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Estimation of soil carbon pool under different land use systems in Kashmir valley

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Abstract
The present investigations entitled "Estimation of soil carbon pool under different land use systems in Kashmir valley" was conducted in Srinagar district of Kashmir valley at two sites viz., Site A and Site B. Results revealed that the tree based land use systems aside, the soil organic carbon stock was higher in grasslands (75t ha-1) at site A and (76.16)at site B, than in agriculture (65.17 t ha^{-1}) at A and (63.36 t ha^{-1}) at B, vegetables (63.75 t ha-1) at A and (65.52 t ha-1) at B and wasteland/uncultivated land (30.45 t ha-1) at A and (29.31 t ha-1) at B. At site A, Dachigam maximum carbon stock (556.731 t ha^{-1}) was recorded in natural forest-Blue Pine land use system at the elevation range of 1700-2000 m a.s.l. Whereas, at site B, upper Dachigam, maximum carbon stock (524.039 t ha^{-1}) was recorded in the forest based land use system viz. natural forest-Blue Pine situated at the altitudinal range of 2000-2500 m a.s.l.

Keywords: Kashmir valley, carbon pool, estimation

Introduction
Carbon in the earth system moves between the four major reservoirs: fossil and geological formations, the atmosphere, the oceans and terrestrial ecosystems including forests [9]. Transfers between these reservoirs occur mainly as carbon dioxide (CO2) in processes such as; fuel combustion, chemical dissolution and diffusion, photosynthesis, respiration, decomposition, wildfires and burning of biomass in the open and in furnaces. Human activities are responsible for making changes in carbon stocks in these pools by changing the land use pattern of the area. If a component of the biosphere such as woody biomass shrinks, carbon is released into the atmosphere. If biomass expands, it becomes as sink, and thus removes carbon from the atmosphere.
A growing interest in the role of different types of land use in reducing atmospheric CO_2 concentration and lowering the emissions rate of this greenhouse gas (GHG), has led to an increased research on the function of forestry and Agroforestry systems as carbon sinks. Tropical deforestation and forest degradation are considered to be an important source of GHG contributing to 17.4% of the global emissions [4].Undoubtedly, forests are the main land based CO_2 sinks [3]. However, it is difficult to determine how and to what extent forest carbon sinks and reservoirs may be managed to mitigate CO_2 [2]. In this context, further research is needed to be able to select areas of priority and adequate land use practices in order to reduce effectively emissions caused by deforestation and at the same time that could provide additional benefits [10].
The United Nations Framework Convention on Climate Change (the Kyoto Protocol) provides a mechanism by which a country that emits carbon in excess of agreed-upon limits can purchase carbon offsets from a country or region that manage carbon sinks. Some observers suggest that through this clean development mechanism (CDM), a ratified Kyoto Protocol could reduce rural poverty by extending payments to low income farmers who provide carbon storage [13]. Carbon sequestration involves the removal and storage of carbon from the atmosphere in carbon sinks (such as oceans, vegetation and soils) through physical or biological process. The incorporation of trees or shrubs in land use systems can increase the amount of carbon sequestered compared to a monoculture field of crop plants or pasture [5, 12]. In addition to the significant amount of carbon stored in above ground biomass, tree base land use systems can also store below ground biomass. Carbon sequestration in different land use systems could be sold in carbon credit markets where such opportunities exist.

Method and Materials
The present investigations entitled "Estimation of soil carbon pool under different land use systems in Kashmir valley" was conducted in Srinagar district of Kashmir valley in the state of Jammu and Kashmir during two years. (2009-10, 2011-12).

Site location

The study was carried out in Srinagar district of Jammu and Kashmir located between 34°5′24″N and 74°47′24″E. It is surrounded by five districts mainly Baramulla, Budgam, Ganderbal, Pulwama and Anantnag.

