International Journal of Ecosystems and Ecology Science (IJEES) **Vol. 12 (3):** 123-136 (2022)
https://doi.org/10.31407/ijees **ISSN: 2224-4980** https://doi.org/10.31407/ijees12.3

COMPARATIVE ANALYSIS OF PHYSICO-CHEMICAL PROPERTIES OF SOIL UNDER DIFFERENT AGROFORESTRY SYSTEMS OF DISTRICT CHARSADA

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Received February 2022; Accepted March 2022; Published April 2022;

DOI: https://doi.org/10.31407/ijees12.316

ABSTRACT

Agroforestry is a system of land utilization that describes trees with different crops fused in a single area for farmers' net income. One or more agroforestry practices in one particular area usually have biological, environmental and economical interaction between the compounds. Whilst the main aim of the AFS is not only economic benefits but also modern studies show that AFS could be used as a prime source carbon pool. Up to 12-228-ton ha^{-1}, with an average of 95 ton ha^{-1}, can be stored via the AFS. Trees with crops can raise the carbon stocks to several folds compared to monocrop systems. In order to meet the CO_2 assimilation targets anticipated at Kyoto while simultaneously maintaining sustainable farm production and preventing further deforestation, integration of agricultural practices and systems in C Sequestration and C trade projects can be highly useful. Pakistan is a low middle income with an average annual rate of growth of 216.6 million people. Agroforestry has a very important role and is a key part of Pakistan's daily life, particularly rural people. In Khyber Pakhtunkhwa agroforestry is practiced in various models and shapes from the protection of naturally growing trees to the artificial cultivation of trees on agricultural lands. Agroforestry is an important timber and fuelwood source, with 70 percent of the urban and 97 percent of the rural domestic fuel wood being the main energy source in Khyber Pakhtunkhwa for centuries. Two different agroforestry systems i.e. Agri-silviculture system and Agri-horti-silviculturesystem were selected at District Charsadda Khyber Pakhtunkhwa, Pakistan. Moisture content was calculated by oven dry method. pH and EC was obtained from mettler Toledo meter. Organic matter was obtained by loss on ignition method in laboratory. To calculate soil organic carbon it was assumed that total organic matter contains 58% organic carbon contents or a relation i.e. organic carbon =SOM% multiply by 0.58. Statistical Analysis were conducted using. The jamovi project (2021) Version 1.6. The mean value of SOC for AHS system is 1.76% while that of AS system is 0.916%. The means of two systems are different from each other, the mean SOM value for AHS system was found to be 3.03% and for AS system it is 1.55%. Our results show that soil organic carbon had an inverse relationship with soil pH. High density of carbon in agricultural Lands including agroforestry is related to the high tree diversity that increases plant production hence increased biomass. Litter fall also contributes to C stock accumulation in Soil. It is the most important known pathway Connecting vegetation and soil and is a good indicator of aboveground productivity.

Keywords: Agroforestry, Carbon stock, organic matter ,soil and biomass, Agri-silviculture , Agri-horti-silviculture system.

