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Structure and carbon stock potential in traditional agro forestry system of Garhwal Himalaya

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The present study was conducted in six traditional agro forestry villages i.e., Budali, Manjakot, Manao, Dungripanth, Chamdaar and Keshu to estimate structure and carbon sequestration potential of traditional agroforestry villages. Among the traditional agroforestry system, majority of villages were dominated by *Grewia oppositifolia* followed by *Toona ciliata*. Among the traditional agroforestry system the highest carbon stock was reported 57.45 t/ha in village Chamdaare and lowest (19.85 t/ha) in the vilage Manjakot. The values of total carbon in other villages were 34.98 t/ha in Budali, 31.47 t/ha in Dungripanth, 30.64 t/ha in Keshu and 20.94 t/ha in Manao. The soil organic carbon was highest (146.88±0.74 t/ha) in the village Budali and lowest (12.78±0.67 t/ha) in the village Keshu. In the traditional agroforestry system the average total carbon stock in trees was 32.56 t /ha, whereas the average soil carbon was 56.74 t/ha.

Key words: Structure, Carbon sequestration, traditional agroforestry system, Garhwal Himalaya.

Introduction

The concentration of greenhouse gases (GHGs) in the atmosphere including CO_2 has increased considerably over the last century. Carbon is accumulating in the atmosphere at a rate of 3.5 Pg (Pg = 10^{15} g or billion tons) per annum, the largest proportion of which resulting from the burning of fossil fuels and the conversion of tropical forests to agricultural production (Paustian *et al*., 2000). Scientific evidence suggests that increased atmospheric CO_2 level could have some positive effects such as improved plant productivity (Schaffer *et al*., 1997; Pan *et al*., 1998; Keutgen and Chen, 2001). Although the negative changes in the global climate i.e., rising temperatures, higher frequency of

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droughts and floods are often the most consequential processes associated with an increased concentration of CO_2 in the atmosphere (USDA NRCS, 2000).

The amount of C sequestered largely depends on the agroforestry system put in place, the structure and function of which are to a great extent, determined by environmental and socio-economic factors (Albrecht and Kandji, 2003). Several other factors are also influencing carbon storage in agroforestry systems such as tree species and its management practices. Agroforests are very complex systems, and have higher plant diversity. These complex systems of trees and agricultural crops are widely practised in several other parts of the world i.e., Latin America, Southeast Asia and Equatorial Africa and are among the most sustainable cropping systems in the tropics (Beer *et al*., 1990; Herzog, 1994). The trees play various functions, including shading crops to reduce evapotranspiration, erosion control and nutrient cycling (Beer, 1987; Young, 1997). The regular harvesting of crops, wood and other products, decline in soil fertility can be considered as minimal in complex agroforestry systems. Abundant litter and/or pruning biomass returned to the soil combined with the decay of roots, contribute to the improvement of soil physical and chemical properties (Albrecht and Kandji, 2003). Including important role of agro forestry systems in carbon sequestration it also reduce the pressure on existing natural forests by providing daily needs to the surrounding population i.e., fuel, fodder, timber as direct benefit as well as providing indirect environmental benefits by soil and water conservation, biodiversity conservation, soil nutrients enrichment etc. India has a long tradition of agroforestry systems and several indigenous agroforestry systems, based on people's needs and site-specific characteristics have been developed over the years.

With the above introductory background, the carbon sequestration studies have been carried out by several parts of the worlds however these studies in relation to traditional agro forestry systems of Garhwal Himalaya lack. Therefore, to understand the importance of the agroforestry trees for carbon sequestration, the present study is focused in traditional agroforestry systems in Garhwal Himalaya with the objectives that structure and carbon sequestration potential of traditional agroforestry systems in Garhwal Himalaya.

