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[Research]

Study on Slash Pine (*Pinus elliottii*) as a Short Rotation Forestry in the North of Iran

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ABSTRACT

Forests of Iran located on the Southern border of the Caspian Sea cover 1.9 million hectares. The Caspian forests are divided into four separate forestry areas. One of these being Guilan influx area with total area of 565000 hectares. About 30 to 40 percent of Guilan province forests are suitable to short rotation forestry for afforestation. Slash pine (*Pinus elliottii*) is one of the main exotic species planted in the Guilan province. The objectives of this research were to estimate: stand parameters, form factors and a provisional volume table of Slash pine planted forest stands. A total of 142 individual trees were randomly sampled. Individual tree variables such as: dbh, height, volume, and form factors (f_{13}, f_m, $f_{0.1}$ *and* f_h) were measured and analyzed. The site index quality of study area, were broadly compared with stands of site index in the southeast USA. The results were shown that the site index quality at the study area in the north of Iran in agreement and parallel with stands of site index is 21m (63 Ft.) in the southeast USA. Therefore, operation of Slash pine is satisfied as short rotation forestry in the Guilan province of Iran.

Keywords: Caspian forests, form factors, Iran, Slash pine, short rotation, volume table, *Pinus elliottii*

INTRODUCTION

The Caspian forests of Iran also called hyrcanian forests are located on the southern borders of the Caspian Sea and cover an area of 1.9 million hectares (Bonyad and Rahimnejad, 2004). The stands in this area are the most valuable and economical forests. The main benefits from these forests are essentially two-fold; its wood production on the one hand and the other various physical and social effects frequently termed forest influence on the other hand. In many instances the latter transcends in importance the significance of forests as wood producers. For forest influence, the Caspian forests are divided into four separate forest management areas. One of these is Guilan influx area with total of 565000 hectares (Bonyad *et al.* 2003). About 30 to 40 percent of Guilan province forests are suitable to afforestation. The different exotic species planted on the low lands of the Caspian region are: *Pinus taeda*, *P. elliottii* and *P. radiata* and in the higher altitudes, *Pinus sylvestris* and *P. nigra* (Bonyad and Rahimnejad, 2004). These species conform to short rotation forestry aspects, which is one of the main aims of the forest plantation in the north of Iran. Slash pine (*P. elliottii*) is one of the hard yellow pines indigenous to southeastern United States. Other names occasionally used for this species include southern pine, yellow slash pine, swamp pine, pitch pine, and Cuban pine (Lohrey and Susan, 2004). It is one of the two southern pines used for naval stores and one of the most frequently planted timber species in North America.

Two varieties are recognized: *P. elliottii* var. *elliottii*, the slash pine most frequently encountered, and *P. elliottii* var. *densa*, that grow naturally only in the southern half of Peninsula Florida (Lohrey and Susan, 2004). *P. elliottii* had significantly the fastest growth and the highest wood density of the commercial species at low altitude in southern Africa. Rodrigo *et al.*, 2004, studied short rotation forestry, on estimated realized gains for first-generation slash pine tree improvement in the southeastern United States. Slash pine is one of the main exotic species, planted in the Guilan province. The objectives of the research are to estimate stand parameters of 25, 27 and 30 years old Slash pine, form factors and a provisional volume table.

MATERIALS AND METHODS

The Slash pine (*P. elliottii*) stands of Siyahkal, Lakan (Rasht) and Talash planted forest stands (120 ha) were selected as study area in Guilan province in the north of Iran. The age of Slash pine planted forest stands were 25, 27 and 30 years old in Siyahkal, Lakan (Rasht) and Talash areas, respectively. The sampling unit was individual of Slash pine tree and in total, 142 single trees were randomly selected. The different variables as: $d_{1.3}$, $d_{0.1}$, $h_{0.3}$, $d_{0.5}$, $d_{0.7}$, $d_{0.9}$, d_c, total height, volume, log diameters and log lengths of each tree were measured. For volume estimation equation, $V = g \times h \times f$ were used. For form factors estimation, following equations were used (Michael 1994):

$$f_{1/3} = \frac{V}{V_{1/3}} = \frac{V}{g_{1/3}h}$$

$$f_{0/5} = \frac{(d_{0/5})^2}{(d_{1/3})^2}$$

$$f_{0/1} = \frac{V}{V_{0/1}} = \frac{V}{g_{0/1}h}$$

$$f_h = 0.2\left[1 + \frac{{d_{0/3}}^2}{{d_{0/1}}^2} + \frac{{d_{0/5}}^2}{{d_{0/1}}^2} + \frac{{d_{0/7}}^2}{{d_{0/1}}^2} + \frac{{d_{0/9}}^2}{{d_{0/1}}^2}\right]$$

