Influences of physiographic factors on growth of Alder stands (*Alnus subcordata*) in north forest of Iran

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Abstract: Generally in old forestry plans, estimation of growth and yield has been processed by static methods without considering effective environmental variables as slopes, aspect (direction of slops), etc. In fact these estimations without taking the dynamic characters of stands into the consideration couldn't interpret actual timber and growth volumes. This study carried out with analysis of Alder stands criteria in physiographic factors in north forest of Iran. The results of statistical analysis showed that altitude less than 400 m in natural stands have minimum dbh growth. Height growth of Alders in natural stands has significant relationship with altitudes. An increase in altitude results in decrease the total height growth, whereas basal area growth decreases when altitude increases. Volume growth in high altitude (1200-1600 m.s.l.) has minimum growth in both plantation and natural area. Maximum growth of dbh (cm) and total height growth (m) in natural stands were seen in west aspect and minimum growth of dbh in natural area related to north, northeast and east and in plantations related to west and south aspects. Maximum volume growth per hectare in natural and plantation area was in northwest and southeast aspects, respectively. Results of growth in different slop showed that in natural stands slop ranged 0 to 15 percent have maximum growth of total height and basal area. Mean comparison of volume growth per hectare indicated that in natural area in low slope (0 -15%) is significantly more than areas with 15 -45% slope.

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1. Introduction

Growth and yield models constricting with consideration of effective ecological variables is useful in the exact estimations of tree's biomass and forest productivity which is effective for harvesting. Harvesting rationalization needs the preparation of growth and yield models base on site proportions, soil and climatic factors, completion in stands, geographical position, elevation from free sea level, and so many other ecological variables. At this way harvesting and silvicultural practices such as thinning, lighting, etc, will be done according to forest reproducibility under sustainable forest management.

Barnes et al. (1998) realized that the groups are used to help distinguish and map landscape ecosystems in the field by their presence or absence and by the relative coverage of plants in each group. They are never used alone, but always with attributes of physiographic, soil, microclimate, and the composition and vigor of overstory trees. Slope position is often used to account for environmental effects associated with landform, such as differences in soil moisture (Helvey et al. 1972). Twenty-three natural red alder stands in western Washington and northwestern Oregon were selected to provide a range in geographic location, site quality, and soil conditions. The information collected on each stand included: (1) elevation, (2) slope, (3) aspect, (4) soil drainage class, and (5) estimated Douglas-fir (Pseudotsuga menziesii (Mirb) Franco) site class (King, 1966).

Comparing distribution of plant ecological groups with topographical factors (i.e. slope, aspect and elevation) revealed that there was significant relationship between aspect and plant ecological group distribution and in some ecological groups with slope, while elevation had no remarkable influence on plant ecological group distribution. In some ecological groups were strongly affected by slope and aspect. For example, in tree and shrub layer some species such as *Ruscus hyrcanus, Alnus subcordata ,Crataegus microphylla* and *Ilxe spinigera* were more frequently distributed in the slopes of 40-70 % and in northeastern aspect in this research, the distribution of different ecological groups was manually compared based on topographical factors (i.e. slope, aspect and elevation). Topography may be sufficient to mark changes in temperature and humidity with increasing altitude. The presences of highland induce orographic rainfall so ecosystem at high altitudes receives more precipitation than low ones (Emberlin, 1984).

Physiographic measurements included elevation, azimuth (defined here as the departure in degrees from due south exposure), slope, position on the slope, profile of the horizon, and proximity of the study tree to a local water supply. Position on slope was rated numerically from 0 (top of slope) to 9 (bottom of slope) based on topographic maps.

In the southern Appalachians, the distribution and growth of trees are highly correlated with local topography, but the relationships have been difficult to describe quantitatively. A quantitative expression of the geometric shape of the land surface (terrain shape index) is described and correlated with overstory tree heights and site quality. Application of the index in three even-aged stands of yellow-popular (*Liriodendron tulipifera* L.) on high-quality uniform sites shows that it is highly correlated with total height of trees in a stand, with r^2 ranging from 0.45 to 0.74. In comparisons among stands, the index accounted for an average of 51% of the variation in site index. The relationship was validated in two supplementary stands and accounted for about 49% of variation in site index (McNab, 1989).

