

## Soil organic carbon in three selected agroforestry system at temperate zone (2000-2800m) of North Western Himalaya, Uttarakhand, India

### Abstract:

Climate change is an emerging issue partly consequences from abundance of carbon dioxide in environment. It persists, and it cannot be stopped. Rather, it can be mitigated. Agroforestrysystems as land use can reduce the atmospheric concentration of carbon dioxide. This study therefore aimed to generate data on the soil organic carbon of three selected agroforestry systems at temperate region in North Western Himalaya , Uttarakhand, India. Stratified random sampling techniques were used for this study. Soil organic carbon was determined using the Walkley and Blackmethod. Weighing bottle method were used for determining bulk density. Results showed that SOC of agroforestry systems goes along with the following order: Agrihortisystem (45.72 MgCha<sup>-1</sup>) >Agrihortisilviculture system (24.99 MgC ha<sup>-1</sup>) >Agrisilvi culture system (23.79 MgC ha<sup>-1</sup>). Therefore, Policy programs promoting the establishment of agroforestry systems in ideal lands in Tehri district should be considered

### Keywords:

### 1. Introduction

Agroforestry has a highly significant and positive effect on SOC sequestration in the temperate zone. SOC stocks in temperate AFS are generally higher than in treeless agricultural sites (Mayer et al., 2022). Soil organic carbon is a key component of terrestrial ecosystem that helps in enhanced sequestration of atmospheric CO<sub>2</sub> in the soil. The hill and mountain environment covers 54 Mha of the total geographical area of 329 Mha of India (Kumar, 2018). The Indian Himalayas are a mountain range characterized by varying altitudes, slopes, aspects, and climate resulting in wide ecological diversity. The northwest Himalayas (NWH) spread over Jammu & Kashmir, Himachal Pradesh, and Uttarakhand and cover 17.7 Mha of the land of India (Arora and Bhatt, 2016). The valleys of NWH receive 1,600–2000 mm of precipitation and have fertile soil (Bhardwaj et al., 2021). While soil properties, including SOC, is decreased over the years due to improper land use practices (Singh et al., 2019), the adoption of improved land use practices (cropping systems, conservation tillage, nutrient management, etc.) has been reported to enhance the SOC, microbial carbon, and available N, P and K contents of Himalayan soils (Gogoi et al., 2021).

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Climate change is largely driven by the increased concentration of greenhouse gases like carbon dioxide (CO<sub>2</sub>) in the atmosphere. While halting climate change entirely may not be feasible at this point, mitigating its effects is crucial, and agroforestry is one of the key strategies that can help in this regard and to mitigate some of its consequences by reducing CO<sub>2</sub> in the atmosphere and promoting sustainable land management.

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Therefore, the objective of this study was to collate and synthesize the existing information on the soil organic carbon with three agroforestry system (viz. Agrihortisystem, Agrihortisilviculture system and Agrisilviculture system ) at temperate region in North Western Himalaya , Uttarakhand, India. Note: Also mention experiment year.

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Ten sample plots (100m<sup>2</sup>) were randomly laid out in each agroforestry system in temperate zone (2000-2800m) of each developmental block. Soil organic carbon was determined at three different depth 0-10, 10-20 and 20-30 cm.

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The results revealed considerable that SOC of agroforestry systems goes along with the following order: Agrihortisystem (45.72 MgCha<sup>-1</sup>) >Agrihortisilviculture system (24.99 MgC ha<sup>-1</sup>) >Agrisilvi culture system (23.79 MgC ha<sup>-1</sup>).

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The study concluded that the agrihorticulture system at higher altitudes (2000-2800 m) had a significantly greater soil organic carbon pool. It was suggested that, if necessary, converting agricultural fields to agrihorticulture systems in the Northwestern Himalayas could enhance soil carbon sequestration.

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The C status of the Himalayan soil varies according to the land use pattern followed, i.e., forests, plantation crops, and grasses are major C sinks because of their high storage potential and low decomposition processes compared to other agricultural crops (Babu et al., 2021; Yadav et al., 2021; Wani et al., 2022).

