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Determining the Best Form Factor Formula for Zarbin (*Cupressus sempervirence* var. horzontalis) in North of Iran

Ardalan Ahmadi, Asghar Fallah, Hamid Jalilvand and Yahya Kooch
Department of Forestry, Faculty of Natural Resources,
University of Agriculture and Natural Resources of Sari,
P.O. Box 737, Sari, Islamic Republic of Iran

Abstract: In order to determine the best form factor formula for Zarbin (*Cupressus sempervirence* var. horzontalis) in Kordkoy region (Golestan province-North of Iran), a number 54 trees were selected based on their distribution in diameter classes, from 8 to 28 cm (in a 2 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 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 m of the total height was measured, respectively. As a consequent, each trees 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 hohenadel·s (f_h) form factors using pair sample t-test. Results showed that there is no significant difference between the averages of Real and Natural from factors (at = 0.05 level). Hence, just Natural form factor is capable to replace the real form factor of Zarbin over the study area.

Key words: Form factor, Zarbin, pair sample t-test, Kordkoy

INTRODUCTION

Now days, wood utilization of forest areas is increased that is due to destroy of forests in extensive areas. Therefore, humans are afforesting pay attention to our knowledge and site conditions every region (Husch *et al*., 2003; Dudzinska, 2003; Bonyad and Rostami Shahraji, 2005; Bakhshi and Parsa Pajoh, 2007). Afforestation in Iran is important and essential by reasons of inappropriate climatic conditions, drought more than 80% of Iran soils, extensive of industry, increases of populations, reduction of vegetation and also for rich of forests. Specially, afforestation with needle leaves that have high production of wood and low utilization age, thus afforestation with these species are necessary for securing of wood needs in societies (Rezayee, 1993; Mahinipour, 2002; Lotfalian *et al*., 2007; Rahim Nejad, 2008).

Zarbin (*Cupressus sempervirence* var. horzontalis) is endemic of Iran that areas of its natural stands decreased now days and is forbidden of cut down. Natural habitat of Zarbin is North of Iran (Rezayee, 1993; Lotfalian *et al*., 2007). This species using for afforestation in Iran North and volume increment of this species is between 0.2 to 0.7 m^3 ha^{-1} per year (Rahim Nejad, 2008). This species is afforested in Kordkoy region of Golestan province (North of Iran) with 153 ha^{-1} areas, thus it is understood that for research in relation to afforestation with this species, total and comprehensive information's should be available pay attention to conditions of forest volume.

Corresponding Author: Asghar Fallah, Department of Forestry, Faculty of Natural Resources, P.O. Box 737, Sari, Islamic Republic of Iran Tel: +98 151 224 2984 Fax: +981524222982

In order to determination of forest stand volume, measuring and wood sale and also many other aspects, aware of growing stock are necessary and important (Woodall *et al*., 2002; Zobeiry and Najarian, 2002). Stem form of tree isn't depend to special form, therefore for determination volume every tree proposed different relations (Zobeiry, 2002; Socha, 2002; Zeide, 2005; Socha and Kulej, 2005; Rezayee and Meibodi, 2006). Pay attention to tree stem isn't cylinder, thus, the cylinder volume should be multiply with coefficient for near the volume to real volume of tree. This coefficient is entitled form factor in forest inventory. Form factor is the third characteristic for determine of tree volume with diameter at breast height and height. This coefficient is depended to some of factors such as tree species, habitat, situation in stand and stand density (Namiranian, 2007).

Form factor is ratio of tree real volume to volume of one geometrical form such as cylinder, cone and or truncated cone that its diameter and height are near to tree (diameter of geometrical from is equal to diameter at breast height and its height is equal to tree height). Form factor is different with other inventories of tree forms as form factor should be calculated afterwards calculation of tree volume. Form factor is one method for harmony and relation between tree form and volume. Form factor is calculable for all of trees (stems and branches) and or for tree stem (that is usage for needle leaves) (Zobeiry, 2000).

