Assessment of Nutrient Flux Through Runoff Water from Forest Ecosystem for Crop Production in Agroecosystem in Himalyan Watershed

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Abstract: The analysis of runoff water from Henwal river watershed (550hac) having 34.8%, 3.0% and 62.3% area under cultivable, pasture and forest lands, respectively revealed that the concentration of nutrients was highly variable during different weeks and months. Ca^{2+}, NO^{3-} and CO_3^{2-} were recorded highest in September; Mg^{2+}, NO^{3-} and HCO^{3-} in August; K^+ and PO_4^{3-} in July; Na^+ and SO_4^{2-} in June and Cl^- in October. The order of dominance of cations was $Ca^{2+} > Mg^{2+} > Na^+ > K^+$ and that of anions was $HCO^- > CO_3^{2-} > Cl^- > NO^{3-} > SO_4^{2-} > PO_4^{3-}$. An estimate of individual ions in runoff water indicates that HCO_3 and CO_3^{2-} constituted about 60%, Ca^{2+} and Mg^{2+} 20%, Cl^- 10% and remaining ions 10% of the total ions. Litter biomass was recorded highest in oak-mixed litter under forest and lowest in deodar. C:N ratio of 30:1, 32:1 and 47.1 was recorded in oak-mixed, deodar and pine forest ecosystem, respectively. Litter under oak-mixed forest contained highest amount of Ca, Mg and K while deodar and pine had N and P contents. NO_3^-, K^+ and CO_3^{2-} in runoff water was highest in deodar, Ca^{2+}, Mg^{2+} and K^+ in pine while PO_4^{3-} and HCO_3^- in oak-mixed forest ecosystem. The contribution of runoff water on pod yield of vegetable pea was 16.7, 31.1 and 24.2%, respectively from deodar, pine and oak-mixed forest ecosystem. The response of NPK at 50 and 100% of recommended dose with runoff water was comparable to each other. Nutrient use efficiency (NUE) under 50% NPK with runoff water was highest and declined sharply at 100% NPK. Further, NUE was highest in deodar as compared to pine and oak forest ecosystems. There was a considerable improvement in amounts of organic C, available N, P and K status of soil with runoff water treatment. Thus forest litter and runoff water in hill and mountain ecosystem are the major pathway of nutrients to meet the crop requirements in agro ecosystem.

Keywords: nutrient flux, forest litter, runoff water, watershed, forest ecosystem, nutrient use efficiency

1 Introuction

Soil, water and vegetation are the major natural resources in any watershed. Among them forest accounts for about 80% of the total geographical area, are the integral part of the hill and mountain ecosystem. According to an estimate about 30 to 35t • ha^{-1} of organic matter lying under the forest, supplies about 4,8 and 3 time as much K, Ca and P as compared to mineral soil. However, the amount varies with forest type and species. Hardwood supplies approximately 2 times as much Ca, Mg, K and P to soil as compared to conifers. Thus litter and runoff water can be the major pathway to supply the nutrients to meet the crop requirements but meagre information is available on these aspects.

In Himalayan region the lands are more sensitive to erosion and vast amount of nutrients are lost in runoff water and eroded soil mass (Dwivedi *et al*., 1998). Soil water conservation methods and technologies can provide development plan for treating these resources for achieving long and sustained use towards production.

Description of watershed

Henwal river watershed (30°15′ —30°20′ N latitude and 78°25′ —78°30; E longitude) located

in Chamba block of Tehri district of Uttaranchal, covers an area of 547.23 ha. Most of the area has undulating topography. The elevation ranges from 900m—2,200m above msl. The mean annual rainfall is 1,350 mm of which 60% occurs in rainy season. The rocks are gneiss, biotite, shale, phyllite and lime stone. The lands have been categorized as forest land (62.2%), pasture land (3.0%) and cultivated lands including agricultural and horticultural lands (34.8%) of the total area. The forest is dominated by chir pine (Pinus roxburghii). Few dense patches of deodar (Cedrus deodara), oak (Quercus leucotrichophoroa) and their associated species.

2 Materials and methods

The runoff from the watershed is discharged into Henwal river. To assess the nutrient and sediment losses from watershed, water samples, collected at weekly intervals as well as after each rains from June to October at extreme off-stream point of the stream, were analyzed for pH, EC, TSS, cations and anions using ion meter (ORION 720). For sediment yield, 100 ml aliquot of water sample was evaporated to dryness on sand bath at 100℃ in a porcelain dish till shattering of dry mass and weighed (Singh, 1980).

