SITE INDEX TABLES FOR MIXED STANDS OF SCOTS PINE (*Pinus sylvestris* L.), ULUDAG FIR (*Abies bornmülleriana* Matff.) AND BEECH (*Fagus orientalis* Lipsky.) IN ZONGULDAK FOREST DISTRICT

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ABSTRACT

Site index curves and tables have been prepared for uneven aged mixed stands of Scots pine (*Pinus sylvestris* L.), Uludag fir (*Abies bornmülleriana* Matff.) and beech (*Fagus orientalis* Lipsky.) in Zonguldak territory, Turkey. Curves and tables have been constructed for every tree species using data from 31 sample plots and 93 stem analyses. Lloyd-Hafley's method (1977) was used to construct site index curves and tables. Results were compared with Uludağ fir and beech site index tables prepared for uneven aged pure stands. Results show that there are differences between uneven aged pure and mixed stands developments, especially at Uludağ fir.

Keywords: Mixed stand, Site quality, Scots pine, Uludag fir, Beech

ZONGULDAK ORMAN BÖLGE MÜDÜRLÜĞÜ SARIÇAM (*Pinus sylvestris* L.), ULUDAĞ GÖKNARI (*Abies bornmülleriana* Matff.) VE KAYIN (*Fagus orientalis* Lipsky.) KARIŞIK MEŞCERELERİ BONİTET TABLOLARI

ÖZET

Zonguldak Orman Bölge Müdürlüğü sınırları içerisindeki Sarıçam (*Pinus sylvestris* L.), Uludağ göknarı (*Abies bornmülleriana* Matff.) ve Doğu kayınından (*Fagus orientalis* Lipsky.) oluşan değişikyaşlı karışık meşcereler için bonitet eğrileri ve tabloları düzenlenmiştir. Eğrilerin ve tabloların düzenlenmesinde 31 örnek alan ve 93 gövde analizinden elde edilen verilerden faydalanılmıştır. Değerlendirme metodu olarak Lloyd-Hafley metodu kullanılmıştır. Sonuçlar saf Uludağ göknarı ve kayın meşcereleri için düzenlenen bonitet tabloları ile kıyaslanmıştır. Sonuçlar özellikle uludağ göknarında saf ve karışık meşcereler arasında farklılıklar olduğunu göstermektedir.

Anahtar Kelimeler: Karışık meşcere, Bonitet, Sarıçam, Uludağ göknarı, Kayın

1. INTRODUCTION

Zonguldak territory in Turkey, have great mixed forest areas composed of Scots pine (*Pinus silvestris* L.), Uludag fir (*Abies bornmülleriana* Mattf.) and beech (*Fagus orientalis* Lipsky.). One of the major needs in forest management planning for these stands is to predict forest stand development. Construction of site index curves and tables is a fundamental task for predicting stand development and to determine site quality differentiation.

In Turkey, for pure stands of Scots pine (Alemdağ, 1967), Uludag fir (Saraçoğlu, 1988) and beech (Kalıpsız, 1962; Carus, 1998; Atıcı, 1998), site quality curves and tables have been developed. But mixed stands of these species have not been studied before.

According to Clutter et al. (1992), direct methods for quantifying site quality, can be classified as follows:

1. Estimation from historical yield records.

2. Estimation based on stand volume data.
3. Estimation based on stand height data.

Common methods are based on stand height data. For even-aged stands, age-height relationship is used. In uneven-aged stands, because of suppression period, diameter-height relationship is preferred.

To construct site index curves and tables for uneven-aged stands, different methods were developed. Some of them are Flury method, Mitscherlich method, Assman-Sommer method, Hoar-Young method and Lloyd-Hafley method (Eraslan, 1982; Saraçoğlu, 1988).

Site quality curves and tables for mixed stands of Scots pine, Uludağ fir and beech have been prepared by using Lloyd-Hafley's method. This method have been used to construct site quality curves and tables of pure uneven-aged Uludağ fir stands by Saraçoğlu (1988) and pure uneven-aged beech stands by Atıcı (1998) in Turkey.

