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Soil, Water and Nutrient Conservation in Deferent Landuse System in Mid Hill of Indian Central Himalaya - A Case Study from Bhetagad Watershed

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ABSTRACT

The paper describes the effect of rains on vegetal cover, different traditional practices and soil properties in the dry and monsoon period. Seven landuse systems i.e. open pine forests, tea plantation, rainfed agriculture, degraded land, grassland, recently restored site and a bare land were identified in the Bhetagad watershed of Central Himalaya (India). The study, conducted during 1^{st} Oct. 2001-30^{th}-September 2002, involved establishment of 20x5 = 100 m^2 plots, which were located in the slope range between 14^0-28^0. Study revealed that the bare plot among all other land use system has produced maximum surface runoff of 68.18 mm and 85.95 mm and loss of 9.982 t/ha and 10.978 t/ha, during dry and monsoon period respectively. Also for the corresponding periods nutrient concentration was highest; O.M. (426.30 kg/ha and 510.80 kg/ha), total N (157.10 kg/ha and 171.40 kg/ha), total P (34.12 kg/ha and 39.52 kg/ha) and total K (34.12 kg/ha and 36.12 kg/ha) for the bare land, which was followed by open pine forest. The rainfed agriculture, terrace bunding, mature tea plantation and restored sites minimized the water, soil and nutrient losses and enhanced the importance of appropriate measures of the parameters, which retard the erosion process.

Key words: Landuse, erosion, practices, watershed and conservation values

INTRODUCTION

Faulty landuse system in the steep Himalayan watersheds have resulted into severe soil erosion (Nair, 1985). Most watersheds in the region are characterized by very low productivity of agriculture crops and high encroachment of livestock and human in the forest areas. Further, the fertility behavior of agricultural lands in most of these watersheds is influenced by on going erosion processes (Sherchan et al., 1990, Rai and Sharma 1998, Basavraj et al., 2000 and Sharma et al. 2000).

In the Central Himalayan region few of the watersheds including the studied one have relatively better maintained cultivated terraces that help in minimizing the erosional losses However, the soil, water and nutrient losses are highly influenced by open grazing in the forest area. The uncontrolled livestock grazing and trampling removes the protective plant cover (Bari et al., 1993. Zobisch, 1993). The heavy grazing significantly reduces biomass amount, ground vegetative cover and increases surface runoff and reduces the infitrability of soil (Mwendra and Saleem 1997) as a results

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of which the fertility of soil is depleted and it also influences down stream water chemistry.

Vegetation has long been recognized as an important means of controlling soil erosion (Morgan, 1986). The vegetation varies among landuses according to the practices and interferences's, which influences the rate of soil erosion. The removal of vegetal cover through indiscriminate activities in open forests grazing patches and few of newly tea planted areas are more prone to soil erosion. Keeping these in view, a study was conducted to assess the factors responsible for soil erosion in Bhetagad watershed of Indian Central Himalaya and to examine the effect of dry season and monsoon storms on different landuse characteristics and erosion losses. The study further envisages to predict the vegetative measures for controlling the erosion losses, and to identify and evaluate the possible soil fertility improving options for the watershed.

STUDY AREA

All the sites were located in the Bhetagad watershed (29^0. 50' to 29^0, 55' N and 79^0 02' to 79^0. 30', E), Indian Central Himalaya, and lie between 1090-2060 m amsl. The landuse survey showed 55.58% area of watershed under pine forest, 42.34% under agriculture/ settlement land and only 2.08% area under barren land and other uses. Over 79% of the area falls in the 14°-28°, slope range (Bisht and Kothayri 2001). The rural communities use forests for fuel wood, timber and leaf litter collection. The watershed has a warm temperate climate with five distinct seasons viz., spring, summer, monsoon, autumn and winter. In general the dry season (spring, summer, autumn and winter) showed a distinct behavior than the monsoon season in respect to rainfall, vegetations and land management practices.

METHODS

Rainfall data for the study period (1^{st} Oct. 2001-30^{th} September, 2002) were collected with the help of tipping buckets (Simon's Raingauge British type), which were installed in close vicinity of erosion plots. Reading was recorded at 8.30 am (IST), each day.