Various studies regarding different SOC pools have been conducted in different parts of the hilly ecosystems like the eastern Himalayas (Yadav et al., 2019; Babu et al., 2020) and western Himalayas (Yadav et al., 2019). However, very few studies on changes in SOC due to land use practices i.e., forest, plantation, agricultural cropland, etc., in the Kashmir Himalayas have so far been conducted. Hence, a comprehensive study on the effects of land use management on soil C stocks is needed to identify viable land-use systems for C buildup in Kashmir Himalaya in face of changing climatic parameters. Furthermore, C stock measurement is also required by an international agreement between 192 countries in the world that have joined to form a treaty (Mathew et al., 2020). North-Western Himalaya is very rich in natural vegetation and plantation crops and has fertile land to cultivate various crops. This study is conducted to determine and compare the carbon stock capacity of three different agroforestry systems in temperate region of North-Western Himalaya, Uttarakhand, India. Certainly, the findings of this study can help in choosing appropriate agroforestry system by the farmers of the region to achieve sustainable crop productivity and income.

## Material and method

### 2. Study Area

The present study was carried out from 2014-2018 in the Tehri Garhwal district of Uttarakhand (Fig.1) which is the part of North Western Himalayan region. The district lies between latitude of 30°03' and 30° 53' North and longitudes 77° 56' and 79° 04' East and has an area of 3,642 km<sup>2</sup> (ISFR, 2019). The Tehri district has been divided into three agro-climatic zones viz: sub-tropical zone (300-1200m), sub-temperate zone (1200-2000m) and temperate zone (2000-2800 m) on the basis of topography, elevation and temperature condition (Singh and Singh, 1992). The site characteristics of study sites are given in Table 1.

**Table 1: Site characteristic of study sites**

S. No.	Attributes	Temperate Zone (2000-2800m)
1	Location	30°38' to 30°40'N and 78°36' to 78°35'S
2	Rainfall	Heavy rainfall(< 2000m)
3	Climate	Heavy cold

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2. MATERIALS AND METHODS

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2.1 Study Area

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The Present investigation was carried out in the year 2014 to 2018 in the Tehri Garhwal district of Uttarakhand, state of India.

4	Soil type	Most loamy, rich in organic matter
5	Dominant agroforestry system	Agrisilviculturesystem,Agrihortisilviculturesystem,Agrihorticulture system
6	Tree density(No. of trees/100m <sup>2</sup> )	AHS=1.90, AS=1.73, AH=1.68
7	Crop density (No. of crops/100m <sup>2</sup> )	AHS=199.5, AS=319.25, AH=213

### 3. Species combination in each agroforestry system

Based on field survey, the common existing agroforestry systems in Tehri district was appeared agrisilviculture system (trees and agriculture crops), agrihorticulture system (edible fruit trees and agriculture crops), and agrihortisilviculture system (trees including edible fruit trees, forest trees and agriculture crops). Species combination in each system has been shown in Table 2-from where soil sample has been collected.

#### Agrisilviculture system (AS)

It is quite common throughout the district. This system is managed for the production of fuel, fodder, fibre and small timber trees with the agricultural crops. Agriculture crops such as *Triticum aestivum*, *Eleusine coracana*, *Fagopyrum esculentum*, *Amarnathusblitum*, *Echinochloa frumentacea* are grown in monoculture or mixed cropping on the permanent terraces prepared across the hill slopes, while fodder, fuel and timber trees such as *Quercus leucotrichophora*, *Rhododendron arboretum*, *Myrica esculenta*, *Grewia oppositifolia* etc are deliberately left or grown on the bunds of terraces.

#### Agrihorticulture system (AH)

This system is commonly practices in those areas where fuel and fodder is easily available from other sources, and or size of the land holding is large compared to other systems. Agriculture crops mainly *Triticum aestivum*, *Amarnathusblitum*, *Echinochloa frumentacea*, *Eleusine coracana*, *Solanum tuberosum* etc with space of horticulture trees such as *Pyrus communis*, *Prunus persica*, *Prunus armenica*, *Juglanse regia*, *Pyrus communi*, *Citrus limon*, *C. sinensis*, *Malus domestica* etc.

