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Volume Functions for Oriental Plane (*Platanus orientalis* L.) Stands in Kastamonu-Akçay Region

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Abstract

The aim of the study is to prepare local single and double entry tree volume tables of oriental plane (*Platanus orientalis* L.) in vicinity of Kastamonu-Akçay. The sample trees for the measurements have been supplied from stands of their own natural environment. By regression analysis method, 10 equations for double entry and 6 equations for single entry tree volume table are tested. Their coefficient of determination, estimated standard deviation, average deviation, absolute average deviation, total error percentage and average absolute error percentage values were also calculated. Best equation for single entry tree volume table yields coefficient of determination of 0.928, standard deviation of 0.092 m³, total error percentage of 0.079% and average absolute error percentage of 17.88%. Best equation for double entry tree volume table yields coefficient of determination of 0.980, standard deviation of 0.048 m³, total error percentage of 0.33% and average absolute error percentage of 8.8%. These both equations for two different types are tested for an independent data ensemble and are successfully employed for Kastamonu oriental plane stands in 5% confidence level.

Key words: Oriental Plane, volume models, Kastamonu-Akçay

Kastamonu Akçay Yöresi Doğu Çınarı (*Platanus orientalis* L.) Meşcereleri İçin Hacim Fonksiyonları

Özet

Bu çalışma ile Kastamonu Orman Bölge Müdürlüğü Çatalzeytin İşletme Müdürlüğü Akçay İşletme Şefliği sınırlarındaki Doğu çınarı meşcereleri için yöresel tek ve çift girişli ağaç hacim tablosunun düzenlenmesi amaçlanmıştır. Bu amaçla doğal yayılış alanı içerisinde bulunan meşcerelerden toplam 292 adet örnek ağaç üzerinde ölçümler yapılmıştır. Bu veriler üzerinde Regresyon analizi yöntemi ile 6 adedi tek girişli hacim tablosu için 10 adedi çift girişli ağaç hacim tablosu için olmak üzere 16 adet denklem denenmiş ve Belirtme katsayısı, Tahminin standart hatası, Ortalama Sapma, Ortalama Mutlak Sapma, Toplam Hata Yüzdesi ve Ortalama Mutlak Hata Yüzdesinden oluşan altı ölçüte göre değerlendirilmiştir. Bu ölçütlere göre seçilen en uygun denklemin tek girişli ağaç hacim tablosu için, belirtme katsayısı 0.928, standart hatası 0.092 m³, toplam hatası % 0.079 ve ortalama mutlak hatası % 17.88 olarak belirlenmiştir. Çift girişli ağaç hacim tablosu için denenilen denklemlerden en uygun olanın belirtme katsayısı 0.98, standart hatası 0.048 m³, toplam hatası %- 0.33 ve ortalama mutlak hatası % 8.8 olarak belirlenmiştir. Bu iki hacim denklemi bağımsız bir veri grubu ile test edilmiş ve 0.05 güven düzeyinde Kastamonu Doğu çınarı meşcereleri için de kullanılabileceği sonucuna varılmıştır.

Anahtar Kelimeler: Doğu çınarı, hacim modelleri, Kastamonu-Akçay

Introduction

Wood, primary product of a forest, is analyzed by its volume. For calculating the overall volume of a forest, the volume of each tree should be calculated separately. Since it is not a feasible method, stem volume of each tree is assigned to estimated values. These values for a standing tree are standard ratios and stem volume tables. Generally, a statistical method is used for calculation of stem volume tables that are used for estimation of volume of a tree.

Therefore, stem volume tables offer an easier way of calculation of tree volume by easier measurement methods such as; diameter and height measurements (Kalipsız, 1984).

Volume functions calculated by statistical methods are numerical results. Although this method is only applicable for coefficient calculations of sampled cultures, it is still the most feasible method and is widely used. By using volume functions and corresponding independent variables, tree volume can be calculated accurately. There are three types

of tree volume tables: single entry (diameter dependence), double entry (diameter and height dependence) and multiple entries (diameter – height – body shape dependence). In Turkey, local, regional and general tree volume tables have been prepared for various tree species (Eraslan, 1954; Miraboğlu, 1955; Alemdağ, 1962; Kalıpsız, 1962; Evcimen, 1963; Alemdağ, 1967; Akalp, 1978; Sun et al., 1978; Asan, 1984; Saraçoğlu, 1988; Batu et al., 1995; Durkaya, 2004).

