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Research Paper

Volume table for Loblolly pine (*Pinus teada* L.) in 18 years old in Plantation Pilambara- Talesh (Guilan province)

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Abstract: This study was conducted on Pilambara- Talesh area in the Guilan province (Nort of Iran). The present research have been carried out on suitable volume table for forest Plantations with *Pinus taeda* L. in Pilambara area which 220 trees were selected and felled from different diameter and height classes. Using different volume equations, suitable volume table were prepared based on diameter and diameter-height. The results in this study show that minimum RMSE was relevant to two variable volume models that measured about 0.0332. Moreover, the minimum amount of estimated error relevant to two variable volume table was -2/7% while this amount for one variable volume table measured about -8.01%.

Keywords: *Pinus taeda* L., Plantation, volume table, volume equation

Introduction

Loblolly pine (*Pinus taeda* L.) is one of the main exotic species, having a successful growth in the forests of Guilan province. About 2350 hectares of the forests of the province (until 1989) has been covered by this species (Keshavarz, 1992). In the references, the volume of wood production in 17years old for this species has been estimated 16.4m^3 ha^{-1} yr^{-1} in the study area. (Gorji Bahri, 1995), this avarege of production is significant. In the utilization of the forest, a large share of forest properties include the trees and forest. Particularly, in production planning and exploitation stages, the estimation of tree volume and forest stand are the essential parts of forest inventory. For different purposes, managers, and forest reserchers should be capable of designating the tree volume, before and after cutting .The tree stem, from root to top, does not have particular geometric shape so as its volume to be determined via geometric formulation. (Zobairi, 2005) that's why; there are specific methods for estimation of tree volume (e.g. Newton, Smalian, Huber, etc.). Although each of proposed formula for volume estimation of tree with regard to their geometrical shapes (paraboloid, cylinder, neiloid, conic, etc) is appropriate, but the measurement of volume by means of combinational formula depends upon the cutting and measurement of tree diameter on different height of trees, by which it is time-consuming and expensive task. However, due to conducted analyses for broadleaves and coniferous, the measurement of diameter in five parts of trees, (0.1, 0.3, 0.5, 0.7, 0.9, height of tree) and volume obtained from these methods is the nearest volume to the real volume (Akgur, 1987). But operationally, due to their dependability to variables in the long run, while dealing with a large mass of trees, measuring these factors in standing trees is neither feasible nor advisable. That's why, afterwards, from the many years ago till now, many methods and statistical formulas have been proposed by forest scientists. Formulas taken from statistical methods are empirical methods. However these obtained relations in forest communities enjoy acceptable care, also they are preferred to other methods while dealing with other tree volume computational method. Tree volume equations according to their free variable number are divided to three sections of one; two and multi-variable.for computation of the volume of a single tree, by adding each free variable, the amount of error percentage will be decreased. (Loetseh,et al 1973; Avery &Burkhart,2002) .These results have be taken by Rahimnejad (2002), in *Pinus teada* Plantation and Mahinpour (2002) in pinus elliottii in Lakan district. The main purpose of volume equations is the estimation of exact volume by means of the fewest number of free variables. That's why tree trunk equations in stands with the regular structures is diameter at height, in stands with irregular structures diameter at height and height and for measuring the exact volume of tree ,diameter at height, height with third free variable(for example diameter at 5.7 or at the suitable height) as well. .(Loetseh, et al 1973; Lavuz, 1995) Since the volume table changes as the age changes (Zobairie, 2005) therefore it seems necessary to prepare volume tables for various ages for even-aged stand. The purpose of this study is the study of determining of volume tables and appropriate volume equations for Plantation in study area at the age of 18. In this case Pilambra, Talesh is taken as a study area.

Material and methods

Study area

The study area, Pilambara Plantation area, has been located in the 35km road to Anzali-Astara (beside Wood Complex). Flat plain area, very wet climate, the mean annual rainfall is 1257 mm and altitude is 20 m above the sea level as well . Having partially hefty texture, the soil of the region is relatively deep. Data used in this study were taken from 220 cut trees in the study zone. It should be noted that, there has been no interference in the stand; also the survivability for trees is 35%.

Method

According to the distribution of tree stand in different diametrical and height classes, and even-aged stand, in each class of 2 cm ,at least 10-15 trees were selected and cut.(figure.1) Before cutting the, the diameter at the height of 0.65m and their (DBH) diameter at breast height by calliper were measured respectively. After cutting tree length was measured via meter. Also the diameter of trees, after cutting, height at breast to the top in 2, 4, 6, 8, were measured. The log volume of each tree (from log to dbh) was computed by Newton formula (Loetsch et al, 1973; Philip, 1994).(formula I)

$$V = \frac{(g_1 + 4g_m + g_2)}{6} \times h \quad \text{(I)}$$

After that the volume of all cuts was computed via Smalian formula. (II)(Zobairi,2005)

$$\text{(II)} \quad V = \frac{g_1 + g_2}{2} \times h$$

And finally for computation of volume of final cut, the cone formula was used. (Philip, 1994)

$$\text{(III)} \quad V = \frac{1}{3} \times g_2 \times h$$

In which:
g1 , g2 ,gm is the cross section in down, middle, top of the log(m2) and the height of log (meter) respectively.

