Research Article

Agroforestry practices and its contribution to combat climate change in subtropical region of Pakistan

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Abstract

Agroforestry systems could have an indirect impact on Carbon (C) sequestrations by reducing the pressure on natural forests, which are the largest C sink in the terrestrial ecosystem. This research was conducted in subtropical region of Pakistan (Tehsil Takht Bhai District Mardan). Two types of sampling methodologies were used for data collection. A questionnaire was compiled for the collection of information on Agroforestry practices, while a stratified random sampling method was used to collect data and made measurements about carbon contents stored in these agroforestry systems. Total 15 trees species were found associated with agricultural practices belonging to 7 families. Four (4) species were belonging to *Moraceae* family. One (1) specie belonged to *Meleiaceae*, *Myrtaceae* and *Simaroubaceae* each, 4 species belonged to *Fabaceae* and 2 species belonged to *Rhamnaceae* family. Total area under Agroforestry practices was about 22,866.4 hectares. Major Agroforestry system was Agrisilviculture system under practice in 11433.2 hectares land area, followed by Silvopastoral system which occupied 6859.9 hectares while area covered by Agrisilvipastoral system was 4573.2 hectares. 275 farmers were interviewed. Through final analysis it was found that 67% farmers were practicing pure Agrisilviculture system, 21% farmers were in favor of Silvopastoral system and 12% farmers practiced Agrisilvipastoral system. The greatest amount of carbon was stored by Silvopastoral system (76.33 t.ha⁻¹) followed by Agrisilvipastoral system (68.05 t.ha⁻¹) while the least carbon was stored by Agrisilvicultural system (11.61 t.ha⁻¹).

Keywords: Agroforestry practices; Agrisilviculture; Agrisilvipastoral; Biomass; Carbon stocks; Climate change; Silvopastoral

Introduction

Agroforestry is recognized as a fundamental science that has the potential to provide many of the environmental services and livelihoods

needed to improve the economic condition of farmers and rural communities [1]. On the other hand, it had been claimed that agroforestry offers opportunities for

improving agricultural land use systems, providing long-term benefits and reducing negative environmental impacts at local and global levels [2].

Agroforestry is a conventional method for combining trees with agricultural crops or pastures, so that it can benefit greatly from the management of the same land [3]. Vegetation with agricultural and pastoral activities on land, either in spatial or temporal order, so that there is an economic as well as an ecological interaction between them. The combination of trees, crops and/or animals into an agroforestry system has the ability to reduce soil infertility, erosion, improve aesthetics, water quality, increase biodiversity and store carbon [2, 4, 5]

The management of agricultural carbon sequestration systems had been reported as a partial solution to climate change [3]. Establishing and maintaining perennial vegetation to improve C sequestration is more cost effective that minimizes environmental and health risks compared to most other techniques. The perennial vegetation is more efficient than the annual vegetation as it distributes a higher amount of carbon underground and often prolongs the growing season [6].

Climate change through improving carbon sequestration and improving the system's ability to manage the harmful effects of changing climatic conditions can be achieved through the use of different Agroforestry systems. In the meantime, agroforestry is the best example of coping with the negative effects of climate change [7]. In addition, improved farming practices, can double crop yields, reduce greenhouse gas emissions and improve the soil carbon storage capacity (SOC) [8].

In addition, agroforestry systems could have an indirect impact on C sequestrations by reducing the pressure on natural forests, which are the largest C sink in the terrestrial ecosystem. It had been estimated that 1

hectare of sustainable agroforestry in tropical regions can potentially save 5 to 20 hectares of deforestation [9]. This report further argued that agroforestry systems can bind carbon at average time rates of 0.2 to 3.1 Mg C ha⁻¹. On a global scale, it was estimated that agroforestry could be implemented on 585 to 1275 x 10⁶ hectares of technically suitable land and that these systems could store 12 to 228 Mg C ha⁻¹ under the prevailing climatic and edaphic conditions. Average carbon storage through forestry practices had been estimated to be 9, 21, 50 and 63 mg C ha⁻¹ in semi-arid, sub-humid, humid and temperate regions. For small-scale agroforestry systems in the tropics, the possible C sequestration rates are between 1.5 and 3.5 mg C ha⁻¹ y⁻¹. This study provides basic findings about agroforestry systems in carbon sequestration and their importance in combating climatic change. With addition, that it would clarify the stress minimizes on natural forest through enhanced agroforestry systems.