To calculation of tree real volume, we need to real form factor, but for calculation of real form factor trees should be cut down and theirs real volume should be calculated with measuring of pieces volume of one and 2 m following the real form factor is calculable using real volume of trees (Khoshnava, 2006). Pay attention to calculation of real form factor isn't possible for ever (by reason of high cost) and relations of different form factor are presented with real form factor by many researchers thus with comparison of aforementioned form factor with real form factor, it is possible for selection of it's nearest and replacement of real form factor.

Hejazi (1964), Mexner (2000), Haghverdi (2002), Khoshnava (2006), Lnoue (2006), Socha and Kulej (2007) and Rahim Nejad (2008) obtained the same results in relation to applicable of different form factors instead of real form factor. The aim of this study is to determine the best formula of form factor between presented form factors.

MATERIALS AND METHODS

Study Area

Afforestation area is located in Kordkoy region that situated in Golestan province-North of Iran. Study area is situated 36°C 48' North latitude and 54°C 8' East longitude. The average slope of forest field is about 10% (Min. 5 and Max. 15%). Afforestation areas have covered of loss sediments, dominant soil type is brown with alkaline soil pH. Electricity Conductivity (EC) is low in these stands. Soil texture of study area is loamy. The average annual temperature of study areas is about 17.9°C (Min. -12 and Max. 45°C) and mean annual precipitation is 55.08 mm. Region climate was calculated using of classification formula of amperage (Q = 57.2), therefore, site climate was humidity moderate with dry and cold winters (Anonymous, 2003). This research was performed in the summer of 2007.

Data Collection and Analysis Method

Study area afforested with Zarbin species in 1987 year (with 153 ha^{-1} area and 2×2 m density). Number of 68 sample plots with 200 m^2 areas and rectangular form selected as random- systematic method (with inventory network of 150×150 m). In next level, number of 54 trees cut down (number 4-5 trees in every 2 cm classes). Pay attention to the least and most of diameters were 8 and 29 cm, respectively and 2 cm diameter classes were selected, therefore, numbers of 10 diameter classes were obtained. Diameter at breast height, collar diameter and diameter at 0.65 heights were estimated in every sample plots using diameter tape before cut down.

After cut down, height and diameter at breast height (to 5 cm diameter and with 2 m distance) were measured using of diameter tape and with centimeter precision. Also, tree diameters were measured in 0.1, 0.3, 0.5, 0.7, 0.9 m of tree total height. Under parameters were measured afterwards measuring of aforementioned variables. For calculate of tree real volume Smalian formula (Eq. 1) (Zobeiry, 2000; Namiranian, 2007) was used and afterwards volume of every log was calculated of end to the height where diameter becomes 5 cm. Total of logs volume were incorporated in calculations as real volume every trees.

$$V = \frac{g_1 + g_2}{2} h \tag{1}$$

where, V is log volume (m^3), g_1 is primary basal area (m^2), g_2 is the end basal area (m^2) and h is length of log (m). Real form factor for every tree is equal to ratio of tree volume to cylinder volume that its height is equal to height of tree and its basal area is equal to tree basal area in diameter at breast height that is obtained using Eq. 2 (Zobeiry, 2000; Namiranian, 2007).

$$f_r = \frac{v}{d_{1.3}^2 \times \frac{\pi}{4} \times h} = \frac{v}{g_{1.3} \times h} \tag{2}$$

where, f_r is real form factor of trees, V is real volume for every tree, $g_{1.3}$ is basal area for every tree in diameter at breast height h is tree height. Artificial form factor for stand tree calculated using Eq. 3 (Zobeiry, 2000; Namiranian, 2007).

$$f_{0.5} = \frac{d_{0.5}^2}{d_{1.3}^2} \tag{3}$$

where, $f_{0.5}$ is artificial form factor, $d_{0.5}$ is diameter at middle height of tree, $d_{1.3}$ is diameter at breast height. Also, natural form factor for stand trees calculated using Eq. 4 (Zobeiry, 2000; Namiranian, 2007).

