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# SOIL CARBON STOCK AND NUTRIENT STUDY IN DIFFERENT AGROFORESTRY SYSTEMS AT KINNAUR DISTRICT, HIMACHAL PRADESH

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## Abstract

The present study was undertaken at Kinnaur district of Himachal Pradesh. The study focused on Soil carbon stock and nutrient analysis under three different agroforestry systems *viz,* Agri-horticulture system AH, Agrisilviculture system AS and Agrihortisilviculture system AHS of North-Western Himalayas during the year of 2014-15. The laboratory tests of soil showed that the organic carbon, extractable phosphorus, calcium and magnesium decreased with an increase in soil depth. Under the physical properties, the reverse trend was observed for bulk density. Bulk density 1.34 g $cm^3$ was higher in the AS system. 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 the agrihorticulture system. The pore space percent 46.99% was significantly higher in the agrisilviculture system while the pore space percent 48.90% was significantly higher at surface soil. Particle density 2.48 g $cm^3$ was significantly higher at 0-15 cm depth. Chemical parameters were found decreasing with increasing soil depth. Organic carbon 1.26% was significantly higher in the agrihortisilviculture system. Organic carbon 1.26% was significantly higher at 0-15 cm depth in high hills temperate dry and cold $C_2$ climatic conditions. Similarly exchangeable Ca 5.52 mg/100g was significantly higher in the AHS system. Exchangeable calcium 6.03 mg/100g was significantly higher at 0-15cm depth. Most of the soil samples were alkaline property. Maximum soil pH 8.21 was recorded in high hills temperate dry and cold $C_2$ climatic conditions which significantly differed with $C_1$ climatic condition. The deep soil layer 15-30 cm showed maximum pH. N (0.25%), P (0.97 mg/100g) and K (1.69 mg/100g) was significantly higher at upper (0-15 cm) layer of soil. Therefore in the present study, an attempt was made to compare the soil Physico-chemical properties under two different climatic conditions dry temperate high hills $C_1$ and High hills temperate dry and cold $C_2$ climatic conditions and their effect on agroforestry systems. Result reveals that C density was higher in 58.75 t $ha^{-1}$ AHS system followed by AH system 56.34 t $ha^{-1}$ and AS system 52.04 t $ha^{-1}$. Carbon density was maximum in $C_1$ climatic condition with comparison to $C_2$ climatic condition.

***Key words:*** Soil Physico-Chemical Properties: Climatic conditions; Agroforestry systems.

## Introduction

The Kinnaur district is one of the twelve administrative districts of Himachal Pradesh. The district came into existence on 1st May, 1960 (DDMA, 2012). 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 produces in this area is apple (Bera, 2015). The farmers of Kinnaur district live in a steep slope area where site quality factors always play a vital role in productivity. Under this situation, the farmer has lean-to agroforestry systems.

Agroforestry is a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as crops and/or animals, in some form of spatial arrangement or temporal sequence. In agroforestry systems, there are both

