UDK 630* 232.4 (001)
https:/doi.org/10.31298/sl.146.9-10.3

Izvorni znanstveni članci – Original scientific papers
Šumarski list, 9–10 (2022): ???–???

PLANT DIVERSITY INDICES FOR TROJAN FIR STANDS IN ALADAĞ REGION OF BOLU

INDEKS BILJNE RAZNOLIKOSTI U SASTOJINI TROJANSKE JELE U ALADAĞ REGIJI BOLU

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SUMMARY

640 samples in quadrates of 0.5 x 0.5 m obtained by systematic sampling method were evaluated. Samplings were made in two repetitions in GA (old), GB (young), GC (medium-aged), and GD (irregular) stand types, on north and south aspects. Field studies were carried out in 4 different periods (June, July, August, September) within the vegetation period. 122 plant taxa were determined at the level of species and intraspecific taxa. While 48 of the 122 plant taxa in fir stands were seen only in one of the stands, 41 plant taxa were detected in all stands. 5 taxa were seen only in GA stands, 7 in GB, 15 in GC and 13 only in GD stands, while 8 taxa could not be identified due to the insufficient vegetative and generative organs of the collected samples. The richest stand type in terms of taxa number was determined as the GC stand type with 84 plant taxa, but more individuals per ha were counted in the GA and GD stand types.

KEY WORDS: Trojan Fir, Plant diversity, Diversity indices, Stand, Aladağ, Turkey.

INTRODUCTION
UVOD

Forests are composed of stands, and stands cause microclimatic conditions by affecting the amount of light reaching the soil. This affects litter decomposition and soil nutritive conditions. These differences are also important in shaping the existence and distribution of plant species, which are described as understory flora or above-ground vegetation, and thus plant diversity. Stand structure is one of the more important factors affecting the similarity of species in a region (Svenning and Skov, 2002). Ister and Gökbulak (2009) stated that stand types have a significant effect on above-ground vegetation, where mixed stands create better growth conditions, while pure stands allow for more frequent and high-diversity flora formation. Pitkanen (1997) stated that there is a high correlation between the change in above-ground vegetation and site or stand age, while basal area, tree species mixture ratio and crown cover are other important factors in this change. Therefore, it is necessary to investigate the existence of such relationships in different sites in terms of different tree species and stand types.

Although forests are rich ecosystems in terms of biodiversity, there is not enough information about biodiversity values of different ecosystems to make comparisons or relative

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evaluations among them. Apart from conservation strategies, biodiversity information at the stand level, which is the smallest forest unit, is needed for planning in order to develop various strategies related to use and to set targets for planning and implementation.

Various floristic studies have been carried out in different regions of Turkey. These studies, which were carried out based on a specific area, not only focused on forest areas, but also tried to identify plants in other habitats in the area under consideration. Thus, although it is revealed which species are found in this area, information suitable for use in forest planning cannot be provided. These floristic studies were also carried out in the Bolu-Aladağ region of Turkey which was chosen as the study area in this research (Akman and Yurdakulol, 1981; Sazak, 1997; İkinci and Güner, 2007; Aksoy, 2010; Güneş Özkan and Aksoy, 2011; Tunçkol and Akkemik, 2013; Kanoğlu et al., 2016; Güneş Özkan et al., 2016; Koçer and Aksoy, 2016).

It will be useful to realize inventory studies on vegetative diversity on a basis that provides more information for forest planning, beyond providing a list of existing species in the area. More detailed studies on forest areas should be carried out, and the information on vegetative diversity should be expressed numerically depending on the stand types. Measuring diversity is of great importance in ecological research and conservation of biodiversity. Various indices have been developed to numerically express plant diversity depending on the presence and abundance of plants in an area (Lu et al., 2007). The Simpson index, Shannon index and total number of species are the most common indices used to describe diversity (Hill, 1973).

According to Nitzelius (1969) the geographically separated populations of *Abies nordmanniana* (Steven) Spach. in western and northern Turkey, described under the subspecies names and at various taxonomic levels, are found to be entirely clinal geographically. The typical subspecies occurs in western Caucasia (Abkhazia, Georgia) and in the mou-

