OPPORTUNITIES TO INCREMENT VOLUME YIELD ON EVEN-AGED BEECH (*FAGUS ORIENTALIS LIPSKY.)* STANDS

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ABSTRACT

Beech forests like other national forests should be managed in a harmony so as to realize not only the maximum quality and quantity but also the sustainability. Hence, conservative and silvicultural treatments should be based on the local ecological features. For this purpose variations on periodic volume growth of West and Middle Black sea region beech stands to site quality (site index), stand age and basal area were investigated. In beech stands the relationship between periodic mean annual volume increment (iv, m^3/ ha) and stand age is right skew normal distribution shape. Stand basal area has been affected linear to the relationship between volume increment and stand age. Model represents periodic mean annual volume increment into of trees in stand in the rate of about 85 percent (R^2= 0.85) depending on age, site quality degree and stand basal area.

Key words: Beech (*Fagus orientalis* Lipsky.), stand periodic volume increment, site quality degree, stand basal area, multiple regression.

1. INTRODUCTION

It is a well-known fact that the wood demand is increasing day by day and the studies to supply this demand will be conducted in 21th century. Fossil or high costed energy sources could only replace wood. But is clear that these sources are also not renewable. The productivity of the forest and the wood yield for today and in the future should be estimated to manage, plan and utilize effectively and sustainable. The annual volume increment is not always the some and affected by age, environmental factors and genetically features. Thus, methods for estimating stand wood yield and increments are developed. It is possible to determine the impact aspects and degree of important factors on wood increment is possible by statistical methods. The productivity of forest is determined by; site characteristics, tree species and treatments that are applied (Firat 1972;Kalipsiz 1982). Adaptation researches and studies are conducted in our country for covering wood deficit by fast growing exotic species. Unfortunately a rotation period is needed to obtain the results of the studies. Moreover insects, snow, freezing damages are observed which cause problems. It’s also our national forestry objective to protect the species adapted to the environment of our country. For this purpose the sustainability of beech forests should be achieved by proper management activities put forward by science and technology. Despite its importance in our national forestry, forest biometry and forest yield scientists do not study beech enough. Kalipsiz (1962), studied on this issue by taking 29 sample plots in unevenaged and 6 in evenaged stands but the sample plot amount was relatively low. Carus (1998), determined the actual and potential wood amount in hectare which is very important in economic analysis by a normal yield table prepared from 116 sample plots in evenaged beech stands. The purpose of production forests for timber is to product the timber raw material in maximum quality and quantity can be generated by site in perpetuity. For this reason, optimal structure of forests must be known and stand structures must be transformed to optimal structure. The aim of this study was to determine the optimum stand formation and wood yield increment possibilities by investigating the relationship between stand wood yield and stand age, site index and stand basal area. The factors affecting the wood yield increment of a stand should be well known as a first step. In pure beech stands beside volume and site index, age relationship, the volume increment influenced by rotation period, site index and stand density (G) should also be known. The help of these results basic forestry objectives such as productivity would realize economy and sustainability. Beech was chosen for it covers a large area in our country. The results obtained in this research could be used in practice.

2. MATERIAL AND METHOD

2.1 MATERIAL

Beech has a %17.8 in all our deciduous and coniferous high forests (10.934.607 ha). Furthermore it has a 40.8 percent in our broad-leaved forests (1.504.521ha) as the first species. Beech forest also has a growing stock of more than 153 million m^3 and allowable cut of 3.34 m^3, which makes it as one of the most important species in our country. The most important ecological feature of the beech is possibly its resistance to the shadow. It's resistance to shadow, relatively fast growing rate and high spreading canopy it doesn't permit other species to grow especially in good site conditions (Saatcioglu 1971).

2.1.1 Treatment and Management Features

As Kalipsiz (1962), suggested wrong treatments are going on in the management of beech stands. Some main points in management indicated both by the legislation and technical are as follows;

1- In the lack of protection, illegal cuttings and damages could not be avoided. Illegal cuttings should be predicted and subtracted from the planed amount. Overcutting is common owing to these unpredicted illegal cuttings.

