Colloquium Biometricum 42
2012, 17–23

TREE CROWN DIMENSIONS AND ITS RELATIONSHIPS WITH TREE VOLUME BASED ON SCOTS PINE (*PINUS SYLVESTRIS* L.)

Katarzyna Kaźmierczak[1] **, Tomasz Najgrakowski**[2]

Department of Forest Management
University of Life Sciences in Poznań
ul. Wojska Polskiego 71c, 60 – 625 Poznań
e-mail: [1] kasiakdendro@wp.pl; [2] dentomn@up.poznan.pl

Summary

The paper presents results of studies on a dependency between tree volume on basic measurements of the tree crown – diameter and length of crown and stem measurements – dbh (diameter at breast height), height, double bark thickness, period increment in breast height diameter. Regression equations were developed for the estimation of tree volume. Material for analyses comprises results of measurements of 50 pine coming from 50-year old stand. In view of the statistically significant dependence between volume of pine and measured tree traits the analysis of regression was conducted, assuming the investigated traits (diameter at breast height, height, double bark thickness, 5-year increment in breast height diameter, crown width and crown length) as explanatory variables. The backward stepwise regression was applied. Tree volume may be determined both on the basis of information on the height and diameter at breast height of a tree and crown diameter.

Keywords and phrases: crown diameter, crown length, diameter at breast height, height, stepwise regression, Scots pine (*Pinus sylvestris* L.)

Classification AMS 2000: 62F25

1. Introduction

For ages, forest has been one of main elements of natural environment. It plays important role in economic and cultural development of world. The production of wood is the basic function of forest. Improvement of the methods of tree volume calculation is fundamental for forest mensuration. Tree's volume is usually defined on basis of measurement dbh and height of a tree. The tree crown determines its growth and increment. Crown width is an important feature in describing stand density and individual tree competition. Extensive studies concerning the structure and shape of crowns in different tree species were conducted by Burger and Badoux (after Borowski 1974). The dependence of crown size on other traits of a tree was evaluated e.g. by Dubravac T., Krejci V. (1993), Dubravac T. (1998, 1999, 2003, 2004), and Hemery et al. (2005). In Poland analyses concerning the crown were conducted mainly in pine stands (Lemke 1966). The dependence increment of dbh on pine crown surface and crown volume studied Dudek (1969). Zajączkowski (1973) researched the relationship between crown projection area and current increment of tree volume.

The aim of this study was:

1. To determine the strength of the relationship between crown dimensions and tree volume,
2. To develop regression equations for the estimation of tree volume basis of crown traits.

2. Experimental material and methods

Empirical material was collected in 50−years−old pure Scots pine stand growing on fresh mixed conifer forest site in the Zielonka Experimental Forest District. The research material consisted of measurements of 50 pine trees. Sample trees were selected randomly from stand. The following was measured for each tree:

1. Dbh in bark in two directions N−S and W−E with a tolerance of up to 0.1 cm; the arithmetic mean of those measurements was assumed as tree dbh.
2. Tree height with a tolerance of up to 0.1 m.
3. Tree crown height with a tolerance of up to 0.1 m.
4. Crown projection area on the basis of the characteristic tree crown points (4 to 14) projected with the use of a crown projector;
5. 5-year increment in breast height diameter with a tolerance of up to 0.01 cm.

Crown widths expressed in meters were obtained from the crown projection area assumed as the area of a circle. Crown length was calculated as the difference between the tree height and the height of its crown.

3. Results

Mean diameter at breast height was 16.97 cm, height 18.72 m (Table 1). The double thickness of bark was 2 cm, 5-year increment in breast height diameter was 1 cm. Mean tree volume was 0.20 m^3. The length of crown was 5.75 m, and the width of crown was 2.28 m (Table 1). Trees' height is feature the least variable, meanwhile the most volume (Table 1).

Table 1. A characteristic of selected measurable traits of trees

Triat	N	$\bar{x}$	min	max	s_{dx}	V (%)
d_{zk} (diameter at breast height outside bark – cm)	50	16.97	10.40	28.90	3.77	22.23
h (height– m)	50	18.72	13.84	21.85	1.63	8.70
k (double bark thickness – cm)	50	1.87	0.75	4.25	0.65	34.57
Zd_5 (5-year increment in breast height diameter – cm)	50	1.00	0.30	2.20	0.48	48.17
V (tree volume – m^3)		0.20	0.05	0.60	0.11	54.77
l_k (crown length – m)	50	5.75	2.03	9.22	1.22	21.31
d_k (crown width – m)	50	2.28	1.24	4.38	0.60	26.33

Table 2. A correlation diagram

Triat	d_{zk}	*h*	*k*	Zd_5	*V*	l_k
h	0.776					
k	0.755	0.417				
Zd_5	0.792	0.719	0.456			
V	**0.975**	**0.788**	**0.681**	**0.789**		
l_k	0.798	0.746	0.520	0.635	**0.785**	
d_k	0.808	0.493	0.596	0.668	**0.841**	0.636

The dependences of pine volume on selected biometric characteristics was examined. The simplest features of measuring trees were chosen - dbh ($d_{1,3}$) and height (*h*). In addition, elements describing the size of the crown were selected – the width of the crown (d_k) and crown length (l_k). Coefficients of linear correlation were calculated. Tree volume showed statistically (at the level $\alpha = 0.05$) significant correlation with all the traits (Table 2). Tree volume increases with the growth of all biometric features. The strongest dependence of the volume was found on the diameter at breast height of trees (0.975) and crown width (0.841).

