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"Evaluation Of Allometric Relationships And Estimation Of Biomass And Carbon Sequestration Potential Of Dominant Tree Species In The Forests Of Nowshera Tehsil Of Rajouri District In J&K"

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ABSTRACT

The present study is an attempt to understand the type of relationship between various structural parameters like Girth at Breast Height (GBH), height and crown diameter. The researcher find out the basal area per hectare of forest and stand density, biomass and carbon sequestered in the forests of Nowshera Rajouri of Jammu and Kashmir. Ten 20m x 50 m plots (representing 0.1 ha of the forest area) were laid randomly in the study area. It was found during the study that the forests of Nowshera are dominated by the species of *P.roxburghii*. The GBH of the *P.roxburghii* ranged from 15 cm to 238 cm. The average number of trees per hectare was found to be 456 trees and the average basal area of the tress was found to be 384.83 square feet/hectare of forest area. The regression analysis was done between GBH and Height, where GBH was independent variable and Height was used as an independent variable. Among them the best fit model to the data set proved to be the power equation with R^2 value of 0.94. Similarly linear equation was tried with the data and it was found that the GBH is a good predictor of the crown diameter with R^2 value of 0.88.

The AGB and AGC were also calculated in kgs per tree and then added across the plots. The AGB and AGC was found to range from 30580.97kgs to 52455.07kgs and 15290.48kgs to 26227.53kgs across all the plots respectively. The AGC was calculated from the AGB by a simplification factors of 0.5. The BGC was also calculated by multiplying the AGC by 0.26. The AGB, AGC and BGC were converted to tonnes/hectare and it was found that the total carbon sequestration potential of the species *P.roxburghii*in the forests of NowsheraRajouri is 265.95 tonnes/ha.

Keywords: *Basal area, Carbon sequestration, Temperate Forest, Biomass.*

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INTRODUCTION

Measurement of biomass and carbon storage has become an important process all over the world and is presently an important component in the implementation of the emerging carbon credit market mechanism (Brown et al 1989). It has also been recognised by United nation (IPCC 2003) that there should be the good biomass equation for the estimation of the carbon stocks. Biomass assessment is important for national development planning as well as for scientific studies of ecosystem productivity, carbon budgets, etc. Biomass analysis is an important element in the carbon cycle especially, carbon sequestration. Recently biomass is being increasingly used to help quantify pools and fluxes of greenhouse gases (GHG) from terrestrial biosphere associated with land use and land cover changes (Cairns et al. 2003). The importance of terrestrial vegetation and soil as significant sinks of atmospheric CO_2 and its other derivatives is highlighted under Kyoto Protocol (Wani et al. 2010). Vegetation especially, forest ecosystems store carbon in the biomass through photosynthetic process, thereby sequestering carbon dioxide that would otherwise be present in the atmosphere.

Quantification of biomass can be done by harvesting the trees, using stem volume information, biomass expansion factors or using biomass models. Biomass models are important tools for understanding the changes related to productivity, energy, stocks and fluxes of carbon and nutrients (Houghton 2007). Typically, biomass models comprise easily measureable tree variables such as diameter at breast height (DBH), tree height, canopy spread, etc. that are closely correlated to the biomass (Chave et al. 2005).

Estimation of the accumulated biomass in the forest ecosystem is important for assessing the productivity and sustainability of the forest. It also gives us an idea of the potential amount of carbon that can be emitted in the form of carbon dioxide when forests are being cleared or burned. Biomass estimation of the forest ecosystem enables us to estimate the amount of carbon dioxide that can be sequestered from the atmosphere by the forest. The accurate assessment of biomass estimates of a forest is important for many applications like timber extraction, tracking changes in the carbon stocks of forest and global carbon cycle. Forest biomass can be estimated through field measurement and remote sensing and GIS methods (Ravindranath 2008).

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Two methods of field measurement are available. The first one is the destructive method of tree biomass estimation. Among all the available biomass estimation method, the destructive method, also known as the harvest method, is the most direct method for estimation of above-ground biomass and the carbon stocks stored in the forest ecosystems (Gibbs et al 2007). This method involves harvesting of all the trees in the known area and measuring the weight of the different components of the harvested tree like the tree trunk, leaves and branches and measuring the weight of these components after they are oven dried. This method of biomass estimation is limited to a small area or small tree sample sizes. Although this method determines the biomass accurately for a particular area, it is time and resource consuming, strenuous, destructive and expensive, and it is not feasible for a large scale analysis. This method is also not applicable for degraded forests containing threatened species. Usually, this method is used for developing biomass equation to be applied for assessing biomass on a larger-scale (Navár 2009).

