The Change of Stand Structure in Uludağ Fir (*Abies nordmanniana subsp. bornmülleriana* MATTF.) Forests Along an Altitudinal Gradient

***Halil Barış ÖZEL, Murat ERTEKİN**
University of Bartın, Faculty of Forestry, Department of Silviculture, 74100 Bartın/TURKEY
Tel:+903782235153, Fax:+903782235062
*****Corresponding author: halilbarisozel@yahoo.com

Abstract

In this study carried out in mixed Uludağ fir forests in Bartın-Arıt district the change of stand structure depending on altitude was investigated. For this reason, experimental plots were established in 5 different altitude ranges (1,000-1,100 m, 1,100-1,200 m, 1,200-1,300 m, 1,300-1,400 m, 1,400-1,500 m, and 1,500-1,600 m) and changes of stand structure were determined in respect to the number of trees as well as volume and mixture rate of fir in the experimental plots. According to the results of this research work, the number of individuals per hectares has decreased depending on increasing altitude. However, there are significant differences at the *P<0.01* level according to the results of ANOVA in respect to the number of trees per hectare of both Uludag fir (*F=85.68****) and oriental beech (*F=73.45****). Later on, the Duncan test was applied to the number of trees per hectare in different altitude ranges. According to the results of Duncan test, three different groups have determined the changes of the number of trees per hectare depending on the altitude ranges at the *P<0.01* significance level. The mean DBH of Uludag fir changed between 53.2 cm and 28.5cm depending on altitude range. On the other hand the mean DBH of oriental beech changed between 48.3 cm and 23.6 cm in relation to the increase of altitude. Furthermore according to the results of regression analyses, there is a significant negative correlation (R^2= -0.96) between the change of DBH of Uludag fir and altitude ranges. Similarly, there is a significant negative correlation (R^2= -0.94) between the change of DBH of oriental beech and altitude ranges. The mean height (H) of Uludag fir changed between 21.6 m and 11.4 m depending on altitude ranges respectively. On the other hand the mean height of oriental beech changed between 19.4 m and 10.7 m depending on the increase of altitude. Furthermore according to the results of regression analyses, there is a significant negative correlation (R^2= -0.95) between the change of height of Uludag fir and altitude ranges. Similarly, there is a significant negative correlation (R^2= -0.93) between the change of height of oriental beech and altitude ranges. The mixture rates (%) of Uludag fir are increased depending on altitude meaning that the Uludag fir is the more dominant tree species in respect to mixture rates than the oriental beech. The volume (m^3/ha) of both tree species have decreased depending on increased altitude. However, there are significant differences at the *P<0.01* level according to the results of ANOVA in respect to the volumes per hectare of both Uludag fir (*F=21.82****) and oriental beech (*F=17.63****). Furthermore, the Duncan test was applied to the volumes (m^3/ha) in different altitude ranges. According to the results of Duncan test, three different groups have determined the changes of volumes (m^3/ha) depending on the altitude ranges at the *P<0.01* significance level.

Key words: Uludag fir, oriental beech, uneven-aged, altitude, stand dynamics

Introduction

Continuous cover forestry, an alternative management system to clear felling, is being increasingly adopted in Turkey as a means for increasing species and structural diversity of natural forest resources. On the other hands all silvicultural treatments have the primary role to regulate increment and growth of forest stands with the aim of obtaining their lifetime stability and production. Particularly site conditions play a very important role in the lifetime forest development. They influence the tree species composition, height and diameter structure as well as the growth and stability of individual trees and stands (Petras, 2002). Environmental conditions, containing climatic, physiographic and soil factors affect the changes of stand structure of even-aged and uneven-aged forest stands (Çepel, 1995). Furthermore, as a signatory to international agreements that include the United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol and the Montreal Process, Turkey is increasingly obliged to provide spatial and temporal information on ecosystem biomass, structure and community composition (OGM, 2006). This information is particularly necessary for regional assessments of biodiversity and

