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Carbon stock estimation (above and below ground biomass) under different land use systems in Kashmir valley

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Abstract
Carbon in the earth system moves between the four major reservoirs: fossil and geological formations, the atmosphere, the oceans and terrestrial ecosystems including forests. Transfers between these reservoirs occur mainly as carbon dioxide (CO_2) 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. Forests contribute to global climate change through their influence on the global carbon (C) cycle. They store large quantities of carbon in vegetation and soil, exchange carbon with the atmosphere through photosynthesis and respiration. The world forests contain about 830 Pg C (1015 g) in their vegetation and soil, with about 1.5 times as much in soil as in vegetation. Results revealed that total carbon stocks of different land use systems at site A and B followed the trend: Natural Forest-Blue Pine (556.731 t ha^{-1}), (524.039 t ha^{-1}) > Plantation forest-Poplar (407.703 t ha^{-1}),(383.241 t ha^{-1}) > Agri-silviculture-willow+rice (80.162 t ha-1), (76.092 t ha^{-1}) > Plantation forest-willow (74.498 t ha^{-1}),(70.131 t ha^{-1}) > Agri-horticulture-apple+vegetable-Beans (64.173 t ha^{-1}), (66.150 t ha^{-1}) > horticulture-apple alone (61.630 t ha^{-1}),(64.279 t ha^{-1}) > agriculture-rice-oats (5.047 t ha^{-1}),(4.809 t ha^{-1}) > vegetable-beans-chilli (2.556 t ha^{-1}),(2.507 t ha^{-1}) > agriculture-rice-mustard (2.288 t ha^{-1}),(2.162 t ha^{-1}) > grasslands (1.195 t ha^{-1}),(1.124 t ha^{-1}) > wasteland/uncultivated land (0.877 t ha-1),(0.852 t ha^{-1}) Similar trends were also seen in carbon sequestration potential of different land use systems

Keywords: Carbon stock, climate change, carbon cycle and land use system

Introduction

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 [6].

Carbon in the earth system moves between the four major reservoirs: fossil and geological formations, the atmosphere, the oceans and terrestrial ecosystems including forests. 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.

However, this may not continue in future as temperate and boreal forests reach maturity and become a smaller C sink, and if rates of tropical deforestation and degradation continue to accelerate. There is a potential to manage forests to conserve and sequester C to mitigate emissions of CO2 by an amount equivalent to 11-15 per cent of the fossil fuel emissions over the same time period[4]. Aggressive adoption of these forest management options are necessary to prevent forests becoming a significant net source of CO2 to the atmosphere in the future and contributing to climate change[4]. An assessment of the current and projected trends of GHG emission from India and some selected countries indicates that though Indian emissions grew at the rate of 4 per cent per annum during 1990 and 2000 period and are projected to grow further to meet the national developmental needs, the absolute level of GHG emissions in 2020 will be below 5 per cent of global emissions and the per capita emissions will still be low as compared to most of the developed countries as well as the global average [16].

The atmospheric CO_2 concentration is 398.35ppm according to latest report by Scripps Institution of oceanography which was published on May 2nd, 2013. It was around 280 ppm prior to industrial revolution [8]. Out of approximate 100 ppm rise in CO_2 concentration in the atmosphere almost 60 ppm rise has occurred in the second half of the 20th century alone [9]. During the decade i.e. 1995-2005 average annual carbon dioxide growth rate was 1.9 ppm/year, then it has been since the beginning of continuous direct atmospheric measurement (1960-2005 average: 1.4 ppm/year) [8]. According to future emission scenario CO_2 emission shall continue to dominate national GHG emission with its share reaching 74 per cent in 2030[17]. The doubling of atmospheric concentration of CO_2 could raise the mean temperature of the earth's surface by 1.5 to 4.5^{0}C[12].

Agricultural activities greatly contribute to global net flux of CH_4, N_2O and CO_2 from the terrestrial biosphere into the atmosphere. The increased flux from the change and intensification of land use in order to feed needs of the rapidly growing human population. Increased biomass burning and soil cultivation, increased number of livestock, increased acreage of paddy fields and increased use of nitrogen fertilizer have been considered as most important factor for the increased flux. Following the agreement of Kyoto-protocol in 1997 policy makers or the Ministers of Agriculture of many countries have involved in discussion about policy measures to decrease greenhouse gases emission from agriculture. Various possible measures have been identified to decrease emission of CO_2, CH_4, and N_2O from agricultural sources. However, few of these measures have been tested at field scale. Vegetation in terrestrial ecosystem has been recognized as an effective and low cost method of offsetting carbon emission. Carbon sequestration problem varies with the kind of land use. Forest has been recognized as most effective land use system because of their abilities to lock carbon for long term in addition to other environmental benefits they bestow upon us. But, since India is a population rich country it cannot spare huge chunk of land for this purpose because it has to feed the growing population, first. Therefore, the need is to assess the potential of different land management options, which can fulfil both environmental and economic goals. Carbon sequestration depends upon the biological productivity which in turn depends upon interaction between species, climate, topography and management practices. Thus, the carbon sequestration potential varies from place to place, which need to be worked out on region to region basis. Estimates of carbon stock in Indian forests in both soil and vegetation range from 8.58 to 9.57 Gt C. The carbon stock in existing forests is projected to be nearly stable over the next 25 year period at 8.79 Gt C. However, if the current rate of afforestation and reforestation is assumed to continue, the carbon stock could increase from 8.79 Gt C in 2006 to 9.75 Gt C by 2030 and increase of 11%[14].