2. MATERIAL AND METHODS

2.1. Data

Data were collected from 31 sample plots in Zonguldak territory in Turkey. Locations and characteristics of plot areas are given below (Table 1).

Table 1. Locations and characteristics of plot areas.

No	Forest enterprise	Planning Unit	Elevation (m)	Exposition	Slope %	Area (ha)
1	Ulus	Uluyayla	940	N-NW	10-12	0.25
2	Ulus	Uluyayla	950	N	15	0.25
3	Ulus	Uluyayla	945	N	20	0.25
4	Ulus	Uluyayla	1090	S	20	0.25
5	Ulus	Uluyayla	1035	S	25-30	0.25
6	Ulus	Uluyayla	1055	S-SE	30	0.25
7	Karabük	Keltepe	1345	N-NW	25	0.25
8	Karabük	Keltepe	1380	N-NW	15-20	0.25
9	Karabük	Keltepe	1335	W	20-25	0.25
10	Karabük	Keltepe	1365	W	10-15	0.25
11	Karabük	Keltepe	1315	W	20	0.25
12	Bartın	Sökü	1100	S	30	0.25
13	Bartın	Sökü	1190	S	35-40	0.25
14	Bartın	Sökü	1220	S	25-30	0.25
15	Bartın	Sökü	1150	SW	35-40	0.25
16	Bartın	Sökü	1120	SW	35-40	0.25
17	Bartın	Merkez	1070	SE	25	0.25
18	Bartın	Merkez	1100	S	25-30	0.25
19	Bartın	Merkez	1130	SE	10-15	0.25
20	Bartın	Merkez	1150	SE	10-15	0.25
21	Yenice	Çitdere	1290	NW	15-20	0.25
22	Yenice	Çitdere	1220	NW	35-40	0.25
23	Yenice	Çitdere	1150	E	25-30	0.25
24	Yenice	Çitdere	1210	NE	40	0.25
25	Yenice	Çitdere	1200	N	20	0.25
26	Dirgine	Çaldere	1180	E	35	0.25
27	Dirgine	Çaldere	1230	E	45	0.25
28	Dirgine	Çaldere	1200	E	45	0.25
29	Dirgine	Çaldere	1050	W	60	0.25
30	Dirgine	Karadere	1140	W	15	0.25
31	Dirgine	Karadere	1150	W	10	0.25

In time, researchers have used different plot area sizes from 0.02 ha to 1.0 ha (Dengler, 1931; Herrick, 1944; Kalipsiz, 1962; Batu, 1977; Kapucu, 1978; Eraslan et al., 1984; Saracoglu, 1988; Calıskan, 1989). The literature were studied and it was decided that 0.25 ha plot area size was sufficient. 31 sample plots were measured. Stem analysis data from 31 sample plot were also used in the study. In each plot, one tree from every species was selected as sample tree. Only co dominant and dominant trees, free of damage were selected.

In uneven-aged stands height-age relationship is not appropriate for constructing site index tables because of suppression period. So, height- diameter relationship was used and diameters and heights of all trees were measured. Using height-diameter relationship, site index curves and tables develop based on III. Diameter class (36 cm-51,9 cm) or IV. diameter class (52 cm-). In measured plots, III. Diameter class was heavy, so site index curves and tables have been constructed based on III. Diameter class.

2.2. Method

The method, developed by Lloyd and Hafley (1977) and used for constructing site index tables of uneven-aged Uludağ fir (Saraçoğlu, 1988) and beech (Atıcı, 1998) in Turkey, was used to prepare site index curves and tables of mixed stands of Scots pine, Uludağ fir and beech.

The method is a guide curve method. Guide curve is generated using following model.

$$\hat{H}=\frac{d^2}{a_0+a_1T+a_2d+a_3dT+a_4d^2+a_5d^2T}+1{,}30 \qquad (1)$$

d = diameter inside bark at breast height (cm), T = species parameter.

"T" parameter is a ratio as given below:

T = hg/dg

hg = height of average tree according to basal area, dg = diameter inside bark at breast height of average tree according to basal area.

