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Soil organic carbon content and nutrient status in temperate agroforestry systems of Kashmir Himalaya

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Abstract
The study was carried out to assess the soil nutrient status in four prominent agroforestry systems *viz.*, home gardens, horti-agriculture, boundary plantation and horti-silvi-pasture in temperate conditions of Kashmir Himalaya. Home garden was the most prominent system being adopted by farmers (98.43% of the total farmers surveyed). All the four agroforestry systems showed significantly higher values of available N, P, K and OC contents. However, home garden system had maximum nutrient (available N: 337.0, available P: 42.02 and available K: 289.38 kgha^{-1}) and soil organic carbon content (1.57%) due to multi-strata canopy systems. Thus all the studied tree based land use systems at temperate zones were found as sustainable because of efficient nutrient cycling and played an important role in carbon mitigation.

Keywords: Agroforestry systems, Carbon mitigation, Nutrient status, Soil, Temperate zones

The term nutrient cycling, used in most agroforestry systems refer to the continuous transmission of nutrients within a soil-plant system (Nair, 1993; Nair *et al.,* 1995; Buresh and Tian, 1997). Plants absorb and use nutrients from the soil for metabolic processes. In turn, plants naturally return nutrients to the soil as litter falls into the unmanaged systems, deliberately as pruning in some agroforestry systems or through senescence in both managed and unmanaged systems. These plant parts are decomposed by micro-organisms of the soil, which release the nutrients in the soil, thus nutrients become available for plant consumption. In a broader sense, nutrient cycling involves the continuous transfer of nutrients within and between different ecosystem components and includes processes such as mineral weathering, activities of soil biota and other transformations occurring in biosphere, lithosphere and hydrosphere (Jordan, 1985). Nutrients in the component of the soil contribute to the pool of soil nutrients. Water can remove nutrients from the soil nutrient pool with the nutrient loss level determined by the percolating water flow rate and soil properties. Nutrients such as nitrates, which are readily dissolved in water and weakly held by the soil matrix, are more likely to be leached than other nutrients, such as phosphates, which have very low solubility and mobility in soils. Tree litter fall is one of the main routes in carbon and nutrient cycles that connect above and below the soil (Vitousek and Sanford, 1986). Litter fall has been well studied over the last few decades as an important and uniform source of nutrients and organic matter (Vitousek, 1984; Meier *et al.,* 2005; Carnol and Bazgir, 2013). However, litter fall varies considerably between ecosystems, depending on the climate, the structure of tree species and soil fertility (Vitousek and Sanford, 1986).

Natural forest ecosystems in tropics are self-sufficient with efficient cycling of nutrients. These are closed nutrient cycling systems with relatively low loss or gain of active cycling nutrients and higher rates of nutrients. Most agricultural systems, however, represent open or leaky systems with a relatively high loss of nutrients. Cycling of nutrients in agroforestry falls between these extremes (Nair *et al.,* 1995). However, there is paucity of information on traditional agroforestry systems of Kashmir. Hence, the present study was conducted to assess the soil nutrient status in four different agroforestry systems *viz.*, home gardens, horti-agriculture, boundary plantation and horti-silvi-pasture in the temperate conditions of Kashmir Himalaya.

The study was carried out at Gandebal district of Jammu and Kashmir during the year 2015-2016. It was located between 34° 12' 59'' N latitude and 74°46' 18'' E longitude at an altitude between 1600 to 3000 m above mean sea level. Its borders is bound with district Baramulla in the West, district Srinagar in the South, newly created district

Bandipora in the North-West and district Kargil in the East. The soil of district Ganderbal varies from silt clay loam to clay loam. The climate is temperate type with the upper areas receives heavy snowfall during winter. Average annual precipitation was 1753.9 and 991.5 during the year 2015 and 2016, respectively.

