AGROFORESTRY STATUS AND ITS ROLE TO SEQUESTER ATMOSPHERIC CO_2 UNDER SEMI-ARID CLIMATIC CONDITIONS IN PAKISTAN

NAWAZ, M. F.[1*] – YOUSAF, M. T. B.[1] – YASIN, G.[1] – GUL, S.[2] – AHMED, I.[1] – ABDULLAH, M.[3] – RAFAY, M.[4] – TANVIR, M. A.[1] – ASIF, M.[1] – AFZAL, S.[5]

[1]*Department of Forestry and Range Management, University of Agricuture, Faisalabad, Pakistan*

[2]*Department of Botany, University of Karachi, Pakistan*

[3]*Cholistan Institute of Desert Studies, The Islamia University of Bahawalpur, Pakistan*

[4]*Department of Forestry, Range and Wildlife Management, The Islamia University of Bahawalpur, Pakistan*

[5]*Department of Forestry, College of Agriculture, University of Sargodha, Pakistan*

**Corresponding author*
e-mail: kf_uaf@yahoo.com; phone:+92-333-651-2087

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Abstract. Carbon dioxide (CO_2) is the major cause of global warming. Many countries including Pakistan have signed the Kyoto Protocol agreement under the United Nations Framework Convention on Climate Change (UNFCC) and agreed to control the release of CO_2 and to increase the CO_2 sequestration. Agroforestry sector can contribute efficiently in carbon sequestration. This study was carried out to determine the status and potential of agroforestry and its role in carbon sequestration under semi-arid conditions. Data was collected through a multi-objective and pre-tested questionnaire from 250 village farmers in tehsil Sumandri, Pakistan. Height and girth of trees were measured from 250 randomly selected 0.405 ha farm plots. Soil samples from each cropping pattern were collected and analyzed. The whole study area has 2069.19 Mt of above ground carbon stocks and has sequestered a total of 7579.46 Mt of carbon dioxide at the rate of 186201.85 t CO_2 yr^{-1}. Furthermore, the study area has the potential of stocking 3607.61 Mt and sequestering 13214.67 Mt of CO_2 at the rate of 327232.46 t CO_2 per year. According to calculations, increasing the number of farm trees/ha, average CO_2 sequestration rate of the study area can be increased from 2.05 t CO_2 $ha^{-1}yr^{-1}$ to 3.59 t CO_2 ha^{-1} yr^{-1}. The role of agroforestry as C sink in not negligible and it should be given a dire consideration in policies, especially, in low forest countries like Pakistan to meets the melinium goals of atmospheric C reduction.
Keywords: *climate change, global warming, carbon cycle, envrionment, forestry*

Introduction

Changes in climate are happening which are unparalleled. If we continue on our present course, life on the Earth will be modified to such an extent that it will be very difficult to fix (IPCC, 2000; Mahowald et al., 2017). Due to several activities like combustion of fossil fuels and deforestation during the last 100 years, chemical makeup of this flimsy layer of the atmosphere has been extremely altered (Pold et al., 2017). Such kind of modifications in chemical composition has a wide range of significant harmful results on the long term weather conditions of the planet, the ecological systems which are being supported by the climate of the Earth, and the welfare of human beings and economy (CDIAC, 2000; Harsch et al., 2017).

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Global warming is among the greatest terrible horrors of the modern times (Salvatore et al., 2017). It is believed that carbon is among the most significant casual factors which cause global warming (Kerr, 2007; Franzluebbers et al., 2017; Jones et al., 2017). So, enhanced carbon discharge in the atmosphere is one of today's major interests and is significantly referred in Kyoto Protocol (Stewart and Hessami, 2005). Globally, transportation and industrial sources are the cause of more than 80% CO_2 anthropogenic emissions. The rest 20% comes mainly from deforestation and biomass combustion (CDIAC, 2000). Moreover, the rate of accumulation to the atmosphere from these sources surpasses the rate of loss to major CO_2 sinks by about 3.3 GtC /year (Schroeder, 1994). Therefore, the concentration of CO_2 in the atmosphere is increasing continuously and it has extended up to 400 ppm in certain regions (Bala, 2013). These current atmospheric CO_2 concentrations are much higher than pre-industrial levels (180-280 ppm) and it goes on increasing exponentially at about 0.5% per year (IPCC, 2000).

Among various carbon storage options, oceanic storage is not a cost-effective method to sequester CO_2 and likely other geological choices of atmospheric CO_2 storage are also vulnerable to leak out and not eco-friendly (Stewart and Hessami, 2005; Khatiwala et al., 2013). However, biotic sequestration overcomes all those environmental concerns which are linked along with geological and ocean storage (Lal, 2004; Weissert et al., 2017). Plants capture atmospheric CO_2 via natural process of photosynthesis. Each tree has a considerable capacity to store CO_2 and the C storage rate varies with the age of trees and it is species dependant under a set of ecological conditions (Nair et al., 2009). Plants store this CO_2 into their leaves, roots, bark, branches and stem (Nair et al., 2009). About 50% of tree's biomass is composed of carbon and its significant amount is stored into trees in the form of cellulose and lignin (De Villiers et al., 2014).

Agroforestry plays a very significant role and it is a very vital part of daily life of population of Pakistan, particularly, population of rural areas (Qureshi, 2005; Nawaz et al., 2016). Agroforestry system has a great potential to capture both above and below-ground carbon (Kotto-Same et al., 1997; Nair et al., 2009). The practices of agroforestry have been approved as a scheme for capturing of soil carbon under reforestation and aforestation programs and Clean Development Mechanisms of the Kyoto Protocol. Agroforestry systems (AFS) not only help in the sequestration of carbon but also responsible for providing a great number of other services to the communities of rural areas (Masera et al., 2001). It has been estimated that up to 12-228 Mg ha^{-1} carbon can be stored through AFS, with an average of 95 Mg ha^{-1} (Schroeder, 1994; de Jong et al., 1995; Nair et al., 2009). The C sequestration capacity by AFS in the most of cases is less than the pure forests but still comparable and more important in the areas with ecological hindrances for forest establishment (Jones et al., 2017). It has been reported that quantity of carbon stored in any agroforestry system depends on number of different factors like age of the system, composition and purpose, management practices of silviculture, climatic conditions of soil like texture and other properties and history of the land-use (Albrecht and Kandji, 2003).