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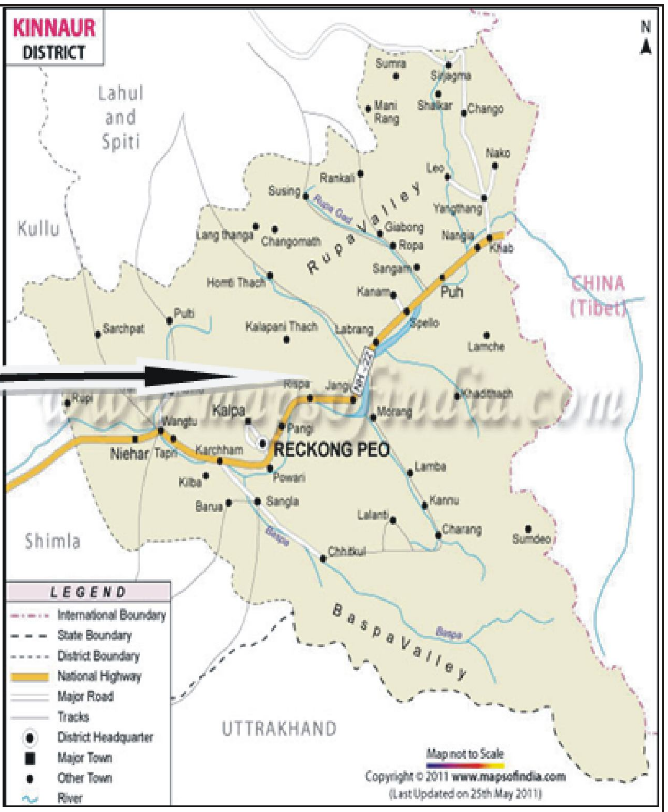
ecological and economical interactions between the different components (Lundgren and Raintree, 1982). Agroforestry practices exploit positive ecological and socioeconomic interactions, minimize undesirable interactions and protect or enhance the sustainability of natural resources for the people who use them. Agroforestry contributes, therefore, a virtuous cycle of the social-ecological system. This linkage between productivity increase or maintenance and resource conservation is vital-trees often provide a stabilizing and regenerative function through a worthy cycle of biomass, nutrient and energy flows-which may be used in interventions to halt and overturn the vicious cycles of degradation (Xu *et al.,* 2011). Lesser availability of land, low returns from traditional crops and the ever-increasing demand for fuel, fodder, timber, etc. are the reasons that compel farmers to integrate multipurpose tree species on their farmland. Variation in a temperate zone can differentiate the soil C content as well as other nutrient and physical and chemical properties of soil. In support of the carbon quality temperature hypothesis, Davidson and Janssens, (2006) reported that the temperature sensitivity of decomposition increases with soil carbon recalcitrance as long as decomposition is not constrained by environmental factors.

Trees add organic matter to the soil system in various manners, whether in the form of roots or litterfall or as root exudates in the rhizosphere (Bertin *et al.,* 2003). In India, the first 30 cm soil layer holds about 9 Pg (1 Pg =1015g) C (Bhattacharya *et al.,* 2000). Western Himalayan Zone consisting of Jammu & Kashmir, Himachal Pradesh and Uttarakhand hill covers an area of 33.85 mha which constitutes about 10% of the total geographical area and the soils contribute about 14% of SOC stock of the country (Bhattacharya *et al.,* 2008). The ability of soils to accumulate C is generally related to characteristics that are little influenced by management, such as texture (clay soils typically accumulate more C than sandy soils), some management practices can influence soil C sequestration, particularly the insertion of trees in agricultural systems (Pinho *et al*., 2012). A well-designed agroforestry intervention provides permanent soil cover, improve soil and water use-efficiency, restore tree cover and increase carbon stocks (Charles *et al*., 2013; Roshetko *et al.,* 2013).

In agroforestry system nutrient addition takes place through leaf litter, pruning of woody compounds and atmospheric fixation. Some nutrients otherwise considered unavailable to crop because they are below the rooting zone of the annual crop, might be brought into the system from deeper layers in the soil with the help of tree roots. Trees able to return nutrients through dead organic matter (leaf, branch, twig, fruits and flower) and thus helps in the enrichment of the topsoil layer, available

Pate-1



Pate-2

for the agriculture crops. The litter deposition in these agroforestry systems is responsible for significant additions to the contents of organic matter (OM) of the soil (Tumwebaze *et al.,* 2012).

## Material and Method

### Study area

The research was conducted at Kinnaur district during May-June and September-October (2014-2015) in the dry temperate region of North-Western Himalaya (31°552 N to 32°052 N and 77°452 E to 79°352 E) of India, (Fig. 1). 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 the 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. 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 $C_1$ and High hills temperate dry and cold $C_2$) 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.

