0.96 g cm^{-3} and 1.10-1.20 g cm^{-3}, respectively, indicating the effect of land use. Organic content was also observed to be higher in surface soils and decreased with depth. Among the land use classes, highest organic carbon contents were found in forest soils, which could might be due to higher tree density resulting in higher amount of litter addition. Banerjee and Badola (1980) and Gupta et al., (1991) also observed that surface soils under coniferous forests contained more organic carbon, which decreased with profile depth.

CEC of the surface soils was comparatively higher than sub-surface and varied from 8.72-13.38 and 7.52-12.78 cmol (p+) kg-1, respectively (Table 2). The effect of land use was more pronounced in surface layers and CEC of forest soil was 11.82 coml (p+) kg-1 and cultivated soil had 8.72-11.40 cmol (p+) kg-1. Higher CEC of surface soils could be attributed to higher organic carbon content, which showed significant positive relationship (r=0.74). Chakraborty and Sinha (1983) have also reported the similar results.

Both water stable aggregates and mean weight diameter of the aggregates were affected by land use and soil depth (Table 3). Aggregates having diameter greater than 0.25 mm were observed to be more in the surface soil under all the land use classes and varied from 66.24-79.31,

Table 2. Physico-chemical properties of the studied soil profiles

Horizon	Dept (cm)	O.C. (%)	Bulk density (g cm^{-3})	CEC [cmol(p^+)kg^{-1}]
Profile-I Nauni, C (Typic Hapludalfs)				
A1	0-15	1.43	1.22	11.27
A3	15-28	0.99	1.25	9.96
B	28-43	0.38	1.23	8.24
C1	43-68	0.27	1.23	7.92
C2	68-150	0.20	1.26	7.82
Mean		0.65	1.24	9.00
Profile-II Nauni, O (Typic Hapludalfs)				
A_1	0-14	1.56	1.2	11.68
A_3	14-30	1.14	1.15	9.86
B	30-68	0.86	1.18	8.44
C	68-130	0.45	1.17	8.12
Mean		1.00		9.53
Profile-III Lavighat, C (Typic Udifluvents)				
A_1	0-15	0.50	1.10	11.40
A_3	15-32	0.85	1.16	10.32
C_1	32-75	0.96	1.20	9.87
IIC_2	75-100	1.23	1.23	8.12
Mean		0.89	1.17	9.93
Profile-IV Mukrari, C (Typic Hapludalfs)				
A_1	0-15	1.07	1.18	8.72
A_3	15-30	0.90	1.19	8.52
B_1	30-57	0.58	1.22	7.64
B_2	57-125	0.32	1.22	7.36
Mean		0.72	1.20	8.06
Profile-V Rundon Ghonron, C (Typic Hapludalfs)				
A_1	0-21	1.76	1.52	9.82
A_3	21-37	1.56	1.54	8.56
B_1	37-60	1.33	1.42	8.12
B_2	60-90	1.04	1.33	7.88
B_3	90-150	0.58	1.25	7.52
Mean		1.25	1.41	8.38
Profile-VI Majhat, F (Typic Eutrochrepts)				
A_1	0-12	1.83	0.96	11.82
A_3	12-25	1.65	1.06	9.74
B	25-48	0.79	1.18	8.66
C_1	48-68	0.52	1.16	8.24
C_2	68-140	0.38	1.20	8.06
Mean		1.03	1.11	9.30
Profile-VII Kandaghat, O (Typic Arguidolls)				
A_1	0-15	1.73	1.05	10.68
A_3	15-31	1.17	1.07	10.36
B_1	31-56	0.98	1.08	9.98
B_2	56-88	0.17	1.10	8.82
B_{22}	88-140	0.51	1.14	9.78
Mean		1.03	1.09	9.92
Profile VIII Ranno, F (Typic Udorthents)				
A_1	0-14	1.95	0.97	13.38
A_3	14-45	1.65	1.01	12.78
AC	45-68	1.25	1.07	10.84
IIC	68-150	0.87	1.10	10.06
Mean		1.43	1.04	11.77

C= Cultivation, O=Orchard and F=Forest

89.17-92.89 and 93.27-95.32% in surface soils and from 62.04-72.80, 84.64-85.76 and 88.27-86.31% in sub-surface soil under cultivation, orchard and forest land use categories, respectively. But the aggregate having diameter less than 0.25 mm followed the reverse trend both with respect to depth and land use i.e. their percentage was observed to be greater in surface soils under cultivation and the lowest under forest soils. Mean weight diameter (MWD) of the aggregate was higher in surface soils, which varied from 0.90-3.12, 2.84-3.86 and 4.18-4.65 mm under cultivated, orchard and forest lands, respectively (Table 3). Water stable aggregates and mean weight diameter were also significantly affected by organic carbon (r=0.82 and 0.73, respectively). The soils under forest land use were more stable as compared to those under orchard and cultivation and this could be ascribed to higher organic matter.

