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. Agroforestry systems as land use can reduce the atmospheric concentration of carbon dioxide. This study therefore aimed to generate data on the soil organic carbonof 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 Black method.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-^{1}) > Agrihortisilviculture system (24.99 MgC ha-^{1}) > Agrisilvi culture system (23.79 MgC ha^{-1}).Therefore, Policy programs promoting the establishment of agroforestry systems in ideal lands in Tehri district shouldbe considered

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 etal., 2022).Soil organic carbon is a key component of terrestrial ecosystem that helps in enhanced sequestration of atmospheric CO_2 in the soilThe 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). 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 $30^0$03' and 30^0 53' North l and longitudes 77^0 56' and 79^0 04' East and has an area of 3,642 km^2 (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^o38’ to $30^0$40’N and $78^0$36’to $78^0$35’S
2	Rainfall	Heavy rainfall(< 2000m)
3	Climate	Heavy cold

4	Soil type	Most loamy, rich in organic matter
5	Dominant agroforestry system	Agrisilviculture system,Agrihortisilviculture system,Agrihorticulture system
6	Tree density(No. of trees/100m^2)	AHS=1.90, AS=1.73, AH=1.68
7	Crop density (No. of crops/100m^2)	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 inTable 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 corps. Agriculture crops such as *Triticum aestivum*, *Eleusine coracana*, *Fagopyrum esculentum,Amarnathusblitum, Ehinochloa 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)

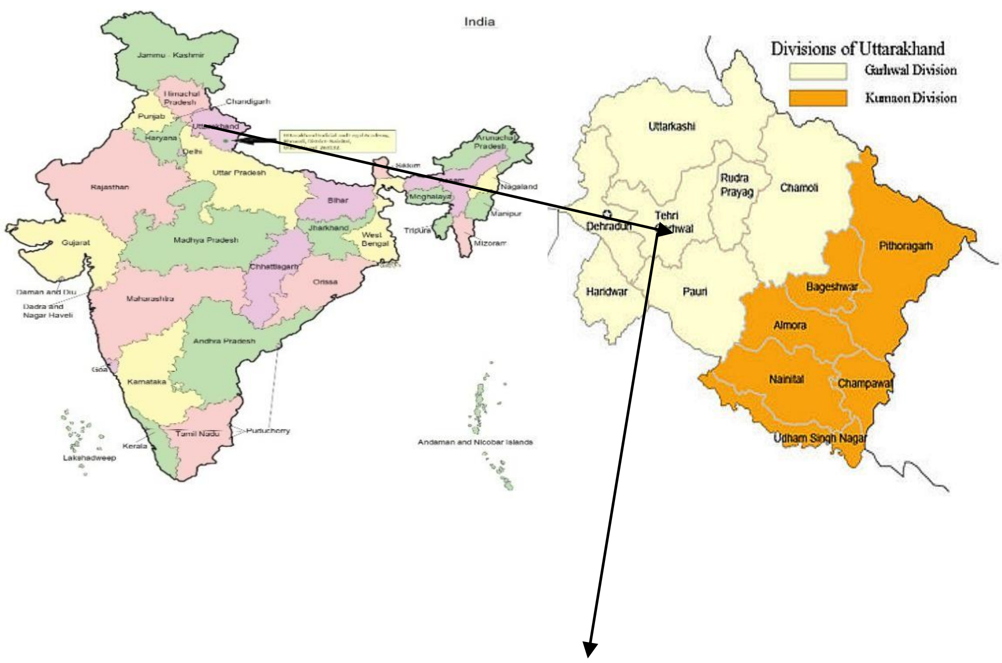
This system is commonly practices in those areas where fuel and fodder is easily available from other sources, and or size of the land holding is large compared to other systems. Agriculture crops mainly *Triticum aestivum, Amarnathus blitum*, *Ehinochloa frumentacea, Eleusine coracana*, *Solanum tuberosum*etcwith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

