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GROWING STOCK OF VARIOUS BROAD-LEAVED AND CONIFER FORESTS OF GARHWAL HIMALAYA

Suchita DIMRI*, Pratibha BALUNI, Chandra Mohan SHARMA

Department of Botany, HNB Garhwal University, Srinagar Garhwal-246174, India

Abstract

The present study was undertaken to assess the Growing Stock and Population Structure of ten temperate forest types of Garhwal Himalaya between 1200-3000m asl. Five sample-plots of 0.1 ha were randomly laid out at two sites (I and II) in each forest type to estimate the GSVD (Growing Stock Volume Density) (by using appropriate volume tables and volume equations). The GSVD values in different forest types oscillated between 198.78 m^3/ha (for Quercus glauca) to 907.74 m^3/ha (for Cedrus deodara forest). The density-diameter distribution was calculated to understand the pattern of Regeneration status of the forest type. Quercus floribunda forest type was recorded as the most dense forest with 710ind/ha (Site I) and 790 ind/ha (Site II). Analysis of Growing stock and density of particular forest type plays an important role in forest management and proper strategies for the conservation of the forests. GSVD estimation leads to quantification of biomass, which in turn is essential to assess the amount of carbon stored in the forest. The estimation of GSVD has, therefore assumed significance in estimating climate change scenario.

Keywords: *Biomass; Temperate forests; Carbon storage; Density.*

Introduction

Forests are among the most productive terrestrial ecosystems, which along with their long-lived woody character, makes them attractive for climate change mitigation [1]. Himalayan forests play a vital role in cooling and purifying the atmosphere, holding the hill-slopes in position, and in building up huge reserves of soil nutrients because of rich vegetation. These forests maintain environmental stability, and supply the essential requirements of the people on a renewable basis.

The Himalayan region falling between 1200-3000m asl is mainly dominated by some coniferous such as, *Abies pindrow*, *Cupressus torulosa*, *Cedrus deodara* and *Pinus roxburghii* and broadleaved (eg. Mainly Q*uercus* spp.) forests. Generally, one or two species in these forests are predominant; hence dominant types are easily recognizable, i.e., *Pinus roxburghii* covers most of part from 1100-1600 m asl elevation. On the other hand *Quercus leucotrichophora* (banj oak) forests cover extensive areas in lower elevations (1500-2000 m asl); *Quercus floribunda* (tilonj oak) forests are also distributed in limited areas between 2000

* Corresponding author: suchi.dimri@gmail.com, prati.baluni@gmail.com

and 2300m asl; *Quercus semecarpifolia* (kharsu oak) forests are predominant oak forests between 2400-3000m asl; and *Abies pindrow* (raga/fir) forests are dominant on the higher ridges of the higher elevation (2700-3100m).

The GSVD is a major predictor for assessing the above-ground biomass [2, 3] and is central for estimating compartment biomass [4] or total above-ground biomass [5] which is a fundamental variable for estimating the net carbon dioxide exchange between the land surface and the atmosphere. The Quantitative assessment of growing stock/ha can be used to calculate biomass of the given forest cover types on various aspects and other parameters of protective forestry. The estimation of biomass is required as a primary inventory data to understand pool changes and productivity of forest [6]. Biomass from Growing stock volume can be calculated by applying biomass expansion factors, which were empirically derived for a certain species or region [5, 7-9].

Climate Change mitigation requires the management of terrestrial carbon (C) either by creating new sinks or by preserving the existing ones [10]. Conservation of forests play a dual role in relation to carbon sinks. Firstly, it prevents the emission of carbon which would be caused by decomposition of the forest biomass. It has been estimated that deforestation contributes to 30% of the current global CO_2 emissions [11]. It has been realized by the international community that the mitigation of global warming will not be achieved without inclusion of forests in the mitigation plan. These activities involved only in new plantation and protection of new forests, but old growths are not protected as they cease to accumulate carbon [12]. However global data sets [13, 14], reported that old growth continue to accumulate, carbon contrary to old view that they are carbon neutral, and will lose much of its carbon if they are disturbed.

The present study was therefore aimed to know the growing stock and population structure variation in some temperate forest types of Garhwal Himalaya of Uttarakhand, India. Assessment of change in forest cover and growing stock and their influencing factors is a difficult task due to lack of compatible data sets across source, space, time, level, scale, boundaries and classification schemes.

