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BIOMASS, CARBON STOCK AND CARBON DIOXIDE MITIGATION POTENTIAL OF *CEDRUS DEODARA* (DEODAR) UNDER TEMPERATE CONDITIONS OF KASHMIR

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ABSTRACT

Carbon management in forests is the global concern to mitigate the increased concentration of greenhouse gases. Carbon sequestration through biomass seems to be a cheap and viable option to mitigate the greenhouse gases in the atmosphere. The study attempted to estimate growth, biomass production, carbon stock and carbon dioxide mitigation potential of 19 year old *Cedrus deodara* plantation under different diameter classes. The volume of trees in the stand varied from 0.072 to 0.596m^3. The average dry stem biomass varied between 27.60 to 226.67kg, branch dry biomass between 7.88 to 64.14kg, needle dry biomass between 1.57 to18.19kg, total above ground dry biomass between 37.06 to 309.0kg and root dry biomass varied from 8.88 to77.25kg. The stem carbon varied from 12.80 to 105.15kg, branch carbon between 3.62 to 29.53kg, needle carbon between 0.67 to 7.78kg, root carbon between 4.09 to 35.66kg and total carbon between 21.18 to 178.12kg. The stem carbon dioxide mitigation potential varied from 46.83 to 384.84kg, branch from 12.91 to 108.07kg, needle from 2.44 to 28.47kg, root from 14.99 to 130.51kg and total carbon dioxide mitigation varied from 73.92 to 651.91kg.

Keywords: *Cedrus deodara*, biomass, carbon stock, carbon dioxide mitigation, growth.

INTRODUCTION

In India 120.72 million hectare area has been delineated as degraded and wastelands of the country and out of this 1.07 million hectares of demarcated forests has been reported as degraded and wastelands in Jammu and Kashmir (Anonymous, 2010). In order to solve the problems associated with wood supply deficiencies, to reduce pressure on natural forests and to increase carbon stocks for climate change mitigation, trees have been proposed as a vital tool for restoration of these degraded and wastelands by affecting the vegetation structure and soil. Trees are used on degraded sites because they produce abundant leaf litter covering the ground and protecting against soil erosion, promotes atmospheric carbon sequestration and restore biodiversity. Sequestration of biomass carbon is considered as the most promising approach to mitigate climate change (Kimble *et al*., 2002). At global level, trees contribute 80-90% of plant biomass carbon and 30-40% of soil carbon (Harvey, 2000). Therefore trees can play an important role in carbon dioxide sequestration due to several reasons. The first is that the tree component fixes and stores carbon from the atmosphere via photosynthesis. They can function as active carbon for the period of many years and continue to store the carbon until they are harvested or die. The second reason is that trees provide a good surface cover which minimizes the loss of nutrients from the surface soil, improves edaphic conditions, increase biomass production, decrease risk of soil degradation by erosion, leaching and nutrient depletion.

On the global scale, deforestation results in the release of approximately 1000 million tons of carbon to the atmosphere each year in the form of carbon dioxide, an important greenhouse gas. This is about 15 percent of the total human caused carbon emissions and is a significant portion of the global carbon cycle that could contribute to global climate change. The trees play a pivotal role in the global carbon cycle. Tremendous amounts are actively exchanged between vegetation and the atmosphere. Any land use practices that increase vegetation cover or reduce its removal, could have an influence on the global carbon budget by increasing the terrestrial carbon sink. Policy makers could attempt to produce increases in carbon sequestration in a variety of ways. The government could provide subsidies in the form of payments, tax credits or cost sharing to private landowners for adopting practices that are known to increase carbon stocks. Alternatively the government could expand its own tree plantations on public lands. Finally trees are one of the viable alternatives to increase forest cover which will widen the area of carbon sink. In view of the above, a study on the most demanding commercial, valuable timber tree species of Kashmir valley commonly known as Deodar (*Cedrus deodara*) having a rotation of 120 years and is a large evergreen conifer belongs to family Pinaceae. It is well distributed over the western Himalayas from Afghanistan

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in the west to parts of Nepal in the east (Luna, 2005). Thus an attempt was made to quantify the ability of the tree species to sequester atmospheric carbon.