forest condition (Burrows et al., 2002). Diversity of management practice is imposed in forests. Stand structure, biomass and species composition are difficult to extrapolate to the landscape. It is known that this variability arises from natural disturbance. So, it leads to uncertainties in local to regional extrapolations of species diversity (Lee et al., 2004). Skaugset et al. (2007) stated that the effects of forest management on stream ecosystems include alteration of hydrology, temperature, habitat, sediment yield, and channel morphology. The environmental effects are affected by the extent and intensity of the harvest, methods, topography, watershed size, and the timing and magnitude of large, infrequent post-harvest storms (Murphy and Hall 1981; Swanson et al., 1989; Hicks et al., 1991; Skaugset et al., 2007). Otherwise, environmental factors also have been affected the forest management and forest practices. These management practices are feasible and practicable, so the adverse impacts of forest management activities on forest ecosystem. The forest practices are serving as a tactical framework for forest management (Saatçiođlu, 1969; Genç, 2004; Skaugset et al., 2007). In this context, present states of environmental factors have been determined as trustworthy before performing silvicultural treatments. This state is more important in the uneven-aged forests requiring more intensive interventions. For this reason, selection methods are applied in the uneven-aged forests. Such forests, composed of shade-tolerant species such as fir, are the most suitable for selection method (Saatçiođlu, 1979; Ata, 1995; Genç, 2004).

The main purpose of selection cutting method is to preserve the best quality stems and maintain the uneven-aged stand dynamics. In this context, diseased and damaged individuals should be cut and natural juvenilities should be given needed light in the ground layer in uneven-aged stands (Ata, 1995; Oliver and Larson, 1996). Pure and mixed (dominated by fir) fir forests are suitable for selection method in Turkey. Furthermore, fir forests, except from Kazdagý fir, are suitable for selection method in Turkey. This is because Kazdagý fir (*Abies equi-trojani* Ascher et Sint.) is faster-growing than other fir species (*Abies nordmanniana* subsp. *nordmanniana* (Stev.) Spach., *Abies nordmanniana* subsp. *bornmülleriana* Mattf. and *Abies cilicica* Carr.) owing to its natural hybrids (Ata, 1975). On the other hand, all natural forest resources were damaged because of incorrect implementation of selection method in Turkey until 1960's (Demirci, 1991; Ata, 1995; Odabaţý et al., 2004).

Turkey has high biological forest resources such as tree species and area. There are different climate types and local conditions. According to the 2006 data, forest area of the country is 21.2 million ha (27.2% of total land area). 50% of it is degraded and coppice forest. The improvement of this situation and the increase of forestry sector's share in the national income depend largely on successful silvicultural practices. Fir species (*Abies* sp.) have the sixth largest range with 626,647 ha (OGM 2006). Fir forests are characterized by highly variable physiographic factors, especially altitude. This is an important physiographic variable influencing local ecological conditions. Depending on the changes in altitude, microclimatic and soil conditions also change dramatically (Çepel 1995).

Fir reaches its optimum development between 1,000 and 1,500 m asl (Saatçiođlu, 1969; Ata, 1975; Bozkuş, 1987). Depending on altitude the density of fir stands decreases, diameter and height decline, crown growth weakens and crown form deteriorates. These changes of fir trees cause the deterioration of stand structure and fertility.

In this context, the object of this research work was to determine changes of Uludag fir (*Abies nordmanniana* subsp. *bornmülleriana* Mattf.) stand dynamics depending on altitude.

Material and Method

Material

Arýt district forests are located in the *Northwest Euxinic* forest subzone of the *Euxinic* forest zone (Mayer and Aksoy, 1998). According to the inventory data for 2011, the total forest area in the region is 8,375 ha, of which 6.2% is degraded forest. Generally the soil type is stony, alkaline,

sandy clay and sandy clayish mud of mediocre depth. Arýt district is under the effect of West Black Sea sub-climate (IIc). All seasons are rainy, the month with highest mean rainfall is December (176.8 mm) and the one with the lowest is May (71.0 mm). The annual average temperature is 9.7 °C, the coldest month is January, and the hottest month July. The vegetation period in the research area is 6 months (May–October) (OGM, 2011).

Method

In this study carried out in mixed Uludağ fir forests in Bartın-Arıt district the change of stand dynamics depending on altitude was investigated. For this reason, sample plots were established in 6 different altitude ranges (1,000-1,100 m, 1,100-1,200 m, 1,200-1,300 m, 1,300-1,400 m, 1,400-1,500 m, and 1,500-1,600 m) and changes of stand dynamics were determined in respect to the number of trees, amount of volume and mixture rate of uneven-aged fir stands. Sample plots of 25x40 m were set up according to the random blocks method to determine the stand dynamics in detail. 30 sample plots were selected for each altitude range. While sample plots were established in the forests, no more silvicultural treatments have been performed in the stand. Thus 180 sample plots were established in the research area.