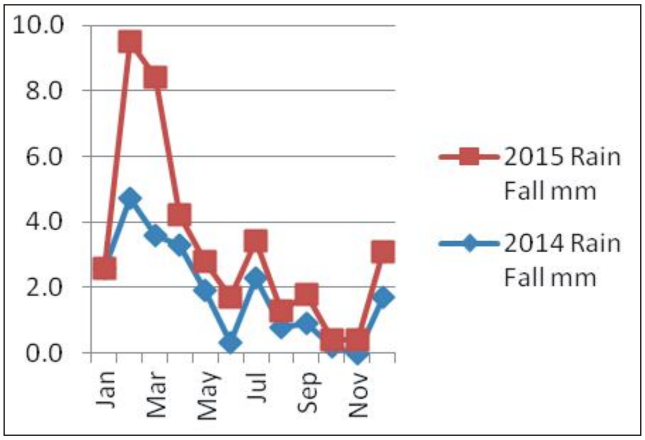


**Fig. 1:** Average annual rainfall 2014-15 at Kinnaur district (H.P.).

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 $60^0$C temperature. Bulk density and pore space percent was analyzed by using pycnometer. Soil texture was analyzed by Hydrometer method. (Bouyocos, 1927).

Carbon stock under soil of different agroforestry systems under different climatic condition were calculated by multiplying of soil depth (cm) and organic carbon percentage into their respective bulk density soil. (Lee *et al.,* 2009)

pH was analyzed by electrometric pH meter using 1:2 ratios of soil and water. Organic carbon was estimated by Wet Combustion method given by Walkley and black, (1934). Total Nitrogen was estimated through Kjeldahl (Kjeldahl, J., 1883) method. Extractable phosphorus was determined by Spectrophotometer through Bray and Kurtz, (1945) method. Available potassium, exchangeable calcium and exchangeable magnesium were analyzed by neutral 1 N ammonium acetate solution method (Merwin and Peach, 1951).

## Results and Discussion

### Soil carbon

Rapidly rising concentrations of atmospheric carbon dioxide ($CO_2$) have prompted a flurry of studies on soils as potential carbon (C) 'sinks'. About 70% of this C is stored in the soil (Dixon *et al.,* 1994). The data in table 1 reveals that the value of soil carbon (0-30 cm depth) was significantly influenced due to climatic conditions and

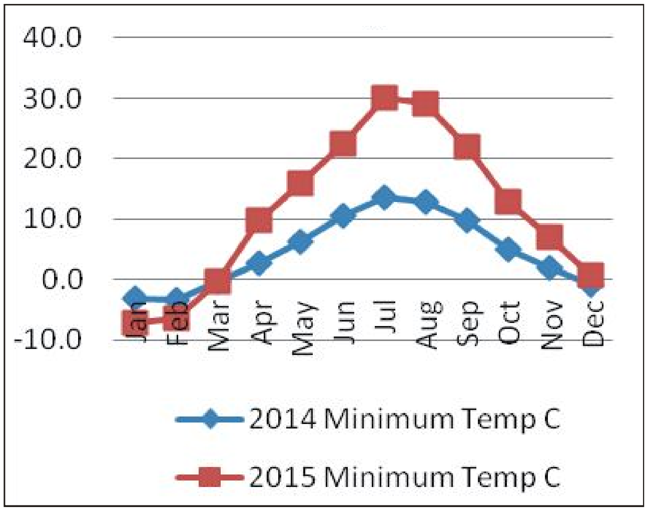


**Fig. 2:** Average Minimum tempertaure 2014-15 at Kinnaur district (H.P.).

**Table 1:** Effect of agroforestry systems, climatic conditions and their interaction effects on different components of carbon inventory (C t ha$^{-1}$).

| Agroforestry systems (T) | (C t ha$^{-1}$) |
|---|---|
| **T1 (AH)** | 56.34 |
| **T2 (AS)** | 52.06 |
| **T3 (AHS)** | 58.75 |
| **SEm±** | **1.09** |
| **C.D0.05** | **3.48** |
| **Climatic conditions(C)** | |
| **$C_1$ – Dry temperate high hills** | 58.68 |
| **$C_2$ – High hills temperate dry and cold** | 52.75 |
| **SEm±** | **0.89** |
| **C.D0.05** | **2.84** |
| **Agroforestry systems (T) × Climatic conditions (C)** | |
| **T1 × C1** | 58.28 |
| **T2 × C1** | 54.02 |
| **T3 × C1** | 63.75 |
| **T1 × C2** | 54.40 |
| **T2 × C2** | 50.11 |
| **T3 × C2** | 53.74 |
| **SEm±** | **1.54** |
| **C.D0.05** | **NS** |