For every species, diameter levels have been formed at 10-cm-width with 1 cm differences (10-20 cm, 11-21 cm, …) between lower and upper diameter measures. Standard deviations of all diameter levels have been calculated.

$$s_j=\sqrt{\frac{\sum_{I=1}^{N_j}(h_{ji}-\hat{h}_{ji})^2}{n_j.3}} \qquad (2)$$

n = number of diameter measures, h = heights of measured trees, $\hat{h}$= calculated heights using guide curve model, j = diameter levels, I = individuals number.

Then, variation widths (R_j) and variation width/standard deviation ratios (d_2) have been determined as follows:

$$R_j=h_{maxj}-h_{minj} \qquad (3)$$

$$d_2=R/s \qquad (4)$$

Relationships between diameter inside bark at breast height (dbh)-standard deviations and dbh-variation width/standard deviation ratio have been modeled. Calculated standard deviations(ŝ) and variation width/standard deviation ratios ($\bar{d}_2$) have been used to calculate average variation width ($\bar{R}$).

$$\bar{R}=\bar{d}_2.\hat{s} \qquad (5)$$

Site quality curves are generated according to Lloyd-Hafley's method, using following equation.

$H=\hat{H}+(BOD-0,5).\ \bar{R}$ (6)

BOD = site quality degree (from 0,0 to 1,0)

These curves divide site quality area into sub areas according to their qualities. Sub areas can be classified as good, mean, poor or rank like I., II., III. Etc.

3. RESULTS

From height-dbh relationship, guide curves have been generated for every tree species. It was shown that all guide curves fit into another's. So, the same guide curve was used for all tree species. Guide curve (Figure 1) and coefficients of the equation (Model 7) are given below.

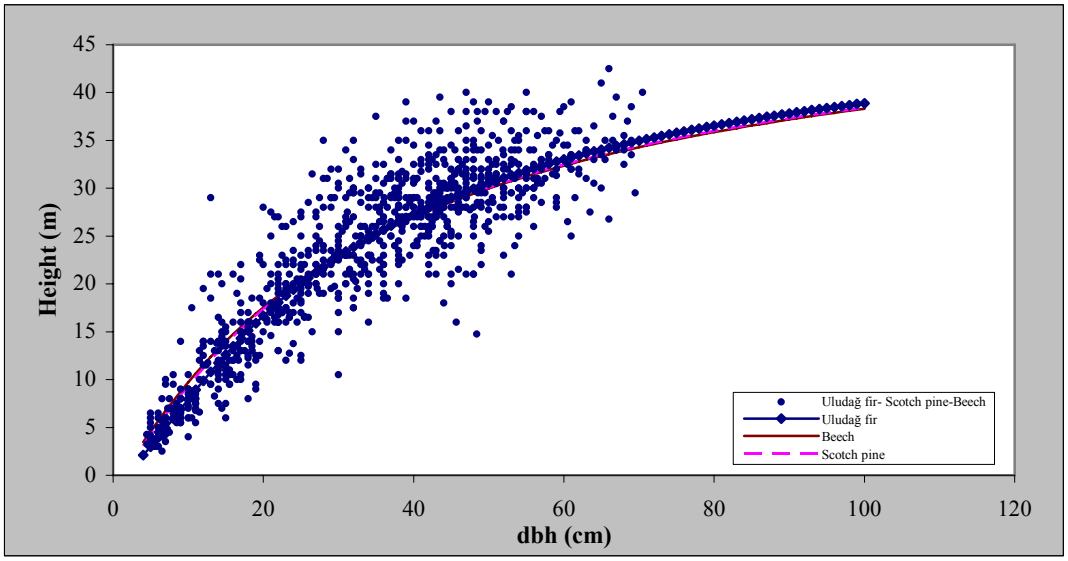

Figure 1. Guide curves of three specieses

$$\hat{H}=\frac{d^2}{201,572+(-301,94)T+(-6,59)d+(10,91)dT+(0,05)d^2+(-0,05)d^2T}+1,30 \quad (7)$$

Statistics belongs to the guide curve regression;
R^2: 0,920, F:2120,5, Se (m):9,180

Species parameter "T" was also determined for every species from hg/dg ratio (Table 2).