Diameter (DBH) and total height (H) were measured and tree items were determined in the sample plots. In addition to total volume per hectare, volume increments per hectare and mixture rate were calculated depending on altitudes range and diameter class. Information about sample plots is shown in Table 1.

Usually Uludag fir forms mixed stands with oriental beech (*Fagus orientalis* Lipsky.) in all altitude ranges in the research area. On the other hand, the state of stand parameters according to diameter class was investigated. For this reason diameter classes taken from the management plans were used in the study (Table 2).

Table 1. General information about sample plots

Number of Altitude Ranges	Altitude Ranges	Amount of Sample Plots	Amount of Investigated Stands
1	1,000-1,100	30	27
2	1,100-1,200	30	26
3	1,200-1,300	30	28
4	1,300-1,400	30	28
5	1,400-1,500	30	20
6	1,500-1,600	30	20

Table 2. Diameter classes

Diameter Classes (DBH)	Limit Values of Diameter Classes (cm)
1	8.0-19.9 cm
2	20.0-35.9
3	36.0-51.9
4	≤ 52.0

The SPSS (Statistical Package for Social Science) 9.0 pack program was used for the statistical analysis of all measured data obtained in the sample plots. Kolmogorov-Smirnov test has been applied to determine whether the data display a normal distribution. Later on, the changes of stand dynamics in Uludag fir forests depending on altitude ranges were investigated using the ANOVA and Duncan test at $p<0.01$ significance level. Furthermore, models were produced using the regression analyses between stand dynamics and altitude ranges.

Results and Discussion

Based on the data obtained from measurements in the sample plots, the changes of tree numbers per hectares and the results of ANOVA and Duncan test, applied to the changes of tree numbers, are shown in Table 3.

Table 3. The results of ANOVA and Duncan test of tree numbers per hectare depending on altitude ranges

Number of Altitude Ranges (m)	*F=85.68***				*F=73.45***			
	Forest Tree Species							
	Uludag Fir				Oriental Beech			
	Diameter Classes				Diameter Classes			
	1	2	3	4	1	2	3	4
1	326.45a	310.34a	147.25a	78.56a	123.15a	116.57a	98.36a	86.73a
2	274.18b	225.82b	125.58b	63.47b	117.93a	103.42a	71.54b	65.42b
3	261.52b	205.48b	108.83b	56.94b	95.87a	94.18a	65.46b	51.13b
4	235.73c	184.36c	96.45b	48.53b	71.79b	63.31b	48.52c	34.26b
5	227.62c	142.13c	79.32c	29.75c	69.82b	48.73c	32.77c	21.14c
6	214.37c	128.76c	52.27c	21.54c	36.28c	35.49c	21.82c	13.95c

***: *P<0.01 significance level* **a, b, c:** *Same letters indicate similar groups*

As shown in table 3, the number of individuals per hectares of both tree species decreased depending on increased altitude. However, there are significant differences at the *P<0.01* level according to the results of ANOVA in respect to the number of trees per hectare for both Uludağ fir (*F=85.68****) and oriental beech (*F=73.45****). Later on, the Duncan test was applied to the number of trees per hectare in the different altitude ranges. According to the results of Duncan test, three different groups have determined the changes of the number of trees per hectare depending on the altitude ranges at *P<0.01* significance level (Table 3). According to the results shown in table 3, the individuals were dominant in the first and second diameter classes for both tree species. In this respect one can be said that Uludag fir and oriental beech mixed stands in the research area are young. In a research carried out by Akgül and Aksoy (1976) in the Research Forest of Bolu-Serif Yüksel, they confirmed that there is an important relation between altitude and number of tree species. On the other hand altitude is an important physiographic variable influencing local habitat conditions. Depending on the changes in altitude, microclimatic and soil conditions also change dramatically (Çepel 1995).

In this context the uneven-aged forests reach their optimum development at 1,000 m-1,400 m altitude. Outside these conditions the density of uneven-aged stands decrease, the diameter and height decline, the crown growth weakens and crown form deteriorates (Eraslan, 1956; Çepel, 1966; Saatçioğlu, 1969). In another study regarding this topic, the growth performances were significantly reduced in uneven-aged fir forests over 1,500 m elevation in the Bolu Şerif Yüksek Research Forest Area in Western Black Sea Region of Turkey (Şad, 1980).

