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Study of carbon stocks in agroforestry systems of district Peshawar, Khyber pukhtunkhwa , Pakistan

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The current studies show that the agroforestry system could be used as a prime source of carbon pool. Up to 12-228 tons ha^{-1}, comprising mean of 95 tons ha^{-1}, can be stored via the agroforestry systems. Agroforestry systems with different trees can deal with climate change more efficiently and sequester more carbon. The crops that consist of trees can raise stocks of carbon to many folds while making in comparison with the single crop system. In Khyber Pakhtunkhwa agro forestry is practiced in various models and shapes from the protection of naturally growing trees to the artificial cultivation of trees on agricultural lands. The bulk density of the silvo pastoraloral system is 1.346 gm/cm^{3}which is more than the agrisilvisystem which is found to be 1.251 gm/cm^3. The lower bulk density in the AgriSilvisystem showed less compaction of soil resulting in enhanced vegetation. The bulk density was founded with the help of soil particle analysis. To calculate soil organic carbon it is assumed that total organic matter contains 58% organic carbon contents or a relation i.e. organic carbon =SOM% multiplied by 0.58 statistical Analyses was conducted. Higher SOC indicates AgriSilvi system shows fertility of the soil. The mean value of soil organic carbon for agrisilviculture system is 2.65 while that of the Silvopastoral system is 2.23. The mean value of SOM for agrisilviculture system was found to be 4.56 and for Silvopastoral system it is 3.84.The percentage of SOM was determined with the help of loss on the ignition method. The higher SOM in the agrisilvi system helps in an increase in the productivity of the soil. The enhanced density of carbon in the fields of agriculture particularly depends upon the diversity of high trees those results in an enhancement of biomass and the production of plants. In soil carbon stock the fall of litter also plays its role. In above-ground production, it plays aprominent role in the connection of soil with vegetation.

Keywords: Agroforestry, Carbon stock, Agriculture Land, Silvopastoral system, Peshawar

INTRODUCTION

The term Agroforestry is basically a land-use system that is used for describing and raising trees with different agricultural crops that are united together in the same unit of area in order to gain some economic values to farmers. (Yasin et al. 2019).Under the guidelines of the Kyoto Protocol, the agroforestry has been used as one of the tool in order to control greenhouse gases and along with this approach it can also be used as one of the agro forestry methods. Many scientists have realized that raising trees with different vegetation results in more carbon absorption compare to monocrop systems keeping in view the environmental and soil organic carbon and economic condition of that particular area.(Yasin et al. 2019)Unfortunately the importance of agroforestry systems to enhance carbon pools and giving prime importance in global C trading system has not been yet gained a due importance. It would be very useful if agroforestry practices are used for carbon sequestration and carbon trading projects in order to meet the Kyoto objectives of abating CO_2 emissions along with sustainable agricultural production and abating deforestation. Prime objective of this paper is the determination of carbon pool and capacity of absorption of carbon by farm tees under partially arid climatic zone. (Nawaz et al. 2018).

Now a days, agroforestry are absorbing around about 0.29 to 15.21 tonnes C/ha/year above ground and from 30 to 300 tonnes C/ha upto 1 meter soil profundity.By the year 2050 the agroforestry have the capacity of stocking 6.3 gigatonnes of carbon and would be able to absorb the atmospheric carbon usually at the higher pace of about

600 metric tonnes C yr^{-1}.It shows that, agroforestry possess higher capacity of carbon absorption than any such other type of land use categories.(Gul, 2017). Increasing soil organic carbon (SOC) stocks would improve the performance of managed soil on crop land and also increase the agriculture resilence on climate change, while decreasing the net GHG emission from the soil (Nath et al. 2020) The findings shows that the potential of carbon storage of agroforestry depends upon the nature of practices it receives, its age, is species composition, its edaphic and climatic conditions. (Nawaz et al. 2018)

Pakistan recently ratified the Paris Agreement on Climate change to reduce greenhouse gas emissions to mitigate the effects of climate change. Unfortunately, Pakistan's terrestrial carbon sequestration is very low among South Asian countries because of bad forestry resources.(Yasin et al. 2019). This land-use system is currently storing about 45.3 Pg carbon, of which more than 75% is stored in woody vegetation. Furthermore, it is reported that the agroforestry systems can stock about 6.3 Gt of atmospheric carbon by 2050 with a sequestration rate of greater than 600 Mt C yr^{-1}, making these systems a potential source of sequestering a greater amount of carbon as equated to other existing land-use options.(Yasin et al. 2021)

