

Carbon Per cent in Different Components of Tree Species and Soil Organic Carbon Pool Under these Tree Species in Kashmir Valley

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ABSTRACT

Carbon is a critical element that trees accumulate and use to support their structure and sustain physiological processes. Besides being a key element in forest ecosystems, carbon is also essential for sustaining life on a global scale. The study attempted to quantify carbon per cent in different tree components of *Cedrus deodara*, *Fraxinus floribunda* and *Ulmus wallichiana*, an important tree species of Kashmir valley were planted in plantation block of Faculty of Forestry at Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar way back in 1992. The soil organic carbon pool under these tree species was also estimated. This information however is poor and fragmented as no published literature is available in this region. Statistical analysis of the data reveals that carbon per cent was significantly higher in *Cedrus deodara* (45.41%) followed by *Fraxinus floribunda* (41.36%) and *Ulmus wallichiana* (40.78%) respectively. Besides the soil attributes like organic carbon and bulk density were also determined and the same were used for preparing the carbon pool inventory. The pooled results revealed that organic carbon was significantly higher in *Ulmus wallichiana* (2.08%) as compared to *Cedrus deodara* (1.86%) and *Fraxinus floribunda* (1.53%). However the bulk density was significantly higher in *Fraxinus floribunda* (1.26 gcm⁻³) as compared to *Cedrus deodara* (1.24 gcm⁻³) and *Ulmus wallichiana* (1.20 gcm⁻³). Moreover the soil organic carbon pool was significantly higher in *Ulmus wallichiana* (75.04 t ha⁻¹) as compared to *Cedrus deodara* (69.37 t ha⁻¹) and *Fraxinus floribunda* (57.82 t ha⁻¹).

Key words: Carbon per cent, Kashmir valley, Soil organic carbon pool, Tree species

INTRODUCTION

Trees play a vital role in mitigating the diverse effects of environmental carbon degradation and increasing concentration of carbon dioxide in the atmosphere. Trees promote sequestration of carbon into soil and plant biomass. Therefore tree based land use practices could be viable alternatives to store atmospheric carbon dioxide due to their cost effectiveness, high potential of carbon uptake and associated environmental as well as social benefits (Dhruw *et al.*, 2009). Increasing levels of carbon dioxide in the atmosphere during the past few decades has drawn the attention of the scientific community towards the process of carbon storage and soil organic carbon store. Concentration of atmospheric carbon

dioxide can be lowered either by reducing emissions or by enabling the storage of carbon dioxide in the terrestrial ecosystem. Soil plays an important role in the carbon cycle by storing it in the form of soil organic carbon. Most of the carbon enters the ecosystem through the process of photosynthesis in the leaves. After the litter fall, the detritus is decomposed and forms soil organic carbon by microbial process (Post and Kwon, 2000). Soils under tree canopies were found to have greater levels of organic matter and other nutrients. The global forest ecosystem has been reported to account for approximately 90 per cent of annual carbon flux between atmosphere and soil carbon. The carbon held in the upper profile is often the most chemically decomposable and directly exposed to natural and anthropogenic disturbances

(IPCC, 2003). Because the input of organic matter is largely from above ground litter, forest soil organic matter tends to concentrate in the upper soil horizons with roughly half of the soil organic carbon of the top 100 cm of mineral soil being held in the upper 30 cm layer. Therefore estimation of soil organic carbon (SOC) up to the depth of 30 cm is attached with enormous importance. Soil stores more carbon than is contained in plants and the atmosphere combined. As a matter of fact the world's soil contains 4.5 times the amount of carbon held in the vegetation (Lal, 2004). Gupta and Rao (1994) made first estimate of the organic carbon stock in Indian soils was 24.3 Pg (1 Pg = 10¹⁵ g) based on 48 soil samples. World wide the top soil layer of first 30 cm holds 1500 Pg carbon whereas for India it is 9 Pg (Bhattacharya *et al.*, 2000). There is a significant proportion of carbon in forest litter layer. Lower rates of decomposition in the forests could increase soil organic carbon (SOC) storage in surface soil. The storage of soil organic carbon is controlled by balance of carbon input from plant production and output through decomposition. The total soil organic content increases with precipitation and clay content decreases with temperature (Jobbagy and Jackson, 2000). The climate affects the soil organic carbon storage in shallow layer, while the clay content affects storage in deeper layer of the soil. The effect of vegetation type is more important than the precipitation in the distribution of carbon. Soil on south facing slopes at lower elevation contained significantly less total organic carbon compared with soil from north facing slope at higher elevation (Schmidt *et al.*, 1993).