$$f_{0.1} = \frac{v}{v_{0.1}} = \frac{v}{g_{0.1} \times h} \tag{4}$$

where, $f_{0.1}$ is natural form factor for every tree, V is real volume for every tree (m^3) (that is equal to ratio of volume every tree to 2 m logs and calculate volume of every log using Smalian formula), $v_{0.1}$ is cylinder volume that its height is equal to tree height and its diameter is equal to diameter at 0.1 height of tree (m^3) and $g_{0.1}$ is basal area of tree in its height 0.1(m) and h, tree height (m). Hohenadel's form factor was calculated using Eq. 5 (Zobeiry, 2000; Namiranian, 2007).

$$f_h = 0.2\left[1 + \frac{d_{0.3}^2}{d_{0.1}^2} + \frac{d_{0.5}^2}{d_{0.1}^2} + \frac{d_{0.7}^2}{d_{0.1}^2} + \frac{d_{0.9}^2}{d_{0.1}^2}\right] \tag{5}$$

where, f_h is Hohenadel's form factor; $d_{0.1}$, $d_{0.3}$, $d_{0.5}$, $d_{0.7}$, $d_{0.9}$ are diameter at 0.1, 0.3, 0.5, 0.7, 0.9 heights of tree end. In this research tree real volume calculated for number of 54 tree using Smalian formula. Also, real (f_r), artificial ($f_{0.5}$), natural ($f_{0.1}$) and Hohenadel's (f_h) form factors calculated for these trees. Chi-square used for normality test of data at first (Rezayee and Meibodi, 2006). Afterwards, for confidence to normality of data, t-student used for averages of calculated form factors with real form factor in order to determine the best appropriate form factor for Zarbin species.

RESULTS AND DISCUSSION

Aforementioned statistic information's for number of 54 trees that used in this research showed that real volume mean, standard deviation, standard error and inventory error were 0.1893, 0.1312, 0.0178 and 3.53, respectively.

Result of Chi-square test showed that calculated χ^2 is less than of table λ^2 (a = 5% and degree of freedom 4 equal to 4.148) (4.148<9.488). Therefore, at 95% confidence limits aforementioned distribution has no significant differences with normal distribution. Statistic data for calculated from factors shown in Table 1.

Finally, real form factor of Zarbin species in study area compared with artificial, natural and Hohenadel's form factors using of pair sample t-test (Table 2). Therefore, results of this research showed that between mean of Real form factor and mean of Natural from factor has no significant differences at probability level of $\alpha = 0.001$, in other word it is possible for using this form factor instead of real form factor for Zarbin. But, between mean of real form factor with means of Hohenadel and artificial form factors has significant differences at probability level of $\alpha = 0.001$, in other word, it is impossible for using these form factors instead of real form factor for Zarbin. Distribution of determined form factor in diameter classes for Zarbin is shown in Fig. 1, also.

For obtain to Real form factor it is necessary to cut down of trees in order to calculation of theirs real volume (Zobeiry, 2000, 2002; Namiranian, 2007; Rahim Nejad, 2008). To calculate of real volume of tree and with division of it on cylinder volume with the same diameter and height, real form factor of tree will obtain. But, the other form factors aren't need to inventory of cut down trees (Zobeiry, 2000, 2002; Namiranian, 2007). In this investigation, mean of calculates form factors compared with real form factor of Zarbin using pair sample t-test, real, artificial, natural and Hohenadel form factors obtained 0.453, 0.505, 0.475 and 0.519, respectively in this study (Table 1). Results of t-student test showed that the natural form factor has significant differences with real form factor (Table 2), thus it is possible for use of it instead of real form factor so that with performing of simple calculations the real volume of tree be calculated easily.

Mexner (2000) investigated the form factor for pinus species in Poland and resulted that the $f_{0.5}$ has application more than $f_{1.3}$ in less of 2.3 of measured trees. Khoshnava (2006) cut down number of 50 trees and obtained the minute volume of trees using 1 m pieces in order to calculation of real form factor for poplar in Changaz region (North of Iran). Afterwards, with calculated real volume, mean of real form factor obtained 0.4015 and with performing mean calculations, the artificial, natural and Hohenadel form factors were calculated 0.4205, 0.4529 and 0.4542, respectively. Result of her research showed that between artificial and real form factor has no significant differences and it is possible for using of artificial form factor instead of real form factor.

