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CARBON SEQUESTRATION POTENTIAL OF DEODARA (*CEDRUS DEODARA)*: A PROMINENT MEDICINAL PLANT OF HIGH HILLS

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ABSTRACT

A dynamic growth model (CO2FIX) has been used for estimating the carbon sequestration potential of Deodara (*Cidrus deodara*), an indigenous multipurpose tree used for timber, fuel wood, fiber and in addition to its medicinal value. The present study has been carried out in the campus of V.C.S.G. College of Horticulture, U.U.H.F., Bharsar, Pauri Garhwal, Uttarakhand. The altitude of the location is ranging from logitude78.59':20.28'E, latitude 79.00':30.05'N and 2000 m MSL altitude. The temperature and rainfall of this hilly area ranged from -4.0 to 28.0^{o}c and more than 10000 mm respectively. It is capable of thriving on snow and heavy rainfall condition. CO2FIX was parameterized for a simulation of 100 years respectively. The results indicate that the long term tree biomass accumulated was179.27t/ha in Biomass Carbon (Above Ground Biomass) and 139.67t/ha in Soil Carbon (Below Ground Biomass) component respectively at the end of simulation period assuming a tree density of 640t/ha (approximately). The net annual carbon sequestration for Pine over the entire simulation period was 3.189MgCha^{-1}yr^{-1} (t/ha/yr).

KEYWORDS: Carbon Sequestration Potential, CO2FIX, *Cedrus, deodara*, Soil Carbon, Tree Biomass, etc

INTRODUCTION

The Himalaya, youngest mountain range of the world covers about 18% of total geographical area of India. Forests constitute (50% of India's forest cover) an important natural resource base in the Himalaya, most important being the temperate broad leaf forests, which are largely dominated by different species of oak (*Quercus* species) Singh and Rawat (2012). Five species of evergreen oak namely *Quercus glauca* (phaliyant/harinj), *Q. leucotrichophora* (banj), *Q. lanuginosa* (rianj), *Q. floribunda* (tilonj/moru) and *Q. semecarpifolia* (brown/kharsu) grow naturally in the western Himalaya.

According toBist*et.al.* (2013) the dominant fodder tree species for western Himalayan region are *Quercus leucotrichophora, Q. floribunda* lindl, *Q. semicarpifolia, Myrica esculenta (kafal), Aesculus indica (Himalayan chestnut), Alunus nepalensis (Utees), Pinus roxburghii (pine), CedrusDeodara(Deodara),Ficus palmata (Anjir), Morus alba (shahtoot) woodforida fruticosa (kurz)*The name deodar comes from a Sanskrit word, *davadaru* which means the timber of God or divine timber. However the tree is prized for its medical properties, and not just for its fragrant wood, which is, admittedly, put to many uses. They can live for more than a thousand years, but up until now, they have not, as far as we know, beaten the Jurupa oak and the yew in the longevity stakes. The old trees can grow to heights of 250 feet and have girths of 14 feet. These trees are revered and can be found planted around temples. The wood is fragrant it is used like sandalwood for chests, and smaller items such as ornamental boxes and picture frames. Deodar wood repels insects and so

chests and barrels are made to store grains such as rice in. The oil can also be diluted and sprayed on crops as a natural insecticide, and can smear it over your arms to prevent them being bitten by mosquitoes.

A new flavonoid has also been discovered, and the tree has also yielded two new types or sesquiterpenoids ά – and β-himachalines along with deodarone and deodardione. Ayurvedic practitioners use preparations from the deodar tree to treat urinary tract problems, diabetes, obesity, to relieve pain, for skin problems, to aid digestion and to strengthen the heart muscles and to improve blood circulation. The oil is used for headaches, coughs, colds, hiccups, arthritis and a number of other ailments including gout.

A number of studies have reported the carbon sequestration potential (CSP) of forest and multipurpose trees in India Haripriya (2001), Lal and Singh (2000), Swamy*et.al.* (2003), Swamy and Puri (2005) however the published literature on assessment of carbon sequestration through the existing trees on croplands is scanty. UNFCC (United Nations Framework Convention on Climate Change) has recognized the importance of planting multipurpose trees as a greenhouse gas mitigation option, as well as the need to monitor, preserve and enhance terrestrial carbon stocks. In addition, production from plantation trees may relieve pressure on timber extraction from natural forest, and thus contribute to forest conservation.

