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RESEARCH PAPER

Measuring Butt Log and Middle Log Volume of *Eucalyptus Camaldulensis* Using Different Methods in Erbil Province

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A B S T R A C T:

Log volume estimation is an important matter in forest science research and forestry practice because precise estimates are required for commercial harvesting, sustainable forest management, and conservation. volume of each butt log and middle log of an individual tree at a 5-meter log length was calculated by using five different formulas (Newton`s, Smalian`s, Huber`s, Hossfeld`s, and Centroid method). The volume of the butt logs and middle logs was compared to the real volume (control), which was calculated by aggregating the volume measurements at (0.5) meters using Newton's method. Measurements were taken from 50 trees of (*Eucalyptus camaldulensis*) planted in Khabat area in Erbil governorate. The diameter at breast height (DBH) of the trees studied ranged from 30.2 to 75.6 cm, with total tree heights ranging from 13 to 27 meters. The result showed that Newton`s formula was superior to all other formulas for estimating butt log volume of Eucalyptus tree species plantation and Smalian`s formula was less accurate than other formulas. On the other hand, the Centroid method was superior to all other formulas for estimating the middle log volume of Eucalyptus tree species in the district of Khabat in Erbil province. Moreover, the Hossfeld formula was less accurate than other formulas. The benefit of the study is selecting the best formula or the most accurate one for specific tree species plantation.

KEY WORDS: Butt log volume, Middle log volume, Eucalyptus, Newton`s formula, Centroid method, Huber`s formula.
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1. INTRODUCTION :

The bottom portion of the main stem of individual tree is known as the butt log, and it differs from the tree's branches, roots, and upper trunk in appearance. Loggers often refer to a tree's butt as the felled tree's bottom log (Bruce 1982). Because timber is forestry's most important source of revenue, its volume must be carefully calculated.

Hardwood and softwood volume are a valuable asset, not only as a component of the environment, but also as a source of current and future revenues, necessitating appropriate assessments.

The most popular characteristics for determining the stem volume of individual trees are tree height and diameter.

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Tree volume equations and tree volume tables have been the most common in the past and so far. The most commonly used approach is volumetric equations, which are frequently adjusted using data from sample tree scaling. To estimate log volume, a variety of formulae are available. (Avery and Burkhart, 2002). (Wiant et al., 1992) developed the Centroid approach more recently. This formula is similar to Newton's, except it uses cross-sectional area at the midvolume point instead of the midlength point. Newton's, Huber's, and Smalian's formulas are the most commonly utilized (Finger 1992). There are two major sources of error in log volume calculation that contribute to the total error in volume estimation the first point to examine is the volume calculation equation. The underlying shape of the log determines the accuracy of a volume equation's prediction (geometric solid).The second source of errors is created when log diameters and lengths are not measured (Akossou et al., 2013). Since exact estimations are needed for economic harvesting, forest management, and preservation, log volume prediction is an essential topic in forest sciences studies and forest application.

In a study (Al-allaf 2018) reported that compared centroid method with three standard formula to estimate the volume of logs (Newton`s, Smalian`s, Huber`s) and four tree species in Mosul province in Iraq, (*Eucalyptus sp, Platanus sp, Cupressus sp and pinus sp)*. (150) trees selected of all species, (30) tree of each types were selected. The measurements taken were the diameter at the breast height and elevations at various levels began to 0.3, 1.3, and 2.3 and up to 6.3 m. three criteria were used to determine the best-fit formula (bias, standard error and T-test). The result showed that equations of comparisons have no-significant result, Newton`s formula was superior to all other method in estimating of volume of the logs of wood.

(Wiant et al., 1996) used five formulas (Newton, Huber, Smalians, Bruce, and Centroid) for estimating the volume of butt logs of Appalachian hardwoods (*Quercus rubra*, *Quercus alba*, *Liriodendron tulipifera*, *Acer rubrum*, and *miscellaneous* spp.) in West Virginia. The true volumes of the logs, calculated for lengths of 2.44, 4.88, and 9.75 m., were derived by summing the smalians estimates of volume of short sections ranging from 0.09 to 1.22 m. The centroid approach was found to be the most accurate among the other formulae.

