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Soil Nutrient study in different agroforestry systems in north western Himalayas

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ABSTRACT

Agroforestry land use, covering 20 per cent of the total geographical area of the Indian Himalaya, is distributed as patches in the matrix of forests covering 52 per cent area. The present study was undertaken at dry temperate high hills (C_1) and High hills temperate dry and cold (C_2) climatic conditions of kinnaur district of Himachal Pradesh. The study focused on nutrient analysis under three different agroforestry systems viz, Agri-horticulture system (AH), Agri-silviculture system (AS) and Agri-horti-silviculture system (AHS)of north-western Himalayas during the year of 2014-15.Some physico-chemical parameters were selected as indicator of soil quality and were investigated in the present study under the selected different land use system. The results revolve that out of 36 soil samples, 10 falls in sandy clay, 17 samples falls in sandy clay loam and 9 samples were categories as clay loam. Organic carbon, extractable phosphorous, calcium, magnesium and chemical properties decreased with an increase in soil depth. *Bulk density (1.34g cm^3) was higher in A Ssystem. Maximum bulk density (1.47 g cm^3) was recorded at 15-30 cm depth whereas minimum bulk density (1.20 g cm^3) observed at 0-15 cm depth. Particle density (2.49 g cm^3) was significantly higher in agri-horticulture system while significantly higher at 0-15 cm depth (2.48 g cm^3). The pore space percent was significantly higher in agri-silviculturesystem (46.99%) and at surface soil (48.90 %). Chemical parameters were found decreasing with increasing of soil depth. Organic carbon was significantly higher in agri-horti-silviculturesystem (1.26%) and at 0-15cm depth in C_2 climatic condition (1.26%). Similarly exchangeable Ca (5.52 mg/100g) was significantly higher in AHS system. and at 0-15cmdepth (6.03 mg/100g).Most of the soil samples were of alkaline property. Maximum soil pH (8.21) was recorded in C_2 climatic condition which was significantly differ with C_1 climatic condition. Deep soil layer (15-30cm) showed maximum pH, N (0.25%), P (0.97 mg/100g) and K (1.69 mg/100g) was significantly higher at upper (0-15cm) layer of soil. Therefore in the present study an attempt was made to compare the soil physico-chemical properties under two different climatic condition dry temperate high hills (C_1) and High hills temperate dry and cold (C_2) climatic conditions and their effect on agroforestry system.*

Keywords: *Agroforestry systems, Climatic conditions, Soil Physico-Chemical Properties,*

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INTRODUCTION

Farmers have been raising and/or allowing trees in their crop fields in one or other forms since ages to meet multi needs of households. In recent times this practice was coined agroforestry (24). The Kinnaur district is one of the twelve administrative districts of Himachal Pradesh. It has a mountainous topography, ranging in altitude from 1,600 m to 6,816 m, having steep valleys carved by streams and rivulets having their origin in the glaciated ridges. In recent times, the farmers of Kinnaur districts of Himachal Pradesh, which falls in the dry temperate Himalaya, have developed their own agroforestry systems integrating fruits, vegetables and field crops.

Agroforestry is a common practice in the mid hill situation of Himalaya. Cultivation of agricultural crops along with fruit trees (agri-horticulture) is an exclusive and unique practice in the Himalayan region. Fruit trees are planted and/or retained by the farmers as associate crops on agricultural fields (10). Himachal Pradesh is one of the ideal locations for apple cultivation, covering the districts of Shimla, Siramour, Kullu, Mandi, Chamba and Kinnaur considering the vast production of apple orchards. The much-awaited delicious variety of apples from Himachal Pradesh's Kalpa (Kinnaur district) where horticulture is considered as a major livelihood source, most of all the households are involved in horticulture activity. The major horticulture produce in this area is apple (6). In Kinnaur, metrological

data was available from a metrological station at Sharbo. The maximum winter temperature lay between 0 to 20^0 C and minimum between 5 and 9^0 C. In spring, the maximum temperature lay between 8 and 28^0 C and the minimum between 0 and 11^0 C. Only a few district had low enough temperature and a high enough number of cold days to meet the chilling requirement of apple. Humidity in all areas lay between 21 and 100 per cent and varied with the season (Fig. 1).
The integration of trees into farmland has also been suggested to combat soil nutrient depletion in cropping systems [50]. Trees are able to mobilize nutrients from the subsoil and then return these nutrients to the topsoil making them available for annual crops. This may be especially important for nitrate in deep soils with high anion exchange capacity in the subsoil [14]. Trees may reduce nutrient leaching and form a “safety-net” under the root zone of the annual crop [45].