INTRODUCTION

The significance of various land use systems in stabilizing atmospheric CO2, reducing CO2 emissions, and increasing the carbon sinks of forestry and agroforestry systems is becoming increasingly essential. Forestry has long been acknowledged as a way to reduce and improve CO2 emissions. Forests (or trees) are well-known for their involvement in carbon cycles, and the forest area serves as a significant carbon sink. Land use methods such as reforestation, afforestation, and the character of forests, forestry systems, and agroforestry considerably improve the carbon storage capacity of terrestrial plants. (Murthy et al., 2013). Agroforestry is a land-use strategy that describes trees with many crops intertwined in a single area for the benefit of farmers' net income. The Kyoto Protocol mentioned agroforestry as a viable strategy to greenhouse gas reduction and forestry. Depending on the socio-economic and environmental characteristics of the location, a number of researchers have discovered that tree plantations with crops provide more carbon sequestration than croplands. (Yasin et al., 2019) The main components of agroforestry are trees or bushes (woody perennials, including bamboos). They are kept or planted on farms with the purpose of providing a variety of goods and services, including carbon sequestration and litter fall, improved soil structure, and reduced erosion risk. (Bajigo et al., 2015). Agroforestry systems with a variety of trees can better deal with climate change and store more carbon. When compared to monocrop systems, trees alongside crops can increase carbon stores by many orders of magnitude. In an agrisilvicultural system, for example, 34.61 tonne ha-1 may be reserved against 18.74 tonne ha-1 in a monocrop system. (Yasin et al., 2019) Agroforestry systems are thought to be more likely to store carbon than pasture or field crops. (Pokhrel et al., 2020). Agricultural land can store 850-900 million tonnes of carbon per year, biomass croplands 550-800 million tons per year, and forests 1000-3000 million tons per year. (Albrecht and Kandji, 2003) (Pokhrel et al., 2020). Agroforestry systems (AFS) are well known for their economic, environmental, and agricultural importance. While carbon sequestration is not the primary goal of the AFS, contemporary research and studies suggest that adequate carbon may be stored in both above and below ground biomass. The AFS can hold up to 12-228 tons ha-1, with an average of 95 tons ha-1. (Nair et al., 2009). AFS is now found in depths of up to 1 m from 30 to 300 tone C/ha and at 0.29-15.21 tonne C/ha/year above ground. As a result, the AFS sequestration potential is the most viable carbon sequestration alternative. (Gul, 2017). Pakistan is a low-middle-income country with a population growth rate of 216.6 million people on a yearly basis. Agroforestry has a significant role in Pakistani society, particularly among rural people. (Nawaz et al., 2016) Pakistan recently accepted the Paris Agreement on Climate Change to reduce greenhouse gas emissions in order to avert the most severe consequences of climate change. Unfortunately, Pakistan's earth-based carbon sequestration is low in South Asia due to a lack of forestry resources. Agroforestry systems, on the other hand, may address both food insecurity and carbon reduction goals. (Yasin et al., 2019). Agroforestry is done in Khyber Pakhtunkhwa in a variety of forms and styles, ranging from the preservation of naturally occurring trees to the artificial planting of trees on agricultural fields. The most traditional kind of agroforestry in the province is a complex agri-silvo-pastoral system that integrates native trees, shrubs, grasses, crops, and animals on farmland. It generally occurs at the level of livelihood. (Ali et al., 2011). According to a farm inventory, 80 million trees are farmed on farms, 67 percent of which are irrigated and 33 percent of which are planted in rainforest. The province's average tree density was 47 trees per hectare. Poplar is the most common tree species planted on farms, accounting for 24% of the total tree stock. (Amjad 1991 and ali et al., 2011). Soils are the world's third biggest carbon pool, after oceanic and geological pools (oil, natural gas, and coal), and the largest carbon pool in the terrestrial environment. (Ciais et al. 2014; Siqueira et al., 2019) Soils have a significant role in the global carbon budget. (Harrison et al., 2007). Currently, the sink absorbs around 30% (C) of the carbon (F) released into the atmosphere through fossil fuel burning and cement manufacturing (including soil and vegetation). (Le Quéré et al., 2014). The objective of this study is to compare SOC stocks in two different AFS i.e. AS and AHS system, as well as to determine the trends in soil organic matter, soil pH, bulk density, EC and moisture content of soil samples from two different fields as there was no significant study in Pakistan especially Khyber Pakhtunkhwa pertaining to soil organic carbon of several agro-forestry systems.

MATERIALS AND METHODS

Description of study area

The District Charsadda Located at an elevation of 302m / 991feet above sea level, lies between 34-03' and 34-38' north latitudes and 71-28' and 71-53' east longitudes. Charsadda is located in the west of the Khyber Pakhtunkhwa and is bounded by Malakand District to the north, Mardan district to the east, Nowshera and Peshawar districts to the south and the Mohmand Agency of the Federally Administered Tribal Areas to the west. The district covers an area of 996 square kilometers (243753 acres) (Khan et al., 2018). Total cultivated area is 210255 acres (61 %), irrigated area is 180339 acres, i.e. 86% of the total cultivated area. Charsadda has a Humid subtropical, no dry season climate (Classification: Cfa). The district’s yearly temperature is 19.74ºC (67.53ºF) and it is -1.15% lower than Pakistan’s averages. Charsadda typically receives about 132.48 millimeters (5.22 inches) of precipitation and has 146.4 rainy days (40.11% of the time) annually The temperature here averages 22.5 ºC. In studied area, there is sufficient amount of rainfall occur throughout the year. The average annual rainfall is 460 mm. the driest month is June, with 11 mm of rainfall with an average of 82 mm, the most precipitation falls in the month of August. The difference between the driest month and the wettest month is 71 mm. Soil of studied area having different types of soil texture therefore vegetation also is of different type. Some of the studied area has sandy soil and some area has loamy soil. In studied area the sandy loam soil occurred therefore dense vegetation occur in studied area. (Enterprises & Authority, 2009).

Methodology

Soil Sampling

A soil sample should be made up of several sub-samples that represent a seemingly uniform area or Field with similar cropping and management history. The sampling was carried out in district Charsadda village Sherpao on October 12 ,2021.The weather was clear with no precipitation Random composite sampling method was used for sample collection. Soil samples were collected from two depths as 0-10 cm and 10-20 cm in each agroforestry systems. Plant residue, litters were removed first from soil surface. Ten composite samples were collected randomly from each agroforestry systems. Depth wise total 20 samples were collected from one agroforestry system. Composite samples were then mixed well, crushed and sieved with 2mm sieve. the samples were collected by random method. (Estefan et al., 2001). A uniform slice should be taken from the surface to the depth of the tool's insertion, with the same volume of soil obtained in each sub-sample.Augers, on the whole, meet these requirements.(Fourqurean et al., 2015). The moisture content of soil also referred to as water content, is an indicator of the amount of water present in soil. Moisture content is the ratio of the mass of water contained in the pore spaces of soil to the solid mass of particles in that material, expressed as a percentage. The method is taken from ASTM D2216: Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass. A standard temperature of 110 ± 5°C is used to determine the mass of the sample. ASTM D2216. Clean, dry and weight W_1 container. The balance needs to be tarred before it is used to measure the weight. Then Weight W_2 a sample of the specimen in the container. Keep the container in the oven for 24 hours. Dry the specimen to a constant weight, maintaining the temperature between 105°C to 115°C. (The time will vary with the type of soil, but 16 to 24 hours is usually sufficient Record). The final constant weight W_3 of the container with the dried soil sample. Peat and other organic soils should be dried at a lower temperature (approximately 60°C) for a longer period of time.