Agrihortisilvi culture (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

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

Component					
Dominant Forest trees			**DominantAnnual crops+grass+weeds**		
Agrisilviculture system	Agrihorti silviculture system	Agrihorticulture system	Agrisilviculture system	Agrihorti silviculture system	Agrihorticulture system
Quercus leucotrichophora, Rhododendron arboretum, Myrica esculenta, Grewia oppositifolia	*Grewia oppositifolia ,Quercus leucotrichophora, Rhododendron arboreum, Myrica esculenta, Citrus limon, C. sinensis, Juglans regia, Malus domestica.*	*Pyrus communis, Prunus persica, Prunus armenica, Juglanse regia, Pyrus communi, Citrus limon, C. sinensis, Malus domestica*	*Triticum aestivum, Eleusine coracana, Fagopyrum esculentum, Amarnathusblitum, Ehinochloa frumentacea, Lantana camara*	*Triticum aestivum, Amarnathus blitum, Fagopyrum esculentum, Ehinochloa frumentacea, Eleusine coracana, Solanum tuberosum, Amranthus virdius*	*Triticum aestivum, Amarnathus blitum, Ehinochloa frumentacea, Eleusine coracana, Solanum tuberosum, Cynodon dactylon*



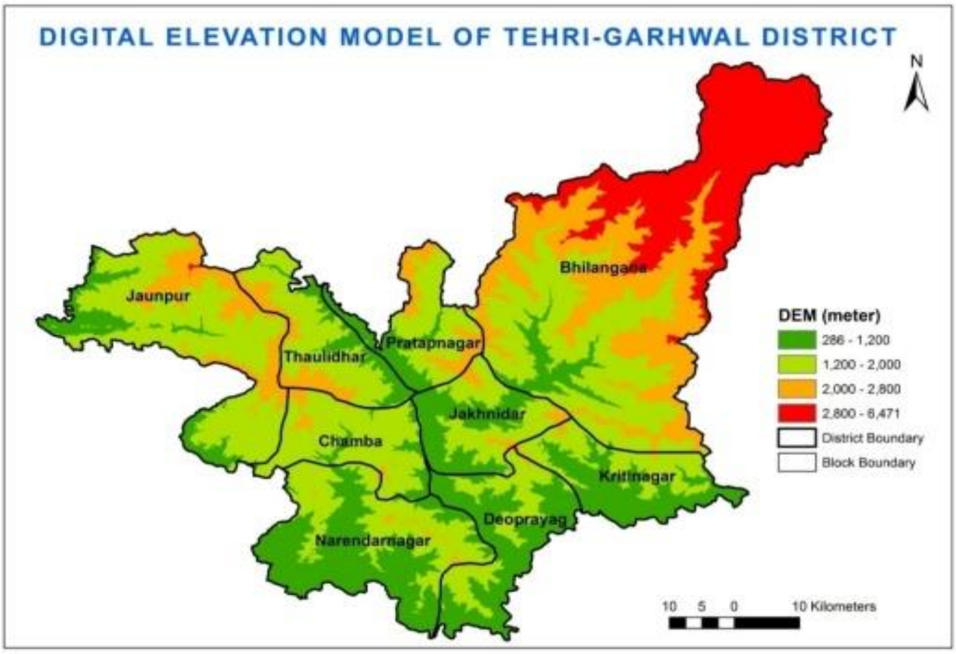


Fig 1. Geographical location of study area

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, Jakhnidhar 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^2) were randomly laid out in each agroforestry system in temperate zone (2000-2800m) of each developmental block.Composite samples were obtainedfor 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).