Where:

$f_{1.3}$= real form factor, $f_{0.1}$= natural form factor, f_h= Hohenadl form factor, $f_{0.5}$= artificial form factor, V= total volume of tree(m^3), $d_{1.3}$= diameter at breast height (cm), $d_{0.1}$= diameter at 0.1 of total height of tree, ... $d_{0.9}$= diameter at 0.9 of total height of tree, h = total height of tree (m).

The following equations were tested and used for one and two factors volume tables for Slash pine in the study area (Jerrold 1999, Kleinbaum *et al.* 1988, Loetsch *et al.* 1973).

$$V = a_0 + a_1 d + a_2 d^2$$

$$V = ad^{\alpha}$$

$$V = a\left(d^2 h\right)^{\beta}$$

$$V = a_0 + a_1\left(d^2 h\right)$$

$$V = a_0 + a_1 d^2 + a_2 d^2 h + a_3 h^2 + a_4 dh^2$$

$$V = b_0 + b_1 d^2 + b_2 dh + b_3 d^2 + b_4 h$$

$$V = a_0 + a_1 d + a_2 dh + a_3 d^2 + a_4 d^2 h$$

$$\log V = a_1 + b_2 \log d + c \log h$$

RESULTS AND DISCUSSION

Statistical parameters on the measured variables

The statistical parameters $\bar{X}_i$, S_x, $S_{\bar{x}}$ and E% were computed on the measured variables of sampling trees and the results are shown in the Table 1.

Form factors in tree volume estimation. The estimated form factors are used for estimation tree volume using $V = g \times h \times f$. Form factors f_r, f_m, $f_{0.1}$ and $f_{1.3}$, of the Slash pine have computed and defined as follows:

$\sum f_{ri} = 68.1884$

$\bar{f}_r = \frac{\sum f_{ri}}{n} = 0.4802$

$s_{\bar{x}} = \pm 0.005849$

$E = \pm 0.0116$

$E\% = \pm 2.44$

$\sum f_{0.1} = 71.17466$

$\bar{f}_{0.1} = \frac{\sum f_{0.1}}{n} = 0.50123$

$s_x = \pm 0.005502$

$E = \pm 0.011$

$E\% = \pm 2.19$

$\sum f_{0.5} = 69.58$

$\bar{f}_{0.5} = \frac{\sum f_{0.5}}{n} = 0.49$

$s_{\bar{x}} = \pm 0.005781$

$E = \pm t \times s_{\bar{x}} = \pm 0.01156$

$E\% = \pm 2.35$

$\sum f_h = 71.7824$

$\bar{f}_h = \frac{\sum f_h}{n} = 0.50551$

$s_x = \pm 0.00382$

$E = \pm 0.00764$

$E\% = \pm 1.51$

Estimating tree volume using regressions models.

Simple linear regression equation number (1) was computed between two variables diameter (d = diameter) and volume (V = volume) of Slash pine trees and defined as follows:

V= -546722+0.28493531d+ 6.89799795865d^2 **Eq.(1)**

R^2=*0.8449***

Multiple regression equation number (2) was computed between one dependent variable volume (V) and two independent variables diameter (d) and total height (h) of trees and defined as follows:

V=-0.05498786–1.01024638d+0.10071285dh +5.57754332d^2 –0.0291358d^2h **Eq. (2)**

R^2=0.95632**

Growth and yield of planted Slash pine.

The growth and yield of planted Slash pine were analyzed on sampling data in the Siyahkal, Lakan and Talash area. Mean ($\bar{X}_i$) and Mean Annual Increments (MAI) for four variables, diameter, height, basal area and volume of Slash pine were computed and shown in the table 2.