MATERIAL AND METHOD

Study area

The research was conducted at Kinnaur district during May–June and September–October (2014–2015) in dry temperate region of North-Western Himalaya (31° 55'N to 32° 05'N and 77° 45'E to 79° 35°E) of India, (Fig.2). The area is characterized by long winters from October to April and short summers from June to August. Though rains are scanty, precipitation is received mostly in the form of snow during winter. The region is characterized by extreme topographic variation, with most of land having slope more than 10 %, with elevation ranging from 1500 to 3500 m. This region is mountainous having rugged topography, deep and narrow valleys and steep slopes, which makes it extremely prone to different types of slope failure.The soil of this valley reneging between sandy clay loams to sandy clay properties.
Agroforestry is a common practice in the mid hill situation of Himalaya. Cultivation of agricultural crops along with fruit trees (agri-horticulture) is an exclusive and unique practice in the Himalayan region. Fruit trees are planted and/or retained by the farmers as associate crops on agricultural fields. The agroforestry systems provide unique opportunity for integration of different components in the farming systems, which help to optimize the ecosystem functioning and better management of land, water, and biological resources[32]. Under this study we select three different agroforestry systems (Agri-horticulture system, Agri-silviculture system and Agri-horti-silviculture) in two different climatic conditions (Dry temperate high hills and High hills temperate dry and cold) in Kinnaur district Himachal Pradesh. Soil samples were collected from two depths viz. 0-15 cm and 15-30 cm in each agroforestry systems. Plant residue, litters were removed first from soil surface. With the help of spade “V” shape holes were digging and two thick slice of soil collected from the holes at two depths that are 0-15cm and 15-30 cm. Three composite samples were collected randomly from each agroforestry systems. Depth wise total 6 samples were collected from one agroforestry system. Composite samples were then mixed well, crushed and sieved with 2mm. sieve. Soil samples were kept in oven for 24 hours at 60^0C temperature. Bulk density and pore space percent was analyzed by using pycnometer. (Gently tapping divided by its volume). Soil texture was analyzed by Hydrometer method [11].
pH was analyzed by electrometric pH meter using 1:2 ratios of soil and water. Organic carbon was estimated by Wet Combustion method (62). Total Nitrogen was estimated through Kjeldahl method [36]. Extractable phosphorus was determined by Spectrophotometer through Bray and Kurtz method [13]. Available potassium, exchangeable calcium and exchangeable magnesium were analyzed by neutral 1 N ammonium acetate solution method [41].

RESULTS AND DISCUSSION

Soil texture

The sand, silt and clay content in collected samples ranges 61.18-71.28, 0.20-10.00 and 27.72-33.62% under C_1 climatic condition and these soils were categorized as sandy clay loam, sandy clay and clay loam.Similarly C_2 climatic conditions soils sand, silt and clay content ranges between 58.68-70.18, 1.00-7.70 and 28.32-35.42 per cent and these soils were fall in sandy clay and sandy clay loam texture. All samples had high content of sand than that of silt and clay content.Soils of high altitude cold desert which have been originated from weathered rocks; they are immature and have large proportion of sand, gravel and stone in themindicating the dominance of sand forming minerals in parent materials [20]. Sand is the dominant particle in the hill soils and they developed from sandstone parent materials [12]. Similar results were found by Kumar *et al*. [37].
Out of 36 soil samples 10 fall in sandy clay, 17 sample fall in sandy clay loam and 9 samples were categories as clay loam (Table-1-4). Sand content has shown a positive relationship with the soil bulk density while as clay content shows negatively relationship with bulk density of soil samples. Particle density,porosity and bulk density ranges 2.60-3.42 (g/cm^3), 40.92-67.00 and 1.18-1.55(g/cm^3) in C_1 climatic condition. In C_2 climatic condition, Particle density,porosity and bulk density ranges (g/cm^3),

40.92-67.00 and 1.18-1.55(g/cm^3). Porosity shows negative relationship with bulk density and decrease with increase in depth. Clay content found higher in C_2 climatic condition at (0-15cm) depth than the C_1 climatic condition. This is because of more clay deposition in this site through the processes of cold weathering from the adjacent hilly areas and high content of organic carbon. The ratio betweens and/clay, silt/clay and clay ranges 1.88-2.57, 0.01-0.35 and 1.97-2.61 at C_1 climatic condition and 1.69-2.48, 0.01-0.26 and 1.82-2.57 at C_2 climatic condition for both depth.

