

Original Research Article

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Carbon Sequestration Potential of State Flower of Uttarakhand and Himanchal Pradesh, India: *Rhododendron arboretum*

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A dynamic growth model (CO₂FIX) has been used for estimating the carbon sequestration potential of Burans (*Rhododendron arboreum*), an indigenous medicinal plant of higher hills of western Himalayan region. 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 temperature and rainfall of this hilly area ranged from - 4.0 to 28.0°C. It is capable of thriving on snow and heavy rainfall condition. CO₂FIX was parameterized for a simulation of 50 years respectively. The results indicate that at the end of simulation period assuming a tree density of 670 t/ha (approximately), the long term tree biomass accumulated for 670 t/ha was 52.42 t/ha in Biomass Carbon (Above Ground Biomass) and 38.25 t/ha in Soil Carbon (Below Ground Biomass) component respectively. The net annual carbon sequestration for Burans over the entire simulation period was 1.048 Mg C ha⁻¹ yr⁻¹ (t/ha/yr).

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).

According to Bisht *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), *Alnus nepalensis* (Utees), *Ficus*

palmata (Anjir), *Morus alba* (Shahtoot) *woodfordia fruticosa* (kurz).

Burans is national flower of Nepal and state flower of Uttarakhand and Himanchal Pradesh and it's founded in Bhutan, China, India, Nepal, Myanmar, Sri Lanka, and Thailand. Therefore it is considered as species for study. Nectar of Burans is brewed to make wine and effective in diarrhea and dysentery. It is medium size tree; having average height of 15 m and maximum of 24 m. Its name means tending to be 'woody or growing in a tree like form and *Rhododendron* means Greek-Rose tree (wikipedia).

Burans Flowers eaten as raw or made in Sauce, Jellies, Jam or refreshing drinks, flowers and bark have their medicinal uses for digestive and respiratory disorders; Flowers useful as bee forage (Gaur, 1999). Burans flower offers mainly fibers and is good source of Potassium, Calcium, Iron and Vitamin C. Bright red color of this flower is due to presence of vitamin like flavonoid Quercetin. Studies show that the flower offers good amount of phytochemicals of medicinal value including phenols, saponins, xanthoproteins, tannins, flavonoid and coumarins. Three biologically active compounds – quercetin, rutin and coumaric acid have been found in this flower. Interestingly these are the three compounds found in apple and responsible for its health benefits.

Local people from Nepal have been using burans flower for treating diabetes. Latest studies have confirmed anti-diabetic potential of burans flower and suggested its uses as functional food in treating type I and II diabetes. Methanol extract of burans flower have showed in-vitro anti-diabetic activity suggesting its potential in development of new medicines for diabetes. Animal studies with burans flower extract showed reduced blood sugar and cholesterol levels in rats. This property can be attributed to presence of compound hyperin with antioxidant property and ability to inhibit action of certain glucose enzymes (valueFood.info). A number of studies have reported the carbon sequestration potential (CSP) of forest and multipurpose trees in India (Dhyani *et al.*, 1996; Ravindranath *et al.*, 1997; Haripriya, 2001; Lal and Singh, 2000; Swamy *et al.*, 2003; Swamy and Puri, 2005).

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 Burans tree in western Himalayan region

of Uttarakhand for estimation of carbon sequestration potential of Burans on per year basis and also estimated total carbon sequestered on per year for hundred years.

Materials and Methods

The present study has been conducted in the V.C.S.G. College of Horticulture a campus of Uttarakhand University of Horticulture and Forestry, Bharsar, Pauri Garhwal, Uttarakhand, which is situated at longitude 78.59°:20.28°E, latitude 79.00°:30.05°N and 2000 m MSL altitude. The campus spread over an area of 174.94ha; out of that area 114.3ha is mixed forest of *Pinus roxburghii*, Oak (3 species of *Quercus*), Burans (*Rhododendron arboreum*), kafal (*Myrica esculenta*) etc. The data has been recorded over selected area of campus. 10 plots (size 5x5 meter) in different location of campus. In given plots only number of Burans (*Rhododendron arboreum*), tree counted along with CBH (Circumference at Breast Height); the average number of trees per plot is 1.7 *i.e.* 670 tree/ha.

CO2FIX Model used the present study for simulate the carbon dynamics with varied ages. Moreover, CO2FIX outputs the biomass and C separately in above and below ground, tree components in addition to soil carbon dynamics. 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 $\text{m}^3 \text{ha}^{-1} \text{year}^{-1}$) 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 $^{\circ}\text{C}$). 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.

Basic data required for running the CO2FIX model

For the purpose of simulating carbon stocks under Burans forest on per ha basis, the modules taken into considerations are biomass, soil and carbon accounting modules. CO2FIX model requires primary as well as secondary data on tree (called 'cohorts' in CO2FIX terminology) for preparing the account of carbon sequestered under Burans forest on per hectare basis. The primary data includes name of the existing tree species on farmlands along with their number, diameter at breast height (DBH). Whereas the secondary data includes the growth rates of tree biomass components (stem, branch, foliage, root) for Burans, accordingly, to account for the carbon sequestered under Burans forest the basic parameters (viz. rotation length, wood density, carbon contents) set for the tree cohorts have been detailed in table 1. DBH of the surveyed plants has been used to approximately find out the age of the standing trees. To derive the

incremental data of tree stem growth, the volume equations published in State Forest Report-2009 (Forest Survey of India (FSI), Dehradun, Ministry of Environment and Forests) were used as the secondary data.