MATERIALS AND METHODS

Site description

The experimental site is located between 74.89^{0}East longitude and 34.08^{0}North latitude at an altitude of about 1600 meters above mean sea level. It is roughly 15km southeast of the Srinagar city and the soil of the site is silty 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^{0}C in winter to a maximum of 33^{0}C in the summers. The annual precipitation of the area is about 676mm and most of the precipitation is received in the form of snow during winter months. The present study was carried out in *Cedrus deodara* 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.The trees were planted during March, 1990 having 19 years of age during the study.

Demarcation and enumeration for measurements

After surveying of the experimental site, a quadrate of size 10 x 10m was laid in the area and total 24 trees in a particular quadrate were enumerated according to diameter at breast height (DBH). These trees were then classified into three diameter classes viz. 10-20cm, 20-30cm and 30-40cm for measuring various parameters.

Estimations

Volume and tree biomass

Tree biomass was estimated by adopting non-destructive methods for different plant parts viz. stem, branch and leaf.

Stem biomass

The diameters at breast height (DBH) of the trees falling in the plot of size 10 x 10 m were measured with diameter tape and height with Ravi's multimeter respectively. Form factor and volume was calculated by using the following formula given by Pressler (1865) and Bitlerlich (1984).

$f = \frac{2h_1}{3h}$ Where, f is the form factor, h_1 = height at which diameter is half of DBH and h is the total height. The volume (V) was calculated by Pressler's formula:

V = f × h × g Where, f = form factor, h = total height (m) and g = basal area, $g = \pi r^2$ or $\pi\,(dbh/2)^2$ Where, r = radius

Specific gravity

The stem cores were taken to find out the specific gravity of wood, taking into account the variation in different parts of the tree, which was used further to determine the biomass of stem using the maximum moisture method (Smith, 1954).

$$Gf = \frac{1}{\frac{M_n - M_o}{M_o} + \frac{1}{G_{so}}}$$

Where,

G_f = specific gravity based on gross volume

M_n = weight of saturated volume sample

M_o = weight of oven dried sample

G_{so} = Average density of wood substance equal to 1.53

Thus the weight of stem wood = specific gravity × stem volume

Or

Stem biomass = Specific gravity × stem volume

Branch biomass

The total number of branches irrespective of size was counted on each of the sample tree, then these branches were categorized on the basis of basal diameter into three groups viz. small, medium and large. Fresh weight of two sampled branches from each group was recorded separately. The following formula (Chidumaya, 1990) was used to determine the dry weight of branches:

$$B_{dwi} = B_{fwi} \Big/ 1 + M_{cdbi}$$

Where,

B_{dwi} = oven dry weight of branches

B_{fwi} = Fresh/green weight of branches

M_{cdbi}= Moisture content of branches on oven dry weight basis

Total branch biomass (fresh/dry) per sample tree will be determined as given below:

$$B_{bt} = n_1 b_{w1} + n_2 b_{w2} + n_3 b_{w3} \ldots\ldots = \sum_{i=1}^{n} n_i b_{wi}$$

Where,

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

n_i = Number of branches in the ith branch group

b_{wi} = Average weight of branch of ith group

I = 1, 2, 3,.... the branch groups

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±5^{0}C. The average leaf biomass was then arrived at by multiplying the average biomass of the leaves per branch with the number of branches in a single tree and the number of trees in a plot (Koul and Panwar, 2008).

Tree biomass (Above ground)

The total tree biomass (above ground) was the sum of stem, branch and leaf biomass.

Root biomass

The root biomass was determined as per the procedure given by (Dury *et al*., 2002). The aboveground biomass was multiplied by a default ratio of 0.24 for softwood species for estimating root biomass.