The second method of tree biomass estimation is the non-destructive method. This method estimates the biomass of a tree without felling. The non-destructive method of biomass estimation is applicable for those ecosystems with rare or protected tree species where harvesting of such species is not very practical or feasible. Montès et al. (2000)developed a non- destructive method for the above-ground biomass estimation of *Thuriferous juniper* woodlands in the High Central Atlas, South of Morocco. In this study, the biomass of the individual tree was estimated by taking into account the tree shape (by taking two photographs of the tree at orthogonal angles), physical samples of different components of the trees like branches and leaves and dendrometric measurements, volume and bulk density of the different components. Although it is a non-destructive method, to validate the estimated biomass, the trees had to be harvested and weighted.

The most widely used method for estimating biomass of forest isthrough allometric equations. The allometric equations are developed and applied to forest inventory data to assess the biomass and carbon stocks of forests. Many researchers have developed generalised biomass prediction equations for different types of forest and tree species. The allometric equations for biomass estimation are developed by establishing a relationship between the various physical parameters of the trees such as the diameter at breast height, height of the tree trunk, total height of the tree, crown diameter, tree species, etc. Equations developed for single species and for mixture of

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species give the estimate of biomass for specific sites and for large-scale global and regional comparisons (Brown et al 1989).

Brown et al. in 1989 developed allometric regression equations to estimate the above-ground biomass of individual tress for tropical forests as a function of diameter at breast height, total height and wood density. This estimate of Brown's biomass equation takes into account only the live trees and not the fallen litter and the standing dead trees. Nelson et al. (1999) conducted a study to develop species-specific and mixed-species allometric relationships for estimating total above-ground dry weight using eight abundant secondary forest tree species in the Amazon.

Chave et al. (2005) proposed an estimation method for the estimation of biomass in a neo-tropical forest of French Guiana for which they have made use of published data sets providing the biomass and the diameter at breast height of felled and weighted trees. In this study, they have parameterized the regression models using 32 measurements of large trees. Ketterings etal. (2001) also proposed an allometric equation for calculating the biomass of trees in the mixed secondary forest of Sumatra, Indonesia. However, the proposed equation is most suitable for trees having a diameter at breast height of 8-48 cm. conducted a study on a 10-year-old Scots pine to derive allometric relationships of branch and foliage biomass at branch and tree level and confirm the earlier studies on Scots pine in Finland. Segura and Kanninen (2005) conducted a study in the tropical humid forest of Costa Rica to develop allometric models for estimating the stem volume, total volume (stem and branches) and the total aboveground biomass (stem, branches and foliage) for individual trees of that forest.

Objectives of the study

- To develop allometric relationships of tree structure parameters like height, diameter and crown width/diameter.
- To find out the basal area and stand density in the forests in the study area
- To estimate the biomass and carbon sequestration potential in dominant forest tree species of Nowshera

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Methodology

Study Area

Tehsil Nowshera of District Rajouri, Jammu & Kashmir, India lies in south and west of PirPanjal Mountain Range located latitudinally 33° 16' 04" N and longitudinally 74° 24' 43" E at an attitude of 1574 m. The area displays steep slopes and high ridges broken by rocky cliffs and in between narrow valleys. Floristically this area is inhabited by the sub-tropical and temperate forests. This area was taken for the study because no such study has been previously documented in this area.

Species Selection

The work was carried out in the forest area of Nowshera Tehsil of Rajouri District of J&K for the present study and no such study has been previously undertaken for this area. The forests of the Nowshera are dominated by the *Pinus roxburghii* commonly known as Chir pine. It was found that the study area heavily contains the Chir pine. No other tree species could be found abundantly present in the study area. Hence the study was focussed on the single species of *P.roxburghii.*

Data Collection

The data was collected from December to first week of January for the study. Rectangular plots of 20m x 50m were laid randomly in the forest. Ten such plots were laid at different locations randomly. Each such plot represented 0.1 hectare of forest land area. All trees which were>1.5m in heights or > 10cm GBH (Girth at breast height) were enumerated. The total number of trees from which data was taken was 456.