Calculations/ Data Analysis

Moisture content of the given soil sample = $M_w/M_s \times 100\%$. Where Weight of water in the soil sample= $M_{w,}$ $M_{w=}$ weight of wet soil – weight of dry soil weight of the dry soil.= M_s ASTM D2216 (2019). Soil pH, which is defined as the negative log of hydrogen ion activity, is an important soil indicator. The pH range found in soils typically ranges from 3 to 9. pH was analyzed by Mettler toledo pH meter using 1:5 ratios of soil and water.50ml of distilled water is used in100 ml of glass beaker and 5 gm of finely crushed soil is used in a glass beaker. (Salve & Bhardwaj, 2020). Soil salinity refers to the concentration of soluble inorganic salts in the soil. The electrical resistance of a 1:5 soil:water suspension was measured with a Mettler Toledo conductivity cell to determine electrical conductivity (EC). In a 100 ml glass beaker, 50 ml of distilled water was used, and 5 gm of finely crushed soil was used. (Piper, CS 1942). Organic matter in soil was estimated through the loss on ignition (LoI) method (Schumacher 2002; Rehman et al. 2011). This involves the burning of organic matter at high temperatures of 350–440 °C (Nelson and Sommers 1996; Schumacher 2002). A 50-g sample of dehydrated soil was placed in a china dish in a muffle furnace and the tempera- ture was set at 400 °C. The furnace was run continuously for 8 h to burn the samples to ash. The weight of ash was recorded for each sample and organic matter was deter- mined using Eq. 7 (Rehman et al. 2011 and Ali et al., 2020).

$$OM = Wd - Wa \quad (7)$$

Where OM is organic matter (g), Wd weight of oven- dried sample (g), Wa weight of ash (g) Soil organic carbon (SOC) was calculated using a factor of 0.58 (Rehman et al. 2011). (Ali et al., 2020). Bulk density was obtained by SPAW hydrology software of 6.02.75 version using the data of silt and clay as input. Silt and clay was found by volumetric method in laboratory (Girei et al., 2016). Analysis were conducted using The jamovi project (2021). Jamovi. (Version 1.6), R Core Team (2020) R (version4.0) fox,j.,& weisberg,S.2020 CAR. companion to applied [regressionR package]. The assumption of normality were tested by Shapiro wilk test and homogeneity of variances were tested by levene's test. Independent sample t test with 5% significance level were performed using jamovi version 1.6 mendeley software version 1.19.8 were used for citation and referencing. SPAW hydrology was used for finding bulk density. Microsoft excel 2007 were also used for data compilation.

RESULTS AND DISCUSSION

Table 1. Showing Group Descriptive

Showing Group Descriptive	descriptive data					
	Group	N	Mean	Median	SD	SE
moisture content	Agri horti silvi	10	3.81	3.84	0.593	0.1876
	Agri silvi	10	3.948	3.705	0.954	0.3017
pH	Agri horti silvi	10	7.920	8.35	0.241	0.0761
	Agri silvi	10	8.330	7.900	0.155	0.0490
EC	Agri horti silvi	10	1454.80	1463.00	6.579	2.0806
	Agri silvi	10	1463.80	1455.500	3.615	1.1431
SOC	Agri horti silvi	10	1.76	1.04	1.566	0.4951
	Agri silvi	10	0.918	0.560	0.698	0.2209
Som	Agri horti silvi	10	3.03	1.80	2.663	0.8422
	Agri silvi	10	1.555	0.880	1.224	0.3870

Normality test

The first step in using the independent samples t-test is to test the assumption of normality, where the Null Hypothesis is that there is no significant departure from normality.

Null Hypothesis:

$$H0: \sigma^2{}_1 = \sigma^2{}_2$$

The Alternative Hypothesis is that there is a significant departure from normality, as such; rejecting the null hypothesis in favor of the alternative indicates that the assumption of normality has not been met for the given sample

Alternative Hypothesis:

$$Ha: \sigma^2{}_1 \neq \sigma^2{}_2$$

The results of moisture, soil pH, electrical conductivity, soil organic matter and soil organic carbon as shown in descriptive table were subjected to normality test using Shapiro wilk test (Table 1). shows that all the resultant p value for moisture, content soil pH, Electrical conductivity is greater than 0.05 (significance level or α) ($p > 0.05$) thus we accept the null hypothesis but the p value for soil organic matter and soil organic carbon is less than the significance level i.e ($p<0.05$) therefore we reject the null hypothesis.

