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Volume equation and volume table of *pinus pinaster* Ait

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Abstract

Logarithmic stem volume equation based on tree height, diameter at breast height (dbh), and on both variables were determined for *pinus pinaster* Ait.Data were measured in kiashahr region (north of Iran, rainfall 1187 mm year^{-1}, 37º , 26' latitude and 49º , 57'longitude), a remnant of the kiashahr plantation, on 102 sample trees which varied between 2 and 35 cm dbh and 2 and 14m height. Least relative standard error of the volume estimation by two-variable model was 10%. The best model was determined as Ln (v)= -10.996 + 1.984 Ln(d) + 1.211 Ln(h^2 / h-1.3), where stem volume (V) is in cubic meters, diameter(d)is in centimeter and height is in meter.

Keywords: *Pinus pinaster* Ait, plantation, volume equation, volume table.

Introduction

About 35% of the world's supply is currently being met from plantation resources occupying about 3% of the world's total forest area. It is expected that plantation will meet 46% of global demand for wood by 2040 (ABARE-Jaakko poyry,1999). *pinus pinaster* Ait is fast growing and promising species that has been growth and expanded successfully in Iran.It covers an area about 1100ha of plantation in the north of Iran(Fadaie ,2002).In literatures,yield of *pinus pinaster* Ait is given as 15m^3 per hectare per year in 23 years of age (Yousef sajadi,1994).Determination of stem volume is a central task in tree and forest mensuration. For various porpuses,the forest manager or researcher must be able to determine the volume quickly before and after the trees being harvested ,and for those which are stil growing.As an only quick and simple measurement it can be carried out in a practical field inventory,the estimation of stem volume should be possible if (1) only tree height has been measured, (2) only diameter at breast height has been measured,or (3) both diameter at breast height and tree height have been measured.To convert these measurements in to stem volume ,models such as volume tables are needed. Volume equations are more general and more flexible models than the tables.common equations for stem volume are in three general types:

V=V(h) (1)
V=V(d) (2)
V=V(d,h) (3)

Where (V) is the stem volume(usually in cubic meter),(h) is the tree height (in meter) from stump to tip and(d) is the diameter at breast height (in centimeter).The purpose of this study is to determine volume equations of types (1) to (3) as well as appropraite volume tables,for *pinus pinaster* Ait.

Materials and Methods

Field data were obtained in a pure even-aged stand located in the kiashahr, in the north of Iran(some information about the site is available in table 1).102 sample trees (fig1)were selected for stem volume determination from each of the diameter classes.The tree were selected based on random sampling method.The smallest trees (dbh<10cm)were measured,standing,by stem length and by diameter at 1m intervals as well as by diameter at breast height.All diameter were measured with a diameter tape.for the medium-sized and large trees (dbh>10cm),the tree diameter as well as the tree height were measured with

direct measurment by climbing.As reference data the diameter at breast height (1.30 m) and at 0.65m were also measured with a diameter tape.The diameter above 1.30 m were measured in 2m intervals.The first but-log volume were calculated using newton's formula and the volume of the rest of logs were calculated using smalian's formula up to 5cm of diameter.after that the volume of the last log were calculated using cone formula.

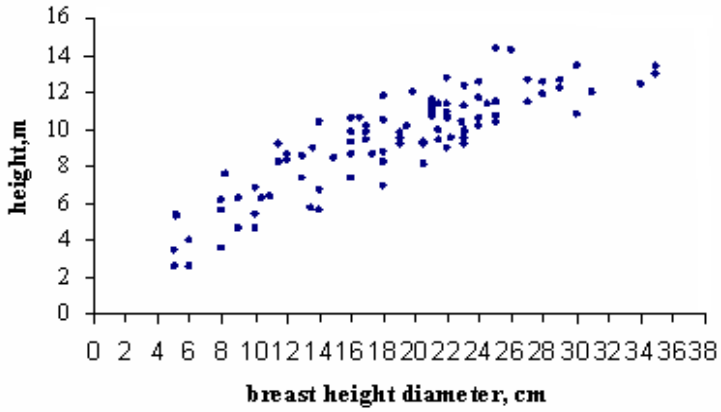

Figure1. Diameter at breast height vs.height relationship for the 102 sample trees.

Table 1. Characteristics of the *pinus pinaster* Ait stand in the kiashahr region,measured in 2002(fadaie,2002)

Area(ha)	Age(years)	Stocking (trees ha^{-1})	Basal area(m^2ha^{-1})	Volume(m^3ha^{-1})	Sample trees measured
8	16	475	10.5	41.44	102

Computation of volume models

In this study,volume equation (type 1,2,3) has been used,table 2 shows a list of these models.

