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Evaluating the precision of growing stock estimation and determination of industrial and fuel wood volumes of beech trees in northern of Iran

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Abstract

The precision of growing stock were assessed. Industrial & fuel wood volumes of beech trees in Shanderman District was surveyed. For this purpose, 10% of the annual marked trees for loggings were randomly selected in five parcel from this District. After measuring the diameter at breast height (DBH) to estimate the volume of trees by Tariff table, the trees were cut; the volumes of the industrial woods of trees were computed by using Huber's formula. The volume of fuel woods with diameter above 12 cm also were calculated by Huber's method and the diameter below 12 cm were estimated as ester. The results indicated that there were significant differences between estimation of total tree volumes by Tariff table and the total volumes of cut trees at 0.01 confidence levels. The suitable model for relationship between DBH and total volumes was a parabolic model. Industrial and fuel wood volumes of beech trees were 68.9% and 31.1% in the study area, respectively (at 95% confidential). The mean industrial volume of beech trees to total volume was between 61.1% & 76.7% and fuel wood volume was between 26.49% & 35.71%.

Keywords: Beech trees, industrial volume, fuel wood volume, Guilan, Iran.

Introduction

The specific objectives of Forestry are mainly wood production or other services (Hassanzad, 2009) which include two important principles: sustainable yield and maximum yield. Appropriate forestry planning for effective wood resource management depends on precise evaluation of stand volume and trees (Sharma *et al.,* 2002). Such information can guide the forest managers for wood evaluation in a specific location for consumption (Akindele & Lemay, 2006). Accurate evaluation of stand volume in addition to appropriate utilizing management, is considered important (Vallet *et al.,* 2006). For better carbon estimation in France's forest by using of collected data equation demonstrated for volume estimation. Özçelik *et al.* (2010) studied on estimating tree bole volume using artificial neural network models; the results of his study suggested that the selected cascade correlation artificial neural network (CCANN) models are reliable for estimating the tree bole volume. Fabrízzio *et al.* (2011) studied on recursive diameter prediction and volume calculation of eucalyptus trees using multilayer perception networks; the results showed that predictions were close to actual measurements and calculated volumes from the predicted diameters were as good as volumetric equations. Akio *et al.* (2011) determined a two-way volume equation for estimating the apparent Culm volume for *Phyllostachys bambusoides* Sieb; it was a need for distinguishing the volume equation among bamboo species, because of the variability in the culm form. Stem volume of trees actually estimated by using of volume equation (Teshome, 2005). The earlier investigators estimated the standing volume for planted species in Nigeria used by volume equations (Okojie & Nokoe, 1975; Abayomi, 1983; Osho, 1983; Akindele, 1987; Onyekwelu & Akindele, 1995; Akindele, 2003). The most predominant method for volume equation is using from the relationship between volume and variables such as diameter and height (Akindele & LeMay, 2006). Diameter at breast height (DBH), because of its easy measurement, can be a suitable factor to estimate the standing trees volume (Zobeiry, 1994).

Diameter at breast height is one of the important tree's variables in forestry to estimate the volume of the stand trees (Corral-Rivas *et al.,* 2007). Some researchers were used diameter as a base to estimate the stand tree volume (Meyer, 1953; Todhunter *et al.,* 1979; Burkhart & Sprinz, 1984; Silva *et al.,* 1993). Wiant *et al.* (1992) also emphasized on the importance of the standing trees volume estimation. Forestry department and Hawaii's wildlife (1999) also used DBH factor for estimation of bulk volume of stand trees. Aslee *et al.* (1976) cut 220 beech trees and he determined their real volume in two meter pieces and he also provided local volume table for beech species. In another study, with cutting 1218 Beech trees (at different diameter classes) and measuring them in one and two meter pieces in two altitude region provided local volume table for this species (Forestry of Technical Bureau, 1985). Keshavarz (1991) also presented a regression model between volume and diameter for *Pinus teada* plantations in the northwest of Iran. Haghverdi (2001), after cutting and measuring of 424 beech trees, provided best equation for standing beech trees volume estimation. Poorshakoori & Hassanzad (2005) showed that DBH had the highest correlation with industrial volume (0.97) and had the minimum correlation with fuel wood (0.66); on this study, they obtained from total tree volume 84.35 % industrial volume, 12.13 % fuel wood and 3.52 % stump volume. Loetch *et al.* (1973) presented different mathematical formulation in order to provide one-factor volume table (tariff table), standard volume table and three-factor table; they concluded that one-factor volume table was best because of high efficiency, low expanse and high measurement accuracy. Silva *et al.* (1994) used form factor to estimation of standing tree volume and to determine the form factor in two sides of the stems with distance 1.5 and 15.2 meter from ground level diameter of some trees measured. Mexner (1995) was used Huber's formula for measuring volume of harvested trees.