Data on girth at breast height (GBH), total height and crown diameter were taken in the following ways;

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a) **GBH:** A measuring tape was used for taking the GBH. GBH was taken at the height of 1.3m. The GBH was taken slightly above or below for the trees having buttresses or burns at 1.3m. The measurements were taken in centimetres.

b) **Height:** Total Height of the trees was measured by Ravi Altimeter which was provided by the forest department of Nowshera. Three measurements from different sides were taken to reduce the error. The height was taken for those trees only where tip of the trees could be easily seen.

c) **Crown diameter:** The crown diameter was taken for the trees by measuring the length of the longest branch from the ground in feet. One more reading was taken in the perpendicular direction of the first reading.

Data Analysis

Basal Area

Using GBH values, basal area was estimated for individual trees and aggregated across the trees within a plot. The basal area calculated was calculated in terms of square feet per hectare. For that the GBH which was taken in cms in field was converted into inches by dividing the GBH by 2.5. Then the following formula was used to calculate the basal area per tree. The basal area was multiplied by the foresters number i.e., 0.005454 to convert the basal area in terms of square feet. The basal area was then added for all the trees within a plot. Then average basal area across all the plots was calculated. Finally basal area per hectare of forest was calculated. The basal area was calculated by the following formulae.

Basal Area/tree = $(GBH)^2/4\pi$

Basal area (in square feet)/tree = $(GBH)^2/4\pi \times .005454$

GBH – Height and GBH – Crown diameter models

The GBH and Height was used to model their relationship in the current study area. Height of only 135 trees was taken by using Ravi Altimeter. This data on trees of *P. roxburghii* was used to develop the allometric relationships between GBH and H. There are different types of regression equations which have been used by many authors including linear, non linear - asymptote, exponential, power (Table 1). We used the linear equation to develop the equation between the GBH and Height and GBH and Crown Diameter.

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Sl No.	Equation	Model	Reference
1	$H = a + bD$	Linear	Buba 2012
2	$H = H_{max} [1 - e^{(-aDb)}]$	Asymptote	Thomas 1996
3	$H = aD^b$	Power	Feldpausch et al 2012

Table 1: Various equations used in literature to model tree height and diameter, where H and D are tree height and diameter, a, b, c are model parameters.

Carbon Stock and Sequestration

Both above and below ground biomass and carbon content were obtained through the following methods;

Above ground biomass

The above ground biomass was calculated an equation developed by the Chave et al (2005). The equation used is given below.

$$AGB = 0.112 \text{ x } (\rho D^2 H)^{0.916}$$

Where, ABG = above-ground biomass (kg), ρ = wood density (cm^3), D = stem diameter over bark at 1.30 m above ground (cm) and H = tree height (m). Wood density was taken from the literature (Uniyal et al 2002). The biomass present in the trees was converted to the carbon content by a simple multiplication factor of 0.5 as used by various authors (Schroeder 1992). The height model developed in this study was used to find out the height of those trees whose height was not taken from the field.

Below Ground Biomass

A default conversion factor of 0.26 was used to convert above ground biomass to below ground biomass (IPCC, 2003).

Materials and tools used for the study:

Ravi Altimeter along with stand, Measuring tapes, GPS, Camera etc.

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Results and Interpretation of the results

Girth Size, Basal Area and Stand density of trees

In the present study, the girth size in the plots that were laid was found to range from 15 cm to 238 cm. The average GBH in the study area was found to be 102.12 cm. The different girth sizes of trees are distributed all over the study area. It was found that the mountain cliffs that don't receive enough sunshine (usually north facing in the present study area) were having comparatively smaller trees than the rest of the areas. It may be attributed to the fact of less growth rate in such areas due to low sunlight.

The stand density of trees of the species *P.roxburghii* in the forests of Nowshera division was found to range from 42 to 55 trees per plot. The average number of trees per hectare was found to be 456 trees. The basal area was found to range from 30.08 square feet/plot to 44.35square feet/ plot. The average basal area of the tress was found to be 384.83 square feet/hectare of forest area. Basal area is an important component that will not only indicate the biomass production in a unit land area but also indicate the structural composition of the vegetation.