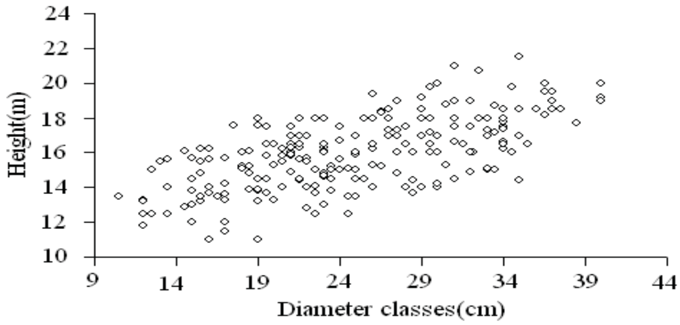

Figure1. The distribution of selected trees in height and diametrical categories

The evaluation of volume models

In this study different volume equations were used. (table.1) for evaluations of each model the information of 220 trees was taken into account. For the evaluation of each model, first the data related to dependent and independent variables were given to SPSS. Then different models have been investigated. For the evaluation of models, selecting best models for data, R2 and root mean square error (RMSE) was used which are as follow:

Table 1. regression models used for determination of the best volume table

Model number	Model	Refrencess
(1)	$V = a + bD^2$	(Kelly & Beltz., 1987)
(2)	$V = aD + bD^2$	(Loetsch et al., 1995)
(3)	$V = a + bD + cD^2$	(Kelly & Beltz., 1987)
(4)	$V = aD^b$	(Brister & Lauer., 1985)
(5)	$LogV = a + bLogD$	(Abbot et al., 1997)
(6)	$LogV = a + bLogD + c(1/D)$	(Loetsch et al., 1995)
(7)	$LogV = a + bLogD + cLogH$	(Rawat et al., 2002)
(8)	$V = aD^2H$	(Kelly & Beltz., 1987)
(9)	$V = a + bD^2H$	(Kelly & Beltz., 1987)
(10)	$V=D^2/(a+bH)$	(Saracoglu, 1998)
(11)	$V = a + bD^2 + cD^2H + dD$	(Avery & Burkhart., 2002)
(12)	$LogV = a + bH^2D$	
(13)	$V = a + bD + cD^2 + dDH + eD^2H$	(Meyer, 1953; Saracoglu, 1998)
(14)	$V = D^2H/(a + bD)$	(Loetsch et al., 1995)
(15)	$LogV = a + bLog(D^2H)$	(Loetsch et al., 1995)
(16)	$V = a(D^2H)^b$	(Bermego et al., 2004)
(17)	$LnV = a + bLnD + cLnH + dDH$	
(18)	$LnV = a + bLnD^2H$	
(19)	$LnV = a + bLnD + cLn(H^2/H - 1/3)$	(Ozcan, 2002)
(20)	$LnV=a+bLnD+cLnH+d(1/D)$	

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(V_i - \hat{V}_i)}{\sum_{i=1}^{n}(V_i - \overline{V_i})}$$

$$RMSE = \sqrt{\sum_{i=1}^{n}(V_i - \hat{V}_i)^2/(n-p)}$$

V is the real volume of the tree, v-; the estimated volume of the model, v¯, the average volume of sample trees, n; number of observation, p is the number of parameter in function.

In the evaluation of models, the best model is the one which enjoys the highest amount of R2.

In this equations is tree volume,(m3),D diameter at breast height (cm),H ,height of tree(meter),Ln natural logarithm ,a,b,c,d,e,f, are the coefficient of equations.

Results

Volume equations based on one variable: At first, one variable equation were made based on volume-diameter, after studying R2 for each model, the RMSE was computed (table.2). Generally, the amount of R2 in one-variable volume models was lower than that in two-variable volume models.

Volume equations based on two variables: Generally, Volume equations based on two variables, v=v(d, h) has got higher R2 in comparison with Volume equations based on one variable. Although in some cases the amount of R2 in Volume equations based on one variable was more than that in Volume equations based on two variables.(as an examole,models,12,14).

Table 2. Evaluation statistics and parameter estimates for the volume equations for Loblolly pine plantation.

models	a	b	c	d	e	R2	RMSE
(1)	-0.058	0.001				0.955	0.2206
(2)	-0.005	0.001				0.956	0.1486
(3)	0.089	0.001	-0.012			0.957	0.1374
(4)	0.0002	2.315				0.963	0.0708
(5)	-3.659	2.315				0.964	0.0578
(6)	-3.361	2.149	-1.559			0.964	0.0579
(7)	-4.485	2.044	0.434			0.985	0.6860
(8)	0.000038					0.985	0.0332
(9)	0.002	0.000038				0.983	0.1052
(10)	-2416.2	253.746				0.931	0.2079
(11)	-0.029	0.000002	0.000035	0.002		0.984	0.0352
(12)	-0.096	0.000077				0.907	0.0801
(13)	0.013	0.0001	0.00002	-0.009	0.0001	0.984	0.0351
(14)	-5533.75	620.698				0.941	0.6401
(15)	-4.499	1.019				0.985	0.0374
(16)	0.000098	0.902				0.978	0.0382
(17)	-11.191	2.209	1.191	0.0001		0.985	0.2581
(18)	-10.359	1.019				0.985	0.0859
(19)	-10.701	2.044	1.101			0.985	0.0861
(20)	-8.916	1.69	1.016	-7.554		0.985	0.0841