Litter biomass under deodar, pine and oak - mixed forest site were collected and weighed using 1 m × 1 m quadrate. The litter was oven dried and analysed for total C, N, P, K, Ca and Mg contents (Singh, 1988). Runoff plot size 5 m × 5 m were constructed on suitable places under deodar, pine and oak-mixed forest ecosystem. The plots were bounded by 50 cm × 50 cm thick raised bunds protected with covering polythene sheet without disturbing the litter biomass in the plot. Multi slot device was installed in the plot to collect runoff water. The runoff water was collected in 100 l cap. plastic drums fixed at the base of plot. The runoff water was analyzed for suspended sediment, cations and anions and organic carbon using ion meter (ORION-720). Field experiments on vegetable pea (var. Arkel) were conducted on farmer's field adjoining to runoff plots in different forest sites. Soils of different sites were as Deodar pH 6.1, EC 0.75 dsm^{-1}, organic C 3.2%, available N, P and K 256, 16.5 and 392 kg • ha^{-1}, pine : pH 8.0, EC 0.65 dsm^{-1}, organic C 1.3%, available N, P and K 192, 19.6 and 493 kg • ha^{-1}, oak mixed; pH 8.2, EC 0.78 dsm^{-1}, organic C 1.7%, available N, P and K 195, 17.5 and 576 kg • ha^{-1}. The treatments comprising of runoff water treatments in main plots and NPK at 50% and 100% of recommended dose in subplots, were laid out in split plot design with three replications. Plot wise pod yield was recorded. Soil samples were analyzed before and at harvest of the crop for pH, organic C, available N, P and K (Jackson 1973) Nutrient Use Efficiency (NUE) was also calculated.

3 Results and discussion

3.1 Sediment and nutrient loads in stream water

Sediment and nutrient loads enable the assessment of water quality. The sediment and nutrient concentrations in stream water were highly variable during different weeks and months depending on rainfall. Sediment varied from 26.1 (June) to 119.9 mg • L^{-1} (August) with an average of 76 mg • L^{-1}. The water was slightly alkaline (pH 7.4) with EC of 123 sm^{-1}. The TSS also varied greatly from 118 to 150 mg • L^{-1} with an average of 134 mg • L^{-1}. Concentration of nutrient cations and anions were also varied. The order of dominance of ions was $Ca^{2+} > Mg^{2+} > Na^{+} > K^{+}$ (cations) and $HCO_3^- > CO_3^{2-} > Cl^- > NO_3^- > SO_4^{2-} > PO_4^{3-}$ (anions). Ca^{2+}, NO_3^- and CO_3^{2-} was recorded highest in September; Mg^{2+}, NO_3^- and HCO_3^- in August; K^+ and PO_4^{3-} in July; Na^+ and SO_4^{2-} in June and Cl^- in October (Table 1). An estimate of individual ion in runoff water indicates that HCO_3^- and CO_3^{2-} constituted about 60%, Ca^{2+} and Mg^{2+} 20%, Cl^- 10% and remaining ions 10% of the total ions. Dwivedi *et al.* (1998) reported HCO_3^- and CO_3^{2-} constituted 50%; Ca^{2+} and Mg^{2+} 25% Cl^- 25% and 10% other ions in stream water of Chamba subwatershed.

3.2 Soil and nutrient losses from watershed

The average soil loss was 90.13 t. Among ions losses of cations were 23.2t, 19.7t, 6.2t and 7.3t for Ca^{2+}, Mg^{2+}, K^{+} and Na^{+} and anions were 3.0t, 0.56t, 2.2t, 18.6t, 21.4t and 74.6t for NO_3^-. PO_4^{3-}, SO_4^{2-}, Cl^-, CO_3^{2-} and HCO_3^-, respectively during study period. Similar type of findings have also been reproted in Chamba subwatershed by Dwivedi *et al.* (1998). The concentration of nutrients in the stream water were relatively lower than Gagas, Bino and Ramganaga rivers in Himalayan region (Prakash 1982, Gautam 1990).