The prime cause of global warming is carbon dioxide. Several countries like Pakistan signed the agreement of Kyoto Protocol under the aegis of United Nations Framework Convention on Climate Change (UNFCC) that mentioned the abating of CO_2 and also enhancing the absorption of CO_2. The agroforestry sector pronouncedly helps in sequestration of carbon.(Nawaz et al. 2018). Efforts in the KPK Province, a mountainous region in the Northern Pakistan (Fig. 2), make an interesting case study in this regard. A study was conducted to identify the linkages between agricultural and forestry extension services and the factors preventing effective linkages. The study revealed that both organizations were providing extension services and advice on fruit trees to the farming community yet a very weak formal and informal working relationships was noticed between both departments, making the whole exercise

ineffective. The study suggested that in order to establish strong linkages between agricultural and forestry extension services, common activities must be undertaken for realizing better fruit trees.(Baig et al. 2021)

Description of study area peshawar

Peshawar's geographical coordinates are 34.008 degrees latitude, 71.578 degrees longitude, and 1,115 feet elevation for the purposes of this report.

In Peshawar, summers are relatively comprised of high temperature and are hot, lengthy, and lucid, while in winters a fall in temperature occurs and are cold but usually lucid. Throughout the year, the approximate temperature encompasses from 38°F to 106°F, with temperatures occasionally falling less than 32°F or rising above 112°F.

Almost all the year Peshawar receives the. In Peshawar March is the wettest month with amean rainfall of 2.6 inches. Peshawar receives minimum rain in November with amean rainfall of 0.6 inches.

MATERIALS AND METHODS

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. Sampling was done at district Peshawar, village Mullazai. Soil samples were obtained at the time of no fertilization or any other treatment.

Composite sampling

Random collection method (Estefan et al. 2001) was used for sample collection. A total of 20 samples were collected from two different agroforestrysystems in which 10 sampleswere collected from each. Sampling was carried out in the month of November, dated 10-11-2021. The weather was clear with no precipitation at the time of collection of samples. The samples were collected in polythene sample bags. Soil auger was used at the depth of 20 cm for soil collection. From each sub-sample a slice of uniform size was taken from the surface to the depth of the tool's insertion, with the same volume of soil obtained. Soil collection of samples were labelled. Composite samples were then mixed well, crushed and sieved with 2mm sieve.

Method

Clean, dry and weigh $W_1$the crucible .The balance needs to be tarred before it is used to measure the weight. Then Weigh W_2 a sample of the specimen in the crucible .Keep the crucible 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 crucible 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

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

Soil organic matter%

The method used for routine estimation of soil organic matter by weight loss in a sample heated to a temperature high enough to burn organic matter but not high enough to decompose carbonates. To remove moisture, a soil sample is dried at 105° C. The sample is weighed, then heated at 360° C for two hours before being weighed again when the temperature falls below 150° C.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 to run without interruption for eight hour to burn the samples to ash. The weight of ash was recorded for each sample and organic matter was determined. (Rehman et al. 2011).

OM = Wd −Wa

Where OM is organic matter (g), Wd weight of oven- dried sample (g), Wa weight of ash (g)

Apparatus and materials:

Oven or muffle furnace capable of reaching 400° C and being controlled to within 10° C.Stainless steel crucible rack.Balance accurate to 0.001 g.Soil scoop with a capacity of 5 g of light-colored silt loam soil.105° C drying oven.

Calculations

An estimation of SOM percentage from the loss on-ignition method.

LOI= (weight at 105° C) – (weight at 360° C) x 100 /Wt. at 105° C (Schulte and Hopkins, 1996) The resultant LOI is the organic matter percent.

Soil organic carbon

To calculate soil organic carbon it is assumed that total organic matter contains 58% organic carbon contents or a relation is used i.e organic carbon =SOM% multiply by 0.58(Rehman et al. 2011). (Ali et al. 2020).

Soil Bulk Density

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. The mean value soil bulk density of agrisilviwas 1.251gm/cm3 and silvo pastoral was1.346gm/cm3.(Girei et al. 2016)

Statistical analysis

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 regression[R package].The assumption of normality were tested by Shapiro wilk test and homogeneity of variances weretested by levene's test. Independent sample t test with 5% significancelevel were performed using jamovi version 1.6.