Pine volume was also describes by multiple empirical equations. All the previously mentioned biometric features were included as the explanatory variables (diameter at breast height, height, double bark thickness, 5-year increment in breast height diameter, crown width and crown length). Stepwise regression was performed, which step by step creates the best regression model. Backward stepwise regression was used, which sequentially removes from the model those variables which in every step have the least significant impact on the response variable – the tree volume. Another equations to determine the volume of pine were given as a result of estimation the parameters:

$$V = -0.4130 + 0.0249 \cdot d_{1,3} + 0.0090 \cdot h - 0.0154 \cdot k - 0.0089 \cdot Zd_5 - 0.0037 \cdot l_k + 0.0373 \cdot d_k \quad (3.1)$$

$$V = -0.3979 + 0.0240 \cdot d_{1,3} + 0.0083 \cdot h - 0.0137 \cdot k - 0.0033 \cdot l_k + 0.0362 \cdot d_k \quad (3.2)$$

$$V = -0.3916 + 0.0235 \cdot d_{1,3} + 0.0075 \cdot h - 0.0133 \cdot k + 0.0355 \cdot d_k \quad (3.3)$$

$$V = -0.4224 + 0.0204 \cdot d_{1,3} + 0.0102 \cdot h + 0.0389 \cdot d_k \quad (3.4)$$

Volume of pine can be determined by regression equation in dependence to the diameter at breast height, height and crown diameter. All of the analyzed traits were determined for standing trees.

Table 3. Multiple and partial correlation coefficients for the tree volume dependence on the selected characteristics of trees

Equation	$R_{multiple}$	$R_{partial}$					
		$d_{1,3}$	h	k	Zd_5	l_k	d_k
(3.1)	0.9843	0.785*	0.342*	-0.275	-0.120	-0.129	0.514*
(3.2)	0.9841	0.793*	0.325*	-0.253		-0.113	0.504*
(3.3)	0.9839	0.795*	0.307*	-0.246			0.497*
(3.4)	0.9828	0.831*	0.428*				0.528*

The correlation coefficient significant at the level α = 0.05

4. Discussion

Scots pine is the most important predominating species forming forests in Poland. Stem volume is function of a tree's height, basal area, tree shape, bark thickness. Foresters have developed allometric relationships to estimate stem volume from measurements made on diameter at breast height and tree height. Regression function for tree volume have been developed as a function of easily measurable tree variables on standing tree. The volume models should be based on the variables that are normally measured in forest inventories or which be estimated easily. The tree crown plays an essential role in tree productivity. Crown is the location of the physiological processes, principally photosynthesis, respiration, leading to growth and developed of the tree. The size of a tree crown is strongly correlated to tree growth. The energy absorbed directly affects tree growth and stands dynamics. The crown has great visual impact. Crown width is an important feature in describing stand density and individual tree competition. Tree crown diameter and crown projection area are important measures to describe growth efficiency (Assmann 1968). Forest trees usually exhibit a significant relationship between their crown width and stem diameter (e.g. Avsar 2004, Avsar and Ayyildiz 2005, Akalp 1983, Bragg 2001, Foli et al. 2003, Franscis 1988, Gering and May 1995, Hasenauer 1997, Kigomo 1980, 1991, 1998, Sun 1977). Crown profile and structure models can be used to obtain measures of inter-tree competition (e.g., Daniels et al. 1986, Biging and Dobbertin 1992), as a measure of tree vigour for use in mortality models (e.g., Hann and Wang 1990; Hasenauer and Monserud 1996) and in stem growth prediction (e.g., Wykoff 1990; Cole and Lorimer 1994).

5. Conclusions

1. With the growth of all biometric features (diameter at breast height, height, double bark thickness, 5-year increment in breast height diameter, crown width and crown length) pine volume increases.
2. The strongest association of the tree volume was found with the diameter at breast height and crown width.
3. Volume of pine can be determined by regression equation in dependence to the diameter at breast height, height and crown diameter, which took the form:

$$V = -0.4224 + 0.0204 \cdot d_{1,3} + 0.0102 \cdot h + 0.0389 \cdot d_k$$

References

Akalp T. (1983). *Simulation of increment and growth in uneven-aged stands*. Istanbul University, Faculty of Forestry. Publication No. 327, Istambul.

Assmann E. (1968). *Nauka o produkcyjności lasu*. PWRiL, Warszawa.

Avsar M.D. (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.

Avsar M.D., Ayyildiz V. (2005). The relationships between diameter at breast height, tree height and crown diameter in Lebanon cedars (Cedrus libani A. Rich.) of the Yavsan Mountain, Kahramanmaras, Turkey. Pak. *J. Biol. Sci*., 8(9), 1228–1232.