Plot mean relative deviations were plotted against elevation, aspect, slope, and drainage class (Harrington and Curtis, 1986). Multiple regressions were used to identify variables that appeared to influence tree growth. These regression equations are not presented as predictive equations, but rather as summaries of the data and an indication of the amount of variability in tree volume growth that can be accounted for by tree, stand, and physiographic factors (Merrill and Michael, 1986).

2. Materials and Methods

Locations:

This study was carried out in central north forest of Iran in Mazandaran province, south of Caspian Sea. Survey area consists of forest region in south of Sari, Ghaemshahr and Neka. Geographical positions was latitude from 36° 09´ 32˝, to 36° 26´ 14˝ N, and longitude 52° 49´ 05˝, to 53° 28´ 29˝ E with area about 500, 000 hectares and distribute. Sari forest region is about 650.000 ha area and there are on 100 to 2800 m altitude but distribution of *Alnus subcordata* is rang of 100 to 1700 meter from free sea level. The dividing line between lowland forests and mountain forest is the presence of thermophyllous species like *Pterocarya fraxinifolia*, *Parrotia persica*, *Diospyros lotus*, *Albizia julibrissin* and *Gleditsia caspica* in the lowland forests. Other characteristic lowland species are *Alnus glutinosa*, *Quercus castaneifolia*, *Zelkova carpinifolia, Carpinus betulus, Acer velutinum* and *Populus caspica*. There are also some characteristic evergreen species like *Buxus hyrcana*, *Hedera pastuchovii*, *Danaë racemosa* and *Ruscus hyrcanus*. All these evergreens are more or less restricted to the hyrcanian forests.

Survey area is including sub humid and humid areas with cold to temperate winters. Mean precipitation of survey area ranged 600 to 1240 mm. An average precipitation also is 907mm. Mean temperature of entire area is about 14.6°C and absolute minimums and maximum temperature ranged -8.5 to 40°C. Relative humidity in entire survey areas is about 80% and average minimum and maximum of humidity varied between 69 and 90%.

As geological data, survey area was emerged in cretaceous of second geological period as Eocene of Paleocene and Neogan of third geological period including Miocene and Pliocene. This parent materials are sediments of calcareous, siltstone, argillite with accompanied sea sediment as lomashals and some Conglomerate stones.

Usually soil is neutral with pH 6.8 to 8.09, in some part acidic, and mostly mature soil with profile A (B) C until ABC as type of brown forest. The soil texture in the most part of Sari forest region emphasized influence of parent materials (eg. Existence of Marl, calcareous, siltstone and argillite) on soil formation to semi heavy texture (clay loam) to heavy (clay) with 30 to 60 percent clay.

Methods:

The approach of sampling and collecting data of this study is the type of randomize systematic design which number of sample plot calculated according to objectives, time, facilities, budget and accuracy.

At first base on information of Sari Natural Resources Service (e.g. forestry plans notebooks details in parcels and series) we identified the natural and plantation area of *Alnus subcordata* stands. Pilot stag of study was done with visiting of alder stands area and had marked these stands on contour line (25_m) map with 1:50000 scale. Base on pilot survey was shown which alder stands distributions in deferent elevation from 100 to 1700 meter (from free sea level). Next stag of work was done for make the normal distribution of sample in alder stands. Forest area divided in map by rang of 200 meter altitude. These selected stands had covered the most of aspect and distribute homogenous in all area. In next stage in each alder stands was selected one sample plot randomly and forest inventory was done by measuring and filing special forms. Overall 80 sample plot used for collecting data of

Alder stands. Sample plot of survey area is circle shape with area about 500 m^2 and nested form (definition to nested plot) with two parts of macro plot and micro plot (sub-plot). Macro plot is whole part of sample plot with area about 500 m^2 and about 12.60 meters radial. Micro plots are about 50 m^2 area in center of macro plot with 4 meter radial for collecting special data. Measurement of 80 SP, each about 500 m2 areas, in natural and plantation stands of alder was done. Data collections include quality and quantity is shown as mentioned below:

1-Alder trees specification: (total height, diameter at breast height, quality and health of trunk and canopy cover of trees, natural regeneration, etc.)