Materials and methods

Study area

The present study villages were selected around the Srinagar city, which is located at 30.22°N and 78.78°E at the left bank of Alaknanda River at an average elevation of 560 m. The climate of the study area is of monsoonic type and has three different marked seasons in a year, i.e., rainy, winter, and summer. The mean annual temperature ranges between 17°C to 23°C. The mean annual rainfall was 960 mm. Srinagar is the hottest place in the Garhwal (hills) in summers and has sever cold in winters.

The quantitative information and carbon stock of each selected traditional agroforestry system was carried out randomly in the villages i.e., Budali, Manjakot, Manao, Dungripanth, Chamdaar and Keshu for the study. The villages were dominated by *Grewia oppositifolia, Celtis australis, Bauhinia retusa, Toona ciliata* etc. and the crops grown were rice in *Kharif* crop and wheat in *Rabi* crop.

Methodology adopted

Structure of agroforestry system

The tree structure in agroforestry system was carried out by using 10×10 m^2 quadrat. A total of 10 randomly placed quadrats were used on each agroforestry system. The size and number of quadrats were determined by the species area curve (Misra, 1968) and the running mean methods (Kershaw 1973). In each quadrat tree >30 cm circumference (at 1.37 m from the ground) were only counted for trees. The vegetation data were quantitatively analyzed for abundance, density and frequency (Curtis and McIntosh, 1950) and total basal cover (TBC).

Tree carbon estimation

Volume of tree species in each site was calculated by measuring the diameter and height of tree species. The diameter at breast height was measured with the help of tree caliper and height using Ravi's multimeter, form factor was calculated with Spiegel relaskope to find out tree volume using as per following formula given by Pressler (1895) and Bitlerlich (1984).

$$F = 2\, h_1 / 3h$$

where, F is the form factor, h_1 is the height at which diameter is half dbh and h is the total height.
Volume (*V*) was calculated by using the Pressler formula (Pressler 1895) as used by Sheikh *et al*. (2012)

$$V = F \times h \times g$$

where *F* is the form factor, *h* is the total tree height and *g* is the basal area.

Above ground biomass density (AGBD) of tree species was estimated using following equation:

AGBD = Volume × Specific gravity

Specific gravity values for the estimation of AGBD were used as given by Sheikh *et al*. (2011) for the trees in Srinagar valley of Garhwal Himalaya (Table.1). Below ground biomass density (BGBD) was calculated as per the method given by Sheikh *et al*. (2011b).

AGBD and BGBD were added to get the total biomass density and the co-efficient of 0.45 was used for conversion from biomass to carbon stocks (Woomer, 1999; Sheikh *et al*., 2011b). The statistically analysed of total carbon of each village was used with Duncan.s Multiple Range Test (Sharma, 1998).

Table 1. Specific gravity of the trees used for carbon estimation

Tree	Specific gravity
Grewia oppositifolia	0.714**
Celtis australis	0.716**
Bauhinia retusa	0.594**
Mallotus philippenis	0.649**
Toona ciliata	0.554**
Leucaena leucocephala	0.747**
Morus alba	0.746**
Melia azedarach	0.691**
Ficus glomerata	0.450**
Acacia catechu	0.776**
Ougeinia oojeinensis	0.606**
Ficus auriculata	0.443**
Syzygium cumini	0.669**
Ficus carica	0.578**
Cassia fistula	0.812**
Terminalia ballerica	0.480**
Pinus roxburghii	0.632**
Ficus glomerata	0.450*
Bombax ceiba	0.350*
Ficus religiosa	0.020*

**Sheikh *et al*., 2011 *Present study

Soil carbon stocks estimation

For soil organic carbon stock estimation, soil samples were collected from each sample plot. Nine representative samples were collected from 0-20, 20-40 and 40-60 cm depths and three replicate at each site. The soil samples were air dried, sieved (<0.2 mm) and then thoroughly mixed before analysis. Soil organic carbon was determined by partial oxidation method (Walkley and Black, 1934). The total SOC stock was estimated by multiplying the values of SOC g/kg by a factor of 8 million, based on the assumption that a layer of soil 60 cm deep covering an area of 1 ha weighs 8 million kg (Dey, 2005; Sheikh *et al*., 2009).The correction factor was used on soil carbon stock as described by Krishnan (2009) for Himalayan soils.