Species richness was analysed by counting the number of plant species in each study plot. For analyzing vegetal cover different parameters, such as plant density, basal area and crown cover, where calculated following Misra (1968). Ten quadrates (10 x 10 cm size for grasses herbs and 10x10 m for trees) were laid in each site, including respective erosion plots.

For erosion studies, plots of 20 x 5 m^2 size (n=3) were laid at each site enclosed with a 50 cm wide metal sheet inserted 20 cm vertically into ground and remaining 30 cm above the soil surface. The surface runoff from each plot was collected in the respective tanks through a channel and a multi-slot devisor. The whole runoff was first collected in a 200-litre tank, then the over flow to a second tank through a 7-slot multi slot devisor. The second tank thus represented only $1/7^{th}$ of total overflow.

The total soil loss from each plot was estimated using composite samples from both the tanks. The concentration of the suspended material was determined by filtration methods (Heron 1990, Hudson 1993) using Whatman No. 1 (pore size 1.2 mm.) samples were dried at 45 °C till constant weight. The weight was then converted into sediment yield t/ha (Heron 1990, Hudson 1993). The chemical analysis of the sediment/solvent was made following standard methods (Jackson 1967 and Allen 1989). The conservation values for water, soil and nutrient were calculated for each site using the formula CV = $100\text{-}S_{wp}/S_{w0}$ x 100) (Ambasht 1970, Ambasht et al., 1984), where S_{wp} in the weight of soil from vegetated system and S_{wo} in the weight of soil from bare plot. For determination of water and nutrient conservation value, W_p, N_p and W_o and N_o were replaced by S_{wp} and S_{w0} respectively. The W_p and N_p were the weight of water and nutrient loss from vegetated area and W_0 and N_0 the weight of water and nutrient loss from the bare land (control).

RESULT AND DISCUSSION

Landuse plant diversity and vegetal cover

Some Characteristics of the vegetal cover, total basal area (TBA), density and crown cover for each landuse category is presented, (Table 1). The grassland had highest number of herb/grass species (21) and tea plantation the lowest (9 species). The tea plantation area showed highest vegetal cover (58%) in the dry season followed by grassland. Almost similar trend between the tea cultivation and grassland was recorded for monsoon period, this is perhaps due to the fact that grassland patches are traditionally preserved as fodder area for the lean periods. The tea plantation site had highest crown cover (71%) in dry period and (78%) in monsoon period. However, total tree basal area was highest for degraded pine forest (30.2 – 30.9 m^2/ha). Continuous grazing in degraded pine forest and grazing land is responsible for reduced number of herb and grass species and consequent enhanced rate of water, soil and nutrient loss.

Physical characteristics

The mean maximum temperature (36°C) is recorded in June and minimum (4°C) in January. Physical and chemical soil analysis of sites showed that the cation exchange capacity (CEC) under tea plantation was the highest (14.56 Meq./l), followed by grassland (13.24 Meq./l) and lowest (8.68Meq./I) was reported for pine forest. The soil colour varied across the sites ranging from light gray to grayish brown. The soil texture ranged from

Table 1. Plant diversity characteristics of different system of Bhetagad watershed, N=10

Landuse	Period	Surface Vegetal cover (%)	Tree density (no/ha)	Total tree basal area	Crown cover (%)
Open pine forest	Dry	29	210	30.2	52
	Monsoon	42	210	30.9	59
Tea plantation	Dry	58	1600	0.42	71
	Monsoon	61	1600	0.56	79
Rainfed agriculture	Dry	49	110 (*G. optiva*, *P. pessia*)	5.08	23
	Monsoon	78	110 (*G. optiva*, *P. pessia*)	5.82	27
Grazed land	Dry	32	-	-	-
	Monsoon	39	-	-	-
Grass land	Dry	56	-	-	-
	Monsoon	87	-	-	-
Bare plot	Dry	0	-	-	-
	Monsoon	0	-	-	-
Recently restored site	Dry	27	(1000) *Thysanolaena maxima*	-	
	Monsoon	66	(1000) *Thysanolaena maxima*	-	

