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Full Length Research Paper

Diameter at breast height-crown diameter prediction models for *Picea orientalis*

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Seven models for predicting crown diameter using diameter at breast height were tested for *Picea orientalis* L. (Link.) in Artvin. Data were obtained from 4208 trees measured on 117 temporary sample plots. Sample plots were grouped into categories with 20 year mean age class intervals. Similarly, sample plots were grouped into categories based on mean tree diameter at breast height (2 cm diameter class interval). Mean diameter at breast height and mean crown diameter of sample plots in age class were analyzed statistically. One linear and six non-linear diameters at breast height-crown diameter functions were selected as candidate functions to model diameters at breast height -crown diameter relationship. Regression analysis showed that there were statistically significant (P > 0.05) and strong (R^2 > 0.80) relationship between diameter at breast height and crown diameter variables in *P. orientalis*. The results of the study indicated that the diameter at breast height-crown diameter relationship can be described by cubic, compound, growth or exponential model because of the same R^2 values. But the cubic model gave the best result for relationship between diameter at breast height and crown diameter.

Key words: Crown diameter, diameter-crown diameter model, oriental spruce, regression analysis.

INTRODUCTION

Diameter at breast height (dbh) and crown width are important tree characteristics and an accurate prediction of tree dimensions has become prominent as analysis techniques, models, and other statistical tools to allow for the rapid evaluation of extensive volumes of data. Some parameters (e.g., diameter or age) are easy to measure with simple instruments and it is widely used by forest inventories. However, a number of studies have shown that other variables which are not so easily obtained are also good predictors of forest dynamics and they can improve the reliability of tools like growth and yield models. One of these parameters is crown size, which has received increasing attention as a means to estimate tree growth (Bragg, 2001). Measurement of tree crown width is more difficult and more time consuming than that of dbh (Avsar, 2004). Crown width is used in tree and crown level growth-modeling systems, where simple competition indices are not available to adequately predict recovery from competition when a competitor is removed (Vanclay, 1994). Crown width is also used in calculating competition indices based on crown overlap (Biging and Dobbertin, 1992; Daniels et al., 1986) and predicting aboveground biomass. Crown width models can be formulated from open-grown trees or from stand-grown trees (González et al., 2007). Equations for predicting the dimensions of crowns in open locations consider maximum biological potential, and so are known as “maximum crown width” (MCW) equations, while those for stand-grown trees which generally have a smaller crown due to competition, are called “largest crown width” (LCW) equations (Hann, 1997). LCW models predict the actual size of tree crowns in forest stands, and have many applications including estimations of crown surface area and volume in order to asses forest health (Zarnoch et al., 2004), tree-crown profiles and canopy architecture (Hann, 1999; Marshall et al., 2003), forest canopy cover (Gill et al., 2000) and the aboveground biomass. Modeling crown diameter as a simple linear model between crown width and diameter at breast height is often adequate (Cañadas, 2000; Paulo et al., 2002;