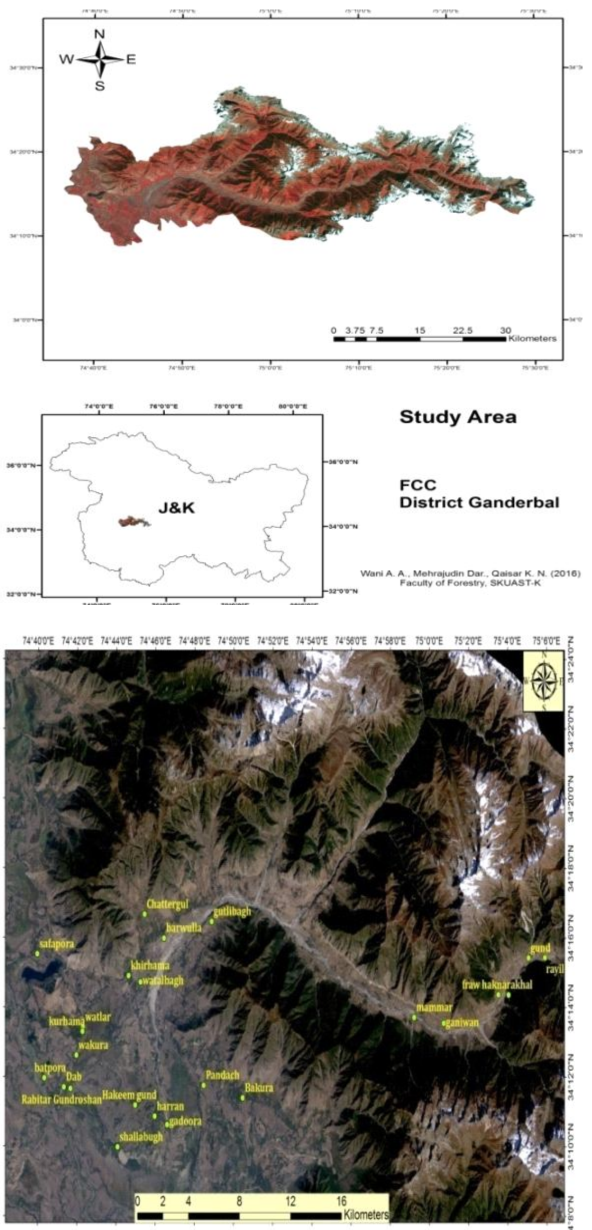

Fig 1. False colour composite (FCC) and map of sampled villages of district Ganderbal, Kashmir

The study was based on field survey of four prominent agroforestry systems *viz.*, home gardens, horti-agriculture, boundary plantation and horti-silvi-pasture in selected representative areas of the temperate conditions of Kashmir Himalaya (Table 1). Adoption and practice of these agroforestry systems depended on the edapho-climatic condition, socioeconomic status and needs of peasants. These attributes lead to variation in the structure and composition of recommended technologies and existing agrarianism. Soil sampling (for available N, P, K and OC content) was carried out during mid-May, mid-July, mid September, and mid November, respectively. Soil samples were collected randomly from six villages (Bakura, Wakura, Hakeem gund, Akhal, Watlar and Gund) at two depths *i.e.*, 0-30 and 30-60 cm in each system. Each sample was then thoroughly mixed, air dried, grinded with pestle and mortar, sieved through a 2 mm mesh screen. The sieved soil samples were stored in paper bags for chemical analysis. Organic carbon was determined by Walkley Black rapid titration method (Jackson, 1958), while available nitrogen by alkaline permanganate method (Subbiah and Asija, 1956) and available phosphorous by Olsen's method (Olsen *et al.,* 1954). But potassium was determined by flame photometry after extraction with neutral normal ammonium acetate (Jackson, 1973). The data was subjected to statistical analysis following the standard methods (Snedecor and Cochran, 1968).