Table 2. Plant diversity of different landuse system in Bhetagad watershed N=10

Species	Period	Open pine forest	Tea plantation area	Agriculture terrace	Grazed land	Grass land	Rec. Restored site	Bare land
Total number of herbs	Dry	04	04	06	03	08	04	00
	Monsoon	11	7	15	7	17	11	00
Total number of grasses	Dry	02	01	02	02	04	05	00
	Monsson	03	02	04	03	04	06	00
Total number of species	Dry	06	05	08	05	12	09	00
	Monsoon	14	09	20	10	21	17	00

Table 3. Physicochemical characteristics of Erosion plots in Bheta Gad watershed

Characteristics	Pine forest	Tea plantation	Rainfed agriculture	Graze land	Grassland	Rec. restored site	Bare plot
Slope-aspect	SE	E	E	S	E	S	E
CEC (meq/l)	8.68	14.56	10.24	12.16	13.24	13.46	13.20
pH	6.39	6.16	6.16	6.84	6.34	6.88	6.34
O.M. (%)	2.82	2.05	2.55	1.64	2.56	1.71	2.55
Total N (%)	0.143	0.167	10.236	0.098	0.162	0.108	0.161
C:N ratio	11.5	7.44	6.28	9.70	9.02	9.18	9.21
Available P (kg/ha)	39.5	34.3	32.3	34.8	32.4	34.62	33.3
Available K (kg/ha)	229	216	286	137	270	146	276
Infiltration rate (cm/hr.)	5.8	6.4	5.7	10.6	6.0	10.4	6.1
Bulk density (gm/cm^3)	1.43	115	1.22	1.01	1.29	1.22	1.25
Soil texture	SL	SL	SL	LS	SL	LS	SL
Sand (%)	63	66	63	73	64	71	68
Silt (%)	22	25	25	16	24	17	25
Clay (%)	15	09	11	11	12	12	07
W.H.C. (%)	30.8	31.9	33.9	26.6	32.8	26.8	31.4

Note: CEC = Cation exchange capacity; OM = Organic matter, SL = Sandy loam, LS = Loamy sand; WHC = Water holding capacity

sandy loam to loamy sand in different sites. The basic infiltration rate was highest (10.6 mm/hr) for grazing land and lowest for degraded pine forest (5.7 mm/hr). A lower infiltration rate at degraded pine forest may probably be attributed to higher clay and silt contents (Table 3) of these sites. Similar observations have been made elsewhere (Busby and Giffard 1981 and Mwemdra and Saleem 1997). The sand content showed positive correlation with infiltration rate and negative to silt and WHC (Table 3 and 8). The water holding capacity (WHC) also varied with the soil texture and infiltration rate. The high sand content enhanced the infiltration rate ant thus reduced the water retention power of soil. The WHC showed negative correlation with infiltration rate.

Chemical characteristics

The soil pH for different sites did not vary significantly (6.1-6.84) In grass land the organic matter was higher (2.82%) than other sites, due to accumulation of shedding leaves and their subsequent decomposition. In case of degraded pine forest and grazing land the lower organic matter was mainly due to severe grazing and trampling which led to increased runoff and soil loss. The low N (0.143%) and high C:N ratio (11.5) for pine forest indicated low net rate of mineralization. The available P for the degraded pine forest and grazing land was 39.5 kg/ha and 34.8 kg/ha, respectively. The higher available P in these sites are likely due to the presence of less biomass as a result of heavy grazing, which caused less absorption of P in the soil. Similar results have been reported in other areas of the region (Singh 1999). The available K varied from 137 kg/ha in grazing land to 286 kg/ha (rainfed agriculture).

