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Original Research

Determining the Homogeneity and Stand Quality Values in Pure Oriental Spruce (*Picea orientalis* (L.) Link.) Grown in Turkey

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Abstract

The forests of the eastern Black Sea in Turkey are populated by Oriental spruce (*Picea orientalis* (L.) Link.), a heterogeneous species in terms of the quality of wood. Oriental spruce forests have been managed and used for lumbering in lack of consideration of the homogeneity of the trees. Furthermore, it is necessary to know what kinds of Oriental spruce have been found and which of them produce best quality of wood so that future improvement can be planned accordingly. In this work, a quantitative value developed. Homogeneous index (HI) and stand quality values (SQV) are calculated from the sample plots taken from 75 areas. The HI value varied from 1,95 to 6,74 in the even-aged stands, and 1,88-7,15 in uneven-aged stands. For both structures, HI = 3 value can be accepted as a general selective range. SQV values range 2,16-4,83 in even-aged stands and 3,47-4,77 in uneven-aged stands. According to regression analysis, mathematical models, and SQV, there are no statistically significant differences between the aspect and slope, but there is a positive correlation among the height, stand volume, and age. According to the results, homogeneous index is a classification method that can be used for discrimination of stands. Moreover, the operation of pure spruce stand according to uneven-aged management principles will contribute to the formation of better quality and stable stands.

Keywords: homogeneous index, stand quality values, Oriental spruce, wood quality

Introduction

Oriental spruce is one of particular spruce species in Turkey and is spread between 40°23′-43°50′ northern latitude and 37°40′-44°13′ eastern longitude. 135,959 ha. of total 350.000 is purely populated by the Oriental spruce [1, 2]. Only 82,361 ha of 135,959 ha contain industrial-quality trees, and the rest is known as an unproductive area [3].

In Turkey, all pure oriental spruce forests have been managed without considering ages and structures of the trees. This limits diversity that might have occurred. On the other hand, the determination of stand structures has brought up the importance of stand structure [4, 5].

Stand is forest ecosystem itself and the basis of a forest in respect of constituting the least unit and it means production, maintenance-regeneration, and protection activities [6]. When using the number of

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trees, basal area, total volume, and volume increment to determine the stand structure, quality value should be taken into consideration too [7-10]. Knowing the quality of a stand with all its value has gained importance especially in stands that consist of timber production forests [11-14].

The structures of the trees, growth characteristics, and homogeneity index values (Lorenz curve) can be determined according to the parameters described by De Camino [15] and Gehrlein [16]. These Lorenz curve values, which can be obtained by frequent measurement of the trees in the forest, should be used to determine the quality of the trees [17]. However, in the near future, it is very difficult to make such comparisons by periodic measurements. However, it is crucial to know the recent quality of the forest to make plans for the future [18, 19]. A quantitative value is easy to understand and can be used. The limitation of getting these values is that the trunk of a tree should be divided into 4 equal volumes [17].

In this paper, we developed a quantitative value to assess the quality and homogeneity of Oriental spruce found in the forests of the eastern Black Sea and later to apply this method for other tree species naturally grown in the same region.

Material and Methods

Study Area

The samples are taken from the pure spruce found in untreated or poorly treated natural forest dynamics, and in normal canopy. Giresun, Rize, Trabzon, and Artvin districts in the eastern Black Sea Region of Turkey were selected for sample plots. Fifty-nine of a total of 75 sample plots were taken from the even-aged trees and the rest of the 16 samples were from trees with uneven ages (Fig. 1).

Sample plot areas ranged 400-700 m^2. General information related to the sample plots is listed in Table 1. Diameters at breast height, ages, and heights of the trees in these sample plots were measured (Table 1).

Age measurements were made by increment cores. All trees in the sample plots were divided into 4 equal parts by a special marked meter from below to up [20]. In addition, every tree in the plot was socially classified by IUFRO criteria [21, 22].

Methods

The Lorenz curve is based on establishing the relationship between the number of individuals in a definite social category and their percentage in a total population. If two social categories have the same percentage and number in a population, their distributions are also equal and homogeneous. Since a stand is also a population, the number of trees and their volumes can evaluate the number of individuals and total income. From this point of view, the homogeneous index (HI) can be determined by equation 1 [15, 16, 23, 24].