Results

Structure of agroforestry system

Among the villages, it has been observed that the highest density of trees was in the village Chamdaar (1560 tree/ha) followed by Keshu (1310 tree/ha), Dungripanth (1230 tree/ha), Budali (1000 tree/ha), Manjakot (950 tree/ha), Manao (940 tree/ha). The total basal cover was recorded maximum in the Dungripanth village (236.43 m^2 ha^{-1}) and the minimum in Keshu village (82.45 m^2 ha^{-1}) as shown in the Table. 2.

Table 2. Total density and total basal cover of tree in traditional agro forestry systems

Villages	Denisty (ind./ha)	TBC (m^2/ha)
Budali	1000	133.55
Manjokot	950	223.09
Manao	940	182.24
Dungripanth	1230	236.43
Chamdaar	1560	164.42
Keshu	1310	82.45

Carbon stocks

Village: Budali

The maximum and minimum above ground biomass in this village were 24.69 t/ha for the species *Grewia oppositifolia* and 0.02 t/ha for *Leucaena luecocephala* respectively. The below ground biomass was also reported highest (6.57 t/ha) for *Grewia oppositifolia* and lowest (0.01t/ha) for *Leucaena* *luecocephala*. The above ground carbon ranged from 0.011t/ha to 11.109 t/ha for *Leucaena luecocephala* and *Grewia oppositifolia* respectively. The below ground carbon was also reported highest (2.955 t/ha) for *Grewia oppositifolia* and lowest for *Leucaena leucocephala* (0.003 t/ha). The maximum total tree carbon stock was reported for *Grewia oppositifolia* (14.064 t/ha) and minimum (0.014 t/ha) for *Leucaena leucocephala* (Table 3).

Table 3. Carbon stocks of agroforestry trees in the village Budali

Species	**t/ha**					
	AGB	BGB	TB	AGC	BGC	TC
Grewia oppositifolia	24.69	6.57	31.25	11.109	2.955	14.064
Celtis australis	5.46	1.45	6.91	2.455	0.653	3.108
Bauhinia retusa	24.65	6.56	31.21	11.093	2.951	14.043
Mallotus philippenis	2.00	0.53	2.53	0.898	0.239	1.137
Toona ciliata	0.40	0.11	0.50	0.179	0.048	0.227
Leucanea leucocephala	0.02	0.01	0.03	0.011	0.003	0.014
Morus alba	0.85	0.23	1.08	0.384	0.102	0.486
Melia azedarach	2.14	0.57	2.70	0.961	0.256	1.217
Ficus glomerata	1.22	0.32	1.54	0.547	0.146	0.693

Village: Majakot

The maximum and minimum above ground biomass was 14.39 t/ha for *Grewia oppositifolia* and 0.01 t/ha for *Leucaena leucocephala* respectively. The maximum and minimum values of below ground biomass was reported for *Grewia oppositifolia* and *Leucaena leucocephala* respectively (Table 4). Similar as biomass the maximum and minimum values of above ground carbon was 6.478 t/ha for *Grewia oppositifolia* and *Leucaena leucocephala* (0.003 t/ha) respectively. The values of below ground carbon were also reported for the same species. The total carbon stock of tree was maximum (8.201 t/ha) reported for *Grewia oppositifolia* and minimum for *Leucaena luecocephala* (0.004 t/ha) (Table 4).