agroforestry systems. The maximum carbon density in soil was recorded in AHS system (58.75 C t ha$^{-1}$), which was found to be significantly higher than AH system only. Studies done by Jha *et al.,* (2001) showed that agroforestry could store nearly 83.6 t C ha$^{-1}$ up to 30 cm soil depth. Because of More number of trees in AHS system provide higher quantity of organic matter which results higher density of C found in AHS system, Sollins *et al.,* (2007) also reported that Higher C density in agroforestry system can be particularly achieved by increasing the amount of biomass C returned to the soil and by rise soil organic matter (SOM) stabilization and/ or by decreasing the rate of biomass decomposition and SOM destabilization. Irrespective of climatic conditions the soil carbon density decreased from climatic condition $C_1$ to climatic condition $C_2$. This may be due to less number of trees under different agroforestry system. The effect of interaction between agroforestry systems and climatic conditions was found to be nonsignificant.

The carbon storage calculated in present study is higher than the C density value reported by Sing *et al.,* (2018) during the study of different agroforestry systems along an elevation gradient in north-western Himalaya. The variation in C density value in different agroforestry system can be attributed to the prevailing temperate climatic conditions, rainfall pattern and sandy texture of soil.

## Effect of climate and soil depth on physicochemical properties of soil

### • Bulk density:

Data in (Fig. 1) shows that maximum bulk density was found in agrisilviculture and agrihortisilviculture system (1.34g/cm$^3$) followed by agrihorticulture system (1.32g/cm$^3$). Dry temperate ($C_1$) climatic condition had the maximum bulk density (1.38g/cm$^3$) which significantly differed with high hills temperate dry and cold ($C_2$) climatic condition this is because of the higher content of sand. According to Chaudhari *et al.,* (2013) effect of sand content on soil bulk density was found to be higher than that of the other soil properties. He found that a high degree of a positive association of bulk density was observed with sand content. Climate also subjective bulk density; generally, SOC content (%) was increased with an increase in altitude. Atmospheric temperature is the main climatic variable that controls SOC at the cold desert, concluded by Charan *et al.,* (2013). Sanjay *et al.,* (2010) also pointed out that the lower bulk density at top altitudes is a good indication of soils that have occupied the 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 from least soil organic matter decomposition that makes the higher accumulation of SOC (Bhattacharya *et al.,* 2008; Jacot *et al.,* 2000). Soil bulk density values had a significantly negative relationship with organic carbon resulted by Sakin *et al.,* (2011).

Bulk density increases an increase in soil depth. It was observed that the highest value of bulk density (1.47g/cm$^3$) was recorded in 15-30cm depth ($D_2$) followed by 0-15cm depth ($D_1$). These observations are supported by Singh *et al.,* (2011) and Barreto *et al.,* (2010). Results show that bulk density increases with an increase in soil depth and a decrease in SOC. Generally, bulk density has inversely associated with SOC. Several workers Gupta and Sharma, (2008);

