SEASONAL ASSESSMENT OF BIOMASS AND CARBON SEQUESTRAION OF HERBS AND LITTER IN HOMEGARDEN AGROFORESTRY SYSTEM OF SHUATS CAMPUS, PRAYAGRAJ.

ABSTRACT

An increase in greenhouse gases (GHGs) in the atmosphere, such as CO_2, is what drives global warming. Strong carbon management is the first step in helping to stop climate change, safeguard human health, and create profitable businesses. A key strategy for lowering GHG emissions is carbon capture and storage.The study aimed to investigate the carbon sequestration potential of the herbaceous vegetation and litter layer in homegarden agroforestry systems during the rainy, winter, and summer seasons in the SHUATS Campus, Prayagraj. The total dry weight of the herbaceous layer and litter layer was measured, and the corresponding carbon sequestration values were calculated.During the rainy season, the herbaceous layer exhibited a total dry weight ranging from 0.31 kg $m-^{2}$ to 0.36 kg $m-^{2}$, resulting in carbon sequestration values ranging from 1.83 Mg C ha-1 to 2.13 Mg C ha-1. The litter layer had a total dry weight ranging from 0.13 kg $m-^{2}$ to 0.16 kg $m-^{2}$, contributing to carbon sequestration values ranging from 0.76 Mg C ha-1 to 0.92 Mg C ha-1.In the winter season, the herbaceous layer demonstrated a total dry weight ranging from 0.22 kg m-2 to 0.28 kg m-2, resulting in carbon sequestration values ranging from 1.29 Mg C ha-1 to 1.65 Mg C ha-1. Similarly, the litter layer exhibited a total dry weight ranging from 0.18 kg m-2 to 0.216 kg m-2, contributing to carbon sequestration values ranging from 1.05 Mg C ha-1 to 1.25 Mg C ha-1.During the summer season, the herbaceous layer displayed a total dry weight ranging from 0.303 kg m-2 to 0.361 kg m-2, resulting in carbon sequestration values ranging from 1.76 Mg C ha-1 to 2.10 Mg C ha-1. The litter layer had a total dry weight ranging from 0.16 kg m-2 to 0.24 kg m-2, contributing to carbon sequestration values ranging from 1.00 Mg C ha-1 to 1.32 Mg C ha-1.The results indicate that the herbaceous layer and litter layer of homegarden agroforestry systems in the SHUATS Campus, Prayagraj, have the potential to sequester significant amounts of carbon during different seasons. This highlights the importance of homegardens in mitigating climate change and promoting sustainable land management practices.

Keywords: Carbon Sequestration, Herbaceous Vegetation, Litter Layer, Homegarden Agroforestry, Rainy Season, Winter Season, Summer Season.

INTRODUCTION

Carbon dioxide, a trace gas found in Earth's atmosphere, is necessary for photosynthesis, the greenhouse effect, and the marine carbon cycle. One of the many greenhouse gases that are in the earth's atmosphere is this one. Carbon appears throughout life in numerous ways. Carbon is a chemical element, just like hydrogen or nitrogen, and an essential component of biomolecules. It exists on Earth as a solid, dissolved substance, or gas. For instance, gaseous carbon dioxide (CO_2) is created when carbon and oxygen interact; this chemical is also present in graphite and diamond. Animal cells and other structural components are primarily composed of organic substances that sustain cellular processes. Life as we know it would not exist without the presence of carbon. The oceans have 48,000 Gt of the planet's total carbon, of which 39,000 Gt are in the seas. Only 6,000 Gt of fossil C, the second-largest deposit, is available. Furthermore, the amount of terrestrial carbon (C) stored in the world's forests, plants, and soils is only 2500 Gt, as opposed to the 800 Gt in the atmosphere. As a result of human activity, the normal movement of carbon compounds between the atmosphere, the oceans, and terrestrial ecosystems is currently being changed. The annual emissions from the use of fossil fuels, including the manufacture of cement, are 6.3 Gt of carbon dioxide, of which 2.3 Gt is taken up by the seas, 0.7 Gt is used by terrestrial ecosystems, and 3.3 Gt is added to the atmosphere. Hairiah et al. (2009)

Two major issues that humans are currently facing—the loss of biodiversity and rising atmospheric CO_2 levels—both eventually result in a change in the planet's climate (Kumar, 2011). An increase in greenhouse gases (GHGs) in the atmosphere, such as CO_2, is what drives global warming. Strong carbon management is the first step in helping to stop climate change, safeguard human health, and create profitable businesses. A key strategy for lowering GHG emissions is carbon capture and storage. One technique that researchers use to postpone the effects of climate change is learning how to absorb and store carbon dioxide. The significance of this approach in the fight against climate change is becoming more widely acknowledged by the scientific community.