The prospective role of agroforestry systems to serve as a C sink and to be incorporated into a global C trading system has not been given the deserved importance. Thus, incorporation of agroforestry practices and systems into C sequestration and C trading projects can be very useful to meet up the targets of CO_2 emissions anticipated at Kyoto while at the same time maintaining sustainable agricultural production and preventing further deforestation. It is very necessary to know about the accurate

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information about agroforestry practives and the spatial distribution of carbon in both vegetation and soil. As there was no any significant study in Pakistan relevant to the carbon stocks of farm trees, so, the first objective of this study was to assess agroforestry status and peoples's interaction with agroforestry in the study area. The second major obective of this study was to assess the carbon stocks and analyse the potential of carbon sequestration by farm trees in study area under semi-arid climatic conditiosn. Tehsil Sumandri has been selected due to presence of diversified nature of agroforestry systems there.

Materials and methods

Description of Study Area

Tehsil Samundri of district Faisalabad was selected for our study. Samundri was on a major trade route during the reign of Sher Shaha Suri. Samundri is located at 30°48'30N 71°52'15E, with an altitude of 130 metres (429 ft), and is 45 km from Faisalabad. The driest month is November, with 3 mm of rain. In July, the precipitation reaches its peak, with an average of 107 mm (*Fig. 1* and *Fig. 2*).

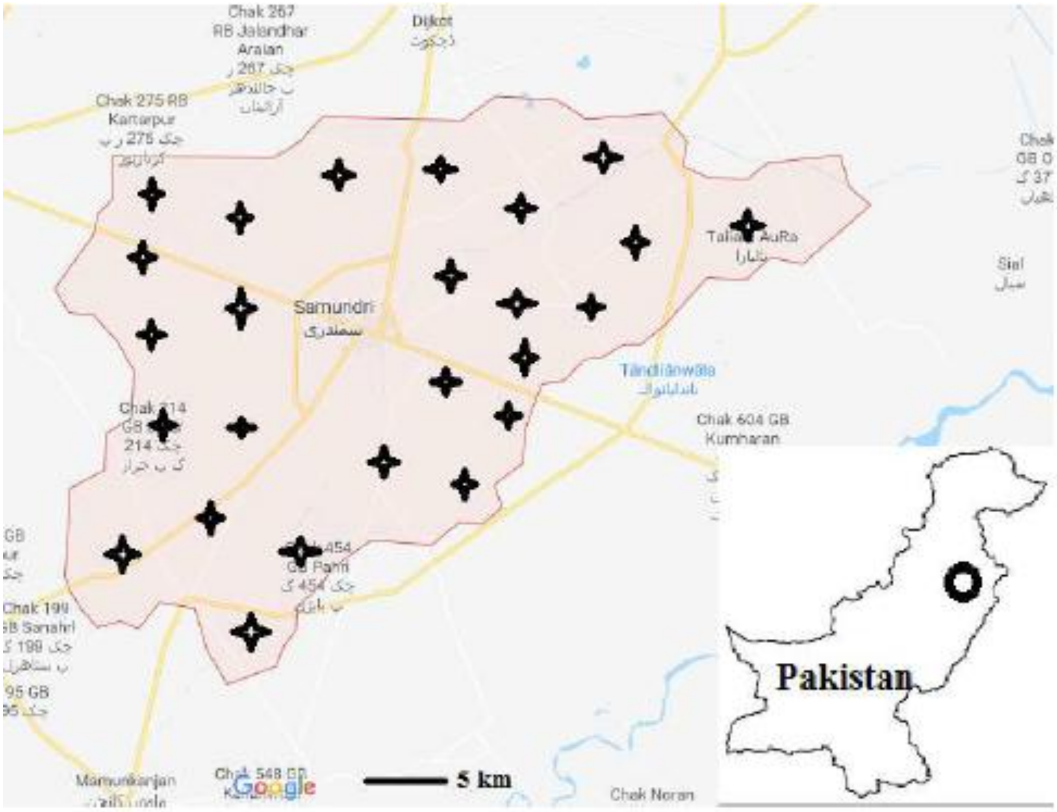

***Figure 1.** Location of study area with sampled locations*

Agroforestry Status and Potential

To analyze the current status of agroforestry and peoples interaction with agroforestry, a questionnaire was developed through a proper and consultative process, keeping in view the goals and objective of study. Keeping in view the administration

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distribution of Samundri tehsil, it had 28 union councils. Out of which 3 were urban and 25 were rural. Data from 2 villages of each rural union council was collected. Five farmers were interviewed from each village. Thus, total numbers of interviewed farmers were 250 from 25 rural union councils. The attributes which were being studied were: income, education, land holding, income source, annual income from trees, annual trees products used domestically, maximum number of trees per acre, agroforestry pattern, trees services, tree products sold per anum, distribution of trees Species.

10 plots of 0.405 ha (one acre) were being selected from each union council randomly. All the trees were counted at each plot. Their girth, height and age was calculated of each tree and carbon was calculated. Total number of trees per plot was calculated. And then the average number of trees per ha were calculated. The total number of trees in a union council were calculated by multiplying the average number of trees per ha with total area of each union council in ha.