Different land use systems has potential to optimize biomass productivity and storage that fixes carbon for long time in wood.

Method and Materials

The present investigations entitled **"**Carbon appraisal of different land use systems of Srinagar District of 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.

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 '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'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 93mm 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.

To estimate carbon stock (above and below ground biomass) under different land use systems following systems were taken into consideration.

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

1. Above ground biomass (t /ha)

Stem biomass

To estimate biomass all the trees falling in the plot (10 m x 10 m) were enumerated. The diameter at breast height (dbh) was measured with caliper and height with Ravi's multimeter. Form factor and tree volume was calculated using the formula given by Pressler's (1865) and Bitlerlich (1984).

$$\mathbf{F = 2h_1/3h}$$

Where, f = form factor, h_1 =height at which diameter is half of dbh

h = total height, Volume was calculated by Pressler's formula (1865) and Bitlerlich (1984).

$$\mathbf{V = f \times h \times g}$$

Where, V = volume, f = form factor, h = total height, g = Basal area, g = πr^2 or π (dbh/2)

Where, r = radius, dbh – diameter at breast height.

Branch Biomass of forest trees

Total numbers of branches irrespective of size were counted on each of the sample tree, then these were categorized on the basis of basal diameter into three groups, viz., < 6cm, 6-10cm, and >10 cm. Fresh weight of two sampled branches from each group was recorded separately. The formula (Chidumayo 1990) was used to determine the dry weight of branches.

$B_{dwi} = B_{twi}/1 + M_{cbdi}$

Where, B_{dwi} - oven dry weight of branch

B_{dwi} - Fresh/green weight of branches

M_{cbdi} - Moisture content of branch on dry weight basis

Total branch biomass (Fresh/dry) per sample tree was determined by the formula given by Chidumayo (1990).

$B_{bt} = n_1bw_1 + n_2bw_2 + n_3bw_3 - \Sigma\ nibwi$

Where,

B_{bt} - Branch biomass (fresh/dry) per tree

n_i - Number of branches in the i^{th} branch group

b_{wi} - average weight of branch of i^{th} group

i - 1, 2, 3……….refers to branch group

Leaf biomass

Leaves from five branches of individual trees were removed. Five trees per plot were taken for observation. The leaves were weighed and oven dried separately to a constant weight at 80 ± 5ºC. The average leaf biomass was calculated by multiplying average biomass of the leaves per branch with the number of branches in a single tree and the number of trees in a plot [10].

Crop and grass biomass

Crop and grass biomass was estimated using quadrates (1m x1 m). All the crop and grass biomass occurring within the borders of the quadrates was cut at ground level and collected samples were weighed, sub sampled and oven dried at 65 ± 5 ºC to a constant weight. The crop and grass biomass was converted into carbon by multiplying with a factor of 0.45 [19].

Below ground biomass

Root samples of crops and grasses were collected from an area of 20 cm within each quadrant up to a depth of 40 cm. The roots and the soil were placed in the bags for further laboratory analysis. The samples were dispersed in water and passed through a 2 mm sieve. Roots were thus collected from the sieve and washed in water without distinguishing live and dead roots. Roots were then oven dried at 65± 5 ºc to a constant weight and weighed. The below ground biomass of trees was calculated as per the factor (aboveground biomass x 0.25). The below ground biomass then converted into carbon by a factor of 0.45 [19].

Carbon stocks

Carbon stock was calculated by multiplying the biomass with factor 0.45 [19]

Results and Discussion

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 Potential (t ha^{-1}) as affected by different land use systems in district Srinagar. (Pooled value of two years)

Land use System(LU)	Site	Mean ± SE	95 % Confidence Interval	
			L.B	U.B
T_1- Wasteland/Uncultivated Land	2.613	2.576±0.037	2.503	2.648
T_2- Agriculture (Rice-Mustard)	6.764	6.572±0.191	6.197	6.947
T_3- Agriculture (Rice-Oats)	15.079	14.714±0.365	13.998	15.429
T_4- Vegetable (Beans-chilli)	7.614	7.447±0.167	7.119	7.774
T_5- Horticulture(Apple alone)	180.952	184.837±3.885	177.221	192.453
T_6-AgriHorticulture(Apple+Vegetables)	183.815	189.373±5.558	178.479	200.266
T_7AgriSilviculture(Willow+RiceMusta)	232.250	224.811±7.438	210.232	239.391
T_8- Plantation Forest (Willow)	218.725	212.315±6.409	199.752	224.878
T_9- Plantation Forest (Poplar)	1197.017	1161.106±35.911	1090.720	1231.492
T_{10}- Natural Forest (Blue Pine)	1634.561	1586.57±47.991	1492.508	1680.632
T_{11}- Grassland	3.589	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), 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}.

