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BIOMETRIC MODELS FOR ESTIMATION OF BIOMASS AND CARBON STORAGE IN ELM (ULMUS WALLICHIANA PLANCH) PLANTATION UNDER TEMPERATE CONDITIONS

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ABSTRACT

The current study was conducted on 22-year old Elm plantation at Wadura campus of SKUAST-K. Four diameter classes viz., D_1 (5-10 cm), D_2 (10-15 cm), D_3 (15-20 cm) and D_4 (>20 cm) were stratified from the plantation. Twenty four trees (six from each diameter class) were randomly selected and felled in the year 2015. The best fit model for volume estimation in Elm was found to be curvilinear in form with R^2 = 0.955, Adj. R^2 = 0.951 and RMSE = 0.032 and the model developed was $V = 0.044 - 0.010 D + 0.001 D^2$. For total dry biomass and carbon stock per tree, the logarithmic model proved to be best compared to the rest of models. The models developed for estimation of total dry biomass and carbon stock per tree were Log Biomass = -2.299 + 2.490 Log D and Log C = -2.993 + 2.491 Log D, respectively.

Keywords: Elm, Plantation, Biometric Models, Temperate, Diameter Classes

I.INTRODUCTION

Reliable estimates of growth rate and biomass of Elm are essential for assessing the yield of commercial products obtained from it. There is need to quantify the amount of wood produced by the trees for selling in the market and to the end users. So, the attention must be paid for the development of techniques to estimate tree biomass from easily measurable tree attributes i.e., diameter at breast height. Biometric models that relate variables like diameter at breast height (DBH) to variables that are more difficult to measure are often used to estimate tree biomass and volume (Brown, 2002). These are viewed as important research and management tools to estimate approximate volume of a particular tree stand quickly without use of destructive sampling to a large extent.

The need for quantification of carbon stocks for different plantations and forest types is also relevant for the emerging carbon credit market mechanism such as Reducing Emission from Deforestation and Forest Degradation (REDD). This requires that appropriate biometric models specific for a given plantation and forest type are in place

(Molto *et al*., 2013). There is no shortage of biometric models in the literature relating stem diameter to tree biomass but no models have been developed specifically for the determination of volume and biomass/carbon in Elm plantation in temperate conditions. It is against this background that this study entails developing biometric models for estimating tree volume and biomass/carbon in Elm plantations.

II MATERIAL AND METHODS

The present study was conducted on a 22- year old Elm plantation established at the Faculty of Agriculture, SKUAST-K, Wadura during the year 2014-2015. The details of the experimental site, materials used and methodologies adopted during the course of investigation are given below:

2.1 Experimental area description

2.1.1 Location

The plantation site falls in the Baramulla district of Jammu and Kashmir state situated at an altitude of 1510 m amsl. It is located 60 km away from the Srinagar city in the north-west direction at Wadura (Sopore) and lies at $34^0 3'$N latitude and $74^0 5'$E longitude.

2.1.2 Climate

The area has a temperate climate with average annual temperature of 14.1^0C. July is the warmest month of the year with an average temperature of 24.1^0C. At 2.6^0C on average, January is the coldest month of the year. The area receives an average annual rainfall of about 810 mm, most of which is concentrated in the winter season, with relatively little rain in the summer.

2.2 Methodology

The Elm plantation was stratified into four diameter classes viz., D_1 (5-10cm), D_2 (10-15cm), D_3 (15-20cm) and D_4 (>20cm). Twenty four trees were randomly selected from the plantation (six from each diameter class) and harvested during the year 2015 for measurement different parameters and subsequent development of suitable biometric models for prediction of yield and carbon storage. The following four simple regression models were tested using R software version (2.10.1):

(i) Linear ($Y = a + bX$)
(ii) Non-linear ($Y = aX^b$)
(iii) Curvilinear ($Y = a + b_1 X + b_2 X^2$)
(iv) Logarithm ($\text{Log}Y = a + b\text{Log}X$)

III.RESULTS AND DISCUSSION

The fit statistical models for prediction of volume (m^3/tree) of *Ulmus wallichiana* plantation using DBH (D) as independent variable are presented in the Table-1. The values of R^2, Adj. R^2 and RMSE were used to compare the models (Huang *et al*., 2003). The higher the adjusted R^2 values the better and the lower the RMSE the better. Akindele (1985) and Odunlami (1992) confirmed the efficiency of this procedure. In general, curvilinear model with R^2 = 0.955, Adj. R^2 = 0.951 and RMSE = 0.032 provided the best fit and gave the best results followed by non-linear with R^2 = 0.913, Adj. R^2 = 0.901and RMSE = 0.037. The developed curvilinear model was V = 0.044 - 0.010 D + 0.001 D^2. These results are in conformity with the findings of Gautam and Thappa (2007), Dhillon *et al*. (2011), Bohre *et al*. (2013) and Wagay (2012).