Fig 1: Map of Jammu and Kashmir showing location of Srinagar district of Kashmir valley

Soil and Climate

Srinagar has a temperate climate, which is cooler than rest of India, due to its moderately high elevation and northerly position. Altitude determines the degree of cold, the form of precipitation and summer temperature. The state has got three distinct regions viz., Arctic cold desert areas of Ladakh, temperate Kashmir valley and subtropical region of Jammu. In the hot season, Jammu region is very hot and temperature can reach up to 40 ^{0}C. By October, conditions are hot but extremely dry, with minimum temperature of around 29'C. ln Kashmir and Ladakh region, the average January temperature is -20'C with extremes as low as -40 ^{0}C. In summer, in Ladakh and Zanskar, days are typically warm upto 20'C but with the low humidity and thin air, nights are cold. The average annual rainfall also varies from region to region with 93 mm in Leh to 650 mm in Srinagar and 1116 mm in Jammu[2]. In the region of Jammu & Kashmir, the soils are loamy and there is little clay content in them, poor in lime but with a high content of Magnesia. There is sufficient organic matter and nitrogen content in the alluvium of the Kashmir valley as a result of plant residue, crops stubble, natural vegetation and animal excretion. The valley of Kashmir has many types of soils like clay, loam, sandy, peats, floating garden soils.

Following experiments was conducted during the study to estimate the soil carbon pool under different land use systems in Kashmir valley:

A. Land use systems

T_1 Wasteland/ Uncultivated Land
T_2 Agriculture (Rice-Mustard)
T_3 Agriculture (Rice-Oats)
T_4 Vegetable (Beans-chilli)
T_5 Horticulture (Apple Only)
T_6 Agri-Horticulture (Apple + Vegetables-Bean)
T_7 Agri-Silviculture (Willow + Rice-Mustard)
T_8 Plantation Forest (Willow)
T_9 Plantation Forest (Poplar)
T_{10} Natural Forest (Blue Pine)
T_{11} Grassland

B. Collection and preparation of soil samples

Soil samples were collected by dividing each main plot area into five areas each having 10 m x 10 m. Soil samples for each sub area were obtained by digging profiles 20x50 cm (sub-surface area) up to 50 cm deep (20x50x50). Composite samples from all sub area were obtained for each depth. Soil samples were air dried in shade, grinded with wooden pestle, passed through 2 mm sieve and stored in cloth bags for further laboratory analysis. The following physico-chemical attributes of soil samples were determined.

Sr. No.	Parameters	Method employed
1.	Bulk density (g cm^{-3})	Specific gravity method (Singh, 1980)
2.	Organic carbon (%)	Walkley and Black (1934)

Soil organic carbon (SOC) pool

The soil organic carbon pool inventory expressed as t ha^{-1} for a specific depth was computed by using the formulae of Nelson and Sommers (1996). The bulk density and carbon concentration data was used to compute the amounts of carbon per unit area of land use as follows:

Soil Organic Carbon (t ha^{-1}) = [(soil bulk density (g cm^{-3}) x soil depth (cm) x C (%)]

Total carbon stock

Total carbon stock is the total of carbon stock present in plant and soil.

Total carbon stock = Plant + Soil

Statistical analysis

The data obtained were subjected to one sample statistics with standard error mean and 95% confidence interval with lower and upper bonds.

Results

Carbon stocks in different land use systems

Above ground biomass carbon stock (t ha^{-1})

Aboveground biomass carbon stocks as influenced by different land use systems have been presented in Table 1. In all the land use systems, highest (445.385 t ha^{-1}) above ground biomass carbon stock was observed in the T_{10}-Natural Forest-(Blue Pine). The above ground biomass carbon stock in T_5-Horticulture and T_6-Agri-Horticulture were almost similar. The next second highest (326.163 t ha^{-1}) above ground biomass carbon was recorded in T_9- Plantation Forest-(Poplar). The lowest aboveground biomass carbon was recorded in the T_1-wasteland/uncultivated land use system at Site A.

At site B which was at an altitude of 2507m amsl, the above ground carbon was maximum (419.231 t ha^{-1}) with T_{10}-Natural forest (Blue Pine) among all the land use systems at site B. The same trend was followed at site B that is T_{10} was followed by T_9 and then T_7. The minimum above ground carbon was recorded at T_1 (wasteland/uncultivated land) which was 0.692 t ha^{-1}.