Effect of climate and soil depth on physicochemical properties of soil

Bulk density

Data in Table 5 shows that maximum bulk density was found in agri-silviculture and agri-horti-silviculture system (1.34g/cm^3) followed by agri-horticulture system (1.32g/cm^3). sDry temperate (C_1) climatic condition had the maximum bulk density (1.38g/cm^3) which was significantly differ with high hills temperate dry and cold (C_2) climatic condition this is because of higher content of sand.According to Chaudhari *et al*. (17) effect of sand content on soil bulk density was found to be higher than that of the other soil properties. He found high degree positive correlation of bulk density was observed with sand content. Climate also influenced bulk density; generally SOM content (%) was increasing with altitude in this investigation. Atmospheric temperature is the main climatic variable which control SOC at cold desert, concluded by Charan *et.al*.[15]. Sanjay *et al*. [52] also pointed out that the lower bulk density at top altitudes are good indication of soils that has occupied coarser structure of organic matter and enriches the spaces by soil organic carbon.

Cold desert high altitude and suppression of microbial and enzymatic activities which results least soil organic matter decomposition that makes higher accumulation of SOC (9, 28, and 53).They analysed that the bulk density values had significantly negative relationship with organic carbon.

Bulk density increases with increase in soil depth. It was observed that highest value of bulk density (1.47g/cm^3) was recorded in 15-30cm depth (D_2) followed by 0-15cm depth(D_1). Similar observations were reported by Aumtong *et al.*[3],Barreto *et al.*[4], Franzluebbers and Stuedemann [21] and Singh *et al.*(56). The soil bulk density has inverse relationship with soil organic carbon.Nayak *et al.*[44] also reported similar results. Organic carbon in soil and inverse relationship of bulk density and OC percentage is established by several workers [25, 33].

Particle density

The results indicated (Table 5) thatparticle density was highest in agri-horticulture system (2.49g/cm^3) which is at par with agri-silviculture (2.42/cm^3) and (2.39) agri-horti-silviculture system. Similar results observed by khan and Kamalakr [34] in their study. Dry temperate high hills climatic conditions (C_1) having maximum particle density (2.44g/cm^3) followed by high hills temperate dry and cold (C_2) climatic conditions. Result indicates that upper layer of soil (0-15cm) depth (D_1) having grater particle density (2.48g/cm^3) which was significantly differ with sub-soil (15-30cm) depth (D_2). Our investigation highly supported by Khan *et al.*[35]. They found similar particle density in different depth in Paddy field. Result shows that particle density was make a negative relationship with bulk density. Particle density was increase with decrease in bulk density in all samples. According to Walters [63], dry bulk density values are lower than soil particle density.

Pore space percent

Table-5 revealed that pore spare percent was higher in agri-horticulture (46.99%) which was significantly differ with agri-silviculture (44.88%) and agri-horti-silviculture (42.37%). Similar porosity was recorded by Gardini *et al.*[22] in Improved Native Agroforestry System (INAS) and Improved Traditional Agroforestry System (ITAS). Pore space percent (46.31%) was higher in high hills temperate dry and cold (C_2) climatic condition which was significantly differ with the dry temperate high hills climatic conditions (C_1). Soil pore space percent (48.90%) was higher in upper layer of soil at (0-15cm) depth (D_1) which was significantly differ with subsoil at (15-30cm) depth (D_2). Due to negative relationship with BD Soil porosity was increase when BD decreases. Same trade found in porosity by Igwe [27] and Gupta and Narain [26].

Soil chemical properties as influenced by average effect of land use systems, climatic conditions and soil layers

Soil pH (1:2)

Data presented in Table 6 revealed that soil pH was higher inagri-horti-silviculture (7.62) which was significantly followed by agri-silviculture (7.59) and agri-horticulture (7.57). Similar pH was recorded by Bhardwaj *et al.*[7], Sirohi and Bangarwa [58]. Soil pH (8.21) was higher in high hills temperate dry and cold (C_2) climatic condition which was significantly differ with the dry temperate high hills (C_1) climatic condition. Kaistha and Gupta [31] also found that soils of Central Himalayas of Himachal Pradesh had pH of 6.7-7.7. Soil pH (7.75) was higher in sub soil layer of soil at (15-30cm) depth (D_2) which was significantly differing with upper soil at (0-15cm) depth (D_1). Soil pH was less at upper soil due to continuous use of FYM in agriculture soil result decrease the soil pH value at surface layer. The reduction in soil pH was mainly due to release of organic acids in the soil upon decomposition of organics [43]. Earlier similar observation was recorded by Singh *et al.*[55].Decrease in soil pH, with the application of FYM was also reported by Dang and Verma [18].

