49
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Prediction Models for Biomass, Volume, Carbon Stock and Carbon Dioxide Removal for Eucalyptus Hybrid Plantations in Punjab

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ABSTRACT

The data from 53 trees with girth at breast ranging from 25 cm to 110 cm (17 diameter classes, 5 cm class interval) was collected to develop regression models to predict the biomass of different components and total tree, tree volume, carbon sequestered and CO_2 removed from the atmosphere. Out of ten linear and curvilinear models tested to find out the best fit prediction equation, curvilinear models have found to be the best fit with coefficient of determination (R^2) ranging from 0.97 to 0.99. The high value of R^2 showed that these models can be used to predict biomass (whole tree and different components), total tree volume, carbon sequestered and CO_2 absorbed from the atmosphere.

Key words:

Biomass, carbon stock, Eucalyptus, prediction models, volume

INTRODUCTION

Besides tangible benefits, the trees sequester carbon/absorb carbon dioxide (CO_2) but this intangible benefits were realised only after Kyoto treaty to reduce Green House gas load in the atmosphere. India is the largest planter of *Eucalyptus* in the world with more than 4 million ha under cultivation (MoEF 2009). Thus, productivity and carbon sequestration potential of *Eucalyptus* is of great importance to farmers and wood based industries, to know the quantity of produce in the standing crop and convert the same in monetary terms, and carbon stocks in different components of trees of particular diameter and height for researchers. To make assessment of all these parameters, accurate regional volume and biomass models are very common tools in the hand of foresters and researchers. Besides volume and biomass, models for carbon sequestered and carbon dioxide absorbed in tree biomass can also be useful in the present growing interest in the forest plantations as sinks for carbon dioxide from the atmosphere (Arora et al. 2014). Biomass or volume equations for different tree species are developed for management, scientific and trading purposes. These models have the objectives: to evaluate some difficult-to measure tree characteristics from easily collected data such as diameter at breast height (dbh) or girth at breast height (gbh) and tree height. The area specific models help the field foresters and tree growers to estimate the quantity of timber in the tree/stand and the economic returns which would accrue from their sale. CO_2 removal can be estimated after calculating biomass taking densities at different heights and converting it into biomass, which needs lot of laboratory work. However, regression models based on one or two variables are accurate and time saving. Although, volume and biomass tables for *Eucalyptus* have been developed for different states, which may not fit for plantations in Punjab. Therefore, the present study was carried out to develop regression equations to estimate the biomass in different components, volume, carbon stock and CO_2removal from atmosphere.

MATERIAL AND METHODS

The sample trees (of seedling origin), three for each girth class of 5 cm in a range of 25-110 cm (25-30, 30-35, 35-40, 40-45, 45-50, 50-55, 55-60, 60-65, 65-70, 70-75, 75-80, 80-85, 85-90, 90-95, 95-100, 100-105, 105-110 cm) were measured for girth at breast height (gbh) and height to the nearest centimetre with the help of measuring tape and clinometer, respectively. The sampled trees were felled with saw 5 cm above ground. The stumps with main roots were also dug out. The leaves and twigs, and branches were removed from the main stem. Each component was weighed in the field itself to record fresh weight. Representative samples were then oven dried till constant weight at 80 $\pm$ 5°C temperature (Chidumayo, 1990). The dry biomass for each component of individual tree was calculated. The logs were measured for length and mid girth and the volume of each log was calculated by the formula $\frac{\pi D^2 X H}{4}$. The volume of all the logs was summed up to calculate the timber volume of individual tree for each diameter class.

The total dry biomass was converted to total carbon stock/tree by multiplying by factor of 0.51 (Micales and Skog 1997; Dury et al. 2002). After estimating the carbon stocks, the same was converted to CO_2 equivalents by multiplying the carbon stock of 3.67 (AACM 1997; Van Kooten 1999).