Soil organic matter retains the largest terrestrial reservoir of carbon in the global carbon cycle. Soils store 2.5 to 3.0 times as much carbon that is stored in plants and 2 to 3 times more than the atmospheric carbon as CO₂ (Davidson *et al.*, 2000). As much it plays a major role in the control of carbon dioxide levels in the atmosphere (Follett *et al.*, 2007). Soil organic matter is in a state of dynamic balance between inputs and outputs of organic carbon. Inputs are largely determined by the forest productivity, the decomposition of litter and its incorporation into the mineral soil whereas rates of organic matter decay and the return of carbon to the atmosphere through respiration control outputs (Pregitzer, 2003). Other losses of soil organic carbon

occur through erosion. Deforestation can contribute a large volume of carbon to the atmosphere either by reducing the amount stored in above ground biomass or increasing the oxidation of soil organic carbon.

Forests act as one of the largest carbon sinks and helps to control atmospheric CO₂ concentrations (Zhou *et al.*, 2006). Forest soil contains a globally significant amount of carbon approximately half of earth's terrestrial carbon is in forests (1146×10¹⁵ g), and of this amount, about two-thirds is retained in soil pools (Dixon *et al.*, 1994). Temperate forests ecosystems contain a significant amount of soil organic carbon both globally and regionally (Rasmussen *et al.*, 2006). It has been estimated that present carbon stock in the world's forests is 861 ± 66 Pg C, of which 383 ± 30 Pg (44%) is in soil to a depth of 1 meter. Temperate forests contribution to world forest carbon stock is 14 % (119 ± 6 Pg), (Pan *et al.*, 2011). Based on average global or regional soil carbon densities estimated in Indian forest soils, it has been calculated that our soil organic carbon pool ranges from 5.4 to 6.7 Pg (Ravindemath *et al.*, 1997) while Chhabra *et al.*, 2003 had estimated that the total soil organic pool in Indian forests in the top 50 cm and top 1 m soil depth were 4.13 and 6.81 Pg, respectively. Soil organic carbon is normally estimated to a depth of 0-30 cm since most of it is present in the top layers and root activity is also concentrated in this horizon (Ravindra nath and Ostwald, 2008). Thus the quantity of SOC in the 0-30 cm layer is about twice the amount of carbon in atmospheric carbon dioxide (CO₂) and three times that in global above ground vegetation (Powlson *et al.*, 2011). It is estimated that the global stock of SOC to a depth of 30 cm is 684-724 Pg (Batjes, 1996). A small change in soil carbon results in a large change in atmospheric concentration (IPCC, 2000). It is essential to study the mechanisms and changes of forest SOC to better understand and mitigate climate change (Fang *et al.*, 1996). Mountainous cold-temperate areas like Kashmir have high SOC content but large spatial variability, due to variable climate and vegetation (Li *et al.*, 2010). This spatial variability has made it difficult to predict the spatial distribution of SOC in forest soils (Fahey *et al.*, 2005). Various studies have reported the influence of topography, climatic conditions ,

soil composition, litter quality and its decomposition rate and species composition or vegetation type on the spatial distribution of SOC (Schulp *et al.*, 2008). Since no scientific systematic study has been undertaken to estimate the carbon per cent in different tree components of *Cedrus deodara*, *Fraxinus floribunda* and *Ulmus wallichiana* an important tree species of Kashmir valley and also soil organic carbon pool under these tree species. Therefore an attempt was made with the objective to estimate the carbon percent of tree components (leaves, branches, wood, bark and roots) and also soil organic carbon pool under temperate conditions of Kashmir.

MATERIALS AND METHODS

Study area

The experimental site is located between 74.89° East longitude and 34.08° North latitude at an altitude of about 1600 meters above mean sea level. It is roughly 15 km south east to the Srinagar city and the soil of the site is silt loam and is well drained. The climate is generally temperate with severe winter extending from December to March. The region faces a wide temperature range from a minimum of -4°C in winter to a maximum of 33°C in the summers. The annual precipitation of the area is about 676 mm and most of the precipitation is received in the form of snow during winter months. The present study was carried out in Plantation Block of Faculty of Forestry during the year 2009 and 2010 at Sher-e-Kashmir university of Agricultural sciences and technology of Kashmir (SKUAST-K), Shalimar and was planted during March 1990 having 19 years of age. The tree species planted were *Cedrus deodara*, *Fraxinus floribunda* and *Ulmus wallichiana* were selected for the study.

