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Delineation of best land use system for carbon sequestration in Kashmir valley

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Abstract
The present investigations entitled "Delineation of best land use system for carbon sequestration in Kashmir valley" was conducted in Srinagar district of Kashmir valley at two sites viz., Site A and Site B. Total carbon stocks were recorded maximum in T_{10} -Natural forest – (Blue Pine) 773.98 t ha^{-1} at site A and followed by T_{10} - Natural forest-(Blue Pine) 738.85 t ha^{-1} at site B (Table-04). Thus, T_{10} - Natural forest-(Blue Pine) is the best land use system for carbon sequestration. The second best was T_9 - Plantation forest-(Poplar) with 528.65 t ha^{-1} at site A and T_9 - Plantation forest-(Poplar) with 504.33 t ha^{-1} at site B (Table-04). The minimum was recorded in T_1- wasteland /uncultivated land 30.16 t ha^{-1} at site B and in T_1 - wasteland/uncultivated land 31.32 t ha^{-1} at site A (Table-04) and (Fig. 01).

Keywords: Kashmir valley, carbon sequestration, delineation

Introduction
The state of Jammu and Kashmir lies in Western Himalayas which has been recognised as floristically under explored by the Botanical Survey of India [3]. It has been rightly referred to as a '*Terrestrial Paradise*' on the Earth. J&K is a hilly state with an area of 2, 22,236 km [2]. Biogeographically, it comprises of three distinct provinces: the subtropical Jammu, the predominantly temperate Kashmir, and the cold-arid Ladakh. The region lies between coordinates of 32º20′ to 34º50′ North latitude and 73º55′ to 75º35″ East longitude[9]. About 2/3rd of the state's total area is under recorded forest and the substantial part of this is non-conducive for the growth, being under permanent snow, glaciers and cold deserts [5]. The distribution of vegetation in this region is strongly influenced by various parameters such as temperature, precipitation, wind, isolation, topography, soils, and seral development which rapidly change along the elevational gradient[10]. Climate of the region, marked by well-defined seasonality, resembles that of mountainous and continental parts of the temperate latitudes. The temperature ranges from an average daily maximum of 31ºC and minimum of 15ºC during summer to an average daily maximum of 4ºC and minimum of-4ºC during winter. It receives annual precipitation of about 1,050 mm, mostly in the form of snow during the winter months. Due to the vast variety of edapho-climatic and physiographic heterogeneity, the region harbors diverse habitats, including lakes, springs, swamps, marshes, rivers, cultivated fields, orchards, subalpine and alpine meadows, mountain slopes and terraces, permanent glaciers, etc., which support equally diverse floristic elements [15]. The mountains around the valley send their ramifications into the valley ending in mounds and knolls; thus, creating lot of space for pastures to develop and flourish. These pastures have played important role in flourishing of livestock and wildlife in the valley. Owing to great variety of habitats all along these provinces, the state is very rich in floristic diversity. Its flora has attracted the attention of many foreign and local botanists since the last two centuries. The region supports a rich and spectacular biodiversity of great scientific curiosity and promising economic benefits; chiefly owing to its topographic variations spanning from valley floor through the terraced tablelands (*Karewas*) and dense forests, elevating up to snowcapped alpine peaks. The floristic and vegetation studies are of prime importance in the present biodiversity conscious world. In particular, the floristic studies and spatial distribution patterns of natural vegetation in a mountainous region can provide important inputs for conservation and bio prospecting of biodiversity. It has been estimated that due to increase in the cover of unpalatable species the herbage production in the Himalayan grasslands has decreased by 20-50% in terms of quantity and 10-15% in terms of quality compared with their potential [9].
Global warming is inevitable. Therefore, the need is to develop strategies to reduce the greenhouse gases from the atmosphere.