So, we assume that the data for moisture content, soil pH and electrical conductivity are normally distributed within each of two populations as can be seen in Q-Q plots while soil organic matter and soil organic carbon are not normally distributed.

Table 2. Showing data of normality Test, Normality Test (Shapiro-Wilk)

Assumptions		
Note. A low p-value suggests a violation of the assumption of normality		
	W	P
moisture%	0.950	0.372
pH	0.976	0.868
EC	0.965	0.642
SOC	0.871	0.012
SOM	0.867	0.011

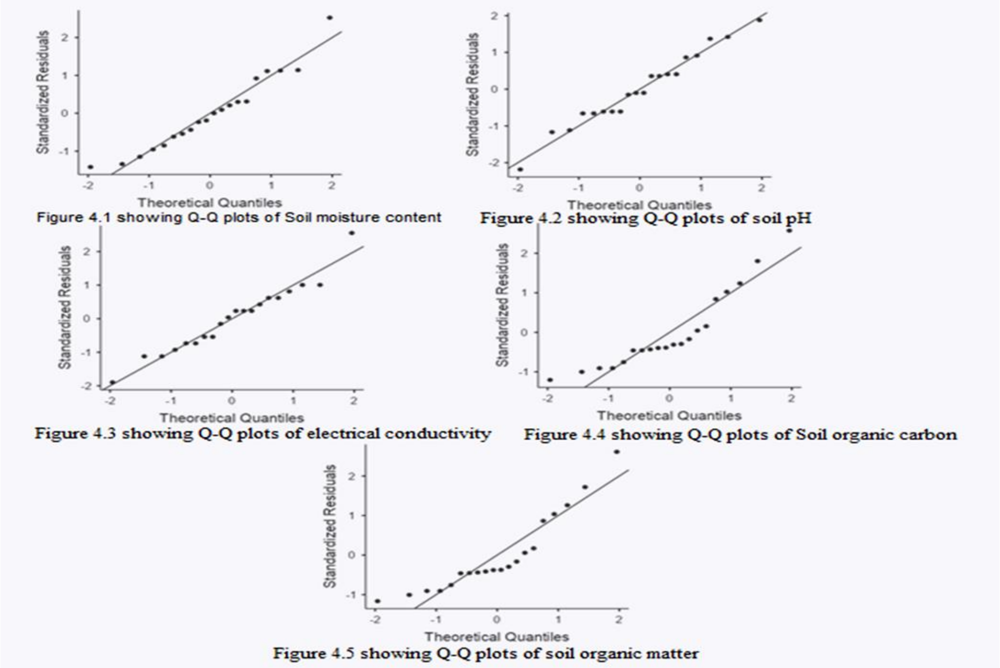

Figure 4.1 showing Q-Q plots of Soil moisture content

Figure 4.2 showing Q-Q plots of soil pH

Figure 4.3 showing Q-Q plots of electrical conductivity

Figure 4.4 showing Q-Q plots of Soil organic carbon

Figure 4.5 showing Q-Q plots of soil organic matter

Figure 1. Homogeneity of variance

Another of the first steps in using the independent-samples t test statistical analysis is to test the assumption of homogeneity of variance, where the null hypothesis assumes no difference between the two group’s variances. The homogeneity of variances test was conducted on the data table using levene’s test. The Levene’s test uses the level of significance set a priori for the t test analysis (e.g., $\alpha = .05$) to test the assumption of homogeneity of variance. Table 3 shows that the data of moisture content, soil pH and electrical conductivity has a p value more than the significance level (α=0.05), therefore we retained the null hypothesis and concluded that the variances are equal while that of soil organic matter and soil organic carbon is less than the significance level thus we reject the null hypothesis and concluded that the variances are not equal.

Homogeneity of Variances Test (Levene's)

Note. A low p-value suggests a violation of the assumption of equal variances

Table 3. Showing data of homogeneity of variance test

	F	df	df2	P
moisture%	2.26	1	18	0.150
pH	1.76	1	18	0.201
EC	3.21	1	18	0.090
SOC	6.71	1	18	0.018
SOM	6.22	1	18	0.023

Table 4. Independent Samples T-Test, *95% Confidence Interval*

	Statistic		Df	P	Mean difference	SE difference	Lower	Upper
moisture%	Student's t	0.391	18.0	0.700	0.139	0.3553	-0.607	0.885
	Welch's t	0.391	15.1	0.701	0.139	0.3553	-0.618	0.896
pH	Student's t	4.531	18.0	< .001	0.410	0.0905	0.220	0.600
	Welch's t	4.531	15.4	< .001	0.410	0.0905	0.218	0.602
EC	Student's t	3.791	18.0	0.001	9.000	2.3739	4.013	13.987
	Welch's t	3.791	14.0	0.002	9.000	2.3739	3.908	14.092
SOC	Student's t	1.555a	18.0	0.137	0.843	0.5422	-0.296	1.982
	Welch's t	1.555	12.4	0.145	0.843	0.5422	-0.334	2.020
SOM	Student's t	1.591a	18.0	0.129	1.475	0.9269	-0.472	3.422
	Welch's t	1.591	12.6	0.136	1.475	0.9269	-0.533	3.483