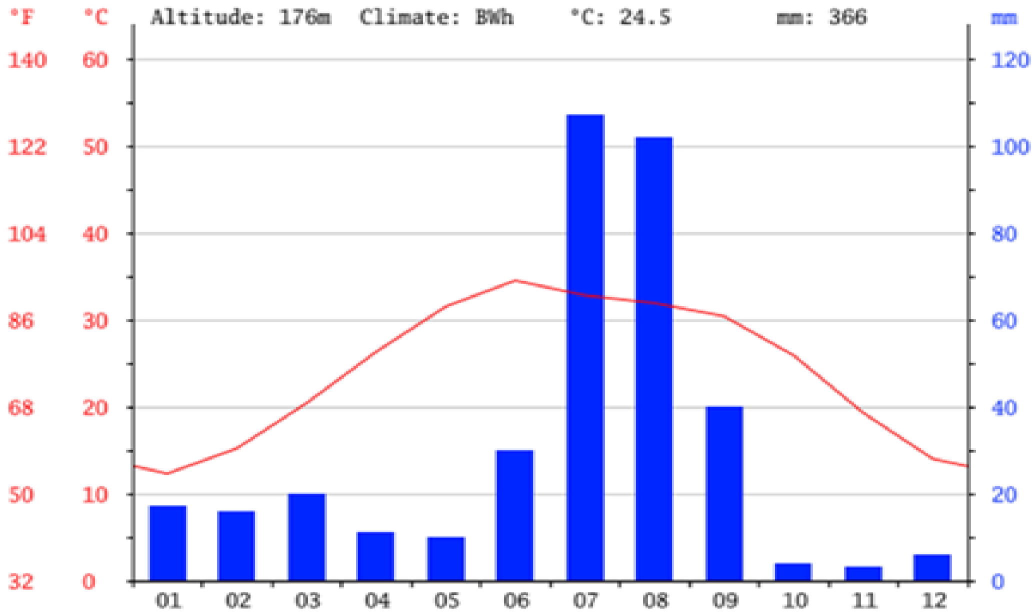

Figure 2. *Climat of Tehsil Sumandri*

Carbon Status and Potential of Carbon Sequestration

Carbon stock and CO_2 sequestration rate was determined by using the standard methods in the literature by calculating the true tree volume and biomass with the available equations and wood density in literature (Juwarkar et al., 2011; Kumar and Nair, 2011). The below ground root mass was supposed 20% of the above ground biomass, so, it was added in above ground biomass and dry biomass was calculated on the supposition of 27% moisture. Carbon was estimated as 50% of the biomass of the tree (Afzal and Aqeela, 2013; Nawaz et al., 2017a).

The potential of carbon sequestration refers to the ability or capacity of the amount of carbon and CO_2 which can be stored by farm trees of tehsil Samundri. To determine this, first of all the maximum number of trees grown at a single plot of each union council were determined by using the statistical tool of Range. Then the average was taken of theses maximum number of trees grown at one ha. The average of the

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maximum number of trees was 54ha^{-1}. It means that 54 trees can be grown at one ha. 54 trees were taken as potential trees and the potential of each union council to capture carbon and carbon dioxide was calculated by using statistical tools (Nawaz et al., 2017b).

Collection of Soil Samples

Soil samples from each agroforestry combination from Tehsil Samundri were collected from two depths (0-15 cm) and (15-30 cm) by using Soil Auger. And carbon concentration of soil for each cropping pattern was calculated by using Walkely Black method (Savoy, 2013). The other characteristics of soils which were being studied are soil EC, pH, Organic Matter (%), Saturation percentage, N, P, K and C/N according to standard protocols (Nawaz et al., 2017b).

Statistical Analysis

To calculate the average, range, frequency and standard deviation for different sets of data, the statistical tools in MS-Excel were employed.

Results

Current C status

Table 1 shows the current status of carbon stocks and CO_2 sequestered by farm trees. The average number of trees were found 31 trees ha^{-1} with the maximum 39 trees ha^{-1} in union council number 105 and the minum 28 treesha^{-1} in few unin councils. For the whole study area, it was estimated to be the 2069.19 and 7579.46 Mt respectively with an average of 0.02 Mt C ha^{-1}and 0.08 Mt of CO_2 ha^{-1}. The average rate of sequestration of CO_2 was estimated to be the 2.05 t CO_2 ha^{-1}yr^{-1}. The total amount of rate of CO_2 sequestered in one year was estimated to be 186201.85 t CO_2 yr^{-1}. The C storage and sequestration capacity varied among union coucils (UC) and some times it was independt of number of trees. Due to rounding off the figures, the variation in C stock/ha was less visible among UCs as compared to CO_2 sequstration rate/ha/year. It can be seen that despite less tree/ha in UC-111 (28) as compared to UC-101 (38) the CO_2 sequstration rate/ha/year wascomparable in both of them. Similarly, Despite more number of trees in UC-103 (33) it has less CO_2 sequstration rate/ha/year (1.87) as compared to UC-110 (2.01) with 28 trees ha^{-1}. However, the differences among UCs for total C stocks, total CO_2 sequestration rate and total CO_2 sequestration rate per year were not only dependant on number of trees to some extent but on the total area of that union council as well. The area of UC-125 was the highest, so, all the above metnioned area dependant parameters were high in the UC-125.

C Sequestration Potential

In *Table 2,* the average trees/ha for each UC were calculated from radomly sampled 10 plots. However, the maximum number of trees/ha is for one plot in that UC with the highest number of trees (without compact plantation). The maxumimum number of trees/ha were the highest (62) in UC-101 and the lowest (49) in UC-106 and UC-118. The average of maximum number of treees/ha in all Ucs was found 54 trees/ha. Considering the 54 trees/ha as practicable AFS in the study area, it was set as potetial

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number of trees that can be grown in this area. The average potential of farm trees for carbon stocks and CO_2 were estimated to be the 0.04 Mt ha^{-1} and 0.08 Mt ha^{-1} respectively (*Table 2*). The total amount of carbon which can be stored by farm trees of tehsil Samundri was estimated to be the 3607.61 Mt of carbon and 13214.67 Mt CO_2. It was estimated that farm trees have the potential to store 327232.46 t of CO_2 per year at an average rate of 3.59 CO_2 t ha^{-1} yr^{-1} (*Table 2*). Likewise to current status, the area dependat parameters such as total C stocks, total CO_2 sequestration rate and total CO_2 sequestration rate per year were highest in UC125.

Table 1. *Current Status of Agroforestry, Carbon Stocks and CO2 sequestration rate by farm trees in Tehsil Samundri*