For estimating log volumes, (Yavuz 1999) employed various conventional formula such as (Huber's, Smalian's, Hosfeld's, and Newton-and Riecke's centroid technique). A total of 221 Ash (*Fraxinus angustifolia* subsp. oxycarpa.) trees, 388 Spruce (*Picea orientalis* (L.) trees, and 33 Beech (*Fagus orientalis* Lipsky.) trees were destroyed. The cumulative volumes of 1-meter portions estimated using Smalian's method, the presumed true volume, were then compared. The Centroid technique generated less skewed estimates of 6-meter log volumes than the usual formulae for each of the three species evaluated.

(Obeyed 2019) used seven formulas: (Smalian's, Huber's, Newton's, Hossfeld's, Bruce's, Sorenson's and Centroid method) for testing the accuracy of butt log volume and Comparison between these equations. 150 trees of (*pinus brutia* were selected. Studies have shown that the Centroid method is the most accurate and Sorenson Formula is the least accurate.

For determining the volume of logs and comparison between specified formulae (Ozcelik et al., 2006) employed six formulas (Newton, Huber, Smalians, Bruce, center of gravity, and centroid). Eighteen (18) *Cedrus libani* trees, twenty-five (25) *Abies cilicica* trees, and twenty-seven (27) *Pinus brutia* trees were chosen. Summing both the Bruce and Smalian estimations of volume for a very short, 10-cm segment yielded the correct volumes of each 3-m log and 6-m log. The centroid method/center of gravity and Newton were obviously better than the other formulae, according to the results.

The main objective of this study was: comparison between five deferent formulas at 5 m length to find the most accurate formulas for estimating butt log and middle log volumes of Eucalyptus tree (*Eucalyptus camaldulensis*) in the districts of Khabat in Erbil province.

2. MATERIALS AND METHODS

2.1. STUDY AREA

The study area is located in northern part of Iraq (Kurdistan region of Iraq) particularly in the Erbil governorate, district of (Khabat); Erbil is located between 36° 12' 11" and 36° 15' 10" north latitude and 44° 12' 11" and 44° 15' 10" east longitude, at an elevation of (400-500) meter above mean sea level. It covers about 15,038.93km^2. Erbil governorate covers about 29% of total forest cover in northern Iraq reported Regional Development Strategy for Kurdistan Region, 2012–2016 Final Report to the Ministry of Planning, Kurdistan Region (2017). According to (Lück 2014) the temperature range is (5°C) in the winter and (35°C) in the summer; nevertheless, in the region's southern section of Erbil governorate, the temperature increases to (50°C). The climate in the study area classified as a Mediterranean climate (arid and semi-arid) mentioned by (Saeed and Abas, 2012).The Eucalyptus plantation of Khabat district is located in lowland area north-west direction and about 33 km far from Erbil city, It falls between latitudes 36° 16' 20" N and longitudes 43° 40' 24" E, and its elevation range between (240-290) meter above sea level. The area of Eucalyptus plantation is roughly (50 to 55) ha according to information collected from (Directorate of forest).