The data so obtained were fitted to unweighted linear regression analysis. The linear and curvilinear equations tested for best fit have been given in Table 1. The prediction equations for each component and parameter with one variable (girth) or with two variables (girth and height) and girth squared or girth squared multiplied height were computed with their coefficient of determination (r^2) for each tree.

RESULTS AND DISCUSSION

Unweighted least square linear regression analysis was done by taking Y as some measure of dry biomass of leaves, branches and total above ground biomass, volume, carbon stock and CO_2 sequestered by different components. The simple correlation coefficients between pairs of variables of above said parameters, and girth, and height were calculated.

Biomass and volume prediction models

The best fit models for predicting the dry biomass of leaves and twigs, fuel wood, logs, and total tree biomass and tree volume are presented in Table 2. The results revealed that out of ten different linear and curvilinear models tried, equation of the form $Y=a+bG^2H+cH$ for leaves and twig biomass, $Y=a+bG^2+cH^2$ for fuel wood and tree volume, $Y=a+bGH+cG^2$ for log and total tree biomass were found best fit with respective values of coefficients of determination (R^2) as 0.98, 0.97, 0.97, 0.99 and 0.99 (Table 2). The present analysis evinced that dry weight (total tree and components) and total tree volume of *Eucalyptus* hybrid can be precisely predicted through curvilinear models based on two variables i.e. girth and height only with trueness of 96 to 99 per cent. Earlier models developed by Dogra and Shrama (2003;'2009) for *Eucalyptus* hybrid for Punjab, for biomass and volume, involve logarithmic calculations, which need more computational work. However, the present models with high values of regression coefficient can be used directly by the novice foresters and researchers in field with ease.

Carbon stock prediction models

The best fit prediction models based on girth and height, for carbon stocks for tree components and total tree carbon have been presented Table 3. The results revealed that the prediction models $Y=a+bG^2H+cH$ for carbon sequestered in leaves and twigs, $Y=a+bG^2+cH^2$ for carbon sequestered in fuel wood, and $Y=a+bGH+cG^2$ for carbon sequestered in logs and whole tree biomass with R^2 value of 0.98, 0.97, 0.99 and 0.99, respectively were more suitable for making predictions of standing trees. Thus, results evinced that the carbon sequestration of

Table 1: Prediction equations used to estimate biomass of different components, total tree volume, carbon stocks and CO_2 sequestered by different components of Eucalyptus hybrid in Punjab

Sr. No.	Name	Equation forms
	Linear	
1.		Y=a+bG
2.		Y=a+bH
3.		Y=a+bGH
4.		Y=a+bG+cH
	Curvilinear	
1.		$Y=a+bG^2$
2.		$Y=a+bH^2$
3.		$Y=a+bG^2H$
4.		$Y=a+bG^2+cH^2$
5.		$Y=a+bGH+cG^2$
6.		$Y=a+bG^2H+cH$

Y=dependent variables for biomass, volume, carbon stock and CO_2 sequestered; G=girth at breast height (cm); H=tree height (m)

Table 2: Best fit models for predicting dry biomass of different components and tree volume of Eucalyptus hybrid for Punjab

Sr. No.	Tree component	Prediction model	R^2
1	Dry leaf and twig weight (kg $tree^{-1}$)	$12.264+0.00020375G^2H-0.93354H$ (1.7724, 0.0000062682 and 0.011645)*	0.98
2	Dry fuel wood weight (kg $tree^{-1}$)	$-3.7413+0.0086428G^2-0.027708H^2$ (1.6062, 0.0001665 and 0.0060522) *	0.97
3	Dry weight of log with bark (kg $tree^{-1}$)	$-37.43-0.008292GH+0.055232G^2$ (6.8962, 0.014788 and 0.0032901) *	0.99
4	Total tree biomass (kg $tree^{-1}$)	$-43.621-0.031324GH+0.071891G^2$ (7.4024, 0.015873 and 0.0035317) *	0.99
5	Tree volume (m^3 $tree^{-1}$)	$-0.04503+0.000057381G^2+0.00011721H^2$ (0.014765, 0.0000029108 and 0.000055634) *	0.97

