RESEARCH ARTICLE
Journal of Biometry Studies (2021) 1(2): 45-48 www.biometrystudies.com
DOI: 10.29329/JofBS.2021.349.02

Journal of Biometry Studies

Estimating the tree bole volume of Brutian pine (*Pinus brutia* Ten.) and Taurus cedar (*Cedrus libani* A. Rich.) using paracone and centroid methods in Turkey

Ramazan ÖZÇELİK[1], Onur ALKAN[1,*]

[1]Isparta University of Applied Sciences, Faculty of Forestry, Department of Forest Engineering, Isparta/TURKEY

[*]Corresponding author: onuralkan@isparta.edu.tr

Received: 20/09/2021, Accepted: 18/12/2021

Abstract

In this study, the most suitable methods for estimating tree bole volume were tested on seventy-six Brutian pine (*Pinus brutia* Ten.) and fourty-five Taurus cedar (*Cedrus libani* A. Rich.) trees. The volume of each tree bole was predicted by utilizing Paracone model, Centroid sampling, Huber formula, and local volume table (LVT) for Brutian pine and Taurus cedar. Volume predictions were then evaluated with "true" volume of every tree that was calculated through summing up the volumes of sub-sections (approximately one meter in length) using Smalian's formula. The mean errors of Paracone model estimation of the tree bole volumes were not significant for both Brutian pine and Taurus cedar and less than those obtained from the Centroid sampling, Huber's formula, and LVT. When four formulas were compared, the Paracone method valuation was clearly more accurate, and mean error of Paracone method was not significant at 0.05 confidence level.

Keywords: Paracone model, Centroid sampling, Tree bole volume, Local volume tables

Please cite this article as follows:

Özçelik, R., & Alkan, O. (2021). Estimating the Tree Bole Volume of Brutian Pine (*Pinus brutia* Ten.) and Taurus Cedar (*Cedrus libani* A. Rich.) Using Paracone and Centroid Methods in Turkey. *Journal of Biometry Studies, 1*(2), 45-48. https://doi.org/10.29329/JofBS.2021.349.02

1. Introduction

Taurus cedar (*Cedrus libani* A. Rich.) and Brutian pine (*Pinus brutia* Ten.) are considered as economically and ecologically important trees in Turkey. While pure Taurus cedar forests occupy an area of 343 thousand hectares in Turkey, pure Brutian pine forests cover 3.1 million hectares as well (GDF, 2019). Patterson et al. (1993) and Wiant et al. (2002) indicated that the volume of a tree in a stand is required to be estimated when these trees purchased or sold as timber. Conventionally, simple volume tables are used to estimate the volume of a stand by collecting tree data and sampling the stand. Different volume tables are often used for every tree species. Recently, taper models are developed to estimate the tree volume to any diameter limits, as well as predicts height at any diameters and diameters at any height. However, the information about taper models for Brutian pine and Taurus cedar is limited. Thus, local volume tables are often used to assess the volume of both felled and standing trees in Turkey Forestry.

Forslund (1982) has introduced a model called "Paracone" which describes the tree bole as a geometrical shape like paraboloids and cone. This model claims that the center of gravity of a branchless tree stem is located between 3/10 of the stem length from its base. Using Eq. 1derived from the Paracone model with A=1.5, the total volume (V, m^3) of a tree bole can be derived nondestructively given its total height (H, m) and its diameter (d_k, cm) measured at a relative height (k) along the bole:

$$V = \frac{A}{A+2}\left(\frac{1}{1-k}\right)^{2/A}\left(\frac{\pi {d_k}^2 H}{40000}\right) \quad (1)$$

Forslund (1982), indicated that the gravitational center of the tree stem may be the best reference location to estimate the tree volume. Thus, k=0.3 can be the proper value for measuring d_k. This reference position occours at about 0.3

of the total height (Wiant et al., 1991; Wiant et al., 1992). Ueno (1978) also expressed that this position has an important role for volume equations.