Landuse and erosional losses

The total annual surface runoff generating precipitation was recorded as 345.6mm in dry and 643.4mm in monsoon period. The minimum runoff generating intensity was recorded for bare plot 0.225mm/hr in dry period and 0.130 mm in monsoon period. However, the agriculture land remained unaffected even with 2.131 mm/hr of average rain in the dry period and 1.55 mm/hr in the monsoon period. The highest soil moisture was for grassland in the dry (15.8%) and monsoon period (21.9%). The highest runoff coefficient and the rate of soil losses were recorded for bare land followed by open pine forst (Table 6). The bare plot produced maximum surface runoff in both the studied period (68.18 mm and 85.95mm), and soil loss (9.982 t/ha and 10.978 t/ha). The nutrient concentration was also recorded highest : O.M. (426.30 and 510.80 kg/ha), total N (157.10 kg/ha and 171.40 kg/ha), total P (34.12 kg/ha and 39.52 kg/ha) and toal K (34.12 kg/ha and 36.12 kg/ha) for the bare land in dry and monsoon period respectively. This was followed by open pine forest. The lowest surface runoff, soil and nutrient losses were recorded for the rainfed agriculture land in dry period and tea cultivation in monsoon (Table 6). The high runoff in pine forest can probably be attributed to the combined effect of grazing, tampling and poor surface vegetation cover. Grasslands considerably reduced runoff and soil loss due to presence of good grass cover. The standing vegetal cover obstructs the flow and reduces the velocity of runoff, which in turn induced more infiltration resulting in reduction of runoff (Sharda et al., 1999). The traditionally maintained agriculture terraces also resulted into lower surface runoff and soil loss. The degraded pine forest and grazed land had highest values for soil and nutrient loss. The reduction in soil and nutrint losses through erosion has laso been reported due to vegetative cover (Khanna and Mathur 1993). The surface runoff showed positive correlation with soil loss (Table 4 and 5), however, it did not show correlation with soil texture. The surface runoff and soil losses were significantly different between the entire study site in different period, except the tea plantation and grassland (Table 6). However, in case of organic matter and total nitrogen differences were not significant among tea plantation, agriculture land, grazing land and grassland. Surface runoff and soil losses were significantly different among all the study sites, except between tea and grassland. The organic matter and total nitrogen loss were insignificant between the grazing land and other three sites (tea plantation, rainfed agriculture and grassland). This is mainly due to low organic matter and nitrogen content in parent soil (Table 3). The higher surface runoff

Table 4. *Correlation matrix between vegetation status, surface runoff and soil loss for dry season in between different sites of the watershed*

Parameters	Surface vegetal cover	Tree density area	Total basal (%)	Crown cover (mm)	Surface runoff	Soil loss (t/ha)
Surface vegetal cover (%)	1	0.191	-0.0954	0.420	0.917	-0.816
Tree density		1	-0.056	0.833	-0.395	-0.239
Total basal area			1	0.49	0.181	-0.168
Crown cover (%)				1	-0.319	-0.330
Surface runoff (mm)					1	0.842
Soil loss (t/ha)						1

Table 5. Correlation matrix between vegetation status, surface runoff and soil loss for monsoon season in between different sites of the watershed

Parameters	Surface vegetal cover	Tree density area	Total basal (%)	Crown cover (mm)	Surface runoff	Soil loss (t/ha)
Surface vegetal cover (%)	1	0.122	-0.099	0.083	-0.768	-0.836
Tree density		1	-0.054	0.792	-0.417	-0.229
Total basal area			1	0.556	0.455	-0.147
Crown cover (%)				1	-0.132	-0.301
Surface runoff (mm)					1	0.672
Soil loss (t/ha)						1

in open pine forest is also favoured by the higher clay content and low infiltration rate.

Water and Soil Conservation Values

Results (Table 8), suggested that the terraces on agriculture land obstruct runoff flow. The cultural practices in agricultural land slightly lowered the conservation value of agriculture land compared to the grassland, due to weeding and soil exposure, resulting in high soil loss. This observation was verified by the vegetal status of grass land where grass roots bind the soil.

Landuse and Practices

All the studied landuses are located on comparable slope range (14°-28°) but the practices varied considerably among landuses and thus showed different hydrological responses. The tea plantation and grassland sties having highest rainfall interceptions due to higher surface vegetal cover and crown cover, minimized soil erosion in both the season. In case of rainfed agriculture terraces, the higher surface cover and traditional bunding is helpful in minimizing soil erosion. Both grass lands and raifned agriculture terrace lands used for grass cultivation reduced soil and nutrient losses, but the well maintained terrace edges acted as additional conservation measures in minimizing soil loss. Even though both the open pine forest and grazed land have similar type of interferences but these showed vast difference in water, soil and nutrient losses (Table 3, 6 and 7).