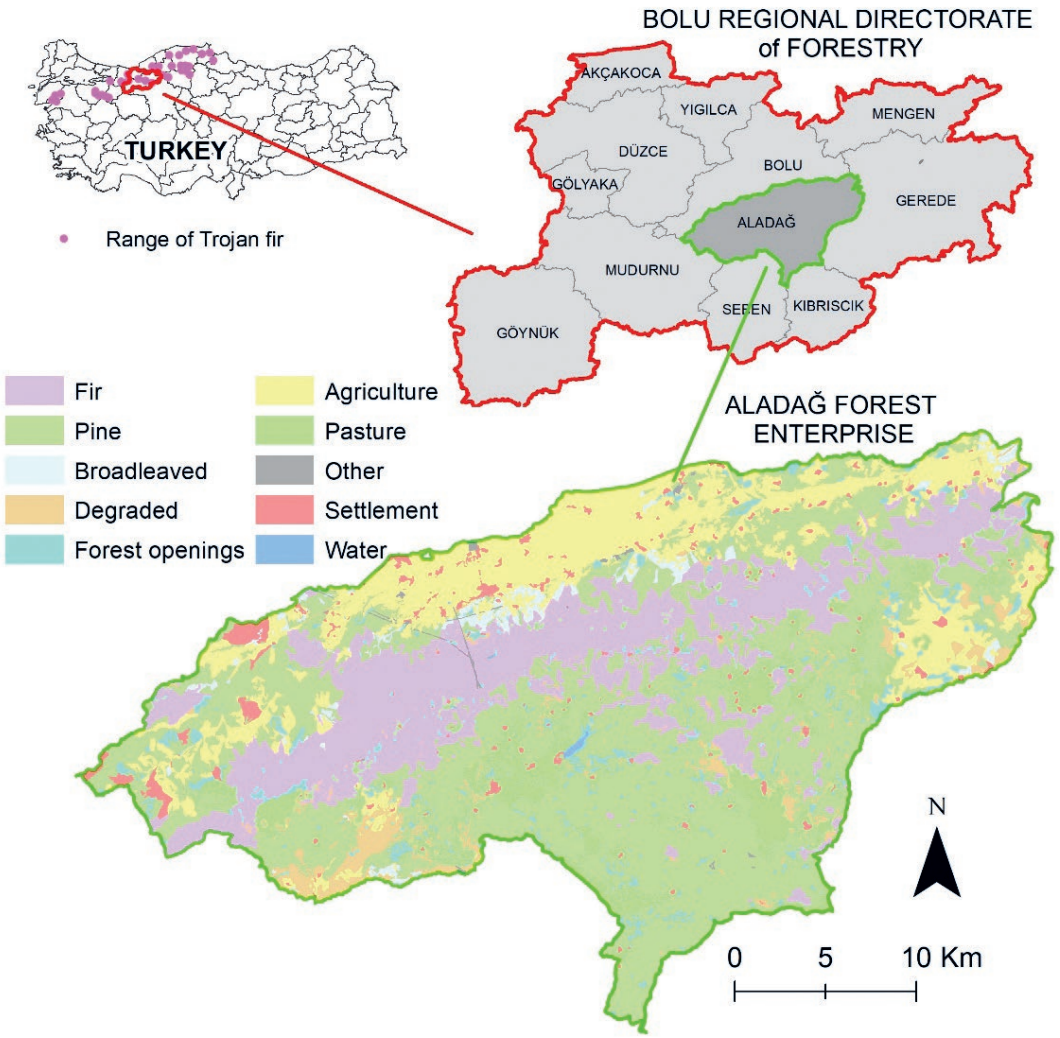

Figure 1. Location of the study area
Slika 1. Položaj područja istraživanja

ntains of north-eastern and north-western Turkey. Introgression with *Abies nordmanniana* (Steven) Spach. subsp. *equi-trojani* (Asch. & Sint. ex Boiss.) Coode & Cullen occurs in the western part of its range. *Abies nordmanniana* subsp. *equi-trojani* grows in pure stands as isolated relict populations on the north slopes of high mountains in western Turkey and on Uludağ in the western Black Sea Region of Turkey. It is a drought sensitive species (Yildiz et al., 2007) and prefers calcareous soils (Farjon, 1990).

In this study, beyond the standard flora studies, it is aimed to group the plant species and numbers in the Trojan fir (*Abies nordmanniana* (Steven) Spach. subsp. *equi-trojani* (Asch. & Sint. ex Boiss.) Coode & Cullen) forests in the Bolu-Aladağ region of Turkey depending on the stand types and to reveal the relationship of diversity indices with Trojan fir stands.

MATERIAL AND METHODS
MATERIJAL I METODE

General Characteristics of the Study Area – *Opće značajke područja istraživanja*

In order to reveal the vegetative diversity in the Trojan fir forests, the stands to be sampled were determined within the borders of the Aladağ Forest Enterprise, where the species is widely distributed. The study area is located between 31° 32' 35" - 31° 47' 15" E and 40° 34' 24" - 40° 40' 03" L (European Datum 1950) (Figure 1). The region is characterized by high mountainous terrain and generally consists of flat plateaus and wide plains between them (Dündar, 1989).