UC#	Trees per ha	C Stock/ha (Mt)	CO_2 Sequestered /ha (Mt)	CO_2 Sequestration rate /ha/year (t)	Total Area (ha)	Total C Stock (Mt)	Total CO_2 Sequestered (Mt)	Total CO_2 Sequest. rate/year (t)
101	38	0.03	0.11	2.35	3148.47	90.47	331.38	7398.90
102	37	0.03	0.10	2.33	3142.40	88.80	325.28	7334.35
103	33	0.03	0.09	1.87	4653.45	119.75	438.63	8701.95
104	38	0.03	0.11	1.95	3519.05	102.05	373.81	6862.14
105	39	0.03	0.11	2.24	3345.30	96.76	354.44	7493.47
106	30	0.02	0.08	2.35	3061.40	69.07	252.99	7194.28
107	29	0.02	0.08	1.89	3070.31	66.59	243.91	5802.88
108	29	0.02	0.08	1.81	3971.43	85.66	313.76	7188.29
109	31	0.02	0.08	1.92	2973.11	67.01	245.46	5708.36
110	28	0.02	0.08	2.01	4586.22	95.70	350.57	9218.30
111	28	0.02	0.08	2.34	3428.33	71.19	260.77	8022.28
112	30	0.02	0.08	2.05	3179.25	68.92	252.46	6517.46
113	30	0.02	0.08	2.11	4093.34	88.37	323.69	8616.47
114	28	0.02	0.07	1.85	3814.70	77.55	284.07	7057.19
115	29	0.02	0.08	1.82	2757.65	57.08	209.09	5018.91
116	28	0.02	0.08	1.87	2534.49	52.69	193.00	4747.10
117	30	0.02	0.08	2.06	2208.47	50.35	184.44	4540.60
118	31	0.02	0.09	2.13	3669.30	85.86	314.50	7815.61
122	36	0.03	0.09	2.26	3289.41	84.83	310.73	7420.91
123	28	0.02	0.07	1.93	2913.17	58.64	214.80	5634.06
124	32	0.02	0.08	2.12	3798.09	85.66	313.79	8063.35
125	30	0.02	0.08	2.35	7533.41	163.02	597.12	17680.90
126	28	0.02	0.08	1.90	3881.52	79.76	292.16	7355.48
127	28	0.02	0.08	1.94	4846.23	102.48	375.37	9377.46
128	28	0.02	0.08	1.83	2967.84	60.95	223.26	5431.15
Total	25	--------	-------	-------	90386.28	2069.19	7579.46	186201.8
Av.	-----	0.02	0.08	2.05	-------	--------	---------	--------

Soil Carbon

It was found that farmers are mostly planting diverse trees species (not mono-species per plot) alongwith all crops. However, four types of tree-crop combinations were frequent as compared to all other types. Farmers liked to plant trees with wheat (*Triticum aestivum*), sugarcane (*Saccharum officinarum*), berseem (*Trifolium alexandrinum*) and sarsoun or mastard (*Brassica rapa*). So, soil C was measured for these four combinations (*Fig. 3*). At the soil depth of 0-15 cm, it was estimated that maximum amount of soil carbon was present under the combination of trees plus berseem crop (0.45%). It was followed by sugarcane plus trees (0.43%) as shown in *Fig. 3*. Results showed that trees grown in combination with wheat crop captures less

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soil carbon than tree plus sugarcane but more carbon than the sarsoun plus trees. At 15-30 cm soil depth, the minimu carbon (%) was observed for sarsoun plus trees with no significant difference for other three combinations. The overall carbon percentage in the soils was less than 0.5 signifying that studied soils were carbon deficient and have poor organic matter contents.

Table 2. *Potential of Agroforestry, Carbon Stocks and CO_2 Sequestration rate of farm trees in Tehsil Samundri*

Union Council #	Average trees/ha	Max No. of Trees/ha	Potential trees	Potential Carbon Stock (Mt)	Potential CO_2 sequestered (Mt)	Potential CO_2 sequestration rate/ha/year(t)	Potential Co2 Sequestration rate per year(t)
101	38	62	54	128.56	470.90	3.34	10514.23
102	37	50	54	129.60	474.73	3.41	10704.19
103	33	52	54	195.95	717.75	3.06	14239.56
104	38	55	54	145.02	531.21	2.77	9751.46
105	39	53	54	133.98	490.77	3.10	10375.58
106	30	49	54	124.32	455.38	4.23	12949.70
107	29	51	54	123.99	454.18	3.52	10805.36
108	29	56	54	159.50	584.25	3.37	13385.09
109	31	58	54	116.73	427.57	3.34	9943.60
110	28	60	54	184.57	676.09	3.88	17778.15
111	28	59	54	137.30	502.92	4.51	15471.54
112	30	53	54	124.06	454.42	3.69	11731.43
113	30	55	54	159.06	582.64	3.79	15509.65
114	28	56	54	149.56	547.85	3.57	13610.29
115	29	51	54	106.29	389.34	3.39	9345.56
116	28	57	54	101.61	372.21	3.61	9155.12
117	30	52	54	90.63	331.99	3.70	8173.09
118	31	49	54	149.56	547.84	3.71	13614.29
122	36	50	54	127.24	466.09	3.38	11131.36
123	28	52	54	113.09	414.26	3.73	10865.69
124	32	55	54	144.56	529.52	3.58	13606.89
125	30	57	54	293.43	1074.82	4.22	31825.62
126	28	61	54	153.82	563.44	3.65	14185.57
127	28	55	54	197.63	723.93	3.73	18085.09
128	28	57	54	117.54	430.56	3.53	10474.36
Total=25	**Av. =31**	**Av.=54**	**54**	**Total=3607**	**Total=13214**	**Av.= 3.59**	**Total=327232**

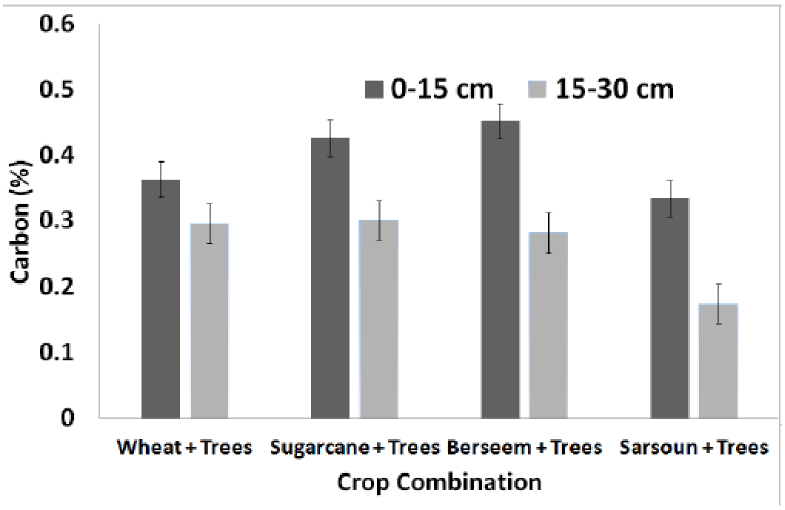

Figure 3. *Measurement of carbon for different cropping combinations*

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Socioeconomic Conditions of Farmers

Fig. 4 shows that maximum number of farmers have the age between 31-40 years followed by 41-50 years and then 51-60 years. The majority of the respondents have the annual income in between 4-8 lac followed by the respondents which have income less than 4 lac.

