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Soil Erodibility in Relation to Poplar Based Agro-forestry System in North Western India

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ABSTRACT

Agro-forestry is generally practiced for checking soil erosion, land reclamation and increased productivity. At the same time it adds sufficient biomass into the soil, which has been shown to improve the physical as well as chemical fertility thereby reducing the erodibility of soil. A study was carried out to evaluate the effect of poplar-based agro-forestry on soil erodibility in relation to tree age under different textured soils. The surface and subsurface soil samples were collected from agro-forestry and adjoining non-agro-forestry sites with different years of poplar plantation (1, 3 & 6 years) and varying soil textures (loamy sand, loam & sandy clay). The dispersion ratio, erosion ratio and WSA > 0.5 mm increased with the increasing age of the poplar trees. The decrease was maximum in loamy sand followed by loam and minimum is sandy clay soils.

Key Words: Agro-forestry; Soil erodibility; Poplar; Soil texture

INTRODUCTION

Soil erosion by water is a hazard traditionally found to cause long-term adverse effects on agriculture by depleting soil's productive potential and diminishing the resource base. The Shivalik foothills belt in the north-western India suffers from severe soil erosion by water due to steep slopes, heavy rainstorms, sparse vegetation and highly erodible soils. Spot studies in the area (Kukal & Sur, 1992) indicate that about 25, 27 and 48% of land is suffering from high, severe and moderate erosion hazard, respectively. Soil erodibility, an inherent tendency of soils to get eroded at different rates due to differences in soils themselves, plays a major role in determining the extent of soil erosion in addition to other land and vegetation parameters in the region (Kukal *et al.,* 1991). It plays a major role in erosion prediction and land use planning. Soils with high erodibility need more intensive conservation practices than those with low erodibility. Also with increasing population pressure on agricultural lands, it may become necessary in near future to cultivate marginal lands that are highly erodible.

Agro-forestry, growing of multipurpose trees along with agricultural crops and rearing of animals has been an important soil conservation practice. Agro-forestry systems are believed to increase or at least maintain the organic matter level of soils (Young, 1989) mainly through litter-fall. Erodibility of soils, affected by the organic matter content of soils, needs to be studied in relation to agro-forestry at different ages. Poplar has proved to be the most promising species under agro-forestry systems in the region. Studies (Rasool, 1996) have shown that approximately 3.0 - 4.1 t ha^{-1} of litter fall is added to the soil in a poplar (*Populus deltoids* Bartr.) based agro-forestry system from second to fifth year of plantation. It benefits the farmers both economically (Chaturvedi, 1981) and from soil physical fertility point of view. Poplar has been reported to play a significant role in improving the soil physical environment following the loss of topsoil from an erosion event (Escobar *et al.,* 2002). However, very little information is available in the region regarding the effect of poplar based agro-forestry system on erodibility of the soils. Keeping this in mind, the present study was planned to study the effect of poplar tree age on soil erodibility under different textured soils.

MATERIALS AND METHODS

The present study was carried out on farmer's fields in a poplar-based agro-forestry plantation in central and submontane Punjab. The study site in central Punjab is situated between 30° 54'N latitude and 75° 40' E longitude along river Sutlej, at an altitude of 244 m above mean sea level. The study site in submontane Punjab is situated between 30° 40' to 32° 30'N latitude and 75° 30' to 76° 48' E longitude in district Nawanshahr. The soils of submontane Punjab in general are highly erodible. About 68% of the soils have erodibility values greater than 0.4 and of these, 6% soils have the values greater than 0.6 (Kukal *et al.,* 1991). The soil samples were collected from agro-forestry system comprising of poplar (*Populus deltoids* Bartr.) with wheat crop, being commonly practiced in the state. One, three and six years old poplar plantation with row-to-row distance of 6.5 m and plant-to-plant distance of 4.3 m under agri-siliviculture system were selected from the sites having similar soil texture (loamy sand). The surface (0 - 15 cm) and subsurface (15 - 30 cm) soil samples were collected from 3 - 4 places within each agro-forestry and adjoining non-agro-forestry sites and analysed in the laboratory. Similarly, surface and subsurface soil samples were collected from fields with three years plantation in soils varying from loamy sand to loam to sandy clay. The soil samples were also collected from the adjoining non-agro forestry sites. These samples were analysed in the laboratory. The loam soil was located in submontane Punjab and rest were located in central Punjab region (Table I).