Although Aladağ is located in the Black Sea macro-climatic region, it shows some distinctions from this climate due to the presence of large mountain ranges in-between and because it is far away from the Black Sea coast. At the same time, a summer drought prevails in the region, which is characteristic for the area adjacent to the Central Anatolia steppe transition zone, although the rainfall is high. The annual average precipitation is 963 mm, and the annual average temperature is 6.2 °C (Dündar, 1989). The elevation of the sampling areas varies between 1500 m and 1700 m above sea level.

Determination of Stands for Sampling of Ground Flora – *Određivanje sastojina sa uzorkovanja prizemne flore*

The study was carried out in mixed-aged vertically layered fir stands. In the study, it was aimed to reveal the plant diversity in fir stands (GA, GB, GC, GD) on different aspects (north, south) in different periods (June, July, August, September) with two repetitions. 10 quadrates were taken in each stand in every sampling in different periods. The sam-

Table 1. Sampling pattern applied in the study
Tablica 1. Primijenjeni obrazac uzorkovanja

Stand Type (Tip Stalka) (4)	Aspect (Izgled) (2)	Repeat (Opet) (2)	Observation time (Vrijeme promatranja) (4)	Quadrate (četvrtast) (10)	Total Number Of Samples (Ukupni broj uzoraka) (640)
GA GB GC GD	North (Sjever) South (Jug)	2	June (Lipanj) July (Srpanj) August (Kolovoz) September (Rujan)	10	4*2*2*4*10=640

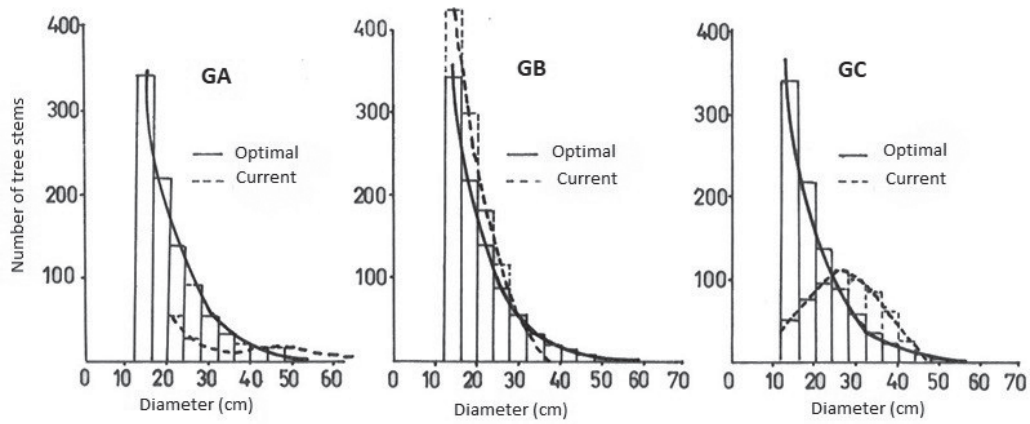

Figure 2. Current establishment types in fir forests
Slika 2. Trenutni tipovi objekata u jelovim šumama