The mean diameter (DBH) values of Uludag fir and oriental beech, determined according to the altitude ranges, and the regression equations describing the changes of diameter depending on altitudes ranges are shown in figure 1.

The mean DBH of Uludag fir changed between 53.2 cm and 28.5 cm depending on altitude ranges respectively. On the other hand the mean DBH of oriental beech changed between 48.3 cm and 23.6 cm according to the altitude increase. Furthermore according to the results of regression analyses, there is a significant negative correlation (R^2 = -0.96) between the change of DBH of Uludag fir and altitude ranges. Similarly, there is a significant negative correlation (R^2 = -0.94) between the change of DBH of oriental beech and altitude ranges (Figure 1).

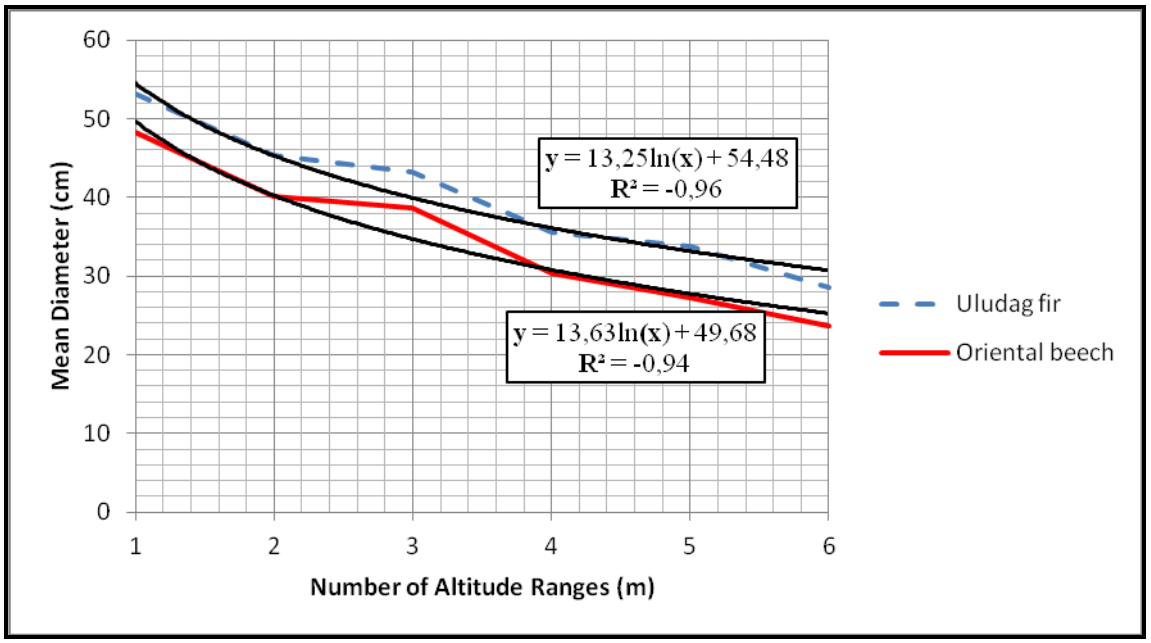

Figure 1. The correlation between mean DBH and altitude ranges

In a research carried out by Eraslan (1956) in the Research Forest of Bolu-Serif Yüksel, the important negative correlation between DBH and altitude increase was confirmed. The reasons for this fact are the location closer to the forest border and the distance from the optimum site conditions for Uludag fir and oriental beech. When the altitude increases, the climate conditions become more difficult so deteriorate the physical and chemical soil properties (Çepel, 1995).

The values of mean height growth (H) of Uludag fir and oriental beech, determined according to the altitude ranges, and the regression equations describing the changes of diameter depending on altitude are shown in Figure 2.