Soil texture was determined by using International Pipette method. Dispersion ratio was determined as the ratio of % silt plus clay in un-dispersed soil to % silt plus clay in dispersed soil. Erosion ratio was calculated as ratio of dispersion ratio to % clay to the moisture equivalent. The index water stable aggregates (WSA) > 0.5 mm, was determined using Yoder's wet sieving technique.

RESULTS AND DISCUSSION

The erodibility indices viz. dispersion ratio, erosion ratio and WSA > 0.5 mm of surface (0 - 15 cm) and subsurface (15 - 30 cm) soils under poplar trees for different ages is presented in Table II. The average value of dispersion ratio was 76.5% lower in soils under agro-forestry than in control. Dispersion ratio indicates the ease with which the silt and clay particles go into suspension. This depends on the stability of aggregates, which is a function of organic matter content of soils, resulting in reduced soil erosion. McDonald *et al.* (2002) reported that agro-forestry caused a seven-fold decrease in surface runoff and 21-fold decrease in soil erosion than in control soils. The dispersion ratio decreased with increase in the age of the trees. The dispersion ratio of soils under the trees of one-year age was 1.9 and 6.0 times higher than in the soils under 3 and 6 years plantation, respectively. It could be due to increase in organic matter with age of tree. Pandey *et al.* (1995) reported that with increase in organic matter content the soil erosion decreased. The age of tree and land use interacted significantly for dispersion ratio of the surface soils. The dispersion ratio was 58.2, 78.2 and 93% lower in 1, 3 and 6 years of poplar plantation, respectively than in case of sole crop. The average value of erosion ratio was 77% lower in soils under agro-forestry than in control soils. With the increase in tree age the erosion ratio decreased, but the difference was non-significant. The interactive effect of agro-forestry and land use was also significant. The average value of WSA > 0.5 mm was significantly higher (19.8 times) in soils under agro-forestry than in the control soils. Yadav and Banerjee (1968) reported higher WSA of soils under Eucalyptus than in control soils. The WSA > 0.5 mm of 0 - 15 cm soil layer increased with increase in the age of the trees. Under the trees of 3 years age, it was 1.8 times higher than in the soils under 1 year plantation. With further increase in tree age to 6 years it resulted in 3.6 times higher WSA > 0.5 mm. The WSA > 0.5 mm under poplar based agro-forestry was 10.5, 14.9 and 33.3 times higher in 1, 3 and 6 years of plantation, respectively than in case of sole crop.

The dispersion ratio, erosion ratio and WSA > 0.5 mm in surface (0 - 15 cm) and subsurface (15 - 30 cm) soils under poplar trees is presented in Table III. The average value of dispersion ratio in subsurface soils was 30.5% lower in soils under agro-forestry than in control soils. As in surface layers, the dispersion ratio in subsurface layers decreased with increase in tree ages. It was 16.97 and 54.5% lower in 3 and 6 years, respectively than in case of one year plantation. Lee *et al.* (2000) reported that organic matter helps in reducing soil erosion. The interactive effect of land use and tree age was significant for dispersion ratio of subsurface layers. The dispersion ratio of subsurface layers was higher than in surface layers. It could be due to addition of leaf biomass under agro-forestry in the surface layers. The average value of erosion ratio in subsurface soils was 33.1% lower in soils under agro-forestry than in control soils. As in surface layer, with increase in tree age the difference was non-significant. The interactive effect of land use and agro-forestry was also non-significant. However, the reduction in the soil erodibility based on erosion ratio was more in surface layer than in subsurface layer. The effect of agro-forestry on clay ratio was non-significant in subsurface soils. The WSA > 0.5 mm in subsurface soils under poplar-based agro-forestry was 14.9 times higher than in non-agro forestry soils. As in surface layers, the WSA > 0.5 mm in subsurface layers increased with increase in tree age. It increased by 2.6 and 4.5 times with increase in tree age from 1 to 3 and 6 years, respectively. The WSA > 0.5 mm was 6.5, 11.2 and 28.8 times higher in 1, 3 and 6 years of poplar plantation, respectively than in case of sole crop. Contractor and Badanur (1996) reported that WSA > 0.25 mm under *Tectona grandis* were 22.4% higher than in control soils.

