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[Research]

Determining the best form factor formula for Loblolly Pine (*Pinus taeda* L.) plantations at the age of 18, in Guilan- northern Iran

F. Fadaei, A. Fallah, H. Latifi* and K. Mohammadi

Dept. of Forestry, Faculty of Natural Resources, University of Mazandaran, Sari. Iran.
** Corresponding author's E-mail: taxus22@gmail.com*

ABSTRACT
In order to determine the best form factor formula for Loblolly Pine (*Pinus taeda* L.) plantations in Talesh (Western Guilan province-Iran), a number of 110 trees were selected based on their distribution in diameter classes, from 12 to 34 cm (in a two- cm diameter interval). First, several quantitative factors including diameter at breast height, diameter at 0.65 m of height, and diameter at stump were measured using a diameter tape, just before the trees being felled. After cutting the trees, the heights and diameter from breast height up to the height where diameter is 5 cm was measured using a diameter tape in a two meter interval. Finally, diameter at 0.1, 0.3, 0.5, 0.7, and 0.9 meter of the total height was measured respectively. As a consequent, each tree's volume was precisely calculated as the real volume. Next, the real form factor (f_r) was calculated and its average was statistically compared to the averages of Natural ($f_{0.1}$), Artificial ($f_{0.5}$), and Hohenadl's (f_h) form factors using pair sample T-test. Results showed that there is no significant difference between the averages of real and Hohenadl's form factors (at = 0.01 level). Furthermore, the averages of real and artificial form factors were not significantly different. Hence, both artificial and Hohenadl's form factors are capable to replace the real form factor of Loblolly Pine over the study area.

Keywords: Form factors, Loblolly Pine Plantations, T-test, Guilan.

INTODUCTION
Loblolly Pine (*Pinus taeda* L.) has been considered as one of the exotic- fast growing conifers showing a successful rate of growth in plantations located in the northern Iran. The amount of its wood production has been observed to be almost 23.9 m^3 ha^{-1} per year (Fadaei, 2005). Based on the current available statistics, 2350 ha of the area is currently under Loblolly Pine plantations in northern Iran (Fadaei, 2005). Furthermore, it is predicted that the species can be established in a wide scale of plantations in the region, due to its wide range of applications in wood industry. Regarding the great sum of Loblolly Pine-planted area, developing accurate plans to improve the performance of forestry operations as well as the plantations seems to be essential. In forest utilization, a vast amount of investment is normally allocated to the stand and tree volume assessments. Moreover, the assessment of tree and stand volume in forest planning and harvesting is considered as one of the necessities in forest inventory.

Basically, the tree volume is derived from $V=g\times h\times f$ equation; where "V" is tree volume (in m^3), "g" is basal area at breast height (in m^2), "h" is tree height (in m), and "f" is the tree form factor. Basal area measurement inside the forest stand can be carried out in a relatively cheap and easy way. However, measuring form factor and height is critically time- consuming and expensive work inside the stand. Although the problems associated with height measurement is somehow solved by applying different diameter and height equations and curves, measuring real form factor is still a crucial problem. Real form factor is explained as the real volume divided by the volume of a cylinder having the basal area equivalent to the tree's basal area at breast height and the height equal to the tree's height (Zobeiri, 2000). Therefore, if such a form factor featuring the defined height and Diameter at Breast Height (DBH) can be achieved, the tree volume assessment will be much easier (Zobeiri and Najjaran, 1984). To calculate the Real form factor, the tree should be cut down and its precise volume should be measured. This is considered as a time-consuming and costly work. As a result, forest researchers have proposed a variety of form factor formulas in order to replace with the Real form factor. As a case in point, Girard (1933) and Hohenadl (1936) can be noted.

The amount of precision of these form factors varies based on the site, age, and species. For instance, based on the study by Bruchwald and Grochowski (1977) on 12 even aged *Pinus sylvestris* stands in Poland, Artificial form factor showed to be extensively different in various stands; hence, the stand volume error ranged between -2% and -8%. Heger (1965) and Assman (1970) have mentioned the advantages of total volume estimation using Natural form factor formula derived from Hohenadl's method. Rahim-nejad (2002) studied on 150 Loblolly Pine trees in Lakan- Guilan province in order to replace an appropriate form factor instead of real form factor.

