National Conference on the Caspian forests of Iran

"Past, Current, Future"

University of Guilan, Rasht, Iran, April 26-27, 2017

Estimation of growth model in uneven – aged forests (Case study: Iranian Caspian forests)

Zohreh Mohammadi[1], Soleiman Mohammadi Limaei[2*], Peter Lohmander[3], Leif Olsson[4]

1- PhD Student in Forestry, Faculty of Natural Resources, University of Guilan, Iran
*Corresponding author's E-mail: limaei@guilan.ac.ir
2- Associate Professor, Faculty of Natural Resources, University of Guilan, Iran
3- Professor, Optimal Solutions in cooperation with Linnaeus University, Sweden
4- Associate Professor, Faculty of Sciences, Technology and Media, Mid Sweden University, Sweden

Abstract

The aim of this study was to estimate a diameter growth model for individual trees in uneven –aged Caspian forests. Three sample plots in the same aspect and of the same forest type were selected. In each sample plot, full callipering was conducted and the parameters such as total tree height, diameter at breast height, distance of neighbor trees and azimuth were measured. In each plot, 30 trees were selected and drilled with increment borer, in order to determine the growth model. Regression analysis was used to estimate the growth model. The analysis shows that, for individual trees, there is a strongly significant nonlinear relation between the annual basal area increment, as the dependent variable, and the basal area of the individual trees. The results also show, that the basal area of competing trees, in the sample, has a positive influence on growth. The estimated result that increment is higher with more competing neighbor trees is probably obtained because of the following reason: The plots with higher volume per hectare, and more "competition", most likely also have higher "site index" or "better soil" or "better forest production conditions" than the plot with lower volume per hectare.

Keywords: Basal area increment, diameter growth, regression analysis, Caspian forests.

Introduction

In forest management the objectives often are achieved by controlling the characteristics of a forest stand or set of forest stands in order to influence the growth and yield of those stands. The availability of information on diameter increment and growth patterns for individual trees is an important asset in forest management which allows the selection of tree species for logging or protection as well as the estimation of cutting cycles and the prescription of silvicultural treatments. Diameter increment measurements are also required to feed statistical models of forest dynamics both for modelling and simulation (Pereira da Silva *et al*., 2002). Schutz (2006) used an incremental growth model based on a basal area oriented density index (GCUM) for pure beech plenter forests. The determination of the optimal stand density ensuring equilibrium uses an incremental growth model based on GCUM. Lohmander (2016) developed an increment diameter model for the optimal stochastic dynamic control of spatially distributed interdependent production units. The Caspian forests are mixed uneven-aged consisting of broadleaf species exploited for timber production according to the forest management plans for over 40 years. There are a few studies dealt with estimation of growth in Iranian Caspian forests, Attarod (1999) investigated and estimated of forest growth in southern and northern aspects at Caspian forests using multivariate statically method. Heshmatol Vaezin *et al*., (2008) provided a pilot increment model for major species in the Caspian forests including Common Hornbeam (*Carpinus betulus L.*), Oriental Beech (*Fagus orientalis*) and Heart Leaved Alder (Alnus cordata) by routinely measured variables in forest inventories, Amini *et al*., (2009) investigated on the homogeneity of diameter increment models in beech Trees. Lohmander *et al*., (2016) estimated basal area growth and volume functions for beech in Iranian Caspian forest. In all of the previous mentioned studies in Iranian Caspian forests, the competitions of neighbour trees were ignored. Hence, the aim of this study was to develop a basal area growth model for uneven- aged considering the competition of neighbour trees in Caspian forests.