Sequestration is a method used to remove greenhouse gases from the atmosphere (Sreejesh, 2016). As a result of learning about the many advantages of agroforestry, the Indian government released an ambitious National Agroforestry Policy in 2014 to encourage planting trees on farms. To increase smallholder farmers' productivity, income, and standard of life, the strategy aims to integrate diverse agroforestry-focused policies, initiatives, and groups. When India presented the National Agroforestry plan (NAP) at the World Agroforestry Congress in Delhi in February 2014, it became the first country in the world to adopt a full agroforestry plan. Gifawesen et al. (2020) estimate that the agriculture sector is currently to blame for 25% of the world's greenhouse gas emissions. Home gardens with multi-layered canopy and a variety of floral composition can stock C (Above-ground biomass; AGB) from medium to high levels, mimicking secondary forests, as opposed to monoculture systems with annual and perennial crops (Kumar, 2006). Agroforestry has been recognized as a promising tactic in addressing the problem since storing carbon in plants is a practical method to reduce greenhouse gas emissions in the atmosphere (Gedefaw et al., 2014).

Home gardens are considered to be climate-smart, tree-crop integrated, subsistence-level agricultural systems that are resistant to extreme climatic hazards, which is consistent with our findings (Gifawesen et al., 2020). In order to lower atmospheric CO_2 and lessen the effects of climate change, tree-based agroforestry hastens the process of atmospheric carbon sequestration (Wilson and Lovell, 2016). Trees absorb carbon dioxide through the biological process of photosynthesis and store it as carbon in their trunks, branches, leaves, and roots. Furthermore, soil serves as a significant carbon sink in forests due to the fact that it stores carbon. Natural forests, plantations, agroforestry techniques, and a number of other activities all serve as biomass and carbon dioxide (CO_2) sinks via photosynthesis (David and Crane, 2002). Standing biomass from plants, such as wood, and underground plant roots are two examples of long-living carbon pools where the carbon that plants accumulate during photosynthesis is stored. It seems reasonable that larger plants sequester more carbon since biomass is where plants store carbon. Because of this, adding trees to agricultural landscapes will unquestionably improve the capacity of agricultural systems to store carbon (Atangana et al., 2014). Biomass is the term used to describe the entire mass of all organic stuff, both living and dead. When an area's biomass is taken into account (Kuyah et al., 2013), it is expressed in kg per unit area, and when a specific tree is mentioned, it is stated in kg per tree. Carbon makes approximately about half of plant biomass. The most straightforward and accurate pool to measure in agroforestry trees is the above-ground tree carbon pool (Raj, 2014). Deforestation and degradation have a direct impact on this pool. The challenging to quantify belowground biomass of trees is a significant additional carbon sink. The root-to-shoot ratio is often used to gauge belowground root biomass since there is a continuous relationship between the two types of biomass. Standing subterranean vegetation, shrubs, herbs, and cover crops are a few types of herbaceous and understory vegetation that absorb carbon. In sample plots, this pool is classified as damaging. According to Collins et al. (2000) and the entire carbon cycle, the dynamics of soil organic carbon (SOC) are crucial for the long-term productivity of ecosystems. Nair et al. (2009) reviewed soil carbon sequestration in agroforestry in comparison to other land-use systems, noting a general trend of rising soil organic carbon (SOC), an indicator of SCS, in agroforestry and ranking the various land-use systems according to their SOC content in the following order: forests > agroforests > tree plantations > arable crops. In Indian soils, the total SOC pool is thought to be 21 Pg to a depth of 30 cm and 63 Pg to a depth of 150 cm. Lal (2004) estimates that the SOC pool in Indian soils makes up 2.2% of the global pool at 1 m of depth and 2.6% at 2 m. Lal (2004). According to Davis et al. (2017), a variety of factors, including species richness, plantation age, management rigor, spacing, and cropping type, affect the ability of plantation crops to store carbon. Long-term CSP increases are a result of slower-growing species' wood having a higher specific gravity (Nair et al., 2010).