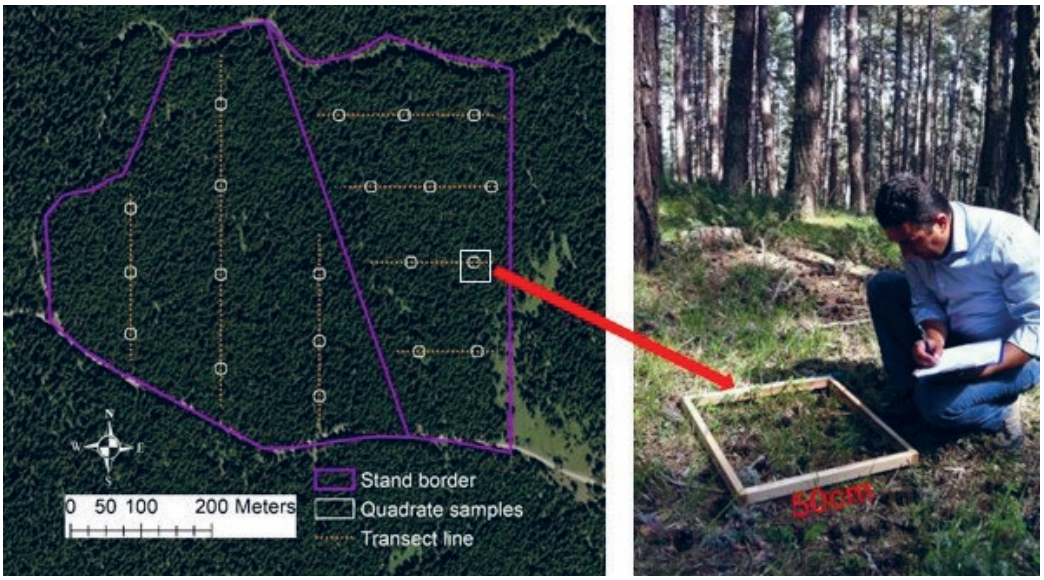

Figure 3. Quadrate sampling scheme for a sample stand
Slika 3. Kvadratna shema uzorkovanja za stalak za uzorke

pling design applied for this purpose and the information on the number of sample areas are given in Table 1. In the study, a total of 640 quadrate samples were taken from fir stands.

Trojan fir stands are divided into GA, GB, GC and GD groups (stand types) according to their structure. This distinction is made according to the distribution of the number of trees in the area to the diameter classes (Figure 2). GA stands represent a relatively old forest, and there is an excess in the thick diameter class of actual structure compared to the assumed optimal distribution of the tree numbers to the diameter classes. The GB type represents young stands, while GC stands represent middle-aged, vertically layered fir forests. The current number of trees in the thin layer in the GB stands and in the medium diameter class in the GC stands is higher than the optimal distribution. The GD type, on the other hand, shows different-aged vertically layered fir stands, which are not similar to the previous three types in terms of the distribution of stem numbers to the diameter class, and have an irregular structure. The stem volumes of the stands in the study area vary between 425-616 m^3/ha, and basal area is between 41.6-55.7 m^2/ha.

Sampling of the lower flora was carried out by applying the quadrate (frame) method along the strips (transects) (Figure 3). Before going into the field, the transect lines and the quadrate sampling locations on these lines were determined on the map. Transect lines were determined to be generally parallel to contour lines and to cover the whole area of the stands. Transect lines were constantly changed in the samplings made in different observation periods, and it was aimed to represent the whole area of the stands. Therefore, sampling was made in different places in the stands each time. 10 quadrate samples were taken every month in each stand. In this way, a total of 160 quadrate samples were taken each month for 16 stands. Quadrate sizes were 0.5 x 0.5m=0.25 m^2 and the number of different plants included in the frame were recorded in the survey report sheets. The names of the plants known in the field were recorded on the sheets, and for those that could not be identified, explanatory statements were written and plant samples were taken or photographed to identify them in the herbarium.

Calculation of Diversity Indices and Data Analysis – *Izračun indeksa raznolikosti i analiza podataka*

The values of the indices used to define plant diversity vary depending on the number of taxa in the area, the number of individuals belonging to the taxa, or the homogeneous distribution of the total number of individuals to the taxa. In this study, plant diversity is expressed by taxa diversity. Different indices are used to determine vegetative diversity in an area. When revealing diversity, two factors are generally taken into account, the richness and the abundance. The greater the richness and abundance, the greater the diversity. The evenness value is an approach based on whether the taxa in the area are represented by an equal number of individuals. In this study, the Shannon-Wiener, Simpson dominance, Simpson diversity and Pielou's evenness indices were used to define plant diversity.

The mathematical expressions used in calculating the indices are given below (Simpson, 1949; Shannon and Weaver 1963; Pielou, 1966).

Shannon-Wiener Diversity Index (SH):

$$SH = -\sum_{i=1}^{s} p_i \times \ln p_i$$

Simpson Dominance Index (D):

$$D = \sum_{i=1}^{s} p_i^2$$

Simpson Diversity Index (SI):

$$SI = 1 - D$$

Pielou's Evenness Index (PI):

$$PI = \sum_{i=1}^{s} \frac{SH}{\ln S}$$

In these indices, p_i: ratio of the number of plant species i to the total number of species, S: the total number of species.

The indices were analyzed at alpha and gamma levels. If a diversity calculation is made for each part of the community, the diversity in question is alpha diversity. Gamma diversity is a larger scale consideration made by bringing together a large number of communities. It is the total species diversity in a landscape. The same indices were used for alpha and gamma diversity. While values from 10 quadrates were brought together as one sample to find out the alpha diversity for a stand, gamma diversity was calculated from all the quadrates for a group of stand, aspect or observation time.