Materials and methods

Present study was conducted in the subtropical region of Pakistan, Tehsil Takht Bhai District Mardan KPK (Figure 1). It is in the subtropical zone; its geographical coordinates was 34° 16' 55" N and 071° 55' 42" E. Total area of Tehsil Takht Bhai was 404 km² (40400 ha). Altitude/Elevation of the study area ranges from 1120 feet to 1430 feet above sea level. Average temperature in Tehsil Takht Bhai is 22.2°C; while the annual rainfall averages to 559mm. Study area was under different practices. Land covered by infrastructure was about 23% (9,292 hectare). Similarly, water points had covered an area of 0.4% (161.6 hectares) non-cultivated area was 14% (5,656 hectare), other miscellaneous uses 6% (2,424 hectares) while the cultivated or cropped land which support the agroforestry practices was 56.6% (22,866.4 hectares) of its total area. (Figure 2).

Figure 1. Map of the study area

Figure 2. Land use of Study area

Research design

Two types of sampling methodologies were used for data collection in this research study. A questionnaire was compiled for the collection of information on agroforestry practices, while a stratified random sampling method was used to collect data on the carbon contents stored in these agroforestry systems. Study area was divided on the basis of union councils. Thereafter, in each union council, a

sample of each agroforestry system (Agrisilvicultural, Silvopastoral and Agrisilvopastoral System) was made. The entire Tehsil was divided into 17 union councils. Three samples were taken in each union council. The total number of sampling plots was 51.

Sampling plot selection and size (For diameter at breast height (DBH) and height measurement)

The samples were randomly selected in each union council in different agroforestry systems. The plot was square with a fixed dimension of 100 x 100 m² [10] in linear guard belt border plantations, while for block plantations the dimensions of the sample plot were 33 x 33 m². Using the Global Positioning System (GPS), elevation and coordinates of the individual sample plots were taken. The size of each sample plot was 1 and 0.1 ha, respectively.

Measurement of tree volume (m³)

Tree volume was measured from tree diameter (cm) at diameter at breast height (DBH) and height (m). Height was taken from Dia-height ratio table present in Divisional forest office. Diameter tape and caliper were used for Diameter measurement. Volume of total tree m³ha⁻¹ present in the study area was calculated by using the following formulae [11].

$$V (\text{m}^3 \text{ ha}^{-1}) = AH \times FF \times SD$$

As,

V= volume of trees (m³)

A= cross sectional area at breast height point (m²)

H= height (m)

FF= form factor and

SD= Stem Density (ha⁻¹)

Measurement of stem biomass

Stem biomass was further estimated by multiplying BWD (Basic Wood Density) kg.m⁻³ and tree volume (m³). The value of Basic Wood Density was taken from current literature. For the estimation of biomass, following formulae was used.

$$SB (\text{t ha}^{-1}) = BWD (\text{kg/m}^3) \times TV (\text{m}^3 \text{ ha}^{-1}) / 1000$$

Where,

SB= stem biomass

BWD= basic wood density and

TV= tree volume

Estimation of trees total biomass and carbon stocks

Total tree biomass (t ha⁻¹) was calculated from stem biomass and biomass expansion

factor (BEF). Total biomass was calculated using formulae below. BEF is the contribution of branches leaves and roots biomass to the total biomass of a tree [11].

$$TTB (\text{t ha}^{-1}) = SB (\text{t ha}^{-1}) \times BEF$$

Where,

TTB= total trees biomass

SB= stem biomass and

BEF= biomass expansion factor

While for carbon stocks estimation, total biomass was multiplied with the conversion factor of 0.5 which had been proved globally as it is the partial of fresh biomass [11]. Total carbon stocks were estimated by using formulae below.

$$\text{Total C-stocks} (\text{t ha}^{-1}) = \text{Total biomass} (\text{t ha}^{-1}) \times 0.5$$

Measurement of under story vegetation, deadwood and litter biomass

For understory vegetation and deadwood litter biomass, 1 m² plots were lay down in each sample plot through fixed dimensional quadrat for estimation of grasses, deadwood and litter biomass. Fresh weight of grasses, deadwood and litter was estimated of all sample plots. 1 kg of green weight was taken and dried in an oven for 48 hours at 72 degree Celsius temperature. Finally, dry weight was taken and proceeds ahead.