However, as Bonyad and Rostami (2005) reported following a form factor investi-gation of *Pinus elliottii* stands in 25, 27, and 30 year-ages, no significant difference was observed amongst $f_{0.1}$, $f_{0.5}$, and f_r. Thus, they proposed the application of $f_{0.5}$, instead of f_r in tree volume assessment ($V=g\times h\times f$).

The aim of this study is to determine the best form factor in order to replace with the real form factor across the study area.

MATERIALS AND METHODS

The study area consists of 50 ha of Pilambara plantations with Loblolly Pine, which is located in 35 km Anzali-Astara main road (next to the fields of Iran wood and paper company). The area is located in plateau with the approximate altitude of 20 meters above sea level. Annual precipitation of the region is almost 1257 mm; the climate is very wet. Soil is relatively deep with semi-heavy to heavy texture.

The data needed for the study was measured from 110 trees, which were cut as a part of the first thinning operation at the age of 18 years in the area. Regarding the distribution of the trees in diameter classes in the stand, it was decided to select and cut at least 5 to 7 trees in each 2- cm diameter class (Fig 1).

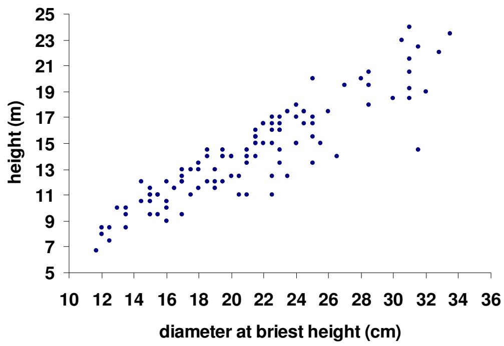

Fig 1. Distribution of the trees in diameter and height classes.

Prior to felling the trees, a couple of quantitative factors were measured as follows: diameter at breast height (1.3 m), collar diameter, and diameter at 0.75 m of height using a diameter tape. Then, the trees were cut from the stump; and their heights were measured from breast height up to the height where diameter becomes 5 cm. The diameters were measured in a 2- meter interval using a tape meter, featuring the precision of decimeter. Furthermore, diameters of the felled trees were measured at 0.1, 0.3, 0.5, 0.7, and 0.9 of the total height. Following the measurment of those quantities, the bellow-mentioned factors were calculated in sequence.

Tree real volume

In order to calculate the tree's real volume, each log's volume was calculated from its stump to breast height using Newton's formula. Then, each log's volume was calculated from its breast height to the height where diameter becomes 5 cm, applying Smalian's formula. Finally, volume of the highest part of each tree was calculated using the cone's volume equation. Then, each tree's real volume was calculated as the sum of all above mentioned log volumes.

Form factor equation

Four different form factors were calculated as follows:

Real form factor

This form factor was calculated using the following equation:

$$f_r = \frac{v}{g_{13} h} \quad (1)$$

Where (f_r) is the tree real form factor, (v) is the tree real volume (in m[3]), ($g_{1.3}$) is each tree's basal area at breast height (in m[2]), and (h) is each tree's height (in m).

Artificial Form factor of the standing trees:

This measure was calculated using the equation as follows:

$$f_{0.5} = \frac{(d_{0.5})^2}{(d_{1.3})^2} \quad (2)$$

Where ($f_{0.5}$) is the Artificial Form factor, ($d_{0.5}$) is the diameter at the half total height, and ($d_{1.3}$) is the diameter at breast height (Zobeiri, 2000).

Natural Form factor

This Factor is derived from the ratio of the real volume to the volume of a cylinder having the same basal area as the tree's basal area at 0.1 of its height, and the same height as the tree's height. The Natural Form factor formula is demonstrated as follows:

$$f_{0.1} = \frac{v}{g_{0.1} h} \quad (3)$$

Where ($f_{0.1}$) is the tree's Natural Form factor, (V) is the tree real volume (in m[3]), ($g_{0.1}$) is the tree basal area at 0.1of its height (in m[2]), and (h) is the tree height (in m) (Philip, 1994).

Hohenadl's Form factor

The standing trees Form factor can be calculated using Hohenadl's formula as shown below:

$$f_h = 0.2\left[1 + \frac{d_{0.3}^2}{d_{0.1}^2} + \frac{d_{0.5}^2}{d_{0.1}^2} + \frac{d_{0.7}^2}{d_{0.1}^2} + \frac{d_{0.9}^2}{d_{0.1}^2}\right] \quad (4)$$

Where (f_h) is Hohenadl's Form factor and ($d_{0.1},....,d_{0.3},d_{0.9}$) are tree diameters at 0.1. 0.3 …0.9 of the height from the bottomrespectively (Zobeiri, 2000).