Material and methods

Growing stock Estimation

The study was conducted in ten major temperate coniferous and broadleaved forests i.e., *Abies pindrow*, *Cedrus deodara, Cupressus torulosa, Picea smithiana, Pinus roxburghii, Betula alnoides, Q. floribunda, Q. glauca, Q. leucotrichophora, Q. semecarpifolia* in different areas of Garhwal. The volume of individual tree species for various sample plots was calculated on the basis of existing standard volume table or equations [15] given in Table 1. The volumetric estimation of the tree species have been done on the basis of standard volume tables/equations based on the Indian forest records, F.R.I. & F.S.I. publications of the respective species. The trees were divided into successive diameter classes i.e., 30-50, 50-70, 70-90cm and so on to determine the population structure of that particular forest cover type. The density, diameter distribution was calculated to understand the pattern of Regeneration status of the forest type.

Study area

The state is located in North-West part of the country. Uttarakhand's geographical area is 53,483 square km which constitutes 1.63% of the country's total area [16]. Garhwal

Himalaya, which is situated in western part of the Central Himalaya encompasses biodiversity rich forests and is located between the latitudes $30^0$00.993' to $30^0$03.764' N and longitudes $79^0$9.724' to $79^0$12.040' E. The study area ranged from 1200 - 3000m asl of altitude. The climate of the study area was typical moist temperate type with moderate to high snowfall from December to February. The precipitation effectiveness increases with elevation because of temperature and sunshine decline [17]. The mean annual rainfall and snowfall in the study area ranged between 2731mm and 23 inches (at 1500m asl) to 1745mm and 170 inches (at 3100m) asl. The rainy season accounts for about three-quarters of the annual rainfall. Mean minimum monthly temperature ranged between 8°C (Jan) to 20.65°C (Jun) at 1500 asl and 2.68° C (Jan) to 9.30°C (Jun) at 3100m asl. Whereas, maximum monthly temperature ranged between 20.0°C to 30.15°C at 1500m asl and 7.45°C to 18.73°C at 3100m asl [18]. The soil type was basically brown- black forest soils and podozolic soils. Soils were generally gravelly and large boulders were common in the area. Geologically, the rocks were complex mixture of mainly sedimentary, low grade metamorphosed with sequence capped by crystalline nappe [18, 19].

Table 1. Volume equations used for different tree species

S.No.	Forest type	Volume equations
1	*Abies pindrow*	$0.175070+0.226058* D^2H$
2	*Betula alnoides*	$0.2021+0.0000281* D^2H$
3	*Cedrus deodara*	$0.06168+0.27696* D^2H$
4	*Cupressus torulosa*	$0.087+0.289* D^2H$
5	*Pinus roxburghii*	$0.00249+0.27408* D^2H$
6	*Picea smithiana*	$0.033695+0.283177 D^2H$
7	*Quercus floribunda*	$0.035601+0.351041* D^2H$
8	*Quercus glauca*	$0.013+0.296*D^2H$
9	*Quercus leucotrichophora*	$0.014796+0.319061* D^2H$
10	*Quercus semecarpifolia*	$0.014796+0.319061* D^2H$
11	*Rhododendron arboreum*	$0.008169+0.298862* D^2H$
12	*Lyonia ovalifolia*	$0.008169+.298862* D^2H$
13	*Alnus nepalensis*	$0.2021+0.0000281* D^2H$
14	*Pinus wallichiana*	$0.03085/(D^2H +0.30649)* D^2H$
15	**Rest species of temperate**	$0.01284+.2138* D^2H$

Results and discussions

Among all the ten forest types studied , *Cedrus deodara* was recorded to be having the highest average growing stock (907.74m^3/ha) followed by *Quercus semecarpifolia* (900.91m^3/ha), *Cupressus torulosa* (894.68m^3/ha), *Pinus roxburghii* (617.53m^3/ha), *Abies pindrow*(604.51m^3/ha), *Picea smithiana* (360.54m^3/ha), *Quercus leucotrichophora* (346.94m^3/ha), *Betula alnoides*, (312.80m^3/ha), *Quercus floribunda* (266.53m^3/ha).The least growing stock was observed for *Quercus glauca* (198.78m^3/ha). The Growing stock (table 2) and productivity potential of these forest types were higher than the reported values published for the temperate Himalayan and other forests Sharma and Ambasht [20], Singh and Singh [21], Sundriyal and Sharma [22]. Growing stock values recorded in Mandal-Chopta forest was 34.91-499.19m^3/ha Gairola et al. [23].