RESULTS

After collection and processing of the samples their results were recorded. Table 1 indicates the comparative results of both agri-silvi and silvopistoral cultures. As summarized in table 1, the percentage moisture content of the silvi pastoral was found to be 4.47 ± 1.8, which is lesser than the agri-silvi (9.44 ± 1.4). The EC of silvo pastoral was 1512.50±7.472 as compare to agri-silvi that was 1522.40±6.720 that is slightly higher than silvo pastoral system. The soil organic carbon of silvo pastoral was 2.23±1.021 as compare to agrisilvi that was 2.65±0.699 that is also slightly higher than silvo pastoral system. At final the SOM of silvi pastoral was 3.84±1.775 as compare to agrisilvi system that was 4.56±1.188 that is also slightly higher than silvo pastoral system.

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.

Table 1: showing comparative analysis of two different agroforestry systems.
Group Descriptive

Group	N	Mean	Median	SD	SE
moisture% silvi-pastoral	10	4.47	5.00	1.839	0.5816
agri-silvi	10	9.44	9.35	1.413	0.4467
soil organic carbon silvi-pastoral	10	2.23	2.17	1.021	0.3228
agri-silvi	10	2.65	2.75	0.699	0.2212
SOM silvi-pastoral	10	3.84	3.73	1.775	0.5612
agri-silvi	10	4.56	4.73	1.188	0.3758

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 organic matter and soil organic carbonas shown in descriptive table were subjected to normality test using Shapiro wilk test .Fig shows that all the resultant p value for SOM, soil organic carbon, moisture contentis greater than 0.05(significance level or α) ($p > 0.05$) thus we accept the null hypothesis.

So we assume that the data for moisture content, soil organic carbonand soil organic matterare normally distributed within each of two populations as can be seen in Q-Q plots.

Table 2: Normality Test (Shapiro-Wilk)

	W	p
moisture% soil organic carbon SOM	0.958 0.943 0.948	0.511 0.273 0.331

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

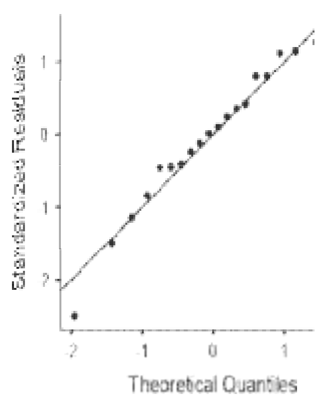


Table : Showing normal ity test

Figure 1: Q-Q plots of Soil Moisture Content

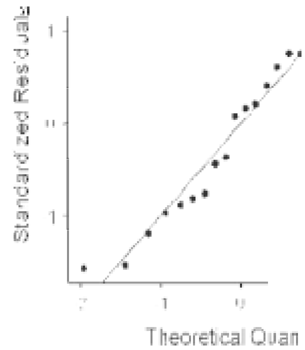


Figure 2: Q-Q plots for Soil organic carbon

Table 03: Legend

Legend	
Key	**Description**
•	Plots for Collection of Data

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 in descriptive table using levene'stest. TheLevene'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. Fig shows that the data of moisture content,SOM and soil organic carbonhas a p value more than the significance level (α=0.05), therefore we retained the null hypothesis and concluded that the variances are equal.

Table 4: Homogeneity of Variances Test (Levene's)

	F	df	df2	P
moisture%	0.9529	1	18	0.342
soil organic carbon	2.2690	1	18	0.149
SOM	2.5809	1	18	0.126

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

T-test

The independent-samples t test was conducted with a significance level of 95 % to evaluate the difference between the means of independent groups of two agroforestry systems i.e. agrisilviculture system and silvi-pastoral system. As the assumption of normality and homogeneity of variances were found to be significant.

Table 5: Showing independent sample T-Test

Statistics		Df	P	Mean Difference	SE difference
Moisture %	Student's	18.0	< .001	-4.965	0.733
Soil organic carbon	Student's	18.0	0.295	-0.422	0.391
SOM	Student's	18.0	0.305	-0.713	0.675

Moisture content

Moisture content has a p value of 0.342 (student's t test) which is greater than the significance level i.e p>0.05 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 silvi-pastoral system is 4.47 and that of agri-silviculture system is 9.44 as shown in fig.