Table 2. Species parameters (T) according to tree species.

Tree specieses	T
Uludağ Fir	0,654896
Scotch pine	0,664453
Beech	0,666678

Standard deviations, calculated for all diameter levels have been modeled with following equation (Model 8).

ŝ=-16,4206+(37,813xT)+(0,047291xd)+(-0,03097xdT) (8)

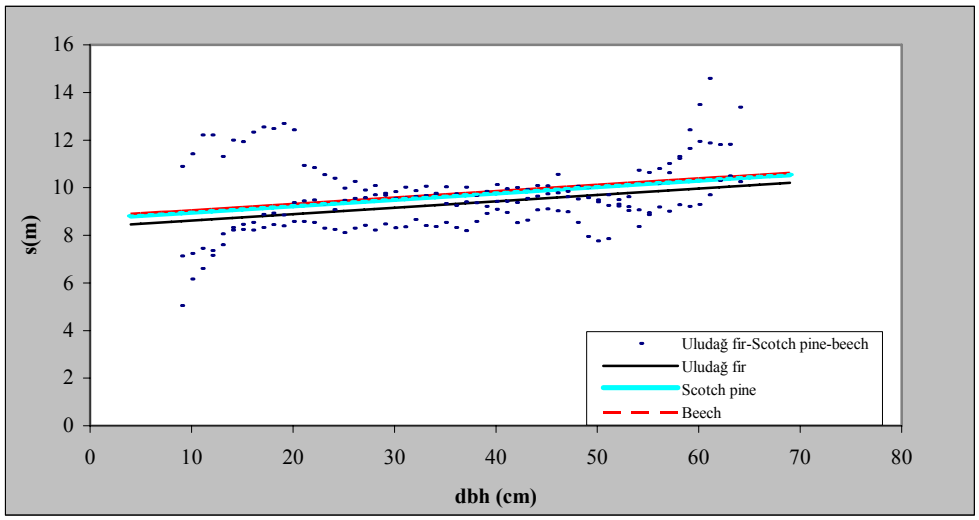

Figure 2. dbh-s relationship

Statistics belongs to dbh-s relationship (Figure 2); R^2=0,109209, F=6,579396, Se (m)= 1,340337

For all diameter levels, variation width/standard deviation ratios (d_2) have been found (Model 9). The relationship is given at Figure 3. As;

d_2=16,91899+(-22,3981xT) (9)

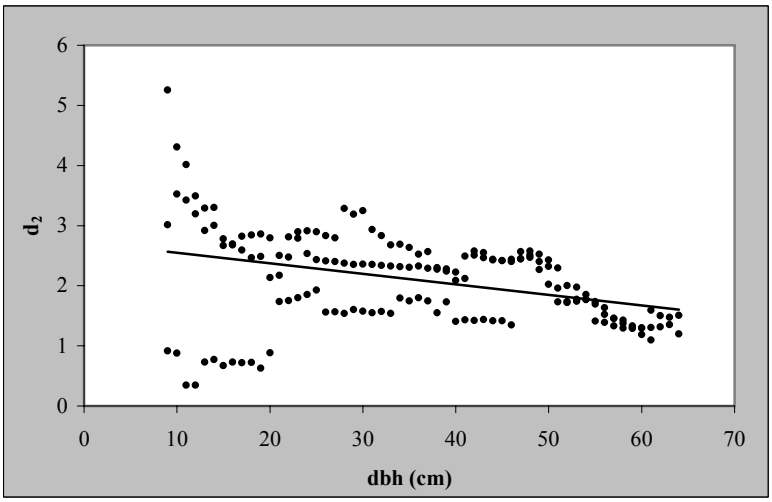

Figure 3. dbh-d_2 relationship

$\bar{R}$, Ĥ and BOD have been used together at following equation (Model 10) and site index curves have been generated as;

$H=\hat{H}+(BOD-0,5).\bar{R}$ (10)

The equation is general equation of stand height curves according to site quality degrees. Figure 4, 5 and 6 show site index curves for every species. Site quality tables are given below (Table 3, 4 and 5).