GBH and Height Models

A correlation was performed between GBH and H in which it was found that they are strongly correlated. The correlation coefficient was found to be 0.95. The regression analysis also was done between GBH and Height, where GBH was independent variable and Height was used as an independent variable. Various regression equations were tried for the data which included linear, asymptote and power. Among them the best fit model to the data set proved to be the power equation with R^2 value of 0.94 (fig. 3). Linear model was also satisfactory with the R^2 value of 0.90 (fig. 1). The logarithmic model however showed R^2 value of 0.88 (fig. 2) and is not recommended for the *P. roxburghii*. The various equations that were developed for the *P.roxburghii* species are shown in the table 2. The best fit of power equation shows that the species under consideration tends to achieve its maximum height during the early stages of growth.

GBH and H models are very important for studying the forest dynamics. Tree height can be used to estimate important variables related to forest growth. However, H is more difficult to measure than GBH. Because of this difficulty and the costs associated with field inventories, it is common practice to fit H–GBH models to predict H from the measured GBH. An improved understanding

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of the H–GBH relationship is critical for reliable regional and global estimates of forest biomass and carbon storage because many large-scale studies rely on allometric equations that involve the H–GBH relationship (Gao X et al 2014).

Fig 1: Linear model of GBH and Height

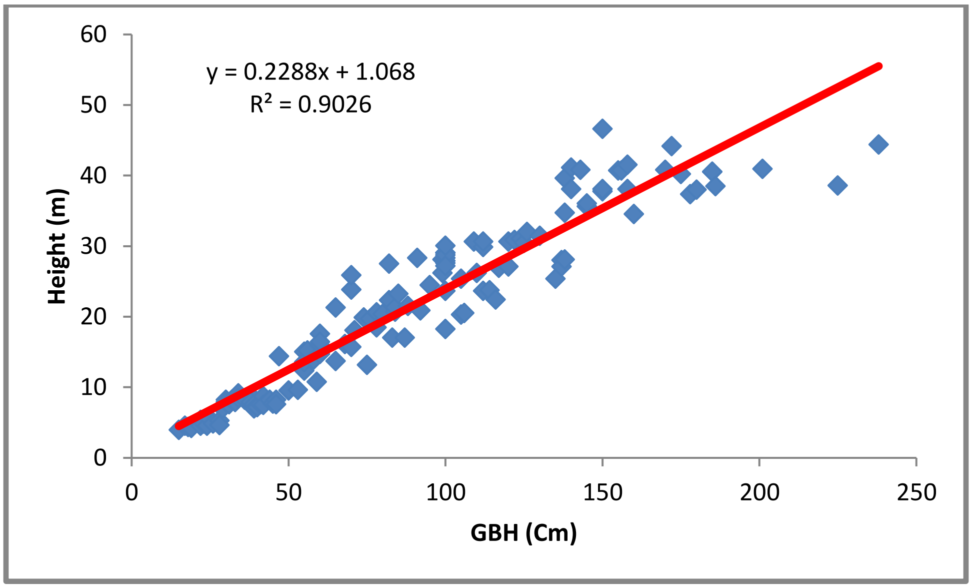

Fig 2: Logarithmic model between GBH and H

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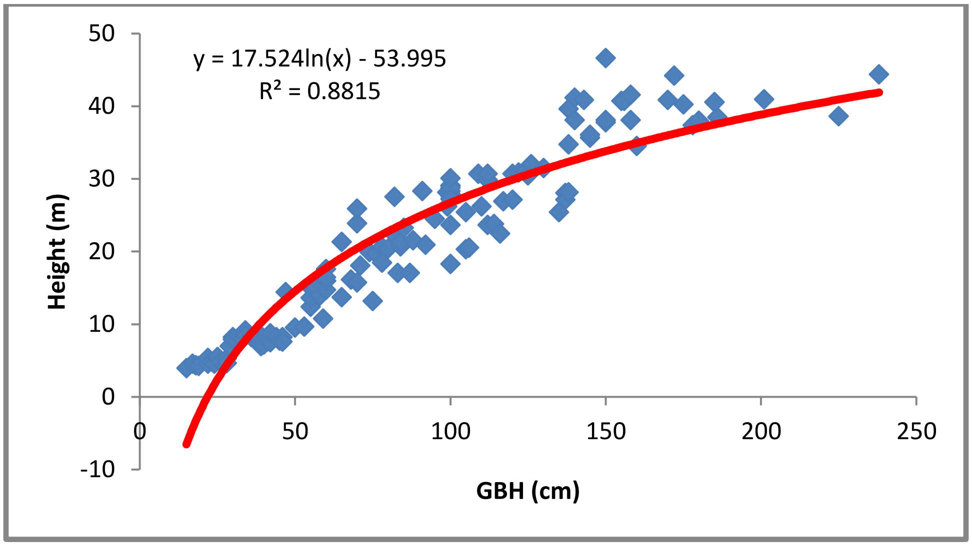