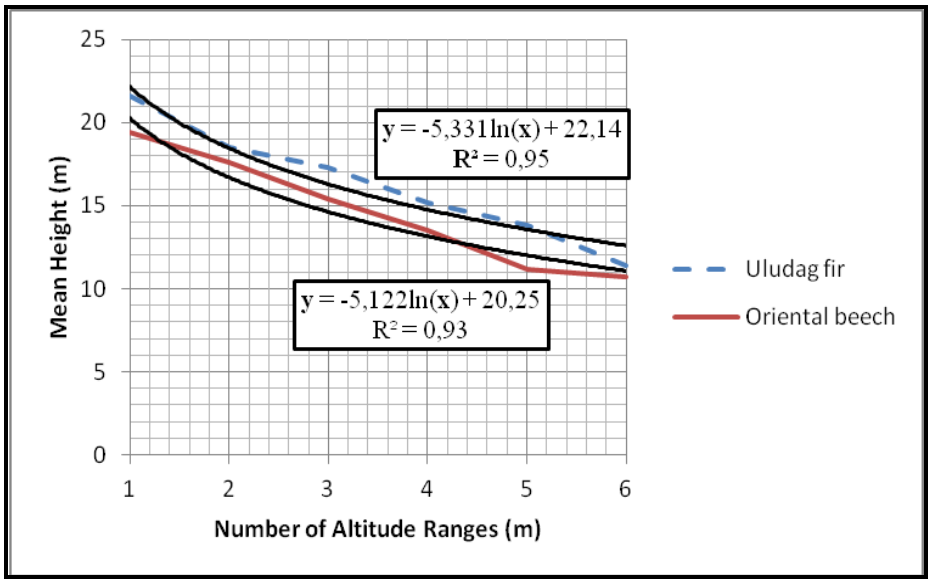

Figure 2. The relation between mean height growth (H) and altitude ranges

The mean height (H) of Uludag fir changed between 21.6 m and 11.4 m depending on altitude ranges respectively. On the other hand the mean height of oriental beech changed between 19.4 m and 10.7 m according to the altitude range increase.

Furthermore according to the results of regression analyses, there is a significant negative correlation (R^2 = -0.95) between the change of height of Uludag fir and altitude ranges. Similarly, there is a significant negative correlation (R^2 = -0.93) between the change of height of oriental beech and altitude ranges (Figure 2). According to research projects carried out by Durkaya and Durkaya (2003), Özel et al. (2010) and Kantarcý (1978) in the Bartýn and Bolu Forest Districts in Western Black Sea Region, there is an important negative correlation between height and altitude increase. The reasons for this situation can be the location closer to the forest border and the distance from the optimum site conditions for both forest tree species (Çepel, 1963).

The changes of mixture rates (%) depending on altitude ranges were also investigated in this research. According to the data obtained in the sample plots, the changes of mixture rates (%) per ha and the results of ANOVA, applied to the changes of mixture rates, are shown in Table 4. Moreover Arc.Sin transformation was applied on values of mixture rates before statistical analyses.

Table 4. The results of ANOVA of mixture rates (%) depending on altitude ranges

Number of Altitude Ranges (m)	*F=3.459^{NS}*				*F=1.752^{NS}*			
	Forest Tree Species							
	Uludag Fir				Oriental Beech			
	Diameter Classes				Diameter Classes			
	1	2	3	4	1	2	3	4
1	80	80	80	80	20	20	20	20
2	80	80	80	80	20	20	20	20
3	80	80	80	90	20	20	20	10
4	80	80	90	90	20	20	10	10
5	80	90	90	90	20	10	10	10
6	90	90	90	90	10	10	10	10

NS: *Non-significant* ***a, b, c:*** *Same letters indicate similar groups*

According to table 4, the mixture rates (%) of Uludag fir per ha had increased depending on altitude ranges. It means that Uludag fir is the dominant tree species in respect to mixture rate than oriental beech. But, there are not significant differences to the results of ANOVA in respect to the mixture rates for both diameter classes and forest tree species in relation to altitude. In a research carried out by Eraslan (1956) in the Research Forest of Bolu-Serif Yüksel, it was confirmed that Uludag fir is the dominant tree species in the higher altitude ranges of Bolu region. This is due to the fact that the regional ecological conditions are more suitable for Uludag fir. The reasons for this situation can be the location closer to the forest border and the distance from the optimum site conditions for Uludag fir and Scots pine (Çepel et al., 1977). On the other hand oriental beech reaches its optimum growth between 800 m and 1,000 m asl (Peters, 1992).