The dispersion and erosion ratios have been used by various workers (Chibber *et al.*, 1961; Singh and Prakash, 1985; Salvi et al., 1993 and Satapathy, 1995) to assess the erosion behavior of soils. The soils having dispersion ratio>15 and erosion ratio>10 are considered as erodible in nature (Middleton, 1930). In the present investigation the dispersion ratio of he studied profiles varied from 11.64-20.42 and 13.54-23.26 in surface and sub-surface soils, respectively (Table 3). It was observed comparatively higher under cultivated lands (19.37-22.54) followed by orchard (14.36-14.99) and the lowest under soils (12.59-13.70). The erosion ratio also observed similar trend. The dispersion ratio was found to be significantly and positively correlated with erosion ratio (r= 0.95). Similar results have also been obtained by earlier researchers (Chakrabarti, 1971 and Sharma et al., 1987) and used these erodibility indices for the erosion assessment. However, both dispersion ratio and erosion ratio showed significant and negative relationship with OC (r=-0.68 and –0.69) and MWD (r=-0.93 and –0.91). The soils under forest land use were found to be more stable as compared to the soils under orchard and cultivation and it could be ascribed to higher OC resulting in higher percentage of water stable aggregates and higher MWD. Similar results have also been reported by earlier workers (Chakrabarti, 1971; Bhatia and Sarmah, 1976).

Table 3. Erodibility characteristics of soils under different land uses

Location	Surface/ Sub-surface	Soil structure	Dispersion ratio	Erosion ratio	% water stable aggregates		MWD (mm)
					>0.25 mm	<0.25 mm	
Nauni (C)	I	Gr	18.92	17.78	72.11	27.89	2.70
	II	M_2sbk	20.18	19.63	65.51	34.49	2.05
Nauni	I	Gr	14.46	13.42	89.17	10.83	3.86
(O)	II	Gr, sbk	15.52	14.86	84.64	15.36	3.12
Lavighat (C)	I	Gr	20.42	21.14	68.36	31.64	1.73
	II	Gr, sbk	22.32	23.42	62.04	37.96	1.12
Rundan	I	Gr	21.82	20.80	66.24	33.76	1.25
Ghonron (C)	II	Gr, sbk	23.26	21.64	62.36	37.64	0.90
Mukrari (C)	I	Gr	18.50	19.92	79.32	20.68	2.80
	II	M2, sbk	20.28	21.60	72.80	27.20	1.75
Majhat (F)	I	Gr	12.93	14.38	93.27	6.73	5.49
	II	Gr, sbk	14.47	16.93	88.27	11.68	4.65
Kandaghat (O)	I	Gr	13.25	15.50	92.89	7.11	4.26
	II	Gr, sbk	15.47	17.34	85.76	14.24	2.84
Ranno (F)	I	Gr	11.64	13.24	95.32	4.68	5.22
	II	Gr	13.54	14.63	88.31	11.69	4.18

I=surface; II= sub-surface

Table 4. Simple correlation coefficient between soil properties and erodibility indices

Simple correlation between	r-value
CEC and OC	0.74*
MWD and OC	0.73*
Dispersion ratio and OC	-0.68*
Erosion ratio and OC	-0.69*
Dispersion ratio and MWD	-0.93*
Erosion ratio and MWD	-0.91*
Dispersion ratio and erosion ratio	0.95*
WSA and OC	0.82*

Of the total rainfall (1137.6 mm) received during the study period, 71.20% (809.6 mm) was recorded during the rainy season i.e. June to September (Table 5). Of the total rainfall, 153.65 (13.5 percent), 100.7 (8.85 per cent) 65.4 mm (5.74 per cent) was recorded as runoff under three land uses viz. cultivation, orchards and forests, respectively. Under these land use classes during the study period, 137.97 mm (89.79 percent) 88.82 mm (88.20 percent) and 56.72 mm (86.72 percent), respectively was recorded during the four months period i.e. from June to September (Table 5). Higher runoff losses during July to September could be attributed to higher intensity of rainfall. The highest runoff of 12.66, 3.44, 19.18 and 23.78 mm under cultivated lands, 8.60, 2.18, 10.81 and 18.40 mm under orchards and 5.62, 1.22, 26.42 and 13.69 mm in forest land use was observed during these months. Runoff losses under these land use classes were comparatively low (14.47, 15.59 and 8.64 per cent) in the month of June than in September (22.57, 10.75 & 5.80 per cent). This could be due to the fact that in the month of June, soils were invariably dry and a good amount of rainfall was either stored in profile or lost in evaporation.