Biomass carbon stock

Carbon percentage was estimated by the ash content method described by Negi *et al.* (2003). In this method oven dried plant components (bark, leaves, stem wood and root) were burnt in a muffle furnace at 400^0C. The ash content left after burning was weighed and carbon content was calculated by using the following equation:

Carbon % = 100 – (ash weight + molecular weight of O_2 (53.3) in $C_6H_{12}O_6$

The carbon (%) was then multiplied with the biomass to get biomass carbon stock.

Carbon stock = Biomass × carbon (%)

Carbon dioxide equivalent (CO_2e)

The carbon dioxide equivalent was calculated as per the following equation:

Carbon dioxide equivalent = Carbon stock × 3.66

STATISTICAL ANALYSIS

The data was statistically analyzed for the computation of standard error (Gomez and Gomez, 1989).

RESULTS AND DISCUSSION

Growth characteristics of *Cedrus deodara*

The data pertaining to the growth characteristics of *Cedrus deodara* is presented in (Table 1). Among the different diameter classes, the DBH, height, basal area and volume showed an increasing trend with the increase in diameter class and the maximum DBH (34.12 cm/tree) was recorded in diameter class 30-40cm during 2010 and minimum (15.95 cm/tree) DBH was observed in diameter class 10-20cm during 2009. Similarly, Negi (1997) has reported that DBH increases with the increase in diameter class by virtue of secondary or radial growth which is responsible for the increase in diameter of the tree. The maximum height (20.42m/tree) was registered in diameter class 30-40cm during 2010 and minimum (10.31m/tree) was recorded under diameter class 10-20cm during the year 2009. Enhancement of primary or apical growth in the buds of a tree increases significantly the height with the increase in diameter class (Negi, 1997). The basal area was found to be maximum (0.091m^2/tree) in diameter class 30-40 cm during 2010 and minimum (0.020m^2/tree) in diameter class 10-20cm during 2009. The increase in basal area with the increase in diameter class is due to increase in diameter which proportionally increases the basal area (Singh and Gupta, 2008). Consequently the stem volume was recorded maximum (0.596m^3/tree) under higher diameter class 30-40cm during 2010 and minimum (0.072m^3/tree) under lower diameter class 10-20cm during 2009. The increase in stem volume with the increase in DBH and height is attributed to natural and proportionate growth of the trees (Rawat and Kumar, 1989). Singh and Gupta (2008) while studying growth and standing volume estimation of *Cedrus deodara* stands in Himachal Pradesh and reported that the growth parameters like DBH, height, basal area and volume increases with the increase in diameter class. Further current findings are in close conformity with the results of Tewari (1998), Dogra and Sharma (2003) and Roy *et al.* (2006).