The PAST software (Hammer et al., 2001) was used to calculate the various index values used to determine the plant diversity. In order to determine the effect of stand type, aspect and observation time on plant diversity, multiple analysis of variance was performed and the averages were compared using the Tukey test.

RESULTS
REZULTATI

Observed Taxa – *Promatrani Taksoni*

The study area is within the borders of the Euro-Siberian phytogeographic region in terms of plant geography and is in the transition section to the xeric zone of Inner Anatolia. A total of 122 plant taxa were identified in the Trojan fir forests, of which 2 are family, 49 are genus, 59 are species, and 4 are subspecies and variety. Eight of these taxa could not be identified due to the insufficient vegetative and generative organs of the collected samples. While 48 plant taxa were seen in only one stand type in fir stands, 41 plant taxa were found in all stands. Except for unidentified taxa, 5 plant taxa were seen only in GA stands, 7 plant taxa in GB, 15 plant taxa in GC and 13 plant taxa only in GD stands (Table 2).

In terms of stand types, the highest number of taxa were found in GC (84) stands. This was followed by the GD (78), GA (70) and GB (63) stands, respectively. By periods, the highest number of taxa was seen in July with 82 units. The lowest number was observed in September with 54 units. When evaluated in terms of aspects, more taxa were detected on the southern aspects (100 taxa) than on the northern aspects (89 taxa) in fir stands. As a result of the study, the highest number of taxa was found in GC stands with 39 units in July and on the south aspect, while the fewest taxa

Table 2. Occurrence of taxa according to stand types in fir forests
Tablica 2. Pridolazak svojti prema tipovima sastojina u jelovim šumama

GA	GB	All stands (Svi stalci)	
Galium verum	*Cytisus hirsitus*	*Epilobium angustifolia*	*Veronica chamaedrys*
Mercurialis perennis	*Echium vulgare*	*Lapsana communis*	*Luzula campestris.*
Pitosphorum	*Juniperus oxicedrus*	*Pteridium aquilinum*	*Orthilia secunda*
Ranunculus brutius	*Lotus cornuculatus*	*Urtica dioica*	*Lathyrus laxiflorus*
Sanicula europea	*Polygala anatolica*	*Daphne pontica*	*Brachypodium sylvaticum*
	Silene italica	*Lapsana communis*	*Primula vulgaris*
	Verbascum blattaria	*Polystichum setiferum*	*Euphorbia amygdaloides*
		Cardamine bulbifera	*Veronica gentinoides*
GC	GD	*Lamium purpureum*	*Calamintha grandiflora*
Astragalus glycyphyllos	*Asperula involucrata*	*Epilobium montanum*	*Galium rotindifolium*
Centaurea triumfettii	*Brachypodium sylvaticum*	*Crepis foetida*	*Sanicula europea*
Cephalanthera longifolia	*Clinopodium vulgarea*	*Lathyrus laxiflorus*	*Trifolium spadiceum*
Dorycnium graecum	*Caucalis platycarpos*	*Mycelis muralis*	*Viola odorata*
Fagus orientalis	*Delphinium venilousum*	*Circium hypoleucum*	*Fragaria vesca*
Galium aperine	*Euphrasia pectinata*	*Doronicum orientale*	*Rubus hirsitus*
Salvia virgataMonotropa hypopitys	*Hypericum montbretii*	*Geranium pyrenacum*	*Galium rotundifolium*
Pilosella hoppeana	*Lapsana communis*	*Cyclamen coum*	*Veronica officinalis*
Potentilla recta	*Plantago lanceolta*	*Hieracium medianiforme*	*Abies nordmanniana*
Pyrola chlorantha	*Poa pratensis*	*Myosotis sylvatica*	*Oxalis acetosella*
Quercus cerris	*Sangiosorba minor*	*Helleborus orientalis*	*Phleum alpinum*
Sedum album	*Trifolium pratense*	*Erodium cicutarium*	
Silene vulgaris	*Vicia sativa*		
Sorbus torminalis			

Table 3. Number of taxa in fir stands according to aspect and observation period
Tablica 3. Broj svojti u jelovim sastojinama s obzirom na izloženost i razdoblju promatranja

	June (Lipanj)	July (Srpanj)	August (Kolovoz)	September (Rujan)	Total (Ukupno)
GA	42	41	35	34	70
South (Jug)	32	31	26	27	56
North (Sjeverno)	32	25	31	24	51
GB	36	32	30	35	63
South (Jug)	24	19	22	22	43
North (Sjeverno)	23	29	22	29	50
GC	41	50	47	37	84
South (Jug)	31	39	34	29	64
North (Sjeverno)	20	31	25	23	54
GD	47	41	37	36	78
South (Jug)	31	30	34	22	61
North (Sjeverno)	33	27	24	28	53
Total (Ukupno)	77	82	61	54	122