Table 1: Aboveground Carbon (t ha^{-1}) as affected by different land use systems at Site A & B in district Srinagar

Land use System(LU)	Sites (S)		Mean ± ST error	95% Confidence Interval	
	Site-A	Site-B		L.B	U.B
T_1-Wasteland/Uncultivated Land	0.712	0.692	0.702±0.010	0.682	0.721
T_2-Agriculture (Rice-Mustard)	1.843	1.738	1.790±0.052	1.687	1.893
T_3-Agriculture (Rice-Oats)	4.108	3.910	4.009±0.099	3.814	4.203
T_4-Vegetable (Beans-chilli)	2.075	1.984	2.029±0.045	1.940	2.118
T_5-Horticulture(apple alone)	49.305	51.423	50.364±1.059	48.288	52.439
T_6-Agri-Horticulture (Apple + Vegetables)	50.086	53.114	51.6±1.514	48.632	54.567
T_7-Agri-Silviculture (Willow + Rice Mustard)	63.283	59.230	61.256±2.026	57.284	65.228
T_8-Plantation Forest (Willow)	59.598	56.105	57.851±1.746	54.428	61.274
T_9-Plantation Forest (Poplar)	326.163	306.593	316.378±9.785	297.199	335.556
T_{10}-Natural Forest (Blue Pine)	445.385	419.231	432.308±13.077	406.677	457.938
T_{11}-Grassland	0.978	0.919	0.948±0.029	0.890	1.006

Below ground biomass carbon stock (t ha^{-1})

It is apparent from the data in the Table 2 that below ground biomass carbon stocks was influenced by land use systems. In all the land use systems, highest below ground biomass carbon stock was in the T_{10}-Natural Forest-(Blue Pine) (111.346 t ha^{-1}), whereas, lowest value (0.165 t ha^{-1})) was observed in T_1 -wasteland/uncultivated land use system. The values observed in Agriculture based land use system T_2-(Rice-Mustard) and T_4-Vegetable (Beans-chilli) were a bit similar at Site A.

The belowground carbon was highest at T_{10} -Natural Forest-(Blue Pine) (104.808 t ha^{-1}) among all the land use systems at site B followed by T_9 -Plantation forest-(Poplar) (76.648 t ha^{-1}), the T_7 and T_6 land use system. The lowest below ground carbon was at T_1 - wasteland/uncultivated land (0.160 t ha^{-1}).

Table 2: Belowground Carbon (t ha^{-1}) as affected by different land use systems at Site A & B in district Srinagar

Land use System(LU)	Sites-(S)		Mean ± SE	95% Confidence Interval	
	Site-A	Site-B		L.B	U.B
T_1-Wasteland/Uncultivated Land	0.165	0.160	0.1625±0.002	0.157	0.167
T_2-Agriculture (Rice-Mustard)	0.445	0.422	0.4335±0.011	0.410	0.456
T_3-Agriculture (Rice-Oats)	0.938	0.899	0.9185±0.019	0.880	0.956
T_4-Vegetable (Beans-chilli)	0.481	0.523	0.502±0.021	0.460	0.543
T_5-Horticulture (Apple alone)	12.326	12.856	12.591±0.265	12.071	13.110
T_6-Agri-Horticulture (Apple + Vegetables)	14.051	14.936	14.4935±0.442	13.626	15.360
T_7-Agri-Silviculture (Willow + Rice Mustard)	16.878	16.863	16.8705±0.007	16.855	16.885
T_8-Plantation Forest (Willow)	14.899	14.026	14.4625±0.436	13.606	15.318
T_9-Plantation Forest (Poplar)	81.540	76.648	79.094±2.446	74.299	83.888
T_{10}-Natural Forest (Blue Pine)	111.346	104.808	108.077±3.269	101.669	114.484
T_{11}-Grassland	0.217	0.204	0.2105±0.006	0.197	0.223

Total biomass carbon stock (t ha^{-1})

Total biomass based carbon stock (t ha^{-1}) is influenced due to different land use systems. (Table-3). The maximum total biomass carbon stock (556.731 t ha^{-1}) was accumulated by T_{10}- Natural Forest-(Blue Pine) followed by T_9- Plantation Forest-Poplar (407.703 t ha^{-1}), T_7- Agri-silviculture system (80.162 t ha^{-1}). Minimum total biomass carbon stock (0.877 t ha^{-1}) was recorded in wasteland/uncultivated land. The total biomass carbon stock in T_5- Horticulture and in T_6- Agri-Horticulture was having little difference, but the T_4-vegetable

has contributed in the overall biomass of the system and is a little increased at Site A.
At site B, the T_{10} -Natural forest (Blue Pine) recorded the maximum total biomass carbon stock (524.039 t ha^{-1}) which was followed by T_9-Plantation Forest (Poplar) (383.241 t ha^{-1}). The minimum total carbon stock was recorded from T_1-wasteland/uncultivated land (0.852 t ha^{-1}).