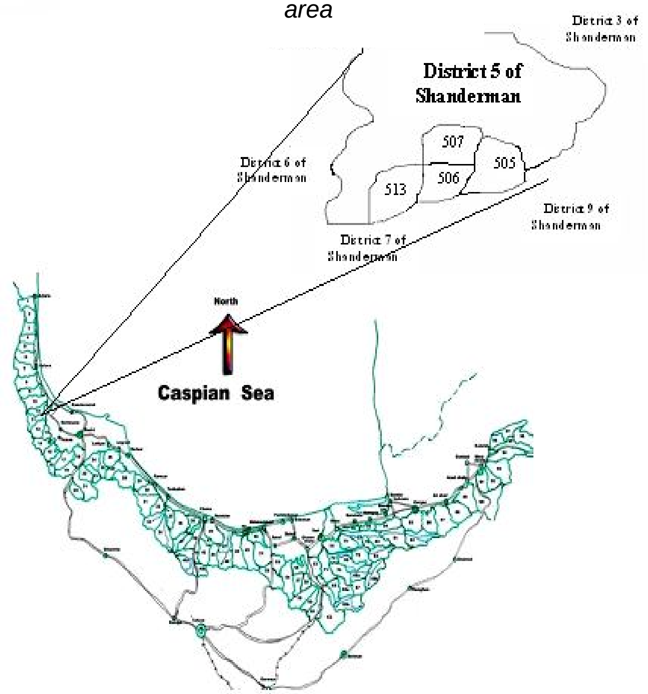
The aim of the present paper is to determine the precision of the used volume table, compare the estimated standing trees volumes (using the volume table) with calculated trees ones after cutting the trees and also find feasible model for estimating total, industrial and fuel wood volume.

Material and methods

Site of study

The study area is located in Shanderman district (watershed 11 from division of watersheds in northern forest of Iran). This forest is exploited and managed by Shafarood Forest Company (in Guilan province). The min elevation from sea level is 450 meter and max is 2200 meter; it's consisted of three forest types: pure beech, beech mixed with hard wood and other mixed hardwoods. Total study area is 2384 ha, directed to northward and pH of soil is variables from 6 to 6.5. Compartments no 505, 506, 507 and 513 of this district (total area 263ha) selected for study purpose (Fig. 1); the elevation from sea level was 1200-1800 m in the north direction. Soil type is

Fig.1. Situation of the study area



brown forest and texture is loam to clay loam with high soil depth and suitable drainage (forestry plan, district 5 Shanderman notebook, 1983).

In order to make precise estimation of trees volume in Shanderman district and also creating a feasible model

Fig. 2. Relationship between DBH (cm) and calculated total tree volume after cutting (m^3)

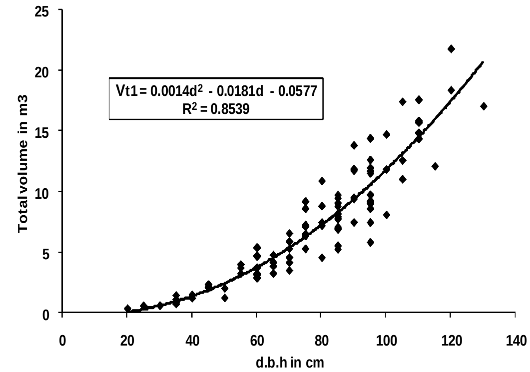


Fig. 3. Relationship between DBH (cm) and total volume of trees derived from volume table (silve)

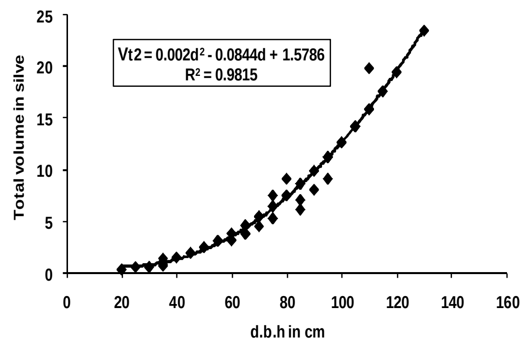


Fig. 4. Relationship between DBH (cm) and industrial volume of trees (m^3)