Table 4. Plant individual numbers (individuals/m²) in fir stands according to the aspect and observation period
Tablica 4. Broj jedinki biljaka (jedinki/m² u sastojinama jele s obzirom na izloženost i razdoblje promatranja

	June (Lipanj)	July (Srpanj)	August (Kolovoz)	September (Rujan)	Average (Prosjek)
GA	124	144	180	113	140
South (Jug)	130	157	189	132	152
North (Sjeverno)	119	131	171	94	129
GB	63	127	128	109	107
South (Jug)	79	119	103	88	97
North (Sjeverno)	48	134	152	129	116
GC	83	127	136	106	113
South (Jug)	102	132	141	124	125
North (Sjeverno)	64	122	131	89	101
GD	134	189	181	122	156
South (Jug)	153	191	215	102	165
North (Sjeverno)	116	187	148	141	148
Average (Prosjek)	101	147	156	113	129

were observed in the GB stands in July and on the south aspect (Table 3).

In terms of stands, the highest average number of individuals per unit area (m²) was found in GD (156) stands. This was followed by the GA (140), GC (113) and GB (107) stands, respectively (Table 4). The highest number of individuals with 215 units/m² was observed in GD stands in August and on the south aspect, while the lowest number of individuals was observed in June in the GA stands and on the north aspect. In terms of periods, the highest average number of individuals was seen in August with 156 units. The lowest number was observed in June with 101 units. When evaluated in terms of aspects, 135 individuals/m² were found on the south-facing slopes, while 123 units/m² were found on the north-facing slopes. (Table 4).

The number of plant taxa differs according to the observation period. While some plant taxa such as *Astragalus glycyphyllos* (June), *Centaurea triumfettii* (July), *Filipendula vulgaris* (August), and *Pilosella hoppeana* (September) were observed only in a certain period, some taxa such as *Calamintha grandiflora*, *Cirsium hypoleucum*, *Digitalis ferruginea*, and *Helleborus orientalis* were observed during all pe-

Table 5. Occurrence of taxa in fir forests according to observation time
Tablica 5. Pridolazak svojti u jelovim šumama prema vremenu promatranja

June (Lipanj)	July (Srpanj)	August (Kolovoz)	Seen Every Period (Uvijek videno)	
Astragalus glycyphyllos	*Campanula glomerata ssp. hispida*	*Cephalanthera longifolia*	*Abies nordmanniana* **ssp**	*Lathyrus laxiflorus*
Brachypodium sylvaticum	*Centaurea triumfettii*	*Euphrasia pectinata*	*Brachypodium sylvaticum*	*Lathyrus laxiflorus*
Cardamine bulbifera	*Cytisus hirsutus*	*Filipendula vulgaris*	*Calamintha grandiflora*	*Melica uniflora*
Clinopodium vulgare	*Dauscus laciniata*	*Rubia sanctus*	*Circium hypoleucum*	*Orthilia secunda*
Dorycnium greaecum.	*Delphinium venulosum*	*Sangiosorba minor*	*Crepis foetida*	*Oxalis acetosella*
Echium vulgare	*Dorycnium graecum*	*Vicia sativa*	*Daphne pontica*	*polystichum setiferum*
Euphorbia amygdaloides	*Galium aperine*		*Digitalis ferruginea*	*Primula vulgaris.*
Fagus orientalis	*Hypericum hyssopifolium*		*Epilobium montanum*	*Pteridium aquilinum*
Lamium garganicum	*Sucutlelleria oreintalis*		*Erodium cicutaurium*	*Rubus sanctus*
Lapsana communis	*Monotropa hypopitys*	**September (Rujan)**	*Euphorbia*	*Salvia forskahlei*
Moneses uniflora	*Plantago major*	*Asperula involucrata*	*Fragaria vesca*	*Sanicula europea*
Ranunculus brutius	*Plantago lanceolata*	*Galium verum*	*Galium rotundifolium*	*Trifolium hybridum*
Sedum acre	*Poa protensis*	*Lotus cornuculatus*	*Galium odoratum*	*Urtica dioica*
Sorbus torminalis	*Polygala anatolica*	*Pilosella hoppeana*	*Geranium asphodeloides*	*Veronica officinalis*
Verbascum blattaria	*Potentilla rupetris*	*Pyrola chlorantha*	*Helleborus orientalis*	*Veronica gentinoides*
	Quercus cerris	*Trifolium pratense*	*Hieracium medianiforme*	*Viola odarata*
	Sanicula europea			*Viola suavis*
	Silene italica			
	Silene vulgaris			