Statistical analysis

For statistical analysis of data, various software was used. The statistics were organized in MS Excel, Univariate statistics was carried out in PAST while graphical representation was done in sigma plot version 14.

Results

GPS Co-ordinates and elevation of each sample plot

Total 51 sample plot were taken in the study area. Study area was divided on the basis of union councils. Total numbers of union councils were 17. In each union council different agroforestry systems were studied. One sample plot was taken in each agroforestry system. Elevation and GPS co-

ordinates of each sample plot were taken with the help of GPS (Global Positioning System) showed in (Table 1).

Table 1. GPS Co-Ordinates and Elevation of each Sample Plot

Plot. No	Elevation (ft)	Latitude	Longitude	Plot .No	Elevation (ft)	Latitude	Longitude
1	1201	N 34 18' 58"	071° 51' 33"	2	1211	34° 19' 17"	071° 52' 12"
3	1202	34° 19' 31"	071° 53' 09"	4	1206	34° 20' 13"	071° 51' 31"
5	1102	34° 19' 08"	071° 49' 45"	6	1063	34° 19' 31"	071° 50' 27"
7	1181	34° 20' 22"	071° 52' 41"	8	1144	34° 20' 16"	071° 53' 47"
9	1197	34° 21' 10"	071° 53' 57"	10	1174	34° 18' 7"	71° 51' 59"
11	1145	34° 17' 18"	71° 52' 28"	12	1174	34° 17' 5"	71° 53' 8"
13	1079	34° 17' 2"	71° 53' 59"	14	1079	34° 17' 3"	71° 54' 0"
15	1151	34° 19' 1"	71° 54' 39"	16	1082	34° 15' 23 "	71° 54' 44"
17	1099	34° 15' 16"	71° 54' 56"	18	1072	34° 15' 0"	71° 54' 48"
19	1069	34° 15' 36"	71° 55' 36"	20	1075	34° 15' 30"	71° 55' 53"
21	1099	34° 15' 56"	71° 55' 43"	22	1177	34° 18' 40"	71° 54' 31"
23	1184	34° 18' 52"	71° 54' 43"	24	1173	34° 18' 10"	71° 54' 14"
25	1154	34° 19' 47"	71° 55' 29"	26	1145	34° 19' 58"	71° 56' 1"
27	1177	34° 19' 14"	71° 56' 47"	28	1122	34° 19' 43"	71° 57' 13"
29	1158	34° 19' 37"	71° 57' 29"	30	1170	34° 19' 14"	71° 56' 26"
31	1116	34° 16' 17"	71° 56' 47"	32	1093	34° 15' 02"	71° 56' 19"
33	1090	34° 15' 32"	71° 56' 42"	34	1440	34° 17' 16"	71° 56' 09"
35	1163	34° 17' 20"	71° 55' 39"	36	1323	34° 17' 22"	71° 56' 04"
37	1281	34° 23' 00"	71° 59' 03"	38	1267	34° 22' 55"	71° 58' 55"
39	1234	34° 23' 12"	71° 59' 02"	40	1247	34° 23' 29"	71° 59' 17"
41	1257	34° 23' 34 "	71° 59' 02"	42	1239	34° 23' 25"	71° 59' 19"
43	1263	34° 23' 44"	71° 55' 28"	44	1287	34° 24' 21"	71° 55' 56"
45	1272	34° 23' 24"	71° 56' 09"	46	1349	34° 25' 21"	71° 59' 26"
47	1330	34° 24' 35"	71° 59' 52"	48	1314	34° 24' 29"	71° 58' 56"
49	1071	34° 14' 40"	71° 57' 51"	50	1064	34° 13' 50"	71° 57' 47"
51	1080	34° 14' 55"	71° 57' 21"				

Forest trees species and their identification

Samples of forest trees were taken of each species and were put on herbarium sheets in the laboratory. Herbarium sheets were brought to the Department of Botanical Sciences, Abdul Wali Khan University Mardan for further identification. Total 15 species were found in the study area (rising

with agriculture crops) belonging to 7 families. 4 species were belonging to *Moraceae* family. One species belonged to *Meleiaceae*, *Myrtaceae* and *Simaroubaceae* each, 4 species belonged to *Fabaceae* and 2 species belonged to *Rhamnaceae* family. Species - *Populous alba*, *Populous nigra*, *Morus nigra*, *Morus alba*, *Morus indica*,

Melia azedarach and *Ailanthus altissima* were mostly grown with food crops in which boundary plantation, alley cropping, shelter belt and block plantation practices were up to

the mark. Details of species, their local names, botanical names and families were given in (Table 2).