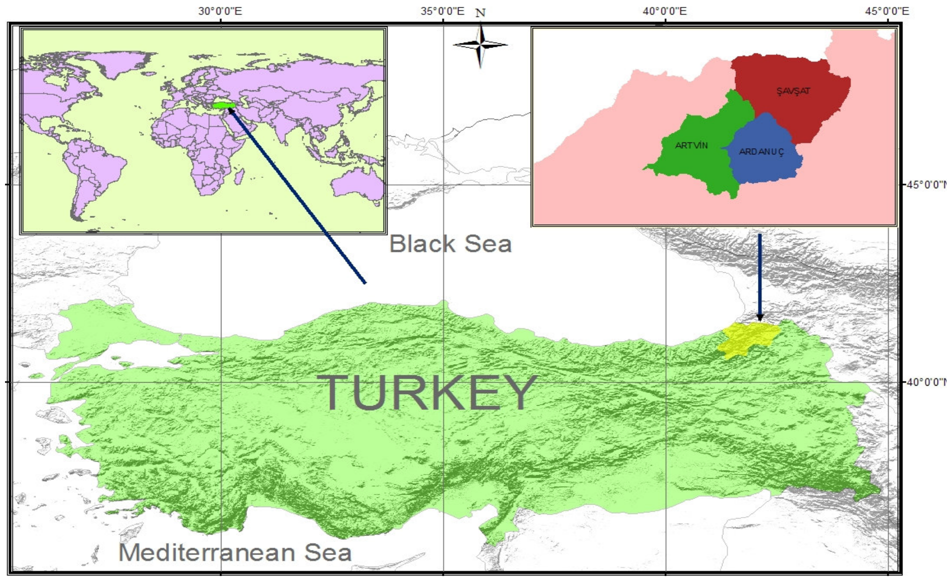

Figure 1. Location of study area.

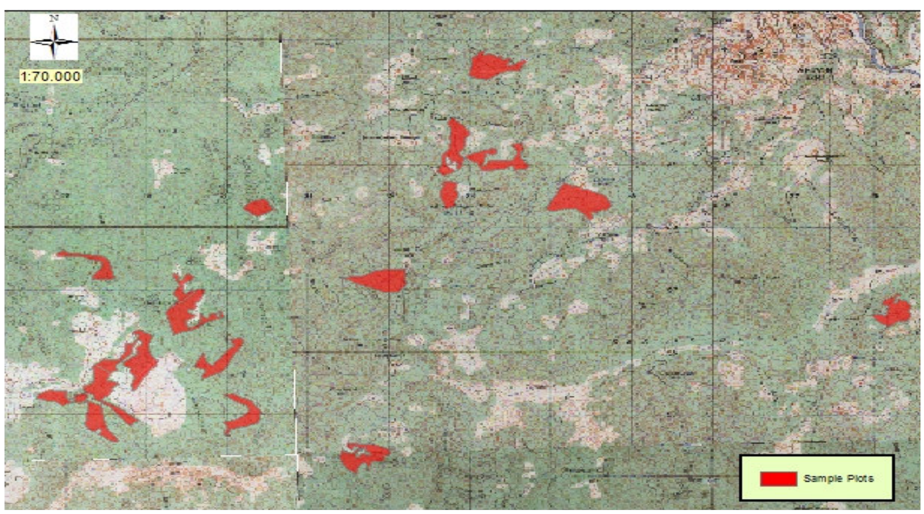

Figure 2. Example of measured pure *P. orientalis* stands

Benítez et al., 2003). Other studies suggest that these linear models can be improved with quadratic expressions of diameter (Bechtold, 2003). Non-linear models have also been used, such as the power function and the monomolecular function (Bragg, 2001; Tomé et al., 2001; Avsar, 2004).

The objective of this study is to develop a crown diameter prediction model for Oriental spruce (*Picea orientalis*) grown in Artvin. Thus, it would be easier to determine tree crown diameter by means of regression equations and it would cost less for the ground-based forest inventory studies and stand structure determination in pure Oriental spruce stands.

MATERIALS AND METHODS

Data for developing the models were obtained from 117 plots natural *P. orientalis* stands in the Artvin, Ardanuç and Şavşat Forest Enterprise (north-eastern part of Turkey 40° 57´ N, 41° 30´ E and 41° 30´ N, 42° 37´ E) (Figure 1). A total of 4208 standing trees were measured from July to September 2007. All stands were selected as pure and even-aged. The representative plots were located on forest maps for each forest enterprises using a GIS software program (ArcGIS 9.2) (Figure 2).

The sample plot's dimensions were 20 x 50 m. At plot establish-

Table 1. Characterization of data set.

	Mean	Min.	Max.	S.D.
dbh	33.68	6.18	70.00	17.00
cd	4.05	1.57	8.25	1.59

S.D.: Standard Deviation

Table 2. Crown diameter functions analyzed.