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2.2 Species combination in each agroforestry system

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2.2.1 Agrisilviculture system (AS)

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2.2.2 Agrihorticulture system (AH)

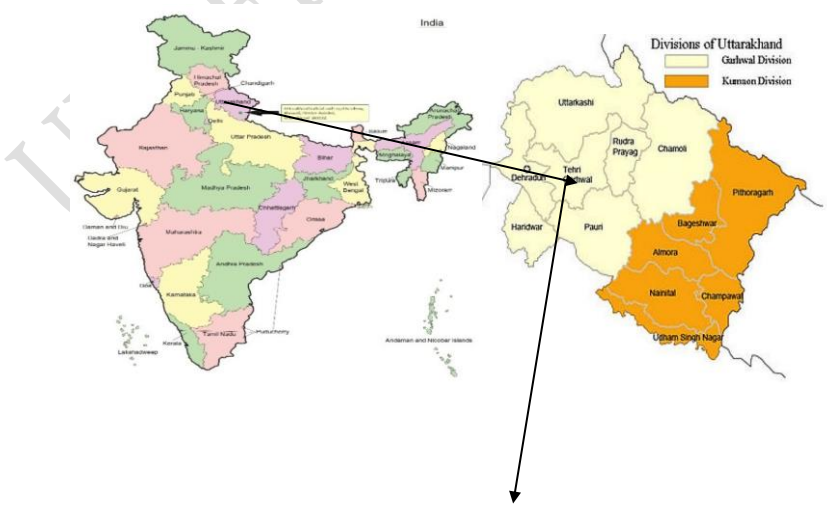
**Agrihortisilviculture (AHS)**

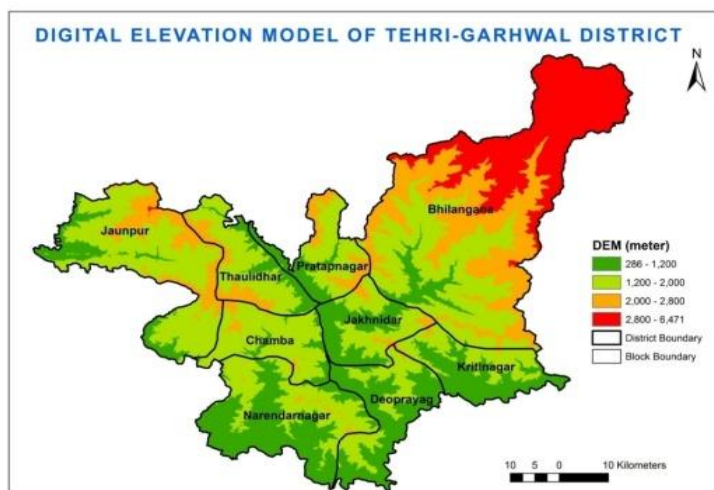
This system is managed for production of fruits, grains, fodder and fuelwood. Fruit trees are planted at regular space with in the fields, and fodder or small timber trees are left on the field bunds while the annuals are grown as intercrop of the tree. Species are grown same as that in the other two systems.

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**Table 2: Species combination in each Agroforestry system at Temperate Zone (2000-2800m).**

Component					
Dominant Forest trees			Dominant Annual crops+grass+weeds		
Agrisilviculture system	Agrihorti silviculture system	Agrihorticulture system	Agrisilviculture system	Agrihorti silviculture system	Agrihorticulture system
<i>Quercus leucotrichophora</i> , <i>Rhododendron arboretum</i> , <i>Myrica esculenta</i> , <i>Grewia oppositifolia</i>	<i>Grewia oppositifolia</i> , <i>Quercus leucotrichophora</i> , <i>Rhododendron arboreum</i> , <i>Myrica esculenta</i> , <i>Citrus limon</i> , <i>C. sinensis</i> , <i>Juglans regia</i> , <i>Malus domestica</i> .	<i>Pyrus communis</i> , <i>Prunus persica</i> , <i>Prunus armenica</i> , <i>Juglans regia</i> , <i>Pyrus communi</i> , <i>Citrus limon</i> , <i>C. sinensis</i> , <i>Malus domestica</i>	<i>Triticum aestivum</i> , <i>Eleusine coracana</i> , <i>Fagopyrum esculentum</i> , <i>Amarnathusblitum</i> , <i>Echinochloa frumentacea</i> , <i>Lantana camara</i>	<i>Triticum aestivum</i> , <i>Amarnathusblitum</i> , <i>Fagopyrum esculentum</i> , <i>Echinochloa frumentacea</i> , <i>Eleusine coracana</i> , <i>Solanum tuberosum</i> , <i>Amranthusviridius</i>	<i>Triticum aestivum</i> , <i>Amarnathusblitum</i> , <i>Echinochloa frumentacea</i> , <i>Eleusine coracana</i> , <i>Solanum tuberosum</i> , <i>Cynodondactylon</i>