Table 2. Forest trees species of the study area

S/no	Botanical Name	Local Name	Family
1	<i>Morus nigra</i>	Mulberry	<i>Moraceae</i>
2	<i>Morus alba</i>	Mulberry	
3	<i>Morus indica</i>	Mulberry	
4	<i>Broussonetia papyrifera</i>	Paper mulberry	
5	<i>Melia azedarach</i>	China berry tree	<i>Meleiaceae</i>
6	<i>Ailanthus altissima</i>	Tree of heaven	<i>Simaroubaceae</i>
7	<i>Eucalyptus camaldulensis</i>	Safeeda	<i>Myrtaceae</i>
8	<i>Dalbergia sissoo</i>	Sheesham	<i>Fabaceae</i>
9	<i>Dalbergia latifolia</i>	Sheesham	
10	<i>Acacia nilotica</i>	Arabic tree	
11	<i>Acacia modesta</i>	Arabic tree	
12	<i>Ziziphus mauritiana</i>	Beer	<i>Rhamnaceae</i>
13	<i>Ziziphus jujuba</i>	Beer	
14	<i>Populous alba</i>	Poplar	<i>Salicaceae</i>
15	<i>Populous nigra</i>	Poplar	

Agroforestry systems of the study area

The following agro-forestry systems were studied in the study area.

1. Agrisilvicultural system (ASS)
2. Silvopastoral system (SPS)
3. Agrisilvopastoral system (ASPS) or Mixed system

Area covered by agroforestry systems in the study area

There whole Tehsil supporting and keep maintaining enhanced agroforestry practices in which three major agroforestry systems were found - Agrisilvicultural system, Silvopastoral system and Agrisilvopastoral system. Total area under agroforestry practices was about 22866.4 hectares. Study area support different agroforestry systems with different proportion. The major agroforestry system was Agrisilviculture

system which occupied about (11433.2 hectares), following by Silvopastoral system (6859.9 hectares) while the lower area covered by Agrisilvopastoral system was (4573.2 hectares) of its total cropped area. (Figure 3) showed contribution of different agroforestry systems in the study area.

Farmer's approaches towards agroforestry systems

To find out the farmer's approach towards agro-forestry systems, questionnaire was developed and 275 households/farmers were interviewed. Through final analysis it was found that maximum farmers (67%) were practicing pure Agrisilviculture system, 21% farmers were in favor of Silvopastoral system and 12% farmers practiced Agrisilvopastoral system (Figure 4).

Figure 3. Area occupancy of the study area by different agroforestry systems

Figure Error! No text of specified style in document.. Farmers approaches towards agroforestry systems

Union councils wise carbon stock tons ha⁻¹ in all agroforestry system

In each union council the different agroforestry system had different contribution in carbon sequestration. The minimum amount of carbon stored in UC Pir saddi, which was 112.64 t.ha⁻¹ (tons per hectare) while the richest union council was UC Pat Baba, which has stored maximum amount of carbon in all agroforestry systems (207.89 t.ha⁻¹) (Figure 5).

Minimum amount of carbon stored by Silvopastoral system in all union councils was recorded (37.15 t.ha⁻¹) and maximum amount of carbon stored was (124.09 t.ha⁻¹). (Table 3)

Greatest amount of carbon stored by the Silvopastoral system was recorded as 76.33 t.ha⁻¹. Similarly, minimum C sequestration by Agrisilvopastoral system was recorded as 29.99 t.ha⁻¹ and maximum amount of carbon sequestration was 115.52 t.ha⁻¹ while the average carbon stored by Agrisilvopastoral system was recorded as 68.05 t.ha⁻¹ (Table 3). Lowest contribution made by Agrisilvicultural system which was 4.35 t.ha⁻¹ minimum and maximum amount was 35.21 t.ha⁻¹, the average carbon stored by Agrisilvicultural system was 11.61 t.ha⁻¹. Details of carbon sequestration by different agroforestry systems was given in (Figure 6).

