



Soil erosion-productivity relationship assessment in sloping lands of north-west Himalayas*

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Soil erosion inevitably reduces crop productivity but how much reduction occurs depends upon soil profile characteristics, crop grown, soil management and micro-climate (Lal 1981). European researcher (Baker *et al.* 2007) has recently assessed the effects of soil erosion on agricultural productivity. They found that soil erosion has little impact on crop productivity. Nevertheless, they highlighted other parameters such as ecological and social impacts should be taken into account when assessing soil erosion impacts. Recent estimates of Sharda *et al.* 2010 have documented a productivity loss of 13.4 m tonnes of foodgrain worth rupees 111.3 billion due to soil erosion by water in rainfed area of different states of India based on modified productivity loss factor derived from potential soil erosion rates–productivity loss relationship of different soil groups (Sehgal and Abrol 1994). The basic concept of soil loss tolerance (T value) illustrates the sustainable crop productivity keeping dynamic balance between soil formation and soil erosion rates which have been estimated between 2.5 to 12.5 tonnes/ha/yr in different agroclimatic region of India depending upon soil depths and quality with soil tolerance limits of Doon valleys soils having depth of more than 1.0 m have been reported to the extent of 12.5 tonnes/ha/yr (Mandal *et al.* 2006). The basic links between erosion productivity relationship were soil depth and soil water content (porosity) and have given emphasis on decline of available water content due to soil erosion as major pathways for productivity decline (Lal 1981).

Permanent reductions in crop productivity of hilly soils are caused mainly by changes in soil physical properties, especially poor soil water retention (Prakash *et al.* 2004). We

hypothesized that the selected soil quality parameters were negatively affected by the soil erosion level of the experiment within the treatments and were adjudged as basis for selection of treatment for relationship assessment. In this paper attempt has been made with the objective to examine (i) productivity loss with respect to critical soil properties responsible for productivity decline due to erosion below the soil tolerance level and below the lowest limit (very slight) of potential erosion rates where productivity loss due to erosion considered nil and (ii) to prepare revised erosion productivity chart based on observed and predicted (estimated) productivity loss in recent alluvial soils of Uttarakhand.

A fixed plot field study was carried out for four years (2007-08 to 2010-11) at Central Soil and Water Conservation Research and Training Institute, Research Farm, Selakui, Dehradun, Uttarakhand on 2% slope. The soils of the experimental sites were classified as fine mixed hyperthermic family of Typic Udorthent and slightly acidic in nature having pH 5.8, organic carbon 6.0 g/kg, and available N, P and K as 270, 24 and 110 kg/ha, respectively. The soils were silty clay loam in texture having 12.5% clay and 35.5% silt with bulk density 1.36 Mg/m³ and basic infiltration rate of 1.42 mm/hr. The total rainfall for the study period varied from 1 510–2 750 mm of which total rainfall caused runoff during crop growth period ranged 850–1240 mm. On an average 22–32 number rainfall events occurred causing runoff and the rainfall intensity which caused runoff ranged from 32–85 mm/hr for the study period. Data was recorded from the ongoing experiment laid out in a randomized block design with three replications having 100 m × 20 m run off plot comprising four treatments.

- T1: 100:60:40 N:P₂O₅:K₂O + conventional tillage (CT) + chemical weeding + *Panicum* vegetative barrier
T2 : FYM (5 tonnes/ha) + minimum tillage (MT) + 1 weed mulch (30 DAS)+ palmarosa vegetative barrier
T3: FYM (5 tonnes/ha) + vermi-compost (1.0 t/ha) + MT + 2 weed mulch (25 and 50 DAS) + palmarosa vegetative barrier

*Short note

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T4: FYM (5 tonnes/ha) + vermicompost (1.0 tonnes/ha) + poultry manure (2.5 tonnes/ha) + MT + 3 weed mulch (20, 40 and 60 DAS) + palmarosa vegetative barrier.

In CT plots, tillage operations were performed four times with tractor drawn cultivator, whereas in MT plots, two tillage operations were provided. Atrazine herbicide for maize and Isoproturon for wheat at 1.5 active ingredient/litre were applied to control weeds in conventional tillage plots, respectively. Details of the experiments regarding tillage, manuring and mulching were reported by Ghosh *et al.* 2012.