Biomass production of *Cedrus deodara*

The results on above and below ground biomass of *Cedrus deodara* (Table 2) suggests that average dry stem biomass (kg/tree) increased with a corresponding increase in DBH class and it was recorded maximum (226.67kg/tree) in diameter class 30-40 cm during 2010 and minimum (27.60kg/tree) in diameter class 10-20 cm during 2009. The present findings are well in accordance with the observations made by Singh and Puri (1990), Koul and Panwar (2008), Yadava (2010a) and Heryati *et al.* (2011). They reported that biomass production per tree increased with an increase in diameter of trees and biomass allocation is more towards the stem. The branch biomass also showed a steady increase with the increase in diameter of trees and it was recorded maximum (64.14kg/tree) under diameter class 30-40cm during 2010 and minimum (7.88kg/tree) under diameter class 10-20 cm during 2009. The branch biomass depends on the average number of branches on the trees and also the branch biomass increased with an increase in diameter class of trees. The findings are in conformity with that of Tandon *et al.* (1988), Singh and Lodhiyal (2009) and Uma *et al.* (2011). They reported that with the increase in diameter class, the number of branches increases which in turn increases the branch biomass. The needle biomass increased from lower diameter class (10-20cm) to higher diameter class (30-40cm). The reason is due to more number of branches in higher diameter class. Also the needle biomass depend upon the size of the branches and structure of large and small branch sizes in the canopy (Heriansyah *et al*., 2007). The present findings are in line with the observations made by Brenes and Montagnini (2006) and Fonseca *et al*. (2012). The total aboveground biomass was recorded maximum (309kg/tree) in diameter class 30-40cm during 2010 and minimum (37.06kg/tree) in diameter class10-20cm during 2009. A study conducted by Rawat and Tandon (1993) on biomass production in young Chir pine (*Pinus roxburghii*) plantations,16 years old in Himachal Pradesh under different spacing and reported that the total aboveground biomass on dry weight basis was recorded maximum (158.18kg/tree) in higher diameter class and minimum (15.10kg/tree) in lower diameter class. But our values are higher as reported earlier for other conifers because the biomass production of tree species varies considerably from place to place according to climatic and edaphic factors even for the same species. Another study similar results have also been reported by Swamy and Puri (2005), Singh and Lodhiyal (2009) and Yadava (2010b). The root biomass showed an increasing trend with an increase in diameter class and it was recorded maximum (77.25kg/tree) in diameter class 30-40cm during 2010 and minimum (8.88kg/tree) in diameter class 10-20cm during 2009. Hase and Foeister (1983) observed that trees produce a larger root system that needed for the uptake of soil resources, thus resulting in higher values in higher diameter class. A current result corroborates with the findings of several other workers (Shanmughavel and Ramarathinam, 1993; Yadava, 2010a) who reported that higher the diameter class, more will be the root biomass. The biomass productivity of *Cedrus deodara* trees (19 years old) was observed maximum (9.15 t ha^{-1} yr^{-1}) in higher diameter class 30-40cm and minimum (3.26 t ha^{-1} yr^{-1}) in lower diameter class 10-20cm. Since the *Cedrus deodara* trees are in juvenile phase, their growth is accelerating exponentially. Rana and Singh (1990) estimated the biomass productivity for central Himalayan Chir pine forest (20 years age) under different diameter classes in the west Almora Division and reported that the biomass productivity increased from lower diameter class to higher diameter class (4.12 to 11.9 t ha^{-1} yr^{-1}). Since biomass productivity varies from species to species and also on the age, climatic and edaphic factors. Further our findings are well in accordance with the findings of Brenes and Montagnini (2006) and Heryati *et al*. (2011).

Production of carbon stock of *Cedrus deodara*

It is evinced from the data in (Table 3) that stem carbon shows an increasing trend with the increase in diameter class and was maximum (105.15 kg/tree) under diameter class 30-40cm during 2010 and minimum (12.80kg/tree) under diameter class 10-20cm during 2009. These values also correspond perfectly to the findings of Kumar *et al.* (2009),Yadava (2010a) and Juwarkar *et al.* (2011) who reported that trees during their initial stages of growth i.e. when their DBH is lower will thus sequester less carbon but gradually as it increases in DBH would accumulate more carbon. Hence, it can be concluded that carbon stock is more in higher diameter class as compared to lower diameter class. Moreover, Ogawa *et al.* (2009) has reported that the component which constitutes a maximum portion of biomass will store the maximum amount of carbon. Since the stem is contributing more biomass as compared to other components hence is storing more carbon in its biomass. The branch carbon is recorded maximum (29.53kg/tree) under diameter class 30-40cm during 2010 and minimum (3.62kg/tree) under diameter class 10-20cm during 2009. The branch carbon depends on the average number of branches on the trees and also it increases with the increase in diameter class. These findings are in conformity with that of Koul and Panwar (2008), Yadava (2010b) and Uma *et al.* (2011). The carbon stock of *Cedrus deodara* needles increased from diameter class 10-20cm to diameter class 30-40cm. The increase in needle carbon stock from lower diameter class to higher diameter class could be due to a more number of branches in higher diameter class and hence more needles and subsequently more carbon stock. The present findings corroborate with the observations made by Losi *et al.* (2003), Singh and Lodhiyal (2009) and Juwarkar *et al.* (2011). The root carbon stock shows an increasing trend with the increase in diameter class and was recorded maximum (35.66kg/tree) under diameter class 30-40cm during 2010 and minimum (4.09kg/tree) under diameter class 10-20cm during 2009. The present findings are well in accordance with the observations made by Jana *et al.* (2009), Yadava (2010a) and Fonseca *et al.* (2012) who reported that root carbon stock is more in higher diameter class as compared to lower diameter class. Finally the total carbon stock was recorded maximum (178.12kg/tree or 89.06 t ha^{-1}) under higher diameter class 30-40cm of *Cedrus deodara* during 2010 and minimum (21.18 kg/tree or 27.53 t ha^{-1}) under lower diameter class 10-20cm during 2009. Similar results have also been reported by Albrecht and Kandji (2003), Yadava (2010b) and Fonseca *et al.* (2012). The carbon productivity of *Cedrus deodara* was recorded maximum (4.22 t ha^{-1} yr^{-1}) under diameter class 30-40cm and minimum (1.50 t ha^{-1} yr^{-1}) under diameter class 10-20cm. The present findings are well in accordance with the findings of Brenes and Montagnini (2006), Jana *et al.* (2009) and Yadava (2010a).