RESULTS

In the current study, first, the real volumes of 110 trees were calculated as it was explained above. Next, the Real Form factor (f_r), the Natural Form factor $(f_{0.1})$, the Artificial Form factor $(f_{0.5})$, and the Hohenadl's Form factor (f_h) were calculated respectively (Table 1, Fig 2).

Following the calculation, in order to use the statistical T-test, the Normal distribution of the population should be ensured. If the number of samples would be more than 40, the class-frequency would not be less than 2. X^2 test (chi-square) can be used to determine the normal/abnormal statistical distribution (Zar, 1984, and Zobeiri, 2002). Owing to the fact that the amount of calculated X^2 was less than the amount of X^2 in the table (if α= 0.05 level, and the degree of freedom for 9= 16.9), in %95 probability, the null hypothesis which means that there is no significant difference among the data used in the study, is not rejected. In other words, distribution of the trees in % 95 probability is normal for further investigations (Fig. 3). As a consequence, T-test was implemented to the trees studied across the site.

Table 1. Statistical features of Loblolly Pine form factors for 110 measured trees in the study site.

Form factor	No. of Trees	Mean	Standard deviation	Min	Max	CV
(f_r)	110	0.4722	0.05606	0.2306	0.6384	11.9
($f_{0.5}$)	110	0.4628	0.09151	0.2120	0.6849	19.8
($f_{0.1}$)	110	0.5004	0.05571	0.3758	0.6647	11.1
(f_h)	110	0.4704	0.05849	0.2306	0.6384	12.4

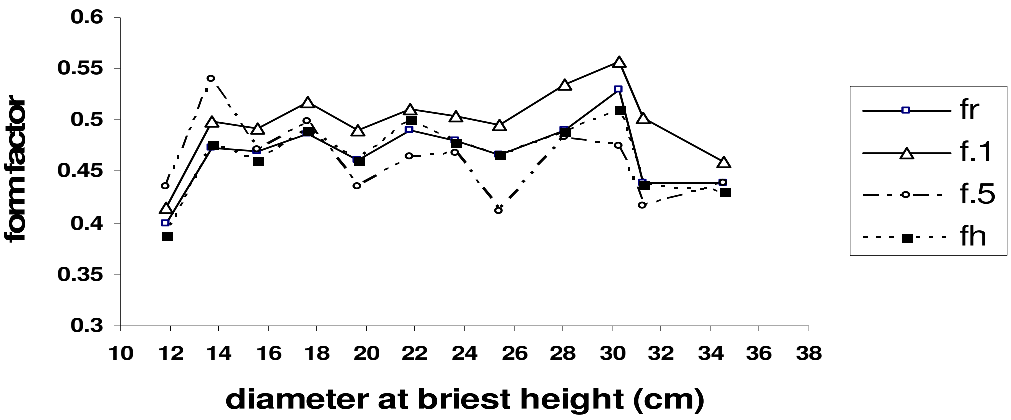

Fig 2. Distribution of Loblolly Pine determined Form factors in Pilambara (at the age of 18 years).

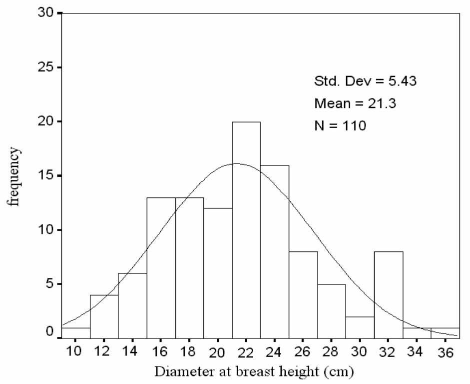

Fig 3. Normal distribution of the population in 2cm diameter classes.

Afterwards, the average of each calculated Form factor was compared to the Real Form factor using pair sample T-test, in order to determine the most appropriate Form factor. The results are shown in table 2.

According to table 2, a significant difference can be observed between the averages of Real and Natural Form factors at 0.01 and 0.05 levels. However, there was not a significant difference between the Artificial and Real Form factors, and also between the Real and Hohenadl's Form factors at the same level.