The average value of dispersion ratio was 74% lower in soils under agro-forestry than in control soils (Table III). The dispersion ratio of soils under sole crop was maximum (15.44) in loamy sand, followed by 8.30 in loam and 6.28 in sandy clay soil. Similar trend was there in soils under agro-forestry except that the magnitude of the values was less. The average value of erosion ratio was 75.8% lower in soils under agro-forestry than in control soils. It could be due to higher organic matter in soils under agro-forestry than in control soils. Chaudhary *et al.* (1999) reported that forest soils were less erodible than control soils due to high organic carbon. The erosion ratio of 0 - 15 cm soil layer under sole crop was maximum in loamy sand (52.7) followed by loam (7.75) and minimum (3.04) in sandy clay. This again shows the dependence of erosion ratio on the clay content of the soil. The erosion ratio decreased by 94% with increase in clay content from 7 to 35%. Narain *et al.* (1994) reported that soil loss in sandy loam under agro-forestry was 19.45 times less than in control soil.

The average value of WSA > 0.5mm was significantly higher (2.94 times) in soils under agro-forestry than in

Table I. General soil and site characteristics of the study areas

Properties	Central Punjab	Submontane Punjab
Rainfall, mm	750	1100
Temperature, °C		
Maximum	39.5	39.1
Minimum	7.3	5.2
Organic carbon	High	Low
Total N, kg ha^{-1}	218-222	272
Available P, kg ha^{-1}	17	5-20
Available K, kg ha^{-1}	123-139	118-280

Table II. Agro-forestry effects on soil erodibility in relation to tree age

Land use	Tree age, years							
	Surface soil (0-15 cm)				Subsurface soil (15-30 cm)			
	1	3	6	Mean	1	3	6	Mean
Dispersion ratio								
Agro-forestry	6.5	3.4	1.1	3.6	12.6	10.8	8.2	10.5
Non-agroforestry	15.5	15.4	15.4	15.4	15.1	14.8	15.6	15.1
LSD (0.05)								
Land use (LU)	0.97				0.84			
Tree age (TA)	1.2				1.03			
LU x TA	1.68				1.46			
Erosion ratio								
Agro-forestry	21.1	11.6	4.3	12.3	28.1	31.5	29.4	29.6
Non-agroforestry	51.0	59.6	49.8	53.5	37.2	39.6	36.3	37.7
LSD (0.05)								
Land use (LU)	15.2				10.4			
Tree age (TA)	NS				NS			
LU x TA	NS				NS			
WSA > 0.5 mm								
Agro-forestry	5.6	10.3	20.3	12.1	2.8	7.3	12.7	7.6
Non-agroforestry	0.53	0.69	0.61	0.61	0.43	0.65	0.44	0.51
LSD (0.05)								
Land use (LU)	0.87				0.55			
Tree age (TA)	1.1				0.67			
LU x TA	1.5				0.95			

Table III. Agro-forestry effects on soil erodibility in different textured soils

Land use	Surface soil (0-15 cm)				Subsurface soil (15-30 cm)			
	ls	l	sa cl	Mean	ls	l	sa cl	Mean
Dispersion ratio								
Agro-forestry	3.4	2.4	2.1	2.6	11.0	4.5	4.7	6.7
Non-agroforestry	15.4	8.3	6.3	10.0	14.8	8.2	6.9	10.0
LSD (0.05)								
Land use (LU)	0.66				1.08			
Texture (T)	0.81				1.32			
LU x T	1.14				NS			
Erosion ratio								
Agro-forestry	11.6	2.5	1.2	5.1	30.0	5.1	2.3	12.5
Non-agroforestry	52.7	7.8	3.0	21.0	34.2	8.4	3.2	15.2
LSD (0.05)								
Land use (LU)	11.6				NS			
Texture (T)	14.2				10.1			
LU x T	21.1				NS			
WSA > 0.5 mm								
Agro-forestry	10.6	2.0	11.1	7.9	8.0	5.0	7.0	6.7
Non-agroforestry	2.0	0.51	5.6	2.69	0.57	0.16	2.0	0.92
LSD (0.05)								
Land use (LU)	1.82				1.13			
Texture (T)	2.22				1.39			
LU x T	3.15				NS			