Nitrogen is an important factor in soil fertility, plant strata and therefore, it is necessary to manage the delicate balance between nitrogen (N) supply and crop demand in order to achieve economic profitability and environmental protection objectives (Zebarth *et al.*, 2009).The available nitrogen content was declined with the increase in depth in all the agroforestry systems studied. The maximum available nitrogen content was recorded in home gardens (349.8 kg ha^{-1}) at D_1 and (295.2 kg ha^{-1}) at D_2, while minimum in boundary plantation (309.0 kga^{-1}) at depth D_1 and (260.3 kg ha^{-1}) at D_2 (Table 2). Further maximum nitrogen content was recorded in autumn, whereas its minimum value was recorded in early spring in the all four land use systems which could be attributed to increased requirement of energy and nutrients by microbes and new root system under the influence of increased moisture regime and temperature of the soil. Higher available nitrogen in home garden and horti-silvi-pastoral system than boundary plantation might be due to the increasing level of soil exploitation, intensive farming, soil erosion, organic matter mineralization in the leaf litter (Haag and Kaupenjoham, 2001). Curtin and Campbell (2008) reported that organic matter, crop residues and organic amendments plus residual soil mineral N from the previous growing season are also important sources of nitrogen supply. Cassman and Munns (1980) indicated that surface soil was responsible for a considerable part of mineral N release, however, deeper soil layers could not be ignored because of their potential contribution to net soil N mineralization.

During the month of May, the concentrations of soil N and other nutrients were lower in prominent agroforestry systems, but the concentration of these nutrients gradually increased in the months of July, September and November. Indeed, microbial population present in the soil, soil temperature and moisture regime played an important role in the temporal increase of soil nutrients (Ravlna *et al.,* 1995; Hoskinson *et al.,* 1999). Reynolds *et al*. (2000) reported that the availability of nutrients decreased with decrease in temperature.

The available phosphorus level varied in all the four prominent agroforestry systems. In our findings home gardens recorded higher available phosphorus, while it was lower in boundary plantation (Table 3). This might be due to dense finer root, rapid microbial activity, higher proportion of leaf litter and the effect of plant root on soil and phosphorus availability (Yitbarek *et al*., 2013). The lower concentration of available phosphorus in higher soil depth D_2 when compared to D_1 in all prominent land use systems could be attributed to surface enrichment due to the litter production and decomposition in tree-based production systems (Starr *et al*., 2005).

The available potassium level also varied in four prominent agroforestry systems. The maximum available potassium (305.2 kg ha^{-1}) was recorded in the home garden and the minimum potassium level (256.6 kg ha^{-1}) was recorded in boundary plantation (Table 4). Higher available potassium in home garden or other agroforestry systems was probably due to nutrient rich litters of trees which contributed to substantial amount of potassium returned back to the soil (Puri *et al.,* 1994; Saha *et al.*, 1999; Lin and Kao., 2001) and relatively higher pumping of potassium from the sub-soil by vegetation (Moges *et*

Table 1. Details of most prominent agroforestry systems selected for the study

Agroforestry system	No. of farmers adopted*	Tree	Fruit	Crop components	
				Rabi	***Kharif***
Home gardens	189 (98.43%)	Poplar, Salix	Apple, Pear	Turnip, Radish, Kale	Chilli, Beans, Kale
Horti-agriculture	117 (60.93%)	-	Apple	Turnip, Radish, Kale	Beans, Knol-khol, Kale
Boundary plantation	67 (34.89%)	Poplar,Salix	-	Oats/ Mustard	Paddy
Horti-silvi-pasture	46 (23.95%)	Poplar,Salix	Apple	*Trifolium repens* (white clover), *Polygonium hydropiper* (water pepper), *Trifolium pretense* (red clover), *Aegilops tauschii* (Tausch's goat grass), *Amaranthus spinosus* (spiny amaranth), *Echinochloa crus-galli* (cockspur grass), *Lolium perenne* (rye grass), *Bromus japonicas* (Japanese brome), *Clinopodium umbrosum* (shady calamint), *Chenopodium album* (pig weed) and *Avena sativa* (wild oats)	

*Out of total 192 farmers surveyed

Table 2. Status of available nitrogen (kg ha^{-1}) under prominent agroforestry systems (pooled data of 2015- 2016)