The independent-samples t test was conducted with a significance level of 5 % to evaluate the difference between the means of independent groups of two agroforestry systems i.e AS system and AHS system. As the assumption of normality and homogeneity of variances were found to be significant for moisture content, soil pH and electrical conductivity so we will use student's t test for them while we will use Welch's test for soil organic matter and soil organic carbon as they are not significantly normal and there is a significant difference between the variances of two groups. Moisture content has a p value of 0.700 (student's t test) which is greater than the significance level i.e $p>0.05$ as indicted in table 4 thus we accept the null hypothesis and assume that there is no significant difference in the mean of moisture content of the two agroforestry system and the data is not statistically significant .the mean MC% of

AHS system is 3.80 and of AS system

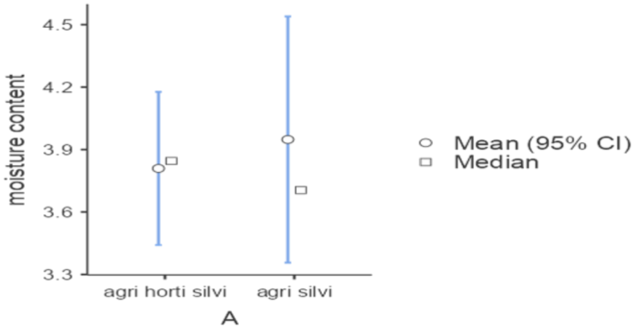

Figure 6. Showing comparison of mean moisture content of two AFS

Soil pH

Soil pH has a low p value (<0.001) than the significance level ($p<0.05$) therefore we reject the null hypothesis of no difference and assume that the pH of two agroforestry system is statistically significant in their mean as can be seen in table 4 the mean pH of AHS system is 7.9 which is slightly lower than AS system of 8.3 as shown in figure 7.

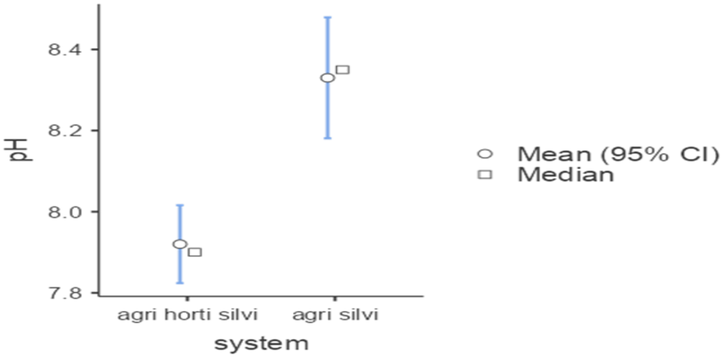

Figure 7. showing the comparison of mean pH of two AFS

Electrical conductivity

Electrical conductivity of two agroforestry system is found to be statistically significant i.e $p<0.05$ in their means. The p value for EC is 0.001 which is less than the significance level thus we reject the null hypothesis of no difference and conclude that the electrical conductivity of AHS (M=1453.80 µs/cm) is lower than that of AS system (M=1463.80 µs/cm) as shown in figure 8.

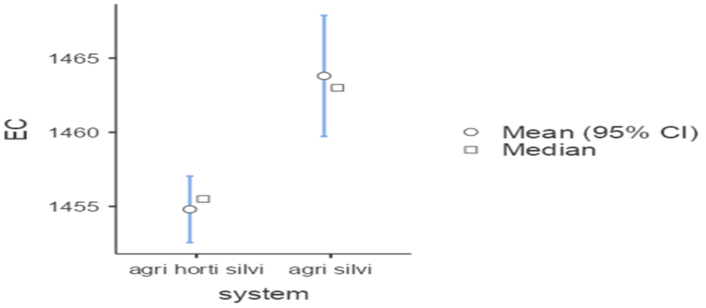

Figure 8. Showing comparison of mean EC of two AFS

Soil organic matter

Soil organic matter is found to have a p value of 0.136 as shown in table 4 which is higher than our significance level of 0.05. So, we accept the null hypothesis of no difference and assume that the data is not statistically significant. But the means of two systems are different from each other. The mean value for AHS system was found to be 3.03 and for AS it is 1.55 as shown in figure 9. We conclude that the differences between the two Means are likely due to chance and not due to any independent variable manipulation.