2- Enough importance is not paid so far for the interactions with other species. Hence decreases in beech percentage is observed in stands especially in late reforested forests. Beech stands were clearcutted around Bolu in 1960's and replaced by black and scotch pine (Bolu forest subditrict headquarters). However it's good to take lessons from experiences and give the needed attention to beech.

3- In improvement cuttings, the block wood yield is not supplied from all compartments equally but from a few of them. Thus some compartments are not treated and some others overtreated.

4- Huge harvests were performed especially during World War II in order to supply the mine timber in young beech forests (especially middle and west blacksea region). During these cuttings technical forestry objectives and principles were ignored. Thus a lot of clearcutting areas were occurred.

5- Annual wood yield can not be harvested in such places where there are no production and transport opportunities. Hence overgrown and unsuitable trees are formed but the most important thing is the thousands of m^3 wood fortune are left to decay.

2.1.2 Study Area, Determination of Sample Plots and the Measurements Conducted

Beech being one of the unite species of Turkey distributed in Blacksea macro climatic region. In this region three subclimatic regions can be delineated. Eastern blacksea is characterized by mild winters and warm, rainy summers. The middle Blacksea region climate is similar to Mediterranean climate where a water deficit in summer months is observed. Western part of the region is drier and warmer than the eastern Blacksea region both summer and winter beech is generally distributed on volcanic sedimentary, igneous and metamorphic parent material that formed in Kreatese or of after Kreatese (Çepel 1966).

In this study, the volume increment according to stand age, basal area and site index was investigated in evenaged beech forests of West and Middle Blacksea Region. Naturally grown, undisturbed, normally closed, pure and evenaged beech forests were considered. For this purpose 116 sample plots were determined around Istanbul, Zonguldak, Sinop, Kastamonu and Bolu in 1994-1996. The following processes were implemented in the sample plots. The main criterion for choosing the sample plots were the evenaged formation. For doing this "increment cures" taken from 6-10 trees of different diameter classes and least a stem analysis were used. Stand middle age was calculated using to average of breast height reaching age and breast height age. The dimensions and the areas of sample plots were computed. After the determination of the sample plots, diameter of the trees bigger than 4cm were measured. In the sample plots pressler increment borer measured bark and last 10 years ring thickness in 6-20 trees in mm sensitivity. Some chemical materials were tried to enable the ring measurements and Phloroglucinol was found to be the best for this purpose. Blume Leiss was used for measuring the height of trees for determining the site index.

2.2 METHOD

The measured data were stored and processed in computer by using SPSS for Windows Ver 5.0.1 Package software. This software also performed statistical analyses. In the computation of the coefficients and statistics of regression equations are used least squares method. The fitting rate of regression equations was determined by analysis of variance. The correlation coefficients of the equations were investigated – whether 0 or not – using t test. Additionally error variances (SE^2) of regression equations were computed too.

In all sample plots basal area of trees at 4cm diameter steps was beginning with 6cm-class middle value. The addition of basal areas and the multiplication of sampling site by conversion coefficient calculated basal area per hectare. The average diameter and height of 20-30 trees were used to draw the stand height graph in order to determine the site indexes of sample plots. The mean value of diameters on the apsis and the mean values of heights were illustrated on the ordinate so as to balance by least squares method. The help of this curve site obtained indexes of the sample plots. Periodic diameter increments of sample trees were used considering Σid_{kbz} as two times thicker than last 10 years ring thickness. Bark thickness was balanced by regression equations according to diameter at breast height for transforming peeled diameter increment to barked diameter increment. MEYER (1942), had found an equation named (equation 1) after him that gives the annual volume increment of a tree in d_i diameter class in stand that has a volume function of $v = k*d^b$

$$iv = k.d^{b-1}.id \qquad (1)$$

iv= volume increment (m^3/ha/year), id= annual diameter increment (mm/year), d= diameter at breast height (cm), k,b= coefficient.