Table 4. Carbon stocks of agroforestry trees in the village Manjakot

Species	**t/ha**					
	AGB	BGB	TB	AGC	BGC	TC
Grewia oppositifolia	14.39	3.83	18.22	6.478	1.723	8.201
Acacia catechu	3.66	0.97	4.64	1.648	0.438	2.086
Ougeinia oojeinensis	4.98	1.33	6.31	2.242	0.596	2.839
Celtis australis	1.07	0.28	1.35	0.480	0.128	0.607
Bauhinia retusa	2.34	0.62	2.96	1.052	0.280	1.332
Mallotus philippenis	0.16	0.04	0.20	0.072	0.019	0.091
Toona ciliata	2.96	0.79	3.74	1.331	0.354	1.685
Leucanea leucocephala	0.01	0.00	0.01	0.003	0.001	0.004
Melia azedarach	2.30	0.61	2.92	1.036	0.276	1.312
Ficus glomerata	2.77	0.74	3.50	1.246	0.331	1.577
Ficus auriculata	0.71	0.19	0.90	0.319	0.085	0.403
Syzygium cumini	1.59	0.42	2.01	0.716	0.190	0.906
Ficus carica	0.22	0.06	0.28	0.098	0.026	0.125

Village: Manao

The above ground biomass was highest (17.93 t/ha) for *Grewia oppositifolia* and the lowest (0.68 t/ha) for *Cassia fistula* respectively. The highest (4.77 t/ha) below ground biomass was reported for *Grewia oppositifolia* and lowest (0.18 t/ha) for *Cassia fistula*. The above ground carbon was also highest (8.070 t/ha) for *Grewia oppositifolia* and lowest (0.305 t/ha) for *Cassia fistula*. However, below ground carbon was estimated maximum (2.147 t/ha) for *Grewia oppositifolia* and minimum (0.081 t/ha) for *Cassia fistula*.The total tree carbon stock was recorded maximum (10.216 t/ha) for *Grewia oppositifolia* and minimum (0.386 t/ha) for *Cassia fistula*. (Table 5)

Table 5. Carbon stocks of agroforestry trees in the village Manao

Species	**t/ha**					
	AGB	BGB	TB	AGC	BGC	TC
Grewia oppositifolia	17.93	4.77	22.70	8.070	2.147	10.216
Toona ciliata	3.02	0.80	3.82	1.358	0.361	1.719
Melia azedarach	2.45	0.65	3.10	1.103	0.293	1.396
Leucaena leucochela	1.22	0.32	1.55	0.549	0.146	0.696
Cassia fistula	0.68	0.18	0.86	0.305	0.081	0.386
Terminalia ballerica	4.87	1.30	6.17	2.193	0.583	2.777
Acacia catechu	6.60	1.75	8.35	2.969	0.790	3.758

Village: Dungripanth

In the village Dungripanth, the above ground biomass was maximum (25.95 t/ha) obtained for *Toona ciliata* and the minimum (0.05 t/ha) for *Ficus religiosa*. The highest and lowest values of below ground biomass was reported 6.90 t/ha and 0.01 t/ha for *Toona ciliata* and *Ficus religiosa* respectively. The above ground carbon and below ground carbon was recorded for *Toona ciliata* and *Ficus religiosa* respectively (Table 6).The total tree carbon stock was recorded highest (14.783 t/ha) for *Toona ciliata* and lowest (0.027 t/ha) for *Ficus religiosa* (Table 6).

Table 6. Carbon stocks of agroforestry trees in the village Dungripanth

Species	**t/ha**					
	AGB	BGB	TB	AGC	BGC	TC
Toona ciliata	25.95	6.90	32.85	11.677	3.106	14.783
Ficus glomerata	1.35	0.36	1.71	0.607	0.161	0.769
Ficus auriculata	1.34	0.36	1.70	0.604	0.161	0.765
Celtis australis	1.36	0.36	1.72	0.610	0.162	0.773
Syzygium cumini	5.96	1.58	7.54	2.680	0.713	3.393
Grewia oppositifolia	4.19	1.11	5.30	1.884	0.501	2.385
Bombax ceiba	1.18	0.31	1.49	0.531	0.141	0.672
Ficus religiosa	0.05	0.01	0.06	0.022	0.006	0.027
Aegle marmelos	1.83	0.49	2.31	0.822	0.219	1.041
Melia azedarach	6.23	1.66	7.89	2.805	0.746	3.551
Leucaena leucocephla	2.72	0.72	3.44	1.222	0.325	1.547
Terminalia bellirica	3.11	0.83	3.93	1.398	0.372	1.770