Due to their excellent ability to adapt to and mitigate climate change as well as their role in lowering household food security and nutrition due to rising food prices (Minanget al. 2012; Nair 2012; Galhenaet al. 2013), agroforestry systems have recently attracted increased attention. Since agroforestry systems may retain agricultural output while also capturing carbon, they are an effective alternative for environmental management (Schoeneberger 2009; Kumar and Nair 2011). Establishing links between protected forests, preserving watershed hydrology, conserving soil, increasing farm income, ensuring food security and stable land tenure in developing countries, and restoring and maintaining above- and below-ground biodiversity are some of the secondary benefits that could result (Pandey, 2002). The difficulty with agroforestry systems is preserving the benefits of various tree species while minimizing the negative effects of crop competition (Lott et al., 2000). Homegardens are traditional agroforestry systems that contribute significantly to local biodiversity conservation and provide various ecosystem services. Understanding the composition and structure of homegardens is crucial for assessing their ecological significance. This study focuses on the Homegarden Agroforestry system of the SHUATS Campus in Prayagraj, aiming to evaluate the biomass and carbon sequestration of homegardens during the rainy,winter and summer seasons.

EXPERIMENTAL METHODOLOGY

Direct method involving sampling area i.e. as mentioned above (Homegarden Agroforestry system in SHUATS Campus, Prayagraj) and also based on secondary data. EXPERIMENTAL FINDINGS AND DISCUSSION

MATERIALS AND METHODOLOGY

Study Area: Prayagraj is located at 25.87° North, 81.15° East, and has an elevation of 78 metres above sea level.The study was conducted in SHUATS Campus, Prayagraj. Total six plots and 24 sites were taken for data collection.

Climate: In the South-East of the U.P., have a subtropical climate with both seasonal temperature extremes—winter and summer—predominates. In extremely cold winters, it can get as cold as 32°F in December and January, while in extremely hot summers, it can be as hot as 115°F in May and June. Frost in the winter and sweltering summer winds are also frequent. The annual average rainfall is about 1013.4 millimetres, with the rainiest months being July through September and the winter months seeing sporadic showers.

Data Collection:The dry weight of the herbaceous layer and litter layer was measured in each plot during the rainy, winter, and summer seasons.Harvest the aboveground biomass of each sampled plant, separating leaves, stems, and flowers when applicable. Dry the biomass samples in an oven at a specified temperature until constant weight is achieved. Weigh the dried samples to determine the biomass of each plant component. Randomly select a specified number of litter sampling points within each garden. Collect the surface litter material from each sampling point by systematically sampling a defined area. Remove any non-litter materials (e.g., rocks, twigs) from the collected litter samples. Dry the litter samples in an oven at a specified temperature until constant weight is achieved. Weigh the dried samples to determine the litter biomass. For Carbon Content Analysistake subsamples of the dried biomass and litter samples. Grind the subsamples into a fine powder using a mortar and pestle or a grinding mill. Analyze the carbon content of the subsamples using a carbon analyzer or similar equipment. Calculate the carbon content of the biomass and litter samples.

Data Analysis: Calculate the average biomass and carbon content for each herb species and litter across all homegardens.Calculate the total biomass and carbon sequestration potential of herbs and litter for each homegarden and the entire sample.Analyze the data statistically using appropriate methods (e.g., t-tests, ANOVA) to identify significant differences between herb species, garden sizes, or management practices.

Methodology:

For the purpose of calculating the biomass and carbon content of the understory herbaceous vegetation and litter layer, destructive sampling were employed. Four subplots (quadrats of 1m x 1m area) were sampled for herbaceous vegetation and litter layers at a distance of 1m from the mainplot's exterior boundary in each of the four cardinal directions: N, E, S, and W. An aluminum/wooden square frame measuring 1 m × 1 m will be used to sample the litter layer and herbaceous material at these four subplots (diameter 5 cm). A digital scale wereused to weigh and record each sample of plant material and litter. After thoroughly mixing the samples, 100g of each subsample will be obtained to determine the moisture content.