Month	Home gardens			Horti-agri system			Boundary plantation			Horti-silvi-pastoral system		
	Soil depth		Mean depth	Soil depth		Mean depth	Soil depth		Mean depth	Soil depth		Mean depth
	D_1	D_2		D_1	D_2		D_1	D_2		D_1	D_2	
M_1	329.5	273.7	301.6	302.4	242.4	272.44	293.3	239.3	266.28	318.6	267.5	293.1
M_2	347.3	292.2	319.8	317.0	259.8	288.38	305.0	265.2	285.10	332.0	281.5	306.3
M_3	358.2	305.7	332.2	323.1	267.5	295.28	317.7	275.6	296.64	341.5	288.6	315.1
M_4	364.4	309.5	337.0	326.4	271.8	299.10	320.2	279.7	299.95	346.2	293.3	320.3
Mean	349.8	295.2		317.4	260.4		309.0	264.3		334.6	282.7	
CD(P < 0.05)												
M		30.06			12.28			13.88				11.16
D		21.24			8.68			9.82				7.88
M × D		42.5			17.36			19.62				15.78

Soil depth: D_1 = 0-30 cm, D_2 = 30-60 cm; Month: M_1 = May, M_2 = July, M_3 = September, M_4= November al., 2013), besides variation in cropping pattern (Annapurna *et al.,* 2017). The available potassium followed the same trend as of nitrogen and phosphorus. This was probably due to higher microbial activities with recycling of nutrients through leaf litters and more favou--rable physical conditions *viz.,* better soil moisture and temperature under the trees (Qaisar *et al.,* 2007; Vanlalhluba and Sahoo, 2010). Semwal *et al.* (2009) also observed maximum available phosphorus in winter season, which was due to accumulation of minerals that usually takes place in winter season.

Table 3. Status of available phosphorous (P_2O_5; kg ha^{-1}) under prominent agroforestry systems (pooled data of 2015-2016)

Month	Home gardens			Horti-agri system			Boundary plantation			Horti-silvi-pastoral system		
	Soil depth		Mean depth	Soil depth		Mean depth	Soil depth		Mean depth	Soil depth		Mean depth
	D_1	D_2		D_1	D_2		D_1	D_2		D_1	D_2	
M_1	28.30	18.87	23.58	23.57	15.92	19.74	19.85	13.60	16.72	25.77	16.83	21.30
M_2	37.67	26.03	31.85	29.17	23.40	26.28	26.57	19.93	23.24	33.67	25.23	29.45
M_3	43.47	34.57	39.02	36.53	29.17	32.85	32.49	24.40	28.44	39.53	30.23	34.88
M_4	45.97	38.97	42.02	38.73	32.53	35.63	34.03	27.54	30.78	41.60	33.47	37.53
Mean	38.85	29.38		32.00	25.26		28.23	21.36		35.14	26.44	
CD (P<0.05)												
M		5.66			4.04			7.84			5.54	
D		4.00			2.86			5.56			3.39	
M × D		8.02			5.72			11.12			7.84	

Table 4. Status of available potassium (K_2O; kg ha^{-1}) under prominent agroforestry systems (pooled data of 2015-2016)

Month	Home gardens			Horti-agri system			Boundary plantation			Horti-silvi-pastoral system		
	Soil depth		Mean depth	Soil depth		Mean depth	Soil depth		Mean depth	Soil depth		Mean depth
	D_1	D_2		D_1	D_2		D_1	D_2		D_1	D_2	
M_1	289.3	233.5	261.4	257.3	202.5	229.9	239.8	205.5	222.6	265.7	241.3	253.5
M_2	302.4	247.2	274.7	273.4	216.3	244.9	255.1	219.1	237.1	277.1	257.4	267.2
M_3	312.2	256.6	284.4	281.6	222.1	251.8	263.5	223.7	243.6	285.6	266.6	275.8
M_4	317.2	261.7	289.3	286.7	225.1	255.9	268.0	225.8	246.9	289.4	271.3	280.4
Mean	305.2	249.7		274.7	216.5		256.6	218.0		279.3	259.3	
CD (P<0.05)												
M		14.58			8.72			17.16			15.68	
D		10.3			6.18			12.12			11.10	
M × D		20.62			12.34			24.26			22.18	