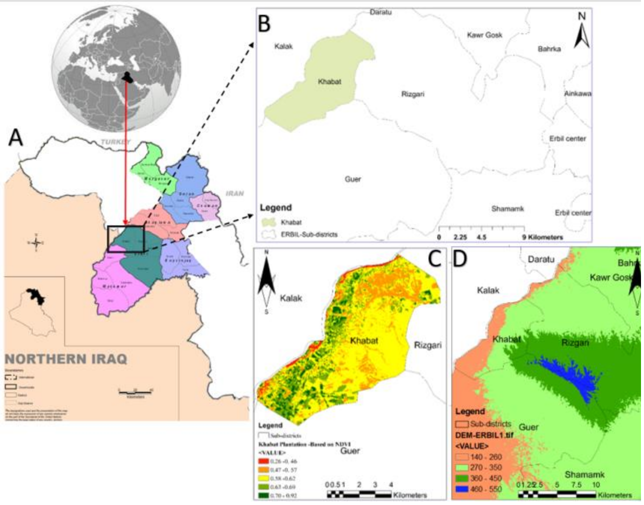

Figure 1. (A) Location map of the study area;(B) The Sub-District map of Khabat; (C)The normalized difference vegetation index (NDVI)Map of Study area;(D); Digital Elevation Model (DEM) of study area.

2.2. DATA COLLECTION

Data came from temporary plots laid out in Khabat plantations. The information was gathered from September to November 2021. A total (50) trees were selected randomly from Eucalyptus plantation. The overall height ranged from 13 to 27 meters, while the diameter at breast height (DBH) ranged from 30.2 to 75.6 cm. All diameters measured by caliper via two measures taken of diameter at right angles to one another and use the average (West 2009). Total tree height (H) of the sampled trees measured by Haga Altimeter (Husch 2002). Before taking any measurements, you must select the normal tree without any damage or broken tree in the stand. In addition, trees possessing multiple stems, obvious cankers, or crooked boles were not included in the sample. The butt log measurements were made by measuring the stump diameter ($d_{0.3}$) outside bark at 0.3 m above the stump, as well as all diameters outside bark at 0.5 m intervals above the stump ($d_{0.8}$, $d_{1.3}$, $d_{1.8}$, $d_{2.3}$, $d_{2.8}$, $d_{3.3}$, $d_{3.8}$, $d_{4.3}$, $d_{4.8}$, and $d_{5.3}$) respectively, on the other hand, the middle log volume measurements represent measuring all diameters outside bark for a 0.5 m interval at 5.3 m above the stump ($d_{5.3}$,$d_{5.8}$, $d_{6.3}$, $d_{6.8}$, $d_{7.3}$, $d_{7.8}$, $d_{8.3}$, $d_{8.8}$, $d_{9.3}$, $d_{9.8}$, and $d_{10.3}$).

2.3. METHODS

To obtain a "true" volume or control volumes of each butt log and middle log at (0.5) meters intervals along the lengths of every log, the diameter of the exterior bark were determined with a calipers., the volume of each small section was estimated by using Newton's formula and aggregate all 0.5-m sections. Butt log volumes were calculated for 5 meter log length above the stump and middle log at 5.3 m above the stump ($d_{5.3}$) by using five formulas. They were then compared to the collected volumes of (0.5) meter sections estimated using Newton's formula, which was supposed to be the true volume. The material used includes (Caliper, Haga, normal tape, Crane, Ladder, GPS devise for recording coordinate and note book).

Formulas were used for estimating butt log volume and middle log volume were (Newton`s, Smalian`s, Huber`s, Hossfeld`s and Centroid method):

a- Newton`s Formula: (Husch, 2002) reported that Newton's formula is considered more exact than other standard formula such as (Smalian's and Huber's formula), Newton's formula requires three diameter measurement small end, mid- point, and large end of a log.

b- Huber's Formula: Only a single diameter measurement from the outside of the bark (dob) from the center of the log and the length of the log are utilized to calculate the cubic volumes of the logs in this calculation (Grave, 1906).

c - Smalian's Formula: this type of formula uses two diameter measurements which are small ends and large ends with the log length for estimating log volume measurement (Graves, 1906).

d- Hossfeld Formula: this type of formula- require two diameter measurement on the outside bark (dob), one of them from small ends of the log and another one at a point two-thirds of the log. Johann Hossfeld was a German forester in the early 19th century, Graves (1906, p. 94) presented "Hossfeld's method" for obtaining the cubic volume.

e - Centroid method: Centroid method is more new formula used in this research to estimate butt log and middle log volume at 5 m length, developed by Wood et al. (1992), it is the same to the Newton method but utilizes cross-sectional area at the mid-volume point rather than at mid-length.