3.3 Nutrient content in forest litter and runoff water under different forest ecosystem

Litter biomass varied greatly under different forest ecosystem depending on type. It ranged from 2.5 to 5.3t • ha^{-1}. Oak-mixed forest recorded highest quantity of litter and lowest under deodar with narrow C:N ratio of 30:1 and 32:1 respectively while pine litter had a C:N ratio of 47:1. The narrow and wide ratios depends upon lignin content and reflect the microbial decomposition and mineralisation of litter as well as release of nutreints. Oak-mixed litter contained highest amount of Ca, Mg and K; N and P in deodar and N in pine litter (Table 2).

pH of the runoff water from deodar, pine and oak mixed forest was acidic ranging from 5.15 to 5.95. The pH of runoff water from deodar and pine was 5.15 and 5.20 while it was 5.95 in oak-mixed forest. The low pH (acidic nature) of water was due to presence of large number of organic acids in varying concentrations released from microbial decomposition of forest litter under low temperature and excessive moisture conditions. Highest sediment was recorded from deodar and lowest from oak-mixed forest. Ca^{2+}, Mg^{2+} and K^{+} were highest in runoff water from pine, NO_3^-, K^{+} and CO_3^{2-} in deodar while PO_4^{3-} and HCO_3^- in oak-mixed forest ecosystem. Thus forest litter and runoff water are the major pathway of nutrients and can be efficiently utilized crop for production.

3.4 Effect of runoff water and fertilizers on crop yield and soil fertility

The pod yield of vegetable pea was markedly influenced by the runoff water as well as NPK. The runoff water significantly increased the yield however, the magnitude of response varied depending on forest type. The contribution of pine, deodar and oak-mixed forests was 31.1%, 24.2% and 16.7%, respectively. The response of NPK at 50% and 100% of recommended dose was at par to each other which was more pronounced under runoff treatments. It was 17.7%, 29.9% and 24.8% with 50% NPK while it was 16.4%, 33.8% and 24.5% with 100% NPK respectively under deodar, pine and oak mixed forest ecosystem (Table 3). The nutrient use efficiency (NUE) was also recorded highest with 50% NPK and increased further with runoff water treatment. The NUE was sharply declined at 100% NPK under both runoff and without runoff possibly due to leaching losses from soil. Highest NUE was recorded under deodar followed by pine and oak mixed forest ecosystem (Table 4).

The fertility status of the soil was also greatly improved over to initial status after treatment with runoff water. Organic C, available N, P and K were increased by 20.0%, 7.0%, 46.3% and 3.8% (deodar), 11.5%, 7.8%, 19.4% and 3.3% (pine) and 16.5%, 13%, 14.3% and 2.4% (oak-mixed) respectively. The improvement was due to addition of nutrient input in varying amounts through runoff water from deodar, pine and oak-mixed forest ecosystem.

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Table 1 Concentration of sediment yield and concentration of nutrients in water of Henwal stream during different months

Months	Sediment (mgL^{-1})	pH	EC $\mu s \cdot m^{-1}$	TSS ($mg \cdot L^{-1}$)	Ca^{2+} ($mg \cdot L^{-1}$)	Mg^{2+} ($mg \cdot L^{-1}$)	K^{+} ($mg \cdot L^{-1}$)	Na^{+} ($mg \cdot L^{-1}$)	NO_3^{-} ($mg \cdot L^{-1}$)	PO_4^{3-} ($mg \cdot L^{-1}$)	SO_4^{2-} ($mg \cdot L^{-1}$)	Cl^{-} ($mg \cdot L^{-1}$)	CO_3^{2-} ($mg \cdot L^{-1}$)	HCO_3^{-} ($mg \cdot L^{-1}$)	Total ions cons. ($mg \cdot L^{-1}$)
June	26.1	7.4	130	150	15	10	3.4	5.3	1.3	0.30	1.7	8.5	15.3	49.7	110.5
July	110.4	7.3	124	147	12	13	3.5	3.9	1.6	0.04	1.3	10.7	15.0	50.1	111.5
August	119.9	7.6	135	134	16	14	3.1	3.4	1.7	0.38	1.6	12.5	15.3	29.5	127.5
September	71.5	7.3	114	123	17	11	3.0	2.6	1.7	0.30	1.4	14.0	16.5	58.3	125.8
October	52.3	7.3	110	118	12	11	2.0	3.7	1.6	0.34	1.5	14.2	15.1	52.3	113.7
Average	76.0	7.4	123	134	14	12	3.0	3.8	1.6	0.34	1.5	12.0	15.4	54.0	117.6