Carbon sequestration through biomass seems to be a cheap and viable option. There are several land-use options which can sequester carbon. Their potential of locking carbon differs not only with the type of species, but also with the agro climatic zones. Hence, location specific land-use systems need to be prioritized taking both carbon sequestration potential and socio-economic needs into account [4].

The accumulation of greenhouse gases in the upper atmosphere is a global concern, and finding low cost methods to sequester carbon is emerging as a major international policy goal. At current greens house gas emission rates average global surface temperature is expected to rise by approximately 0.3-2.5ºC in the next fifty years and 1.4-5.8ºC in the next century [7, 8]. Although the economic and ecological consequences of global warming continue to be debated[14], many scientists believe that costs will likely out weight benefits [2]. To date, most interest has focused on carbon dioxide, which is the most important greenhouse gas[6].

Materials and Methods

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 delineate of best land use system for carbon sequestration in Kashmir valley:

A. Land use systems

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

Results

Carbon sequestration by different land use systems:

1. Aboveground biomass carbon sequestration (t ha^{-1})

Data in the Table 01 evinced that the carbon sequestered (CO_2 equivalent) by aboveground biomass was influenced by the different land use systems.

Table 1: Aboveground carbon sequestration (CO_2 equivalent) t ha^{-1} as affected by different land use systems at Site A & B in district Srinagar. (Pooled value of two years)

Land use System(LU)	Sites- (S)		Mean ± SE	95 % Confidence Interval	
	Site-A	Site-B		L.B	U.B
T_1- Wasteland/Uncultivated Land	2.613	2.539	2.576±0.037	2.503	2.648
T_2- Agriculture (Rice-Mustard)	6.764	6.381	6.572±0.191	6.197	6.947
T_3- Agriculture (Rice-Oats)	15.079	14.349	14.714±0.365	13.998	15.429
T_4- Vegetable (Beans-chilli)	7.614	7.280	7.447±0.167	7.119	7.774
T_5- Horticulture(Apple alone)	180.952	188.723	184.837±3.885	177.221	192.453
T_6- Agri-Horticulture (Apple +Vegetables)	183.815	194.931	189.373±5.558	178.479	200.266
T_7- Agri-Silviculture (Willow+ Rice Mustard)	232.250	217.373	224.811±7.438	210.232	239.391
T_8- Plantation Forest (Willow)	218.725	205.906	212.315±6.409	199.752	224.878
T_9- Plantation Forest (Poplar)	1197.017	1125.195	1161.106±35.911	1090.720	1231.492
T_{10}- Natural Forest (Blue Pine)	1634.561	1538.579	1586.57±47.991	1492.508	1680.632
T_{11}- Grassland	3.589	3.374	3.481±0.107	3.270	3.692

In the mean effects of all the land use systems, maximum (1634.561 t ha^{-1}) carbon sequestration was recorded in T_{10}-Natural Forest-(Blue Pine) at site A followed by T_9-Plantation Forest-(Poplar). Among the fruit based land use systems, again the T_5-Horticulture and the T_6-Agri-Horticulture have got little difference in the carbon sequestration (CO_2 equivalent). The minimum value of carbon sequestration (2.613 t ha^{-1}) was recorded in T_1- wasteland /uncultivated land use system followed by the T_{11}-Grassland 3.589 t ha^{-1} at site A.

Similarly at site B, above ground carbon sequestration potential was maximum 1538.579 t ha^{-1}, recorded in T_{10} - Natural Forest-(Blue Pine) which was also followed by T_9-Plantation Forest-(Poplar) 1125.195 t ha^{-1}. The minimum above ground carbon sequestration potential was with T_1-wasteland/uncultivated land use system 2.539 t ha^{-1}.

2. Below ground Carbon sequestration (CO_2 equivalent) potential (t ha^{-1})

Table 02 shows that carbon sequestration potential in the Srinagar district of Kashmir valley is influenced by land use systems.