Run off data was recorded through stage level recorder, whereas soil loss was measured through collection of sediment in run off water. Bulk density was determined through core sample and infiltration by using double infiltration ring. The soil loss thickness in three positions (shoulder, middle and toe) of the land forms were calculated using bulk density in the respective position and soil loss. The available water content of soils was determined collecting core samples and using pressure plate apparatus. A representative portion of each soil sample was air dried, powdered, and passed through <2 mm sieve for determination of pH in a 1:2.5 soil: water suspension, organic carbon (OC) by Walkley and Black's method, available soil nitrogen by alkaline-KMnO₄ method and Olsen-P (using standard procedures as outlined by Jackson 1973). The established techniques of assessing the effect of erosion on soil productivity with the multiple regression analysis applied random samples of associated crop yield and measured soil erosion methods described by Langdale and Schrader 1982 were followed. Statistical analyses were performed using standard analysis of variance (Gomez and Gomez 1984). Treatment means were compared at the $P < 5$ 0.05 level of significance using least significant difference (LSD).

The average maize and wheat grain yield though significantly affected with the different treatment depending upon the fertilization level but it does not showed any definite trend with average soil erosion level (Table 1) indicating commercial fertilizers and organic amendments can improve crop productivity of most hilly soils and mask the effects of soil loss. Over the years with the increase of soil loss (cumulative), it was found that maize and wheat grain yield

declined in all the treatments with cumulative soil loss. The least erosion was recorded on plots T4 and highest in T2 treatments. The selected soil properties of pH, SOC, available N, P and porosity and infiltration were also significantly affected with the treatments (Table 1) but influence of erosion on these soil properties was confirmed by the significant negative correlation with the soil erosion level. The more rapid decline in crop productivity on these gently sloping plots can be attributed to influence of erosion on soil physical and chemical properties as was evidenced by the significant negative correlation coefficient between the parameters of soil erosion and soil quality. Raindrop impact resulted in severe crusting and sealing of the surface layer which reduced infiltration and increased runoff might be the reason for productivity loss (Lal 1981). Further, multiple regression analysis of maize grain yield, with four variables related to soil quality, indicated that the changes in soil properties brought about by erosion had significant effect on maize and wheat grain yield (Table 2). In spite of low risk of erosion in these plots, it has been estimated that on an average, maize grain yields declined to the tune of 7.2, 13.0, 3.50 and 2.80 kg/ha/mm for plots of T1, T2, T3 and T4, respectively with average values of 6.62 kg/ha/mm which corresponds to 0.3 to 2.33 % of the productivity level with average reduction of 1.06% for maize. The corresponding values of productivity decline of wheat ranged from 2.30–3.70 kg/ha/mm with average value of 3.05 kg/ha/mm which corresponds to average reduction of 0.93% (Sharda *et al.* 2010). The highest productivity loss was observed in T2 plots might be ascribed to less canopy cover in the initial stage before mulching and less nutrient supplying capacity. On the other hand wheat yield declined to 3.70 kg/ha/mm (1.35%) for T2 plots only owing to highest level of soil erosion. It is inferred from the study that there is a significant maize and wheat yield decline even the soil erosion not only below the soil loss tolerance but also below the lowest limit (very slight) of potential erosion rates where productivity loss were considered nil. This information is quite useful while estimating economic loss of crop productivity due to erosion in gentle slopes where soil erosion level is quite low. It can be ascribed with the fact that available water content reduced by 16% with

Table 1 Average (2007-08 – 2010-11) productivity of maize and wheat, soil loss, soil thickness loss and average selected soil properties of surface soils (0–15 cm) as affected by different treatments and utilized for correlation and multiple regressions

Treatment	Maize (tonnes/ ha)	Wheat (tonnes/ ha)	Soil loss (tonnes/ ha/yr)	Soil thickness loss (mm)	SOC (g/kg)	Avail. N (kg/ha)	Avail. P (kg/ha)	pH	Porosity (%)	Infiltration (mm/hr)
T1	2.34	1.15	5.07	0.37	6.20	264	27.3	5.85	48.28	1.49
T2	1.05	1.19	5.69	0.42	6.14	239	23.8	5.80	47.94	1.43
T3	1.71	1.44	4.38	0.32	6.41	257	25.3	5.90	48.76	1.53
T4	1.96	1.70	3.46	0.25	6.60	275	27.5	6.10	49.40	1.69
CD ($P = 0.05$)	0.42	0.23	1.86	0.012	0.056	2.24	0.84	0.012	0.034	0.074