HI can be calculated by the equation below:

$$HI = \frac{\sum_{i=1}^{n-1}\sum_{i=1}^{n-1}\%P_i}{\sum_{i=1}^{n-1}\sum_{i=1}^{n-1}\%P_i - \sum_{i=1}^{n-1}\sum_{i=1}^{n-1}\%V_i} \quad (1)$$

HI: Homogeneity index

%Pi: Cumulative relative frequency values of tree numbers

%Vi: cumulative relative frequency values of tree volumes

n: number of diameter class

Fig. 1. Map of the research areas.

Table 1. General information about the sample plots.

Sample Plot	Aspect	Altitude (m)	Slope (%)	Number of trees (ha)	Mean height (m)	Volume (m^3/ha)	Stand Age	Site quality Index (m)	Stand structure
1	N	1110	45	1587	15,1	328,39	61*	29,69	Uneven-aged
2	NE	1050	35	1253	16,5	370,45	73*	27,36	Uneven-aged
3	SW	1745	40	743	22,0	763,46	119	21,94	Even-aged
4	S	1700	45	943	21,3	883,96	111*	22,63	Uneven-aged
5	S	1755	25	843	21,8	812,00	127	23,96	Even-aged
6	W	1800	35	957	18,6	793,60	127	21,23	Even-aged
7	SW	1820	25	2350	13,5	723,95	95*	20,55	Uneven-aged
8	N	1730	60	2400	14,5	506,83	62*	25,17	Uneven-aged
9	NW	1771	40	1150	21,5	934,03	119	22,34	Even-aged
10	SW	1425	15	1225	20,2	1025,85	102*	24,98	Uneven-aged
11	S	1706	15	3225	13,8	1066,38	87*	27,52	Uneven-aged
12	SW	1673	60	1750	18,8	915,28	87	25,14	Even-aged
13	NE	1619	65	1250	17,8	745,45	80*	23,60	Uneven-aged
14	NW	1826	65	1950	16,8	1098,22	99	25,76	Even-aged
15	N	1806	25	1825	13,5	531,28	92	20,06	Even-aged
16	E	1840	33	1425	23,2	896,88	116	22,35	Even-aged
17	NW	1717	75	1283	21,8	703,72	83	28,78	Even-aged
18	SW	1495	55	2975	14,8	480,80	57*	29,07	Uneven-aged
19	NE	1776	55	1950	15,8	917,13	78*	27,77	Uneven-aged
20	NE	1285	45	2000	14,8	540,15	89	22,89	Even-aged
21	NW	1516	40	1700	22,3	1427,20	95	27,11	Even-aged
22	NW	1550	65	1650	20,9	928,65	101	25,14	Even-aged
23	SW	1489	20	1200	22,2	1363,80	119	23,23	Even-aged
24	W	1586	20	950	22,4	947,11	88	28,46	Even-aged
25	NE	1827	45	1625	20,7	865,10	79	26,71	Even-aged
26	SE	1724	25	1875	16,6	704,78	73	24,82	Even-aged
27	NW	1525	50	1625	21,4	1316,18	95	29,74	Even-aged
28	NE	1000	45	1500	18,3	942,58	75	25,89	Even-aged
29	SE	950	45	1500	16,4	757,50	78	25,64	Even-aged
30	NE	1584	50	2117	15,1	533,93	79*	23,31	Uneven-aged
31	NE	1862	60	1425	14,9	719,28	97	18,38	Even-aged
32	SE	1860	45	3050	16,1	835,70	81	28,40	Even-aged
33	S	1710	35	1300	24,5	676,08	117	32,51	Even-aged
34	S	1350	40	1533	22,0	661,03	74	34,90	Even-aged
35	W	1800	50	1850	19,3	1109,72	86	27,14	Even-aged
36	SW	1920	65	2550	15,5	856,25	88	27,25	Even-aged
37	N	1760	55	1400	22,9	862,70	103	28,43	Even-aged
38	E	1880	40	1517	19,1	756,40	161	18,15	Even-aged
39	SE	1790	25	1600	15,8	614,05	135	16,66	Even-aged

Table 1. Continued.