Parametrization of the tree cohorts

Stem volume equations, available in Forest Survey of India Report (2009) for the Oak 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 Burans (Table 2). 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.

Parametrization of the soil module

The climatic data of district on monthly temperature and precipitation has obtained from sub-station of IMD (Indian Meteorological Department), which is in the campus. The general CAI on per tree basis for Burans tree has been estimated from State Forest Report 2009, Forest Survey of India, Ministry of Environment and Forests, New

Delhi (India). The dynamic soil carbon model YASSO describes decomposition and dynamics of soil carbon in well-drained soils. The soil module consists of three litter compartments (non-woody, coarse-woody and fine-woody) and five decomposition compartments (extractives, cellulose, lignin like compound, humus-1 and humus- 2). Litter is produced in the biomass module through biomass turnover.

Results and Discussion

CO2FIX simulated Burans tree biomass/carbon stocks

The tree biomass (above and below ground) during the 50 years simulation period

increased from 11.68 to 121.89 Mg DM ha⁻¹. The 50 year simulation results of CO2FIX model predict that biomass carbon would enhance to the tune of 27.52 to 132.36 Mg C ha⁻¹. 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 with 0.765 Mg C ha⁻¹ year⁻¹. The soil carbon is expected to increase from 15.90 to 54.18 Mg C ha⁻¹ for 50 year simulation.

Table.1 Input parameter used in CO2FIX model for simulating tree biomass

Cohorts	Burans Tree
No of tree ha ⁻¹	670
Rotation year	50
Starting Age years estimated for 2013	34
Observed Average DBH (cm)	84
Wood density Mg DM/m ³	0.65
Turnover rate foliage	1.0
Turnover rate branch	0.02
Turnover rate root	0.03
Product allocation for thinning harvesting	
Stem log wood	0
Stem slash	1
Branch log wood	0
Branch slash	1
Foliage slash	1
Foliage slash soil	0.1

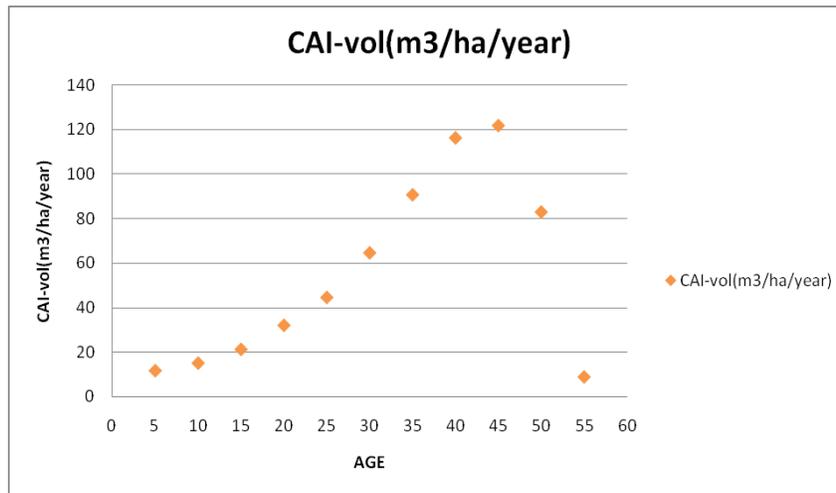
Table.2 Current Annual Increment (CAI) of stem volume growth m³ ha⁻¹ year⁻¹ over years for Burans

Age	CAI-Vol m³/ha/year	Age	CAI-Vol m³/ha/year
5	11.68	35	90.75
10	15.06	40	116.36
15	21.22	45	121.89
20	32.06	50	83.02
25	44.58	55	8.84
30	64.66		

Table.3 Biomass accumulated in the Burans tree species and carbon sequestered under Western Himalayan Region simulated using CO2FIX model

Parameters			Observed number of existing Burans trees 670 tree/ha in Western Himalayan region
Tree biomass (above and below ground) (Mg DM ha ⁻¹)	Baseline	Biomass	11.68
	Simulated		121.89
Soil carbon (Mg C ha ⁻¹)	Baseline	Carbon	15.90
	Simulated		54.18
Biomass carbon (Mg C ha ⁻¹)	Baseline	Carbon	22.75
	Simulated		66.18
Total carbon (biomass + soil) (Mg C ha ⁻¹)	Baseline	Carbon	37.65
	Simulated		120.36
Net carbon sequestered of Burans forest of Western Himalayan region over the simulated period of 50 years Mg C ha ⁻¹		Carbon sequestered	52.42
Estimated annual carbon sequestration potential of Burans forest of Western Himalayan region Mg C ha ⁻¹ year ⁻¹			1.048

Fig.1 Current Annual Increment (CAI) for burans



Similar results have been reported by Singh *et al.*, (2011) that agricultural soils of IGPs, on an average, contain 12.4–22.6 Mg ha⁻¹ of organic carbon.

CO2FIX simulated carbon sequestration potential (CSP) of existing Burans tree

The CSP of existing Burans forest has been estimated to be as 1.048 Mg C ha⁻¹ year⁻¹ (Table 3). 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. 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 soils are influenced strongly by rainfall. Lal (2004) reported that SOC concentration increased with increased rainfall in several Indian soils. Moreover, as the

tree density increases the total biomass increases and hence C-sequestration rate increases. Pandey *et al.*, (2015) reported Carbon Sequestration Potential of Deodara (*Cedrus Deodara*): A Prominent Medicinal Plant of High Hills for 640t/ha (approximately) and the net annual carbon sequestration for Pine over the entire simulation period was 3.189MgCha-1yr-1 (t/ha/yr).

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