Carbon dioxide mitigation potential of different components of *Cedrus deodara*

The carbon dioxide mitigation (CO_2 equivalent) potential of different components of *Cedrus deodara* has been presented in (Table 4). The data reveals that stem CO_2 equivalent shows an increasing trend with the increasing diameter class and was recorded maximum (384.84 kg/tree) under diameter class 30-40cm during 2010 and minimum (46.83 kg/tree) under diameter class 10-20cm during 2009.CO_2 mitigation by trees is directly related to biomass production of the different plant components. The higher mitigation potential of stem in higher diameter class can be attributed to more biomass (Yadava, 2010a). Similar results were reported earlier by many other workers (Wang and Fenz,1995 and Kursten, 2000). The branch CO_2 equivalent was recorded maximum (108.07kg/tree) in diameter class 30-40 cm during 2010 and minimum (12.91kg/tree) under diameter class 10-20cm during 2009. In a recent study Yadava (2010b) has reported that CO_2 mitigation potential is more in higher diameter class as compared to lower diameter class because of more biomass in higher diameter class. The results are in conformity with the findings of Lal and Singh (2000) and Albrecht and Kandji (2003). The leaf CO_2 equivalent was registered maximum (28.47kg/tree)

Table 1. Growth parameters of *Cedrus deodara* trees under different diameter classes.

Diameter class (cm)	DBH (cm)			Height (m)			Basal area (m^2/tree)			Stem volume (m^3/tree)		
	2009	2010	Increment	2009	2010	Increment	2009	2010	Increment	2009	2010	Increment
10-20	15.95 (±0.73)	16.56 (±0.80)	0.61 (±0.07)	10.31 (±0.30)	10.84 (±0.34)	0.53 (±0.04)	0.020 (±0.001)	0.022 (±0.002)	0.002 (±0.001)	0.072 (±0.007)	0.082 (±0.010)	0.010 (±0.008)
20-30	21.75 (±0.46)	22.70 (±0.64)	0.95 (±0.18)	13.85 (±0.45)	14.02 (±0.48)	0.17 (±0.02)	0.037 (±0.001)	0.040 (±0.002)	0.003 (±0.001)	0.167 (±0.010)	0.213 (±0.016)	0.046 (±0.013)
30-40	33.30 (±0.71)	34.12 (±0.92)	0.82 (±0.21)	19.94 (±1.30)	20.42 (±1.37)	0.48 (±0.07)	0.087 (±0.003)	0.091 (±0.005)	0.004 (±0.002)	0.510 (±0.050)	0.596 (±0.065)	0.086 (±0.027)

Figures in parenthesis are standard error of mean

Table 2. Production of above and below ground biomass of *Cedrus deodara* trees under different diameter classes.