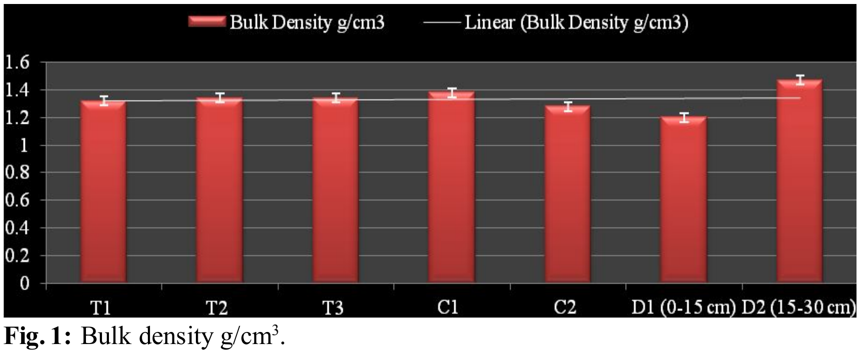


**Fig. 1:** Bulk density g/cm$^3$.

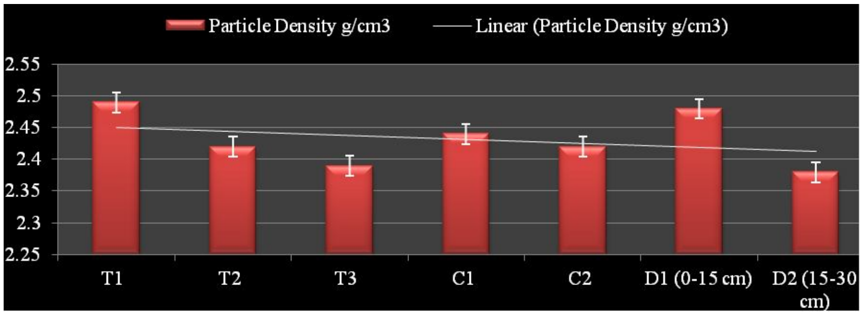


**Fig. 2:** Particle density $g/cm^3$.

Kaur and Bhat, (2017) supported this investigation.

- **Particle density:**

The results indicated (Fig. 2) that particle density was highest in agrihorticulture system ($2.49 g/cm^3$) which is at par with agrisilviculture ($2.42 g/cm^3$) and ($2.39 g/cm^3$) agrihortisilviculture system. Similar results observed by Khan and Kamalakr, (2012) in their study. Dry temperate high hills climatic conditions ($C_1$) having maximum particle density ($2.44 g/cm^3$) followed by high hills temperate dry and cold ($C_2$) climatic conditions. The result indicates that the upper layer of soil (0-15cm) depth ($D_1$) having a grater particle density ($2.48 g/cm^3$) which significantly differed with sub-soil (15-30cm) depth ($D_2$). Our investigation highly supported by Khan *et al.,* (2006). They found similar particle density in different depths in the Paddy field. The result shows that particle density made a negative relationship with bulk density. Particle density was increase with a decrease in bulk density in all samples. According to Walters, (2016), dry bulk density values are lower than soil particle density.

- **Pore space percent:**

Fig. 3 revealed that pore spare percent was higher in agrihorticulture (46.99%) which significantly differed with agrisilviculture (44.88%) and agrihortisilviculture (42.37%). Similar porosity was recorded by Gardini *et al.,* (2015), 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 significantly differed with the dry temperate high hills climatic conditions ($C_1$) which may be due to moisture content or soil texture.

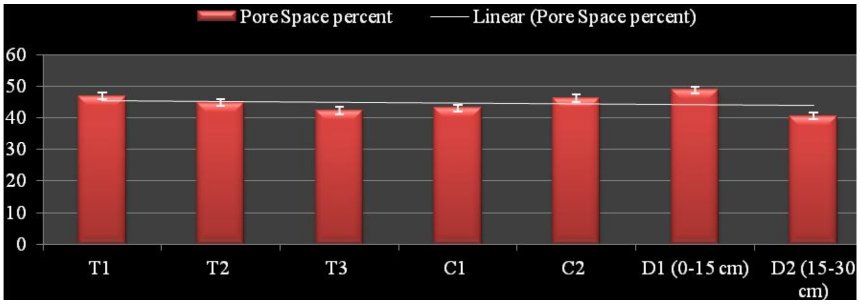


**Fig. 3:** Pore space percent (%).

Soil porosity and moisture content as it is dependent on soil texture and structure Casanova *et al.,* (2016) and Han *et al.,* (2017). Soil pore space percent (48.90%) was higher in the upper layer of soil at (0-15cm) depth ($D_1$) which significantly differed with subsoil at (15-30cm) depth ($D_2$). Due to the negative relationship with BD soil porosity was increased when BD decreases. Same trade of increases porosity with decrease BD supported by Igwe, (2005) and Gupta and Narain, (1971).