40	N	1875	40	1450	17,9	718,78	118	22,67	Even-aged
41	W	1860	55	6000	9,6	826,35	66*	26,96	Uneven-aged
42	NW	1610	65	717	12,1	243,85	67	21,76	Even-aged
43	NE	1790	65	1425	17,6	605,63	94	22,82	Even-aged
44	E	1704	55	1750	18,0	834,55	89	28,02	Even-aged
45	SW	1805	50	1625	13,0	343,38	95	17,69	Even-aged
46	NW	1767	15	1250	21,0	916,57	107	24,78	Even-aged
47	SE	1707	45	1525	14,0	713,45	104*	22,90	Uneven-aged
48	SE	1725	60	1850	13,1	557,83	93	22,29	Even-aged
49	NW	2070	50	650	15,1	363,60	99	18,46	Even-aged
50	NE	2050	65	2600	13,0	311,43	70	25,52	Even-aged
51	NW	820	65	875	16,2	353,00	91	20,33	Even-aged
52	N	960	68	850	15,4	491,80	118	16,77	Even-aged
53	N	1280	73	750	19,7	833,23	110	25,00	Even-aged
54	N	1160	82	775	16,8	453,90	99	23,67	Even-aged
55	NE	1050	57	1025	17,1	624,08	129	17,64	Even-aged
56	NE	1120	45	1025	14,1	430,35	122	13,69	Even-aged
57	NW	870	42	975	15,4	381,00	90	20,00	Even-aged
58	N	940	76	950	15,5	475,05	120	16,90	Even-aged
59	NE	1700	15	883	17,0	626,03	99*	27,28	Uneven-aged
60	N	1750	20	958	18,4	626,84	99*	26,88	Uneven-aged
61	NE	1680	20	786	17,0	327,46	97	24,21	Even-aged
62	E	1650	20	786	19,8	404,90	95	25,89	Even-aged
63	NW	1119	75	1275	20,0	619,05	120*	22,50	Uneven-aged
64	NW	1815	85	1367	15,8	499,10	101	23,44	Even-aged
65	SE	1630	55	1475	14,4	430,90	111	16,82	Even-aged
66	N	1660	30	1975	21,0	1116,22	112	24,64	Even-aged
67	SW	1624	25	1225	20,3	968,83	114	24,48	Even-aged
68	NE	1765	30	2050	15,2	722,20	80	23,40	Even-aged
69	NW	1780	65	1000	19,1	622,83	92	24,16	Even-aged
70	W	1820	95	1575	14,3	487,23	87	24,18	Even-aged
71	E	1850	95	1500	15,6	572,53	119	19,08	Even-aged
72	N	1800	110	1275	15,9	588,83	118	18,54	Even-aged
73	NE	1800	85	3500	11,5	432,37	61	20,89	Even-aged
74	E	1710	100	1967	12,3	502,60	94	17,24	Even-aged
75	NE	1055	30	4866	7,7	326,87	42	27,63	Even-aged

*mean age of the stand

Speidel [17] suggested that, in order to establish stand structure using relative heights, four equal volumes of a tree should be selected. Therefore, the stem classification of all trees in the sample plots were determined within 4 quality categories: A = high-quality stem, B = middle-quality stem, C = low-quality stem, and D = high-quality firewood.

Table 2. Stand homogeneity indexes (HI).

Sample plot	HI	Sample plot	HI	Sample plot	HI	Sample plot	HI	Sample plot	HI
1	2,06	16	2,95	31	3,81	46	3,72	61	3,95
2	2,64	17	4,16	32	3,13	47	1,92	62	2,55
3	4,46	18	3,78	33	2,43	48	2,76	63	1,99
4	7,15	19	2,22	34	2,95	49	1,95	64	2,44
5	5,80	20	2,66	35	2,70	50	2,67	65	4,22
6	4,70	21	3,67	36	2,61	51	3,34	66	2,62
7	2,94	22	2,44	37	2,94	52	3,49	67	3,26
8	3,68	23	3,50	38	3,11	53	2,00	68	3,18
9	3,01	24	4,70	39	2,39	54	2,25	69	2,14
10	2,98	25	4,30	40	3,69	55	3,71	70	2,82
11	2,66	26	4,28	41	2,58	56	3,99	71	3,27
12	3,45	27	2,56	42	2,60	57	6,74	72	3,15
13	2,51	28	6,58	43	4,22	58	2,30	73	2,75
14	3,20	29	4,54	44	2,15	59	1,88	74	3,40
15	3,13	30	3,90	45	5,11	60	2,55	75	4,74

In order to make comparisons between the stands and to establish the volume of the groups, one value factor has been given for every quality class, since the relationships between the qualifications in the stands are not exactly clear, A = 1, B = 3, C = 4, and D = 5 value factors have been used for comparison. Therefore, the quality values of each sample area were formulated and stand quality values (SQV) were calculated using equation 2 [23].