Demarcation and enumeration for measurements

After survey of the entire area, trees of *Cedrus deodara*, *Fraxinus floribunda* and *Ulmus wallichiana* were enumerated according to diameter at breast height at SKUAST-Kashmir. In total 72 trees were enumerated in order to determine the diameter at breast height (DBH). These trees were then classified into three diameter classes viz; 10-20 cm, 20-30 cm and 30-40 cm except

Fraxinus floribunda whose first diameter class was 0-10 cm owing to their small diameter. The total numbers of trees in three diameter classes were 24 in a quadrat of size 10 x 10 m having spacing of 2 x 2 m. The layout plan of experimental site at SKUAST-Kashmir, Shalimar is given as in (Table 1).

Estimations

Estimation of carbon per cent in different tree components

Carbon per cent was estimated by ash content method described by Negi *et al.* (2003). In this method oven dried plant components (bark, leaves, stem wood and root) were burnt into muffle furnace at 400°C temperature. The ash content left after burning was weighed and carbon content was calculated by using the following equation:

$$\text{Carbon \%} = 100 - (\text{ash weight} + \text{molecular weight of O}_2 (53.3) \text{ in C}_6\text{H}_{12}\text{O}_6$$

Soil analysis

Soil samples were collected by dividing each main plot (10 x 10 m) area into three sub-areas. Representative soil samples from each sub-area were collected by digging 3 pits of 30 cm wide, 30 cm deep and 50 cm in length. Composite samples from all three sub-areas were obtained. Soil samples were air dried in shade, ground with wooden pestle, passed through a 2 mm sieve mesh and stored in cloth bags for further analysis. The following physico-chemical attributes of the soil samples were determined.

Bulk density (gcm⁻³)

It was determined by core method (Wilde *et al.*, 1964). In this method, a cylindrical metal sampler was pressed or driven into the soil to the desired depth and was carefully removed to preserve a known volume of sample. The sample was dried at 105°C to 110°C and weighed. Bulk density is the oven dried mass divided by the field volume of the sample.

Organic carbon (%)

Organic carbon was determined by Walkley and Black (1934) rapid titration method. In this method 1.0 g soil was digested with a mixture of potassium dichromate (10 ml) and concentrated sulphuric acid (20 ml). The excess of potassium dichromate not reduced by the organic matter of

the soil was determined by titration using standard ferrous ammonium sulphate solution in the presence of ortho-phosphoric acid using diphenylamine as an indicator.

Soil Carbon inventory

The soil organic carbon pool inventory expressed as mega grams per hectare (Mg ha^{-1}) for a specific depth was computed by multiplying the soil organic carbon (g kg^{-1}) with bulk density (g cm^{-3}) and depth in cm (Joao Carlos *et al.*, 2001).

Statistical analysis

The data were statistically analysed by analysis of variance technique (ANOVA).

RESULTS

Carbon per cent of different tree species

The data on carbon per cent in different components of tree species in plantation block of SKUAST-Kashmir is depicted in Table 2 (Fig. 1-3). The data indicates that carbon per cent was

significantly more in *Cedrus deodara* (45.41%) as compared to *Fraxinus floribunda* (41.36%) and *Ulmus wallichiana* (40.78%). Moreover, the highest carbon per cent was recorded in stem wood of *Cedrus deodara* (46.39%) followed by *Ulmus wallichiana* (43.66%) and *Fraxinus floribunda* (43.21%), respectively. However, the lowest carbon per cent was observed in leaves of *Ulmus wallichiana* (36.41%), *Fraxinus floribunda* (36.7%) and *Cedrus deodara* (42.81%). Further, carbon per cent in leaf and bark of *Fraxinus floribunda* was comparatively higher than *Ulmus wallichiana*.