Function code	Function form	Designation
1	$cd = b_0 + b_1 \,.\, dbh$	Linear
2	$cd = b_0 + b_1 \,.\, dbh + b_2 \,.\, dbh^2 + b_3$	Quadratic
3	$cd = b_0 + b_1 \,.\, dbh + b_2 \,.\, dbh^2 + b_3 \,.\, dbh^3$	Cubic
4	$cd = b_0 \,.\, dbh^{b1}$	Power
5	$cd = b_0 \,.\, b_1^{dbh}$	Compound
6	$cd = e^{(b0 + b1 \,.\, dbh)}$	Growth
7	$cd = b_0 \,.\, e^{(b1 \,.\, dbh)}$	Exponential

cd: crown diameter.

Table 3. Model statistics and parameter estimates from crown diameter prediction equations.

Function code	Model statistics		Parameter estimates			
	R^2_{adj}	MSE	b_0	b_1	b_2	b_3
1	0.834	0.4194	1.1730	0.0855	-	-
2	0.853	0.3714	0.9220	0.0296	0.0008	-
3	0.862	0.3494	1.0389	0.1401	-0.0028	0.000033
4	0.855	0.0223	1.8352	1.0215	-	-
5	0.835	0,0253	0.5491	0.5737	-	-
6	0.855	0.0227	0.6072	0.0213	-	-
7	0.855	0.0227	1.8352	0.0213	-	-

ment, following data were recorded for every sample tree; species, ages, diameter over bark at breast height (dbh ≥ 5 cm) to the nearest 0.1 cm and cower diameter to the nearest 0.1 m. dbh were measured with calipers in two perpendicular directions. In a second stage, 30 - 40 trees per plot were randomly selected to record crown diameter. In a third stage, 6 dominant trees per plot were selected to measure age. Each plot's age was calculated as arithmetic mean of measured tree age. Two crown diameters were measured per tree, one being the horizontal diameter of the axis of the crown which passes through the centre of the plot and the second being perpendicular to the first. The arithmetic mean crown dia-meter is calculated from these two field measurements. Table 1 shows a characterization of the data set.

To investigate relationship between dbh and crown diameter, sample plots were classified by age (e.g. 21 - 40 years; 41 - 60 years), firstly. Secondly, all tree diameters in each age class were grouped as 2 cm range. A low value of first diameter class is 5 cm. Arithmetic means of dbh and crown diameter in each diameter class were carried out by using SPSS statistical software package program. Arithmetic mean diameter over bark at breast height is the dbh considered as an independent variable and arithmetic mean crown diameter is the crown diameter considered as dependent variable.

Seven dbh-crown diameter equations (Table 2) were selected as candidate functions to model the dbh-crown diameter relationship. One of these models is linear and others are non-linear. Comparison of the model estimates was based on graphical and numerical analysis of the residuals and values of two statistics: the mean square error (MSE), which analyses the precision of the estimates; and the adjusted coefficient of determination (R^2_{adj}), which reflects the part of the total variance that is explained by the model. In all statistical analyses, a confidence level p = 0.05 was used for statistical significance.

RESULTS AND DISCUSSION

The results obtained by fitting the candidate equations are shown in Table 3. For dbh-crown diameter relationship, the dbh was taken as the independent variable, while the crown diameter was taken as the dependent variable. All parameters were found to be significant at the 5% level. Several models for fitting data were performed well and produced very similar results. The cubic model gave the best performance according to the values of the statistics used to compare the models in the fitting phase. Consequently, this model was selected. The regression equation was:

$$cd = 1.039 + 0.14dbh - 0.0028dbh^2 = 0.00003dbh^3$$

where *cd* is crown diameter; *dbh* is the diameter at breast height over bark.

The adjusted coefficient of determination and the mean square error of estimate were R^2_{adj} = 0.862 and MSE = 0.3494, respectively. There was a strong positive, non-linear relationship between crown diameter and dbh (Figure 3). Figure 4 showed the plot of the residuals versus crown diameter estimated from the selected model.

The regression models between dbh and crown diameter variables were statistically significant (P < 0.05). That the R^2 value is more than 0.75 in the models established. This indicates that dbh is the strongest predictor of crown diameter for *P. orientalis*. The cubic model is the best to predict the crown diameter for fitting data (R^2_{adj} = 0.862; MSE = 0.3494).