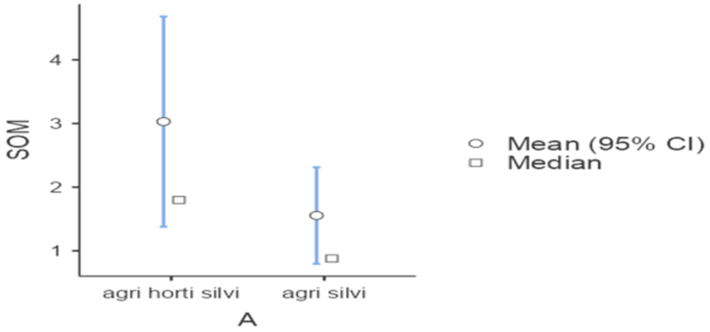

Figure 9. Showing comparison of mean SOM% of two AFS

Soil organic carbon

Soil organic carbon has a p value of 1.45 as shown in table 4, which is greater than the significance level of 0.05 i.e $p>\alpha$. Therefore, we accept the null hypothesis of no difference and assume that there is no statistically significant difference between the means of soc of two agroforestry system. But the mean value as seen in descriptive table for AHS system is 1.76 while that of AS system is 0.916 as shown in figure 10. We conclude that the differences between the two Means are likely due to chance.

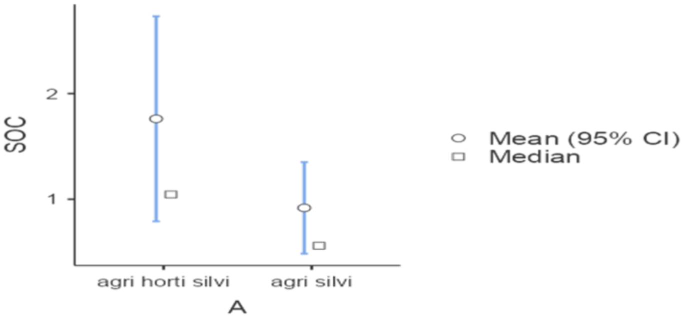

Figure 10. Showing comparison of mean SOC% of two AFS

Bulk density

The results for soil bulk density in the top 20-cm layers of two agroforestry systems are shown in Fig 11. Mean bulk densities of AS system and AHS system were found to be 1.44gm/cm^3 and 1.18gm/cm^3, respectively.

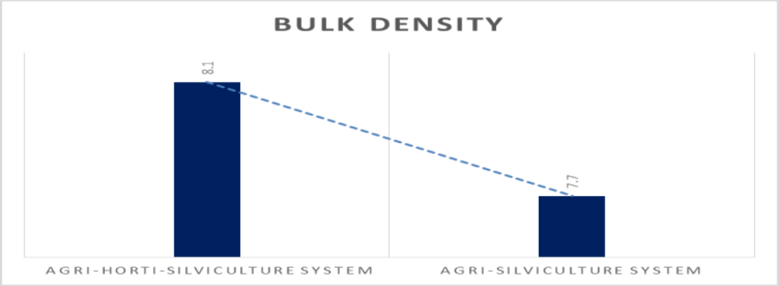

Figure 11. Showing comparison of mean BD of two AFS

Discussion

After collection and processing of the samples their results were recorded. Table 1 indicates the comparative results of both AS and AHS systems. As summarized in table 1, the percentage moisture content of the agri-silvi system was found to be 3.94±0.95%, which higher than the agri-horti-silvi system of 3.81±0.59%. It was further observed that the pH of AS system was 8.33 ± 0.15 as compare to AHS system which was 7.92±0.24 that is slightly less than agri-silvi system. The EC of AS system was 1463.80±3.61ps/cm as compare to agri-silvi-horti system that was 1454±6.57ps/cm that is slightly lower than AS system. The SOC of AS was 0.918±0.69% as compare to AHS system that was 1.76±1.56% that is slightly higher than agri-silvi system. At final the SOM of AS system was 1.55±1.22% as compare to AHS system that was 3.03±2.66% that is also slightly higher than AS system. In our study the mean moisture content observed under AHS system was 3.80% while that of AS system was 3.95%. The reason behind the low moisture content under tree based system was due to deep root system of tree species which absorb more water as compared to sole cropping system The results of Devi et al.(2020) shows Mean soil moisture percentage with respect to depth followed the order: 60- 90>30-60>15-30>0-15 cm and this was significantly higher under control (12.6%) followed by Kinnow +wheat (11.7%) and lowest under Kinnow +Eucalyptus +wheat system (10.7%). Similarly, Alemie (2009) also reported soil moisture reduction under Eucalyptus plantations with the reductions being highest at distances nearer to the tree. According to Li et al. 2011 the soil moisture content was observed significantly higher in AS system than AHS system.SM conditions are an important environmental factor that controls survival and activity of microorganisms in soils. The rapid change in SM may cause osmotic shock, inducing cell lysis and release of labile intracellular substrates (Li et al. 2011). Therefore, SM plays a key role in controlling soil respiration (SR) and can replace temperature as the dominant factor affecting soil carbon dioxide (CO2) effluxes. However, seasonal changes in soil and air temperature may lead to change in SM, thus influencing microbial activity and SR. Wang et al., (2013).Changes in soil moisture can affect the composition and function of soil microbial community due to differences in drought tolerance among taxonomic and functional groups of microorganisms. For example, fungi can survive drought stress better than bacteria due to their ability to grow at lower metric potentials. (Zhao et al., 2014).