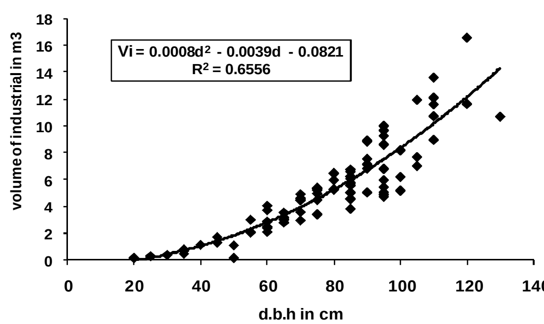


Fig. 5. Relationship between DBH (cm) and fuel wood volume of trees (m^3)

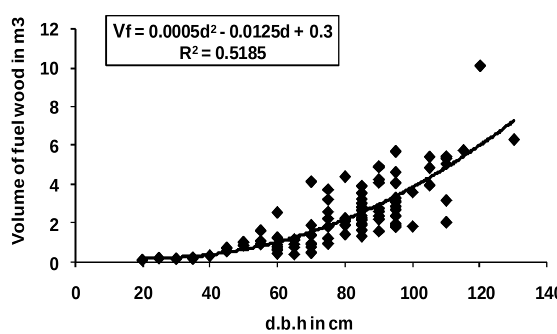


Table 2. T-test for comparing extracted model from volume table and extracted model from calculated volume after cutting of beech trees

Paired samples test	Paired differences					t	df	Sig. 2-tailed
	Mean	Std. Deviation	Std. Error Mean	95% confidence interval of the difference				
				Lower	Upper			
Pair 1 V_{t1} (m^3) V_{t2} (silve)	9.7650	9.7308	1.3242	12.4210	7.1090	7.374	53	.000

Table 3. Validity results of models

Models	Diameter at breast height or DBH(cm)									
	40		45		55		70		85	
	R.V. [1]	M.V. [2]	R.V.	M.V.	R.V.	M.V.	R.V.	M.V.	R.V.	M.V.
$V_{t1} = 0.0014d^2 - 0.0181d - 0.0577$	1.46	1.40	2.06	1.83	3.21	2.99	5.27	5.47	8.74	8.85
$V_{t2} = 0.002d^2 - 0.0844d + 1.5786$	1.46	1.46	2.06	1.96	3.21	3.18	5.27	5.24	8.74	8.72
$V_i = 0.0008d^2 - 0.0039d - 0.0821$	1.7	1.04	1.35	1.36	2.15	2.12	4.52	3.56	6.80	5.37
$V_f = 0.0005d^2 - 0.0125d + 0.3$	0.29	0.28	0.71	0.28	1.06	0.27	0.75	0.25	1.94	0.23
	90		95		100		105		110	
	R.V.	M.V.	R.V.	M.V.	R.V.	M.V.	R.V.	M.V.	R.V.	M.V.
$V_{t1} = 0.0014d^2 - 0.0181d - 0.0577$	9.97	10.18	11.67	10.86	12.96	12.13	14.69	13.28	16.57	14.89
$V_{t2} = 0.002d^2 - 0.0844d + 1.5786$	9.97	9.85	11.67	11.61	12.96	13.14	14.69	14.77	16.57	16.50
$V_i = 0.0008d^2 - 0.0039d - 0.0821$	7.28	6.05	9.72	6.77	8.03	7.53	9.46	8.33	12.17	9.17
$V_f = 0.0005d^2 - 0.0125d + 0.3$	2.69	0.22	1.95	0.22	4.93	0.22	5.23	0.22	4.40	0.23

[1]*Real volume;* [2]*Calculated volume by model*

Table 4. Rate of industrial volume of beech trees in the study area

Wood qua lity	Volume average		Std. Deviation	Std. Error	Confidence limits (0.05)	Real average (μ)	
	M^3	%				M^3	%
Industrial volume	5.675	68.9%	3.106	0.326	0.647	5.028<μ<6.322	61.1%<μ<76.7%
Fuel wood volume	2.562	31.1%	1.824	0.191	0.380	2.182<μ<2.942	35.7%<μ<26.5%