Table 2 Multiple regressions between crop productivity and soil erosion; and soil properties affecting productivity

Treat-ments	Multiple regression	Regression coefficients
<i>Maize</i>		
T1	Y= 1.79 -0.0114 (E) + 0.65 (SOC) + 0.056 (TP) + 0.002 (Ic)	R ² = 0.92
T2	Y= 1.49 -0.0223 (E) + 0.75 (SOC) + 0.062 (TP) + 0.028 (Ic)	R ² = 0.94
T3	Y= 2.29 -0.0048 (E) + 0.78 (SOC) + 0.066 (TP) + 0.032 (Ic)	R ² = 0.91
T4	Y= 2.49 -0.0035 (E) + 0.82 (SOC) + 0.071 (TP) + 0.042 (Ic)	R ² = 0.97
<i>Wheat</i>		
T1	Y= 0.62 -0.0103 (E) + 0.68 (SOC) + 0.066 (TP) + 0.0051 (Ic)	R ² = 0.96
T2	Y= 0.84 -0.0135 (E) + 0.74 (SOC) + 0.069 (TP) + 0.0062 (Ic)	R ² = 0.90
T3	Y= 0.92 -0.0084 (E) + 0.78 (SOC) + 0.073 (TP) + 0.0070 (Ic)	R ² = 0.93
T4	Y= 0.96 -0.0054 (E) + 0.82 (SOC) + 0.078 (TP) + 0.0076 (Ic)	R ² = 0.95

Y, Crop productivity; E, cumulative soil loss; SOC, soil organic carbon; TP, total porosity; Ic, vasic infiltration rate

each unit (mm) increase of soil thickness loss because of soil erosion (Ghosh *et al.* 2012). In hill soils, one should expect decreased water retention because of the preferential removal of clay and silt size particles that occur with erosion. Hill soils are usually shallower and plant roots have less volume to exploit for water and nutrients (Bhattacharyya *et al.* 2009). The average observed loss in productivity in Uttarakhand states was found to be 1.06, 2.78, 5.56, 11.12 and 22.24% for

Table 3 Estimated and observed loss of maize and wheat crop productivity due to erosion by water in soils of Uttarakhand.

Soil erosion class	Soil loss (tonnes/ha/yr)	Estimated loss in productivity (%)	Observed loss in productivity in Uttarakhand state (%)	
			Maize	Wheat
Very slight	<5	Nil	0.48–2.33 (1.06)	0.50–1.35 (0.93)
Slight	5–10 (7.5)	<5 (2.5)	1.85–3.71 (2.78)	0.55–1.71 (1.28)
Moderate	10–20 (15.0)	5–10 (7.5)	3.71–7.41 (5.56)	1.71–3.41 (2.56)
Strong	20–40 (30.0)	10–25 (17.5)	7.41–14.83 (11.12)	3.41–6.83 (5.12)
Severe	>40 (60.0)	25–50 (37.5)	14.83–29.66 (22.24)	6.83–13.65 (10.24)

maize and 0.93, 1.28, 2.56, 5.12 and 10.24 % for wheat in very slight, slight, moderate, strong and severe soil erosion class, respectively (Table 3). It was also observed that crop productivity loss due to erosion is negligible in lower limit (very slight) of potential erosion rates but significant loss incurred below permissible soil loss (slight). The variability of results when determined for higher soil erosion class (moderate to severe), the predicted/estimated potential erosion class overestimated compared to observed crop productivity loss (Table 3). However, validation of these findings requires field investigation for its application in regional and national scale.

SUMMARY

Crop productivity loss due to soil erosion by water plays an important role in degrading soil health and economic loss to the farmers. The multiple regression methodology used for determination of soil erosion-productivity relationship is quite reliable and may be utilized to find out erosion – productivity relationship. The results indicated that maize and wheat yield is declined due to soil erosion not only below the soil loss tolerance level but also below the lower limit (very slight) of potential erosion rates. For moderate to severe erosion class, the predicted potential erosion rate overestimated compared to observed productivity loss. The results of this study are useful in estimating the economic loss of crop productivity due to soil erosion and would be helpful in determining crop productivity loss due to soil erosion for other crops of this region.

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