2-Site's specification was noted (Geographic data such as altitude, soil data, aspect, and slope)

3-Other data (type of forest, land use in neighboring region) was recorded carefully.

Tree and stand parameters calculated by standard formula of volume and SPSS software. Data in each experiment was analyzed by MSTATC software (1999, Ver 2.1) separately by split plot method which had been conducted in Randomized Complete Block Design (RCBD). The means of treatments which had significant differences have been compared by using Duncan's method with 0.95 % accuracy (α = 0.05%).

3. Results and Discussion

Elevation:

Average growth of dbh (cm) in different elevations of natural and forestation stands haven't confidence significant (a=0.05) in different altitude. Results in table 1 showed which means of growth of diameter in all area is about 0.9 cm per years.

Average growths of total height of alders (cm) in different elevations of natural stands have shown that increase of altitude due to decrease of mean of total height growth. Rang of average total height growth is 0.35 to 0.56 m 1600 to 0 above m.s.l. respectively. Altitude was deduced from the topographic maps of the area and categorized into three classes; low (210-399), mid (400- 699) and high (≥700 a.s.l.). In general, tree growth varies in space and time depending on the prevailing climatic conditions and the growing stage of the subject trees (Dawkins 1956, Dickinson et al., 2000). In plantation area there aren't confidence significant (a=0.05) among mean of total height growth in different altitude.

Comparisons of average growth basal area at breast height (m^2) per hectare of Alders in different elevations of natural stands have shown that maximum growth of basal area there in altitude 400 to 800 above m.s.l. about 0.62 m^2 and minimum basal area related to elevation rang 1200 to 1600 above m.s.l. about 0.1 m^2. in plantation stands maximum basal area there in altitude 800 to 1200 above m.s.l. about 2.12 m^2 and minimum basal area related to elevation rang 1200 to 1600 above m.s.l. about 0.85 m^2 per hectare.

Volume growth (m^3) of individual Alders in different elevations of natural stands has shown that increase of altitude due to increase of average growth volume. The most individual tree volume growth recorded in Rang of altitude 1200 -1600 above m.s.l. equal to 0.057 m^3. In plantation area maximum average individual tree volume growth was 0.024 m^3 have observed in ringed of altitude 800 to 1200 above m.s.l.

Volume growth of Alders per hectare (m^3/ha) in different elevations of natural stands have shown that rang of altitude 400 to 800 have maximum annual growth volume about 6.04 and minimum annual growth volume about 0.43 related to elevations rang 1200 to 1600 m.s.l. Mania et al. (2005) showed that tree growth increased with altitude on a large scale across regions, and with disturbance intensity on a small scale at the plot (stand) level. In plantation area maximum average of that volume growth was 19.9 m^3 have observed in rang of altitude 800 to 1200 m.s.l and minimums average of that volume growth was 4.54 m^3 had observed in rang of altitude 1200 to 1600 m.s.l.

Aspects (Direction of slope):

Study on different aspects of natural stands has shown that maximum diameter growth of tree observed in west aspect and minimum diameter growth had seen in east aspect. Despite in plantation stands average growth of dbh was confidence significant (a=0.05) among different aspects. Minimum growth observed in west and south aspect about 7 mm and maximum growth is north aspects about one cm.

Results showed that means of growth of tree heightments in different aspects of natural stands which have shown that maximum diameter growth of tree observed in west aspect (0.42 m) and minimum diameter growth had seen in southwest aspect (0.34 m). Despite in plantation stands maximum average growth related to north aspect (0.92 m). Results of basal area per hectare in different aspects of natural was shown the maximum growth of basal area there northwest aspect (0.67 m^2) per years and minimum related to southwest aspect (0.12 m^2). Maximum average growth of basal area in plantation stand related to east aspect about 2.4 m^2 and minimum basal area growth per hectare related to south aspect with about 0.14 m^2.