Village: Chamdaar

The highest (26.07 t/ha) above ground biomass was recorded for *Celtis australis* and lowest (0.005 t/ha) for *Ficus religiosa*. The maximum (6.94 t/ha) below ground biomass was recorded for *Celtis australis* and the minimum (0.001 t/ha) for *Ficus religiosa*. The maximum and minimum above ground carbon stock was 11.73 t/ha for *Celtis australis* and 0.002 t/ha for *Ficus religiosa* respectively. The below ground carbon was also recorded maximum (3.12 t/ha) for *Celtis australis* and minimum (0.0006 t/ha) for *Ficus religiosa*. The total tree carbon stock was highest (14.85 t/ha) for *Celtis australis* and minimum (0.003 t/ha) for *Ficus religiosa* (Table 7).

Table 7. Carbon stocks of agroforestry trees in the village Chamdaar

Species	t/ha					
	AGB	BGB	TB	AGC	BGC	TC
Toona ciliata	25.41	6.76	32.17	11.44	3.04	14.48
Celtis australis	26.07	6.94	33.01	11.73	3.12	14.85
Syzygium cumini	17.04	4.53	21.57	7.67	2.04	9.71
Grewia oppositifolia	16.12	4.29	20.40	7.25	1.93	9.18
Melia azedarach	11.79	3.14	14.93	5.31	1.41	6.72
Leucaena leucocephla	4.41	1.17	5.59	1.99	0.53	2.51
Ficus religiosa	0.005	0.001	0.0068	0.002	0.0006	0.003

Village: Keshu

The maximum (15.98 t/ha) above ground biomass was recorded for *Toona ciliata* and minimum (5.84 t/ha) for *Melia azedarach*. The highest (4.25 t/ha) below ground biomass was recorded for *Toona ciliata* and lowest (1.55 t/ha) for *Melia azedarach*. The maximum and minimum above ground carbon stock was 7.19 t/ha for *Toona ciliata* and 2.63 t/ha for *Melia azedarach* respectively. The highest (1.91 t/ha) and lowest (0.70 t/ha) below ground carbon was estimated for *Toona ciliata* and *Melia azedarach* respectively. The total tree carbon stock was recorded maximum (9.10 t/ha) for *Toona ciliata* and minimum (3.33 t/ha) for *Melia azedarach* (Table 8).

Table 8. Carbon stocks of agroforestry trees in the village Keshu

Species	t/ha					
	AGB	BGB	TB	AGC	BGC	TC
Toona ciliata	15.98	4.25	20.23	7.19	1.91	9.10
Pinus roxburghii	13.00	3.46	16.45	5.85	1.56	7.40
Grewia oppositifolia	9.61	2.56	12.17	4.32	1.15	5.48
Celtis australis	9.36	2.49	11.85	4.21	1.12	5.33
Melia azedarach	5.84	1.55	7.39	2.63	0.70	3.33

Soil organic carbon (g/kg)

In village Budali among the three depths it has been recorded that maximum SOC g/kg was 8.45±1.74 in the depth of 40-60cm and minimum 7.00±1.63 SOC g/kg in the depth of 20-40cm. In the village Manjakot the SOC values ranged from 6.05±5.58 g/kg (20-40cm) to 9.95±1.06 g/kg (40-60cm). In village Manao the maximum SOC was 8.05±2.87 g/kg in the depth of 40-60cm and minimum 3.85±1.93 g/kg in the depth of 20-40cm. In village Dungripanth the highest SOC g/kg was 11.35±1.39 in the depth of 20-40cm and the lowest was 5.70±0.91 in the depth of 40-60cm. In the village Chamdaar the highest value of SOC 6.75±0.40 g/kg was in middle depth and lowest (4.70±2.19 g/kg) in 0-20cm depth. In village Keshu the values of SOC was ranged from 5.50±0.68 (20-40cm) to 6.70±0.43 g/kg (40-60cm) (Table 9).