5. Results and Discussion

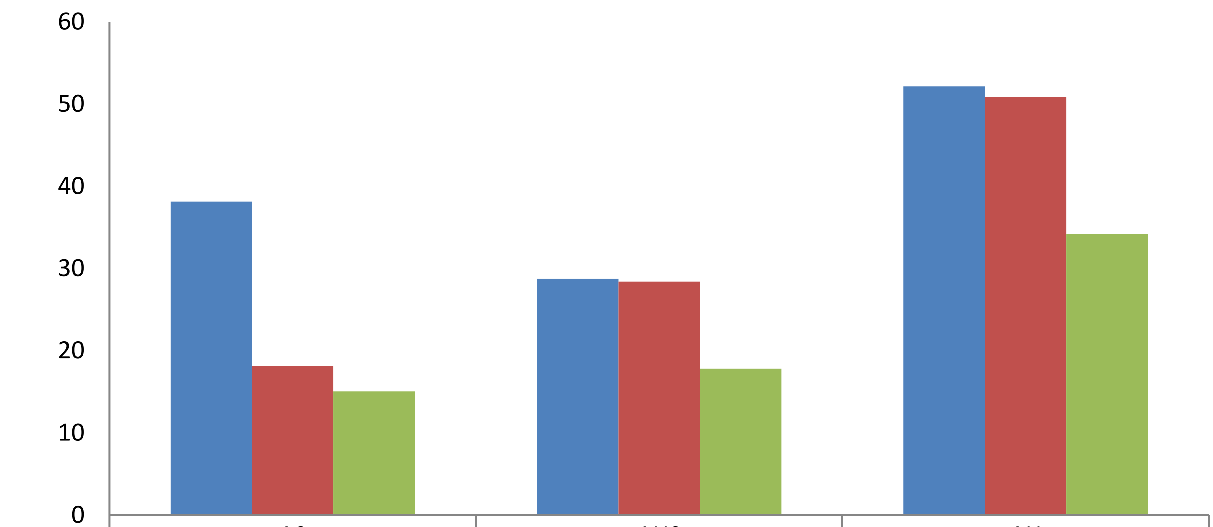
Maximum bulk density (1.33g cm-^{3}) was recorded in the agrisilviculture system and minimum in agrihorticulture system (1.30 g cm-^{3}) .Higher value of soil organic carbon (45.72 Mg ha-^{1}) was found in the agrihorticulture system and lower in agrisilviculture system (23.79 Mg ha^{-1})(Table 3). In 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 (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 ± 3.45Mg ha-^{1}) at 0-10 cm depth followed by (50.86 ± 1.92 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).



	AS	AHS	AH
0-10	38.13	28.74	52.15
10-20.	18.14	28.4	50.86
20-30	15.07	17.8	34.15

Fig. 2: Soil organic carbon (Mg ha-^{1}) on soil depth in agroforestry systems in temperate region.

6. Conclusion

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

7. Reference

1. Arora, S., and Bhatt, R. (2016). Resource conservation technologies (RCTs) forclimate-resilient agriculture in the foothill of northwest Himalayas, *Conservation agriculture*, 71-111.
2. Babu, S., Mohapatra, K., Das, A., Yadav, G., Singh, R., Chandra, P.(2021).Integrated farming systems: climate resilient sustainable food production system in the Himalayan region.*Exploring Synergies and Trade-offs between Climate Change and the Sustainable Development Goals*, 119-143, ISBN: 978-981-15-7300-2.