A lot of works have been done for the estimation of carbon sequestration potential of different tree species (Under forestry and Agroforestry System) but this is first attempt for pine tree in western Himalayan region of Uttarakhand for estimation of carbon sequestration potential of Pine on per year basis and also estimated total carbon sequestered on per year and total simulation of carbon at the end of simulation period of 100 years.

MATERIALS AND METHODS

The present study has been conducted in the V.C.S.G. College of Horticulturea campus of Uttarakhand University of Horticulture and Forestry, Bharsar, Pauri Garhwal, Uttarakhand, which is situated at logitude78.59':20.28'E, latitude 79.00':30.05'N and 2000 m MSL altitude.The campus spread overan area of 174.94ha; out of that area 114.3ha is mixed forest of *Cedrus deodara*, *Pinus roxburghii*, Oak (3 species of Quercus), Burans (*Rhododendron arbereum*), kafal (*Myrica esculenta*) etc, along with more than 250 spp. ofherbs& shrubs. The data has been recorded over selected area of 10plots size 5x5 meter in different location of campus. In given plots only number of Deodara (cidrus deodara*)* tree counted along with CBH (Circumference at Brest Height); the number of trees are approximately 1.6 i.e640 tree/ha for the CO2FIX model.

Detail of CO2FIX

CO2FIX Model used the present study for can simulate the carbon dynamics of single species and can hand letrees with varied ages. Moreover, CO2FIX outputs the biomass and C separately in above and below ground tree component scohorts wise (i.e. species wise) in addition to soilcarbon dynamics. In this study, we are estimating the carbon sequestration potential of existing Deodara tree in the dense forest of western Himalayan region of Pauri district of Uttarakhand. CO2FIX v3.2 model is available free of charge for academic/research institutions(http://www.efi.int/projects/casfor/CO2FIX/register32.php). CO2FIX has been used to estimates the carbon storage and sequestration potential of selected trees species in India. Kaul et.al. (2010) the CO2FIX model has been tested and validated for the forest ecosystem in the Phillipines, mixed pine-oak forest of central Mexico, multi-strata AFS and tropical rainforest in Costa Rica and woodlots in Zambia Kaonga and Smith (2012).

Input Parameters for the CO2FIX Model

The main input parameters relevant to CO2FIX model are the cohort wise values for the stem-CAI (current annual increment in m3 ha^{-1} $year^{-1}$) over years; relative growth of the foliage, branches, leaf and root with respect to the stem growth over years; turnover rates for foliage, branches and roots; and climate data of the site (annual precipitation in mm and monthly values of minimum and maximum temperatures in ^{0}C). Other inputs to the model includes initial surface soil organic carbon (Mg C ha^{-1}), rotation length for the tree species, per cent carbon contents in different tree parts, wood density and initial values of baseline carbon (Mg C ha^{-1}) in different tree parts, when the simulation are being carried out for the existing trees as in the present case.

Parametrization of the Tree Cohorts

Stem volume equations, available in Forest Survey of India Report for the Deodara has been used to generate the DBH (m) and stem volume (m^3/tree) data. . This data set has been used to fit non-linear functions for stem volume–DBH relationships. This tree wise absolute stem volume–DBH relationship has then converted into hectare wise stem volume–DBH relationships, by multiplying the average number of trees found in the 10 patches. This DBH has transformed back into age to obtain hectare wise stem volume–age relationships. Ultimately, this absolute stem volume values have converted into CAI (Current Annual Increment) values of stem volume by taking the difference of current year value from preceding year value. Thus, we obtained the CAI equations for stem volume– age for the Deodar **(Table 1).** The relative growth data of foliage, branch and root is available for different tree species (classified under the slow, medium and fast growing categories/cohorts) at National Research Centre for Agroforestry(NRCAF), Jhansi has used to find out the relative growth of foliage, branch and root with respect to stem on slow growing and also compared by given example of CO2FIX software. These relative proportions were parameterized in CO2FIX model for branch, foliage and root growth.