The changes of volume (m^3) per ha of Uludag fir and oriental beech were also determined. According to the data obtained in the sample plots, the changes of volumes per ha and the results of ANOVA and Duncan Test, applied to the changes of volumes, are shown in Table 5.

As shown in this table, the volume (m^3/ha) of both tree species have decreased depending on increased altitude. However, there are significant differences at the *P<0.01* level according to the results of ANOVA in respect to the volumes per ha of both Uludag fir (*F=21.82****) and oriental beech (*F=17.63****). Later on, the Duncan test was applied to the volumes (m^3/ha) in different altitude ranges. According to the results of Duncan test, three different groups have determined the changes of volumes (m^3/ha) depending on the altitude ranges at the *P<0.01* significance level (Table 5).

Table 5. The results of ANOVA and Duncan test of volume (m^3/ha) depending on altitude ranges

Number of Altitude Ranges (m)	*F=21.82***				*F=17.63***			
	Forest Tree Species							
	Uludag Fir				Oriental Beech			
	Diameter Classes				Diameter Classes			
	1	2	3	4	1	2	3	4
1	27.75a	25.68a	17.35a	15.73a	18.54a	17.74a	14.63a	12.54a
2	24.39a	22.85a	15.83a	13.87a	15.42a	13.25a	11.58b	10.38a
3	21.92a	20.54a	12.88b	9.95b	9.87b	7.41b	6.48c	5.13b
4	20.53b	14.63b	10.62b	8.37b	8.19b	6.33b	5.83c	3.26c
5	18.41b	11.47c	5.36c	4.31c	5.45c	3.72c	2.96c	2.35c
6	13.96c	10.33c	2.27c	1.72c	3.58c	3.19c	2.47c	2.20c

*********: *P<0.01 significance level* ***a, b, c:*** *Same letters indicate similar groups*

According to the results of table 5, the dominant volumes were found in the first and second diameter classes for both tree species. Based on this fact one can be said that Uludag fir and oriental beech mixed forests are young and the highest height and diameter growth are located in the first and second diameter classes. In a research carried out by Akgül and Aksoy (1976) in the Research Forest of Bolu-Serif Yüksel it was confirmed that there is an important correlation between altitude and volume of tree species. On the other hand altitude is an important physiographic variable influencing local habitat conditions. Depending on the changes in altitude, microclimatic and soil conditions also change dramatically (Çepel 1995). In this context uneven-aged forests reach their optimum development at 1,000 m and 1,400 m altitude ranges. In another study regarding this topic the growth performances were significantly reduced in uneven-aged fir forests over 1,500 m altitudes in the Bolu Şerif Yüksek Research Forest Area, Western Black Sea Region of Turkey (Kantarcı, 1978; Şad, 1980; Saraçoğlu, 1988). A research project performed in Uludag fir and oriental beech uneven-aged mixed forests in Zonguldak district, Western Black Sea Region showed that the volume decreased in high altitude ranges (1,500 m-1,800 m). Diameter and height growth of trees had decreased because of decrease of soil organic matter in high altitude ranges (Durkaya and Durkaya, 2003). Similarly, according to the results obtained in a research work performed in uneven-aged forests in the Czech Republic, the volumes had decreased between 745 m^3/ha and 356 m^3/ha depending on altitude increase (Silhanek, 2008).

Conclusion

In the present study, sustainability of uneven-aged Uludag fir and oriental beech mixed forests can be achieved by using the following suggestions:

- Selection cutting methods should be applied according to the positive mass selection. As a priority under these circumstances, the diseased and poor quality stems should be removed. Older individuals, reaching the target diameter, should be removed from the forest. Thus, the forest health state would be increased and the targeted wood raw material would be produced.
- If selection cutting method is applied, there will be no switch among diameter classes.
- The mixture rate of uneven-aged forests should be protected.
- Uneven-aged stand structure should be avoided to convert into even-aged stand structure.
- The changes depending on ecological conditions of stand dynamics of the uneven-aged pure and mixed Uludag fir forests should be monitored closely. For this reason, permanent sample plots should be established in uneven-aged pure and mixed Uludag fir forests in different ecological conditions.
- The more detailed management and silvicultural plans should be prepared for uneven-aged Uludag fir forests.
- Growth models should be used for monitoring the changes in uneven-aged Uludag fir forests. Research works should be produced in this topic.

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