Table 6. Occurrence of taxa in fir forests according to aspects
Tablica 6. Pridolazak svojti u jelovim šumama s obzirom na izloženost

North (Sjeverno)	South (Jug)	Both North and South (I Sjever i Jug)	
Asperula involucrata	*Brachypodium sylvaticum*	*Abies nordmanniana*	*Lamium purpureum*
Astragalus glycyphyllos	*Centaurea triumfettii*	*Barbarea vulgaris.*	*Lapsana communis*
Cephalanthera longifolia	*Cytisus hirsitus*	*Brachypodium sylvaticum*	*Lathyrus laxiflorus*
Clinopodium vulgare	*Dactylis glomerata*	*Bromus ramosus*	*Luzula campestris*
Delphinium venulosum	*Caucalis platycarpos*	*Calamintha grandiflora*	*Melica uniflora*
Echium vulgare	*Dorycnium graecum*	*Campanula rapunculoides*	*Moneses uniflora*
Mercurialis perennis	*Euphorbia amygdaloides*	*Cardamine bulbifera*	*Mycelis muralis*
Monotropa hypopitys	*Euphrasia pectinata*	*Carex muricata*	*Myosotis sylvatica*
Poa pratensis	*Fagus orientalis*	*Circium hypoleucum*	*Orthilia secunda*
Polygala supina	*Galium aperine*	*Circium arvense*	*Oxalis acetosella*
Potentilla recta	*Galium verum*	*Clinopodium vulgare*	*Plantago major*
Pyrola chlorantha	*Hypericum montbretii*	*Crepis foetida*	*Polygonatum orientale*
Ranunculus brutius	*Juniperus oxycedrus*	*Cyclamen coum*	*Polystichum setiferum*
Silene vulgaris	*Lapsana communis*	*Daphne pontica*	*Primula acaulis*
Trifolium medium	*Lotus cornuculatus*	*Digitalis ferruginea*	*Primula vulgaris*
Verbascum blattaria	*Pilosella hoppeana*	*Doronicum orientale*	*Prunella vulagris*
	Plantago major	*Epilobium lanceolatum*	*Pteridium aqulia*
	Platanhera bifolia	*Epilobium montanum*	*Pyrola minor*
	Poa trivalis	*Epilobium montanum*	*Asperula arvenisi*
	Prunella vulgaris	*Erodium cicutarium*	*Rubus sanctus*
	Quercus petraea	*Euphorbia stricta*	*Rumex acetosella*
	Sangiosorba minör	*Filipendula vulgaris*	*Salvia forskahlei*
	Sanicula europea	*Fragaria vesca*	*Salvia verticillata*
	Sedum album	*Galium rotundifolium*	*Sambucus ebulus*
	Silene italica	*Galium verum*	*Sanicula europea*
	Sorbus torminalis	*Geranium purpureum*	*Trifolium medium*
	Trifolium pratense	*Geranium robertianum*	*Urtica dioca*
	Vicia cracca	*Helleborus orientalis*	*Veronica chamaedrys*
		Hieracium medianiforme	*Veronica officinalis*
		Lamium garganicum	*Veronica gentinioides*
			Viola odarata
			Viola suavis

riods during the study. Occurrences of taxa in different periods are given in Table 5.

While 67 taxa were seen on both northern and southern aspects in fir stands, the number of taxa seen only in the north was 22, and the number of taxa seen only in the south was 33. Taxa such as *Barbarea sp.*, *Brachypodium sylvaticum*, *Bromus sp.*, and *Calamintha grandiflora* were observed in both north and south views. However, taxa such as *Asperula involucrata*, *Astragalus glycyphyllos*, and *Cephalanthera longifolia* were seen only in the north, while taxa such as *Brachypodium sylvaticum*, *Centaurea triumfettii*, *Cytisus hirsutus*, and *Dactylis glomerata* were observed only in the south (Table 6). 8 taxa could not be identified due to the insufficient vegetative and generative organs of the collected samples, and were not included in the tables.

Findings on Plant Diversity Indices – *Nalazi o indeksima biljne raznolikosti*

In this study, diversity indices were calculated at two levels, alpha and gamma, and the findings were evaluated under separate sections. Within the scope of the study, diversity indices calculated at alpha level were used in the statistical analyses carried out to determine the differences in diversity indices determined according to stand type, aspect and observation time.