In the Centroid method, the log volume is estimated by three steps:

First step: diameter at large (d_0) and small (d_n) ends of the log, and the log length (L) are measured.

Second step: The Centroid distance (q) from the large end of the log was calculated as follows:

$$q = L - \left(\frac{\left(\frac{do}{dn}\right)^2 - \sqrt{2}}{\sqrt{2}\left(\frac{do}{dn}\right)^2 - \sqrt{2}} \right) L \quad \ldots\ldots\ldots\ldots \text{(Equation 1)}$$

And at this point (q) the Centroid diameter (dc) was measured.

e = L - q …………………………... (Equation 2)

Third step: the parameters (b_1 and b_2) of the Centroid Volume are estimated by Equations bellow;

b_2 = (B-C (L/e)-S (1-L/e)) / (L^2-Le)... (Equation 3)

b_1 = (B-S-b_2L^2)/L ………………….. (Equation 4)

V= SL + (1/2) b_1 L^2 + (1/3) b_2 L^3 …. (Equation 5)

Where;

V = volume of log

B = Cross-sectional area at large end of butt log outside bark (m^2).

S = Cross-sectional area at small end of butt log outside bark (m^2).

L = log length (m).

C = Cross-sectional area at mid volume of butt log (m^2) measured at a distance q from the large end of butt log outside bark.

d_0, d_n = diameter (cm) at large and small end of butt log outside bark, respectively.

In this study five different formula modeling methods were used to estimate butt log and middle log volume at (5 meter log length) of Eucalyptus tree in district of Khabat from Erbil governorate (Kurdistan regional of Iraq) include: Newton's ,Huber's, Smalian's, Hossfeld's, and Centroid method. All different methods could be used for estimating butt log volume and middle log volume as shown in table (1).

Table (1): Formulas were used for estimation butt log and middle log volume of Eucalyptus tree (*Eucalyptus camaldulensis*) at 5-meter log length.

No.	Name	Formula
1	Newton's	V = ((B + 4M + S)/6) L
2	Huber's	V = M L
3	Smalian's	V= ((B + S) /2) L
4	Hossfeld's	V = ((3G + S)/4) L
5	Centroid	V = SL + (1/2) b_1 L^2 + (1/3) b_2 L^3

Where:

V = volume of logs (for all equation)

B = Cross-sectional area at large end of butt log outside bark (m^2).

G = Cross-sectional area at 1/3 of butt log length from the large end of the butt log outside bark (m^2).

M = Cross-sectional area at mid-length of butt log outside bark (m^2).

S = Cross-sectional area at small end of butt log outside bark (m^2).

L = log length (m.)

C = Cross-sectional area at mid volume of butt log (m^2) measured at a distance q from the large end of butt log outside bark.

2.4. DATA ANALYSIS

Three statistical measures were used for a comparison between the equations in terms of accuracy and choose the best mathematical model based estimate butt log volume and middle log volume. The data were processed using the programs (Statgraphics plus: 5) and (Microsoft Excel 2016). For selecting the best-fit formula three criteria were used as follows:

1- Mean Absolute Percent Errors (MAPE).
2- Bias.
3-Two Sample t-Tests.

3. RESULTS AND DISCUSSION

Descriptive statistics refers to a sort of data analysis that not only helps to represent data but also allows us to present it in a more meaningful way, making it easier to comprehend. Table (2) showed the descriptive statistic for butt log and middle log at 0.5 m. these descriptive statistics were from 50 trees selected from the plantation include ((Minimum diameter at 0.3m) smallest tree diameter, (Maximum diameter at 0.3 m) largest tree diameter, average is a mean of tree diameter at 0.3m, for all tree at 0.3 m above the stump), and it's the same for all other variables. Table (3 and 4) showed the descriptive statistic for butt log volume and middle log volume for (control 0.5-m log length section) and all other method at 5-m log length section which include (Minimum volume of butt log, Maximum volume of butt log , average volume of butt log, Variance and standard deviation) and it is the same for middle log.