$$SQV = \frac{A(N_A)+B(N_B)+C(N_C)+D(N_D)}{N_A+N_B+N_C+N_D} \quad (2)$$

SQV: stand quality value
A, B, C, and D: quality categories
NA, NB, NC, and ND: the number of each quality category

The "t" test is used for checking if the stand is homogeneous and if there is a variation among quality values of 59 samples from the even-age trees and 16 from different ages [25, 26]. The variance analysis is used to determine if the stand structure (even-aged and uneven-aged), social levels (overstorey, mid-storey, undergrowth), and diameter class (I, II, III and IV) are coordinated with the stand quality value [26, 27].

Results and Discussion

Homogeneous index is calculated from the samples taken from 75 areas (Table 2). Homogeneous index values varied from 1,95 to 6,74 (x = 3,53 and s = 1,13) in even-aged stands, and between 1,88-7,15 (x = 2,55 and s = 0,54) in uneven-aged stands. The independent t test is used to determine if there is any statistical difference between homogeneous index values of the stands in both groups. The results are listed in Table 3.

According to the results, one can conclude that the homogeneous index values of the even-aged stands are higher than those of the different age stands. Kapucu [8] published that the homogeneity index values are less than 2,50 for uneven-aged stand structure and higher than 2,50 for even-aged stand structure in the eastern Black Sea Region. De Camino [15] found the HI value in low thinning applied to even-aged stands between 4,0 and 10,0, and between 1,3 and 2,8 in uneven-aged stands. However the values ranges between 2,2 and 4,2, in the stands where high thinning was applied.

In comparisons of both groups in sample areas, a standard variation value for even-aged stands (1,13) is higher than uneven-aged stands (0,54). For both

Table 3. *t* test results of homogeneity index values.

Groups	n	($\bar{x}$)	Standard deviation (S)	Standard Error ($S_{\bar{x}}$)	t Statistic	Significant Level
Even-aged	59	3,53	1,13	0,15	4,906	p<0,001
Uneven-aged	16	2,55	0,54	0,14		

Table 4. Stand quality values (SQV).

Sample plot	SQV	Sample plot	SQV	Sample plot	SQV	Sample plot	SQV	Sample plot	SQV
1	3,78	16	3,80	31	4,62	46	3,50	61	3,20
2	3,47	17	4,70	32	4,36	47	3,47	62	3,46
3	3,68	18	4,77	33	2,16	48	4,12	63	3,74
4	3,70	19	4,42	34	2,50	49	4,17	64	4,26
5	3,91	20	4,43	35	3,79	50	4,52	65	4,08
6	3,91	21	4,27	36	4,21	51	2,86	66	3,97
7	4,02	22	4,32	37	3,63	52	3,43	67	3,43
8	4,01	23	3,73	38	3,87	53	2,78	68	4,12
9	4,52	24	4,32	39	3,81	54	3,49	69	3,77
10	4,31	25	4,65	40	4,04	55	3,12	70	4,40
11	4,74	26	4,66	41	4,63	56	3,57	71	4,01
12	4,38	27	4,38	42	4,83	57	3,22	72	3,66
13	4,21	28	3,15	43	3,80	58	3,61	73	4,52
14	4,19	29	3,51	44	3,67	59	3,59	74	4,29
15	2,60	30	4,46	45	3,80	60	3,53	75	3,08

structures, HI = 3 value can be accepted as a general selective range.

Regression analysis is used to determine the stand characteristics related to stand homogeneity index values, and to show a mathematical number of the relationship. According to our results, there is no significant relationship between homogeneity index and elevation, and between aspect and stand volume. Structural and floristic heterogeneity could be changed by the influence of silvicultural applications and the roles of the edaphic factors in natural selection [28, 29]. Furthermore, structural heterogeneity could be explained by the variations of plant species, distributions of age, species in different elevation, and individual tree diameter classes [30, 31]. In this study, the homogeneity index has a negative relationship with gradient and age, but the site index shows a positive relationship with mean height (Equation 3). Despite finding the low clarification coefficient at significant level α=0.01, the regression is R^2=0.203. This means that only 20.3% of the variation in stand homogeneity index could be explained by mean height, stand age, and the site quality index factors.

$$HI = 8.946 - 0.0127X_1 + 0.178X_2 - 0.0342X_3 - 0.2012X_4 \quad (3)$$

HI: Homogeneity index
X1: slope
X2: mean height
X3: age
X4: site quality

SQV values ranges between 2.16 and 4.83 (x = 3.94 and s = 0.58) in even-aged stands and 3.47 and 4.77 (x = 3.70 and s = 0.48) in uneven-aged stands (Table 4).