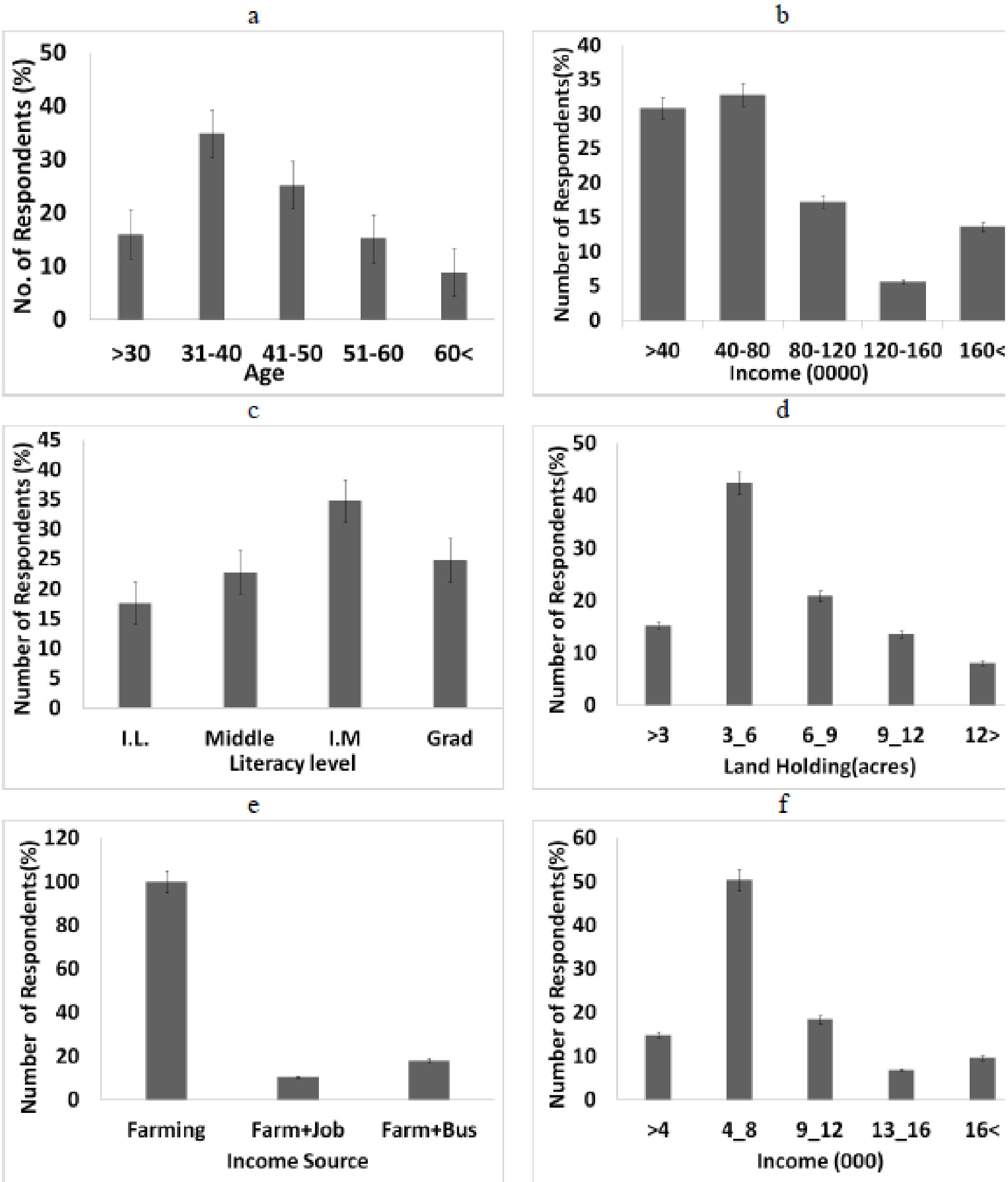

Figure 4. *Socioeconomic conditions of respondents. a; age of respondants. b; income of respondents. c; literacy level. d; land holding of respondents. e; income source of the respondents. f; income from trees per anum*

Then comes the category which has income in between 8-12 lac followed by those respondents which have income more than Rs. 16 lac. Mostly respondents were from middle to intermediate level of education. The maximum number of respondents has

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land holding of 3-6 acres. Mostly farmers are small land holders followed by the category of farmers which possess the land holding of 6-9 acres. Very few farmers have more than 12 Acres of land. But those who were having more than 12 acres were financially stable and were daring for new adoptions. Most of the respondents in our study were farmers but there were some respondents who were doing their own business or jobs as well as farming. Mostly respondents earn 4-8 thousand rupees per year from trees followed by 9-12 thousand followed by the category of less than 4000, which is being followed by the category of more than 16 thousand. Minimum number of farmers responded that they earn in between 13-16 thousand (*Fig. 4f*). Annual income from trees is usually earned by selling of timber. Or farmers sell fruit of trees to earn income on annual basis. The timber of the trees doesn't give income on annual basis. So, average was calculated for the period of five or ten years.

Agroforestry Status and Trends

Fig. 5a shows that the maximum number of respondents replied that they mostly use trees for fuel wood purposes. Almost equal number of respondents uses the farm trees to obtain fruit or fodder for their animals. Very less number of farmers obtains timber on yearly basis. The *Fig. 5* shows that almost all farmers (250) use trees for fuel wood (F.W), followed by farmers (50) use trees for fruit and fodder purposes, whereas (> 50) respondents obtains timber on annual basis.