Figure 5. Union councils wise Carbon stocks t.ha⁻¹ in all agro-forestry systems

Table 3. Details of Union council's wise Carbon stocks t.ha⁻¹ in all agro-forestry systems

S/No	Union Councils	A.S.S C-stocks t.ha ⁻¹	S.P.S C-stocks t.ha ⁻¹	A.S.P.S C-stocks t.ha ⁻¹	T.C-S t.ha ⁻¹
1	UC Madey BaBa	7.87	124.63	46.24	178.74
2	UC Pirsaddi	18.41	54.45	39.78	112.64
3	UC Jalala	4.35	37.15	115.52	157.02
4	UC Narai	35.21	49.98	44.89	130.08
5	UC Takkar	7.57	40.19	107.28	155.04
6	UC Saroshah	6.92	93.06	78.74	178.73
7	UC PatBaba	28.09	114.37	65.43	207.89
8	UC Shergarh	8.74	117.69	78.94	205.36
9	UC Parkho Dherai	6.97	66.37	29.99	103.33
10	UC Daman e Koh	7.59	62.13	93.37	163.08
11	UC Seri Bahlol	8.08	87.25	57.27	152.60
12	UC Kot jongara	10.34	64.30	45.54	120.18
13	UC Lundkhar	25.19	60.46	95.46	181.12
14	UC Makori	6.73	73.09	72.10	151.92
15	UC Hathyaan	4.86	93.06	55.25	153.16
16	UC Mia Essa	4.83	96.29	54.24	155.36
17	UC jehangirabad	5.60	63.13	76.80	145.53

Figure 6. Average carbon sequestration by each agro-forestry system

Carbon sequestration by different forest tree species (tons ha⁻¹)

In the whole study area, major carbon sequestration contribution was made by *Populous* (38.43 t.ha⁻¹) while the minimum amount of carbon stored by *acacia* species was 0.22 t.ha⁻¹. Contribution made by *Morus species* was 4.08 t.ha⁻¹, *Melia azedarach* stored 4.08 t.ha⁻¹, *Ailanthus altissima* stored 3.26 t.ha⁻¹, *Eucalyptus species* stored 36.07 t.ha⁻¹, *Dalbergia species* stored 22.64 t.ha⁻¹, *Ziziphus species* stored 2.25 t.ha⁻¹ and *Broussonetia papyrifera* stored 1.74 t.ha⁻¹. Graphical representation of carbon sequestration by different forest trees species was given in (Table 4).

Combine agroforestry systems carbon stocks (grasses, litter and deadwood) t. ha⁻¹

For understory vegetation, subplots of 1m² were taken in each sample plot through quadrature of (1m²) of fixed measurement for estimation of understory vegetation and deadwood litter biomass. The green weight of all vegetation was estimated of all example plots. One (1) kg of green weight was taken and dried in an oven for 48 hours at 72° C and their dry weight was estimated.

In all agroforestry systems, total 51 quadrates of 1m² were laid down. By final analysis it was calculated that lowest contribution of C storage done by a plot was (0.41 t.ha⁻¹) and highest contribution was (2.61 t.ha⁻¹) while the average carbon stocks per hectare was recorded as 1.8 t.ha⁻¹. Detailed calculation can be seen in (Table 5, Figure 7).

Discussion

In the study area, a total of 15 forest trees species were studied belonging to 7 families. All these forest trees species were fast growing species enhancing maximum biomass production from agricultural land with co-relation to agricultural crops. The agriculture zone sector still remains the largest sector as it played an important role in the national economy by contributing about 23.3% to the total GDP of Pakistan [12]. The