According to the results of the t test (t = 1.49, p = 0.193), it was suggested that the mean values of the population were not different at the α = 0.05 significant levels. In other words, stand quality values of even-aged and uneven-aged stands are similar at a significance level of α = 0.05 (95%) (Table 5).

Siitonen et al. [32] emphasized the necessity of determining stand administration goals and evaluation of the goal as a factor during stand value definitions. But even-aged and uneven-aged stands in this study were administrated through the production goals. Consequently, the administrative factor wasn't

Table 5. *t* test results of SQV.

Groups	n	($\bar{x}$)	Standard deviation (S)	Standard Error ($S_{\bar{x}}$)	*t* Statistic	Significant Level
Even-aged	59	3,94	0,58	0,08	1,49	p >0,05
Uneven-aged	16	3,70	0,48	0,12		

Table 6. SQV of social and diameter classes.

Sample plot	SQV of Social classes			SQV of diameter classes			
	Overstorey	Mid-storey	Undergrowth	I	II	II	IV
1	2,34	3,30	4,88	4,67	3,89	3,50	-
2	2,87	3,80	4,67	4,78	4,00	3,70	-
3	3,93	4,56	5,00	5,00	4,65	4,50	-
4	2,77	3,76	4,88	4,65	4,20	3,76	-
5	4,50	4,89	5,00	4,78	4,66	4,00	3,65
6	4,65	4,88	5,00	4,90	4,76	3,99	3,50
7	2,99	3,97	4,97	4,73	3,17	3,50	-
8	2,45	3,78	4,96	4,16	3,56	-	-
9	4,25	4,66	5,00	5,00	4,56	4,04	-
10	3,85	4,71	5,00	4,94	4,39	3,83	3,00
11	4,24	4,71	5,00	4,99	4,53	3,79	4,50
12	3,91	4,80	5,00	4,99	4,17	3,60	-
13	3,58	4,58	5,00	5,00	4,00	3,50	-
14	3,53	4,55	5,00	4,96	4,56	3,75	-
15	2,28	3,21	5,00	3,27	2,26	-	-
16	3,14	3,88	4,93	4,71	3,18	2,75	-
17	4,25	4,60	4,98	5,00	4,59	4,31	-
18	4,29	4,68	5,00	4,82	4,40	4,00	-
19	3,36	4,19	5,00	4,79	3,91	3,17	4,25
20	3,82	4,83	4,98	4,80	3,79	4,00	-
21	3,87	4,44	5,00	5,00	4,29	3,86	3,75
22	4,04	4,57	5,00	4,90	4,26	3,44	-
23	3,53	4,19	5,00	-	4,10	3,62	2,92
24	3,87	4,51	5,00	4,58	4,44	3,99	4,13
25	4,31	4,66	5,00	4,88	4,59	4,44	-
26	4,11	4,62	5,00	4,92	4,56	3,75	-
27	3,79	4,54	5,00	5,00	4,34	3,77	-
28	3,69	4,66	5,00	4,87	4,60	3,88	-
29	4,12	4,77	5,00	4,98	4,70	4,00	-
30	2,98	3,70	5,00	5,00	4,20	2,78	-
31	4,33	4,76	4,98	5,00	4,60	4,50	-
32	4,00	4,56	5,00	5,00	4,65	4,30	-
33	3,56	4,30	4,99	4,65	4,23	4,12	4,00
34	3,00	4,78	5,00	4,88	4,80	4,60	-
35	4,30	4,60	4,76	4,60	3,60	3,40	-
36	4,87	4,77	4,54	5,00	4,87	4,67	-
37	3,54	3,40	3,00	4,78	4,50	4,44	4,30
38	4,54	4,76	5,00	-	4,50	4,32	4,10
39	3,54	4,55	4,76	-	4,50	4,20	4,00

Table 6. Continued.