At site A, maximum below ground biomass carbon was sequestered by T_{10}-Natural Forest-(Blue Pine) was 408.640 t ha^{-1} which was followed by T_9- Plantation Forest-(Poplar), T_7-Agri-silviculture (willow+Rice-Mustard), T_8- Plantation Forest (willow),T_6- Agri-Horticulture (Apple+vegetable), T_5-Horticulture, T_3-Agriculture (Rice+oats), T_4-Vegetable (Beans-Chilli), Agriculture (Rice-Mustard), T_{11}- Grassland, T_1- Wasteland/uncultivated land at site A.

Whereas at site B, the maximum below ground carbon 384.644 t ha^{-1} was sequestered by T_{10}- Natural Forest-(Blue Pine) and the minimum below ground carbon sequestered (0.588 t ha^{-1}) was recorded at T_1- wasteland/uncultivated land.

Table 2: Belowground Carbon sequestration Potential (t ha^{-1}) as affected by different land use systems at Site A & B in district Srinagar. (Pooled value of two years)

Land use System (LU)	Sites- (S)		Mean ± SE	95%Confidence Interval	
	Site-A	Site-B		L.B	U.B
T_1- Wasteland/Uncultivated Land	0.605	0.588	0.5965±0.008	0.579	0.613
T_2- Agriculture (Rice-Mustard)	1.635	1.553	1.594±0.041	1.513	1.674
T_3- Agriculture (Rice-Oats)	3.444	3.300	3.372±0.072	3.230	3.513
T_4- Vegetable (Beans-chilli)	1.766	1.920	1.843±0.077	1.692	1.993
T_5- Horticulture(Apple alone)	45.238	47.181	46.2095±0.971	44.305	48.113
T_6- Agri-Horticulture (Apple +Vegetables)	51.567	54.817	53.192±1.625	50.007	56.377
T_7- Agri-Silviculture (Willow+ Rice Mustard)	61.945	61.885	61.915±0.030	61.856	61.973
T_8- Plantation Forest (Willow)	54.681	51.477	53.079±1.602	49.939	56.218
T_9- Plantation Forest (Poplar)	299.254	281.298	290.276±8.978	272.679	307.872
T_{10}- Natural Forest (Blue Pine)	408.640	384.644	396.642±11.998	373.125	420.158
T_{11}- Grassland	0.797	0.748	0.7725±0.024	0.724	0.820

3. Total carbon sequestration potential (t ha^{-1})

Total carbon sequestration potential was influenced by land use systems in Table 03.

In the land use system, maximum carbon sequestration (CO_2 equivalent) potential is exhibited by T_{10}- Natural Forest-(Blue Pine) 2043.202 t ha^{-1}, which is higher than any other land use system in the investigation. Lower carbon sequestration (CO_2) potential is demonstrated by T_1 -wasteland/uncultivated land use system, which was followed by T_{11}- Grassland having values of 3.220 t ha^{-1} and 4.386 t ha^{-1} respectively at Site A.

At site B, the maximum carbon sequestration was recorded at T_{10} –Natural Forest (Blue Pine) 1923.224 t ha^{-1} and the minimum carbon sequestration potential was recorded at T_1-wasteland/uncultivated land use system 3.128 t ha^{-1}.

Table 3: Total Above and belowground Carbon sequestration (t ha^{-1}) as affected by different land use systems at Site A & B in district Srinagar. (Pooled value of two years)

Land use System(LU)	Sites- (S)		Mean ± SE	95%Confidence Interval	
	Site-A	Site-B		L.B	U.B
T_1- Wasteland/Uncultivated Land	3.220	3.128	3.174±0.046	3.083	3.264
T_2- Agriculture (Rice-Mustard)	8.399	7.934	8.166±0.232	7.710	8.622
T_3- Agriculture (Rice-Oats)	18.523	17.649	18.086±0.437	17.229	18.942
T_4- Vegetable (Beans-chilli)	9.381	9.201	9.291±0.090	9.114	9.467