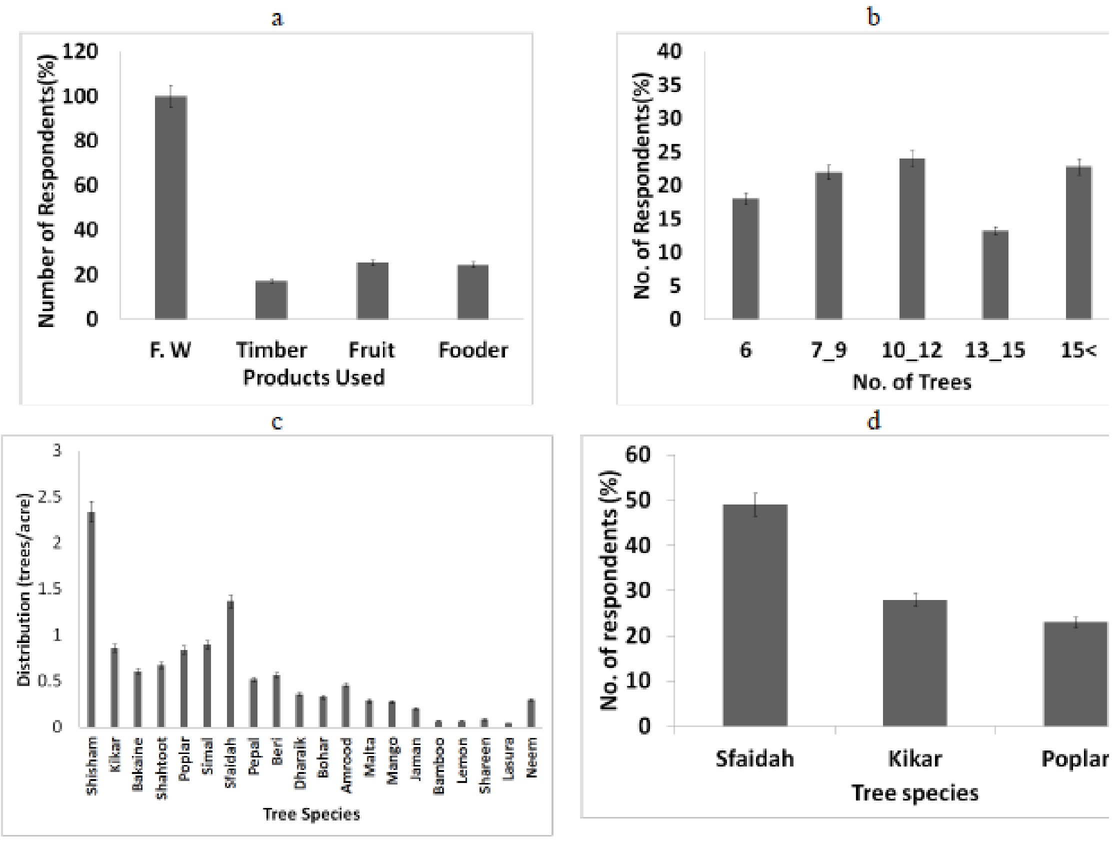

***Figure 5.** Agroforestry status and trends. a; products used. b; no. of trees per acre c;distribution of trees. d;trends of tree planting (previous five years)*

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Fig. 5b shows that maximum number of respondents tells that there should be 10-12 trees at one acre followed by the category of more than 15 trees per acre. Minimum number of respondents said that there should be 13-15 trees at one acre. The farmers were reluctant in growing of trees due to several reasons. The maximum number of shisham trees were grown on the farmers' fields but they were not grown during last five years. Sufaidah is followed by shisham in which is being followed by kikar and so on. The distribution is shown in *Fig. 5c*. The maximum number of farmers planted *Eucalyptus* during the period of last five years. Then people planted kikar and poplar. These tree species are replacing shisham (*Fig. 5d)*.

Allometric relations for farm trees

Allometric relations for two most common farm trees: Shisham (*Dalbergia sissoo*) and Sufaida (*Eucalyptus camaldulensis*), are presented in *Fig. 6*. These relations were derived for other farm trees as well but not presented in this manuscript due to similarity among findings and trends. At the age of 10 years, height and diameter at breast height (DBH) for both shisham and sufaida were about 10 m and 15 cm respectively. It was found that height and DBH of both tree species increased with the increment of age but after 20 years, the height and DBH of sufaida was more than shisham trees.

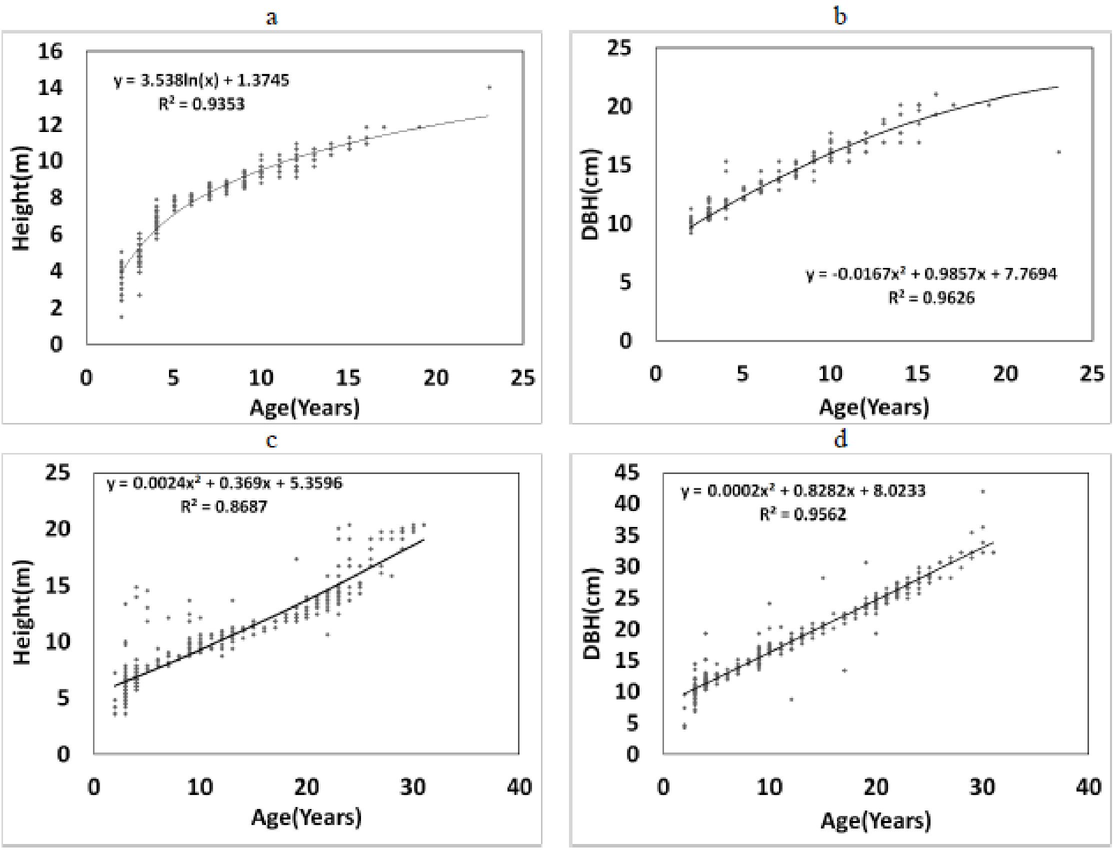

Figure 6. *Alometric relations for Dalbergia Sissoo (a and b) and Eucalyptus Camaldulensis (c and d)*

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Soil Parameters

Fig. 7a shows that the electrical conductivity is more at the depth of 0-15cm rather than 15-30cm. Sarsoun plus trees has the maximum value of electrical conductivity(2.26 mS/cm) followed by sugarcane plus trees (2.10 mS/cm) and then wheat plus trees (2.09 mS/cm). The *Fig. 7b* showed that maximum pH is shown sarsoun plus trees (8.38) followed by wheat plus trees (8.2) followed by sugarcane plus trees (8.16).