Data presented in (Figure4.7) revealed that soil pH was higher in AS system (8.3) which was significantly followed by AHS system (7.9). pH is a measure of the acidity of the water or soil based on its hydrogen ion concentration and is mathematically defined as the negative logarithm of the hydrogen ion concentration, or pH = -log[H+], where the brackets around the H+ symbolize "concentration". The pH of a material ranges on a logarithmic scale from 1-14, where pH 1-6 are acidic, pH 7 is neutral, and pH 8-14 are basic. Lower pH corresponds with higher [H+], while higher pH is associated with lower [H+]. Monica et al., 2021. As moisture increased, pH increased, whereas redox potential (Eh) decrease. (Zárate et al.,2006). The pH of AHS system was lower because of more leaf litter accumulation which on decomposition relese acids and the use of fertilizers and farmyard manure also contribute to lower the pH. 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 Fertilizers, was also reported by Dang and Verma, (1996). 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 (D2) which was significantly differed with upper soil at (0-15cm) depth (D1). Soil pH was less at upper soil due to the continuous use of Farm yard manure in agriculture soil result decrease soil pH value at the surface layer. The plant residues also affect the pH of the soils so AHS system has higher pH as in comparaison with AS system may be due to the accumulation of plant residues in AS system. Wang et al., (2013).

The EC of AHS system (0.1454 siemens/metre) was slightly lower than AS system (0.1463 s/m). The reduction of EC under the tree cover can be attributed to accumulation and subsequent decomposition of organic matter which releases organic acids. Devi et al. (2020) also found a same result, the electrical conductivity of soil was significantly reduced under tree based system by 25% and 15.9% under kinnow + eucalyptus + wheat system and kinnow + wheat system respectively. Dalal et al. (2015) during an experiment observed lesser electrical conductivity and pH under AHS system (0.014- 0.018 S/m) than sole crops (0.022-0.026 S/m). They also observed decrease in electrical conductivity and pH with increase in depths. Electrical conductivity (EC) of soil is a measure of the soil's ability to conduct an electrical current. Most importantly for fertility, EC indicates nutrient availability in the soil. The higher the EC, the more negatively charged sites (clay and organic particles) must exist in the soil, and thus the more cations (which have a positive charge) must be held in the soil. The general rule of thumb for salinity is that extremely high EC values (>1600 mS/m) indicate highly saline soils. Low EC values (0-200 mS/m) on the other hand, indicate the presence of non-saline soils. Sodium is the cation that has the greatest influence on salinity, especially when it exceeds 100 mg/kg in the soil. The EC is more when more moisture is present in a soil, the higher the EC reading at that time will be. This is because the more moisture there is, the more cations are in solution in the soil. In basic terms, water is a good electrical conductor in itself, therefore the more water there is in the soil, the better the soils ability to conduct an electrical pulse (Marno fourie 2019).

The mean soil organic matter percent of 10 samples from each agroforestry system was found to be 1.554% and 3.03% for AS system and AHS system, respectively as shown in figure 4.9. The SOM is high in AHS system as compared to AS system because the first one has more number of trees than the other Soil organic matter (SOM) is a critical component of soil fertility, productivity, and quality, and its depletion is thought to have a wide range of negative effects on crop productivity. It is critical to maintain and improve its level in the soil in order to ensure soil quality, future productivity, and sustainability (Haynes 2005). According to Chan et al. (2000), certain fractions of soil organic matter are more important in maintaining soil quality and, as a result, are more sensitive indicators of the impact of management practises. (Ramesh et al,.2015). Organic matter is commonly thought to reduce soil pH by releasing hydrogen ions associated with organic anions or by nitrification in an open system (Porter et al. 1980). On the other hand, it may cause pH increases due to the mineralization of organic anions to CO2 and water (thereby removing H +) or because of the organic material's 'alkaline' nature (Helyar 1976). Plant material's 'alkaline' nature results from the dissociation of organic acids (metabolised within the plant) in response to a cation/anion imbalance caused by NH4+ uptake or N z fixation. The plant corrects this imbalance by excreting H+ ions, which increases the percentage dissociation of organic acids (i.e. the anion concentration) within the plant. (Israel and Jackson 1978 and Ritchie et al,.2018). As the clay content of the soil increases, so does the organic matter. This increase is the result of two mechanisms. For starters, the decomposition process is slowed by bonds between the surface of clay particles and organic matter. Second, higher clay content soils have a higher potential for aggregate formation. Organic matter molecules are physically protected by macroaggregates from further mineralization caused by microbial attack (Rice, 2002). When earthworm casts and the large soil particles they contain are split by the combined action of several factors (climate, plant growth, and other organisms, for example), nutrients are released and made available to other components of soil microorganisms. Fine textured (clayey) soils have two to four times the organic matter content of coarse textured (sandy) soils under similar climate conditions (Bot and colleagues, 2005).