combination of trees with the cash crops, food crops or grasses for livestock, brings maximum benefits for the human beings as well as to the land itself. The combinations of trees, farming crops and/or animals into an agro-forestry system has the ability to improve soil fertility, water quality, reduce erosion, enhance aesthetics, increase biodiversity and sequester carbon [2, 4, 13]. In the present study, it was found that the maximum practiced system of agro-forestry system was Agrisilvicultural system which was accepted and adopted by maximum farmers (67%) as revealed in (Figure 4) followed by Silvopastoral system which was practiced by 21% farmers and the mixed or Agrisilvopastoral system was practiced by only 12% of the farmers in the study area. The major agro-forestry system was Agrisilviculture system which occupied about 11433.2 hectares, followed by Silvopastoral system which occupied 6859.9 hectares while the lower contribution made by Agrisilvopastoral system was 4573.2 hectares of its total cropped area (Figure 3). Agro-forestry had been projected as approaches not only for adaption to climate change, but also for alleviation and addressing issues of food security and environmental degradation in agricultural systems. Agro-forestry is achieving recognition as an adaptation strategy, because traditional agricultural systems frequently include agroforestry practices [14]. In this regard, the implementation of agro-forestry is costly and more useful than other approaches [6]. Agricultural forestry is known to be of particular importance as a carbon sink strategy because of its applicability to agricultural land and the restoration of degraded land and reforestation programs [15, 11]. Therefore, in the present study, it was concluded that the maximum amount of carbon was stored by Silvopastoral system (76.33 t.ha⁻¹) which plays role just like an

undisturbed natural forest. Similarly, the amount of carbon stored by mixed or Agrisilvopastoral system (68.05 ton ha⁻¹) was also greater than the carbon stored by Agrisilvicultural system (11.61 t.ha⁻¹) as shown in (Figure 6). It was because of the density of trees present per hectare. The number of trees on a piece of land increases the chances for capturing of atmospheric carbon.

In the study area, fast growing species like *Populus species*, *Eucalyptus species*, and *Ailanthus* and *Malia species* has maximum carbon capturing capacity. The maximum accepted species for agro-forestry practices was *Populus* species which had short rotation period of 6 to 12 years. In this short period of time the average carbon storage capacity of *Populus* species was calculated to be 38.43 t.ha⁻¹ (Table 4).

According to Noble *et al.* [16] by improving existing management strategies and practices (e.g. sustainable management of trees on agricultural land) in existing agroforestry, these practices could tie up an additional 12,000 Mg C y⁻¹ by 2010 and 17,000 Mg C y⁻¹ by 2040, In addition, 630 million hectares of the sequestering potential of 391,000 Mg C y⁻¹ by 2010 and of 586,000 Mg C y⁻¹ by 2040. The present study concluded that the carbon sequestration potential of agroforestry systems is increasing in ascending order by advanced farming practices. It was calculated

that the average carbon capture capacity for the Silvopastoral system was highest at 76.33 t ha⁻¹ compared to the Agrisilvopastoral system, which contains 68.05 C t.ha⁻¹. Lowest contribution from Agrisilvicultural system (11.61 t.ha⁻¹) (Figure 6). Dixon [9] concluded that agroforestry sequester carbon with average rates of 0.2 to 3.1 Mg C ha⁻¹. On a global scale, it was estimated that agroforestry could be implemented on 585 to 1275 x 10⁶ hectares of technically suitable land and that these systems could store 12 to 228 Mg C ha⁻¹ under prevailing climatic and edaphic conditions. Average carbon storage through agricultural and forestry practices had been estimated to be 9, 21, 50 and 63 Mg C ha⁻¹ in semi-arid, sub-humid, humid and temperate regions. For small-scale agroforestry systems in the tropics, the potential C sequestration rates were between 1.5 and 3.5 mg C ha⁻¹ y⁻¹.

With addition to live biomass present in an agro-forestry system, grasses, litter and deadwood biomass has also a key potential for carbon sequestration. The maximum amount of carbon stored by these under story deadwood, litter and grasses biomass in all agroforestry system (Figure 7) was calculated as 2.61 t.ha⁻¹ and the lowest capacity for carbon sequestration was 0.41 t.ha⁻¹, while the average amount of carbon stocks present in all these agro-forestry system was calculated as 1.81 t.ha⁻¹.