control soils. The WSA > 0.5 mm in 0 - 15 cm soil layer was maximum in sandy clay, followed by loamy sand and loam soils both in agro-forestry and sole crop. The soil texture and land use interacted significantly for WSA > 0.5 mm of the surface soils. The WSA > 0.5 mm under poplar based agro-forestry and 5.38, 3.8 and 1.99 times higher in loamy sand, loam and sandy clay soils, respectively than in case of sole crop.

The average value of dispersion ratio in subsurface soils was 32.5% lower in soils under agro-forestry than in control soils. As in surface layers the dispersion ratio followed the same trend in different soils. The texture of soil and land use did not interact significantly for dispersion ratio of subsurface soils. The average value of erosion ratio in subsurface soils was non-significantly higher in soils under control than in agro-forestry. The WSA > 0.5 mm in surface soils under poplar based agro-forestry behaved similarly as in surface soils. However, the magnitude of values was less in subsurface soil. It could be due to lower organic matter in the subsurface soil layers.

REFERENCES

Chaturvedi, A.N., 1981. *Popular Farming in UP.* Forest Bull No. 85

Chaudhary, R.S., H. Gradekar and U.S. Patnaik, 1999. Erodibility under different land uses in soils of eastern ghat high land zone. *Indian J. Soil Cons.*, 27: 118–21

Contractor, R.M. and V.P. Badanur, 1996. Effect of forest vegetation on properties of a vertisol. *J. Indian Soc. Soil Sci.*, 44: 510–1

Escobar, A.G., P.D. Kemp, A.D. Mackay and J. Hodgson, 2002. Soil properties of a widely spaced, planted poplar (*Populus deltoids)* pasture system in a hill environment. *Australian J. Soil Res.*, 40: 873–86

Kukal, S.S. and H.S. Sur, 1992. Soil erosion hazards in the foothills of lower Shivaliks. *J. Indian Soc. Soil Sci.*, 40: 162–7

Kukal, S.S., H.S. Sur and S.S. Gill, 1991. Factors responsible for soil erosion hazard in submontane Punjab. *Soil Use Mgmt.*, 7: 38–44

Lee, K.H., T.M. Insenhart, R.C. Schultg and S.K. Mickelson, 2000. Multispecies riparian buffers trap sediment and nutrients during rainfall simulation. *J. Environ. Quality*, 29: 1200–5

McDonald, M.A., J.R. Healey and P.A. Stevens, 2002. The effects of secondary forest clearance and subsequent land use on erosion losses and soil properties in the Blue mountains of Jamaica. *Agric. Ecosyst. Environ.*, 92: 1–9

Narain, P., R.S. Chaudhary and R.K. Singh, 1994. Efficacy of conservation measure in north-eastern hilly regions. *J. Soil Cons.*, 22: 42–62

Pandey, A.N., R.C. Purohit and M.V. Rokand, 1995. Soil aggregates and stabilization of sand dunes in the Thar desert of India. *Environ. Conser.*, 22: 69–71

Rasool, A., 1996. Leaf litter decomposition and nutrient release from populus deltoids plantation in Agri-silivicultural system in Punjab. *M.Sc Thesis*, Punjab Agricultural University, Ludhiana, India

Yadav, J.S.P. and S.P. Banerjee, 1968. Water stable aggregates in a forest soil of West Dehra Dun division. *J. Indian Soc. Soil Sci.*, 16: 31–5

Young, A., 1989. *Agro-forestry for Soil Conservation,* P: 276. CAB International ICRAF

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