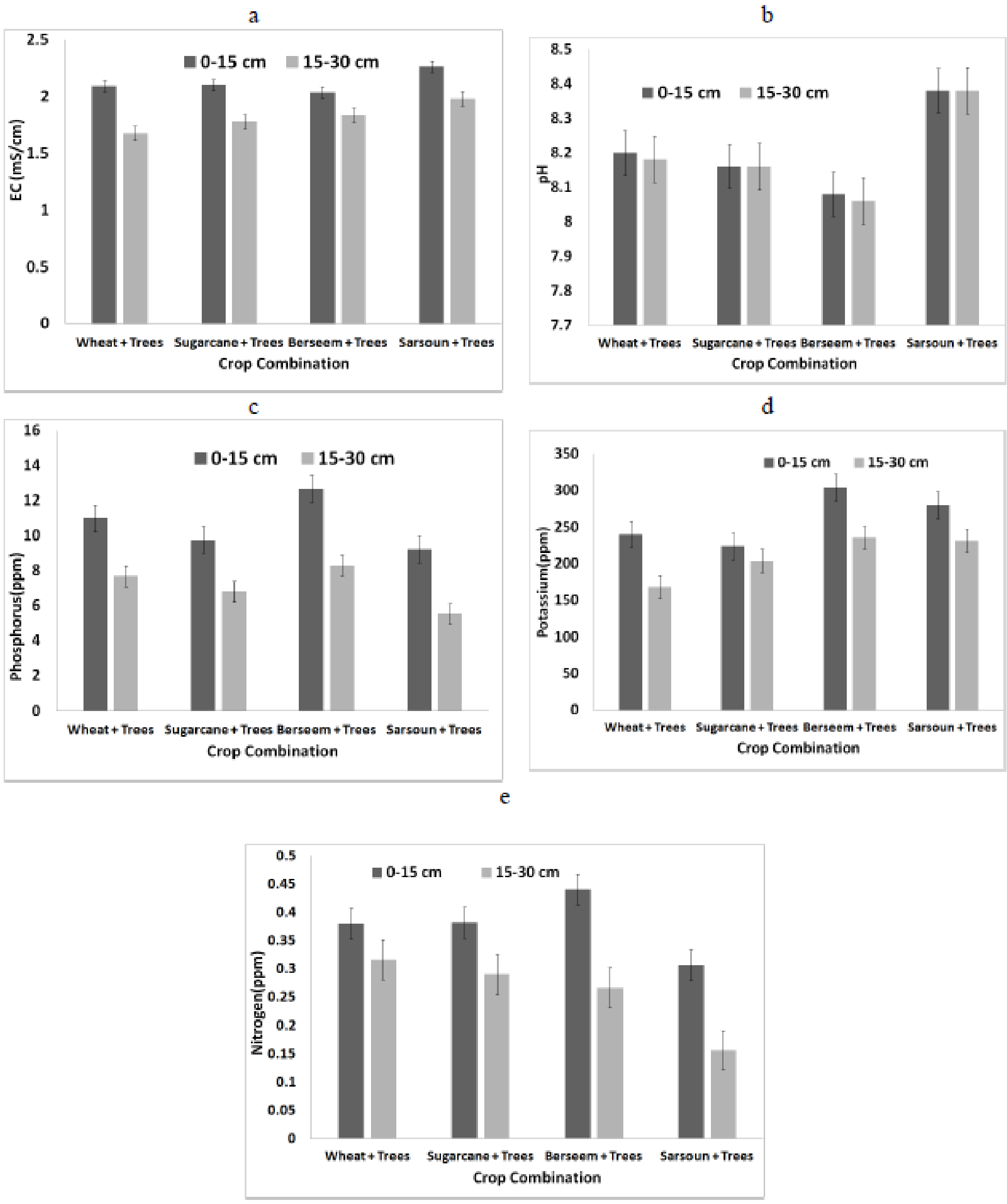

Figure 7. *Measurement of soil parameters for different cropping combinations a; EC. b; pH. c; Phosphorus d; Potassium. e; nitrogen*

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The minimum pH is shown by berseem plus trees (8.08). The data in the *Fig. 7c* represents that maximum amount of phosphorus was present in the combination of berseem plus trees followed by wheat plus trees which was being followed by sugarcane plus trees. The minimum amount of phosphorus was found in the sarsoun plus trees combination at both depths.

The data in the *Fig. 7d* shows that berseem plus trees have higher amount of potassium in their soil which is being followed by sarsoun plus trees. And then comes the areas where trees are grown along with wheat. Minimum amount of potassium is shown by the combination of sugarcane plus trees. The data in the *Fig. 7e* shows that the maximum amount of nitrogen is fixed by berseem plus trees followed by sugarcane plus trees. Almost equal amount of nitrogen was present in the soils for the combinations of wheat plus trees and sarsoun plus trees. This trend was observed at the depth of 0-15 cm, whereas at the depth of 15-30 cm the trend was wheat plus trees followed by sugarcane plus trees followed by berseem plus trees which was being followed by sarsoun plus trees.

Discussion

Current Status and Potential

The amount of carbon sequestered in each union council differs from each other slightly. The climatic conditions of the tehsil Samundri are almost same. But species distribution also determines the amount of carbon sequestered in each union council. Moreover the area of each union council is different. So the statistical tools which are being used also depend on the area of each union council. It was also observed that if the average number of trees per hectare is greater than the amount of carbon sequestered by the trees is also in huge amount. The carbon storage capacity in agroforestry differs across species and geography. Furthermore, the amount of carbon in any agroforestry system depends on the structure and function of different components within the systems (Schroeder, 1994; Albrecht and Kandji, 2003; Nawaz et al., 2017a).