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

- **Soil pH (1:2):**

Data presented in (Fig. 4) revealed that soil pH was higher in agrihortisilviculture (7.62) which was significantly followed by agrisilviculture (7.59) and agrihorticulture (7.57). A similar pH was recorded by Sirohi and Bangarwa (2017). Soil pH (8.21) was higher in high hills temperate dry and cold ($C_2$) climatic condition which significantly differed with the dry temperate high hills ($C_1$) climatic condition. Kaistha and Gupta, (1993) also found that soils of Central Himalayas of Himachal Pradesh had pH of 6.7-7.7. Soil pH (7.75) was higher in the subsoil layer of soil at (15-30cm) depth ($D_2$) which was significantly differed with upper soil at (0-15cm) depth ($D_1$). Soil pH was less at upper soil due to the continuous use of FYM in agriculture soil result decrease soil pH value at the surface layer. The reduction in soil pH was mainly due to the release of organic acids in the soil upon decomposition of organics stated by More (1994). A decrease in soil pH, with the application of FYM, was also reported by Dang and Verma, (1996).

- **Organic carbon percentage:**

Data presented in (Fig. 5) shows that organic carbon was found maximum in (1.26%) agrihortisilviculture system; it significantly differs with agrihorticulture system (1.24%) and agrisilviculture system (1.14%). The 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

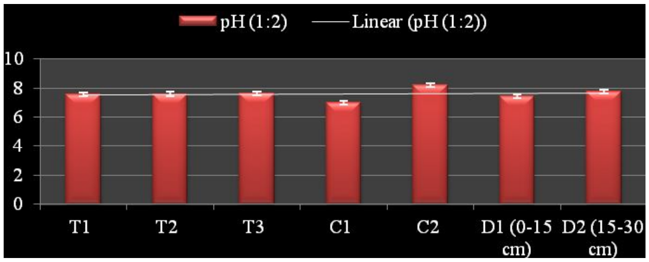


**Fig. 4:** pH (1:2).

altitude (Banerjee *et al.*, 1998). 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 a higher altitude than at lower ones. The increase in organic matter with altitude has also been reported by Rajput *et al.*, (2017), in soil profiles of northwestern Himalaya. A similar result was observed by, He *et al.*, (2016). 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 ($D_2$). According to Esteban and Jackson, (2000), the trend of decreasing SOC with increasing depth may be due to the increased proportion of slower cycling of SOC pools at depth. A similar decreasing trend of soil organic carbon was also observed by Sheikh *et al.*, (2009). The higher concentration of soil organic carbon in the top layer has also been reported by various authors, Notaro *et al.,* (2013); Dinakaran and Krishnayya, (2008).

- **Total nitrogen percentage:**

Soil's total nitrogen percentage (Fig. 6) was maximum in agrihorticulture system (0.19%) followed by agrisilviculture system (0.16%) and agrihortisilviculture system (0.15%). Non significant variation in total N under different agroforestry system may be given by crop composition and fertilizer application. Moges and Holden, (2008) also stated that total nitrogen was not significantly varied with land uses. 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 that reported by Jina *et al.,* (2011) 0.19% at Central Himalayas. It is probably due to humus added to the soil in and slow decomposition rate at the cold desert. Slightly variation may be given by increasing elevation. He *et al.,* (2016) 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 significantly differed 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. A similar decreasing trend of N with increasing soil depth was also reported earlier by Bhardwaj *et al.,* (2001). The variation of soil N losses under different land uses with soil erosion and leaching may also cause the differences.