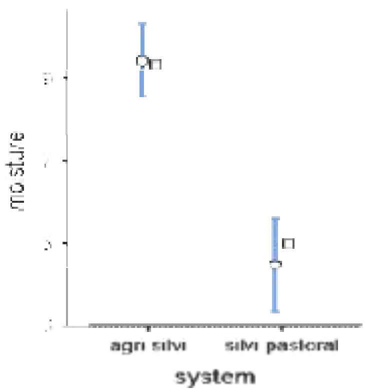


Figure 3: Showing comparison of mean moisture content of two agroforestry Systems

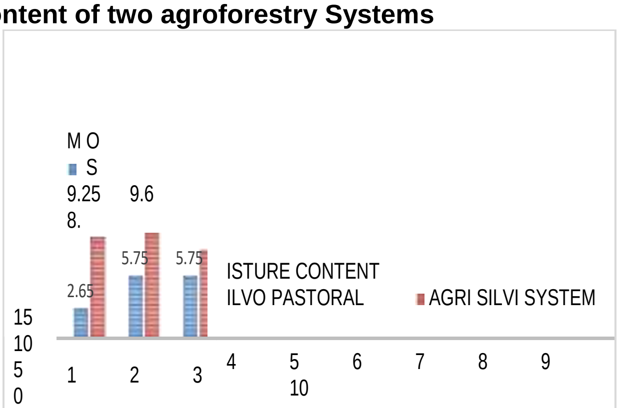


Figure 4: Comparison between Moisture content of sample plots

Figure 04 indicates the comparison between moisture contents of different samples of silvo pastoral system and agrisilvi system. It implies that sample 5 had lowest moisture content about 0.5% in silvo pastoral system as compare to agrisilvi system a sample 10 indicates highest moisture content in silvo pastoral system of about 6.25%. While sample 5 in agrisilvi system showed highest moisture content of about 11.75% and sample 6 indicates lowest moisture content of about 7.05%.

Soil organic matter

Soil organic matter is found to have a p value of 0.126 as shown in table,which is more 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 agri-silviculture system was found to be 4.56 and for silvi-pastoral system it is 3.84 as shown in fig. We conclude that the silvo pastoral system possess slightly less organic matter as compare to agrisilvi system.

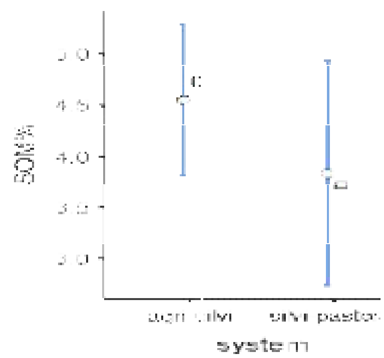


Figure: showing comparison of mean SOM% of two agroforestry systems

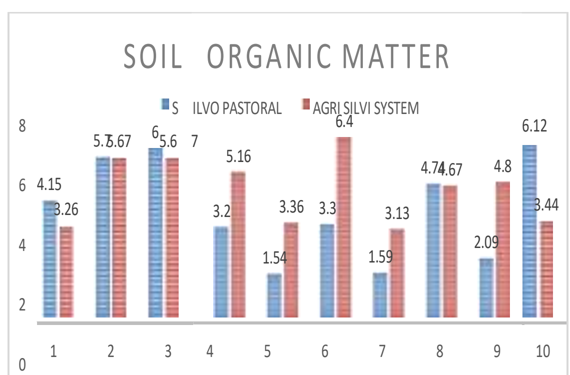
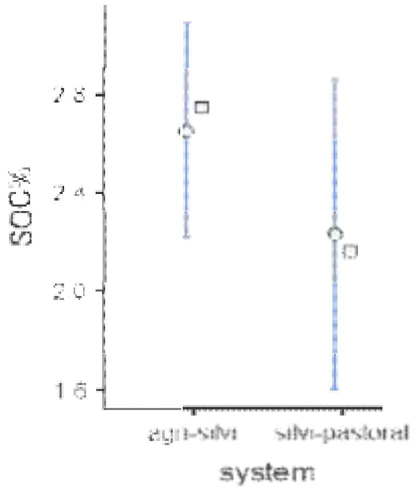


Figure 6: Comparison between Soil Organic Matter of sample plots

Figure 06 indicates the comparison between Soil Organic Matter of different samples of silvo pastoral system and agrisilvi system. . It implies that sample 5 had lowest. Soil Organic Matter in silvo pastoral system of about 1.54% and sample 10 indicates highest Soil Organic Matter in silvo pastoral system of about 6.12%. While sample 1 indicates lowest Soil Organic Matter of about 3.26% in agrisilvi system and sample 6 indicates highestSoil Organic Matter of about 6.4%.