Table 9. SOC of soil in the villages of Uttarakhand

Village	Depth	SOC g/kg
Budali	0-20	7.5±3.92
	20-40	7.0±1.63
	40-60	8.45±1.74
Manjakot	0-20	6.8±2.33
	20-40	6.05±5.58
	40-60	9.95±1.06
Manao	0-20	5.4±1.17
	20-40	3.85±1.93
	40-60	8.05±2.87
Dungripanth	0-20	6.1±1.73
	20-40	11.35±1.39
	40-60	5.70±0.91
Chamdaar	0-20	4.70±2.19
	20-40	6.75±0.40
	40-60	5.3±1.44
Keshu	0-20	5.6±0.61
	20-40	5.50±0.68
	40-60	6.70±0.43

Soil organic carbon (t/ha)

In traditional agroforestry system of Garhwal Himalayas the values of SOC stocks was maximum in the village Budali of 146.88±0.74 t/ha followed by village Dungripanth (60.54±3.15 t/ha), Manao (40.78±2.12 t/ha), Manjokot (39.73±2.07 t/ha), Chamdaar (39.73±2.07 t/ha) and Keshu (12.78±0.67 t/ha) (Table 10).

Table 10. SOC stocks of soil in the villages of Uttarakhand

Village	SOC t/ha
Budali	146.88±0.74
Manjakot	39.73±2.07
Manao	40.78±2.12
Dungripanth	60.54±3.15
Chamdaar	39.73±2.07
Keshu	12.78±0.67

Discussion

Structure of agroforestry system

In the traditional agroforestry system, among the villages Budali, Manjakot, Manao and Chamdaar were dominated by *Grewia oppositifolia* however Dungripant and Keshu were dominated by *Toona ciliata*. In the traditional agroforestry system of Garhwal Himalaya, most of the agroforestry systems are dominated by *Grewia oppositifolia*. It is one of the most important fodder trees in Himalayan agroforestry systems. Kumar *et al*. (2006) reported in tropical and sub-tropical villages that *Grewia oppositifolia* preferred by the villagers as fodder species because of its good quality fodder, high nutritive value and other properties. Kumar and Singh (2009) also carried out a study in sub-tropical agroforestry system of Garhwal Himalaya, reported *Grewia oppositifolia* was dominant tree in five different agroforestry system and other common reported species were *Celtis australis, Bauhinia retusa, Morus alba, Ougeinia oojeinensis, Ficus* spp. *Toona ciliata*. Bijalwan *et al*. (2009) also conducted a study in the agroforestry system of Tehri Garhwal between elevation 1000 to 2000 m for the structure and composition of different agroforestry systems and their effect on crop yield. Sharma *et al*. (2009) also carried out phytosociological studies of trees in agrisilvicultural system of different villages in temperate regions, where species composition was recorded of *Grewia oppositifolia, Celtis australis, Quercus leucotrichophora* etc. Kala (2010) reported that the major woody species grown by the farmers in their agro-forestry systems were *Celtis australis*, *Melia azedarach*, *Grewia oppositifolia*, *Pinus roxburghii* and *Toona serrata*.

Carbon stocks

Among the traditional agroforestry system the highest carbon stock was reported 57.45 t/ha in Chamdaar village and lowest (19.85 t/ha) in Manjakot village. The highest carbon stock in Chamdaar village could be because of the highest contributing species were *Toona ciliata* and *Celtis australis*. Both the species have contributed approximate 14 t/ha carbon. The lowest carbon stock in Manjakot village could be because of higher contributing young growth of trees in agroforestry system. The other values of total carbon in other villages were 34.98 t/ha in Budali, 31.47 t/ha in Dungripanth, 30.64 t/ha in Keshu and 20.94 t/ha in Manao. The variations in carbon stock in each site depend of several factors such as type of agroforestry system, site quality and previous land use system. Besides on the notion that tree incorporation in cropland and pastures would result in greater net carbon storage above and belowground

(Palm *et al*., 2004; Haile *et al*., 2008; Kumar and Nair, 20011). Among the similar ecological conditions, agro forestry systems considered higher carbon sequestration potential compared to pasture and crop filed (Roshetk *et al*., 2002).