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.

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

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

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

Total carbon sequestration potential was influenced by land use systems (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.

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

Land use System(LU)	Site	Mean ± SE	95%Confidence Interval	
			L.B	U.B
T_1- Wasteland/Uncultivated Land	3.220	3.174±0.046	3.083	3.264
T_2- Agriculture (Rice-Mustard)	8.399	8.166±0.232	7.710	8.622
T_3- Agriculture (Rice-Oats)	18.523	18.086±0.437	17.229	18.942
T_4- Vegetable (Beans-chilli)	9.381	9.291±0.090	9.114	9.467
T_5- Horticulture(Apple alone)	226.191	231.048±4.857	221.528	240.567
T_6- Agri-Horticulture (Apple +Vegetables)	235.383	242.565±7.182	228.487	256.643
T_7- Agri-Silviculture (Willow+ Rice Mustard)	294.196	286.727±7.468	272.089	301.365
T_8- Plantation Forest (Willow)	273.406	265.394±8.011	249.692	281.097
T_9- Plantation Forest (Poplar)	1496.271	1451.383±44.888	1363.401	1539.364
T_{10}- Natural Forest (Blue Pine)	2043.202	1983.213±59.989	1865.635	2100.791
T_{11}- Grassland	4.386	4.255±0.131	3.998	4.511

Discussion

The biomass carbon stock in a particular land use system to a great extent depends upon its age, structure, functional component and its number and intensity of management. The above, below and total biomass carbon density in respect of different land use systems in district Srinagar of Kashmir valley has been presented in the Table 1, 2, and 3.

Data revealed that all the traits of biomass i.e. above ground biomass, below ground biomass and total biomass were influenced due to land use system was maximum above ground biomass (445.385 t ha^{-1}) carbon was exhibited by Natural Forest-Blue Pine system, which was closely followed by other Plantation Forest-Poplar based systems.

Minimum above ground biomass carbon at both the sites were in wasteland/uncultivated land use systems. Whereas, maximum above ground carbon was exhibited by Natural Forest-Blue Pine based land use systems, which can be attributed to continuous accumulation of biomass in the woody component.

The below ground carbon and total biomass carbon in general, followed more or less same trend as depicted by the above ground biomass carbon. Only slight variation was detected in annually based cropping systems, which can be attributed to their variation in carbon allocation pattern to aerial and below ground component.

It can again inferred from the above discussion that variability in the carbon stock of different land use system types depends primarily on its age, structure, functional components and their number, intensity of management. The variability in the productivity of agroforestry system as recorded in our case is in consonance with the observations [1]. They opined that carbon variability in plant biomass can be high with in complex agroforestry system and productivity depends on several factors including age, the structure and the way the system is managed. The biomass carbon storage capacity as calculated in our fruit based temperate agroforestry system was similar to the values (60 t ha^{-1} C) calculated[11] in two tree combination in Costa Rica Cacao (*Theobroma cacoa*) - laurel (*Cordia allieadora*) and Cocopora (*Erythrina poeppigiana*) and for fruit based agroforestry systems (51.85 t ha^{-1}) of wet temperate north western Himalaya [15].

The average biomass carbon storage potential of our forest based systems recorded as (336.057 t ha^{-1}) in our forest system is higher[18] than Himalayan forest i.e. 190 t ha^{-1} and for wet temperate Himalayan forest ecosystem (185.0 t ha^{-1}) [15]. But, the value is higher side in comparison to the average value of 160.0 t per ha [7]. The variation in the value of our forests and global temperate region coniferous forest is mainly due to difference in the nature of the temperate forest. The average annual temperature of our forest is higher than the temperate forest found in other parts of the world this may be one of the reasons for their higher productivity.

Conclusion

All the land use systems presently under consideration showed net deficit of carbon stock in relation to natural forest land use system. This deficit was higher in wasteland/uncultivated land use system and agriculture land use system than in perennial tree based land use systems viz., agri-horticulture, agri-silviculture, and horticulture. But, when comparison was made with respect to pure horticulture, the agri-horticulture showed gains over pure crop of horticulture. The trend was Natural forest-Blue Pine (+915.46) > Plantation forest-Poplar (+593.58) > Plantation forest-willow (+142.19) > Agri-silviculture-willow +rice-mustard (+95.26) > Agri-horticulture-apple +vegetables-beans (+75.97) > Horticulture-apple alone (+65.57) and net loss was maximum in wasteland/uncultivated land use system (-58.89) followed by agriculture-rice-oats (-23.13), vegetables –beans-chilli (-13.04) and agriculture-rice-mustard (-11.51) in descending order.

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