Table (2): Descriptive statistic for butt log and middle log of *(Eucalyptus camaldulensis*).

Variable	Minimum	Average	Maximum	Variance	S.deviation
$d_{0.30}$	33.4	51.1	75.6	156.50	12.51
$d_{0.80}$	31.5	47.9	77.2	136.25	11.92
$d_{1.30}$	30.2	45.8	75.6	129.41	11.49
$d_{1.80}$	28.3	43.5	71.5	118.97	11.12
$d_{2.30}$	27.0	42.3	71.3	113.13	10.76
$d_{2.80}$	26.0	40.9	68.0	108.23	10.53
$d_{3.30}$	25.3	39.5	67.0	107.03	10.27
$d_{3.80}$	24.1	38.2	66.2	101.80	10.20
$d_{4.30}$	22.3	36.9	64.3	98.12	10.06
$d_{4.80}$	20.8	35.6	62.8	98.71	10.11
$d_{5.30}$	18.7	34.2	58.3	99.59	9.98
$d_{5.80}$	17.1	32.9	57.1	100.33	10.05
$d_{6.30}$	15.8	31.7	55.9	96.26	9.82
$d_{6.80}$	15.1	30.1	53.3	92.43	9.71
$d_{7.30}$	13.5	28.8	53.0	91.87	9.63
$d_{7.80}$	13.2	27.6	51.4	90.93	9.50
$d_{8.30}$	12.7	26.4	50.1	91.16	9.53
$d_{8.80}$	11.1	25.1	50.0	89.07	9.54
$d_{9.30}$	10.3	23.9	48.7	87.82	9.32
$d_{9.80}$	9.6	22.8	47.9	86.66	9.320
$d_{10.30}$	9.0	21.6	46.3	82.43	9.07
H	13.0	18.1	27.0	12.38	3.52

Table (3): Descriptive statistic for control (0.5 m) log length of butt log volume and five deferent formulas at 5 meter above stump ($d_{0.3}$) of (*Eucalyptus camaldulensis*).

Formula	Minimum	Average	Maximum	Variance	S.deviation
Control	0.279640	0.723599	1.925270	0.146595	0.382877
Newton	0.277496	0.730280	1.882950	0.147426	0.383961
Huber	0.265465	0.700017	1.815840	0.136354	0.036926
Smalian	0.301556	0.790805	2.017170	0.172308	0.415100
Hossfeld	0.283011	0.738246	1.938990	0.147193	0.383657
Centroid	0.293243	0.751872	1.989060	0.157718	0.397137

Table (4): Descriptive statistic for control (0.5m) log length of middle log volume and five deferent formulas at 5 meter from ($d_{5.3}$) of (*Eucalyptus camaldulensis*).

Formula	Minimum	Average	Maximum	Variance	S.deviation
Control	0.074478	0.342704	1.064540	0.055716	0.236042

Newton	0.075048	0.341593	1.054430	0.054486	0.233421
Huber	0.068424	0.334228	1.037500	0.054063	0.232515
Smalian	0.088297	0.356321	1.088290	0.055873	0.236374
Hossfeld	0.080121	0.362134	1.088480	0.058326	0.241508
Centroid	0.072923	0.345896	1.083430	0.057876	0.240575

