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Variation in soil properties under different land uses and attitudinal gradients in soils of the Indian Himalayas

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ABSTRACT

We studied the interaction effects of 8-different land uses systems viz., forestry (T_1), silvopastoral (T_2), horticulture (T_3), agrihorticulture (T_4), agrisilviculture (T_5), agrihortisilviculture (T_6) > grassland (T_7) and agriculture (T_8) in 2-altitudinal gradient for three consecutive soil layers of up to 1 m deep from sub-montane to low hill sub-tropical zone of Western Himalayas in Himachal Pradesh State of India. All the land uses under agroforestry practices viz., agrisilviculture, silvopastoral, agrihorticulture and agrihortisilviculture showed significantly enhanced values of pH, organic carbon (OC %), available N, P, K and exchangeable Ca, Mg and available S than agriculture land use. A maximum value of soil carbon (1.08%) was observed in forest land use followed by silvopastoral, horticulture, agrihorticulture, agrisilviculture, agrihortisilviculture, grassland and agriculture, respectively. Overall highest values of available N, P and K were observed under forest land use and silvopastoral among agroforestry systems. Available N, P, and K declined with increasing altitude. Exchangeable Mg followed the trend $T_7 > T_2 > T_5 > T_1 > T_6 > T_3 > T_4 > T_8$ and available Sulphur as $T_7 > T_3 > T_2 > T_6 > T_5 > T_4 > T_8 > T_1$, respectively. The value of exchangeable Ca and available S increased with increasing altitude. From the study it can be concluded that tree based land use systems of subtropical zone of the Himalayan region are more sustainable and environment friendly than agriculture and grassland use systems. Hence, they need to be conserved and promoted on large scale. The outcome of this paper will be helpful in convincing the farmers for adoptions of agroforestry practices in large scale.

1. Introduction

Climate and parent material have been considered as factors of soil conditions on global scale [1] and agroforestry systems have long been considered viable alternatives to degrading land uses [2]. Soil quality under agroforestry systems is more similar to that under natural vegetation than under traditional or intensive agricultural systems [3–5]. The difficulty is compounded by the fact that carbon sequestered in agroforestry systems varies with a number of site- and system-specific characteristics, including climate, soil type, tree planting densities, and tree management. Nevertheless the IPCC Report [6] estimates the area currently under agroforestry worldwide as 400 million hectares with an estimated C gain of 0.72 Mg C ha yr^{-1}, with potential for sequestering 26 Tg C yr^{-1} by 2010 and 45 Tg C yr^{-1} by 2040 1 Tg = 1012 g or 1 million tons. There is robust evidence that agroforestry systems have the potential for improving water use efficiency by reducing the unproductive components of the water balance (run-off, soil evaporation and drainage) [7]. Integration of persistent perennial species with traditional agriculture also provides satisfactory drainage control to ameliorate existing outbreaks of salinity [8].

Total Organic Carbon (TOC) and Bulk Density (BD) have been used as soil quality indicators, as physical degradation of some soils is commonly related to organic matter reduction and increase in BD [9]. Total organic carbon (TOC) and soil bulk density (BD) reflect the effects of conservative management [10]. The capacity of soil to sustain biological productivity sometimes referred to as soil quality, can be estimated by the evaluation of physical, chemical and biological parameters [11]. Ecosystem functionality have been given high priority as indicators of soil quality, but no consensus has been reached about their exact nature or number [11].The evaluation of soil parameters for organic carbon and nutrient dynamics of different landuse systems in montane to tropical zone of Indian Himalaya has a particular importance in relation to the soil carbon stock storage and its impact on climate change in mountain ecosystems. Although the agroforestry systems are well known for improving the soil quality but hitherto no scientific study has been carried out to quantify the role of different types of the agroforestry systems vis-à-vis agriculture, grassland and forest as standard in the subtropical parts of the Himachal's Himalaya. In this context, the objective of this study was to quantify the variation in soil properties under different land uses and attitudinal gradients in soils of the Indian Himalayas.

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2. Materials and methods

2.1. Study area

The present study was carried out in sub-montane and low hill sub-tropical zone of Himachal Pradesh, India. This zone covers an area of 55,673 km^2 spreading over seven districts viz., Kangra, Chamba, Hamirpur, Una, Bilaspur, Solan and Sirmaur and is located between 32° 50′ to 30° 22′N latitude to 76° 18′ to 77° 47′ E longitude with altitudinal range of 365 to 914 m above sea level. For selection of sites three districts were randomly selected at two different altitudes (A_1) 365–635 and (A_2) 636–914 m a.s.l. At each altitudinal range three representative sites were selected in such a manner that they have all, selected land use systems like agriculture, horticulture, agri-silvicultural, silvopastoral, agrihorticulture, agrihortisilviculture, forest and grass land, having symbol of T_1, T_2, T_3, T_4, T_5, T_6, T_7 and $T_{8,}$ respectively in this manuscript. Different landuse systems and altitudinal gradients were having different crop interactions and combinations (Table 1).This zone is subjected to three extreme climatic conditions i.e., high temperature in summers (18–35 °C), very low of winter (5–21 °C) and heavy rainfall during rainy season. The average annual rainfall varies from 1400 to 1800 mm and almost 80% of which is concentrated during July–August. The dominant soil texture is sandy loam to clay loam and soil pH is 6.3–6.6.