In our study single entry volume functions of every sample plots should be prepared in order to use the equation above. For this purpose double entry volume function was used (Carus 1998). In sample plots volume of all trees were calculated using diameter and stand height curves. After that by using diameter- volume values single entry volume functions for all sample plots. In that is needed for the computation of volume increment with Meyer's direct method equation was obtained by a statistical model developed by Carus (1998). This model can calculate diameter increment of the trees in sample plots according to stand age, basal area and diameter. Volume increments of all sample plots were calculated by using the formula 1 and 3.

3. FINDINGS AND DISCUSSION

The treatment in a stand that influences the tree growth affects its diameter and volume increment. Regulating the biological and social environment of the tree performs this effect. For the definition of volume increment in the stand, the interaction between the volume increment and age was investigated, then the volume increment was calculated according to the function (iv=f (t,BOD,G)) formed by site index and basal area.

3.1 Stand Volume Increment – Age Interaction

When the annual rings are observed in a tree cross section, the variations among the thickness of rings are seen. Annual ring thickness increment formerly but it begins to decrease after a part. Thus the thickness decrease with the increment in age. It's observed that stand volume increment reaches the peak value between 30-70 ages and then decreases (Firat 1972; Kalipsiz 1982). It can be seen at the volume increment- age graph derived from the data obtained from sample plots.

3.2 Stand Volume Increment – Site Index Relation

In our study sample plots are differentiated to site index classes so as to examine the relation between site index and annual volume increment– age interaction. To see it clearly, volume increment- age points of sample sites that have site indexes of II and IV are carried to coordinate system with different symbols.

In the distribution graphic values representing II nd site index were higher than IVth site index. This indicates that site index has an influence on volume increment–age interaction. It's an expected situation for IInd site index to be higher always. This may be caused the more basal area in good site index.

3.3 Stand Volume Increment- Basal Area Interaction

One of the factors that affect volume increment is the diameter increment at breast height. The relation between diameter and diameter increment is expressed with a linear equation below (Kalipsiz 1984).

$$id = a + b * d_{130} \qquad (2)$$

The slope of the line calculated with these equation changes with the stand age. In young and closed stands this line rises sharply. In the middle aged stands the slope of the line decreases where it becomes nearly horizontal in old stand. These lines can be considered as the tangents of a gaussion curve. In young stands where an essential struggle between the trees is common, the rational diameter increment difference between the diameter increment of the trees found to be great and as a consequence diameter – diameter increment line rises more vertical (Kal?ps?z 1984). As the sample plots were untreated and the beech species had a shadow resistant characteristic, thin individuals could be seen. For this reasons the diameter– diameter increment relation were expressed with a nonlinear model (equation 3) although the stands in our study were evenaged (Carus 1998).

$$\Sigma id = e^{(a0+a1*t+a2*\ln t)+(a3+a4*t+a5*\ln t)*d+(a6+a7*t+a8*\ln t)*d**2+} \\ [(a9+a10*t+a11*\ln t)+(a12+a13*t+a14*\ln t)*d+(a15+a16*t+a17*\ln t)*d**2]*G$$

(3)

Σid=diameter increment (mm/10 year), t=stand age (year),d=diameter at breast height (cm), G= stand basal area (m^2/ha), ln= natural logarithm, e=2.718, a0,a1,…,a17= coefficient.

In our study for understanding the influence of stand basal area to volume increment- age relation, periodic mean annual volume increment- age values of sample plots that have 25-35 and 45-55 m^2/ha two basal area classes were scattered on the coordinate.

It's inferred from the figure that the sample plots with bigger basal area (45-55 m^2/ha) have higher volume increment values than smaller stands in the same age. This shows that the basal area has an influence on annual volume increment – age interaction. The higher volume increment of stands that have bigger basal areas may to result from the better site index. Stand density had a similar influence on volume increment – age relation as site index. Owing to this parallel impact, it is inevitable to add basal area into the model that would represent volume increment – age relation.