**Fig 1. Geographical location of study area**

#### 4. Methodology

Stratified random sampling techniques were used for this study. Out of nine blocks, six blocks on mid elevation were selected in the district for first stage sampling. Five villages were selected randomly from three blocks, one village from Devparayag block, two villages from Chamba block and Pratapnagar block. There were no settlement area in temperate zone (2000-2800m) at Thauldhar, Jakhmidhar and Kritinagar block. Three agroforestry systems; Agrihorticulture (AH), Agrisilviculture (AS) and Agrihortisilviculture (AHS) have been selected in temperate zone (2000-2800m) of each developmental block. Ten sample plots (100m<sup>2</sup>) were randomly laid out in each agroforestry system in temperate zone (2000-2800m) of each developmental block. Composite samples were obtained for three soil layers, 0-10, 10-20 and 20-30 cm. Weighing bottle method were used for determining bulk density (Singh,1980). Soil organic carbon was determined using the (Walkley and Black, 1934) method. Soil organic carbon stock was calculated by using the equation given by Pearson et al., (2007).

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2.3 Methodology

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2.3.1 Soil sampling methods  
2.3.2 Laboratory procedure  
2.3.3 statistical analysis

## 5. Results and Discussion

Maximum bulk density ( $1.33 \text{ g cm}^{-3}$ ) was recorded in the agrisilviculture system and minimum in agrihorticulture system ( $1.30 \text{ g cm}^{-3}$ ). Higher value of soil organic carbon ( $45.72 \text{ Mg ha}^{-1}$ ) was found in the agrihorticulture system and lower in agrisilviculture system ( $23.79 \text{ Mg ha}^{-1}$ ) (Table 3). In our finding it was observed the agroforestry system which is intensively managed have significantly ( $P \leq 0.01$ ) higher bulk density and it declined as the intensity of land management systems. It was proved from the value was given below, soil organic carbon was significantly ( $P \leq 0.01$ ) influenced by different agroforestry system may happened because of enhanced accumulation of leaf litter in the crop and fruit based agrihorticulture system (Parmaret al., 2022) (Table 3).

**Table 3. Bulk density, SOC (%) and SOC ( $\text{Mg ha}^{-1}$ ) on agroforestry systems of temperate region**

AFS	Bulk density	SOC%	SOC
AS	1.33	2.73	23.79
AHS	1.31	2.88	24.99
AH	1.30	3.44	45.72
CD	0.02	0.31	3.56

Significance at the level of probability of 1% ( $P \leq 0.01$ )

SOC was recorded higher ( $52.15 \pm 3.45 \text{ Mg ha}^{-1}$ ) at 0-10 cm depth followed by ( $50.86 \pm 1.92 \text{ Mg ha}^{-1}$ ) at 10-20 cm depth respectively in AH system. It was indicated that SOC decreased with increasing depths which can be owed to continuous accumulation of leaf litter and slower decomposition rate at the higher altitude Slower decomposition means less mineralization and hence losses of organic carbon through erosion will be lower at higher altitude and hence more carbon content conservation (Bhardwaj et al., 2013) (Fig.1).