Materials and Methods

Study area

This research was conducted in compartment No 320 of district No 3 at Asalem forests, Guilan province in northern Iran. The compartment number 320 of this district with latitude and longitude of 37°39' 30″ to 48° 45' 57″ to 48° 45' 30″ east was selected, respectively (Anonymous, 2006). According to studies by Amanzadeh (2015) in this compartment, three forest types including hornbeam-beech, beech- hornbeam and mixed hardwood were detected. Therefore, the results of his data collection were used in order to find 3 sample plots in the same direction and forest types (Schutz, 2006). In each sample plot, full callipering was conducted and the parameters such as tree total height (m), diameter at breast height (DBH) of all trees with diameter larger than 7.5 cm, distance of neighbour tree (m) and azimuth were measured. In each plot the number and volume per hectare was classified into three diameter classes of lower diameter (< 30cm), "average (30-60 cm) and higher tree (> 60cm). Furthermore, 10 trees in each diameter classes were selected for each plot using the random number tables. Then, the numbers of 30 trees were selected in each plot for the estimation of increment. Increment borer was used to take the samples from individual selected trees. The locations of all trees were specified in 3 plots using Arc Gis 9.3 software In addition, the trees of neighbour from the given tree were determined within a radius of ten meters. The regression analysis for the 3 plots together was performed using Excel

software. Various models were applied on the data. Finally the most appropriate model for all three plots were selected Eq. (1) (based on p value).

$$\frac{db}{dt} \approx \alpha b^{0.5} + \beta b^{1.5} + \lambda b^{0.5} b_c \qquad (1)$$

Where, $\frac{db}{dt}$ or b_{inc} is the basal area increment per year (cm^2/year), as a function of "b", the basal area ten years ago (cm^2). The basal area increment (cm^2) is also affected by "b_c", which is the basal area of smaller & larger competing trees divided by 2 (cm^2) (all within the 10 meter radius circle) (Lohmander, 2016).

Results

Results of regression analysis showed that there is a significant relation between b_{inc} and $b^{0.5}$, $b^{1.5}$, b_c at the significance level of 0.05 $R^2 = 0.92$. The estimated parameters of the regression model based on Eq. (1) are shown in Table 1.

$$\frac{db}{dt} \approx 0.790544 b^{0.5} - 2.5\times10^{-5} b^{1.5} + 2.26\times10^{-5} b^{0.5} b_c \qquad (2)$$

Table1. Estimated parameters of the regression model including competition effects

Variable	Coefficients	Standard Error	t Stat	P-value
Intercept	0	-	-	-
$b^{0.5}$	0.790544	0.05976	13.22857	1.55E-22
$b^{1.5}$	-2.5E-05	6.01E-06	-4.19666	6.51E-05
$b^{0.5}b_c$	2.26E-05	5.77E-06	3.912503	0.000181

The result showed that b_c has positive effects on growth (Table 1), when $b_c = 0$, the function shows the estimated "$\frac{db}{dt}$" (called y in Fig.1) as a function of b (called x in Fig. 1). When $b = 0$, the growth is zero. Growth first increases with b, then decreases, and finally reaches to zero (Fig.1).

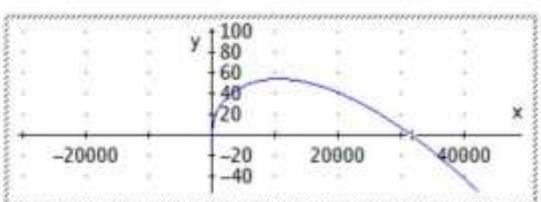

Fig. 1 Basal area increment per year (y) as a function of basal area (x) when $b_c = 0$

Results of regression analysis when the basal area competing trees is zero showed that there is a significant relation between b_{inc} and $b^{0.5}$, $b^{1.5}$ at the significance level of 0.05 $R^2 = 0.91$. The estimated parameters of the regression model based on Eq. (3) are shown in Table 2.

$$\frac{db}{dt} \approx 0.953539 b^{0.5} - 2 \times 10^{-5} b^{1.5} \tag{3}$$

Table 2. Estimated parameters of the regression model without including competition effects

Variable	Coefficients	Standard Error	t Stat	P-value
$b^{0.5}$	0.953539	0.046197	20.64054	1.75E-35
$b^{1.5}$	-2E-05	6.31E-06	-3.14845	0.002242