Table 6. Surface runoff, soil and nutrient losses for from different landuse system of Bhetagad watershed (A computed mean of dry period, 1st Oct. 2001-30th June 2002 and 1st July 2002-30th September, for monsoon period)

Landuse	Period	Runoff producing rainfall (mm)	Surface runoff (mm)	Runoff coefficient (%)	Soil loss (t/ha)	O.M. loss (kg/ha)	Total N (kg/ha)	Total P (kg/ha)	Total K (kg/ha)
Open pine forest	Dry	345.6	39.72^{B}	11.5	0.667^{B}	116.42^{B}	22.40^{B}	4.20^{B}	3.38^{B}
	Monsoon	643.4	$74..04^{b}$	11.5	0.930^{b}	181.56^{b}	27.89^{b}	4.84^{b}	3.86^{b}
Tea plantation	Dry	345.6	5.35^{E}	1.5	0.042^{E}	43.11^{C}	6.08^{C}	1.04^{C}	1.01^{B}
	Monsoon	643.4	10.42^{e}	1.6	0.086^{f}	36.40^{d}	5.94^{c}	1.21^{c}	1.19^{b}
Rainfed agriculture	Dry	345.6	0.00^{F}	0.00F	0.000^{F}	0.00^{F}	0.00^{D}	0.00^{C}	0.00^{C}
	Monsoon	643.4	6.07^{f}	1.0	0.120^{ef}	16.44^{e}	3.81^{c}	0.98^{c}	0.99^{b}
Grazed land	Dry	345.6	30.73^{C}	8.9	0.440^{C}	27.42^{D}	4.10^{C}	1.09^{C}	1.01^{B}
	Monsoon	643.4	37.23^{c}	5.8	0.556^{d}	46.10^{c}	434^{c}	1.146^{c}	1.04^{b}
Grass land	Dry	345.6	14.93^{D}	4.2	0.231^{D}	18.22^{E}	3.27^{C}	0.96^{C}	1.00^{B}
	Monsoon	643.4	32.28^{d}	5.0	0.127^{e}	14.28^{e}	3.08^{c}	0.90^{c}	1.02^{b}
Recently restored	Dry	345.6	14.93^{D}	6.2	0.407^{C}	23.44^{DE}	4.46^{C}	1.04^{C}	1.01^{B}
site	Monsoon	643.4	32.28^{d}	5.2	0.511^{c}	21.58^{e}	4.92^{c}	1.07^{c}	1.27^{b}
Bare land	Dry	345.6	68.18^{D}	19.7	9.982^{A}	426.30^{A}	157.1^{A}	34.56^{A}	34.12^{A}
	Monsoon	643.4	85.95^{a}	13.3	10.978^{a}	510.80^{a}	171.4^{a}	39.52^{a}	36.42^{a}

A-F represent analysis of variation in the dry period.
a-f represent analysis of variation in the monsoon period

Table 7. Correlation matrix between soil property, surface runoff and soil loss in between different sties

	Sand	Silt	Clay	WHC	Infiltration rate	Runoff dry	Runoff monsoon	Soil loss in dry	Soil loss in monsoon
Sand	1	-0.792	-0.283	-0.888	0.915	0.278	0.068	0.156	0.13
Silt		1	-0.355	0.952	-0.945	-0.074	-0.061	0.285	0.30
Clay			1	-0.154	0.072	-0.251	0.064	-0.660	-0.6
WHC				1	-0.943	-0.256	-0.194	0.069	0.08
Infiltration rate					1	0.014	-0.097	-0.198	-0.2
Runoff in dry						1	0.937	0.842	0.8
Runoff in monsoon							1	0.666	0.6
Soil loss in dry monsoon								1	0.9
Soil loss *in monsoon*									1

Table 8. Conservation values for water, soil and nutrients for different landuse system for Bhetagad Watershed