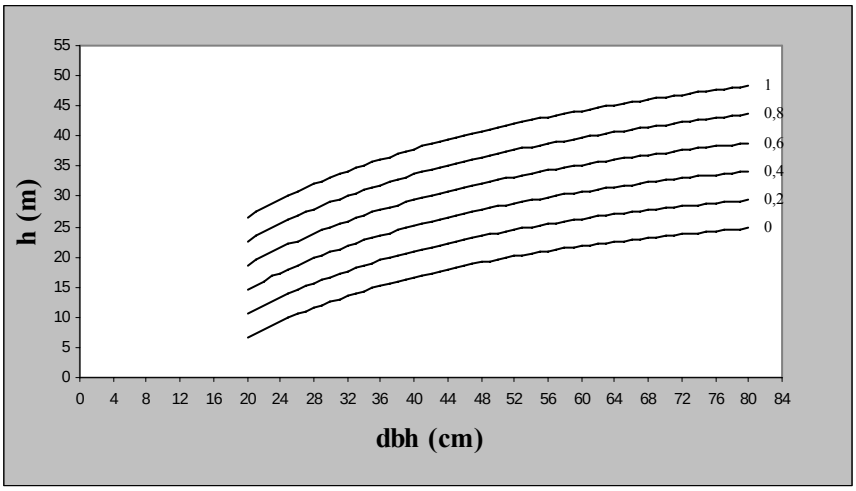

Figure 4.Site index curves of Uludağ fir

Table 3. Site quality table of Uludağ fir

Diameter	Site quality index (d_g=44 cm for)										
(d_g)	17,965	20,111	22,256	24,401	26,546	28,691	30,836	32,981	35,126	37,271	39,416
	Site quality										
cm	**0**	**0,1**	**0,2**	**0,3**	**0,4**	**0,5**	**0,6**	**0,7**	**0,8**	**0,9**	**1**
36	15,196	17,293	19,389	21,486	23,582	25,679	27,775	29,871	31,968	34,064	36,161
38	15,959	18,068	20,176	22,285	24,394	26,502	28,611	30,720	32,828	34,937	37,045
40	16,672	18,793	20,914	23,035	25,156	27,276	29,397	31,518	33,639	35,759	37,880
42	17,340	19,473	21,606	23,739	25,872	28,005	30,138	32,271	34,403	36,536	38,669
44	17,965	20,111	22,256	24,401	26,546	28,691	30,836	32,981	35,126	37,271	39,416
46	18,552	20,710	22,867	25,024	27,181	29,339	31,496	33,653	35,810	37,968	40,125
48	19,103	21,273	23,442	25,612	27,781	29,951	32,120	34,289	36,459	38,628	40,798
50	19,622	21,803	23,985	26,166	28,348	30,530	32,711	34,893	37,074	39,256	41,437
52	20,110	22,303	24,497	26,691	28,885	31,078	33,272	35,466	37,659	39,853	42,047
54	20,569	22,775	24,981	27,187	29,393	31,599	33,805	36,011	38,216	40,422	42,628
56	21,003	23,221	25,439	27,657	29,875	32,093	34,311	36,529	38,747	40,965	43,183
58	21,412	23,642	25,873	28,103	30,333	32,563	34,793	37,024	39,254	41,484	43,714
60	21,799	24,041	26,284	28,526	30,768	33,011	35,253	37,495	39,738	41,980	44,223