Table 3: Total Carbon Stock (t ha^{-1}) as affected by different land use systems at Site A & B in district Srinagar

Land use System(LU)	Sites-(S)		Mean ± SE	95% Confidence Interval	
	Site-A	Site-B		L.B	U.B
T_1-Wasteland/Uncultivated Land	0.877	0.852	0.864±0.012	0.84	0.889
T_2-Agriculture (Rice-Mustard)	2.288	2.162	2.225±0.063	2.101	2.348
T_3-Agriculture (Rice-Oats)	5.047	4.809	4.928±0.119	4.694	5.161
T_4-Vegetable (Beans-chilli)	2.556	2.507	2.531±0.024	2.483	2.579
T_5-Horticulture (Apple alone)	61.632	64.279	62.955±1.323	60.361	65.549
T_6-Agri-Horticulture (Apple + Vegetables)	64.137	66.150	65.143±1.006	63.170	67.116
T_7-Agri-Silviculture (Willow + Rice Mustard)	80.162	76.092	78.127±2.035	74.138	82.115
T_8-Plantation Forest (Willow)	74.498	70.131	72.314±2.183	68.034	76.594
T_9-Plantation Forest (Poplar)	407.703	383.241	395.472±12.231	371.499	419.444
T_{10}-Natural Forest (Blue Pine)	556.731	524.039	540.385±16.346	508.346	572.423
T_{11}-Grassland	1.195	1.124	1.159±0.035	1.089	1.229

Carbon pool in soil, vegetation and their ratio

Soil and plant carbon ratio of different land use system is depicted in the Table 4 for two different locations in the Srinagar district of Kashmir valley. It is evident from the Table 4 that at site A, minimum soil: plant carbon ratio was found to be in the T_9- Plantation forest-(Poplar) 0.296 and at site B minimum was also in plantation forest-Poplar (T_9) (0.315), followed by $T_{10} < T_8 < T_7 < T_5 < T_6 < T_3 < T_4 < T_2 < T_1 < T_{11}$ in the ascending order at both the locations A and B. The trend is reverse as we have seen in the biomass and carbon, this shows that the soils in the grasslands are having more carbon than in the vegetation. The average ratio comes almost same on both the locations 15.193 and 15.858 at site A and B respectively.

Table 4: Comparison of soil plant ratio of carbon (t ha^{-1}) under different land use systems at two different sites in district Srinagar. (Pooled value of two years)

Land use System(T)	Site-A		Ratio Soil: Plant	Site-B		Ratio Soil: Plant
	Plant	Soil		Plant	Soil	
T_1-Wasteland/Uncultivated Land	0.87	30.45	35.00	0.85	29.31	34.482
T_2-Agriculture (Rice-Mustard)	2.28	65.17	28.583	2.16	63.36	29.333
T_3-Agriculture (Rice-Oats)	5.04	53.55	10.625	4.80	54.61	11.377
T_4-Vegetable (Beans-Chilli)	2.55	63.75	25.00	2.50	65.52	26.208
T_5-Horticulture (Apple alone)	61.63	64.57	1.047	64.27	66.34	1.032
T_6-Agri-Horticulture (Apple + Vegetables)	64.13	70.00	1.091	66.15	71.19	1.076
T_7-Agri-Silviculture (Willow + Rice Mustard)	80.16	68.67	0.856	76.09	67.5	0.887
T_8-Plantation Forest (Willow)	74.49	110.11	1.478	70.13	109.8	1.565
T_9-Plantation Forest (Poplar)	407.70	120.95	0.296	383.24	121.09	0.315
T_{10}-Natural Forest (Blue Pine)	556.73	217.25	0.390	524.03	215.82	0.411
T_{11}-Grassland	1.195	75.00	62.761	1.124	76.16	67.758
Mean	114.252	85.406	15.193	108.667	85.518	15.858