Organic carbon percentage

Data presented in table 6 shows that organic carbon was found maximum in (1.26%) agri-horti-silviculture system; it significantly differs with agri-horticulture system (1.24%) and agri-silviculture system (1.14%). Result showed that organic carbon was higher (1.39%) at high altitude in high hills temperate dry and cold (C_2) climatic condition fallowed by (1.04%) dry temperate high hills (C_1) climatic condition. The organic matter has a significant positive correlation with altitude [5]. Our study shows that organic carbon increased with increasing altitudinal ranges, which can be owed to continuous accumulation of leaf litter and slower decomposition rate at higher altitude than at lower ones. The increase in organic matter with altitude has also been reported by Rajput *et al.*[48], in soil profiles of northwestern Himalaya. Similar result was observed by, He *et. al.*[38]. Organic carbon (1.46%) found higher at surface soil (0-15cm) depth (D_1) than the (0.98%) subsurface soil at (15-30 cm) depth (D_2).The trend of decreasing SOC with increasing depth may be due to the increased proportion of slower cycling of SOC pools at depth. Similar decreasing trend of soil organic carbon was also observed by Sheikh *et. al.*[54].The higher concentration of soil organic carbon in top layer has also been reported by various authors [2, 19, 46].

Total nitrogen percentage

Soil total nitrogen percentage (Table 6) was maximum in agri-horticulture system (0.19%) followed by agri-silviculture system (0.16%) and agri-horti-silviculture system (0.15%).Moges and Holden [42] also reported that total nitrogen was not significantly varied with land uses. Similar observation of total nitrogen was also recorded by Joshi and Negi(30).Total nitrogen percentage was higher in dry temperate high hills (C_1) climatic condition (0.18%), followed by high hills temperate dry and cold (C_2) climatic condition (0.15%). Total N percentage was recorded in the present study (range 0.09– 0.25%) was comparable to other studies. It is probably due to humus added to the soil in and slow decomposition rate at cold desert. Garten and Hanson [23], found SOC stocks become altered with elevation in their investigation. He *et al.* [38] also reported that soil total N significantly and linearly increased with altitude. Total nitrogen percentage decreased with increased soil depth, upper layer of soil (0-15 cm) depth (D_1) reported higher amount of total nitrogen (0.25%) which was significantly differ with deep soil layer (15-30 cm) depth (D_2) where total nitrogen value was (0.05%). There was a significant effect noticed between soil depth and total nitrogen percentage. Similar decreasing trend of N with increase soil depth was also reported earlier by Jobbagy *et. al*. [29], Bhardwaj *et al.* [8].

Extractable P

Soil extractable phosphorus (Table 6) was higher in agri-silviculture system (0.81mg/100g) followed by agri-horticulture system and agri-silvi-horticulture system (0.79mg/100g). No significant effect was observed in agroforestry systems on extractable phosphorus content. Our finding was best supported by Toky*et.al* .(59). The extractable phosphorus noticed significant effect of climatic condition. The amount of extractable phosphorus (P) was higher in high hills temperate dry and cold (C_2) climatic condition (0.81mg/100g) which was significantly at par with dry temperate high hills (C_1) climatic condition (0.78 mg/100g). Similar decreased of phosphorus content in soil with increased elevation was also reported byVincent *et al*. [61]. Results showed that extractable phosphorus (P) was higher at (D_1) upper layer of soil at (0-15 cm) depth (0.97 mg/100g) which was significantly differ with (D_2) depth subsurface soil (15-30 cm depth). Agroforestry systems contained greater extractable soil P at surface soil as suggested by Tornquist *et. al.*[61].

Available potassium (K)

Available potassium content in soil data reveled in Table 6 which revealed that no significant effect of agroforestry systems on potassium content of soil. The highest amount of potassium content was reported in agri-silviculture system (1.29 mg/100g) fallowed by agri-horticulture system (1.26 mg/100g) and agri-horti-silviculture system (1.21 mg/100g). Similar result was also report by Ahmed *et al.*[1]. Available potassium was showed significant effect of climatic condition. Due to continuous use of FYM at the field, the concentration of higher potassium was observed indry temperate high hills (C_1) climatic condition (1.35 mg/100g) which was at par significantly with high hills temperate dry and cold (C_2) climatic condition (1.16 mg/100g). Available potassium noticed significant effect of soil depth. Available potassium (K) was higher in upper (D_1) soil depth at (0-15 cm) depth (1.69 mg/100g) which was significantly at par with (D_2) soil depth (0.61 mg/100g) at (15-30 cm). The potassium content decreased with increase with depth. Similar decreased of potassium content was also reported by Costa and Chandrapala [16]. Higher available potassium in tree based systems may be due to nutrient rich litter of trees, which may have contributed to higher amount of potassium returned back to the soil in the form of litter [47,49].