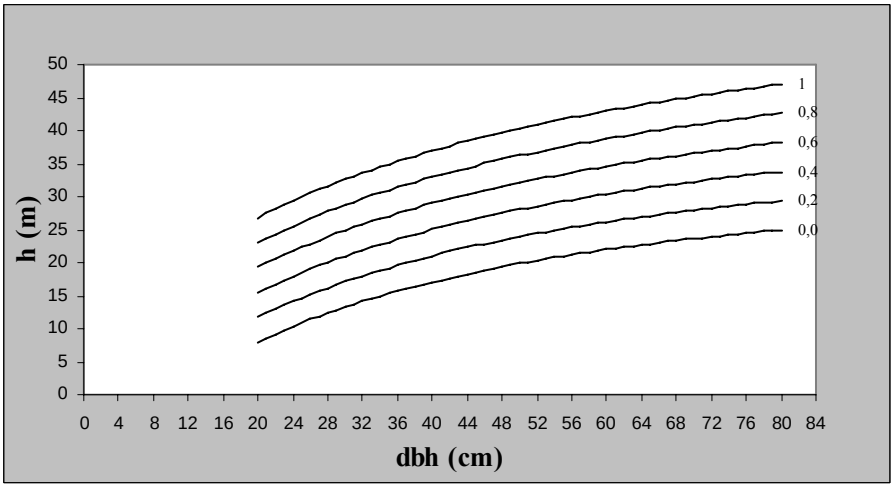

Figure 5. Site index curves of Scots pine

Table 4. Site quality table of Scots pine

Diameter	Site quality index (d_g=44 cm for)										
(d_g)	18,274	20,286	22,298	24,310	26,322	28,334	30,346	32,358	34,370	36,382	38,394
	Site quality										
cm	0	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1
36	15,686	17,654	19,623	21,591	23,560	25,528	27,496	29,465	31,433	33,402	35,370
38	16,393	18,372	20,351	22,331	24,310	26,290	28,269	30,248	32,228	34,207	36,186
40	17,058	19,048	21,038	23,028	25,019	27,009	28,999	30,989	32,980	34,970	36,960
42	17,684	19,685	21,686	23,687	25,688	27,689	29,690	31,692	33,693	35,694	37,695
44	18,274	20,286	22,298	24,310	26,322	28,334	30,346	32,358	34,370	36,382	38,394
46	18,831	20,854	22,877	24,900	26,922	28,945	30,968	32,991	35,014	37,037	39,060
48	19,357	21,391	23,425	25,459	27,492	29,526	31,560	33,594	35,627	37,661	39,695
50	19,855	21,900	23,945	25,989	28,034	30,078	32,123	34,168	36,212	38,257	40,302
52	20,327	22,382	24,438	26,493	28,549	30,604	32,660	34,716	36,771	38,827	40,882
54	20,774	22,840	24,907	26,973	29,039	31,106	33,172	35,239	37,305	39,371	41,438
56	21,198	23,275	25,352	27,430	29,507	31,584	33,662	35,739	37,816	39,893	41,971
58	21,600	23,689	25,777	27,865	29,953	32,041	34,130	36,218	38,306	40,394	42,482
60	21,983	24,082	26,181	28,280	30,379	32,478	34,577	36,677	38,776	40,875	42,974