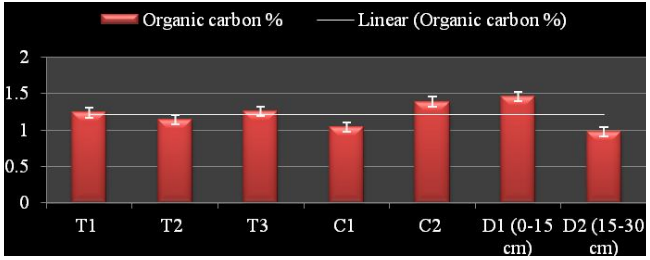


**Fig. 5:** Organic Carbon %.

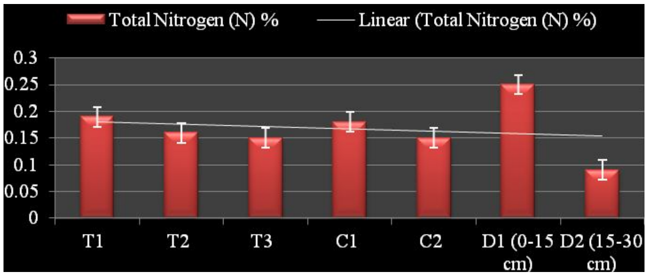


**Fig. 6:** Total Nitrogen (N) %.

- **Extractable P:**

Soil extractable phosphorus (Fig. 7) was higher in agrisilviculture system (0.81mg/100g) fallowed by agrihorticulture system and agrisilvihorticulture 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.,* (1989). The extractable phosphorus noticed a significant effect of climatic conditions. 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). A decrease in phosphorus with increase in soil depth has been reported by various workers Sood, (1991) and Dongale, (1993). A similar decrease of phosphorus content in soil with increased elevation was also reported by Vincent *et al.,* (2014). 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 significantly differed with ($D_2$) depth subsurface soil (15-30 cm depth). Agroforestry

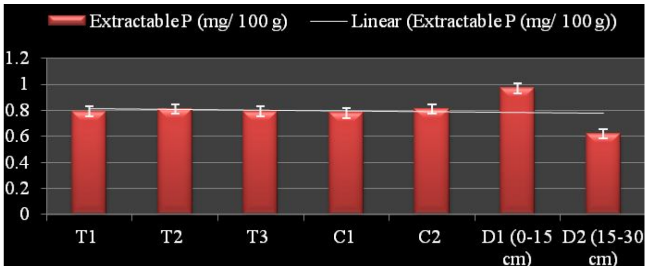


**Fig. 7:** Extractable P (mg/100 g).

systems contained greater extractable soil P at surface soil as suggested by Tornquist *et al.,* (1999).

- **Available potassium (K):**

Available potassium content in soil data reveled in (Fig. 8) which revealed that no significant effect of agroforestry systems on potassium content of the soil. The highest amount of potassium content was reported in agrisilviculture system (1.29 mg/100g) fallowed by agrihorticulture system (1.26 mg/100g) and agrihortisilviculture system (1.21 mg/100g). A similar result was also reported by Ahmed *et al.,* (2012). Available potassium was showed a significant effect on climatic conditions. Due to the continuous use of FYM at the field, the concentration of higher potassium was observed in dry 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 a 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 an increase in depth. Similar decreased potassium content was also reported by Costa and Chandrapala, (2000). Higher available potassium in tree-based systems may be due to nutrient-rich litter of trees, which may have contributed to the higher amount of potassium, returned back to the soil in the form of litter Puri *et al.,* (1994) and Saha *et al.,* (1999).