The samples that were obtained were dried in an oven and by air.The samples will be dried in the oven for at least 48 hours or until they reach their stable weight, with the temperature set between 65 and 70 ^{o}C. In order to calculate the total dry weights, the oven-dryweights of subsamples will be calculated (Hairiahet al., 2001):

$$\text{Total Dry Weight (kg m}^{-2}) = \frac{\text{Total Fresh Weight (kg)} \times \text{Subsample Dry Weight (g)}}{\text{Subsample Fresh Weight (g)} \times \text{Sample Area (m}^{2})}$$

Carbon Content Analysis: A small sample (2 grams) of each one of the herbaceous vegetation and litter layer werepowdered using a mortar and pestle or a grinding mill and 0.5gm same sieved and weighed .sample kept in muffle furnace for five hours at 550^{0}C. weight of the ash was taken for calculating ash%or carbon content .Calculate the carbon content of the biomass and litter samples.

$$\text{carbon content } \% = \frac{\text{weight of the ash}}{\text{Subsample Dry Weight (g)}} \text{x100}$$

Conversion Factor = (100 – ash%) x 0.58

Carbon storage in herbaceous vegetation and litter layer will be computed using the formula (Lascoet al., 2006):

$$\text{Carbon Sequestration/Carbon Density in Herbaceous Vegetation and Litter (Mg C ha}^{-1})$$

$$= \text{Total Dry Weight (Mg ha}^{-1}) \times \text{Carbon Conc.}\,\%$$

[Where, Total Dry Weight = Mg/ ha;   Carbon Conc. (%) = g C/ 100 g biomass]

RESULTS AND DISCUSSION

CARBON SEQUESTRATION OF HERBACEOUS VEGETATION AND LITTER LAYER OF HOMEGARDENS DURING RAINY, WINTER AND SUMMER SEASONS

Carbon sequestration of herbaceous vegetation and litter layer of homegardens during Rainy

Table-1 depicts the data relevant to the calculation of carbon sequestration of herbaceous vegetation and litter layer in homegardens across selected areas of the SHUATS Campus, Prayagrajin Rainy season

TotaldryweightofherbaceousLayer (Kg m^{-2}) and litter layer in Rainy season

Highest value was observed in Intermediate College(0.36 kg m^{-2}) followed by Yeshu Darbar South(0.35kg m^{-2}) Chapel South(0.34kg m^{-2}) Yeshu Darbar North(0.33 kg m^{-2}) Chapel North(0.32 kg m^{-2}) Yeshu Darbar east (0.31 kg m^{-2}) Similar results were also reported by (Liu *et al*., 2017). Highest value was observed in Chapel North(0.161 kg m^{-2}) followed by Intermediate College(0.150 kg m^{-2}), Chapel South(0.146 kg m^{-2}), Yeshu Darbar South(0.142 kg m^{-2}), Yeshu Darbar North(0.133 kg m^{-2}) Yeshu Darbar east(0.130 kg m^{-2}).

Carbondensityofherbaceousand litter layer(MgCha^{-1}) Rainy season

Results revealed that highest carbon density of herbaceous layer were observedinIntermediate College(2.13 MgCha^{-1})followedbyYeshu Darbar South(2.06MgCha^{-1}) Chapel South(1.98 Mg C ha^{-1}) Yeshu Darbar North(1.92 Mg C ha^{-1}) Chapel North(1.89 Mg C ha^{-1}) and Yeshu Darbar east (1.83 Mg C ha^{-1}). Results revealed that highest carbon density of litter layer were observed in Chapel North(0.92 Mg C ha^{-1}) followed by Intermediate College(0.87 Mg C ha^{-1}), Chapel South(0.84 Mg C ha^{-1}), Yeshu Darbar South(0.82 Mg C ha^{-1}), Yeshu Darbar North(0.77 Mg C ha^{-1}), Yeshu Darbar east(0.76 Mg C ha^{-1}).