Fig 3: Power model between GBH and H

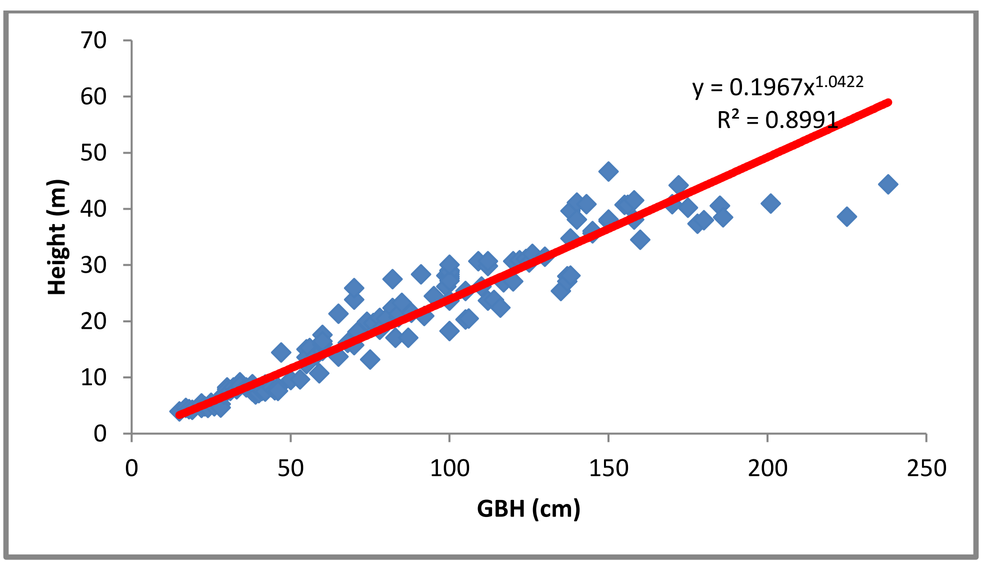


Table2: Regression equations between GBH and H, y = H and x = GBH.

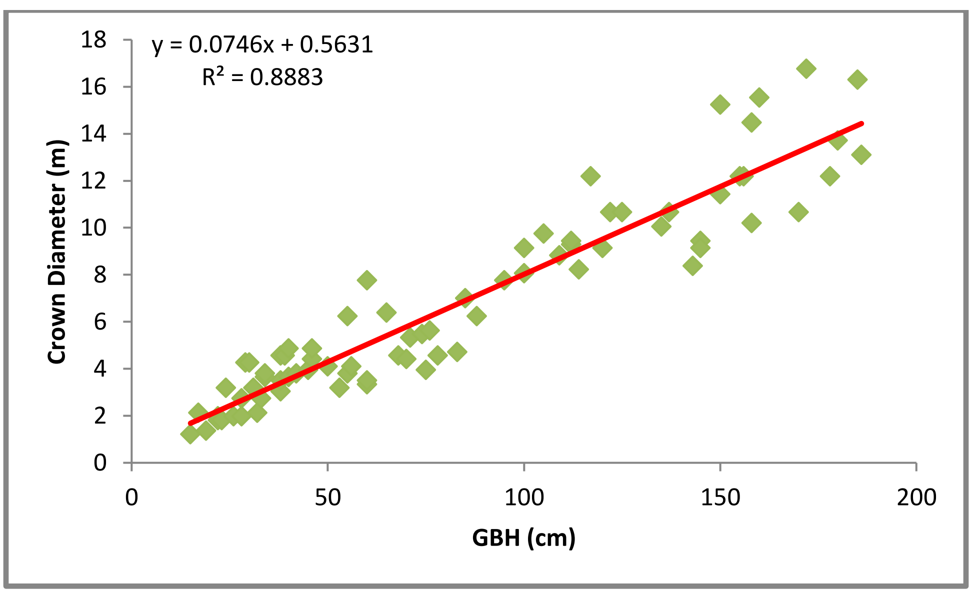
Equation type	Equation	R^2
Linear	$y = 0.2288x + 1.068$	0.90
Logarithmic	$y = 17.524\ln(x) - 53.995$	0.88
Power	$y = 0.1967x^{1.0422}$	0.94