Sharma et al. [24] has recorded values of growing stock for *Q. Semecarpifolia*, *Q. floribunda*, *A. pindrow* , *Quercus* spp. and Moist temperate forest of Pauri Garhwal as 157.40-

287.09m^3/ha,125.21-348.93m^3/ha,239.66-389.95m^3/ha, 57.31-95.06m^3/ha and 77.38-121.30m^3/ha respectively. A preliminary study based on 180 plots of chir pine forests of Uttarakhand by Forest Department found that the growing stock (that is a function of crop height and density) was better at sunny sites under seeding felling plots that makes a basis for scientific management (i.e., allow felling trees selectively) only on sunny slopes. Growing stock is related to biomass productivity and to the carbon accumulation/ sequestration. Temperate plantation forests have a significant potential of carbon storage in form of tree biomass, with an estimated mean value of 64tC/ha [25]. Indian temperate coniferous forests generally sustain the high levels of growing stock. While comparing with other life forms, conifers have been observed to have maximum carbon stored in them [26].

Table 2. Growing Stock and Density values of different forest types studied

	Forest types	Vern. Names	Elevation (m asl)	Sites	Density (ind/ha)	GS(t/ha)	Status of forest
FT1	*Abies pindrow*	Raga	2750-	Site1	193±9.6	544.14±6.7	Mature Forest
			3100	Site2	641.4±15.2	664.88±19.4	Mature Forest
FT2	*Betula alnoides*	Sodu	2500-	Site1	342.8±12.3	242.03±12.2	Regenerating Forest
			2600	Site2	659±39.1	383.56±8.2	Regenerating Forest
FT3	*Cedrus deodara*	Deodar	2350-	Site1	338.4±34.8	1231.582±10.5	Old growth Forest
			2450	Site2	280±20.3	583.902±4.3	Old growth Forest
FT4	*Cupressus torulosa*	Surai	2400-	Site1	71.6±2.1	1458.984±11.0	Old growth Forest
			2600	Site2	279.2±27.5	330.374±11.2	Regenerating Forest
FT5	*Pinus roxburghii*	Chir	1900-	Site1	268±20.2	476.056±11.7	Mature Forest
			2000	Site2	276±8.1	758.994±18.8	Mature Forest
FT6	*Picea smithiana*	Rai	2650-	Site1	254.4±6.7	232.096±8.6	Mature Forest
			2700	Site2	356.2±17.6	488.978±3.2	Mature Forest
FT7	*Quercus floribunda*	Moru	2550-	Site1	697.2±12.1	217.328±12.3	Mature Forest
			2650	Site2	764.2±27.2	315.74±25.8	Regenerating Forest
FT8	*Quercus glauca*	Harinj	1950-	Site1	564.2±4.5	241.148±13.3	Regenerating Forest
			2100	Site2	442±23.5	156.406±12.2	Regenerating Forest
FT9	*Quercus leucotrichophora*	Banj	1500-	Site1	420.8±23.2	245.138±	Regenerating Forest
			1650	Site2	642±12.4	448.736±10.4	Mature Forest
FT10	*Quercus semecarpifolia*	Kharsu	2650-	Site1	331±25.9	856.228±11.2	Old growth Forest
			2800	Site2	448.4±10.2	945.59±15.9	Old growth Forest

The population structure of the forest types studied is shown in figure1. It is clear that the forest types selected for the study were mature and old growth. Mean density was recorded to be highest 710ind/ha (Site I) and 790ind/ha (Site II) in *Quercus floribunda* forest type which were greater than Sharma et al [27]. The values of present study were higher than the values recorded by Sharma. The growing stocks in different forest types presently studied were mature, productive and more established tended to be on higher end when compared with previously reported values for physiognomicaly similar forest types. Less occurrence of disturbance in the studied forest types was also a reason. Tree density and growing stock are greatly interdependent because density determines the growing stock of a particular forest type. Such studies will be helpful in understanding the possibilities of commercial plantation, regeneration pattern, and management of each forest type for sustainable development.