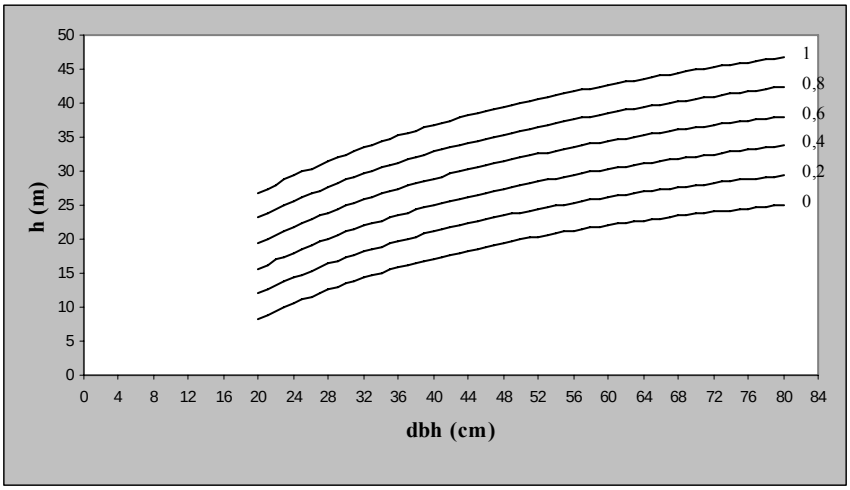

Figure 6. Site index curves of beech

Table 5. Site quality table of beech

Diameter	Site quality index (d_g=44 cm for)										
(d_g)	18,358	20,336	22,315	24,294	26,273	28,252	30,231	32,210	34,189	36,168	38,146
	Site quality										
cm	0	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1
36	15,811	17,747	19,684	21,620	23,557	25,493	27,430	29,366	31,303	33,239	35,176
38	16,505	18,452	20,399	22,346	24,293	26,240	28,188	30,135	32,082	34,029	35,976
40	17,159	19,116	21,074	23,032	24,990	26,947	28,905	30,863	32,820	34,778	36,736
42	17,775	19,744	21,712	23,680	25,649	27,617	29,585	31,553	33,522	35,490	37,458
44	18,358	20,336	22,315	24,294	26,273	28,252	30,231	32,210	34,189	36,168	38,146
46	18,908	20,897	22,887	24,876	26,866	28,855	30,845	32,834	34,824	36,813	38,803
48	19,429	21,429	23,429	25,429	27,429	29,429	31,429	33,429	35,429	37,429	39,429
50	19,922	21,933	23,943	25,954	27,965	29,975	31,986	33,997	36,007	38,018	40,029
52	20,390	22,411	24,432	26,454	28,475	30,496	32,517	34,539	36,560	38,581	40,602
54	20,834	22,866	24,898	26,930	28,961	30,993	33,025	35,057	37,089	39,121	41,152
56	21,256	23,298	25,341	27,383	29,426	31,468	33,511	35,553	37,595	39,638	41,680
58	21,657	23,710	25,763	27,816	29,869	31,922	33,975	36,028	38,081	40,134	42,187
60	22,039	24,103	26,166	28,230	30,293	32,357	34,421	36,484	38,548	40,611	42,675

4. DISCUSSION

To exist for a mixed forest stand at any site, all conditions have to be suitable for all species. But site conditions probably will not be optimum for all species and stand structures and growths under interrelations will be different from pure stands. Therefore, to determine site classes of specieses in mixed stands by using site index curves or tables of pure stands may not be appropriate and confident. Moreover, scots pine site index tables have been constructed for pure even-aged stands. In spite of site index tables are exist for uneven-aged stands of Uludağ fir and beech, they are for pure stands.

A comparison between site indexes of pure uneven aged stands and mixed uneven aged stands of beech and Uludağ fir are given below (Table 6). All site class tables have been constructed by using Lloyd-Hafley's method.

Table 6. Site indexes belongs to Pure beech, beech, Pure Uludağ fir and Uludağ fir

Pure beech (for average diameter of III.diameter)											
BOD	0,0	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1
Site indexes	19,83	21,70	23,56	25,42	27,29	29,15	31,01	32,88	34,74	36,60	38,46
Beech in Mixed Stands (for average diameter of III.diameter)											
BOD	0,0	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1
Site indexes	18,35	20,33	22,31	24,29	26,27	28,25	30,23	32,21	34,18	36,16	38,14
Pure Uludağ fir (for average diameter of III.diameter)											
BOD	0,0	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1
Site indexes	19,71	21,21	22,70	24,20	25,70	27,20	30,20	31,69	31,69	33,19	34,69
Uludağ fir in mixed stands (for average diameter of III.diameter)											
BOD	0,0	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1
Site indexes	17,96	20,11	22,25	24,40	26,54	28,69	30,83	32,98	35,12	37,27	39,41

Site indexes of Pure and mixed beech stands have little differences, but site indexes of Uludağ fir have important differences.

Scots pine-Uludağ fir-beech mixed stands are uneven-aged stands and site classes of these stands can be identified using prepared site class tables. This study will be useful at forest management activities in Zonguldak forest territory. To understand these stands adequately, previous studies and this study should be supported with new studies on mixed stands; especially according to mixing ratios.

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