Diameter class (cm)	Stem biomass (kg/tree)			Branch biomass (kg/tree)			Needle biomass (kg/tree)			Total above ground biomass (kg/tree)		
	2009	2010	Increment	2009	2010	Increment	2009	2010	Increment	2009	2010	Increment
10-20	27.60 (±2.72)	31.16 (±3.88)	3.55 (±1.16)	7.88 (±0.77)	8.89 (±1.10)	1.01 (±0.33)	1.57 (±0.15)	1.77 (±0.22)	0.20 (±0.07)	37.06 (±3.65)	41.82 (±5.21)	4.76 (±0.31)
20-30	63.73 (±8.26)	81.20 (±12.71)	17.47 (±4.45)	18.20 (±2.01)	23.19 (±2.37)	4.99 (±0.36)	3.63 (±0.29)	4.63 (±0.36)	1.0 (±0.12)	85.56 (±11.04)	109.03 (±14.92)	23.47 (±3.88)
30-40	193.91 (±18.16)	226.67 (±24.77)	32.76 (±6.61)	55.41 (±6.93)	64.14 (±8.31)	8.73 (±1.38)	15.17 (±1.83)	18.19 (±1.99)	3.02 (±0.54)	264.49 (±26.72)	309.0 (±33.26)	44.51 (±6.54)

Diameter class (cm)	Root biomass (kg/tree)			Total biomass (kg/tree)			Total biomass (t ha^{-1})		Biomass productivity (t ha^{-1} yr^{-1})
	2009	2010	Increment	2009	2010	Increment	2009	2010	
10-20	8.88 (±0.87)	10.03 (±1.25)	1.15 (±0.38)	45.95 (±5.83)	51.85 (±6.46)	5.90 (±0.81)	59.73 (±6.91)	67.40 (± 7.57)	3.26 (±0.17)
20-30	20.53 (±2.21)	26.16 (±2.61)	5.63 (±0.40)	106.09 (±14.13)	135.2 (±16.39)	29.11 (±2.87)	63.65 (±7.02)	81.12 (±8.21)	3.71 (±0.36)
30-40	63.48 (±6.22)	77.25 (±7.98)	13.77 (±1.76)	327.97 (±35.02)	386.25 (±41.24)	58.28 (±7.02)	163.98 (±18.04)	193.12 (±17.87)	9.15 (±0.48)

Figures in parenthesis are standard error of mean

Table 3. Production of above and below ground carbon stock of *Cedrus deodara* trees under different diameter classes.

Diameter class (cm)	Stem carbon (kg/tree)			Branch carbon (kg/tree)			Needle carbon (kg/tree)		
	2009	2010	Increment	2009	2010	Increment	2009	2010	Increment
10-20	12.80 (±1.26)	14.45 (±1.80)	1.65 (±0.54)	3.62 (±0.35)	4.09 (±0.51)	0.47 (±0.11)	0.67 (±0.06)	0.75 (±0.09)	0.08 (±0.02)
20-30	29.56 (±2.91)	37.66 (±3.28)	8.10 (±1.19)	8.38 (±0.84)	10.67 (±0.93)	2.29 (±0.87)	1.55 (±0.09)	1.98 (±0.15)	0.43 (±0.09)
30-40	89.96 (±8.89)	105.15 (±11.49)	15.19 (±2.07)	25.51 (±2.52)	29.53 (±2.89)	4.02 (±1.10)	6.49 (±0.61)	7.78 (±0.73)	1.29 (±0.47)

Diameter class (cm)	Root carbon (kg/tree)			Total carbon (kg/tree)			Total carbon (t ha^{-1})		Carbon productivity (t ha^{-1} yr^{-1})
	2009	2010	Increment	2009	2010	Increment	2009	2010	
10-20	4.09 (±0.40)	4.63 (±0.57)	0.54 (±0.13)	21.18 (±2.09)	23.93 (±2.98)	2.75 (±0.15)	27.53 (±2.01)	31.10 (±3.21)	1.50 (±0.07)
20-30	9.47 (±0.89)	12.07 (±1.01)	2.60 (±0.91)	48.96 (±4.62)	62.40 (±5.23)	13.44 (±1.12)	29.37 (±2.74)	37.44 (±3.88)	1.71 (±0.19)
30-40	29.30 (±2.85)	35.66 (±3.68)	6.36 (±1.04)	151.27 (±15.26)	178.12 (±17.31)	26.85 (±1.98)	75.63 (±7.41)	89.06 (±8.57)	4.22 (±0.23)