between DBH and determining industrial and fuel wood volumes, 10 percent of trees (102 numbers) were selected randomly from marked annual quota in 505, 506, 507 and 513 compartments from Shanderman district. After measuring DBH, trees have been cut. Then the diameter were measured (each in two meter pieces) and finally industrial log volumes were computed by Huber's formula ($V = G_m * H$). Woods with diameter less than 20 cm were considered as fuel wood and higher than 20 cm considered as industrial wood. Volumes of industrial woods and volumes of fuel woods with 12 cm diameter and higher were estimated by Huber's method (Hewage & Subasighe, 2005). In this formula V = volume (m^3), G_m = middle cross-section of 2 meters pieces (m^2) and H = Length of logs (m). Diameter below than 12 cm computed as ester. Volumes of standing trees were derived from Chooka's tariff table. After calculating industrial and fuel wood volumes for all trees separately, initially the precise trees volumes which derived from table volume were assessed; then distribution points between DBH and total volume were drawn on X, Y-axis. Linear, logarithm, parabolic and exponential models were tested. After the suitable models were gained; the validity of models were assessed; for this purpose, 10% of measured trees were evaluated by selected models and compared with the computed real volumes. For evaluating the significant differences between treatments t-test were used.

Results

The results are presented in Table 1 indicated that there is a significant difference between derived volumes from volume table for standing trees (Vst) and the calculated volume after cutting (Vac) at 0.05 confidence level ($p<0.05$). The min and max of measured DBH in different diameter classes were also 20 and 130 cm.

Relationship between DBH with total, industrial and fuel wood volumes

For relation between DBH and total volume (calculated after cutting trees in m^3) the parabola model of "$V_{t1} = 0.0014d^2 - 0.0181d - 0.0577$ & r = 0.924" (Fig. 2) was suitable than others. While the gained model between DBH and total volume (derived from Chooka's volume table in silve) ($V_{t2} = 0.002d^2 - 0.0844d + 1.5786$ & r = 0.99), was considerably increased correlation coefficient (Fig. 3) and was shown more suitable relation.

In these models d = DBH, V_{t1} = total volume of trees measured after cutting and V_{t2} = total volume of trees derived from Chooka's volume table.

From tested models to determine relation between DBH and industrial volume (V_i) parabolic model of "$V_i = 0.0008d^2 - 0.0039d - 0.0821$) & r = 0.81" (Fig. 4) showed higher correlation, Although the rate of correlation in comparison with relation between DBH and total volume considerably decreased. In this model d = DBH and V_i = total volume of industrial trees.

Among the different fuel wood volume models that assessed, parabolic model of "$V_f = 0.0005d^2 - 0.0125d + 0.3$ & r = 0.72" (Fig. 5) was reliable. In this model d = DBH and V_f = fuel wood volume of trees.

Validity of total, industrial, and fuel wood volumes models

As shown in Table 2, there are significant differences between total volume models of "$V_{t2} = 0.002d^2 - 0.0844d + 1.5786$ & r = 0.99)" and "$V_{t1} = 0.0014d^2 - 0.0181d - 0.0577$ & r = 0.924" of beech trees (p<0.01). The validity of "V_{t2}" model is better than "V_{t1}" (table 3). The Validity of industrial and fuel wood volumes models were also shown in Table 3.

Determination the rate of industrial and fuel wood volumes of beech trees

From total average volume of beech tree in the study area (8.237 m^3), mean industrial volume calculated was 5.675 m^3 (equal to 68.9 percent of total volume) that it is estimating the real mean and probability at 95 percent; mean real industrial volume ranges between 5.028 and 6.322 m^3. In other word probability at 95%, real mean percentage of industrial volume to total volume of tree is between 61.1 and 76.7 percent. Also from total mean volume of beech tree in the study area, mean volume of fuel wood calculated is 2.562 m^3 (equal to 31.10 percent); this is estimation of real mean and probability at 95 percent; mean real fuel wood volume ranges between 2.182 and 2.942 m^3. In other word probability at 95 percent, real mean percentage of fuel wood volume to total volume of trees ranges between 26.49 and 35.71 percent. These results are shown in Table 4.