T_5- Horticulture(Apple alone)	226.191	235.905	231.048±4.857	221.528	240.567
T_6- Agri-Horticulture (Apple +Vegetables)	235.383	249.748	242.565±7.182	228.487	256.643
T_7- Agri-Silviculture (Willow+ Rice Mustard)	294.196	279.259	286.727±7.468	272.089	301.365
T_8- Plantation Forest (Willow)	273.406	257.383	265.394±8.011	249.692	281.097
T_9- Plantation Forest (Poplar)	1496.271	1406.494	1451.383±44.888	1363.401	1539.364
T_{10}- Natural Forest (Blue Pine)	2043.202	1923.224	1983.213±59.989	1865.635	2100.791
T_{11}- Grassland	4.386	4.124	4.255±0.131	3.998	4.511

Table 4: Comparison of Total Carbon Stocks (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		Total	Site-B		Total
	Plant	Soil		Plant	Soil	
T_1- Wasteland/Uncultivated Land	0.87	30.45	31.32	0.85	29.31	30.16
T_2- Agriculture (Rice-Mustard)	2.28	65.17	67.45	2.16	63.36	65.52
T_3- Agriculture (Rice-Oats)	5.04	53.55	58.59	4.80	54.61	59.41
T_4- Vegetable (Beans-chilli)	2.55	63.75	66.3	2.50	65.52	68.02
T_5- Horticultue	61.63	64.57	126.2	64.27	66.34	130.61
T_6- Agri-Horticulture (Apple +Vegetables)	64.13	70.00	134.13	66.15	71.19	137.34
T_7- Agri-Silviculture (Willow+ Rice Mustard)	80.16	68.67	148.83	76.09	67.5	143.59
T_8- Plantation Forest (Willow)	74.49	110.11	184.6	70.13	109.8	179.93
T_9- Plantation Forest (Poplar)	407.70	120.95	528.65	383.24	121.09	504.33
T_{10}- Natural Forest (Blue Pine)	556.73	217.25	773.98	524.03	215.82	738.85
T_{11}- Grassland	1.195	75.00	76.195	1.124	76.16	77.284
Mean	114.252	85.406	199.658	108.667	85.518	194.094

Total carbon stocks were recorded maximum in T_{10} -Natural forest –(Blue Pine) 773.98 t ha^{-1} at site A and followed by T_{10} - Natural forest-(Blue Pine) 738.85 t ha^{-1} at site B. Thus, T_{10} - Natural forest-(Blue Pine) is the best land use system for carbon sequestration. The second best was T_9 -Plantation forest-(Poplar) with 528.65 t ha^{-1} at site A and T_9 - Plantation forest-(Poplar) with 504.33 t ha^{-1} at site B. The minimum was recorded in T_1- wasteland /uncultivated land 30.16 t ha^{-1} at site B and in T_1- wasteland/uncultivated land 31.32 t ha^{-1} at site A (Table-04).

Discussion

Table 04 demonstrated the total carbon stock in the Kashmir valley ecosystems at site A and B in the district Srinagar. Maximum total carbon density (773.98 t ha^{-1}) was observed in T_{10}- natural forest-(Blue Pine) land use system, which was closely followed by the T_9- plantation forest -poplar systems, T_8-Plantation forest-willow, T_6-Agri-horticulture, T_5 - horticulture, T_{11}-grassland, T_2-agriculture, T_4-vegetables and then T_1-wasteland/uncultivated land. The total carbon stock (soil + plant) as observed in the natural forest systems is appreciably higher than sole cropping based systems i.e. plantation forest, horticulture, agriculture, vegetables, at all the attitudinal ranges i.e., both sites.