Following the determination of the proper form factor, the question was: "is it possible to replace the evaluated Loblolly Pine's volume (using $f_{0.5}, f_{0.1,}$ and f_h form factors) with the species' real volume?" Therefore, each tree's volume was calculated using the "$V=g\times h\times f$" formula. The calculated volumes using each of the form factors are shown in table3 and fig 4. In addition, the results of pair sample T-test has been summarized in table 4.

Table 2. Results derived from pair sample T-test of Loblolly Pine Form factors in the study site.

tested Pairs	Mean Difference	Standard error Mean Difference	Degree of Freedom	99% Confidence Level		Colculated t	Observed Significance Level
				Low limit	High limit		
f_r *and* $f_{0.5}$	0.00949	0.00605	109	-0.00637	0.02536	1.569	0.120
f_r *and* $f_{0.1}$	0.02809	0.00316	109	-0.03638	-0.01981	-8.891	0.000
f_r and f_h	0.00181	0.00143	109	-0.00193	0.00555	1.269	0.207

Table 3. Statistical features of Loblolly pine stem volume for 110 measured trees in the study area.

Stem Volume	No. of Trees	Mean	Standard deviation	Min	Max
(V_r)	110	0.27767	0.15433	0.04670	0.6913
($V_{f0.5}$)	110	0.27406	0.15292	0.04757	0.69363
($V_{f0.1}$)	110	0.29353	0.16569	0.05148	0.29353
(V_{fh})	110	0.28039	0.15543	0.04569	0.28039

Table 4.Results derived from Pair sample T-test of Loblolly Pine stem volume in the study.

tested Pairs	Mean difference	Standard error mean difference	Degree of Freedom	99%confidence Level		Calculated t	Sig. Level
				Lower limit	Upper limit		
(V_r) and ($V_{f0.5}$)	0.00362	0.00205	109	-0.00044	0.007671	1.767	0.080
(V_r) and ($V_{f0.1}$)	0.01586	0.00159	109	-0.019003	0.012713	-9.993	0.000
(V_r) and(V_{fh})	0.00272	0.00147	109	-0.00564	0.000199	-1.847	0.067

The results showed that no significant difference can be observed between the real volume and the estimated volumes derived from f_h and $f_{0.5}$, at %1 and %5 levels. However, the difference between the $f_{0.1}$-derived estimated volume and the real volume was significant at 0.01 and 0.05 levels. Moreover, the estimated errors in various classes are shown in fig 5. The estimated errors of the $f_{0.5}$, $f_{0.1}$, and f_h –derived volumes were 0.66, 6.6, and % 1.2 respectively.

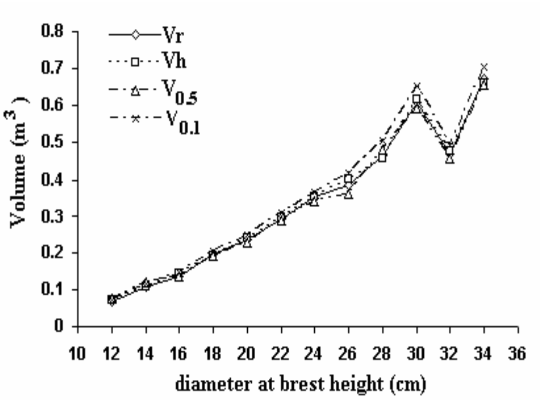

Fig 4. The derived volumes (from fourfold form factors) of Loblolly Pine.

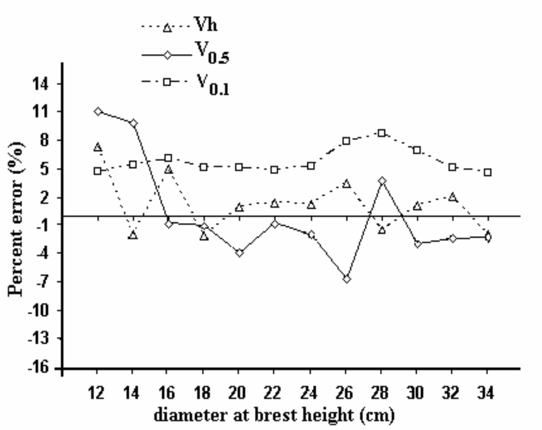

Fig 5. Error distribution of the Loblolly Pine Volumes derived from fourfold form factors.