Table 2 Sitter biomass, total nutrients in litter, sediment and nutrient load in runoff water under different forest ecosystem

	Deodar forest	Chir pine forest	Oak-mixed forest	Average
Forest litter				
Biomass ($Kg \cdot ha^{-1}$)	2,458	4,375	5,268	4,034
C:N ratio	32:1	47:1	30:1	36:1
Total N ($Kg \cdot ha^{-1}$)	23.8	24.5	15.8	21.4
Total P ($Kg \cdot ha^{-1}$)	4.2	1.8	3.2	3.1
Total K ($Kg \cdot ha^{-1}$)	12.5	8.2	14.0	11.6
Total Ca ($Kg \cdot ha^{-1}$)	15.8	28.5	65.8	36.7
Total Mg ($Kg \cdot ha^{-1}$)	4.8	5.8	10.6	7.1
Runoff water				
Sediment ($Mg \cdot L^{-1}$)	135.6	119.8	95.5	117.0
pH	5.20	5.15	5.95	5.43
Organic C ($Mg \cdot L^{-1}$)	16.5	25.0	45.5	29.0
Ca^{2+} ($Mg \cdot L^{-1}$)	1.8	1.4	1.2	1.47
Mg^{2+} ($Mg \cdot L^{-1}$)	0.15	0.13	0.25	0.18
K^{+} ($Mg \cdot L^{-1}$)	4.5	4.5	2.8	3.9
NO_3^{-} ($Mg \cdot L^{-1}$)	10.6	15.8	11.5	12.6
PO_4^{3-} ($Mg \cdot L^{-1}$)	7.0	8.5	5.6	7.0
CO_3^{2-} ($Mg \cdot L^{-1}$)	16.2	12.8	14.6	14.5
HCO_3^{-} ($Mg \cdot L^{-1}$)	38.5	42.5	46.2	42.5

Table 3 Green pod yield of vegetable pea and nutrient use efficiency as influenced by runoff water and fertilizers under different forests ecosystem

Treat,emts	Deodar	Chirpine	Oak-mixed	Average	Deodar	Chirpine	Oak-mixed	Average
Without runoff	Green pod(q • ha^{-1})				Nitrient use efficiency (NUE) kg NPK^{-1}			
50% NPK	65.0	57.8	54.5	59.1	86.7	77.1	72.7	78.8
100% NPK	81.0	67.8	65.4	71.4	54.0	45.2	43.6	47.6
Mean	73.2	62.8	60.0	-	70.4	61.2	58.2	-
Run off								
50% NPK	76.5	73.9	67.6	72.7	102.0	98.5	90.1	96.9
100% NPK	94.3	90.7	81.4	88.8	62.9	60.5	54.3	59.2
Mean	85.4	82.3	74.5	-	82.5	79.5	72.2	-
CD at 5% runoff				2.6	4.1	2.9		
NPK				3.8	3.5	3.0		
Interaction				3.7	5.8	4.3		

Table 4 Fertility status of soil as influenced by runoff water different forest ecosystem and fertilizer

	Deodar					Pine					Oak-mixed				
		Without Runoff		With Runoff			Without Runoff		With Runoff			Without Runoff		With Runoff	
	Initial status of soil	50% NPK	100% NPK	50% NPK	100% NPK	Initial status of soil	50% NPK	100% NPK	50% NPK	100% NPK	Initial status of soil	50% NPK	100% NPK	50% NPK	100% NPK
pH	6.1	6.2	6.0	6.2	6.1	8.2	8.2	8.0	7.8	7.8	8.2	7.8	8.0	7.8	7.8
organic C(%)	2.5	2.2	2.5	2.8	3.2	1.3	1.3	1.4	1.4	1.5	1.7	1.8	1.9	2.8	2.2
Available N (kg • ha^{-1})	256	257	262	263	285	192	1.98	207	211	215	195	216	218	223	228
Avail. P kg. P_2O_5	16.5	21.7	22.3	23.4	25.0	19.4	20.5	24.7	21.5	26.8	17.5	18.1	20.2	20.3	21.3
Avail K (kg K_2O ha^{-1})	392	412	417	398	416	493	500	512	505	520	576	585	590	578	610
CD at 5% Organic C N P K		0.01 4.2 1.2 6.5					0.01 3.8 1.6 4.5					0.03 4.6 2.0 7.2			