Table 4. Details of Carbon sequestration by different forest trees species

Species	Avg C-stocks t.ha ⁻¹	Species	Avg C-stocks t.ha ⁻¹
<i>M.alba</i>	4.08	<i>Ziziphus spp</i>	2.25
<i>M.azedarach</i>	4.08	<i>Populous spp</i>	38.43
<i>A.altissima</i>	3.26	<i>B.papyrifera</i>	1.74
<i>Eucalyptus Spp</i>	36.07	<i>Acacia spp</i>	0.22
<i>D.sissoo</i>	22.64		

Table 5. Details of Combine agroforestry systems carbon stocks t.ha⁻¹ (grasses, litter and deadwood)

Plot no	System	Grasses Oven dry wt.Kg/m ²	Deadwood, litter Oven dry wt.Kg/m ²	Total biomass Kg/m ²	Total biomass Kg/ha	C.stocks t.ha ⁻¹
1	A.S.S	0.05	0.26	0.30	3030.66	1.51
2	=	0.05	0.04	0.08	830	0.41
3	=	0.03	0.16	0.19	1937.33	0.96
4	=	0.07	0.13	0.19	1935.3	0.96
5	=	0.06	0.16	0.22	2211.3	1.10
6	=	0.05	0.21	0.26	2575.3	1.28
7	=	0.06	0.26	0.31	3130.0	1.56
8	=	0.05	0.29	0.34	3429.33	1.71
9	=	0.05	0.35	0.40	3983.3	1.99
10	=	0.06	0.39	0.45	4496.0	2.24
11	=	0.06	0.24	0.30	2955.3	1.47
12	=	0.07	0.19	0.26	2616.7	1.30
13	=	0.06	0.33	0.39	3932.7	1.96
14	=	0.06	0.15	0.20	2074	1.03
15	=	0.06	0.15	0.21	2099.33	1.04
16	=	0.07	0.16	0.23	2259.3	1.12
17	=	0.06	0.09	0.15	1504.66	0.75
18	S.P.S	0.09	0.21	0.29	2906.0	1.45
19	=	0.08	0.26	0.33	3358.66	1.67
20	=	0.07	0.29	0.36	3649.3	1.82
21	=	0.07	0.23	0.29	2918.0	1.45
22	=	0.06	0.39	0.45	4524.0	2.26
23	=	0.09	0.42	0.51	5085.3	2.54
24	=	0.11	0.28	0.38	3854	1.92
25	=	0.09	0.35	0.44	4440.66	2.22
26	=	0.10	0.19	0.28	2855.33	1.42
27	=	0.10	0.26	0.36	3563.3	1.78
28	=	0.10	0.21	0.30	3030.0	1.51
29	=	0.08	0.22	0.30	2996.0	1.49
30	=	0.09	0.36	0.45	4486.0	2.24
31	=	0.08	0.44	0.52	5208.7	2.60
32	=	0.10	0.37	0.47	4671.33	2.33
33	=	0.10	0.19	0.28	2847.3	1.42
34	=	0.10	0.21	0.31	3066.0	1.53
35	A.S.P.S	0.14	0.37	0.50	5047.3	2.52
36	=	0.15	0.37	0.52	5224.7	2.61
37	=	0.15	0.24	0.4	3915.3	1.95

38	=	0.16	0.28	0.43	4398	2.19
39	=	0.16	0.29	0.46	4569.33	2.28
40	=	0.13	0.16	0.29	2900.67	1.45
41	=	0.16	0.15	0.30	3018.67	1.50
42	=	0.12	0.13	0.26	2552.67	1.27
43	=	0.12	0.13	0.25	2527.33	1.26
44	=	0.12	0.11	0.22	2235.33	1.11
45	=	0.12	0.12	0.23	2334	1.167
46	=	0.15	0.16	0.30	3047.33	1.52
47	=	0.13	0.08	0.21	2119.3	1.05
48	=	0.12	0.10	0.22	2210.7	1.10
49	=	0.13	0.28	0.40	4022.7	2.01
50	=	0.14	0.22	0.35	3580	1.79
51	=	0.15	0.35	0.49	4964	2.48

Figure 7. Combine agro-forestry systems carbon stocks (grasses, litter and deadwood) t.ha⁻¹