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3. Results and Discussion

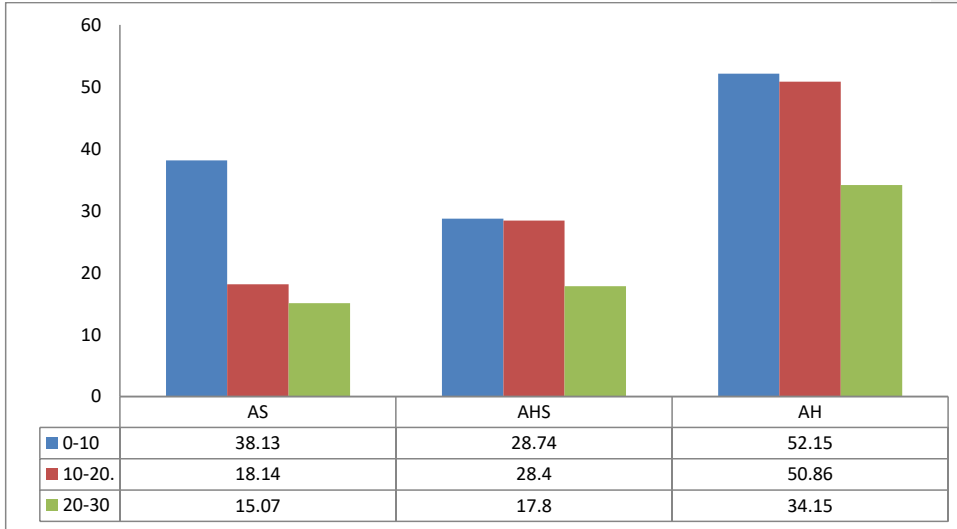
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e.g.: The value indicated that the bulk density was significantly ( $P \leq 0.01$ ) different with three selected agroforestry systems. The highest bulk density was recorded ( $1.33 \text{ g cm}^{-3}$ ) in Agrisilviculture system (AS) followed by Agrihortisilviculture system (AHS) and found least in Agrihorticulture system ( $1.30 \text{ g cm}^{-3}$ ) (Table 3). The plausible reason for higher density in agrisilviculture system (AS) may be due to the more tillage operations for cultivating agricultural crops and low input of litter fall as well minimum accumulation of leaf litter. Similar work reported by (Bhalawe, et al. 2024, Henneron, et al. 2022 and Bhalawe, et al. 2019).

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e.g.: Soil organic carbon is a function of vegetation, rainfall and temperature and a determining factor of soil quality, productivity and carbon sequestration potential. Soil organic carbon (SOC) and Soil organic carbon percentage (SOC%) was significantly ( $P \leq 0.01$ ) of three selected agroforestry systems are vary greatly. It was comparatively highest ( $45.72 \text{ Mg ha}^{-1}$ ) in Agrihorticulture systems (AH) Which was followed by Agrihortisilviculture system (AHS) and found minimum ( $23.79 \text{ Mg ha}^{-1}$ ) in Agrisilviculture system (Table 3) due to the abundant litter or pruned biomass returns to soil, combined with the decay of roots contribute to the improvement of organic matter and addition of FYM under fruit tree based systems (Parmar et al., 2022 ; Bhalawe, et al., 2024, Bhalawe, et al.2013).

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E.g. Influence of agroforestry systems on bulk density, SOC (%) and SOC ( $\text{Mg ha}^{-1}$ ) in temperate region.

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e.g.: Soil organic carbon content of different soil samples (depth) collected from three selected agroforestry systems was compared and obtained highest soil organic carbon () in 0-10 cm depth, which was followed by () at 10-20 cm depth in Agrihorticulture system (AH) and lowest in 20-30 cm depth due to the percentage of organic carbon decreases with increasing soil depth as a higher amount of plant biomass was confined within the surface and subsurface layer of soil. Similar results were reported by Bhardwaj, et al., 2013; Bhalawe,et al. 2013; Bhalawe, et al.,2019).

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**Fig. 2: Soil organic carbon (Mg ha<sup>-1</sup>) on soil depth in agroforestry systems in temperate region.**

## 6. Conclusion

It was concluded agrihorticulture system had accumulated greater soil organic carbon in temperate region of North Western Himalaya. It is suggested that, if need be, conversion of agriculture field should be into crops and Fruit based system. Farmers should be adopted agrihorticulture system for better soil carbon sequestration. Agroforestry systems can store 23.79 MgC ha<sup>-1</sup> to 45.72MgC ha<sup>-1</sup>. Therefore, policy programs promoting the establishment of agroforestry systems in ideal lands in Tehri district should be considered.

## DISCLAIMER (ARTIFICIAL INTELLIGENCE)

## ACKNOWLEDGEMENTS

## COMPETING INTERESTS

## 7. Reference

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3. Conclusion

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e.g.: Three selected agroforestry systems have been studied for this. In which it was seen that Agrihorticulture system (AH), which is a very good source of business along with food and still has a capability of storing sufficient carbon.

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*offs between Climate Change and the Sustainable Development Goals*, 119-143, ISBN: 978-981-15-7300-2.

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