The data of soil organic carbon for 10 samples from each agroforestry system is shown in the figure4.10. The mean SOC% for AS system and AHS system were found to be 0.91% and 1.76 percent, respectively. The SOC is high in AHS system than AS system because of high organic matter in the first system. Goswami et.al. 2014 reported the soil organic carbon in Kwalkhad watershed Himachal Pradesh, India as 1.71% and 1.82% in agri-silviculture system and agri-horti-silviculture system which is a slightly higher than our estimates. This is possibly due to the fact that soil samples were taken from greater depths, i.e., 40 cm compared to our sampling depth of 20 cm. 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. Our study shows that organic carbon increased with increasing organic matter, which can be owed to continuous accumulation of leaf litter and slower decomposition in AHS system due to low soil temperature than AS system. The Carbon Sequestration rates in some major agroforestry systems around the world are highly variable, ranging from 0.29 – 15.21 tonnes ha yr (Nair et al., 2010) and differs greatly Depending on a number of factors, like the Agro- climatic region, the type of system, site Quality, previous land use, management Practices adopted, etc. In agroforestry systems the carbon stored in soil ranges from 30-300 tonnes C ha up to one meter depth (Nair et al.,2010). Carbon Sequestered in agroforestry systems depends on the quantity and quality of biomass added Through trees and soil parameters such as soil Structure and aggregation. In a poplar system an increase in soil carbon to the extent of 6.07 tonnes ha yr and higher carbon content was Observed in 0-30 cm depth in sandy clay Compared to loamy sand. About 69% of soil Carbon in the profile was confined to the upper 40 cm soil layer wherein carbon stock ranged from 8.5 to 15.2 tonnes C ha. A mix of Agroforestry with crop fields is a promising Option to enhance C sequestration in soils. The average potential of agroforestry has been estimated to be 25 t C / ha. (Ravindranath and Sathaye, 1998).

The bulk density in AHS system is low i.e 1.18g/cm3 whereas AS system has a high bulk density i.e 1.44g/cm3 because this system has more soil organic matter than the other system, making the soil porous and rich. Pokhrel et al.,2020 found the BD of two different agroforestry systems as 1.38 g cm-3 in Terai and 1.076 g cm-3 in Mid-hills region. Soil bulk density values had a significantly negative relationship with organic carbon resulted by Sakin et al., (2011). 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); Kaur and Bhat, (2017) supported this investigation. 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 is also subjective to bulk density; 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.

CONCLUSIONS

The findings of this study indicated that agroforestry system potential to C storage depends on the biomass components and management practices. Trees in particular play substantial roles for enhancing biomass C stocks in agroforestry. Moreover, soil is a vital component in preserving significant amount of C in the system. This will also enhance soil fertility, productivity and food security. Thus, valuing the C storage potential of agroforestry help to promote the ecosystem services of the system, and boost up its acceptance in sustainable natural resource management strategy throughout the world. The MC%, pH, EC, SOC% and SOM% for AHS system was found to be 3.81%, 7.9, 1454.80ps/cm, 1.76% and 3.03% while that of AS system was 3.94%, 8.3, 1463.80ps/cm ,0.918% and 1.55% respectively. Comparison of Different agroforestry systems for soil organic carbon stock revealed the superiority of AHS system followed by AS system. The results provide valuable information about the potential of AFS to promote the capture of atmospheric CO2 and mitigate the agricultural contribution to climate change.

Recommendations. The comparison of two agroforestry systems, AS system and AHS system, revealed differences in carbon accumulation. Because AHS systems have a higher potential to accumulate carbon than AS systems, the system play a greater role in combating the climate change crisis than AS systems. There are some recommendations to be incorporated in future agroforestry systems to enhance the carbon accumulation process. The capacity of carbon build up in an AHS and AS system might be increased by planting as many trees as possible on agricultural fields without having any negative agroforestry effects on field crops. Proper management measures should be used to reduce soil deterioration and thereby increase the soil carbon pool. Technical help should be provided to farmers in order to enhance farmer awareness of various agroforestry methods. Forest regulations should be adjusted to satisfy the current carbon accumulation needs and demands of agroforestry systems. Pasture lands should be expanded to relieve strain on other agroforestry systems for carbon pool protection. Enrichment planting yields positive outcomes as well; planting a variety of species provides soil organic carbonyl, ecological, and environmental benefits. The report also suggests multipurpose activities such as biodiversity protection, sustainable forest management, and carbon management. Because recent climate policies, such as REDD+, incentivise payment for carbon sequestration, precise and accurate agroforestry systems should be used. The study also suggests that the agri-silvi system in the Peshawar region be improved in order to create more and more carbon credits. A proper agroforestry management plan should be developed, with the primary goal of increasing carbon stock.

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