3.4 Volume Increment – Age, Site Index and Basal Area Relation

It's not generally logical to interest volume increment as affected only by age because there are some other factors such as stand density and site index. In this study many models had been tried including these factors but a regression equation considering stand density (basal area), age and site index as free variables was preferred (equation 4). Variations in the volume increment of sample plots due to site index and basal area were determined although they were in the same age. The stands that have better site indexes would have more basal areas, thus stand density and site index would affect would volume increment age interaction in the same age. Based on the data obtained from evenaged beech sample stands, it is found that volume increment- age relationship was a right skewed gaussion curve . Gamma distribution was preferred as the model.

$$S\ iv = e^{(\beta 0+\beta 1*t+\beta 2*\ln t)} \quad (4)$$

With such a model volume increment – age relation can be defined. As the coefficients of this model are related to BOD as b0= a0+a3*BOD, b1=a1+a4*BOD, b2=a2+a5*BOD the following model (equation 5) could be obtained.

$$\Sigma\ iv = e^{(a0+a1*t+a2*\ln t)+(a3+a4*t+a5*\ln t)*BOD} \quad (5)$$

Considering the influence of basal area on volume increment, age and site index as linear model 6 is found. Model would give the annual volume increment of the sample plots.

$$\Sigma iv = e^{(a0+a1*t+a2*\ln t)+(a3+a4*t+a5*\ln t)*BOD+[(a6+a7*t+a8*\ln t)+(a9+a10*t+a11*\ln t)*BOD]*G} \quad (6)$$

Σiv= periodical mean annual volume increment (m^3/ha/ year), t= stand age (year), BOD= site index degree (relative site index $0.0 \leq BOD \leq 1.0$).

The help of these models estimated the volume increment in the next period. Coefficient and statistics of regression equation belongings to model 4-5 and 6 are given in Table 1. Statistics of the regression equations were found to be reliable. For example, model 6 the possibility of correlation coefficients to be zero is less than %0.1 because the critical value $t_{0.001;105}= 3.386$ is found to be less than 24.042. Fitting the data in $F_{0.001;10;105}= 2.279<F= 57.8003$ the model has a significance level higher than %0.999. Values respectively derived from the regression equation (equation 6) defining the influence of 5 site index class, 20m^2 stand basal area and 10 year age classes on volume increment (table 2).

4. RESULTS AND PROPOSALS

In this study the influence of stand age, site index and basal area on volume increment is investigated, because the productivity of forest is affected by site conditions, tree species and the treatments performed. The stand volume increment is related to stand age, site index and basal area in order to build up a regression model for estimating volume increment. Here are the results obtained in the study;

1- Volume increment– age values taken from evenaged beech stands are spread widely which is caused by the different volume increments of evenaged stands. In the sample plots found to be right skewed gaussion curving that is like Gamma distribution.

2- Stand basal area and site index had a linear increasing influence on volume increment– age relation. By the inspection of the stand structures, it has been recognized that the stand volume increment would increase as long as the basal area (G) increase. Stand volume increment young and middle age maximum rise up, forward ages together happens decrease.

3- Annual volume increment influenced by site index, age and basal area could be found with the regression model, which could explain %85 of the variations in volume increment.

Results can be used in the following fields;

1- Calculation of stand volume increment, stand identification, determination of the management objective and rotation age and for planning the utilization.

2- In finding the volume increment which is used for determining the silvicultural technical and level. In silviculture while we are able to provide the sustainability and some other functions of the forest, we also think of the ways for increasing wood yield. For realizing these objectives we should not only know the effects of our treatments but also the laws taking place in stand development.