Table1: Carbon Sequestration of Herbaceous and Litter Layer of Homegarden Agroforestry System during Rainy Season in SHUATS Campus, Prayagraj

Plots	**Total dry weight of herbaceous layer (kg m^{-2})**	**Carbon Sequestration of herbaceous (Mg C ha^{-1})**	**Total dry weight of litter layer (kg m^{-2})**	**Carbon Sequestration of litter (Mg C ha^{-1})**
Yeshu Darbar North	0.33	1.92	0.133	0.77
Yeshu Darbar South	0.35	2.06	0.142	0.82
Yeshu Darbar East	0.31	1.83	0.130	0.76
Chapel North	0.32	1.89	0.161	0.92

Chapel South	0.34	1.98	0.146	0.84
Intermediate College	0.36	2.13	0.150	0.87
F-test	**S**	**S**	**S**	**S**
CD@5%	0.019	0.011	0.016	0.009
SE(m)	0.006	0.004	0.005	0.003
SE(d)	0.009	0.005	0.007	0.004

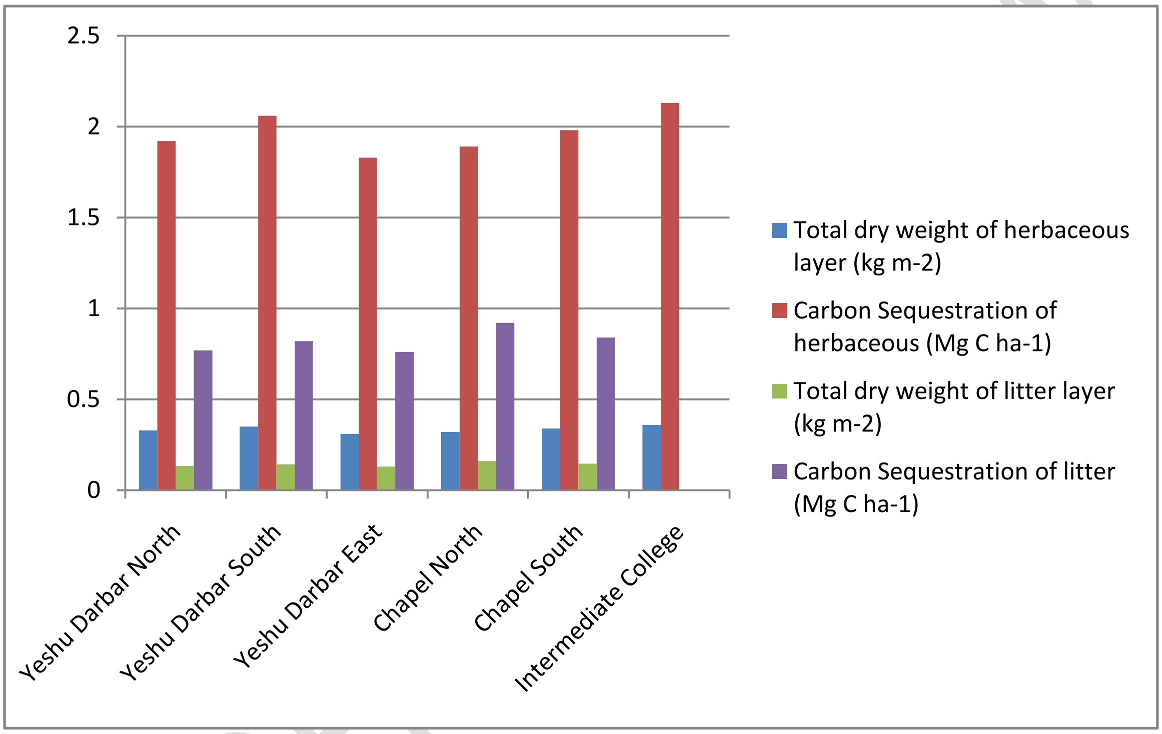


Fig.1:CarbonSequestrationofHerbaceous and Litter LayerofHomegarden Agroforestry System during Rainy Season in SHUATS Campus, Prayagraj.

CARBON SEQUESTRATION OF HERBACEOUS VEGETATION AND LITTER LAYER OF HOMEGARDENS DURING WINTER SEASON

Totaldryweightofherbaceous and LitterLayer (Kg m^{-2}) in Winter season

Highest value was observed in Intermediate College(0.28 kg m^{-2}) followed by Yeshu Darbar South(0.26 kg m^{-2}) Chapel South(0.25 kg m^{-2}) Yeshu Darbar North(0.24 kg m^{-2}) Chapel North(0.23 kg m^{-2}) Yeshu Darbar east (0.22 kg m^{-2}).This is shown in table 2.