Discussion

The aim of this study was to develop a diameter growth model for uneven – aged Caspian forests that allows the development and evaluation of growth functions for later improvement of forest management planning. The results indicated that the basal area of competing trees and basal area of ten years ago (cm^2) have positive effects on growth. The positive effect of b_c on growth is usually not expected. When the competing trees are not considered, growth first increases with the basal area ten years ago (cm^2), then decreases, and finally reaches zero. The estimated result that increment is higher with more competing neighbor trees is probably obtained because of the following reason: The plots with higher volume per hectare, and more "competition", most likely also have higher "site index" or "better soil" or "better forest production conditions" than the plot with lower volume per hectare. Most likely, the estimated result that "increment is higher with more competing neighbor trees" really indicates that "the forest production conditions are better in plot 1, than in plot 2 and even better than in plot 3". Observe that it may be very difficult to determine the "production conditions" of the different plots with objective empirical methods. In the function applied in this new analysis, only competition from trees at distances ten meters or closer is considered. The motivation for the new function, used here, is that competition for light, water and nutrients, obviously is stronger from neighbour trees than from trees far away. Furthermore, also smaller trees use some of the available light, water and nutrients (Lohmander, 2016).

Conclusions

Estimations of the growth of individual trees in the Caspian forests of Iran, considering competition, have not been done before. The growth of an individual tree is affected by several internal and external factors. Hence, in future studies, we recommend that such factors are used when growth models are estimated.

Then, the estimated growth equations will be even more reliable as components in forest management optimization applications. For example, the site index is an important factor that influences growth. Unfortunately, there are presently not any site index studies in the Iranian Caspian forest. If such site index information would have been available, we could have used this factor to get more exact results. We hope to estimate such site index based growth models in the future.

References

1. Amanzadeh, B., 2015. Investigation on structure, natural stand development stages and ecological characteristics of conopy gaps in mixed stands of Nav Forests, Asalem. Ph.D thesis of forestry, Sari Agricultural and Natural Resources University, Faculty of Natural Resources, 208 p.
2. Amini, M., Namiranian, M., Sagheb Talebi, Kh. and Amini, R., 2009. Investigation on The Homogenity of Diameter Increment Models in Fagus orientalis L. Trees. Journal of Wood & Forest Science and Technology, 16(4): 1-23.
3. Anonymous, 2006. Forest planning of district 3 of Nav Asalem. Watershed number 7. Department of Natural Resources of Guilan province, 450 p.
4. Attarod, P., 1999. Investigation and statically analysis of forest growth in two ecological using multivariate southern and northern aspects using multivariate statically method, M.Sc thesis, Dept., of Forestry, University of Guilan, Iran, 200p.
5. Heshmatol Vaezin, S.M., Attarod, P. and Bayramzadeh, V., 2008. Tree volume increment models of broadleaf species in the uneven-aged mixed Caspian forests. Asian Journal of Plant Sciences, 7(8): 700-709.
6. Lohmander, P., 2016. Optimal stochastic dynamic control of spatially distributed interdependent production units. International Conference on Mathematics and Decision Sciences September 12-15, 2016, Guangzhou, China.
7. Lohmander, P., Mohammadi Limaei, S., Olsson, L. and Mohammadi, Z., 2016. Optimal forest management based on growth data from the Iranian Caspian forests. 9th International Iranian Operations Research conference, Shiraz University of Technology (IORC 2016) IORC, April 27-29.
8. Pereira da Silva, R., dos Santos, J., Siza Tribuzy, E., Chambers, J.Q., Nakamura, S, and Higuchi, N., 2002. Diameter increment and growth patterns for individual tree growing in Central Amazon. Brazil. Journal of Forest Ecology and Management, 166(1-3): 295–301.
9. Schütz, J.P., 2006. Modelling the demographic sustainability of pure beech plenter forests in Eastern Germany. Journal of Annals of Forest Science, 63(1): 93–100.