The different variables were measured and analyzed of 25, 27 and 30 years old Slash pine forest stands as short rotation forestry in

Table 1. Statistical parameters on the measured variables of Slash pine

Variables	No. of sampling	$\overline{X}_i$ Cm	S_x Cm	$S_{\bar{x}}$ Cm	± E%
d_c	142	27.876	7.6619	0.6729	2.41
$d_{1.3}$	142	21.8522	5.3421	0.4483	2.05
$h_{0.1}$	142	20.5543	4.7861	0.4016	1.95
$d_{0.3}$	142	17.8956	5.9871	0.5024	2.81
$d_{0.5}$	142	15.0112	4.2372	0.3555	2.37
$d_{0.7}$	142	10.6345	3.3657	0.2824	2.66
$d_{0.9}$	142	5.8975	2.6543	0.2227	3.77
Height	142	18.2156 m	2.2431 m	0.1882 m	1.03
Volume	142	0.3531 m^2	0.1324 m^2	0.0111 m^2	3.14

Guilan province. Form factors f_m, $f_{0.1}$, f_h and f_r were measured and analyzed. The real form factor (f_r) are not statistical significant different with f_m and $f_{0.1}$. Therefore, f_m can be used as f_r in the equation $V = g \times h \times f$ for individual tree volume estimations of Slash pine in study area. Simple linear regression equation number (1) was computed and used to produce one factor tree volume table for Slash pine. The coefficient of variation between dependent variable (V) and independent variable (d) was R^2 = 0.84492

The multiple regression (Meyer model) equation number (2) was computed between one dependent variable volume (V) and two independent variables diameter (d) and total height (h) of Slash pine. In this model the coefficient of variation increased to R^2 = 0.95632. This model was used for two factor volume table of Slash pine in the study area. The results were shown that the computed tree volume tables are applicable to estimate volume of forest stands. The same results obtained on Loblolly pine (Pinus taeda) species study by Rahimnejad (2002). Also, Mahinpoor (2002) showed that, the Mean Annual Increment (MAI) of diameter and height were 0.82 cm and 0.67 meter respectively in the Slash pine forest stands. Lohrey and Susan (2004) were studied on growth and yield and range of estimated annual merchantable volume in unthinned natural stands of slash pine on average sites, 18.3 m (60 ft) at 25 years, by age in the southeastern United States and number of surviving trees as Table 3.

Table 2. Growth and yield parameters of Slash pine

Variables	Age 25 years		Age 27 years		Age 30 years	
	$\overline{X}_i$	M.A.I.	$\overline{X}_i$	M.A.I.	$\overline{X}_i$	M.A.I.
Dbh (cm)	19.25	0.77	21.05	0.78	22.89	0.763
Height (m)	17.15	0.69	17.88	0.66	19.71	0.657
Basal area (m^2/ha)	23.71	0.94	25.82	0.95	27.71	0.92
Volume (m^3/ha)	184.48	7.34	218.42	8.09	243.42	8.11

Table 3. Merchantable yield (m^3/ha) reported by Lohrey and Susan (2004)

Age (year)	741/ha	988/ha	1235/ha
20	109.3 to 147.6	125.5 to 166.7	139.8 to 182.7
25	156.0 to 194.4	175.8 to 218.3	189.4 to 238.1
30	190.2 to 232.8	212.6 to 262.8	230.4 to 287.9

The equation number (1) and (2) were used for one and two factor volume tables of Slash pine in the study area respectively.

The growth and yield of study area in the north of Iran in agreement with stands volume of in the southeastern United States. The site index quality of study area were compared with original site index in the south of USA (Bennett, 1965). Height growth in 19 plantations of Slash pine on the experimental forest in the native area in the southeast USA are shown in the Table 4.

The results have shown the site index quality in the study area in agreement and parallel with forest stands of site index 21m

Table 4. Height growth of Slash pine in the native area in the USA.

Age (year)	PB (No.)	SI (m)	Mh (m)	AG (m)	TT (m)
14	5	22	13.67	0.967	16.67
15	11	23	15	1	19
16	2	23	16	1	2.33
18	1	21	16	0.9	20
Mean	-	22.67	15	1	18.67

PB: Plantation basis; SI: Site index
Mh: Mean height; AG: Annual Growth
TT: Tallest tree

(63 Ft.) in the southeast USA Therefore, operation of Slash pine is satisfied as a short rotation forestry area in the north of Iran.

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