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4- Forest management planning's should be objective, true and logic, but at the same time cheap and punctual. For this reason the inventory performed in the stand should be reliable and fast. Forest management planning could only be successful and rational if the volume increment have been estimated truly. As the volume increment is based in forest management utilization, wood yield should be estimated correct. Thus, value estimation can not be

Table 1: Coefficients and statistics of the regression models computing stand volume increment (m3/ha/year) according to site index, age and basal area.

model : 4 (VOLUME INCREMENT-STAND AGE INTERACTION)		model : 5 (VOLUME INCREMENT-STAND AGE, BOD INTERACTION)		model : 6 VOLUME INCREMENT- STAND AGE , BOD and BASAL AREA INTERACTION)	
a0= 4.069167		a0= -0.993595		a0= -6.39337	a6= 0.2681228
a1= -0.002262		a1= -.009762		a1= -.014257	a7= 3.04355E-04
a2= -.307367		a2= .88284		a2= 1.942555	a8= -0.059311
		a3= 9.204896		a3= 1.659279	a9= -0.066245
		a4= .013682		a4= -.002792	a10= 2.77420E-05
		a5= -2.157544		a5= 0.0*	a11= 0.009223
R= 0.73479	n= 116	R= 0.84261	n= 116	R= 0.91993	n= 116
R^2=0.53992	Se= 0.251	R^2= 0.70999	Se= 0.202	R^2=0.84627	Se= 0.151
$F_{2;113}$= 66. 3***	df= 1.032	$F_{2;110}$=53.859***	df= 1.021	$F_{2;105}$= 57. 800***	df= 1.011
$t_{R;\,113}$ = 11.516***		$t_{R;\,110}$ = 16.410***		$t_{R;\,105}$ = 24. 0420***	

*Found to be insignificant and not processed by SPSS.

Table 2: Influence of 5 site quality, 20m² basal area and 10 year age classes on stand annual volume increment of beech (*Fagus orientalis* Lipsky.).