RESULTS AND DISCUSSION

CO2FIX Simulated Deodaratree Biomass/Carbonstocks

The tree biomass (above and below ground) during the100 years simulation period increased from 35.24 to 393.78Mg DM ha^{-1}. The 100 year simulation results of CO2FIX model predict that total biomass carbon (Biomass and soil carbon) would enhance to the tune of 56.69 to 369.63 Mg C ha^{-1}.Our result is on line of Subedi (2004)reported that Above Ground Biomass of *Quercus semicarpifolia*in temperate region of Nepal was ranging from 272 to 479 t/ha.

CO2FIX Simulated Soil Carbon Stocks

The estimated rate of soil carbon sequestration, though showed an increasing trend, was meager with1.39Mg C ha^{-1} $year^{-1}$. The soil carbon is expected to increase from 33.07 to 172.74 Mg C $ha^{-1}$for **100** year simulation. Similar results have beenreported by Singh *et.al.* (2011) that agricultural soils of IGPs, on an average, contain 12.4–22.6 Mg ha^{-1} oforganic carbon in the top 1 m soil depths.

CO2FIX Simulated Carbon Sequestration Potential(CSP) of Existing Deodara Forest

The CSP of existing Deodara forest has been estimated to be as 3.189Mg C ha^{-1} $year^{-1}$ (**Table 2**). The CSP was also influenced by the site's climatic factors viz. monthly average temperature, total precipitation along with its distribution over different months, evapotranspiration etc. The higher CSP in this location to be attributed higher total precipitation as

well as some amount ofrainfall in each and every month throughout the year. Moreover, Dinajpur is situated in the foot hills, thus there is sufficient moisture in the atmosphere round the year that acts as a positive catalyst favoring enhanced C sequestration Ajit *et.al.* (2013).These results are in line with Pathak *et.al.*(2011) that organic matter contents across soilsare influenced strongly by rainfall. Lal (2004) reported that SOC concentration increased with increase drain fall in several Indian soils. Moreover, as the tree density increases the total biomass increases and hence C-sequestration rate increases. Kongsager and Mertz (2013) reported carbon sequestration on plantation trees and found best in rubber plantation (214 tC/ha) folloed by Cocoa (65tC/ha) and Orange (76tC/ha).Nowak and Crane (2001) reported that coterminous USA currently store 700 million tonnes of carbon with a gross carbon sequestration rate of22.8 million tC/yr on 10 cities of USA.

The estimated CSP of existing Deodara forest in Garhwal Himalayan regionare encouraging, as they would add to the forestcart of C sequestration and would definitely reduce theincreasing pressure on forests for timber and othercommercial requirements. CO2FIX model has been used for accounting the result of Biomass (t/ha), carbon sequestration potential of Deodara on per ha basis for next 100 years.

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APPENDICES

Table 1: Current Annual Increment CAI of the Stem Volume Growth M^3 Ha^{-1} Yea^1 over Years for Deodara

Age	CAI-Vol M3/Ha/Year
0	5.6670
5	7.36049
10	7.70734
15	8.71916
20	10.121
25	11.408
30	13.4596
35	15.2765
40	18.1164
45	21.4874
50	25.4368
55	28.7881
60	33.7402
65	37.7411
70	43.2311
75	48.4464
80	51.7385
85	54.5217
90	54.4613
95	51.9561
100	44.9238
105	33.9522
110	23.8437
115	9.35186

CAI on per tree basis for slow, medium and fast growing trees has been estimated from State Forest Report 2009, Forest Survey of India, Ministry of Environment and Forests, New Delhi India.

Table 2: Biomass Accumulated in the Deodara Tree Species and Carbon Sequestered under Western Himalayan Region Simulated Using CO2FIX Model

Parameters			Observed Number of Existing Deodara Trees 640 Tree/ha in Western Himalayan Region
Tree biomass above and below ground Mg DM ha^{-1}	Baseline	Biomass	35.24
	Simulated		393.78
Soil carbon Mg C ha^{-1}	Baseline	Carbon	33.07
	Simulated		172.74
Biomass carbon Mg C ha^{-1}	Baseline	Carbon	17.62
	Simulated		196.89
Total carbon biomass + soil Mg C ha^{-1}	Baseline	Carbon	56.69
	Simulated		369.63
Net carbon sequestered of Deodara forest of Western Himalayan region over the simulated period of 100 years Mg C ha^{-1}		Carbon Sequestered	318.94
Estimated annual carbon sequestration potential of Deodara forest of Western Himalayan region Mg C ha^{-1} $year^{-1}$			3.189