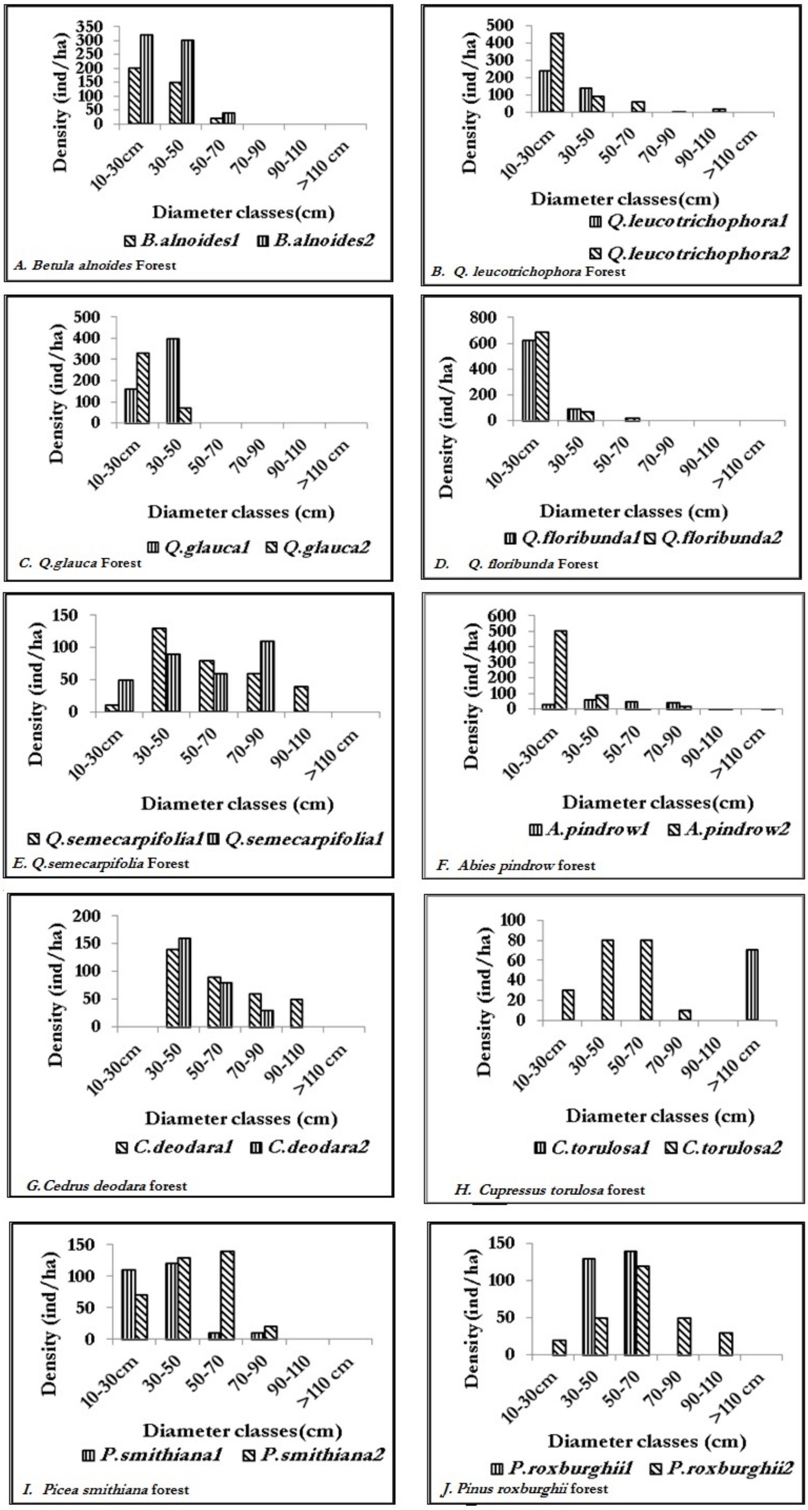

Fig. 1. Population Structure of the various forest types studied
(A-E Broadleaved Forest types; F-J Conifer Forest types)

Conclusions

Forests are the largest carbon pool on earth. They act as a major source and sinks of carbon in nature. Hence they have huge potential to form a chief component in the mitigation of global warming and adaptation to climate change. Estimation of the forest growing stock will enable us to assess the extent of loss of forest cover due to deforestation. The principal element for the estimation of forest's carbon stocks is forest biomass which is calculated by its growing stock. Analysis of density-diameter distribution of particular forest type plays an important role in forest management and to formulate proper strategies for the conservation of the forests. The estimation of stem volume and tree biomass is needed for both sustainable planning of forest resources and for studies on the energy and nutrients flows in ecosystems. Quantification of growing stock is necessary for better management, planning and decision making as forests are source of timber and NTFPs [16]. It provides information on existing timber resources and also a basis for estimation of biomass and carbon contents.

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