Among the villages in the traditional agro forestry system the highest (146.88±0.74 t/ha) value of soil organic carbon was reported in Budali village and lowest (12.78±0.67 t/ha) in Keshu village. In a study of Gupta (2011) reported SOC stock under the forest where maximum (56.48 t/ha) SOC stocks was estimated in sal forest followed by miscellaneous forest (56.48 t/ha). Sal forest have 30.36 % higher SOC pool compare to miscellaneous forest comprising of different species like *Albizia procera, Emblica officinalis, Grewia oppositifolia, Bauhinia varigata* etc. although standard deviation of SOC in miscellaneous forest was higher. The higher variation in SOC pool under miscellaneous forest, it was because of mixture of several species have different litter decomposition rate.

Munesh *et al.* (2012) also carried out studied soil organic carbon stock potential of shrubs, in *Anogeissus latifolia* forest in sub-tropical belt of Garhwal Himalaya. The findings of the study indicating that the soil organic carbon (SOC) stock among the shrubs, *Rhus parviflora* (168.00 t /ha) and *Lantana camara* (164.16 t/ha) showed higher values of SOC as compared to *A. latifolia* forest (161.28 t/ha). However, *Carissa spinarum* showed lower values (152.64 t/ha) of SOC compared to *A. latifolia*. This is because of the litter mass of *R. parviflora* and *L. camara* was 140.4 g m^{-2} and 150.3 g m^{-2}, respectively which was higher compared to *A. latifolia* (98.8 g m^{-2}) forest. The litter mass of *C. spinarum* was the lowest 60.7 g m^{-2} which has reflected lowest SOC stock.

Table 11. Total carbon stocks of traditional agroforestry system

Villages	AGB t/ ha	BGB t/ha	TB t/ha	AGC t/ha	BGC t/ha	TC t/ha
Budali	61.43^{b}	16.35^{b}	77.75^{b}	27.637^{b}	7.353^{b}	34.989^{b}
Manjakot	34.86^{d}	9.27^{c}	44.12^{c}	15.685^{c}	4.171^{c}	19.855^{d}
Manao	36.77^{cd}	9.77^{c}	46.55^{c}	16.547^{c}	4.401^{c}	20.948^{cd}
Dungripanth	55.27^{bc}	14.69^{b}	69.94^{b}	24.862^{b}	6.613^{b}	31.476^{b}
Chamdaar	100.85^{a}	26.83^{a}	127.68^{a}	45.39^{a}	12.07^{a}	57.45^{a}
Keshu	53.79^{cd}	14.31^{b}	68.09^{bc}	24.2^{b}	6.44^{b}	30.64^{bc}

Same letter indicate non-significant statistical difference between treatments at $p < 0.05$ (significant at $p < 0.05$)

Conclusion

In the traditional agroforestry system the average total carbon stock of trees in traditional agro forestry system was 32.56 t /ha and soil organic carbon was 56.74 t/ha. The tree components in agro forestry systems can be significant sinks of atmospheric C because of their good natural growth and high productivity. In agro forestry systems the mixed trees considered to be more efficient than sole stands in carbon sequestration. Although, the carbon sequestration in traditional agroforestry system can also be enhanced by avoiding over exploitation of the resources from the trees were done by lopping of branches and its proper management. The over exploitation of resources from traditional agro forestry trees reduces input of biomass as well as input of litter in the agro forestry system. Thus regular inputs of litter in the soil and its decomposition would also enhance nutrient level for further biomass production of trees.

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