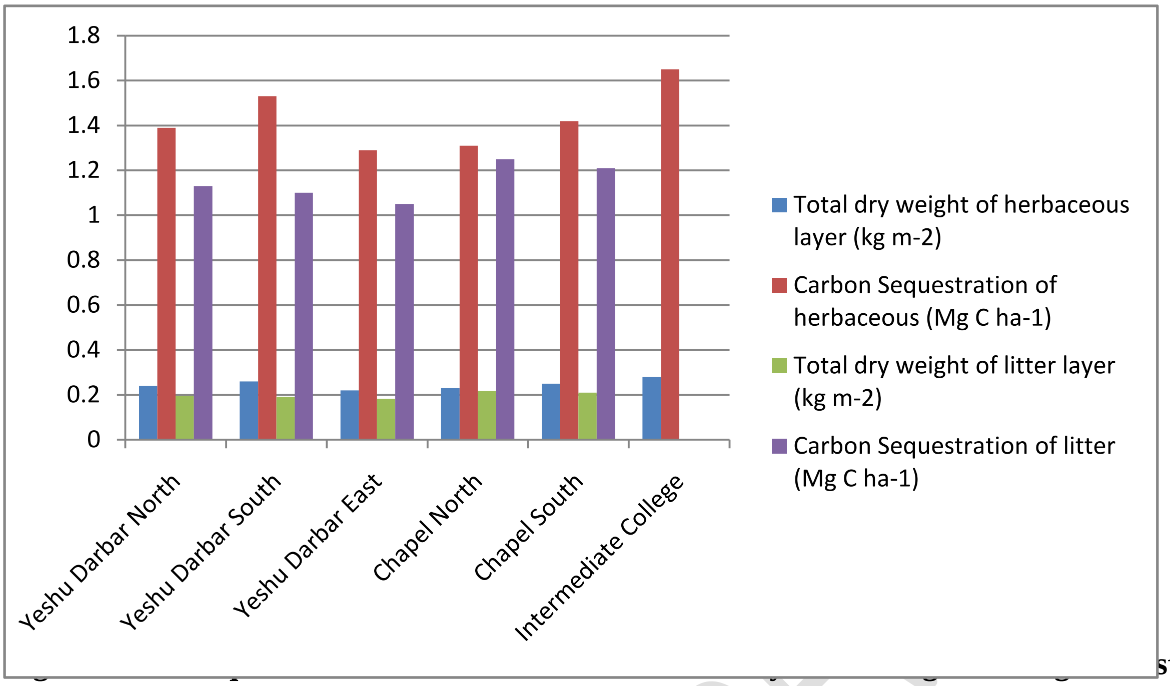
Similar results were also reported by (Liu *et al.*, 2017). litter Layer Highest value was observed in Chapel North(0.216 kg m^{-2}) followed by Chapel South (0.209 kg m^{-2}), Intermediate College(0.205 kg m^{-2}), Yeshu Darbar North(0.195 kg m^{-2}), Yeshu Darbar South(0.191 kg m^{-2}) Yeshu Darbar east (0.183 kg m^{-2}). Surface litter was higher in the AFS system when compared with monoculture, possibly due to an additional litter depositionbytheshadetrees.However,one-timebiomasssamplesdonotreflectthedynamicsof litterfall in the systems.

Carbondensityofherbaceous and Litter layer(MgCha^{-1}) Winter season

Results revealed that highest carbon density of herbaceous layer were observedinIntermediate College(1.65MgCha^{-1})followedbyYeshu Darbar South(1.53 MgCha^{-1}) Chapel South(1.42 Mg C ha^{-1}) Yeshu Darbar North(1.39 Mg C ha^{-1}) Chapel North(1.31 Mg C ha^{-1}) and Yeshu Darbar east (1.29 Mg C ha^{-1})Litter vegetation Results revealed that highest carbon density of litter layer were observed in Chapel North(1.25 Mg C ha^{-1}) followed by Chapel South(1.21 Mg C ha^{-1}), Chapel South(1.190Mg C ha^{-1}), Yeshu Darbar North(1.13Mg C ha^{-1}), Yeshu Darbar South(1.10 Mg C ha^{-1}), Yeshu Darbar east(1.05 Mg C ha^{-1}).