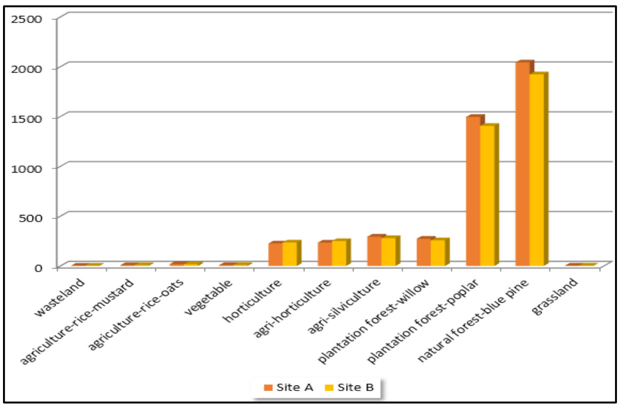

Fig 2: Comparison of total carbon stocks (t ha^{-1}) under different land use systems at two different sites in district Srinagar

Whereas, at site B (Table 04 and Fig. 02) maximum total carbon stock (738.85 t ha^{-1}) was observed in the natural forest land use system, which is around 4-5 times higher than plantation forest-willow. The higher amount of total carbon stock in forest and other perennial plant based system can again be ascribed to regular addition of leaf litter on the surface soil layers over the years that contributed to the build up of soil organic matter and nutrient stocks in the soil, which favours the higher biomass production as reported [11-13]. The average total carbon stock of our forest in both the forest ecosystem is 484.96 t C ha^{-1}, which is higher than reported [7, 8] for temperate evergreen forest (294.1 t C ha^{-1}). The C-sequestration potential of our agroforestry and horticulture land use system ranged between 136.386 t C ha^{-1} and 137.18t C ha^{-1} at site A and B respectively. [1]The carbon sequestration potential of tropical agroforestry was also estimated to be between 128 and 228 t ha^{-1} with a medium value of 95 t ha^{-1}. From above results, it can be inferred that more carbon stocks can be realized from all forestry/fruit/fodder based agroforestry systems at both the locations in the district Srinagar of Kashmir valley. The amount of carbon credits which can be realized from a land use system is the function of rate of CO_2 capturing ability of plants and its locking in the form of biomass. The rate of CO_2 capturing ability in the form of woody biomass in fruit based system is more than pure horticulture because they are intensively managed at the same time only a small fraction of biomass is removed in the form of pruned wood and fruit yield. Although it is fact that fruit trees lock the carbon only for short term period of 30-40 years, only. But maximum locking capacity is with the forest species and can be used for the CDM projects throughout the country. Agroforestry comes after forestry, but we can use the wastelands and uncultivated lands for the purpose and we get the dual benefits of economic stability and additional benefits as food, fodder and small timber.

Conclusion

The rate of carbon sequestration potential at site A was maximum (773.98 t ha^{-1}) was observed in T_{10}- natural forest-(Blue Pine) land use system. At site B, the rate of carbon sequestration potential was found to be maximum (738.85 t $ha^{-1}yr^{-1}$) in the T_{10}- natural forest-(Blue Pine) land use system. Thus, considering the two important characteristics of the studied land use systems like total biomass carbon stocks and relative carbon sequestration potential (biomass plus soils), it is worth concluding that natural forest-Blue Pine with respective plant densities of 1700 trees ha^{-1} and 1500 trees ha^{-1} at site A and B respectively is better land use system for conserving carbon stocks. The second best land use system at both the locations is Plantation forest-Poplar with a density of 2300 trees ha^{-1} at site A and 2100 trees ha^{-1} at site B, having poplar as woody perennial. Forests being under the direct control of forest department and the activities such as land use management practices cannot be allowed due to threat to the Flora and Fauna in these fragile ecosystems. Poplars can be grown on commercial basis, can be best used for the agro forestry systems to take the advantage in the shape of carbon credits and other benefits like timber, fodder and much important the benefit of carbon sequestration which can help us from the hazards effects of climate change in the coming future. The other land use systems like, Plantation forest-willow, Agri-silviculture system-willow+rice, agri-horticulture system- apple+vegetables respectively comes next to the plantation forest –Poplars.

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