3. Babu, S., Mohapatra, K., Yadav, G. S., Lal, R., Singh, R., Avasthe, R.(2020).Soil carbon dynamics in diverse organic land use systems in North EasternHimalayan ecosystem of India. *Catena*, 194,104785. doi:10.1016/j.catena.2020.104785
4. Bhardwaj, D. R., Tahiry, H., Sharma, P., Pala, N. A., Kumar, D., Kumar, A.(2021). Influence of aspect and elevational gradient on vegetation pattern, treecharacteristics and ecosystem carbon density in Northwestern Himalayas. *Land*, 10 (11), 1109. doi:10.3390/land10111109
5. Bhardwaj, D.R., Sanneh A.A., Rajput B.S and Kumar S. (2013). Status of soil organic carbon stocks under different land use systems in wet temperate North Western Himalaya. *Journal of Tree Science*, **32**(1 & 2): 14-22.
6. Gogoi, B., Borah, N., Baishya, A., Dutta, S., Nath, D. J., Das, R.(2021). Yield trends, soil carbon fractions and sequestration in a rice-rice system of North-East India: Effect of 32 years of INM practices. *Field Crops Research*, 272, 108289. doi:10.1016/j.fcr.2021.108289
7. ISFR (2019). Indian State of Forest Report, Forest survey of India, Ministry of Environment, Forest and Climate change, Government of India, Dehradun, Uttarakhand. https://fsi.nic.in/forest-report-2019
8. Kumar, S.(2018). Geospatial approach in modeling soil erosion processes inpredicting soil erosion. *Remote Sensing Northwest Himalayan Ecosystem*, 355.
9. Mathew, I., Shimelis, H., Mutema, M., Minasny, B., Chaplot, V., (2020). Crops for increasing soil organic carbon stocks – a global meta analysis. *Geoderma*, 367, 114230. https://doi.org/10.1016/j.geoderma.2020.114230.
10. Mayer S., Wiesmeier M., Sakamata E., Hubner R. (2022).Soil Organic Carbon Sequestration in temperate agroforestry systems-A Meta-analysis. *Agriculture, Ecosystem & Environment*, 323, 107680.doi.org/10.1016/j.agee.2021.107680
11. Wani, O. A., Kumar, S., Hussain, N., Wani, A. I. A., Subhash, B., Parvej, A. (2022). Multi-scale processes influencing global carbon storage and land-carbonclimatenexus: A critical review. *Pedosphere*, 33(2), 250-267.doi.org/10.1016/j.pedsph.2022.07.002
12. Parmar B., Vishwakarma A., Padbhushan R., Kumar A.(2022). Hedge and Alder-Based Agroforestry Systems: Potential Interventions to Carbon

Sequestration and Better Crop Productivity in Indian Sub-Himalayas. *Frontier in Environmental Science*, 10, 858948.doi: 10.3389/fenvs.2022.858948

13. Pearson T.R., Brown S.L. and Birdsey R.A.(2007). Measurement guidelines for the sequestration of forest carbon, U.S. Northern Research Station, United States Department of Agriculture, 1-47.
14. Singh J.S and Singh, S.P.(1992). Forests of Himalaya: Structure, Functioning and Impact of Man. Gyanodaya Prakashan, Nainital, Uttarakhand, India, 294.
15. Singh, RA. (1980). Soil physical analysis. New Delhi: Kalyani Publishers
16. Singh, S. B., Choudhury, B. U., Saha, S., Hnamte, V., and Hnamte, V. (2019).Transforming jhum to plantations: Effect on soil microbiological and biochemicalproperties in the foot hills of North Eastern Himalayas, India. *Catena*, 177, 84–91.doi:10.1016/j.catena.2019.02.008
17. Walkley A. J. and Black I.(1934).Estimation of soil organic carbon by chromic acid titration method.*Soil Science*, **37**, 29–38.
18. Yadav, G. S., Das, A., Kandpal, B., Babu, S., Lal, R., Datta, M. (2021).The food-energy-water-carbon nexus in a maize-maize-mustard croppingsequence of the Indian Himalayas: An impact of tillage-cum-livemulching. *Renewable Sustainable Energy Reviews*, 151, 111602. doi:10.1016/j.rser.2021.111602
19. Yadav, G. S., Lal, R., Meena, R. S., Babu, S., Das, A., Bhowmik, S. (2019).Conservation tillage and nutrient management effects on productivity and soil carbon sequestration under double cropping of rice in north eastern region of India.*Ecological Indicators*, 105, 303-315. doi:10.1016/j.ecolind.2017.08.071