Table-2 Carbon Sequestration of Herbaceous and Litter Layer of Homegarden Agroforestry System during Winter Season in SHUATS Campus, Prayagraj.

Plots	Total dry weight of herbaceous layer (kg m^{-2})	Carbon Sequestration of herbaceous (Mg C ha^{-1})	Total dry weight of litter layer (kg m^{-2})	Carbon Sequestration of litter (Mg C ha^{-1})
Yeshu Darbar North	0.24	1.39	0.195	1.13
Yeshu Darbar South	0.26	1.53	0.191	1.1
Yeshu Darbar East	0.22	1.29	0.183	1.05
Chapel North	0.23	1.31	0.216	1.25
Chapel South	0.25	1.42	0.209	1.21
Intermediate College	0.28	1.65	0.205	1.19
F-test	**S**	**S**	**S**	**S**
CD@5%	0.031	0.018	0.019	0.012
SE(m)	0.010	0.006	0.006	0.004
SE(d)	0.015	0.009	0.009	0.005



...stry System during Winter Season in SHUATS Campus, Prayagraj.

CARBON SEQUESTRATION OF HERBACEOUS VEGETATION AND LITTER LAYER OF HOMEGARDENS DURING SUMMER SEASON

Totaldryweightofherbaceous and LitterLayer (Kg m^{-2}) in Summer season

Highest value shown in table-3 was observed in Intermediate College(0.361kg m^{-2}) followed by Yeshu Darbar South(0.35kg m^{-2}) Chapel South(0.333kg m^{-2}) Yeshu Darbar North(0.311kg m^{-2}) Chapel North(0.309kg m^{-2}) Yeshu Darbar east (0.303kg m^{-2}) this shown in table 3Similar results were also reported by (Liu *et al.*, 2017). In litter layer Highest value was observed in Chapel North(0.228 kg m^{-2}) followed by Chapel South(0.214kg m^{-2}), Intermediate College(0.210kg m^{-2}), Yeshu Darbar North (0.200kg m^{-2}), Yeshu Darbar South(0.190kg m^{-2}) Yeshu Darbar east(0.173kg m^{-2}). Surface litter was higher in the AFS system when compared with monoculture, possibly due to an additional litter depositionbytheshadetrees.However,one-timebiomasssamplesdonotreflectthedynamicsof litterfall in the systems.

Carbondensityofherbaceous and Litterlayer(MgCha^{-1}) Summer season

Results revealed that highest carbon density of herbaceous layer were observedinIntermediate College(2.10 MgCha^{-1})followedbyYeshu Darbar South(2.03 MgCha^{-1}) Chapel South(1.93 Mg C ha^{-1}) Yeshu Darbar North(1.81 Mg C ha^{-1}) Chapel North(1.79 Mg C ha^{-1}) and Yeshu Darbar east (1.76 Mg C ha^{-1})in Litter vegetation Results revealed that highest carbon density of litter layer were observed in Chapel North(1.32Mg C ha^{-1}) followed by Chapel South (1.24Mg C ha^{-1}), Intermediate College(1.22Mg C ha^{-1}), Yeshu Darbar North(1.16Mg C ha^{-1}), Yeshu Darbar South(1.10Mg C ha^{-1}), Yeshu Darbar east(1.00Mg C ha^{-1}).

Table-3: Carbon Sequestration of Herbaceous and Litter Layer of Homegarden Agroforestry System during Summer Season in SHUATS Campus, Prayagraj.