However, in Turkey, there has no tree volume table for oriental plane tree has been reported so far which has made its management and planning rather difficult. Thus, this study has been done as a first step of yield studies for oriental plane.

Material and Method

Material

Catalzeytin is a district in Western Black Sea region which is surrounded by Black Sea at north, by Taskopru and Devrekani districts at south, by Turkeli district at east and by Abana and Bozkurt districts at west. Its area is 318 km². Akçay is a river zone of Catalzeytin and oriental plane is most common tree species on this area. The dominant climate type in the research area is Black Sea climate type. This type of climate includes four wet seasons, moderately hot summers and mild winters. Due to the research areas being close to the sea and low altitude mountain ranges which are parallel to the shore, temperature difference at the shore decreases, humidity increases and air mass from the Balkans become effective (Anon, 2006).

30 sample trees from oriental plane stands in Akçay district were analyzed and corresponding data are presented. The samples were so carefully chosen that they represented the general properties of the tree population in the region. Only co-dominant and dominant trees, free of damage were selected as sample trees.

Microsoft Excel software is easily employed for analyzing the data taken from the samples. The output is used for calculating the diameter outside bark and volume for corresponding volume factor which is presented in discussion. These

periodic diameter and volume values correspond to the values of an individual tree.

Method

Mathematical and statistical methods are now common methods that are used to prepare stem volume tables (Spurr, 1952; Kalıpsız, 1993). Numerical methods are used instead of graphical methods since computers offer numerous methods in data analysis. In our method, a function was chosen which fits the statistical behavior of the system that uses the coefficients calculated according to the specifications of the system by regression analysis. Then, overall data were used to calculate the volume tables for single entry and double entry. In each different region, a tree is cut and sliced by parts of heights of 2 meters. The sample disks are taken from the middle and 0.30 m away from the sides. Volume of each section was determined by Huber's formula. Remaining side pieces from the parts were analyzed in a conical shape of a given height and base diameter. The disk in 0.3 m was used to determine the age of the tree by counting the annual rings. The radius of each 5 yearly period was measured in each direction perpendicular to each other and these values were averaged to calculate the period diameter. The time for reaching the height was calculated by subtracting annual rings from the age of tree. The time and section height were used to plot height curve. The volumes for 5 yearly periods were also calculated by using the circle diameter and height measurements. Stem analysis has been done on 30 sample tree. The data calculated from the ensemble were used to calculate the diameter and volume values of in side bark ones by multiplying by the corresponding coefficients as each individual is accepted as it has its own periodic value. Then, 292 individuals are presented in this paper.

Bark coefficient was calculated from the slope of a best line of a curve in a diameter inside bark versus diameter outside bark graph as in the case of volume coefficient where the slope of curve in volume inside bark versus volume outside bark is taken into account.

In literature, there are several single entry and double entry volume functions presented so far (Firat, 1973; Loetsch et al., 1973; Akgür, 1982; Kalipsız, 1984; Rustagi-

Loveless, 1990; Sun, 1990; Avery-Burkhardt, 1994).

Single entry volume functions;

$$V = a_0 + a_1 d \quad (1)$$

$$V = a_0 + a_1 d + a_2 d^2 \quad (2)$$

$$V = a_0 + a_1 \ln d \quad (3)$$

$$\ln V = a_0 + a_1 \ln d + a_2 \ln d^{-1} \quad (4)$$

$$\ln V = a_0 + a_1 \ln d + a_2 \ln d^4 \quad (5)$$

$$V = a_0 + a_1 d^2 \quad (6)$$

Double entry volume functions;