Exchangeable (Ca)

Results in Table 6 indicate that land use systems, and soil depths had significant effect on exchangeable calcium whereas climatic condition was non-significant effect on exchangeable calcium. Maximum amount of exchangeable calcium was higher in agri-horticulture systems (5.52 mg/100g) which was statistically at par with agri-silviculture systems (5.21 mg/100g) and agri-horti-silviculture systems (5.19 mg/100g).This might be due to the fact that exchangeable base contents were well maintained in the tree based ecosystems due to nutrient recycling as compared to cultivated land (65). Exchangeable calcium was higher at dry temperate high hills (C_1) climatic condition (5.34 mg/100g)fallowed by fallowed by high hills temperate dry and cold (C_2) climatic condition (5.28 mg/100g). Exchangeable calcium was higher (6.03 mg/100g) at surface soil layer at (0-15cm) depth (D_1) which was significantly at par with subsurface soil layer (4.58 mg/100g)at (15-30cm) soil depth (D_2).In the effect of soil layer, Ca was found to be higher in the top layer was probably due to the pumping of bases from the subsoil by the vegetation and returning them in to topsoil [64]. Majumdar *et al.* [39] also reported that Ca was decreased with increasing soil depth.

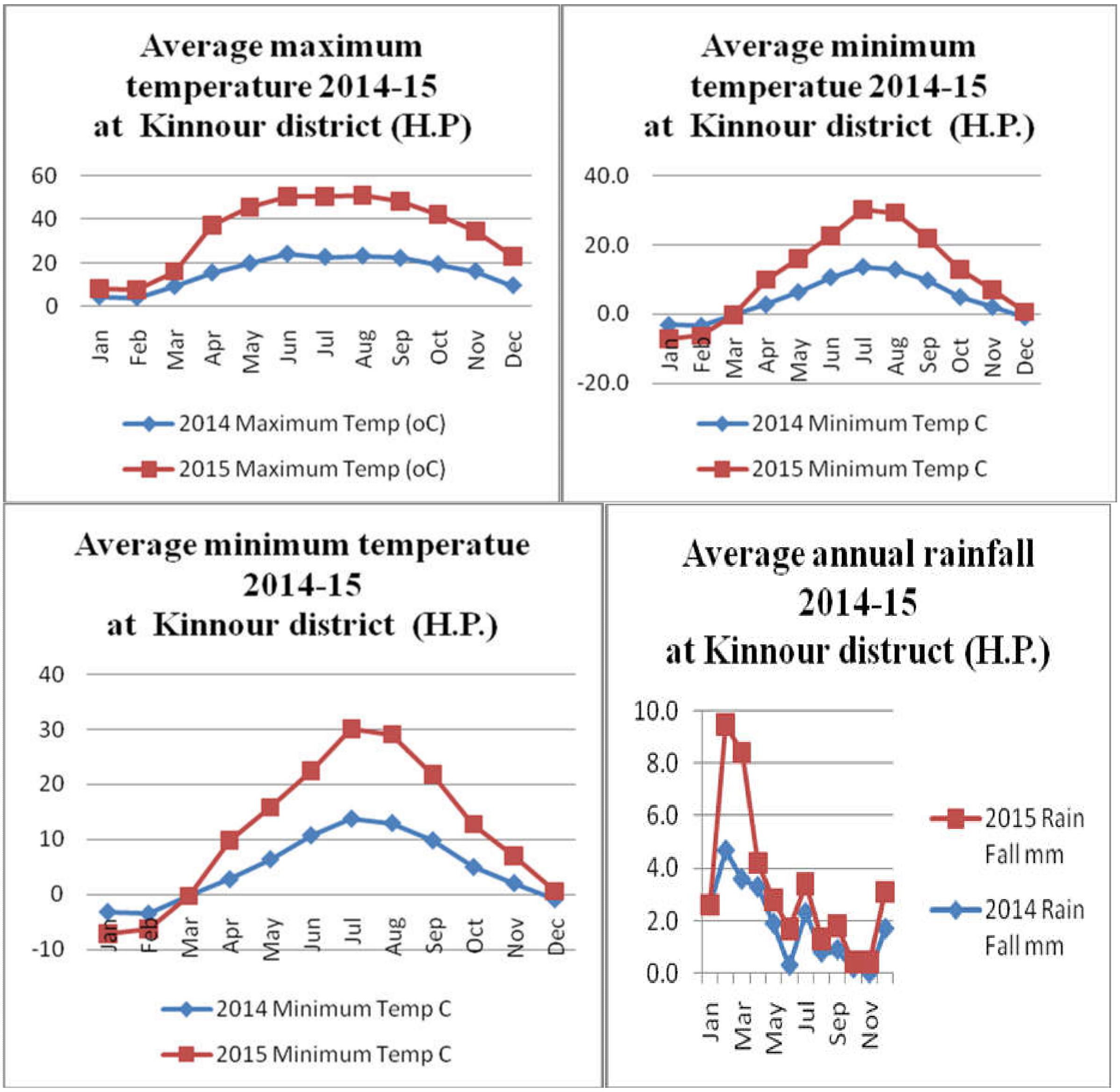

Figure1:- Average weather condition of the kinnour district of Himachal Pradesh.