It has been estimated that the croplands of the whole world have potential to sequester about 0.75-1 Pg yr^{-1} of carbon. It is important to mention that removal of forests and other agricultural activities are responsible for removal of about 1.6-1.8 Pg C yr^{-1} (Lal and Bruce, 1999). The rate of storing carbon in silvopastoral systems was $6.72tCha^{-1}yr^{-1}$ while the rate at which carbon accumulated in grass lands was only 3.14 tC $ha^{-1}yr^{-1}$ (NRCAF, 2007).

Similary to current status, the potential of each union council is different. At the full potential, additional 1.54 CO_2 t ha^{-1} yr^{-1} can be sequestered by increasing and properly managing the farm trees. In the literature it is reported that the tree species which were grown on the agricultural lands have the potential to capture 3.9 tC $ha^{-1}yr^{-1}$. And if tree species are grown on the forest lands which are considered to be degraded then they can sequester 1.79 $tCha^{-1}yr^{-1}$ (Maikhuri et al., 2000; Oelbermann, 2004). So, our findings are well coherent with the previous studies and it shows that even under semi-arid climatic conditions, if these agroforestry areas are well managed they have the great potential to sequester and stock the atmospheric CO_2.

Soil Carbon

For soil carbon, the results are agreed with Ariapour and Asgari (2012) and Hughes et al. (2006), who showed the higher C values under the trees canopies. In the literature, the enhancement of soil carbon and soil organic matter after afforestation practices is well documented fact. A study was performed to calculate the increment in the soil organic carbon (SOC) by growing crop of *Cymbogon sp.* In combination with two types of trees' species. The first one was *Populus deltoides* and the other one was *Eucalyptus*. The results were very astonishing and it was observed that about 33.3% - 83.3% carbon can be enhanced in soil by introducing tree species. It was also concluded that SOC was more where *Populus deltoides* was grown as compared to *Eucalyptus* (Singh et al., 1989).

Socioeconomic Conditions

Similar to other developing countries, mostly farmers of the study area were young with low earnings and less education. Furthermore, small land holdings and lack of advanced technologies were major problems of the atudy area. For poor farmers, farm trees are considred as bank deposits and planted on each farmland, so that, they could be sold at the time of need or emergency (Zubair and Garforth, 2005). Although the additional income from farms trees per year was not too much but its provision timing worths great. So, farmers with small land holdings plant more number of trees as compared to progressive farmers (Nawaz et al., 2017b) . In forest deficient developing countries like Pakistan, farmers can be well motiviated to increase the farm trees through proper policies and provision of financial and technical support (Nawaz et al., 2016).

Agroforestry Status and Trends

Farmers grow trees on their fertile lands for two major benefits: fuels wood and timberwood (Nawaz et al., 2016). Pakistan is an energy deficient country and fuelwood is the major source of energy/fire in the most of the villages and rural areas of Pakistan (Zubair and Garforth, 2005). So, farmers of the study area mostly grow trees for feulwool while a small fraction of fuelwood is directly consumed by farmers to fulfil the domestic needs and remaining trees are sold in the market at weight based prices (Masera et al., 2001). Although trees grown for timberwood provide more income than fuelwood trees but they have to be retained for long periods on farmlands, however, financial conditions of the farmers do not allow them to wait for delayed incomes. So, even timber tree species are oftenly sold out as fuelwood to avail quick incomes (Nawaz et al., 2016). Other additional non-wood benefits like medicine, climatic moderation, climate change mitigation, soil improvement etc. are not given well deserved consideration due to lack of awareness and bad financail conditions (Albrecht and Kandji, 2003). Selecting multipurpose trees such as fruit trees and fodder trees provide additional benefits and more popular when farmer has livestock as well (Githae et al., 2011). 10-12 trees/acre or 25-30 trees/ha can be planted on farmlands under irrigated conditions without severe damage to cultivated crops (Nair, 2011). The results are in agreement as well with previous studies (Qureshi, 2005). Field trends are changing for planting farm trees due dieback disease in shisham (*D. Sissoo*) (Nawaz et al., 2016). Shisham was a very popular tree among farmers and was intensively planted with crops due to its growing characteristics (nitrogen fixing timber tree species) and value in market. However, recently *E. camaldulensis* (Sufaida) is replacing the Shisham only due to fast growing nature and better profitabiltiy. Other than sufaida, widly planted trees are Kikar (*Acacia nilotica*) and Poplar (*Populus deltoides*). Similar findings are reported in Nawaz et al. (2016; 2017b).

Allometric Relations and Soil Parameters

On irrigated farmlands, being fast growing trees, both *D. sissoo* and *E. camaldulensis* show almost similar primary and secondary growth under semi-arid climatic conditions. However, contrary to forest or plantations, secondary growths are more linked with tree ages.Our results are in agreement with Kumar (2010) and Maiknuri et al. (2000).

Physico-chemical properties of soils under tree canopies are different from fallow or cultivated areas and these differences are also significant for different agroforestry combinations (Nair, 2011). Noureen et al. (2007) reported relatively, higher level of EC in under canopy soils while checking the effects of litter of *Calligonum polygonoides* in cholistan desert. Abd El-Fattah and Dahmash (2002) examined lower values of pH while studying the effect of *Alhagi maurorum* (Medio), *Tamarix aphylla* (Ehrenb) *Ege*, *Zygophyllum coccineum* (L), *Halocmmum strobilaceum* (M. Bieb) and also, *Parkinsonia aculata* (L) on soil conditions. The above mentioned results of this study have also been supported by the findings of Rehman et al. (2010).

Xu et al. (2006) studied the soil Physico-chemical properties under the canopy of *Tamarix ramosissima* and higher K content under the canopy of that tree. Same findings were quoted by Githae et al. (2011) while studying the effect of *Acacia Senegal* on soil physico-chemical properties in sub Saharan desert of Africa. The results for soil nitrogen have been supported by Tirpathi et al. (2009). He examined higher N values under the canopy of trees of different agro-forestry systems in India. Similar results were also quoted by Imoro et al. (2014) while studying soil plant improvement as influence by planting *Voandzeia subterranea* and *Arachis hypogea*.

Conclusions

In the forest deficient countries like Pakistan where agroforestry is fulfilling the major demands of wood, farm trees can serve as front lines against the global challenges of climate change by sequestering huge amount of CO_2. Althrough the farm trees are not planted to reduce the atmosheric CO_2 but they are currently sequestring huge amounts of carbon and they have great potential to mitigate climate change. However, there is immediate need for acceptance of farm trees for accrediting the carbon credits to promote the agroforestry in Pakistan and to encourage afforestation on farmlands.

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