$$V = a_0 + a_1 d + a_2 h + a_3 d^2 + a_4 h^2 \quad (7)$$

$$V = a_0 + a_1 d + a_2 dh + a_3 d^2 + a_4 h + a_5 d^2 h \quad (8)$$

$$V = a_0 + a_1 d + a_2 dh + a_3 d^2 + a_4 d^2 h \quad (9)$$

$$V = a_0 + a_1 d^2 h \quad (10)$$

$$V = a_0 + a_1 d^2 + a_2 h^2 + a_3 dh^2 + a_4 d^2 h \quad (11)$$

$$\ln V = a_0 + a_1 \ln d + a_2 \ln h \quad (12)$$

$$\ln V = a_0 + a_1 \ln d + a_2 \ln^2 d + a_3 \ln h + a_4 \ln^2 h \quad (13)$$

$$\ln V = a_0 + a_1 \ln d^2 h \quad (14)$$

$$V = a_0 + a_1 d^2 + a_2 h^2 + a_3 dh^2 + a_4 d^2 h^2 \quad (15)$$

$$V = a_0 + a_1 d + a_2 d^2 + a_3 dh + a_4 d^2 h \quad (16)$$

Where d is stem diameter at breast height and h is its height.

The most suitable function is chosen with respect to a larger value of coefficient of determination (R^2) and smaller values of standard error (Se), total error (TH), absolute mean error (OMH), mean deviation ($\bar{D}$) and absolute mean deviation ($|\bar{D}|$). However, the function obeying these criterions may not yield well for the other parameters.

Therefore, it is better to take all the parameters into account at the same time. Then, every individual parameter in the functions is compared with each other by numbering in an ascending behavior where as the smaller number is the well-matched with the criteria. The numbers in parameters in a function are added to each other simply to find the function which has the smallest value.

$$R^2 = 1 - \frac{SS_{residual} / (n - p)}{SS_{total} / (n - 1)} \quad (17)$$

$$S_e = \sqrt{\frac{\sum (V_i^t - V_i)^2}{(n - p)}} \quad (18)$$

$$\bar{D} = n^{-1} \sum (V_i^t - V_i) \quad (19)$$

$$|\bar{D}| = n^{-1} \sum |V_i^t - V_i| \quad (20)$$

$$TH (\%) = \frac{\sum V_i^t - \sum V_i}{\sum V_i} 100 \quad (21)$$

$$OMH (\%) = \frac{\sum |V_i^t - V_i|}{\sum V_i} 100 \quad (22)$$

Where SSresidual is error variance, SStotal is dependent variables variance, n is number of measured individuals, p is number of parameters, V_i is measured value of dependent variable and V_i^t is estimated value of dependent variable by regression analysis.

Results

Single entry volume tables show volume of tree with respect to its diameter. Since

these tables are easy to use, they are used in stand volume inventory (Avery-Burkhart, 1994). Coefficients for the 16 different models that are practiced for single and double entry volume tables, correction factor for logarithmic functions and F numbers for models are given in table 1. Criterion values for the functions are given in table 2.

Table 1. Values of parameters for single and double entry tree volume tables

Model No	a_0	a_1	a_2	a_3	a_4	a_5	f	F
1	-0.24425	0.028373	-	-	-	-	-	1179
2	0.031805	-0.01067	0.000974	-	-	-	-	1840
3	-8.26128	2.226785	-	-	-	-	1.23	6278
4	-9.51009	2.609199	1.524194	-	-	-	1.25	5631
5	-7.78836	1.8101108	0.00793	-	-	-	1.165	4336
6	-0.05451	0.000727	-	-	-	-	-	3271
7	0.087359	-0.01255	-0.0142	0.00079	0.001029	-	-	2297
8	0.000974	0.006322	0.000285	-0.000358	-0.005471	0.000034	-	2688
9	-0.012213	0.004284	0.0000358	-0.000265	0.0000355	-	-	3322
10	0.009127	0.0000298	-	-	-	-	-	12177
11	0.010754	0.000104	-0.0003	0.00000285	0.0000118	-	-	3425
12	-0.48543	0.108922	0.206457	-	-	-	1.072	135
13	0.441333	-0.16755	0.104282	-0.67035	0.169652	-	1.028	278
14	-0.43927	0.096655	-	-	-	-	1.073	263
15	0.00235	0.000234	-0.00013	0.000018	0.00000431	-	-	3491
16	-0.012213	0.004284	-0.000265	0.0000359	0.0000355	-	-	3332

Table 2. Criterion values of parameters for single and double entry tree volume tables