Wood et al. (1990) introduced a method so called Centroid Sampling (Centroid Method), which is a variant of Importance Sampling, for predicting log or bole volumes. This method requires the measurements of total tree height and a diameter at given relative height, which also stresses importance of relative height of 0.3 while predicting the tree volume. For such solid shapes, the relative height of Centroid (h_c) is 0.2929 (Wood et al., 1990). The basic form of the equation assumes the square of stem radius reduces linear with height among the stem (Gray, 1956). Gregoire et al. (1986), developed an equation that predicts the stem volume by utilizing a proxy or an existing taper equation. The equation is:

$$V = \frac{k}{2} * \frac{A}{(H - HU)} \quad (2)$$

Where;

V: Volume in metric units

k: Interim variable

$$k = 2H(HM - HS) + (HS^2 - HM^2) \quad (3)$$

HM: Merchantable height (for total tree stem volume, *H=HM*)

HS: Stump height

$A = 0.0000785D^2$ (Cross-sectional area at the HU)

D: Diameter outside bark at HU

HU: Centroid position of the tree

$$HU = H - ((H - HS)^2 - 0.5k)^{1/2} \quad (4)$$

H: Total tree height

Many researchers found that Centroid sampling method delivered more accurate results for many tree species than some conventional methods such as Huber and Smalian (Wood and Wiant, 1992; Wiant et al., 1992; Patterson et al., 1993; Wiant et al., 2002). A previous study indicates that Centroid sampling performed better estimating bole volume in Australian hardwoods (Wood and Wiant, 1990). However, Paracone method found to be performed better than Centroid sampling method in tree bole volume estimates (Wiant et al., 1991). Wiant et al. (1991) concluded that the overestimate using the Centroid method may be an advantage when the stems are paraboloid form. If the tree boles conical, the volume is overestimated more than if the Paracone is utilized.

The purpose of this study was to compare the estimations of bole volume which obtained nondestructively using the Centroid sampling, Paracone method, Huber's formula, and local volume tables in Turkey.

2. Material and Methods

Fourty-five Taurus cedar and seventy-six Brutian pine trees were felled in forest areas of Elmalı and Mut regions, respectively. Breast height diameter of trees ranged from 16 to 56 cm. Some descriptive statistics of sample trees are presented in Table 1. Diameter outside bark (dbh_{ob}) was measured with a digital caliper at interval of 1-meter along the stem of the tree.

Centroid sampling (Wood et al., 1990), Paracone method (Forslund, 1982), Huber's formula (*V=MH*, where *V* is volume and *M* is the cross-sectional area at mid-length of a tree of length *H*), and local volume tables for arranged two species have been employed individually to every tree to originate estimations of the volume of the main stem. The "true" volumes of main bole of each tree, and of that is defined by the sections (average 1 meter), were obtained by summing up volumes using Smalian's formula. Total volumes with bark have been estimated for each tree. The results were analyzed using SPSS software package. The Estimations determine whether mean error or bias (Eq. 5) was significantly different from zero by employing Eq. 6 below.

$$Bias = \frac{1}{n}\sum(V_i - V_{ij}) \quad (5)$$

$$t = \left(\frac{Bias}{S.D.of(Bias)}\right)\sqrt{n} \quad (6)$$

Where;

Vi: Predicted tree bole volume

Vij: True tree bole volume

n: Number of trees

S.D.: Standard deviation

Table 1. Descriptive statistics for the data used to compare three methods for predicting bole volume

Species	Number of Trees	dbh_{ob} (cm)		*H* (m)		Forest Type	Location
		Mean	SD	Mean	SD		
Brutian pine	76	35.0	9.34	14.9	2.61	Even-aged Forest	Elmalı-Antalya
Taurus cedar	45	34.2	9.98	15.4	2.82	Even-aged Forest	Mut-Mersin
All species	121	34.7	9.55	15.1	2.69		

3. Results and Discussion

Paracone method has given fewer biased estimations of tree bole volumes than the Centroid Sampling, Huber's formula, and LVT method for both species (Table 2). LVT's yielded the least accurate results for both species. The mean error of the Centroid Sampling, Huber's formula, and LVT estimations were significant at the 0.05 confidence level for both species while of the Paracone method estimation was not significant for both species (Table 2).

When the data of two species merged, the Paracone method prediction was clearly more accurate than Centroid sampling and Huber formula but less accurate than LVT since the mean error was not significant ($p<0.05$). This unexpected result may be due to the fact that LVT gives negative results for Brutian pine and positive results for Taurus cedar when compared to the true volumes. As a result, minimum mean error of the volume was obtained with LVT (Table 2).

The results indicate that the Paracone method predicts tree bole volume better than the Centroid method for both species (Table 2). It is important to note that volumes calculated by Paracone method are consistently smaller than (approximately 2.0 %) the corresponding Centroid method. This corresponds with the findings of Wiant et al. (1991).

These results indicate that the Paracone method can be used for estimating the tree stem volumes of both two tree species in Turkey.