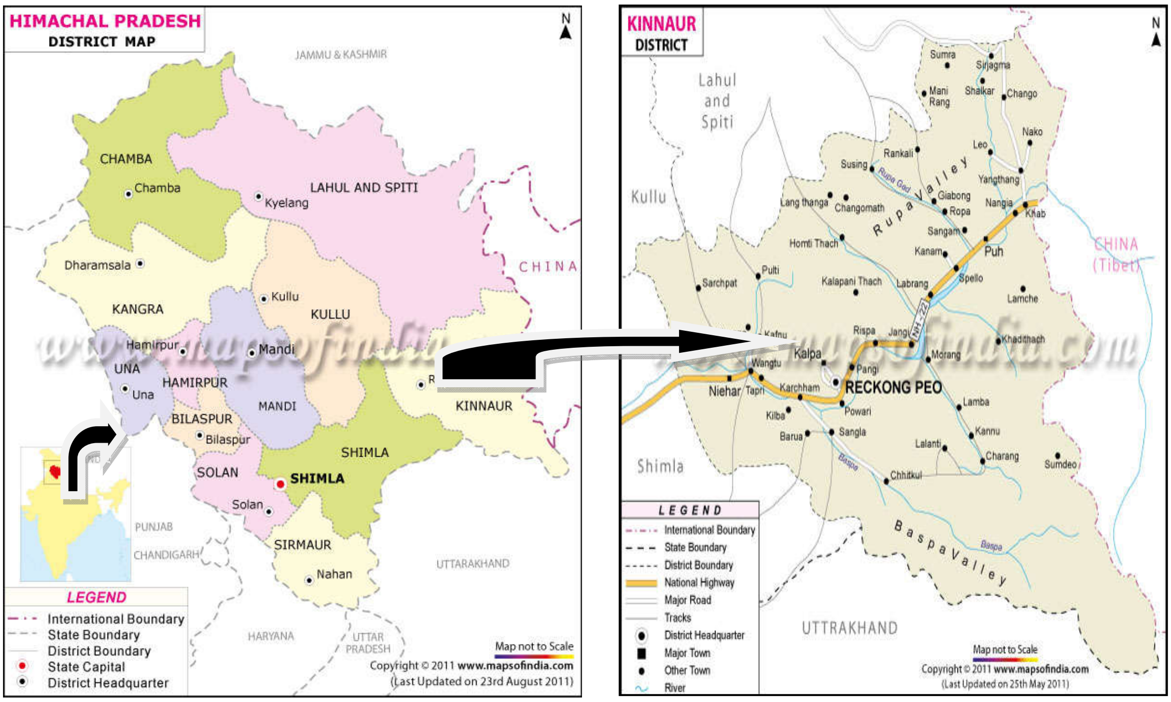

Figure 2:- Geographic map of the Kinnaur District of Himachal Pradesh.

Table 1:Soil physical properties in dry temperate high hills (C_1) climatic condition at 0-15 cm depth

	Soil sample	Sand %	Silt %	Clay %	Soil texture	Clay ratio	Sand/ Clay ratio	Silt/Clay ratio	Pore space percent	Particle Density	Bulk density (g/cm³)
1	$C_1T_1R_1$	64.18	6.10	29.72	Sandy Clay loam	2.36	2.16	0.21	49.96	2.58	1.29
2	$C_1T_1R_2$	70.08	1.98	27.94	Sandy Clay loam	2.58	2.51	0.07	48.25	2.57	1.33
3	$C_1T_1R_3$	64.48	6.80	28.72	Sandy Clay loam	2.48	2.25	0.24	51.53	2.61	1.27
4	$C_1T_2R_1$	70.98	0.30	28.72	Sandy Clay loam	2.48	2.47	0.01	47.43	2.49	1.31
5	$C_1T_2R_2$	63.78	4.50	31.72	Sandy Clay	2.15	2.01	0.14	50.40	2.50	1.24
6	$C_1T_2R_3$	61.18	10.00	28.82	Sandy Clay loam	2.47	2.12	0.35	49.53	2.55	1.29
7	$C_1T_3R_1$	65.08	5.60	29.32	Sandy Clay loam	2.41	2.22	0.19	51.01	2.47	1.24
8	$C_1T_3R_2$	63.08	3.30	33.62	Clay Loam	1.97	1.88	0.10	49.60	2.48	1.25
9	$C_1T_3R_3$	62.18	9.60	28.22	Clay Loam	2.54	2.20	0.34	51.64	2.44	1.18