Landuse	Period	CV for Water	CV for Soil	CV for O.M.	CV for N	CV for P	CV for K
Open pine forest	Dry	41.76	93.32	72.69	85.74	87.5	90.09
	Monsoon	5.51	91.53	64.45	83.73	87.75	89.40
Tea plantation	Dry	92.16	99.57	89.88	96.13	96.99	97.03
	Monsoon	86.70	99.22	92.87	96.53	96.94	96.73
Rainfed agriculture	Dry	100	100	100	100	100	100
	Monsoon	92.25	98.90	96.78	97.77	97.52	97.28
Grazed land	Dry	91.160.7	95.59	93.57	97.39	96.84	97.049
	Monsoon	8	94.93	90.97	97.46	96.30	7.14
Grass land	Dry	78.58.80	97.68	95.72	97.91	97.22	97.07
	Monsoon	1	98.84	97.20	98.20	97.72	97.20
Recently restored *site*	Dry	68.74	93.21	94.50	97.16	96.99	97.04
	Monsoon	57.33	96.62	95.77	97.113	97.29	96.51
Bare land	Dry	00	00	00	00	00	00
	Monsoon	00	00	00	00	00	00

Erosional Losses and Agricultural Soil

Despite low soil loss from agriculture land the soil fertility of these lands still remains in the range of low to moderate in terms of organic carbon, total nitrogen, available phosphorus and potassium. This may be due to soils having high sand content. Factors such as poor FYM (in terms of nutrients), continuous cropping, very small land holding size, inferior quality livestocks, faulty agricultural practices, quality of seeds and varieties and very poor economic conditions of the farmers all work together to lower agricultural crop productivity.

Management Strategies

Due to intensive grazing and human encroachments, the water, soil and nutrient losses were high in open pine forest followed by grazed land but it was recorded least for the rainfed agriculture which is already influenced by combined effects of leaching and poor quality of manures etc. Local people also felt that there was need to apply soil in their community land as well as on individual lands. Thus the broad-leafed trees with evergreen grasses would be minimizing the water, soil and nutrient losses and enhancing the fertility status of soil. *Qurcus , leucotrichphora*, Grewia optiva, *Dalbegia, Sissoo* and *Leucaena leucocepala* trees are good quality of fodder species and they enrich the nutrient pool. Besides, cultivation of grasses such as *Pennisetum purpureum*, *Brachiaria ruziziensis*, *Panicum maximum* and *Thysanolaenia maxima* species are more helpful in minimizing the erosional lossss and provide good quality of fodder for lean period.

The introduction of *Alnus nepalenses*, *Dalberiga sissoo* and *Bauhinia vahli*, nutrient exhaustive species, may be an additional nturient maintaining measure for the watershed. The tea cultivation and horticultural practices may also be helpful to conserving soil water and income generation for the local community. The aforesaid landuse practices may help in maintaining the soil nutrient pool and improve the economy of the inhabitants in the watershed.

Initiation of Land Management Programs

In the Bhetagad watershed community forestry, tea plantation and horticultural landuse have a great scope of reducing soil and water losses and increasing nutrient availability. These efforts are also expected to contribute towards meeting the demand of good quality fodder and income generating sources for the inhabitants. *Albiziza stipulata*, *Delbergia sissoo* and *Alnus nepalensis* are fast growing leguminous trees that are believed to increase the soil fertility levels. Besides, *Grewia optiva* and *Quercus leucotrichphora* species are also important to meet the fodder and fuel demand and other uses.

CONCLUSION

The study concludes that the higher surface runoff and soil and nutrient loss were characteristics of bare land, which was followed by open pine forests. The lower vegetal cover enhances soil and nutrient loss; on contrary grass protection system in grasslands and well maintained agriculture terrace edges reduced water, soil and nutrient losses. The data suggest that adoption of appropriate management practice is essential to prevent water, soil and nutrient losses by minimizing the grazing pressure on forest area and grazing land. This study has implications for watersheds with improperly managed agriculture terraces. This study reveals that vegetative barriers through grasslands may act as an important conservation measure, which will minimize the soil and nutrient loss from open pine forest and grazing lands. The grass protection in agriculture terrace rise and edges may be additional tools for hill farming. Beside this, to maintain the nutrient balance in different landuse systems, farmers also need to apply fertilizer in agriculture land and restored open pine forest, grazing land and the denuded patches. These efforts would also save down stream water quality and low land agriculture.

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