Discussion

It is evident from the data presented in the Table 4 and Fig 1 that soil organic was significantly influenced by land use system effects. Maximum soil organic carbon (SOC) was recorded in T_{10}- natural forest-Blue Pine (217.25 t ha^{-1}), (215.82 t ha^{-1}) at site A and B respectively, which was found to be significantly higher than all other land use systems at site A and B and was followed by T_9-plantation forest-Poplar (120.95 t ha^{-1}), (121.09 t ha-1), T_8-plantation forest-willow (110.11 t ha^{-1}), (109.8 t ha^{-1}), T_{11}-grassland (75t ha^{-1}), (76.16 t ha^{-1}), T_6-agri-horticulture (70 t ha^{-1}), (71.19 t ha^{-1}), T_7- agri-silviculture (68.67 t ha^{-1}), (67.5 t ha^{-1}), T_2-agriculture-rice-mustard (65.17t ha^{-1}), (63.36 t ha^{-1}), T_5-horticulture (64.57t ha^{-1}), (66.34 t ha^{-1}), T_4-vegetables (63.75 t ha^{-1}), (65.52 t ha^{-1}), T_3-agriculture-rice-oats (53.55 t ha^{-1}), (54.61 t ha^{-1}) and T_1-wasteland/uncultivated land (30.45 t ha^{-1}), (29.31 t ha^{-1}) at site A and site B respectively in the descending order. This may have happened because of enhanced accumulation of leaf litter in the tree and fruit based land use systems. The abundant leaf litter or pruned biomass returns to soil, combined with decay of roots contribute to the improvement of organic matter under complex land use systems [1, 6, 8, 11]. Low amounts of soil organic carbon density under the agriculture land use system can be ascribed to intensive cropping as also reported[7] and other workers from time to time.

In agriculture soils, the content of carbon gets depleted because of continuous and intensive inter cropping as well as due to higher rates of mineralization resulting due to higher temperature, soil moisture and atmospheric humidity-characteristic features of Kashmir valley ecosystem. Whereas, in the forest ecosystems the soil is of forest origin in which the intensity of cultivation is less than in the agriculture ecosystem. In addition to it, the rate of mineralization is slower because of rapid fall in temperature and humidity with increasing altitudinal levels hence more soil organic content and soil organic carbon.