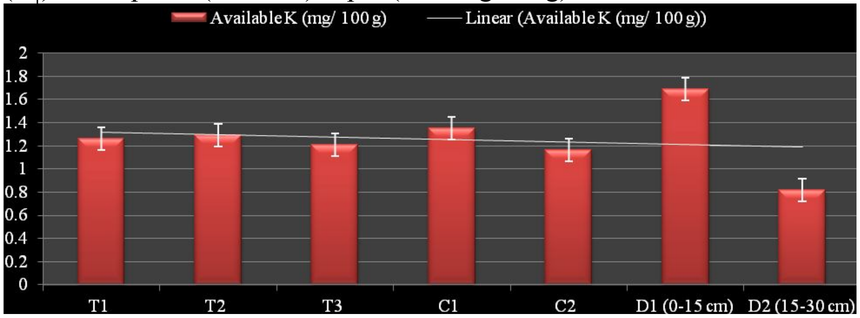


**Fig. 8:** Available K (mg/100 g).

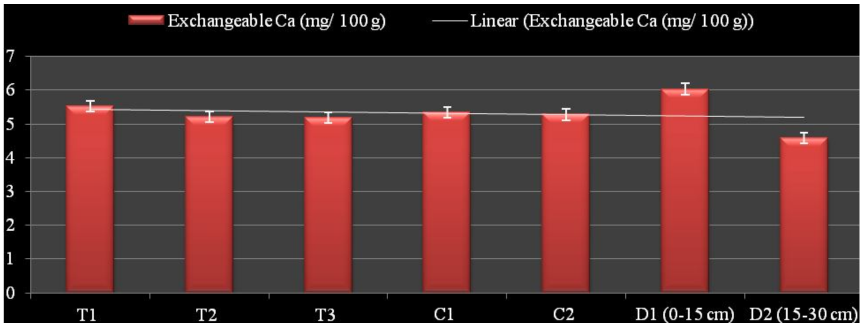


**Fig. 9:** Exchangalbe Ca (mg/100 g).

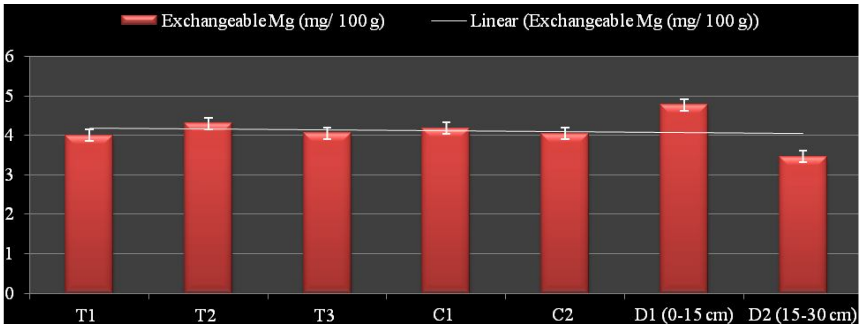


**Fig. 10:** Exchangalbe Mg (mg/100 g).

- **Exchangeable (Ca):**

Results in (Fig. 9) indicate that land-use systems and soil depths had a significant effect on exchangeable calcium whereas climatic condition was the non-significant effect on exchangeable calcium. The maximum amount of exchangeable calcium was higher in agrihorticulture systems (5.52 mg/100g) which were statistically at par with agrisilviculture systems (5.21 mg/100g) and agrihortisilviculture 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 Yitbarek *et al.,* (2013). Exchangeable calcium was higher at dry temperate high hills ($C_1$) climatic condition (5.34 mg/100g) followed 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 the 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 into topsoil Yimer *et al.,* (2008). Majumdar *et al.,* (2004) also reported that Ca was decreased with increasing soil depth.

- **Exchangeable (Mg):**

Data presented in (Fig. 10) revealed that exchangeable Mg was maximum in agrisilviculture (4.30 mg/100g) which differed significantly at par with agrisilvihorticulture system (4.06 mg/100g) and agrisilviculture system (4.00mg/100g). Bertalot *et al.,* (2014) also reported a higher level of Magnesium (Mg) in agroforestry system. Exchangeable Mg was maximum at Exchangeable magnesium (Mg) was higher at dry temperate high hills ($C_1$) climatic condition (4.18 mg/100g) followed by high hills temperate dry and cold ($C_2$) climatic condition (4.05 mg/100g). Exchangeable magnesium (Mg) was higher (4.77 mg/100g) at surface soil layer at (0-15cm) depth ($D_1$) which was significantly at par with subsurface soil layer (3.46 mg/100g) at (15-30cm) soil depth ($D_2$). Gupta and Tripathi (1996) studded the soils of North-Western Himalayas and reported similar results. The soil layer depth significantly influences the content of magnesium (Mg). Depth wise distribution is concerned; Mg in general exhibited a decreasing trend with the increase in soil depth. It may be due to undulating topography and high rate of soil erosion. A similar trend of Mg distribution has also been reported by Singh, (1987).

## 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 were 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 deserts are suitable for various agroforestry systems. Agroforestry plays an important role to make attention soil science researchers and agroforester to study the various combinations of tree species which can help to improve soil fertility as well as cultivation practices at the cold desert.

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