Table 2. mathematical models tried on *p.pinaster* samples to estimate tree volume (sources:Avery.T,2002.plilip.M,1994.Newbold,R.2001,pohjonen,v.1991.ozcan.B,2002.Mcclure,j.1987.kelly,j.1987.Goebel.N.1962.Brister.G.1985.clutter,J.1983.bermejo,I.2004)

number	model
[1]	$V=a+bD^2$
[2]	V=a+bD+cD2
[3]	$V=aD+bD^2$
[4]	$V=aD^b$
[5]	LogV=a+bLogD
[6]	LogV=a+bLogD+c(1/D)
[7]	$V=ae^{bD}$
[8]	$V=a+bh^2$
[9]	$V=a+bh+ch^2$
[10]	$V=ah+bh^2$
[11]	$V=ah^b$
[12]	$V=ae^{bh}$
[13]	$V=aD^2H$
[14]	$V=a+bD^2$ H
[15]	$V=D^2(a+bH)$
[16]	$V=aD^bH^c$
[17]	$V=D^2/(a+bH^{-1})$
[18]	$V=a(D^2H)^b$
[19]	$V=a+bD^2+cD^2H+dH$
[20]	$V=a+bD^2+cDH^2+dH^2$
[21]	$V=a+bD+cD^2+dDH+eD^2H+fH$
[22]	$V=a+bD+cD^2+cDH+dD^2H$
[23]	$V=D^2H/a+bD$
[24]	LogV=a+bLogD+cLogH
[25]	$LogV=a+bLog(D^2H)$
[26]	LnV=a+bLnH+cLnDH
[27]	$LnV=a+bLnD^2H$
[28]	$LnV=a+bLnD+cLn(h^2/h-1.3)$

(V:volume (m^3); D:dbh (cm);H:total height(m);a,b,c,d,e and f are the coefficients of the equations)

Comparison of the models and their reliability

A commonly used yardstick in estimation of reliability of regression models is their coefficient of determination .however,this parameter is not very useful in comparing models for strongly correlated plant

dimensions such as the stem volume ,diameter at breast height and tree height(pohjonen,1990).as a result of outocorrelation , the coefficiency of determination is automatically higher for wider amplitude of the tree charactristics in the measured data(see whittaker and woodwell,1968).in the present study based on the materials and information from the *p.pinaster* trees,the diameter at breast height varied between 2 and 35 cm,the tree height between 2 and 14m and the stem volume between0.0023 and 0.3911 m^3,all of them were strongly correlated to one another.instead of using the coefficient of determination,the reliability of volume and biomass models has recently been studied using the relative standard error of the volume estimate(e.g.Laasasenano,1982 and pohjonen,1991).the standard error of the observed values for the function gives a good picture of the reliability of the equation(Draper and smith,1967) . the relative standard error(s_e) of the volume estimate was approximated with the formula (Vuokila,1960).

$$S_e = 100\sqrt{\sum \left\{\left[\left(V_f - V\right)/V_f\right]^2/(n-1)\right\}}$$

Wher V_f denotes the stem volume calculated with the model and V is the actual stem volume of the tree in question.using this formula,the best model,is known as a model featuring the less amount of relative standard error.

Results

Volume equations based on one variable

One-variable models were used based on the equation between volume-dbh and volume-height at first,after investigation of R^2 for each model, relative standard error was calculated for each of them(table 3).the relative standard error of the volume estimates was rather hight,between 19 and 178%.

Volume equations based on tow variables

The volume equations of two independent variables V= V(d,h) gave the smallest relative standard error for the set of data (table 3).the relative standard error of the volume estimate remained at a level of 10-243% also with the composite models.

Table 3. Evaluation statistics and parameter estimates for the volume equations for maritima pine plantation.

model	a	b	c	d	e		R2	Se
(1)	-0.00696	0.000347					0.89	26.1
(2)	-0.045	0.000235	0.004436				0.894	93.48
(3)	-0.00027	0.000346					0.887	26.79
(4)	0.000028						0.884	29
(5)	-3.96	2.347					0.943	82.21
(6)	-4.724	2.818	2.834				0.946	54.1
(7)	0.00005	2.6168					0.971	19
(8)	-0.04284	0.001893					0.69	187
(9)	0.0094	-0.0131	0.0026				0.69	142
(10)	-0.01094	0.002524					0.69	178
(11)	0.00008	3.2149					0.85	46
(12)	0.0016	0.4277					0.83	87
(13)	0.000029						0.884	19
(14)	0.01789	0.000026					0.897	30.21
(15)	0.000182	0.000013					0.898	21.27
(16)	0.000132	1.435090	1.13386				0.919	21.78
(17)	1733.417	14215.194					0.899	18.1
(18)	0.000173	0.8015416					0.917	23.21
(19)	-0.026	0.0000506	0.000005	0.000606			0.921	53.69
(20)	-0.0107	0.0001704	0.000032	0.000098			0.921	243.46
(21)	0.09855	-0.0114	0.00031	0.002577	-0.000036	-0.0223	0.93	111.31
(22)	0.00397	0.0002463	-0.00529	0.000899	-0.000008		0.921	128.3
(23)	15959.86	696.25085					0.922	19.45
(24)	-4.177	1.777	0.962				0.964	42.3
(25)	-4.168	0.906					0.964	84.4
(26)	-9.618	-0.816	1.77				0.964	22.7
(27)	-9.597	0.906					0.964	17.4
(28)	-10.996	1.984	1.211				0.982	10.3