Soil organic carbon

Soil organic carbonhas a p value of 0.149 as shown in table, which is greater that the significance level of 0.05 i.e. p>α. Therefore we accept the null hypothesis of no difference and assume that there is no statistically significant difference between the means of soil organic carbonof two agroforestry system. But The mean value as seen in descriptive table for salvo-pastoral system is 2.23 while that of agri-silviculture system is 2.65 as shown in fig .We conclude that the differences between the two Means are likely due to soil texture or management practices.. Figure:Showing comparison of mean soil organic carbon% of two agroforestry systems



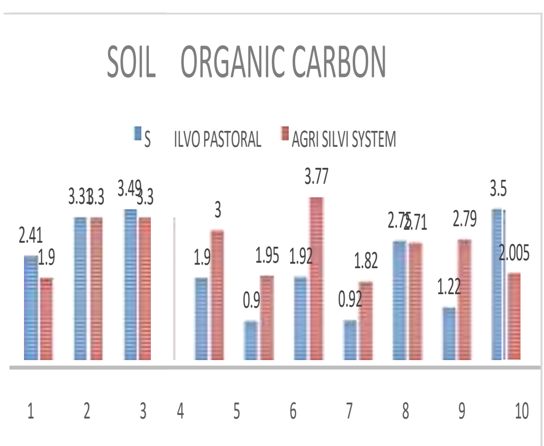


Figure 7: Comparison between Soil organic carbon of sample plots

Figure 07 indicates the comparison between Soil organic carbon of different samples of silvo pastoral system and agrisilvi system. . It implies that sample 5 had lowest.Soil organic carbon in silvo pastoral system of about 0.9% and sample 10 indicates highest Soil organic carbon in silvo pastoral system of about 3.5%. While sample 1 indicates lowest Soil organic carbonof about 1.9% in agrisilvi system and sample 6 indicates highest Soil organic carbonof about 3.77%.

Bulk density

The results for soil bulk density in the top 20-cm layers of two agroforestry systems are shown in Fig 4.11.Mean bulk densities of agrisilvi system and silvo pastoral system were found to be 1.251 gm/cm^3 and 1.346 gm/cm^{3}respectively.

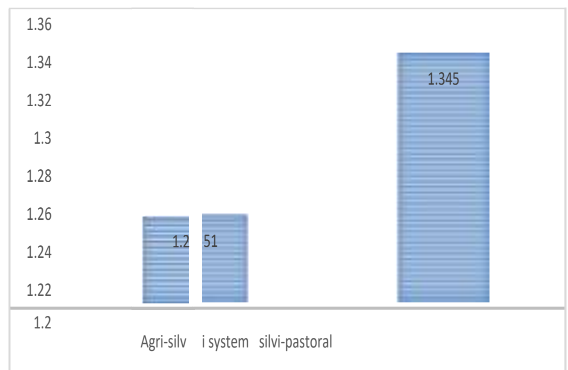


Figure 8: Showing comparison of BD of two agroforestry system

DISCUSSION

Soil Moisture

Moisture content of silvopastoral system is less than agrisilvi system may be due to the compaction of soil by cattle foot trafficking.; Generally, a soil with very low moisture content is less vulnerable to compaction than a soil with high moisture content (Gysi et al. 1999). But when the moisture content is so high that all the soil pores are filled with water, the soil becomes less compressible (Smith et al. 1997). Using the bulk density as the soil compaction indicator, Ishaq et al. (2001) showed as to vulnerability of the soil to compaction increases with increasing water contents up to a limit which it decreases with the increasing water contents. The silvopastoralsystem are subjected to high trampling so as a result, a prominentvariation in physical properties of soil of both agrisilvi systems and silvo pastoral. Nawaz (20).

The soil of silvo pastoral system was more expose to sun light as compare to agrisilvi system that may be the reason for less accumulation of moisture in silvo pastoral system.

Soil organic matter

The Soil organic matter (SOM) is one of precursor element that effects the crop productivity and it serves as the prime element of production, qualitative character of crop and also fertility of soil. The SOM is an essential part of the soil to enhance quality of soil, its future production along with sustainability. (Haynes 2005).