SITE QUALITY CLASSES																				
	I				II				III				IV				V			
STAND BASAL AREA m^2/ha.																				
AGE	20	40	60	80	20	40	60	80	20	40	60	80	20	40	60	80	20	40	60	80
10	3.68	24.29	*		3.18	25.07			2.74	25.87			2.37	26.70			2.04	27.56		
20	6.30	21.89			5.32	21.54			4.50	21.19			3.80	20.85			3.21	20.52		
30	8.27	20.30			6.92	19.45			5.78	18.63			4.84	17.85			4.04	17.11		
40	9.74	19.04			8.10	17.92			6.73	16.86			5.59	15.87			4.65	14.94		
50	10.81	17.97	29.87		8.95	16.69	31.13		7.41	15.50			6.13	14.40			5.08	13.38		
60	11.55	17.03	25.10	37.00	9.54	15.66	25.69	42.17	7.88	14.40	26.03	48.05	6.51	13.24			5.38	12.18		
70	12.03	16.18	21.77	29.28	9.92	14.76	21.96	32.66	8.19	13.46	22.15	36.43	6.75	12.28	22.34	40.63	5.57	11.21		
80	12.28	15.40	19.32	24.22	10.13	13.96	19.24	26.52	8.36	12.66	19.17	29.03	6.89	11.47	19.09	31.78	5.68	10.40	19.02	34.80
90	12.37	14.69	17.45	20.72	10.20	13.24	17.19	22.32	8.41	11.94	16.94	24.04	6.94	10.77	16.70	25.90	5.72	9.71	16.45	27.90
100	12.31	14.03	15.98	18.20	10.16	12.59	15.60	19.33	8.39	11.30	15.23	20.52	6.92	10.14	14.87	21.79	5.71	9.10	14.51	23.14
110	12.14	13.40	14.80	16.34	10.03	11.99	14.33	17.13	8.29	10.72	13.87	17.95	6.84	9.59	13.43	18.82	5.65	8.57	13.00	19.72
120	11.88	12.82	13.84	14.93	9.83	11.43	13.30	15.47	8.13	10.19	12.78	16.02	6.72	9.09	12.28	16.60	5.56	8.10	11.80	17.19
130	11.55	12.27	13.03	13.84	9.57	10.91	12.44	14.19	7.93	9.71	11.88	14.54	6.57	8.63	11.34	14.91	5.44	7.68	10.83	15.28
140	11.17	11.75	12.36	13.00	9.27	10.43	11.73	13.20	7.69	9.26	11.14	13.40	6.38	8.21	10.57	13.60	5.30	7.29	10.03	13.80
150	10.75	11.26	11.79	12.35	8.94	9.98	11.13	12.42	7.43	8.84	10.51	12.49	6.18	7.83	9.92	12.57	5.14	6.94	9.36	12.64
160	10.31	10.80	11.30	11.84	8.59	9.55	10.62	11.81	7.16	8.45	9.98	11.78	5.96	7.47	9.37	11.75	4.97	6.61	8.80	11.72
170	9.85	10.35	10.88	11.44	8.22	9.15	10.18	11.32	6.87	8.08	9.52	11.21	5.73	7.14	8.90	11.09	4.79	6.31	8.33	10.98
180	9.37	9.93	10.52	11.14	7.85	8.77	9.80	10.95	6.57	7.74	9.13	10.76	5.50	6.84	8.50	10.57	4.60	6.04	7.92	10.38
190	8.90	9.53	10.20	10.92	7.47	8.41	9.47	10.66	6.27	7.42	8.79	10.40	5.26	6.55	8.15	10.15	4.41	5.78	7.57	9.91
200	8.43	9.15	9.93	10.77	7.09	8.07	9.18	10.45	5.96	7.12	8.49	10.13	5.02	6.28	7.85	9.82	4.22	5.54	7.26	9.52
210	7.96	8.78	9.69	10.68	6.72	7.74	8.93	10.29	5.67	6.83	8.23	9.92	4.78	6.02	7.59	9.56	4.03	5.31	6.99	9.21
220	7.51	8.43	9.47	10.64	6.35	7.44	8.71	10.20	5.37	6.56	8.00	9.77	4.54	5.78	7.36	9.36	3.84	5.10	6.76	8.97
230	7.06	8.10	9.29	10.65	5.99	7.14	8.51	10.15	5.08	6.30	7.81	9.67	4.31	5.55	7.16	9.22	3.66	4.90	6.56	8.79
240	6.64	7.78	9.12	10.70	5.64	6.86	8.34	10.15	4.80	6.05	7.63	9.62	4.09	5.34	6.98	9.12	3.48	4.71	6.38	8.65
250	6.22	7.48	8.98	10.79	5.31	6.60	8.20	10.18	4.53	5.82	7.48	9.61	3.87	5.14	6.82	9.07	3.30	4.53	6.23	8.55
260	5.83	7.18	8.86	10.92	4.99	6.34	8.07	10.26	4.27	5.60	7.34	9.63	3.65	4.94	6.69	9.05	3.13	4.36	6.09	8.50
270	5.45	6.91	8.75	11.09	4.68	6.10	7.95	10.37	4.02	5.39	7.23	9.69	3.45	4.76	6.57	9.06	2.96	4.20	5.97	8.47
280	5.09	6.64	8.66	11.29	4.38	5.87	7.85	10.51	3.77	5.19	7.12	9.79	3.25	4.58	6.46	9.11	2.80	4.05	5.86	8.48
290	4.75	6.38	8.58	11.52	4.10	5.64	7.77	10.69	3.54	4.99	7.03	9.91	3.06	4.42	6.37	9.19	2.65	3.91	5.77	8.52
300	4.42	6.14	8.51	11.80	3.84	5.43	7.69	10.90	3.32	4.81	6.96	10.07	2.88	4.26	3.29	9.30	2.50	3.77	5.69	8.59

* This is because of the unexistance of stand of that age in nature (i.e. 20 years old stand with 60 m2/ha or 80 m2/ha).

performed in the forest without the productivity data. Model can be utilized for this purpose.

5- The volume increment curve changes with age in evenaged stands, which causes errors, should be corrected (F?rat 1973). The model built could decrease the errors on this issue.

6- Comparisons and corrections on tables showing volume increment – age, site index and basal area should be made with regional research results for the sustainability and productivity of our forests.

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