Conclusions and discussion

The results showed that among the evaluated models for relation between total volume and DBH (such as linear, parabolic, logarithm and exponential models), parabolic model (because of high correlation coefficient) was suitable than the others; similar research done in Asalem coincided with our results (Poorshakoori & Hassanzad, 2005). Fallah (2000) used parabolic model during his study on beech trees in Shastkalateh to determine relation between DBH and total volume; this model showed high correlation coefficient (r = 0.999). There was significant difference between standing trees volumes (derived from tariff table) and computed trees volumes (after cutting trees) at 0.05 confidence level. It is necessary to mention that; used Tariff table for the study area in weight method was extracted from chooka's volume table (Shanderman forestry book, district 5, 1996). In chooka's volume table, trees volume singly estimated separately for different diameter classes. To extract weight Tariff from Chooka's volume table for each diameter class, volume of each tree species at the given class is multiplied by total number of this species to the total number of species. So the sum is equal to the weight Tariff of this diameter class for all species. Estimated volume of total trees by volume table in the study area was 794.51silve and total calculated trees volumes (after cutting these trees) was also 785.75 m^3. In other word, silve coefficient was equal to 0.989. This indicated higher accuracy of the used volume table for estimating the trees volumes in the study area. Also sum of estimated volume from model "$V_{t2} = 0.002d^2 - 0.0844d + 1.5786$ & r = 0.99" was equal to 797.908 silve; because of high correlation coefficient, it were looked as a suitable model. Meanwhile total estimated volume by model of "$V_{t1} = 0.0014d^2 - 0.0181d - 0.0577$ & r = 0.924" was equal to 768.6171 silve, that it has high difference with total estimated volume by used volume table (in silve) and total calculated real volume in m^3 (which obtained after cutting trees). The result of models validity also showed that model of "$V_{t2} = 0.002d^2 - 0.0844d + 1.5786$ & r = 0.99" has higher accuracy than to model of "$V_{t1} = 0.0014d^2 - 0.0181d - 0.0577$ & r = 0.924". For estimating the industrial and fuel wood volumes of beech trees, parabolic models indicated a higher precision; and the industrial volume model of "$V_i = 0.0008d^2 - 0.0039d - 0.0821$ &R^2 = 0.6556" and fuel wood volume model of "$V_f = 0.0005d^2 - 0.0125d + 0.3$ & R^2 = 0.5185" were suitable than others. Although there were no significant differences between real volumes values and estimated volumes by the models, but result of fuel wood model validity showed that the estimated volumes by this model has highly difference with real volumes. Therefore it couldn't be suitable model for relation between DBH and fuel wood volume. Other evaluated models didn't indicate suitable relation between DBH and fuel wood volume.

The results has shown that the mean volume of industrial beech wood in the study area covered 68.90% of total volume and the real mean volume of industrial wood ranges between 61.1 and 76.7% (at 95%). Mean volume of beech fuel wood was also 31.10%; probability at 95%, the real mean volume of fuel wood ranges between 26.49 and 35.71%. Whereas, the volumes of industrial and fuel wood of beech trees have obtained 83.45% and 12.13% in district one of Nav Asalem

(Poorshakoori & Hassanzad, 2005); this difference could be related to site quality. A study proved that Nav Asalem in terms of quality and quantity has better condition and the beech forest stands that have located in the altitude about 1200 m from sea level, trees have the best status (Hassanzad, 2000). The study area is located in altitude between 1200 to 1800 m from the sea level, whereas the compared area (Nav asalem), is located in altitude lower than 1200 m from sea level. Therefore, status of quality and quantity of forest stands in the study area is lesser than Nav asalem. In the study area, tree stem can be rarely observed cylindrical; it can be an important factor for the low industrial volume of beech trees in the study area in comparison to Nav Asalem. It seems, with implementing the scientific principles of Forestry and Silviculture, the percentage of industrial volumes in the study area are increased; this issue needs more study. A study conducted in Cost Erica to estimate industrial volume in agro-forestry system on Cordia alliodora species indicated that 64% of total volumes of trees were related to industrial volumes; if the silviculture operations accomplish accurately in the forest, the percentage of industrial volumes will increase significantly (Somarriba & Beer, 1987).

With respect to evaluation related to parabolic model of "$V_{t2} = 0.002d^2 - 0.0844d + 1.5786$ & $r = 0.99$" in comparison with other models, such as linear, logarithm and exponential models, this model indicated better accuracy for the total volume. In addition to, the model of "$V_{t2} = 0.002d^2 - 0.0844d + 1.5786$ & $r = 0.99$" had shown higher validity than the model of "$V_{t1} = 0.0014d2 - 0.0181d - 0.0577$ & $r = 0.924$". Therefore, because of the high validity of the V_{t2} model and also high precision of this model for estimating tree volumes, it is suggested that this model is more suitable in the study area. The current volume table has also shown for suitable precision.

As an important result in this research, it is emphasized that only by using of DBH factor can be made the volume parabolic model to estimate tree volume with high precision. It is also suggested that the DBH factor in volume models would be used in choice of others; the application of the tariff volume table (one-factor volume table) is easier. Mayer (1953) has suggested parabolic models in their study to estimate relation between DBH and tree volume

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