The production of dead roots and litter induce the fast accumulation of soil organic matter. It may be the reason for higher soil organic matter in agri-silvi system as compare to silvo- pastoral system. Berendse et al. (1998)

General increase occurs in SOM as the content of clay enhances. There are two mechanisms for this enhancement. First,the decomposition rate slowed down due to the bonding between organic matter and the clay particles. Second, the formation of aggregates due to higher content of clay enhances its capability of aggregate formation.The larger aggregates mechanically shield the process of mineralization that are caused by microbial attack and thus retards the process of decomposition. (Rice, 2002). As per example, the nutrients are expelled and readily available to different factions of small organisms only when earthworm casts and big particles of soil are disintegrated in to smaller particles by the combine effect of many factors like that of plant growth, climate and other organisms. It is found that the organic matter is two to four times more in fine textured clayey soil as compare to sandy soils that are coarse texture in nature. (Prasad and Power, 1997). Bot et al. 2005. The agrisilvi system has higher organic matter may also due to the clayey nature of the soil as compare to silvo pastoral system.

Soil organic carbon

The SOC is greatlyaffected by biochemistry of soil along with its physical properties. The silt content that is one of the physical property was also the determinant factor in initial stage of grassland, also the activity of urease and along with the activity of saccharase were also the determinant factor in the initial-middle and middle-final stages, respectively.The litter properties revealed a slight effect on accumulation of soil organic carbon. On the succession gradient, the only prime contributor to soil organic carbon variation lessened as the interaction of different parameter enhanced revealed by variation partitioning analysis. Results suggests that Agri-silvi system possess higher organic carbon as compare to silvo pastoral system. Liu.et al.2015

Bulk density

The comparison of soil BD showed that silvo-pastoral system has higher bulk density of 1.346gm/cm3 as compare to agri-silvi system which was 1.251gm/cm^3. The ploughing of uncultivated soil results in lessening the amount of organic matter along with this practice it also expose the surface of soil to temperature and irrigation practice and that might be the reason of increased bulk density in crops of agriculture and also in agri-silvisystems.The results are in accordance with Tufa et al. (2019).Geetha et al.(2021).Usually in summer season the animals preferred to move in shaded areas particularly in tropical silvo-pastoral system. (Bennett et al. 1985; PaesLeme et al 2005). It implied that the soil would be more prone to compaction as a result of trampling of animals. As soil compaction is the procedure that results in lessening the volume of soil by the exertion of pressure on the soil that results in an enhancement of overall soil density.(Azenegashe et al. 1997), achange in the distribution of soil pore size (Dexter, 1988) also results in higher difficulty in the penetration of roots.The result might be due to the compaction of soil by cattles due to which silvo-pastoral have higher bulk density as compare to agri-silvi system.

CONCLUSION

It is concluded that comparison between two agroforestry systems in district Peshawar that are agrisilvi system and silvo pastoral system shows significant differences with respect to different parameters of soil properties. The moisture content of soil in silvo pastoral system was lessthanagrisilvi system and this result might be due to cattle trampling affect or exposure to sun light. The soil organic matter also varied between stated agroforestry systems. Soil organic matter were found to be more in agrisilvisystemas compare to silvo pastoral system. The reason might be the clayey nature of agrisilvi system of soil. At final the soil organic carbonalso showed slight variation between two stated agroforestry systems. The soil organic carbon were found to be high in agrisilvisystemas compare to silvo pastoral systemand it might be due to some litter characteristics or might be due to some other soil physical properties. Bulk density of silvo pastoral system was more than agrisilvi system and the reason might be due to more cattle trampling effect in silvo pastoral system as compared to agrisilvi system.

The comparison between two agroforestry systems that are agrisilvi system and silvo pastoral system showed variation in respect to its carbon accumulation. As agrisilvi system has higher potential to accumulate the carbon as compared to silvo pastoral system so it played a prominent role in combating crisis of climate change as in comparison to silvo pastoral system.

The capacity of carbon accumulation in agrisilvi system could be enhanced by planting to the maximum degree of trees on agricultural fields without having any adverse effects on field crops.

Technical assistance should be provided to the farmers in order to raise awareness among the farmers regarding different agroforestry systems.

Cattle trampling effect should be reduced in silvo pasture system in order to enhance the vegetation in silvo pasture systems.

Pasture lands should be increased in order to reduce pressure on other agroforestry systems for the conservation of carbon pool.

Enrichment planting also shows promising results, planting a diversity of species provide soil organic carbon, ecological and environmental benefits.

Recent climate policies such as REDD+ has been incentivize payment for carbon sequestration so precise and accurate agroforestry systems should be applied.

The study also recommend that the agrisilvi system should be enhanced in Peshawar region as to generate more and more carbon credits.

Proper agroforestry management plan should be composed in which its main object is to enhance the carbon stock.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

AUTHOR CONTRIBUTIONS

All the authors contributed equally.

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