Table 2: Soil physical properties in dry temperate high hills (C_1) climatic condition at 15-30 cm depth

	Soil sample	Sand %	Silt %	Clay %	Soil texture	Clay ratio	Sand/Clay ratio	Silt/Clay ratio	Pore space percent	Particle Density	Bulk density (g/cm³)
1	$C_1T_1R_1$	66.06	4.22	29.72	Sandy Clay loam	2.36	2.22	0.14	38.87	2.39	1.46
2	$C_1T_1R_2$	70.08	1.00	28.92	Sandy Clay loam	2.46	2.42	0.03	39.28	2.49	1.51
3	$C_1T_1R_3$	68.08	1.80	30.12	Sandy Clay	2.32	2.26	0.06	38.01	2.41	1.49
4	$C_1T_2R_1$	71.08	0.20	28.72	Sandy Clay loam	2.48	2.47	0.01	34.47	2.37	1.55
5	$C_1T_2R_2$	71.28	1.00	27.72	Sandy Clay loam	2.61	2.57	0.04	37.00	2.40	1.51
6	$C_1'T_2R_3$	66.48	3.20	30.32	Sandy Clay	2.30	2.19	0.11	36.35	2.33	1.48
7	$C_1T_3R_1$	66.28	3.20	30.52	Sandy Clay	2.28	2.17	0.10	35.64	2.27	1.46
8	$C_1T_3R_2$	71.18	1.10	27.72	Sandy Clay loam	2.61	2.57	0.04	33.55	2.31	1.54
9	$C_1T_3R_3$	66.08	2.60	31.32	Sandy Clay	2.19	2.11	0.08	34.76	2.29	1.49

Table 3:Soil physical properties in hills temperate dry and cold(C_2) climatic condition at 0-15 cm depth

Soil sample		Sand %	Silt %	Clay %	Soil texture	Clay ratio	Sand/Clay ratio	Silt/Clay ratio	Pore space percent	Particle Density	Bulk density (g/cm^3)
1	$C_1T_1R_1$	62.18	6.00	31.82	Clay Loam	2.14	1.95	0.19	54.44	2.48	1.13
2	$C_1T_1R_2$	65.78	2.60	31.62	Sandy Clay	2.16	2.08	0.08	53.85	2.47	1.14
3	$C_1T_1R_3$	61.48	5.30	33.22	Clay Loam	2.01	1.85	0.16	57.98	2.57	1.08
4	$C_1T_2R_1$	63.18	1.40	35.42	Clay Loam	1.82	1.78	0.04	53.47	2.45	1.14
5	$C_1T_2R_2$	62.88	5.40	31.72	Clay Loam	2.15	1.98	0.17	52.54	2.36	1.12
6	$C_1T_2R_3$	62.68	7.70	29.62	Sandy Clay loam	2.38	2.12	0.26	54.62	2.49	1.13
7	$C_1T_3R_1$	64.08	3.10	32.82	Clay Loam	2.05	1.95	0.09	53.16	2.37	1.11
8	$C_1T_3R_2$	58.68	6.50	34.82	Clay Loam	1.87	1.69	0.19	50.83	2.40	1.18
9	$C_1T_3R_3$	59.18	6.60	34.22	Clay Loam	1.92	1.73	0.19	52.46	2.44	1.16

Table 4:Soil physical properties in hills temperate dry and cold(C_2) climatic conditionat 15-30 cmdepth