Plots	**Total dry weight of herbaceous layer (kg m^{-2})**	**Carbon Sequestration of herbaceous (Mg C ha^{-1})**	**Total dry weight of litter layer (kg m^{-2})**	**Carbon Sequestration of litter (Mg C ha^{-1})**
Yeshu Darbar North	0.311	1.81	0.19	1.16
Yeshu Darbar South	0.35	2.03	0.18	1.1
Yeshu Darbar East	0.303	1.76	0.16	1
Chapel North	0.309	1.79	0.24	1.32
Chapel South	0.333	1.93	0.22	1.24
Intermediate College	0.361	2.1	0.2	1.22
F-test	**S**	**S**	**S**	**S**
CD@5%	0.013	0.01	0.008	0.005
SE(m)	0.004	0.003	0.003	0.001
SE(d)	0.006	0.005	0.004	0.002

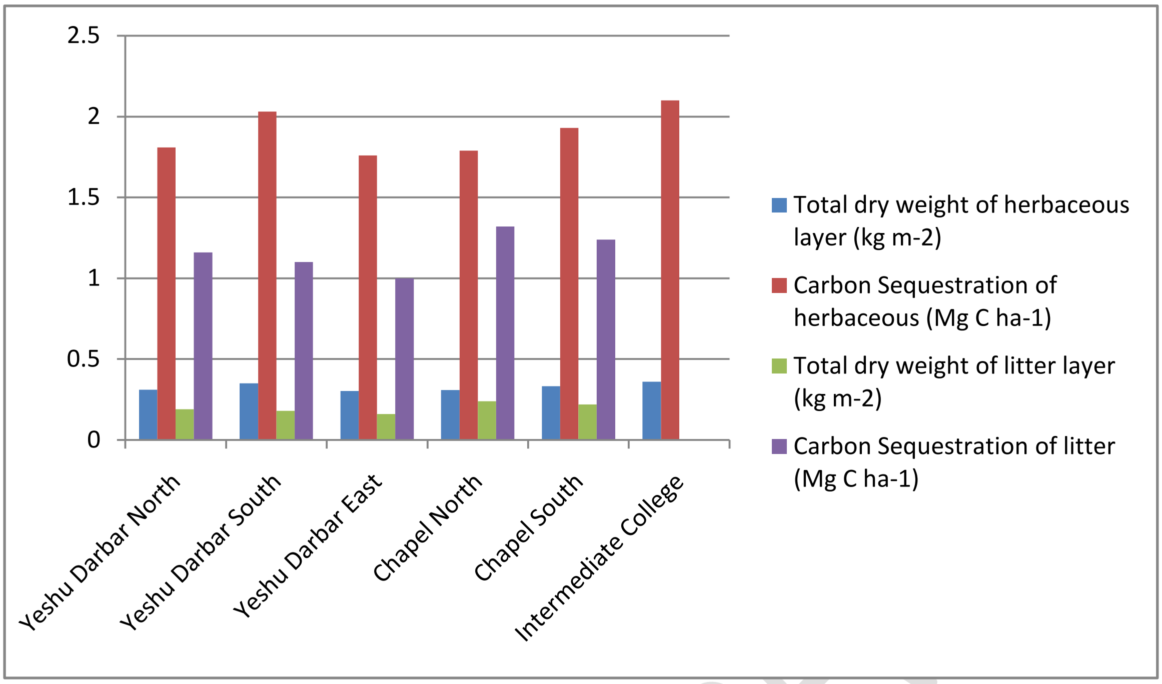


Fig.3:CarbonSequestrationofHerbaceous and Litter LayerofHomegarden Agroforestry System during Summer Season in SHUATS Campus, Prayagraj.

CONCLUSION

Homegardens can play a crucial role in climate change mitigation by sequestering substantial amounts of carbon in their herbaceous vegetation and litter layer.Thehomegarden agroforestry systems in SHUATS Campus, Prayagraj have significant potential for carbon sequestration. The herbaceous layer and litter layer of these systems play a crucial role in capturing and storing carbon. This results highlight the importance of these systems in mitigating climate change by sequestering carbon.From the data, it is concluded thatthe herbaceous layer in homegarden agroforestry systems contributes significantly to carbon sequestration during all seasons. The highest carbon sequestration values were observed in the Intermediate College plot during all seasons, indicating the potential of this system to sequester carbon. The litter layer also contributes to carbon sequestration, although to a lesser extent compared to the herbaceous layer.The carbon sequestration values varied among different plots and seasons, highlighting the importance of considering seasonal variations in carbon sequestration assessments. Further research is needed to assess the long-term carbon sequestration potential of homegardens and to explore management practices that can enhance carbon sequestration in these systems.

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