Bias value, mean absolute percent error (MAPE) and test statistics (t- test) for all different methods used for butt log volume estimation of Eucalyptus tree species are given in table (5). Newton's formula gave lower (MAPE) and (BIAS) values than other formulas for butt log volume estimation, (Fonweban, 1997) reported that he was used four log formula (Huber, Smalian, Newton and Average of end-diameters formulae)and the result showed that Newton formula was superior to all other formula and is the least biased, the most precise and the most accurate formula than other formulae while MAPE and bias value of Newton formula were gave (1.734), (-0.00668) respectively. The Centroid method gave (2.538), (-0.01465) mean absolute percent error and bias value respectively. We can say Newton formula and Centroid method are most appropriate formula for estimating butt log volume at 5 meter log length. MAPE of Huber, Hossfeld and Smalian gave higher value than the Newton formula and Centroid methods which were (3.554, 4.098and 9.470) respectively. According to the t-test (two tailed t-test at alpha = 0.05), all formulas for butt log volume estimation were not significant at alpha = 0.05, so there were no difference between control and estimated values for butt log volume estimation. Finally, all of these statistics show that the Newton formula is a more accurate alternative to other methods according to value of (MAPE) for predicting the butt log volume of the Eucalyptus plantation in Khabat district.

Table (5): The Mean Absolute Percent Error (MAPE), bias value and T-test for all deferent methods used for butt log volume estimation at 5-m log length of Eucalyptus tree.

Formula	MAPE	Bias	T-test	P-Value
Newton	1.734	-0.00668	-0.087	0.931
Huber	3.554	0.02358	0.313	0.755
Smalian	9.470	-0.06721	-0.842	0.402
Hossfeld	4.098	-0.02827	-0.362	0.718
Centroid	2.538	-0.01465	-0.191	0.849

Bias value and T-test for all variables defined:(-) indicates an underestimation, (+) indicates an over estimation.

According to the results of average volume (in table 5 and table 6) for each of these formulas, the difference between the lower and upper diameters of the middle log is less than the difference between the lower and upper diameters of the butt log. This indicates that the middle log, which starts from a height limit of 5.3 m to 10 .3 m, is relatively less tapering than the butt log.

As shown in (table 6) the highest values for MAPE and bias were in the Hossfeld (7.058, -0.01943), Smalian (6.720, -0.01362), and Huber (4.406, 0.00848) formulas respectively. While the lowest value in formulas of Centroid (1.688, -0.00319) and Newton (1.981, 0.00111) formulas respectively. It was noticeable that the Bias in Newton's formula was relatively superior to the Centroid formula, while the difference was minor. According to the t-test statistic, all formulas of the middle log volume were not significant at alpha = 0.05.

Table (6): The Mean Absolute Percent Error (MAPE), bias value and T-test for all deferent methods used for middle log volume estimation at 5-m log length of Eucalyptus tree.

Formula	MAPE	Bias	T-test	P-Value
Newton	1.981	0.00111	0.024	0.981
Huber	4.406	0.00848	0.181	0.857
Smalian	6.720	-0.01362	-0.288	0.774
Hossfeld	7.058	-0.01943	-0.407	0.685
Centroid	1.688	-0.00319	-0.067	0.947

Finally, all these statistics indicate that the Centroid method and Newton formula were useful alternatives to other formulas. The Centroid technique was, without a doubt, the most effective than other formulas for estimating middle log volume at 5-m log length of Eucalyptus tree species plantation in Khabat district. On another hand, the Hossfeld formula is the less accurate formula for estimating middle log volume. our result agree with the previous study because most of the previous study Newton and Centroid method were superior to all other method for estimating volume of the log.

4. CONCLUSIONS

According to our result in the present study for estimating butt log volume(5-m log length) of (*Eucalyptus camaldulensis*),we concluded that newton formula has less MAPE and bias value than other methods and Newton formula was a more accurate alternative to other methods for estimating butt log volume of the Eucalyptus tree species plantation in Khabat district, and the Smalian formula was the worst one and for estimating middle log volume (5-m log length) of (*Eucalyptus camaldulensis*),we concluded that the lowest values for MAPE were from the Centroid method, so centroid method was the most accurate formula for estimating middle log volume of eucalyptus tree species in the Khabat district and Hossfeld formula was the worst formula .

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