3. Methodology

3.1. Collection and preparation of soil samples

Soil samples were collected from each land use system at three different depths up to 1 m (0–20 cm, 20–40 cm and 40–100 cm) by using post hole and screw auger. Composite soil samples for different depths for all land uses were prepared. Collected samples were air dried in shade, grinded with wooden pestle, passed through 2 mm sieve and stored in cloth bags for further laboratory analysis. Random block design (factorial) was followed with three numbers of replications for collection of soil samples.

$$\text{No.of treatments combination} : 48\ \{8\ (\text{land use systems}) \times 2\ (\text{altitudinal ranges}) \times 3\ (\text{Soil layers})\}$$

Bulk density and pore space was determined by core sampler. Soil pH was determined by using pH meter [12], organic carbon by wet combustion method [13] and cation exchange capacity by centrifuge method using flame photometer. Available nitrogen was estimated by alkaline potassium permanganate method [14] using kjeldahl distillation unit. Available Phosphorus was analysed by method adopted from [15] using Specrtronnic 20 D$^+$. Potassium, exchangeable Calcium, Magnesium were estimated by Neutral 1 N ammonium acetate solution method [16] using flame photometer. Available Sulphur was determined by 0.15% $CaCl_2$ extracting method [17] using Spectronnic 20 D$^+$. The data was subjected to statistical analysis by [18] and soil analysis and data interpretation was done using the package “STATISTICS”.

4. Results and discussion

4.1. Soil physical properties

4.1.1. Bulk density and soil porosity

Maximum (1.211 g cm^{-3}) and minimum (0.962 g cm^{-3}) value of bulk density were observed in agriculture ($P = 0.00$; F = 17.90; Degree of freedom = 7) and forestry land use, which were found to be significantly different from others agroforestry land use systems (Table 2). Little variation in bulk density was observed among various agroforestry

Table 1
Experimental details indicating specific tree-crop combinations and their distribution underland use systems of sub-montane and low hills sub-tropical Zone-I of Himachal Pradesh.

Land use systems/elevation ranges	Code	Tree-crop combination	Plot size (m)	Net cropped area (ha^{-1})	Area under trees (ha^{-1})	Area under grass (ha^{-1})	No. of tree ha^{-1}
Agriculture	T_1						
365–635 m a.s.l		Maize-wheat, black gram-mustard	50 ×	1.00	–	–	–
636–914 m a.s.l		Maize-wheat, paddy-wheat	20	1.00	–	–	–
Horticulture	T_2						
365–635 m a.s.l		Mango, Kinnow	50 ×	–	1.00	–	160, 520
636–914 m a.s.l		Mango	20	–	1.00	–	230
Agrisilviculture	T_3						
365–635 m a.s.l		Popular + toona + maize-barley, toona + sissoo + paddy-wheat	50 ×	0.60	0.40	–	450,180,70
636–914 m a.s.l		Toon + morus + celtis + black gram-wheat, grewia + sissoo + maize–pea	20	0.60	0.40	–	130, 20, 20, 150, 70
Silvopastoral	T_4						
365–635 m a.s.l		Eucalyptus, toona, morus + natural grass	50 ×	–	0.30	0.70	160, 80,40
636–914 m a.s.l		Khair + sissoo + grewia + natural grass	20	–	0.30	0.70	100, 110, 20
Agrihorticulture	T_5						
365–635 m a.s.l		Kinnow + tomato-wheat, kinnow + maize-mustard	50 ×	0.60	0.40	–	230
636–914 m a.s.l		Mango + maize–wheat, mango + tomato-mustard	20	0.60	0.40	–	160
Agrihortisilviculture	T_6						
365–635 m a.s.l		Maize-wheat + kinnow + toona + popular, paddy-wheat + mango + toona, black gram-onion + kinnow + toona	50 × 20	0.40	0.60	–	160,150,220,120
636–914 m a.s.l		Paddy-wheat + mango + eucalyptus, maize-galic + mango + toon		0.40	0.60	–	80, 100, 80
Forest	T_7						
365–635 m a.s.l		*Shorearobusta*, *Albizialebbeck*, *A. procera*, *Termineliaarjuna*, *D. sissoo*, *Toonaciliata*, *Acacia catechu*, *Leucaenaleucocephala.*	50 × 20	–	1.00	–	330
636–914 m a.s.l		*Pinusroxburghii* + *A.catechu*		–	1.00	–	400, 150
Grassland	T_8						
365–635 m a.s.l		Natural Grass	50 ×	–	–	1.00	–
636–914 m a.s.l		Natural Grass	20	–	–	1.00	–

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