DISCUSSION

Results of the study showed that there is no significant difference not only between the Artificial and Real Form factors, but also between Real and Hohenadl's Form factors at 0.01 and 0.05 probability levels, at the age of 18 years. In other words, Artificial and Hohenadl's Form factors ($f_{0.5}$ and f_h) are capable enough to replace the Real Form factor (f_r) at the age of 18 years over the study area. However, the Real and Natural Form factors proved to be significantly different at 0.01 and 0.05 levels.

As the previous case studies, no significant difference was observed between the Real and Hohenadl's Form factor (α= 0.05) in the study carried out by Bonyad and Rahimnejad (2004) in Loblolly Pine stands at the age of 26 years. In the other study performed by Mahinpour (2002), in *Pinus elliottii* stands at the age of 27, none of the calculated Form factors proved the capability to replace the Real Form factor.

The amount of accuracy varies based on the site, age, and species. Moreover, the form factor's capability to replace the Real form factor does not guarantee its preference at the tree's all growth levels and ages. Therefore, the results obtained here can hold true only in the studied stand at the age of 18 years. That is mainly because the tree shape highly varies due to its growth. Even sometimes the trees belonging to a particular stand tend to turn into a cone shape from their normal cylinder shape as they grow. Fadaei (2005) studied in Loblolly Pine stands in Pilambara and reported that the Real Form factor in these stands tends to decrease as the stand's age increases. Hence, any sort of changes in the tree's shape can highly affect its Form factor. It results in preference of one Form factor over the others at a particular age.

In this study, a significant difference was observed between neither Artificial nor Hohenadl's and Real Form factors. Nevertheless, the Artificial Form factor showed a great preference over the Hohenadl's Form factor. This is because of the fact that just one diameter higher than the breast height for calculating Artificial Form factor is required to be measured inside the stand for calculating Artificial Form factor. Hence, it can be considered as an effective tool in terms of reducing measurement costs and time.

In addition, the results showed that the volumes yielded from $f_{0.5}$ and f_h were not significantly different from the real volume,and were much less erroneous compared to the volume derived from $f_{0.1}$.

REFERENCES

Assman, E. (1970) The Principles of Forest Yield Study. Pergmon press, Oxford (Translated by S. H. Gardiner), p. 457.

Bonyad, A., Rahimnejad,S. (2004) volume table estimation of loblolly pine in the north of Iran. *Pajouhesh-va-sazandegi*. **66,** 43-47.

Bonyad, A., Rostami shahraji, T. (2005) Study on Slash pine (*Pinus elliottii*) as a short rotation forestry in the North of Iran. *Caspian Journal of Environmental Sciences.* **1,** 55-58.

Bruchwald, A. and Grochowski, J. (1977) Tree Form Factor f1/2 of Scots Pine Stands as a Measure of Stand Taper and as a Basis for Testing the Accuracy of Huber's Method. *SYLWAN.* **121 (12),** 1-9.

Fadaei, F. (2005) Investigating Loblolly Pine Growth in Guilan Plantations Using Stem Analysis (A Case Study of Pilambara-Talesh). MS.c dissertation, University of Mazandaran, Faculty of Natural Resources, p. 96.

Girard, J.W. (1933) Volume Tables of Mississippi Bohomland Hardwoods and Southern Pine. *Journal of Forestry.* **31,** 34-41.

Heger, L. (1965) A Trial of Hohenadl's Method of Stem Form and Stem Volume Esimation. *Forest Chronology*. **41,** 466- 475.

Hohenadl, W. (1936) Die Bestandesmessung. Forstwiss. *Centraldl*. **58,** 51-61.

Mahinpour, M. (2002) Quantitative Investigation and Volume Estimation of Eliotty Pine in Lakan- Guilan. MS.c dissertation, University of Guilan, Faculty of Natural Resources, p. 83.

Philip, M. (1994) Mensuring Trees and Forest. CAB International, p. 310.

Rahimnejad, S. (2002) Quantitative Investigation and Volume Estimation of Loblolly Pine in Lakan- Guilan. MS.c dissertation, University of Guilan, Faculty of Natural Resources, p. 83.

Zar, J.H (1998) Bio statistical Analysis. Prentice Hall Press, N.J-USA. p. 929.

Zobeiri, M. (2000) Forest Inventory. University of Tehran Press, p. 401.

Zobeiri, M. (2002) Forest Biometry. University of Tehran Press. p. 411.

Zobeiri, M. and Najjaran, Gh. (1984) Investigation of Beech Form factor in Veisar Forests- Nowshahr. *Iranian Journal of Natural Resources*. **38,** 33-37.