Soil loss during rainy season was 30.37, 18.93 and 10.93 t ha^{-1} under cultivation, orchards and forests, respectively accounting for 94.6-0, 94.55 and 93.50 per cent of the total annual soil loss under these land use categories (Table 5). This higher runoff could be attributed to higher intensity of rainfall and sol saturation. Both, runoff and soil loss, were comparatively higher under cultivated lands followed by orchards and least under forest lands. These results are in accordance with the findings of Kothyari *et al.*, 2004 and Tiwari *et al.*, 2009. This could be ascribed to better vegetative covers under orchards and forests resulting in interception of falling rain drops and preventing the direct beating action and also due to beneficial effect of vegetation on soil

Table 5. Rainfall-runoff-soil loss relationships under different land uses

Months	Rainfall (mm)	Runoff (mm)			Soil loss (t ha^{-1})		
		Cultivation	Orchard	Forest	Cultivation	Orchard	Forest
First year							
June	176.2	25.50	15.22	10.22	5.90	4.46	2.66
July	81.6	3.66	2.33	1.31	0.64	0.45	0.27
August	353.6	64.74	40.37	23.89	15.06	9.45	5.30
September	198.2	44.07	30.90	21.30	7.84	4.55	2.70
October	36.8	0.34	0.24	0.14	0.02	0.01	0.01
November	-	-	-	-	-	-	-
December	3.4	-	-	-	-	-	-
Second year							
January	54.0	5.28	4.63	3.72	0.67	0.41	0.25
February	14.0	-	-	-	-	-	-
March	36.8	-	-	-	-	-	-
April	128.6	7.12	4.43	3.85	0.77	0.51	0.38
May	52.6	2.94	1.58	0.97	0.21	0.16	0.10
Total	1137.6	153.65	100.7	65.4	32.11	20.00	11.68

properties. Of the three land use classes, forest soils had highest infiltration rate (5.91 cm hr^{-1}) as compared to the cultivated lands (1.08 cm hr^{-1}) and orchards (2090 cm hr^{-1}). The profiles under forests lands also had well aggregated top soil layer resulting in higher infiltration, less detachment and migration of soil particles through runoff (Mathan and Kannan, 1993).

Both runoff and soil losses were recorded to be the lowest during October to May period and runoff was found to be 10.20, 1.79 and 13.27 per cent of the total runoff under cultivation, orchards and forests, respectively. Off the annual soil loss, the soil loss under cultivated and forest lands use categories varied from 5023 to 6.41 per cent and were 505 per cent under orchards soils. It is evident that even under cultivated lands, the runoff and soil losses were at par with the losses under orchards and forests, during October to May.

The loss of available nutrients (N, P and K) estimated in the runoff water was 58.47, 16.46 and 10.62 kg ha^{-1}) from cultivated lands, 28.22, 7.20 and 4.58 kg ha^{-1} from orchards soils and 10.74, 3.58 and 2.13 kg ha^{-1} from forest land during June 96 to May 97 period (Table 6). Maximum loss was recorded in the rainy season. The loss of N, P and K during rainy season under three land uses viz. cultivation, orchards and forests was 96.69, 96.84 and 96.23 percent; 95.92, 96.66 and 95.63 per cent and 95.34, 95.81 and 95.77 per cent, respectively of the total loss. The loss of nutrients was highest from cultivated lands followed by orchards and lowest under forest area. The trend of nutrient loss with time was similar to that observed for runoff and soil loss. Off the three nutrients, N loss was found to be highest in all the land use classes and this could be ascribed to more solubility and less absorption of different forms of nitrogen by soil colloids resulting in more losses through runoff (Kale et al. 1992; Mathan and Kannan, 1993; Kothyari et al., 2004).

Conclusion

From the above findings, it is concluded that various land uses has direct impact on soil organic carbon, structure and CEC, which significantly influence the soil erodibility indices viz. dispersion ratio, erosion ratio, WSA and MWD. From the results, it is inferred that forest soils are more stable than orchards and cultivated soils. Runoff, soil and nutrient losses were more in cultivated lands. The present results revealed that vegetation protects the soil against impact of falling rain drops, increases the interception and infiltration rate, hold runoff water on soil surface for longer time, reduces the speed of surface runoff, binds

Table 6. Available N, P and K losses (kg ha^{-1}) in sediment under different land uses

Month	Cultivation			Orchard			Forest		
	N	P	K	N	P	K	N	P	K
					1996				
June	13.11	3.78	2.26	6.52	1.70	1.03	2.64	0.84	0.54
July	1.01	0.30	0.19	0.61	0.15	0.10	0.23	0.07	0.04
August	30.28	8.57	5.28	14.19	3.51	2.29	5.31	1.79	0.00
September	12.11	3.29	2.49	5.75	1.60	0.96	2.05	0.73	0.47
October	0.03	-	-	-	-	-	-	-	-
November	-	-	-	-	-	-	-	-	
December	-	-	-	-	-	-	-	-	-
					1997				
January	0.79	0.22	0.18	0.45	0.09	0.08	0.19	0.05	0.04
February	-	-	-	-	-	-	-	-	-
March	-	-	-	-	-	-	-	-	-
April	0.87	0.24	0.17	0.54	0.11	0.09	0.24	0.08	0.04
May	0.24	0.06	0.05	0.16	0.04	0.03	0.07	0.02	0.01
Total	58.47	16.46	10.62	28.22	7.20	4.58	10.74	3.58	2.13

the soil mechanically and improves the physical, chemical and biological properties of the soil. This indicate that there is an urgent need to put more and more area under vegetation and to adopt suitable soil and water conservation measures to conserve soil and water and check the losses of nutrients.

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