A number of studies also investigated the relationship between dbh and crown diameter for *Picea* spp. Similar studies were also carried out using different tree species (for example Bragg, 2001; Bechtold, 2003), and a strong relationship between dbh and crown diameter was noted. For *P. orientalis*, this present study also showed strong relationship between dbh and crown diameter.

From the results of this study, it was seen that dbh and crown diameter could be estimated by means of dbh, which is easy to measure for the studies in ground-based forest inventory and stand structure determination for pure *P. orientalis* stands. The dbh-crown diameter relationship should be used for the estimation of crown dia-

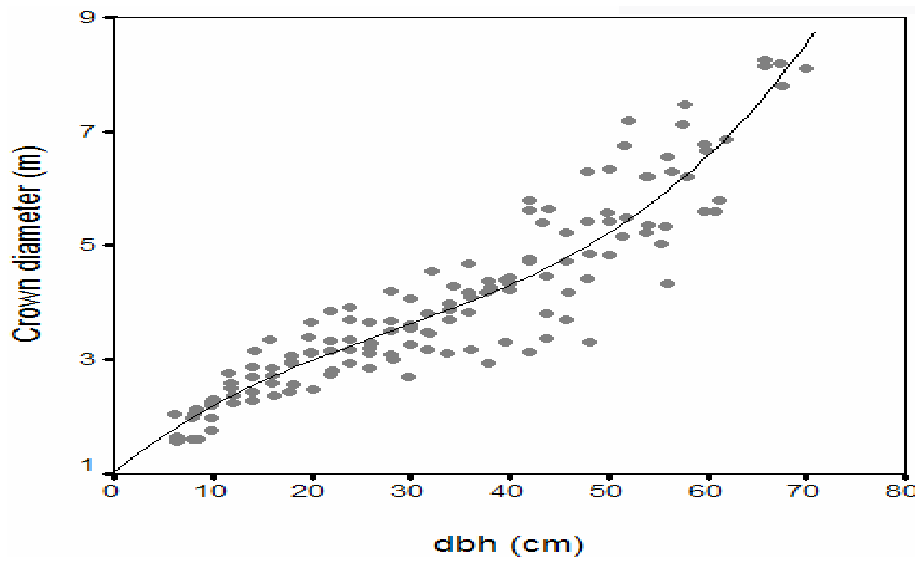

Figure 3. Relationship between dbh and crown diameter (Cubic model).