Volume growth of individual Alders in different aspects of natural stands was shown in table 4-2 and maximum growth volume there are in southwest and northwest aspects (0.077 and 0.074 m^3 respectively) and minimum mean of volume growth related to south aspect about 0.026 m^3. In plantation stands maximum average volume growth of individual alders related to southeast (0.027 m^3) and minimum of that average related to south aspect (0.006 m^3). Maximum growth volume there are in northwest aspects equal 8.17 m^3 /ha and minimum mean of volume growth related to southwest aspect about 0.44 m^3. In plantation stands maximum average volume growth of alders related to southeast (19.2 m^3/ha) and east (18.9 m^3/ha). Minimum of that average related to south aspect about 0.65 m^3/ha.

Slopes:

Analysis of diameter growth in natural and plantation stands and different slopes showed there aren't confidences significant (a=0.05) in different aspects. Analysis mean of alder total height growth in natural stands and different slopes were shown in areas with low slope (0 to 15 percent) have minimum mean of growth (about 0.39 m). In plantation stands height growth means weren't confidence significant (a=0.05) among slopes (table 3).

Analysis means of basal area growth per hectare in different slopes of natural area shown that maximum amount related to rang of slope 0-15 percent about 0.77 m^2 and minimum basal area there ranges to 30 to 45 percent about 0.1 m^2. In plantation stands weren't shown confidence significant (a=0.05) among slopes. The spatial heterogeneity of ecological conditions was represented using simple environmental information such as altitude, aspect, slope, topographical position in relation to the top and bottom of the ridge, and disturbance level (Vanclay 1989b, Vanclay, 1992).

Also analysis means of volume growth of individual alders in different slop of natural stands were shown high volume of individual alders found about 0.057 m^3 in slopes rang 45 to 60 percent. Minimum average volume growth of individual alders found 0.041 m^3 in slope rang 15 to 30 percents. Means of volume in deferent slopes of plantation stands weren't shown confidence significant (a=0.05) among slopes. Analysis means of volume growth alders per hectare in deferent slop of natural stands shown high growth volume of alders calculated about 9 m^3 in slopes rang 0 to 15 percent. Minimum average volume growth had found 1.65 m^3 per hectare in slope rang 30 to 45 percents. Means of volume in deferent slopes of plantation stands weren't shown confidence significant (a=0.05) among slopes. Gunatilleke et al. (1996) and Veenendaal et al. (1996) in experimental studies of seedling growth also demonstrated that topographic gradients in soil fertility can cause differences in growth of individual species.

Table1: Growth parameters of Alders in different elevations.

		Natural			Plantation		
	Elevation	Mean	Duncan's Group	Number of Sample plot	Mean	Duncan's Group	Number of Sample plot
Annual diameter growth (cm)	0– 400	0.879	B	6	1.053	A	6
	401– 800	0.95	A	6	1.008	A	6
	801–1200	0.953	A	6	1.064	A	6
	1201–1600	0.995	A	6	0.839	A	6
Annual total height growth (m)	0– 400	0.56	A	6	0.76	A	6
	401– 800	0.5	B	6	0.81	A	6

	801–1200	0.44	C	6	0.84	A	6
	1201–1600	0.35	D	6	0.66	A	6
Basal area growth (m^2) per hectare	0– 400	0.166	BC	6	1.36	AB	6
	401– 800	0.62	A	6	1.845	A	6
	801–1200	0.327	B	6	2.12	A	6
	1201–1600	0.101	C	6	0.855	B	6
Volume growth of individual alder trees (m^3)	0– 400	0.031	B	6	0.014	AB	6
	401– 800	0.046	A	6	0.016	AB	6
	801–1200	0.049	A	6	0.024	A	6
	1201–1600	0.057	A	6	0.006	B	6
Average volume growth (m^3) per hectare	0– 400	1.6	C	6	10.3	AB	6
	401– 800	6.04	A	6	14.3	AB	6
	801–1200	3.77	B	6	19.9	A	6
	1201–1600	0.43	C	6	4.55	B	6

Table 2: Growth parameters of Alders in different Aspects.