The different models for estimation of total dry biomass (kg/tree) of *Ulmus wallichiana* plantation with their respective R^2, Adj. R^2 and RMSE are presented in the Table-2. Logarithmic model with R^2 = 0.956, Adj. R^2 = 0.954 and RMSE = 0.219 proved to be the best model followed by non-linear with R^2 = 0.895, Adj. R^2 = 0.890 and RMSE = 35.461. The logarithmic model developed was Log Biomass = -2.299 + 2.490 Log D. The linear model with R^2 = 0.803, Adj. R^2 = 0.794 and RMSE = 52.781 stands at the bottom as compared to other models. The models developed to predict the carbon stock (kg/tree) in *Ulmus wallichiana* plantation have been presented in the Table-3. The respective values of R^2, Adj. R^2 and RMSE for these models are also tabulated. Logarithmic model with R^2 = 0.956, Adj. R^2 = 0.954 and RMSE = 0.219 provided the best fit followed by non-linear with R^2 = 0.895, Adj. R^2 = 0.890 and RMSE = 17.729. The logarithmic model developed was Log C = -2.993 + 2.491 Log D. The linear model with R^2 = 0.803, Adj. R^2 = 0.794 and RMSE = 26.390 stands at the bottom as compared to other models. The log transformation reduced the error and provided the best fit. Therefore, logarithmic model may be used for prediction of total dry biomass and carbon stock of Elm trees within the diameter range of 5 – 25cm in temperate regions. These results are well supported by the findings of Nogueira Junior *et al*. (2014) and Kraenzel *et al*. (2003). Islam and Masoodi (2007) also found that DBH is the most simple and yet most valuable predictor for woody and total biomass in Elm.

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Table 1. Fit statistical models for prediction of volume (m^3/tree) in 22-year old *Ulmus wallichiana* plantation.

Models	R^2	Adj. R^2	RMSE	Models developed
Linear $Y = a + bX$	0.900	0.896	0.048	$V = -0.199 + 0.024\ D$
Non-linear $Y = aX^b$	0.913	0.901	0.037	$V = 0.00015\ D^{2.491}$
Curvilinear $Y = a + b_1X + b_2\ X^2$	0.955	0.951	0.032	$V = 0.044 - 0.010\ D + 0.001\ D^2$
Logarithm $LogY = a + bLogX$	0.982	0.981	0.144	$Log\ V = -8.951 + 2.545\ Log\ D$

D = Diameter at breast height

Table 2. Fit statistical models for prediction of total dry biomass (kg/tree) in 22-year old *Ulmus wallichiana* plantation.

Models	R^2	Adj. R^2	RMSE	Models developed
Linear $Y = a + bX$	0.803	0.794	52.781	Biomass = -157.048 + 18.071D
Non-linear $Y = aX^b$	0.895	0.890	35.461	Biomass = 0.017 $D^{3.079}$
Curvilinear $Y = a + b_1X + b_2X^2$	0.905	0.896	36.649	Biomass = 103.152 -19.216 D + 1.155 D^2
Logarithm $LogY = a + bLogX$	0.956	0.954	0.219	Log Biomass = -2.299 + 2.490 Log D

D = Diameter at breast height

Table 3. Fit statistical models for prediction of carbon stock (kg/tree) in 22-year old *Ulmus wallichiana* plantation.

Models	R^2	Adj. R^2	RMSE	Models developed
Linear $Y = a + bX$	0.803	0.794	26.390	C = -78.528 + 9.036 D
Non-linear $Y = aX^b$	0.895	0.890	17.729	C = 0.0087 $D^{3.0796}$
Curvilinear $Y = a + b_1X + b_2X^2$	0.905	0.896	18.324	C = 51.576 - 9.609 D + 0.578 D^2
Logarithm $LogY = a + bLogX$	0.956	0.954	0.219	Log C = -2.993 + 2.491 Log D

D = Diameter at breast height