GBH and CD Models

Present study found that the GBH is a good predictor of the crown diameter. Linear equation was tried with the data and it was found that the GBH is a good predictor of the crown diameter with R^2 value of 0.88 (fig 4). A good relation was found between the GBH and CD. The tree with the lowest GBH of 15 cm had a CD of 1.2 m and the tree with the GBH had a CD of 16 m. It is often difficult to measure the CD in the dense forest as the crown of various trees gets overlapped and thus the equation developed can serve as an easy way to find out the crown diameter of any *P.roxburghii* tree in or around the study area.

The equation developed for the GBH and CD was $y = 0.0746x + 0.5631$, where y is the CD in m and x is the GBH in cm.

Fig. 4: Linear regression model between GBH and CD



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Biomass, Carbon Stock and Sequestration

The biomass and carbon stock per tree in Kilograms (Kgs) was calculated from the Chave et al (2005) equation. The power equation of GBH and H developed in this study was used to estimate the height of the trees in meters. Then the same height was used to calculate the biomass of the trees. The wood density (or wood specific gravity) of *P.roxburghii*was taken from the literature as 0.496 (Uniyal et al 2002). The AGB and AGC were calculated in kgs per tree and then added across the plots. The AGB and AGC were found to range from 30580.97kgs to 52455.07kgs and 15290.48kgs to 26227.53kgs across all the plots respectively. The AGC was calculated from the AGB by simplification factors of 0.5 (Schroeder 1992). The BGC was also calculated by multiplying the AGC by 0.26 (IPCC 2003). The AGB, AGC and BGC were converted to tonnes/hectare and it was found that the total carbon sequestration potential of the species *P.roxburghii*in the forests of Nowshera Rajouri is 265.95 tonnes/ha.

Shaheen et al (2016) have found similar results in their study where they found that the carbon content was 326 tonnes/ha in the pinus forests. Our results show that the forests of Nowshera which are dominated by *p.roxiburghii* store a large amount of carbon in them. They contribute a lot towards mitigation of global warming and climate change. The quantitative assessment of carbon stocks in subtropical forests is of great importance since they refer to estimates obtained in a very poorly studied vegetation type as compared to other forests (Rosenfield& Souza, 2013).

The contribution of above ground carbon sequestration is higher than below ground carbon sequestration because below ground carbon is mainly depending on the above ground biomass.

Conclusion

Rising of atmospheric CO_2 levels is one of the major environmental challenges facing the world today. One of the best ways to solve the problem of rising CO_2 levels in the atmosphere is the maintenance forests and afforestation. In order to have a proper estimate of the CO_2 stock present in the forests, we need to know the amount of the biomass present in them. In the current study we conclude that the *P.roxburghii*has an average basal area of 384.83 sqft/ha. Besides the average biomass and carbon sequestered by this species is 422.15 and 265.95 tonnes/ ha respectively.

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For the estimation of the biomass, different authors have worked on the biomass models and have developed different equations. But most of such equations are dependent on the height of the trees, which is both time consuming and resource dependent. Our effort was to develop a relation between GBH and H and GBH and CD in the current study area as no such work has been carried out in the said area.

In the present study, predictive models for height and crown diameter estimation were developed for *P.roxburghii*. Allometric model provided the best goodness-of-fit statistics, increasing statistical efficiency in height and crown diameter estimate. In case of GBH and H model, the power equation proved to be more efficient than the linear and logarithmic equations. Similarly for GBH and CD relationship, the linear equation was developed.

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