Soil sample		Sand %	Silt %	Clay %	Soil texture	Clay ratio	Sand/Clay ratio	Silt/Clay ratio	Pore space percent	Partical Density	Bulk density (g/cm^3)
1	$C_1T_1R_1$	67.28	1.00	31.72	Sandy Clay	2.15	2.12	0.03	46.77	2.48	1.32
2	$C_1T_1R_2$	68.48	1.60	29.92	Sandy Clay loam	2.34	2.29	0.05	43.88	2.37	1.38
3	$C_1T_1R_3$	68.68	1.40	29.92	Sandy Clay loam	2.34	2.30	0.05	41.08	2.41	1.42
4	$C_1T_2R_1$	67.48	1.20	31.32	Sandy Clay	2.19	2.15	0.04	43.78	2.49	1.40
5	$C_1T_2R_2$	64.28	3.60	32.12	Sandy Clay	2.11	2.00	0.11	46.09	2.30	1.42
6	$C_1T_2R_3$	70.18	1.50	28.32	Sandy Clay loam	2.53	2.48	0.05	32.89	2.25	1.51
7	$C_1T_3R_1$	66.28	1.60	32.12	Sandy Clay	2.11	2.06	0.05	48.95	2.37	1.47
8	$C_1T_3R_2$	70.18	1.50	28.32	Sandy Clay loam	2.53	2.48	0.05	48.35	2.42	1.50
9	$C_1T_3R_3$	69.48	1.00	29.52	Sandy Clay loam	2.39	2.35	0.03	51.04	2.41	1.49

Table 5: Soil physical properties as influenced by average effect of land use systems, climatic conditions and soil layers

Land Use system (T)	Bulk Density	Particle Density	Pore Space percent
T_1(Agrihorticulture)	1.32	2.49	46.99
T_2 (Agrisilviculture)	1.34	2.42	44.88
T_3 (Agrihortisilviculture)	1.34	2.39	42.37
SEm±	**0.01**	**0.02**	0.76
$CD_{0.05}$	**N/S**	**0.05**	2.22
Climatic Conditions			
C_1 – Dry temperate high hills	1.38	2.44	43.18
C_2 – High hills temperate dry and cold	1.28	2.42	46.31
SEm±	**0.01**	**0.01**	**0.62**
$CD_{0.05}$	**0.03**	**N/S**	**1.81**
Soil depth			
D_1 (0-15 cm)	1.20	2.48	48.90
D_2 (15-30 cm)	1.47	2.38	40.60
SEm±	**0.01**	**0.01**	**0.62**
$CD_{0.05}$	**0.03**	**0.04**	**1.81**

Table 6: - Soil chemical properties as influenced by average effect of land use systems, climatic conditions and soil layers

Land Use system (T)	pH (1:2)	Organic carbon %	Total Nitrogen (N) %	Extractable P (mg/ 100 g)	Available K (mg/ 100 g)	Exchangeable Ca (mg/ 100 g)	Exchangeable Mg (mg/ 100 g)
T_1 (Agrihorticulture)	7.57	1.24	0.19	0.79	1.26	5.52	4.00
T_2 (Agrisilviculture)	7.59	1.14	0.16	0.81	1.29	5.21	4.30
T_3 (Agrihortisilviculture)	7.62	1.26	0.15	0.79	1.21	5.19	4.06
SEm±	**0.06**	**0.05**	**0.017**	**0.01**	**0.07**	**0.04**	**0.09**
$CD_{0.05}$	**N/S**	**0.10**	**N/S**	**N/S**	**N/S**	**0.10**	**0.25**
Climatic Conditions							
C_1 – Dry temperate high hills	6.97	1.04	0.18	0.78	1.35	5.34	4.18
C_2 – High hills temperate dry and cold	8.21	1.39	0.15	0.81	1.16	5.28	4.05
SEm±	**0.05**	**0.04**	**0.014**	**0.01**	**0.06**	**0.03**	**0.07**
$CD_{0.05}$	**0.14**	**0.08**	**N/S**	**0.02**	**0.17**	**N/S**	**N/S**
Soil depth							
D_1 (0-15 cm)	7.44	1.46	0.25	0.97	1.69	6.03	4.77
D_2 (15-30 cm)	7.75	0.98	0.09	0.62	0.82	4.58	3.46
SEm±	**0.05**	**0.04**	**0.014**	**0.01**	**0.06**	**0.03**	**0.07**
$CD_{0.05}$	**0.14**	**0.08**	**0.04**	**0.02**	**0.17**	**0.08**	**0.20**

CONCLUSION

These results revealed that the soil in agroforestry systems at temperate dry and cold desert high altitude region between sandy clay, clay loam sandy and clay loam class, and calcareous and acidic to alkaline in nature.This study also indicated the altitudinal variations in certain physico-chemical characteristics of agroforestry systems soil at cold desert high altitude. Bulk density, particle density, and total nitrogen percentage, available potassium (K), exchangeable Ca and Mg was higher at Dry temperate high hills. Similarly Pore Space percent, soil pH,Organic carbon percentage (OC) and Extractable phosphorus (P) found to be higher at high hills temperate dry and cold. The soils of cold desert are suitable for various agroforestry systems. Agroforestry play important role to make attention soil science researcher and agroforesters to study the various combination of tree species which can help to improve soil fertility as well as cultivation practices at cold desert.

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