Soil organic carbon pool under different tree species

Perusal of the data presented in (Table 3) reveals that organic carbon content was recorded significantly more in case of *Ulmus wallichiana* (2.08%) as compared to *Cedrus deodara* and *Fraxinus floribunda* which was 1.86 and 1.53 per cent, respectively. However, organic carbon content registered an increasing trend from 2009 to 2010. Similarly the maximum bulk density was observed

Table 1: Layout Plan of Experimental Site at SKUAST- Kashmir, Shalimar

S. No.	Species	Quadrat /plot size (m)	Diameter class (cm)	Density (trees ha^{-1})
1.	<i>Cedrus deodara</i>	10 x 10	10-20	1300
			20-30	600
			30-40	500
			0-10	900
2.	<i>Fraxinus floribunda</i>	10 x 10	10-20	1000
			20-30	500
			10-20	1400
3.	<i>Ulmus wallichiana</i>	10 x 10	20-30	500
			30-40	500

Table 2: Carbon per cent in different components of tree species at SKUAST-Kashmir, Shalimar

Carbon per cent Species	Leaf	Bark	Branch	Root	Stem wood	Mean
<i>Cedrus deodara</i>	42.81	45.67	46.05	46.17	46.39	45.41
<i>Fraxinus floribunda</i>	36.70	41.50	42.42	43.01	43.21	41.36
<i>Ulmus wallichiana</i>	36.41	37.60	43.03	43.21	43.66	40.78
SE _(m±)	0.30	0.39	0.40	0.37	0.20	
CD _(p=0.05)	1.21	1.61	1.62	1.51	0.82	

in case of *Fraxinus floribunda* (1.26 g cm⁻³) as compared to rest of the species. Moreover, bulk density demonstrated a decreasing trend from 2009 onwards till 2010. Further the pooled data reveals that soil organic carbon pool was significantly higher in *Ulmus wallichiana* (75.04 t ha⁻¹) followed by *Cedrus deodara* (69.37 t ha⁻¹) and *Fraxinus floribunda* (57.82 t ha⁻¹), respectively. Soil organic carbon pool depicted an increasing trend from 2009 to later half of the study.

DISCUSSION

Carbon per cent of different tree species

The data on carbon per cent in different components of tree species (Table 2) indicates that carbon per cent was significantly higher in *Cedrus deodara* (45.41%) as compared to *Fraxinus floribunda* (41.36%) and *Ulmus wallichiana* (40.78%). Negi *et al.* (2003) has reported that

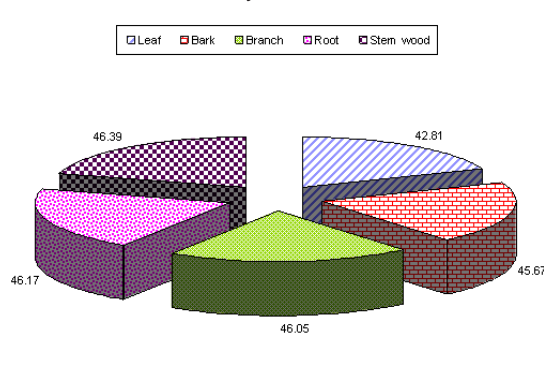


Fig. 1: Carbon per cent in different components of *Cedrus deodara*

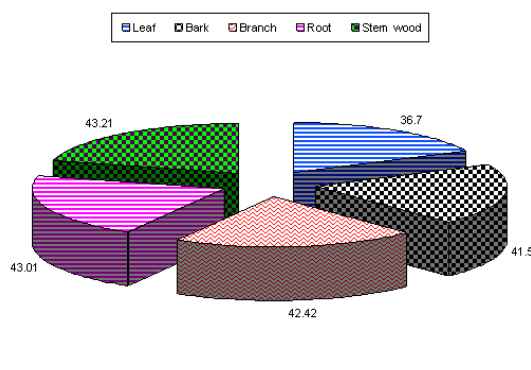


Fig. 2: Carbon per cent in different components of *Fraxinus floribunda*

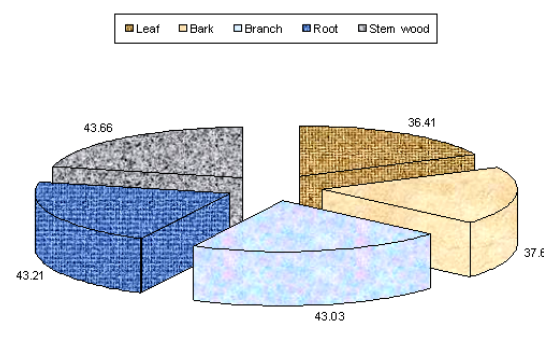


Fig. 3: Carbon per cent in different components of *Ulmus wallichiana*

carbon content in different parts of various species depends upon the ash content and the ash content depends upon the amount of structural components. More the structural tissue higher will be the ash content and lower will be the carbon content. Since *Cedrus deodara* contains less ash content as compared to *Fraxinus floribunda* and *Ulmus wallichiana* so its carbon per cent was more as compared to other tree species. Several other workers also support our findings (Shepherd and Montagnini, 2001; Dhruw *et al.*, 2009 and Jana *et al.*, 2009). Moreover, carbon per cent was recorded