Selecting suitable volume equations: After evaluating R2 and RMSE for each of one and two variable(s),models(5) and (8) because of having higher R2 and lower RMSE were selected as the best models of predicting stand volume . Having selected suitable models (one and two-variable), volume table of one and based on diameter at breast height (table3) and diameter-height were made. (table4)

(5) LogV=-3.695+2.315LogD

(8)V=0.000038D2H

Accuracy evaluation of volume table one and two-variable: The volume table based on either of models (5), (8) was calculated. (tables.3&4) for accuracy assessment of volume tables and selecting appropriate volume table for the study area, the data taken from 15 trees not used in volume equation were used. (table5).the estimated error was calculated from following formula:

$$e = \frac{\sum V - \sum V_r}{\sum V_r} \times 100$$

in which e is the percentage of error, v is the real volume of tree(m3) and v is the volume calculated from the volume table. The amount of error for two-variable volume table is more than that in one variable volume table. This amount for one and two-variable volume table was calculated -8.01% and -2.7% respectively, therefore for the estimation of stand volume in this area two-variable volume table has more to do.

Table 3. one variable Volume table for 18 years old *Pinus taeda* L .trees in Pilambra region

Diameter(cm)	Volume(m3)	Diameter(cm)	Volume(m3)
10	0.04529	30	0.57616
15	0.11578	35	0.82323
20	0.22536	40	1.12142
25	0.37777	-	-

Table 4. Tow- variable Volume table for 18 years old *Pinus taeda* L .trees in Pilambra region

	10	12	14	16	18	20	22	24
10	0.038	0.046	0.053	0.061				
12	0.055	0.066	0.077	0.088				
14	0.074	0.089	0.104	0.119				
16	0.097	0.117	0.136	0.156	0.175			
18	0.123	0.148	0.172	0.197	0.222			
20	0.152	0.182	0.213	0.243	0.274	0.304		
22	0.184	0.221	0.257	0.294	0.331	0.368	0.405	0.441
24		0.263	0.306	0.350	0.394	0.438	0.482	0.525
26		0.308	0.360	0.411	0.462	0.514	0.565	0.616
28			0.417	0.477	0.536	0.596	0.655	0.715
30			0.479	0.547	0.616	0.684	0.752	0.821
32				0.623	0.700	0.778	0.856	0.934
34				0.703	0.791	0.879	0.966	1.054
36					0.886	0.985	1.083	1.182
38					0.988	1.097	1.207	1.317
40						1.216	1.338	1.459

Discussion

Loblolly pine is one of the main exotic fast-growing species, having a great place in Plantation of the north of the country. Plantation in the large scale requires accurate pre- planning. Providing volume tables can effectively help managers and researchers in managing of forest stands planting. The results driven from this study revealed that in the study area,(at age of 18 years), two-variable volume table has got more accuracy than one-variable volume table. Loetsch et al (1995) explicated that for the calculation of the volume of single tree, with regard to adding of each free variable, there would be a decrease in error percentage. The results of this study also showed that with regard to adding height to the model, its accuracy would be increased. These results is congruent with studies of Rahimnejad (2002) in Loblolly pine Plantation, Mahinpour(2002) in slash pine Plantation in Lakan, Rasht, too. Although the two-variable volume table has higher accuracy over one-variable volume table, but there is a longer time for measuring volume stand due to its dependability to two factors, namely diameter and height. Therefore the use of one-variable volume table is preferred, but it is recommended to use two-variable volume table for those practical studies which requires high accuracy. It should be noted that there is no age neither cite limitation in using these tables. Thus it is recommended to utilize different ages and vast habitats for determination of volume table.

Table 5. Accuracy evaluation of volume table one and two-variable

Number	Diameter(cm)	Height(m)	Real volume(m3)	estimated volume of one factor table(m3)	estemated volume of two factor table(m3)
1	11	12	0.0465	0.0565	0.0552
2	12	13.3	0.068	0.0691	0.0711
3	14	10.6	0.0696	0.0987	0.0745
4	16	14.5	0.1406	0.1344	0.1449
5	18	15.7	0.1890	0.1766	0.1570
6	22	17.8	0.3889	0.2810	0.3311
7	25	15	0.4228	0.3777	0.3563
8	26	21.5	0.6204	0.4137	0.5394
9	28	17	0.5017	0.4911	0.5065
10	30	21.5	0.7212	0.5762	0.7182
11	32	14.5	0.5930	0.6689	0.5837
12	35	17	0.7290	0.8232	0.7914
13	40	19.2	1.185	1.1214	1.1552
14	37	19.5	1.048	0.9362	1.0404
15	27	18	0.5340	0.4545	0.4986
			7.2578	6.6764	7.0645

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