Table 1: Statistic results of form factors for Zarbin in Kordkoy region

Form factor	Mean ($\bar{x}$)	Standard deviation $\pm S_x$ (cm)	Standard error $\pm S_{\bar{x}}$ (cm)	Confidence limit $\pm E\%$ (cm)
f_r	0.453	0.06787	0.009235833	1.810223313
$f_{0.5}$	0.505	0.08890	0.012097361	2.37108253
$f_{0.1}$	0.457	0.06834	0.009299777	1.822756217
f_h	0.519	0.15705	0.021372004	4.188912874

Table 2: Results derived from pair sample t-test for different form factors in study area

Pairs tested	Mean	Standard deviation	Mean of standard error	Confidence limit (99%) Low limit	Confidence limit (99%) Upper limit	Calculated T	Degree of freedom	Observed significant level
f_r-$f_{0.1}$	-0.00369	0.02942	0.00400	-0.01438	0.00701	-0.9200	53	0.361
f_r-$f_{0.5}$	-0.05231	0.09268	0.01261	-0.08601	-- 0.01862	-0.4148	53	0.000
f_r-f_h	-0.06578	0.16184	0.02202	-0.12462	0.00693	-2.9870	53	0.004

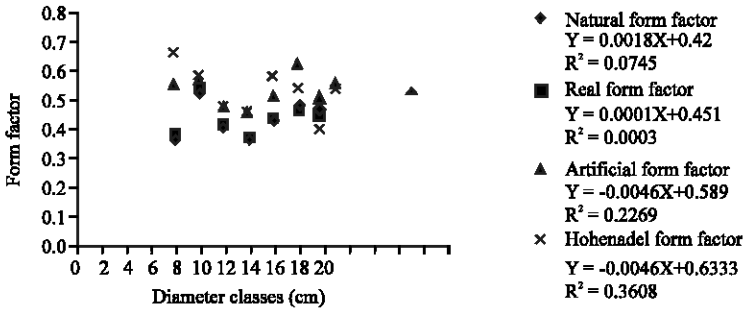

Fig. 1: Distribution of determined form factor in diameter classes for Zarbin in study area

Scocha and Kulej (2007) investigated the difference between form factor in diameter at breast height ($f_{1.3}$) and Real form factor ($f_{0.5}$) for European pinus species in Kornika region of Poland. Result of theirs research showed that $f_{1.3}$ is between 0.441-0.493 and $f_{1.3}$ in five investigated regions had no significant differences. Also, showed significant differences in aforementioned regions. Analysis of variance in theirs research showed that real form factor is depend to diameter and height. Also, difference of real form factor in five geography regions are very high compare with form factor of diameter at breast height.

Rahim Nejad (2008) performed the same research. They obtained the real volume of trees with cut down number of 150 trees and inventory of trees diameter in different heights and mean of real form factor calculated by real volume (f = 0.5202). Mean of artificial, natural and Hohenadel form factors obtained 0.4662, 0.5479 and 0.5121, respectively. These form factors were test with real form factor using pair sample t-test. Results of their research showed that between Hohenadel and real form factors hasn't significant differences, thus it is possible for application of Hohenadel form factor instead of real form factor for this species in study area.

Pay attention to, inventory of tree volume is work with high cost and time, thus it is necessary to determine an form factor that is near to real form factor of tree for calculation of tree volume using simple calculations with high accuracy (Zobeiry, 2000). Although, natural form factor is preventative more minute of stem form but artificial form factor has more application because of in common inventories, diameter at breast height are usable for performing of calculations (Zobeiry and Najarian, 2002; Namiranian, 2007). Determination of natural form factor is an work with high cost by reason of in non-research works if artificial form factor had no significant differences with real form factor is try to using of relations that are on basis of diameter at breast height (by reason of lower cost) and using natural form factor is relinquished (Zobeiry, 2000; Namiranian, 2007).

Any way, the amount of accuracy varies based on the site, age and species. Moreover, a 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. That is mainly because the tree shape highly varies due to its growth (Zobeiry, 2000, 2002; Zobeiry and Najarian, 2002; Namiranian, 2007). 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 Lobally Pine stands in Polimbera 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 trees shape can highly affect its form factor. It results in preference of one form factor over the others at a particular age.

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