40	4,10	4,78	5,00	4,87	4,44	4,00	3,53
41	2,66	3,98	4,97	4,88	3,40	2,76	-
42	4,32	4,67	4,88	4,55	4,30	4,25	-
43	3,56	4,00	4,54	4,90	3,66	3,10	-
44	3,35	4,67	4,59	4,50	3,40	3,00	-
45	4,51	4,57	4,98	5,00	4,79	3,20	-
46	3,87	4,86	5,00	4,96	4,43	3,54	-
47	2,40	3,87	5,00	4,76	4,50	3,00	-
48	4,35	4,67	4,89	5,00	4,20	4,60	-
49	4,69	4,68	4,99	4,87	4,69	4,50	-
50	4,62	4,77	5,00	5,00	4,87	4,78	-
51	3,55	3,89	5,00	4,98	4,30	3,76	-
52	3,99	4,65	5,00	-	4,87	4,66	4,30
53	3,79	4,77	4,99	-	4,56	3,97	3,40
54	4,44	4,78	4,88	4,81	4,22	3,65	-
55	3,43	4,78	5,00	5,00	4,55	3,45	2,54
56	3,55	4,87	5,00	-	4,89	4,50	3,00
57	4,12	4,56	5,00	4,98	4,50	4,00	-
58	3,54	4,20	4,78	5,00	4,55	3,40	3,12
59	2,56	3,20	5,00	4,68	4,00	2,76	-
60	2,43	3,67	4,86	4,88	4,00	3,00	-
61	3,59	4,30	4,71	5,00	4,78	4,00	3,76
62	4,50	4,76	4,88	4,97	4,65	3,67	3,40
63	2,54	3,32	5,00	5,00	4,30	3,30	3,00
64	3,98	4,77	5,00	4,88	4,56	4,43	4,22
65	4,43	4,78	4,98	5,00	4,78	4,65	-
66	3,56	4,66	4,78	-	5,00	4,00	3,58
67	3,20	4,34	4,67	-	4,89	3,55	3,10
68	4,55	4,67	5,00	5,00	4,30	4,55	-
69	3,54	4,65	4,79	4,99	4,76	3,20	-
70	4,45	4,87	4,98	5,00	4,66	4,50	-
71	3,45	4,00	5,00	-	5,00	4,79	4,67
72	3,00	4,30	4,67	-	4,80	4,50	3,00
73	4,55	4,78	5,00	5,00	4,69	4,50	-
74	4,00	4,66	5,00	5,00	4,77	4,56	-
75	3,50	4,80	5,00	5,00	3,50	-	-

considered when establishing stand value classes. On the other hand, Michie [33] suggested the necessity of the detailed factor analysis because the single factor analysis is not sufficient for determining the real quality of the wood.

The distribution of stand quality value classes was listed in Table 6 based on social class distribution of IUFRO (overstory, mid-story, and undergrowth) and stem diameter classes (I. Stem diameter class: 8.0-19.9 cm, II. Stem diameter class: 20.0-35.9 cm,

Table 7. *t* test results of SQV according to social classes.

Groups		n	($\bar{x}$)	Standard deviation (S)	Standard Error ($S_{\bar{x}}$)	t Statistic	Significant Level
Overstorey	Even-aged	59	3,92	0,51	0,07	5,11	p<0,05
	Uneven-aged	16	3,02	0,65	0,163		
Midstorey	Even-aged	59	4,56	0,34	0,04	4,55	p<0,05
	Uneven-aged	16	3,95	0,50	0,125		
Undergrowth	Even-aged	59	4,90	0,28	0,04	-0,73	p >0,05
	Uneven-aged	16	4,95	0,09	0,02		

III. Stem diameter class: 36.0-51.9 cm, and IV. Stem diameter class: 52 cm and more; Table 6).

The average stand quality values (SQV) were calculated through the overstory, mid-story, and undergrowth. The results for even-aged stands are 3.92, 4.56, and 4.90, and for uneven-aged stands 3.02, 3.95, and 4.95, respectively. The distribution of average SQV through stem diameter classes I-IV were calculated as 4.87, 4.44, 4.03, and 3.64 in even-aged stands and 4.80, 4.03, 3.36, and 3.69 in uneven-aged stands.

Depending on the t-test results that were used for distributing SQV values through social classes, in even-aged and uneven-aged stands individuals in mid-story and overstories were different from each other, but between the individuals in undergrowth, there were no differences at the 0.05 significant level α (Table 7). Hanewinkel and Pretzch [34] studied the Norway spruce using the same modeling employed in this work and found no quality difference between the individuals in undergrowth during transformation of even-aged stands and uneven-aged stands (Table 7).