Model No	R^2	S_e	TH (%)	OMH (%)	$\bar{D}$	$ \bar{D} $
1	0.80	0.151	-0.0073	34.12	-0.000025	0.116
2	0.93	0.092	0.079	17.88	0.00027	0.061
3	0.96	0.425	8.142	19.31	0.027	0.066
4	0.98	0.320	8.84	18.27	0.03	0.062
5	0.97	0.364	18.46	26.7	0.063	0.091
6	0.92	0.097	-0.047	20.14	-0.00016	0.069
7	0.97	0.059	-0.098	12.57	-0.00034	0.0429
8	0.979	0.049	-1.15	9.04	-0.00394	0.0309
9	0.979	0.049	0.0056	9.08	0.000019	0.03103
10	0.977	0.052	-0.088	9.61	-0.0003	0.0328
11	0.979	0.049	-0.229	9.07	-0.00078	0.0309
12	0.488	0.246	350	350	1.19	1.19
13	0.79	0.155	341	341	1.165	1.165
14	0.48	0.248	351	351	1.199	1.199
15	0.98	0.048	-0.33	8.8	-0.013	-0.0301
16	0.979	0.049	-0.051	9.08	0.000176	0.031

As a result of evaluation of all parameters at the same time, function 2 is chosen which has R^2 of 0.93, S_e of 0.092 m³, TH of %0.079, OMH of %17.88, $\bar{D}$: of 0.00027 m³ and ($|\bar{D}|$) of 0,061 m³ for single entry volume function and function 15 is chosen for double entry volume function which has R^2 of 0.98, S_e of 0.048 m³, TH of %-0.33, OMH of %8.8, $\bar{D}$ of -0.013 m³ and ($|\bar{D}|$)of

-0.0301 m³. Although the values in double entry volume function seem less appropriate, it may work better than that of single entry volume tables.

This study in an independent ensemble from Kastamonu Akçay region shows that the chosen single and double entry volume functions offer P: 0.05 confidence level for oriental plane stands.

Discussion

From different volume functions published in the literature, function 2 and function 15 are chosen for single and double entry volume functions respectively and these functions are applicable for Kastamonu Akcay region. In general, single entry volume tables are preferred for calculations of volumes. However, in the ensemble studied, double entry functions results with a lower absolute mean error than that of single entry functions. Single entry function results an absolute mean error of 17.88% while double entry function results an absolute mean error of 8.8%. Therefore, double entry tree volume table should be used in case of a sensitive volume measurement for every individual is intended.

Oriental plane volume models couldn't be compared with other oriental plane volume models because of inexistence. But, a comparison has been done with other volume models according to criterion values.

At a volume model, OMH should be <10% and TH should be <1% for confident usage (Saraçoğlu, 1988; Bozkuş and Carus, 1997). As shown table 3, OMH values of single entry volume functions are between 7.66% and 9.6% and in expected limits. However, OMH values of single entry volume models are between 12.7% and 25.18%. All of these values are high from expected limits.

Table 3. Criterion values of Oriental Plane volume functions and some volume functions constructed for different tree species in Turkey

Single Entry Volume Models				
Tree Species	R ²	OMH (%)	Se (m ³)	TH (%)
Oriental plane	0.928	17.88	0.092	0.079
Black pine (Yavuz, 1988)	0.968	12.7	0.188	0.001
Scots pine (Çalışkan and Yeşil, 1996)	0.983	16.12	0.212	
Scots pine (Sun, Eren and Orpak, 1977)	0.976	24.65		
Scots pine (Alemdağ, 1967)	0.978	25.18		
Double Entry Volume Models				
Tree Species	R ²	OMH (%)	Se (m ³)	TH (%)
Oriental plane	0.98	8.8	0.048	- 0.33
Black pine (Yavuz, 1988)	0.977	9.3	0.159	0.0
Alder (Saraçoğlu, 1995)	0.992	8.12	0.046	- 0.34
Uludağ fir (Çalışkan and Yeşil, 1998)	0.985	9.6	0.164	
Scots pine (Çalışkan and Yeşil, 1996)	0.996	7.66	0.101	

Volume of a tree can be found from only diameter measurement by using single entry volume functions and tables. Therefore, single entry volume tables provide economy at forestry practices and these are widely used. To determine tree volume confidently from these models or tables, their high OMH values should be reduced. This problem can be solved using a site class factor at single entry volume models.

As a result, single and double entry tree volume model may be employed for silviculture, management, yield and inventory studies for Kastamonu Akcay region.

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