		Natural			Plantation		
	Aspects	Mean	Duncan's Group	Number of Sample plot	Mean	Duncan's Group	Number of Sample plot
Annual diameter growth (cm)	North	0.92	C	3	1.09	A	3
	Northeast	0.93	C	3	1.09	A	3
	Northwest	1	BC	3	1.05	A	3
	East	0.94	C	3	0.98	A	3
	West	1.13	A	3	0.75	B	3
	South	0.8	D	3	0.82	AB	3
	Southeast	0.99	BC	3	1.07	A	3
	Southwest	1.07	AB	3	1.03	A	3
	North	0.42	BC	3	0.92	A	3

Annual total height growth (m)	Northeast	0.51	AB	3	0.84	B	3
	Northwest	0.42	BC	3	0.8	B	3
	East	0.47	AB	3	0.68	C	3
	West	0.52	A	3	0.45	D	3
	South	0.44	BC	3	0.48	D	3
	Southeast	0.43	BC	3	0.94	A	3
	Southwest	0.34	C	3	-	-	-
Basal area growth (m^2) per hectare	North	0.167	CD	3	1.539	D	3
	Northeast	0.066	D	3	1.832	C	3
	Northwest	0.675	A	3	2.086	B	3
	East	0.215	C	3	2.465	A	3
	West	0.094	D	3	1.693	CD	3
	South	0.472	B	3	0.14	E	3
	Southeast	0.33	BC	3	1.792	C	3
	Southwest	0.126	D	3	-	-	-
Volume growth of individual alder trees (m^3)	North	0.044	BC	3	0.016	AB	3
	Northeast	0.031	D	3	0.015	AB	3
	Northwest	0.074	A	3	0.021	AB	3
	East	0.037	CD	3	0.021	AB	3
	West	0.054	BC	3	0.007	B	3
	South	0.026	D	3	0.006	B	3
	Southeast	0.061	AB	3	0.027	A	3
	Southwest	0.077	A	3	-	-	3
Average volume growth (m^3) per hectare	North	1.66	CD	3	13.1	B	3
	Northeast	0.47	D	3	14.2	B	3
	Northwest	8.17	A	3	18	AB	3
	East	1.27	CD	3	18.9	AB	3
	West	0.65	D	3	9.34	C	3

	South	5.06	B	3	0.65	D	3
	Southeast	3.24	C	3	19.2	A	3
	Southwest	0.44	D	3	14.2	B	3

Table 3: Growth parameters of Alders in different slopes.

		Natural			Plantation		
	Slopes	Mean	Duncan's Group	Number of Sample plot	Mean	Duncan's Group	Number of Sample plot
Annual diameter growth (cm)	0 – 14	0.924	A	6	1.041	A	6
	15 – 29	0.910	A	6	0.996	A	6
	30 – 44	0.943	A	6	1.053	A	6
	45 – 60	1.008	A	6	-	-	-
Annual total height growth (m)	0 – 14	0.395	C	6	0.812	A	6
	15 – 29	0.532	A	6	0.801	A	6
	30 – 44	0.390	C	6	0.770	A	6
	45 – 60	0.463	B	6	-	-	-
Basal area growth (m^2) per hectare	0 – 14	0.772	A	6	1.827	A	6
	15 – 29	0.175	C	6	1.58	A	6
	30 – 44	0.104	C	6	1.917	A	6
	45 – 60	0.525	B	6	-	-	-
Volume growth of individual alder trees (m^3)	0 – 14	0.0479	AB	6	0.0157	A	6
	15 – 29	0.0410	B	6	0.0170	A	6
	30 – 44	0.0453	AB	6	0.0177	A	6
	45 – 60	0.0569	A	6	-	-	6
Average volume growth (m^3) per hectare	0 – 14	9.16	A	6	15.15	A	6
	15 – 29	1.71	C	6	13.99	A	6
	30 – 44	1.65	C	6	16.77	A	6
	45 – 60	5.60	B	6	_-	___-	-

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