Conclusion

Total area under agroforestry practices was about 22,866.4 hectares. Major Agroforestry system was Agrisilviculture system which was under practice in 11,433.2 hectares land area, followed by Silvopastoral system which occupied 6859.9 hectares while area covered by Agrisilvipastoral system was 4573.2 hectares. 67% farmers were

practicing pure Agrisilviculture system, 21% farmers were in favor of Silvopastoral system and 12% farmers were liked to practice Agrisilvopastoral system. The present study concludes that the carbon sequestration potential of agroforestry systems is increasing in ascending order by advanced farming practices. It was calculated that the average carbon capture

capacity for the Silvopastoral system was highest (76.33 t ha^{-1}) compared to the Agrisilvopastoral system, which contains (68.05 t ha^{-1}) C. lowest contribution for C sequestration was studied in Agrisilvicultural system (11.61 t ha^{-1}). With addition to live biomass present in an agroforestry system, maximum amount of carbon stored by these under story (deadwood, litter and grasses) biomass in all agroforestry system was calculated as, (2.61 t ha^{-1}) while minimum amount of carbon sequestration was (0.41 t ha^{-1}), while the average amount of carbon stocks present in all these agroforestry system was calculated as (1.81 t ha^{-1}).

Authors' contributions:

Conceived and designed the experiments: Shah S & Malik AM, Performed the experiments: Saleem A, Iqbal J & Shah S, Analyzed the data: Shah S, Saleem A & Gulzar A, Contributed reagents/ materials/ analysis tools: Shah S & Saleem A, Wrote the paper: Shah S.

References

- Regmi BN (2003). *Contribution of agroforestry for rural livelihoods: A case of Dhading District, Nepal*. Paper presented at the International Conference on Rural Livelihoods, Forests and Biodiversity.
- Garrett H, Rietveld W, Fisher RF, Kral D & Viney M (2009). *North American agroforestry: an integrated science and practice*: American Society of Agronomy Madison. *J Mount Sci* 11(1): 167-179.
- Kalinganire A, Weber J, Uwamariya A & Kone B (2007). Improving rural livelihoods through domestication of indigenous fruit trees in the parklands of the Sahel. *Fruit Trees* 10: 186-203.
- Williams-Guillén K, Perfecto I & Vandermeer J (2008). Bats limit insects in a neotropical agro-forestry system. *Sci* 320(5872): 70-70.
- Garrity DP (2004). Agro-forestry and the achievement of the Millennium Development Goals. *Agro-For Sys* 61(1-3): 5-17.
- Su Y, Lu J, Sujata M, Ashiq A & Xu J (2013). Policy and institutions in adaptation to climate change: case study on tree crop diversity in China, Nepal, and Pakistan. ICIMOD Working Paper (2013/3).
- Verchot LV, Van Noordwijk M, Kandji S, Tomich T, Ong C, Albrecht A & Palm C (2007). Climate change: linking adaptation and mitigation through agro-forestry. *Mitig and Adap Stra for Glo Change* 12(5): 901-918.
- Branca G, Lipper L, McCarthy N & Jolejole MC (2013). Food security, climate change, and sustainable land management. A review. *Agro For Sustain Develop* 33(4): 635-650.
- Dixon R (1995). Agroforestry systems: sources of sinks of greenhouse gases? *Agrofor Sys* 31(2): 99-116.
- Antle JM, Stoorvogel JJ & Valdivia RO (2007). Assessing the economic impacts of agricultural carbon sequestration: terraces and agro-forestry in the Peruvian Andes. *Agric Ecosys & Envi* 122(4): 435-445.
- Ahmad A & Nizami SM (2015). Carbon stocks of different land uses in the Kumrat valley, Hindu Kush Region of Pakistan. *J fores Res* 26(1): 57-64.
- Iqbal M, Ahmad M, Abbas K & Mustafa K (2003). The impact of institutional credit on agricultural production in Pakistan [with comments]. *The Pak Devel Rev* 469-485.
- Nair P (2012). Carbon sequestration studies in agro-forestry systems: a reality-check. *Agro-for Sys* 86(2): 243-253.
- Liang A, Yang X, Zhang X, McLaughlin N, Shen Y & Li W (2009). Soil organic carbon changes in particle-size fractions following cultivation of Black soils in China. *Soil and Tillage Res* 105(1): 21-26.
- Cairns MA & Meganck RA (1994). Carbon sequestration, biological diversity, and sustainable development: integrated forest management. *Env Mgt* 18(1): 13-22.
- Noble I, Bolin B, Ravindranath N, Verardo D & Dokken D (2000). Land use, land use change, and forestry: Cambridge University Press.