Figures in parenthesis are standard error of mean

Table 4. Carbon dioxide mitigation potential of different components of *Cedrus deodara* trees under different diameter classes

Diameter class (cm)	Stem CO_2e (kg/tree)		Increment	Branch CO_2e (kg/tree)		Increment	Needle CO_2e (kg/tree)		Increment
	2009	2010		2009	2010		2009	2010	
10-20	46.83 (±4.62)	52.88 (±6.59)	6.05 (±1.97)	12.91 (±1.31)	14.96 (±1.86)	2.05 (±0.55)	2.44 (±0.24)	2.74 (±0.34)	0.30 (±0.06)
20-30	108.18 (±14.31)	137.83 (±16.69)	29.65 (±2.38)	30.66 (±3.82)	39.05 (±3.96)	8.39 (±0.74)	5.67 (±0.34)	7.24 (±0.56)	1.57 (±0.46)
30-40	329.26 (±38.71)	384.84 (±46.98)	55.58 (±8.27)	93.36 (±13.20)	108.07 (±14.26)	14.71 (±1.06)	23.76 (±2.72)	28.47 (±3.68)	4.71 (±0.31)

Diameter class (cm)	Root CO_2e (kg/tree)		Increment	Total CO_2e (kg/tree)		Increment	Total CO_2e (t ha^{-1})
	2009	2010		2009	2010		
10-20	14.99 (±1.48)	16.94 (±2.11)	1.95 (±0.59)	73.92 (±8.51)	87.52 (±10.93)	13.60 (±1.46)	104.93 (±13.36)
20-30	34.66 (±4.01)	44.17 (±4.51)	9.51 (±2.14)	179.18 (±21.87)	228.29 (±28.56)	49.11 (±4.69)	122.23 (±14.15)
30-40	107.24 (±14.18)	130.51 (±15.34)	23.27 (±6.08)	553.63 (±55.88)	651.91 (±62.29)	98.28 (±13.61)	301.38 (±36.43)

Figures in parenthesis are standard error of mean, (CO_2e= Carbon dioxide equivalent) under diameter class 30-40cm during 2010 and minimum (2.44kg/tree) under diameter class 10-20cm during 2009. It also depends upon the biomass production because CO_2 mitigation is more in the trees having higher diameter class, so leaf CO_2 mitigation potential is more in higher diameter class as compared to lower diameter class (Lal and Singh, 2000). Our results are also well in accordance with the findings of Yadava (2011) and Fonseca (2012). The total CO_2 equivalent was registered maximum (301.38 t ha^{-1}) under diameter class 30-40cm and minimum (109.93 t ha^{-1}) under diameter class 10-20cm. Higher CO_2 mitigation potential in higher diameter class can be attributed to more biomass production (Yadava, 2010b). Our results are well supported by many other workers (Lal and Singh, 2000; Uma *et al*., 2011).

CONCLUSION

Growth parameters like DBH, height, basal area and volume of *Cedrus deodara* increased with the increase in diameter class and maximum volume was recorded under diameter class 30-40cm. Total biomass was noticed maximum under the higher diameter class 30-40cm but in case of individual contribution of biomass allocation of different components of *Cedrus deodara*, maximum biomass was contributed by stem followed by root, branch and needle respectively. The total carbon stock was recorded maximum in higher diameter class 30-40cm. Among the different components, stem recorded the maximum carbon stock followed by root, branch and needle respectively. The Carbon dioxide mitigation potential was registered maximum under the higher diameter class 30-40cm. But among the different components of *Cedrus deodara*, stem recorded the maximum mitigation potential followed by root, branch and needle respectively. *Cedrus deodara* being a slow growing conifer will provide a long term carbon fixation capacity as compared to fast growing species which provide revenues in the short term. Therefore the use of such trees with higher carbon sequestration capacity could improve carbon stocks thus mitigate the carbon dioxide in the atmosphere.

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