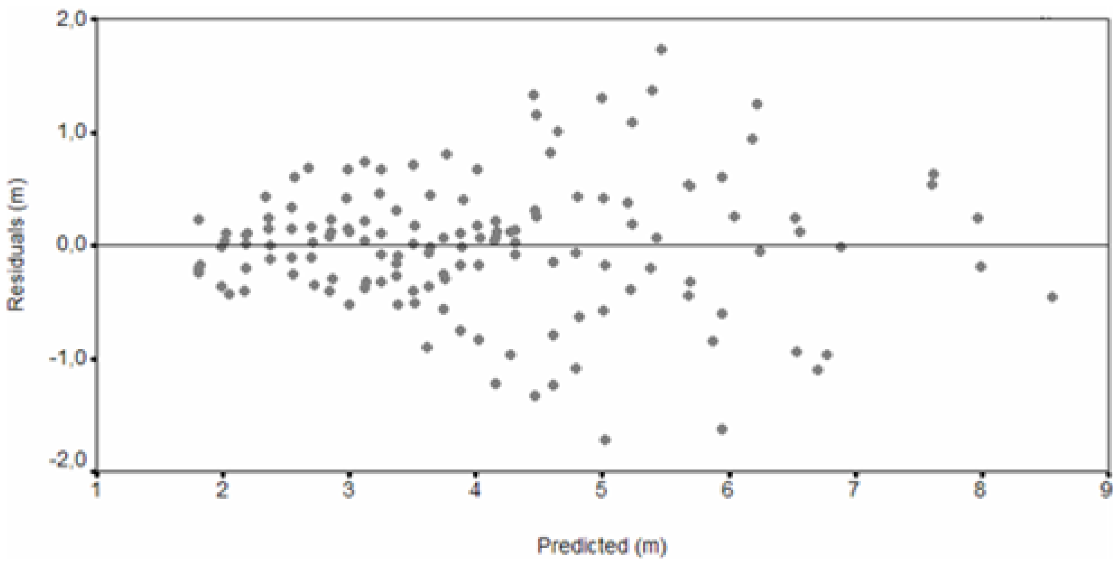

Figure 4. Plots of the residuals versus predicted values for the selected models.

meter. The dbh-crown diameter relationship can be described by the cubic model in pure and even aged *P. orientalis* stands in Artvin.

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REFERENCES

Avsar MD (2004). The relationships between diameter at breast height, tree height and crown diameter in calabrian pines (*Pinus brutia* Ten.) of Baskonus Mountain, Kahramanmaras, Turkey. J. Biol. Sci. 4: 437-440.

Bechtold WA (2003). Crown-diameter predictions models for 87 species of stand-grown trees in the Eastern United States. South. J. Appl. For. 27:269-278.

Bechtold WA (2004). Largest-crown-width prediction models for 53 species in the western United States. West. J. Appl. For. 19:245-251.

Benitez JY, Rivero M, Vidal A, Rodriguez J, Álvarez RC (2003). Estimación del diámetro de copa a partir del diámetro normal (d1,3)

en plantaciones de *Casuarina equisetifolia* Forst. Invest. Agrar: Sist. Recur. For. 12:37-41.
Biging GS, Dobbertin M (1992). A comparison of distance- dependent competition measures for height and basal area growth of individual conifer trees. For. Sci. 38:695-720.
Bragg DC (2001) A local basal area adjustment for crown width prediction. North. J. Appl. For. 18:22-28.
Cañadas N (2000). *Pinus pinea* L. en el Sistema Central (Valles del Tiétar y del Alberche): desarrollo de un modelo de crecimiento y producción de piña. Ph.D. Dissertation, E.T.S.I. de Montes, Universidad Politécnica de Madrid.
Daniels RF, Burkhart HE, Clason TR (1986). A comparison of competition measures for predicting growth of loblolly pine trees. Can. J. For. Res. 16:1230-1237.
Gill SJ, Biging GS, Murphy EC (2000). Modelling conifer tree crown radius and estimating canopy cover. For. Ecol. Manage. 126:405-416.
Hann DW (1997). Equations for predicting the largest crown width of stand-grown trees in Western Oregon. Forestry Research Laboratory, Reseach Contribution 17.Oregon State University, Corvallis.
Hann DW (1999). An adjustable predictor of crown profile for stand-grown Douglas-fir trees. For. Sci. 45:217-225.
Marshall DD, Gregory PJ, Hann DW (2003). Crown profile equations for stand-grown western hemlock trees in northwestern Oregon. Can. J. For. Res. 33:2059-2066.
Paulo MJ, Stein A, Tomé M (2002). A spatial statistical analysis of cork oak competition in two Portuguese silvopastoral systems. Can. J. For. Res. 32, 1893-1903.
Sánchez-González M, Cañellas I, Montero G (2007). Generalized height-diameter and crown diameter prediction models for cork oak forests in Spain. Invest. Agrar: Sist. Recur. For. 16:76-88.
Tomé M, Coelho MB, Almeida A, Lopes F (2001). O modelo SUBER. Estrutura e equações utilizadas. Relatórios técnico-científicos do GIMREF nº 2/2001, Centro de Estudos Florestais, Instituto Superior de Agronomia, Lisboa.
Vanclay JK (1994). Modelling forest growth and yield. Applications to Mixed Tropical Forests. CAB International, Wallingford.
Zarnoch SJ, Bechtold WA, Stolke KW (2004). Using crown condition variables as an indicator of forest health. Can. J. For. Res. 34:1057-1070.