According to Table 7, SQV values are increased from overstory to mid-story to undergrowth, in other words, stem quality of the stands declines from overstory to mid-story and undergrowth. By evaluations from the point of view of even-aged and uneven-aged stands, a significant difference was determined among the individuals only in overstory and mid-story. In undergrowth, among the individuals in uneven-aged and even-aged stands, no significant difference was detected.

There is no difference in SQV between the first stem diameter class of even-aged and uneven-aged stands at significance level α = 0.05. But in the second and third stem diameter classes a significant difference was detected (Table 7). On the other hand, Buongiorno [35] suggested that individuals at thin stem diameter class, which enrich biological diversity, should not be taken into consideration in both stands, which requires keeping the balance between production for maximum benefit from the even-aged and uneven-aged stands and to further sustain biological diversity in uneven-aged stands. Similarly, he established the economical value of the individuals that fall into the thin-diameter class and thus such undergrowth classes could not be taken into consideration if a number to assess the quality of trees or wood developed.

During the management of the existing forests that are populated with various ages of trees, it is necessary to reserve the thick individuals to produce high-quality wood [36-39], but as a result of the natural regeneration, the thin individuals are substituted with thick ones [40-42]. Nevertheless, tree quality is reduced when the basal area increased [43-47] and as a result of changes the biodiversity of the forest, stand structure, and quality classification are also continuously changed.

SQVs in Table 7 are reduced from first to third class in terms of stem diameter. (By the way, the stem quality of thick individuals is higher than that of the thin individuals.) On the other hand, if you compare the second and third stem diameter classes between the even-aged and uneven-aged stands it was clear that the quality of the even-aged spruce stands is worse than the uneven-aged stands.

According to the regression analysis, mathematical models, and SQV, there are no statistically significant differences between aspect and slope, but there is a positive correlation among the height, stand volume, and age. Thus according to the data presented in this paper one can conclude that when the height and stand volume increases, SQV also inclines; however, when the stand age increases, SQV is reduced. There is a negative correlation between stand age and SQV. Accusative coefficient of regression model was calculated as a R2 = 0.303. As a function of height, stand volume, and stand age, SQV can be calculated by the equation below:

$$SQV = 3.089 + 0.007474\,X1 + 0.0003547X2 - 0.00886X3 \quad (5)$$

X1: altitude
X2: volume
X3: age

Conclusions

No statistically significant differences were found between the homogeneity index value of even-aged and uneven-aged stands.

– The homogeneity index values of the even-aged are higher than uneven-aged stands, indicating that the uneven-aged trees are more homogenous.
– HI = 3 was found to be a homogeneity index value that can be used to distinguish even and uneven-aged stands.
– In the normal canopy pure Oriental spruce stands, we found that there is a positive correlation between homogeneity and age and side index of the trees.
– According to stand quality value, no difference was detected between even-aged and uneven-aged stands.
– In a normal canopy of pure Oriental spruce stands, the social class of the trees statically affects the stand quality value, then we can conclude that from the over story to undergrowth, stem quality is reduced.
– In differentiation of even-aged and uneven-aged stands, SQV had been shown to be different only in over-story and mid-story. Namely, in the even-aged stands, the stem quality of the individuals at over and mid-stories are higher quality than the individuals in even-aged stands.
– In the normal canopy of pure Oriental spruce stands, the diameter category of the trees statically affect the stand value class. SQV is reduced from the thin diameters to thick diameters, and also the stand stem quality increases depending on the increases of individuals in thick diameter class.
– In normal canopy pure spruce stands, stem quality increases by age, but is reduced by the increase of height and stand volume.

A quantitative number to determine stand structures and stand quality values can be used for diagnosing many forestry activities, such as silvicultural planning, administration-marketing, and forestry policy.

By determining homogeneity index, the stand structures can be comprehended and annual changes in stand structures can be monitored by age, and the success criteria can be established numerically.

In regeneration works, it is important to select the seed trees considering the stand quality value, which helps increase the quality of the stand.

For controlling the fit of the relative lengths used to determine the stand value classes, must be defined if resulted in equal volumes by calculating the actual volumes in sufficient numbers of the sample trees.

In good ecological conditions with suitable stand structure in high site quality, uneven aged administration principles should be practiced and stands with higher stem quality can be produced.

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Conflict of Interest

The author declares no conflict of interest.

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