Table 3: Soil organic carbon pool under different tree species in plantation block of SKUAST-Kashmir, Shalimar

Tree Species	Organic Carbon (%)			Bulk Density (gcm ⁻³)			SOC Pool (t ha ⁻¹)		
	2009	2010	Pooled	2009	2010	Pooled	2009	2010	Pooled
<i>Ulmus wallichiana</i>	2.06	2.11	2.08	1.21	1.19	1.20	74.77	75.32	75.04
<i>Cedrus deodara</i>	1.84	1.89	1.86	1.25	1.23	1.24	69.00	69.74	69.37
<i>Fraxinus floribunda</i>	1.51	1.55	1.53	1.27	1.25	1.26	57.53	58.12	57.82
SE _(m±)	0.012	0.013	0.010	0.009	0.004	0.006	0.010	0.013	0.008
CD _(p=0.05)	0.038	0.040	0.032	0.029	0.014	0.018	0.032	0.040	0.026

higher in stem wood in all the tree species and it was followed by root, branch, bark and leaf, respectively. Kraenzel *et al.* (2003) have reported that woody tissues like trunk, roots, branches and twigs have higher carbon concentration than soft tissues like leaves, flowers and fine roots. The results are also in conformity with the findings of Navar (2009) and Fonseca *et al.* (2012).

Soil organic carbon pool of different tree species

The perusal of the data presented in (Table 3) reveals that organic carbon was recorded significantly more in *Ulmus wallichiana* (2.08%) as compared to *Cedrus deodara* and *Fraxinus floribunda*. The higher amount of organic carbon under *Ulmus wallichiana* trees may be due to addition of more litter fall on the ground surface which keeps on decomposing and adds organic matter to the soil as this species is fast growing as compared to *Cedrus deodara* and *Fraxinus floribunda* and also the rate of decomposition is fast (Berthold and Beese, 2002). The results are in line with the findings of Kater *et al.* (1992), Rhodes (1995) and Sood (1999). The bulk density showed a decreasing trend from 2009 onwards till 2010 and was recorded significantly more in *Fraxinus floribunda* (1.26 g cm^{-3}) as compared to *Cedrus deodara* and *Ulmus wallichiana*. The increase in bulk density under *Fraxinus floribunda* may be due to decrease in organic carbon which decreases soil porosity resulting in the increase in bulk density. Thus the higher value of bulk density in the soils can also be ascribed to lower soil organic carbon content. These findings are in line with that of Karan *et al.* (1991), Sharma *et al.* (1995) and Cihacek and Ulmer (1997). The soil organic carbon pool was significantly higher in *Ulmus wallichiana* (75.04 t ha^{-1}) as compared to *Cedrus deodara* (69.37 t ha^{-1}) and *Fraxinus floribunda* (57.82 t ha^{-1}). The higher amount of soil organic carbon pool under *Ulmus wallichiana* may be explained in the sense that there

is continuous accumulation of leaf litter on the surface which keeps on decomposing and thus enriches the soil surface. The values in the present study are well within the reported range. Chhabra and Dadhwal (2005) reported the soil organic carbon pool in the range of $38.9\text{-}181.7 \text{ t ha}^{-1}$ in Kashmir valley and similar results have also been reported earlier by many other workers (Negi and Gupta, 2010; Gupta and Sharma, 2010 and Gupta, 2011).

CONCLUSION

In light of the present investigations following conclusions could be drawn:

- *Cedrus deodara* among the three tree species recorded the maximum carbon percent and it was followed by *Fraxinus floribunda* and *Ulmus wallichiana* respectively.
- *Cedrus deodara* being a slow growing conifer will provide a long term carbon fixation capacity as compared to fast growing species like *Fraxinus floribunda* and *Ulmus wallichiana* which provide revenues in the short term.
- Thus it can be said that conifers are more efficient in carbon accumulation than deciduous tree species.
- The pooled results revealed that organic carbon was significantly higher in *Ulmus wallichiana* as compared to *Cedrus deodara* and *Fraxinus floribunda*. However the bulk density was significantly higher in *Fraxinus floribunda* as compared to *Cedrus deodara* and *Ulmus wallichiana*. Moreover the results further revealed that soil organic carbon pool was significantly higher in *Ulmus wallichiana* as compared to *Cedrus deodara* and *Fraxinus floribunda*.

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