Biging G.S., Dobbertin M. (1992). A comparison of distance-dependent competition measures for height and basal area growth of individual conifer tress. *Forest Science* 38, 695–720.

Borowski M. (1974). *Przyrost drzew i drzewostanów*. PWRiL. Warszawa.

Bragg D.C. (2001). A local basal area adjustment for crown width prediction. *North. J. Applied For*., 18, 22–28.

Cole W.G., Lorimer C.G. (1994). Predicting tree growth from crown variables in managed northern hardwood stands. *Forest Ecology and Management* 67, 159–175.

Daniels R.F., Burkhart H.E., Clason T.R. (1986). A comparison of competition measures for predicting growth of loblolly pine trees. *Canadian Journal of Forest Research* 16, 1230–1237.

Dubravac T. (1998). Istrazivanje strukture krosanja hrasta luznjaka i obicnoga graba u zajednici.(Carpino betuli-Quercetum roboris. (Anić 1959 Raus 1969). *Rad. Sum. Inst*. Vol.33 br.2, 61–102.

Dubravac T. (1999). Utjecaj broja stabala na promjer krošnje hrasta lužnjaka u zajednici. (Carpino betuli-Quercetum roboris. Anić ex Rauš 1969). *Radovi* Vol. 34 br. 2, 23–37.

Dubravac T. (2003). Dinamika razvoja promjera krošanja hrasta lužnjaka i običnoga graba ovisno o prsnom promjeru i dobi. *Radovi* Vol. 38 br. 1, 35–54.

Dubravac T. (2004). Dinamika razvoja dužina krošanja hrasta lužnjaka i običnoga graba ovisno o prsnom promjeru i dobi. *Radovi* Vol. 39 br. 1,51–69.

Dubravac T.. Krejci V. (1993). Ovisnost promjera horizontale projekcije krosanja hrasta luznjaka o totalnim visinama stabala pojedinih dobnih razreda ekolosko-gospodarkog tipa II-G-10. (Carpino betuli-Quercetum roboris. (Anic/emend. Raus 1969). *Rad. Sum. Inst*. Vol.28 br.1/2, 79–89.

Dudek A. (1969). Zależność intensywności przyrostu miąższości i przyrostu pierśnicy od wielkości korony (The relationship of intensity of tree volume increment and the increment of dbh of crown size). *Fol. For. Pol*. Seria A. Z. 15, 149–169.

Foli E.G., Alder D., Miller H.G., Swaine M.D. (2003). Modeling growing space requirements for some tropical forest tree species. *For. Ecol. Manage*. 173, 79–88.

Francis J.K. (1988). *The relationship of bole diameters and crown width of seven bottomland hardwood species*. USDA Forest Service, Southern Forest Experiment Station Research Note So–328, New Orleans, LA.

Gering L.R., May D.M. (1995). The relationship of diameter at breast height and crown diameter for four species groups in Hardin County, Tennessee. *South. J. Applied For*. 19, 177–181.

Hann D.W.,Wang C.H. (1990). Mortality equations for individual trees in southwest Oregon. *Research Bulletin* 67, Forest Research Lab., Oregon State University, Corvallis, Oregon.

Hasenauer H. (1997). Dimensional relationships of open-grown trees in Austria. *For. Ecol. Manage*. 96, 197–206.

Hasenauer H., Monserud R.A. (1996). A crown model for Austrian forests. *Forest Ecology and Management* 84, 49–60.

Hemery G. E.. Savill P. S.. Pryor S. N. (2005). Application of the crown diameter-stem diameter relationship for different species of broadleaved trees. *Forest Ecology and Management* 215 (1/3), 285–294.

Kigomo B.N. (1980). Crown-bole diameter relationship of *Juniperus procera* (cedar) and its application to stand density control and production survey in natural stands. *E. Afr. Agric. Forest*. J., 46 (2), 27–37.

Kigomo B.N. (1991). Crown and bole diameter relationship in *Brachyleana huillensis* and its application to silvicultural interventions. *E. Afr. Agric. Forest. J*., 57(1), 67–73.

Kigomo B.N. (1998). Morphological and growth characteristics in *Brachyleana huillensis* (Muhugu); some management considerations. *Kenya J. Sci*. (Series B), 11(1-2), 11–20.

Lemke J. (1966). Korona jako kryterium oceny dynamiki wzrostowej drzew w drzewostanie sosnowym (The crown as a criterion in the evaluation of growth dynamics of trees in a pine stand). *Fol. For. Pol.* Seria A. Z. 12, 185–236.

Sun O. (1977). *Growth model for simulation of a Calabrian pine (Pinus brutia Ten.) tree*. Forestry Research Institute. Technical Bulletin Series 119, Ankara.

Wykoff W.R. (1990). A basal area increment model for individual conifers in the northern Rocky Mountains. *Forest Science* 36, 1077–1104.

Zajączkowski J. (1973). Przyrost miąższości w klasach biosocjalnych starszych drzewostanów sosnowych (The increment of tree volume in biosocialclasses of older pine stands). *Sylwan* 1, 1–10.