Table 2. Statistics of compared predictions of tree main bole volume obtained using Paracone, Centroid, and Huber Method

Species	Number of Trees	Methods	Mean Volume (m^3)	Mean Error (m^3)	S.D. of Error (m^3)	t statistics	Probability (*)
Brutian pine	76	True	0.6782				
		Huber	0.6182	-0.0600	0.1281	-4.088	0.000
		Paracone	0.6854	0.0072	0.0428	1.448	0.152
		Centroid	0.6987	0.0205	0.0435	4.111	0.000
		LVT	0.6014	-0.0768	0.1519	-4.408	0.000
Taurus Cedar	45	True	0.7013				
		Huber	0.6577	-0.0436	0.0851	-3.432	0.001
		Paracone	0.7106	0.0093	0.0632	0.993	0.020
		Centroid	0.7241	0.0228	0.0635	2.409	0.326
		LVT	0.8168	0.1155	0.1942	3.989	0.000
All	121	True	0.6868				
		Huber	0.6329	-0.0539	0.1139	-5.207	0.000
		Paracone	0.6948	0.0080	0.0511	1.711	0.090
		Centroid	0.7087	0.0219	0.0519	4.654	0.000
		LVT	0.6815	-0.0053	0.1923	-0.303	0.762

(*) Null hypothesis (H_0): Mean error = 0

Conflict of interest

The authors declare that there is no conflict of interest.

References

Forslund, R. R. (1982). A Geometrical Tree Volume Model Based on the Location of the Centre of Gravity of the Bole. *Canadian Journal of Forest Research*, *12*(2), 215-221. https://doi.org/10.1139/x82-033

GDF (2019). Forestry Statistics. https://www.ogm.gov.tr/tr/ormanlarimiz/resmi-istatistikler

Gray, H. R. (1956). *The form and taper of forest-tree stems*. Oxford: Imperial Forestry Institute, University of Oxford.

Gregoire, T. G., Valentine, H. T., & Furnival, G. M. (1986). Estimation of Bole Volume by Importance Sampling. *Canadian Journal of Forest Research*, *16*(3), 554-557. https://doi.org/10.1139/x86-096

Patterson, D. W., Wiant Jr, H. V., & Wood, G. B. (1993). Comparison of the Centroid Method and Taper Systems for Estimating Tree Volumes. *Northern Journal of Applied Forestry*, *10*(1), 8-9. https://doi.org/10.1093/njaf/10.1.8

Ueno, Y. (1978). On the Nature of Form Factors and Its Application for Stand Volume Estimation (I). *Journal*

of The Japanese Forestry Society, *60*(3), 87-93. https://doi.org/10.11519/jjfs1953.60.3_87

Wiant Jr, H. V., Wood, G. B., & Forslund, R. R. (1991). Comparison of Centroid and Paracone Estimates of Tree Volume. *Canadian Journal of Forest Research*, *21*(5), 714-717. https://doi.org/10.1139/x91-099

Wiant Jr, H. V., Wood, G. B., & Gregoire, T. G. (1992). Practical Guide for Estimating the Volume of a Standing Sample Tree Using either Importance or Centroid Sampling. *Forest Ecology and Management*, *49*(3-4), 333-339. https://doi.org/10.1016/0378-1127(92)90144-X

Wiant Jr, H. V., Spangler, M. L., & Baumgras, J. E. (2002). Field Note-Comparison of Estimates of Hardwood Bole Volume Using Importance Sampling, the Centroid Method, and Some Taper Equations. *Northern Journal of Applied Forestry*, *19*(3), 141-142. https://doi.org/10.1093/njaf/19.3.141

Wood, G. B., & Wiant Jr, H. V. (1990). Estimating the Volume of Australian Hardwoods Using Centroid Sampling. *Australian Forestry*, *53*(4), 271-274. https://doi.org/10.1080/00049158.1990.10676087

Wood, G. B., Wiant Jr, H. V., Loy, R. J., & Miles, J. A. (1990). Centroid Sampling: A Variant of Importance Sampling for Estimating the Volume of Sample Trees of Radiata Pine. *Forest Ecology and Management*, *36*(2-4), 233-243. https://doi.org/10.1016/0378-1127(90)90027-9

Wood, G. B., & Wiant Jr, H. V. (1992). Test of Application of Centroid and Importance Sampling in a Point-3P Forest Inventory. *Forest Ecology and Management*, *53*(1-4), 107-115. https://doi.org/10.1016/0378-1127(92)90038-B