Table 5. Status of oil organic carbon (OC; %) in prominent agroforestry systems (pooled data of 2015- 2016)

Month	Home gardens			Horti-agri system			Boundary plantation			Horti-silvi-pastoral system		
	Soil depth		Mean depth	Soil depth		Mean depth	Soil depth		Mean depth	Soil depth		Mean depth
	D_1	D_2		D_1	D_2		D_1	D_2		D_1	D_2	
M_1	1.91	0.95	1.43	1.12	0.91	1.01	1.09	0.65	0.87	1.62	1.09	1.36
M_2	1.95	1.06	1.51	1.22	1.07	1.15	1.14	0.69	0.91	1.76	1.18	1.47
M_3	1.99	1.09	1.53	1.32	1.16	1.24	1.19	0.74	0.96	1.82	1.29	1.55
M_4	2.01	1.13	1.57	1.38	1.09	1.30	1.22	0.79	1.00	1.86	1.34	1.60
Mean	1.96	1.05		1.26	1.05		1.16	0.71		1.76	1.22	
CD (P<0.05)												
M		0.10			0.12			0.05			0.12	
D		0.70			0.09			0.04			0.08	
M × D		0.15			0.18			0.08			0.16	

Soil depth: D_1 = 0-30 cm, D_2 = 30-60 cm; Month: M_1 = May, M_2 = July, M_3 = September, M_4= November

The potential of agroforestry systems to increase both above ground and below ground carbon stock is an important tool for mitigation of climate change (Bangroo *et al*., 2013; Cardineal *et al*., 2015; Chaturvedi *et al*., 2016). Soil organic carbon (SOC) content was significantly influenced due to change in agroforestry systems as well as increase in soil depth (Table 5). Maximum organic carbon (1.96%) was found in home garden and minimum (1.16%) in boundary plantation. The increased organic carbon content in soils under home garden might be ascribed to more leaf litter, root turnover from trees, crops and organic waste deposition (Zegeye, 1999). The enrichment in SOC under tree-based systems could be due to several factors such as addition of litter, annual fine root biomass recycling, root exudates and reduced oxidation of organic matter under tree shade (Singh *et al*., 1989). Lower organic carbon content in boundary plantation was also reported by Cihacek and Ulmer (1998) and Pal *et al.* (2013) earlier. The higher organic carbon in home garden and horti-silvi-pastoral system was also attributed to increased accumulation followed by decomposition under tree based land use system.

Further organic carbon in soil under different agroforestry systems was minimum in the month of May. It increased throughout the season and it was maximum in November. The turn-over of carbon in soil is controlled mainly by water regime and temperature. Lower organic carbon content in soil in late spring and early summer might be due to increased requirement of energy and nutrients by microbes and new root systems developing under the influence of increased moisture regime and temperature of the soil. The increase in organic carbon towards the end of the growing season might be attributed to slower rate of decomposition. High rates of decomposition during growth season results in decrease in organic carbon concentration of soil. The present findings corroborated with the earlier findings of Raich (1983), who recorded lowest soil organic carbon in summer, which was ascribed to higher soil temperature. Further in the present study organic carbon showed decreasing trend with respect to depth. Similar findings were also documented in earlier studies (Wells *et al.,* 2013; Sinoga *et al.,* 2012; Lawrence *et al.,* 2015).

It was concluded that all four prominent agroforestry systems *viz.,* home gardens, horti-agriculture, boundary plantation and horti-silvi-pasture system showed significantly higher values of available N, P, K and OC content. Although maximum nitrogen (337.0 kg ha^{-1}), phosphorus (42.02 kg ha^{-1}), potassium (289.3 kg ha^{-1}) and organic carbon contents (1.57%) were recorded in home garden due to multi-strata canopy systems. Thus the prominent tree based land use systems of temperate zone were found sustainable because of efficient nutrient cycling and these are playing an important role in carbon dioxide mitigation.

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