*values in parenthesis are coefficients of standard error of constant, a and b, respectively

Table 3: Best fit models for predicting carbon stocks in different components of Eucalyptus hybrid for Punjab

Sr. No.	Tree component	Prediction model	R^2
1	Carbon sequestered in leaves and twigs (kg $tree^{-1}$)	$6.2559+0.00010391G^2H-0.47613H$ (0.9039, 0.0000031967 and 0.059389)*	0.98
2	Carbon sequestered in fuel wood (kg $tree^{-1}$)	$-1.9069+0.0044078G^2-0.014132H^2$ (0.081935, 0.00016152 and 0.0030872)*	0.97
3	Carbon sequestered in logs (kg $tree^{-1}$)	$-19.044-0.0042302GH+0.028169G^2$ (3.5171, 0.0075419 and 0.001678)*	0.99
4	Carbon sequester ed in whole tree (kg $tree^{-1}$)	$-22.247-0.015976GH+0.036665G^2$ (3.7754, 0.0080957 and 0.018012)*	0.99

*values in parenthesis are coefficients of standard error of constant, a and b, respectively

Table 4: Best fit models for predicting carbon dioxide removal by different components of Eucalyptus hybrid for Punjab

Sr. No.	Tree component	Prediction model	R^2
1.	Carbon dioxide absorbed in leaves and twigs (kg $tree^{-1}$)	$22.956+0.00038137G^2H-1.7474H$ (3.3169, 0.000011731 and 0.21793)*	0.98
2.	Carbo n dioxide absorbed in fuel wood (kg $tree^{-1}$)	$-7.0023+0.016177G^2-0.051862H^2$ (3.0063, 0.00059266 and 0.011328)	0.97
3.	Carbon dioxide absorbed in logs (kg $tree^{-1}$)	$-69.89-0.015519GH+0.10338G^2$ (12.907, 0.027678 and 0.0061581)	0.99
4.	Carbon dioxide absorbed in whole tree (kg $tree^{-1}$)	$-81.645-0.058632GH+0.13456G^2$ (13.855, 0.02971 and 0.0066102)	0.99

*values in parenthesis are coefficients of standard error of constant, a and b, respectively

Eucalyptus hybrid can be estimated precisely measuring girth and height of the standing crop. These models can be used for early estimates of carbon sequestration potential in situations where destructive method cannot be followed considering the long term harvesting programmes.

CO_2 removal prediction models

The CO_2 absorbed by tree components and in the total tree biomass was regressed on some measures of girth and diameter. The results of unweighted linear regression analysis revealed that the curvilinear regression models of the form $Y=a+bG^2H+cH$ for CO_2 absorbed in the leaves and twigs, $Y=a+bG^2+cH^2$ for CO_2 absorbed fuel wood and $Y=a+bGH+cG^2$ for CO_2 absorbed in logs and whole tree with respective R^2 value of 0.98, 0.97, 0.99 and 0.99, were found best fit (Table 4). The regression analysis revealed that girth and height are the best predictors of CO_2 absorbed in *Eucalyptus* hybrid trees and also in different components. Thus, by measuring girth and height of standing trees growing in the forests or in any land use systems present regression models can be used to estimate their potential for CO_2 removal from atmosphere.

CONCLUSIONS

The regression analysis carried out on 53 sample trees showed that curvilinear models based on two variables (girth at breast height and total tree height) were best fit models to estimate the biomass (total tree and components), volume, carbon sequestered and CO_2 removed from the atmosphere. These models based on linear regression are easy to handle and require fewer calculations, therefore, are user friendly for the farmers/manager to estimate their produce precisely. Thus, these models would also be of great help for the scientists, researchers and policy makers who are involved in carbon trading under clean development mechanism and REDD in future

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