Selection of the volume equation

The final volume equations were selected on the baisis of the studying the magnitude of the relative standard error of both volume estimates and volume predictions. The models based on two variableles give better reliability than those whit one variable only.finally,the model (28) featuring the less amount of (s_e) was selected as the best model.

$Ln(V)=-10.996+1.984Ln(d)+1.211Ln(h^2/h-1.3)$

Volume table

The volume table of *p.pinaster* Ait were calculated with the selected models(eqn.(28))for all trees.

Table 4. Volume table for 16 years old pinus pinaster Ait.trees in kiashahr region.(Volume to dm^3)

	Height(m)												
	2	3	4	5	6	7	8	9	10	11	12	13	14
2	.126	.310	.485										
3	.222	.540	.485										
4	.347	.841	.858	1.83	3.33								
5	.497	1.21	1.34	1.83	3.34								
DBH 6	.675	1.64	1.92	2.63	4.53								
(CM) 7	.880	2.14	2.55	3.57	5.91	7.17							
8	1.11	2.70	3.40	4.65	7.46	9.10							
9	1.37	3.33	4.29	5.88	9.20	11.12	13.11						
10	1.66	4.02	5.28	7.24	11.11	13.48	15.84						
11		4.78	6.38	8.75	13.20	16.02	18.83	21.63					
12		5.60	7.59	10.40	15.48	18.77	22.07	25.36					
13			8.89	12.19	17.93	21.74	25.56	29.38	33.20	37.01	42.07		
14			10.30	14.12	20.56	24.94	29.31	33.69	38.10	42.44	46.82		
15			11.81	16.19	23.37	28.35	33.32	38.29	43.27	48.24	53.21	58.18	
16			13.43	18.40	26.36	31.97	37.58	44.05	48.79	54.40	60.01	65.62	
17			15.14	20.75	29.53	35.81	42.10	48.37	54.65	60.94	67.23	73.50	79.78
18				23.24	32.87	39.86	46.86	53.85	60.84	67.84	74.83	81.83	88.82
19				25.88	36.39	44.13	51.88	59.62	67.36	75.10	82.85	90.59	98.33
20				28.63	40.10	48.61	57.15	65.68	74.21	82.74	91.27	99.80	108.32
21				31.56	43.97	53.32	62.67	72.03	81.38	90.74	100.10	109.44	118.80
22				34.61	48.02	58.23	68.45	78.45	88.89	99.10	109.32	119.54	129.75
23					52.25	63.37	74.48	85.60	96.72	107.83	118.95	130.07	141.18
24					56.66	68.71	80.77	92.82	104.37	116.93	128.94	141.04	153.09
25					61.24	74.27	87.30	100.33	113.36	126.39	139.42	152.45	165.48
26						80.05	94.09	108.13	122.18	136.22	150.26	164.31	178.35
27						86.54	101.13	116.22	131.32	146.41	161.50	176.60	191.69
28						92.24	108.42	124.60	140.79	156.97	173.15	189.33	205.51
29						98.66	115.94	128.27	150.58	167.89	185.20	202.51	219.81
30							123.76	142.23	160.70	179.17	197.65	216.12	234.59
31							131.81	151.48	171.15	190.82	210.50	230.17	249.84
32							140.10	161.01	181.93	202.84	223.75	244.66	265.57
33								170.84	193.03	215.21	237.40	259.59	281.77
34								180.95	204.45	227.95	251.45	274.95	298.45
35								191.35	216.20	241.10	265.91	290.76	315.61
36									228.28	254.52	280.76	307.01	333.24
37									246.86	268.35	296.02	323.68	351.35

Discussion

p.pinaster Ait ,is one of the species that has been planted in the forested areas of the north of iran, and it has shown a successful result through the years.the rate of it's yield($15m^3$/ha/year)in the north shows it's success.volume table is one of the most important devices for all the forest managers,to investigate the situation of forest for several porpuses.other wise,using these kinds of tables are limited to the determined sites and determined ages.but,it can be helpful for the forest researchers and managers.finally,it's suggested that researchers work out on some higher age and site range,to prerare more comprehensive volume tables.

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