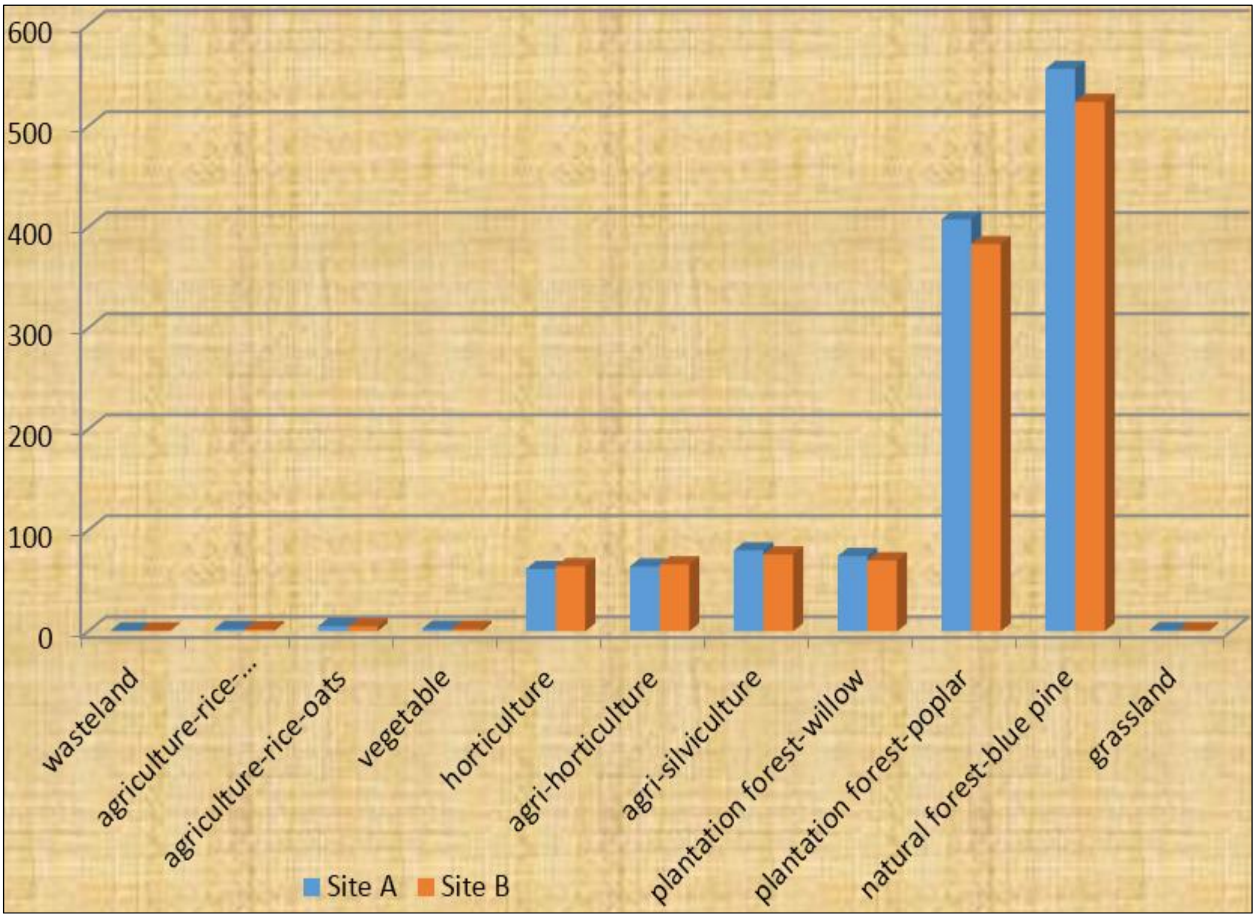

Fig 2: Total Carbon Stocks (t ha^{-1}) at two different sites in district Srinagar

Conclusion

Soil organic carbon (SOC) stock was recorded maximum (217.25 t ha-1) at natural forest-Blue Pine at Site A (Dachigam) at an altitude of 2205 m amsl, which was followed by Plantation Forest-Poplar (120.95 t ha^{-1}) at an altitude of 1593 m amsl at Shalimar, Plantation forest-willow (110.11t ha^{-1}), grassland (75 t ha^{-1}), agri-horticulture (70 t ha^{-1}), agriculture-rice-mustard (65.17t ha^{-1}), horticulture (64.57 t ha^{-1}), vegetables-beans-chilli (63.75 t ha^{-1}), agriculture-rice-oats (53.55 t ha^{-1}) and wasteland/uncultivated land (30.45 t ha^{-1}) respectively in the descending order.

Whereas, at site B maximum was also recorded in natural forest (upper Dachigam) which is at an altitude of 2507 m amsl, which was followed by Plantation Forest-Poplar (121.09 t ha^{-1}) at an altitude of 1812 m amsl, Plantation forest-willow (109.8 t ha^{-1}), grassland (76.16 t ha^{-1}), agri-horticulture (71.19 t ha^{-1}), horticulture (66.34 t ha^{-1}), vegetables (65.52 t ha^{-1}), agriculture-rice-mustard (63.36 t ha^{-1}), agriculture-rice-oats (54.61 t ha^{-1}) and wasteland/ uncultivated land (29.31 t ha^{-1}) respectively in the descending order.

At site A, the total carbon stocks (Plant +Soil) was recorded in the natural forest-Blue Pine (773.98 t ha^{-1}) which was maximum at site A, followed by the land use systems viz. T_9, T_8, T_7, T_6, T_5, T_{11}, T_2, T_4,T_3, T_1 in descending order with values of (528t ha^{-1}), (184.6 t ha^{-1}), (148.83 t ha^{-1}), (134.13 t ha^{-1}), (126.2 t ha^{-1}), (76.195 t ha^{-1}), (67.45 t ha^{-1}), (66.3 t ha^{-1}), (58.59 t ha^{-1}) and (31.32 t ha^{-1}) respectively.

Whereas, at site B, the total carbon stocks (Plant + Soil) was recorded in the natural forest-Blue Pine (738.85 t ha-1) which was maximum at site B, followed by the land use systems viz. T_9, T_8, T_7, T_6, T_5, T_{11}, T_4, T_2,T_3, T_1 in descending order with values of (504.33 t ha^{-1}), (179.93 t ha^{-1}),(143.59 t ha^{-1}), (137.34 t ha^{-1}), (130.61 t ha^{-1}), (77.284 t ha^{-1}), (68.02 t ha^{-1}), (65.52 t ha^{-1}), (59.41 t ha^{-1}) and (30.16 t ha^{-1}) respectively. The minimum total carbon stock was recorded in wasteland/uncultivated land use system which was (30.16 t ha^{-1}) at site B which was less than recorded at site A (31.32 t ha^{-1}).

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