Findings of Alpha Diversity – *Rezultati alpha raznolikosti*

When the fir stands were compared with each other in terms of the Simpson diversity index, it was determined that the stand type, aspect and observation time did not have a statistically significant effect on taxa diversity. However, it was found that the stand type-aspect interaction had a statistically significant effect on diversity ($P<0.05$). According to these results, in terms of the Simpson diversity index, the lowest diversity was measured in the GB stands with 0.84 on south aspects, and the highest diversity was measured as 0.89 on south aspects of GC stands and north aspects of GB stands (Table 7).

When the fir stands were evaluated in terms of the Shannon diversity index, it was determined that the stand type and aspect did not have a statistically significant effect on taxa

Table 7. Aspect-stand type interaction in fir stands according to Simpson's index
Tablica 7. Interakcija izloženost – tip sastojine u jelovim sastojinama prema Simpsonovom indeksu

Stand Type (Tip Stalka)	South (Jug)	North (Sjever)
GA	$0,88^{ab} \pm 0,01$	$0,86^{ab} \pm 0,02$
GB	$0,84^{a} \pm 0,03$	$0,89^{ab} \pm 0,03$
GC	$0,89^{b} \pm 0,04$	$0,86^{ab} \pm 0,03$
GD	$0,87^{ab} \pm 0,04$	$0,85^{ab} \pm 0,02$

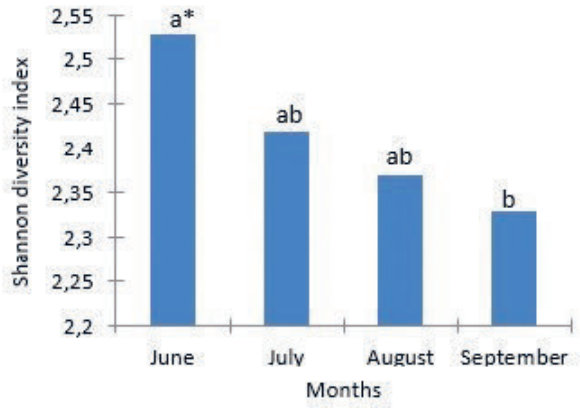

Figure 4. Periodic variation of Shannon diversity index in fir stands
*Similar letters on the columns show there is no significant differences between the means

Slika 4. Sezonska varijabilnost Shannonovog indeksa raznolikosti u sastojinama jele
* Slična slova na stupcima pokazuju da nema značajnih razlika između srednjih vrijednosti

diversity (P>0.05), but a significant change in plant diversity in observation periods was registered (P<0.05). The highest taxa diversity was measured in June (2.53), while the lowest diversity was measured in September (2.33) (Figure 4).

It was also determined that the stand type-aspect interaction had a significant effect on diversity (P<0.05). According to the Shannon diversity index, the highest diversity was measured in the GC stands with 2.65 on the south aspect and the lowest diversity was measured in the GB stands on the south aspect with 2.15 (Table 8).

Table 8. Aspect-stand type interaction in fir stands according to Shannon index
Tablica 8. Interakcija aspekt-sastojina u jelovim sastojinama prema Shanononovom indeksu

Stand Type (Tip stalka)	South (Jug)	North (Sjeverne)
GA	$2,51^{bc} \pm 0,12$	$2,41^{abc} \pm 0,14$
GB	$2,15^{a} \pm 0,20$	$2,51^{bc} \pm 0,22$
GC	$2,65^{c} \pm 0,28$	$2,28^{ab} \pm 0,15$
GD	$2,41^{abc} \pm 0,32$	$2,36^{abc} \pm 0,14$

When the fir stands were examined in terms of evenness values, it was determined that the stand type, aspect and observation period did not have a significant effect on the homogeneous distribution of the plants in the area (P>0.05). In addition to this, the interactions did not affect the species distribution (P>0.05).

Findings of Gamma Diversity – *Rezultati gamma raznolikosti*

The indices in this section, which represent larger populations (e.g, fir stands on south aspects), represent gamma diversity. Therefore, large regions were evaluated as the sampling area, and the species and numbers belonging to this area were evaluated together. While calculating the diversity indices of the GA stands, the taxa and numbers of 4 (observation time) *2 (aspect)*10 (quadrate)*2 (repetition) =160 quadrate samples were evaluated together. Also, the other stands were evaluated similarly.

In the study, a total of 122 taxa were determined in fir stands. Gamma diversity in fir stands is 0.96 according to the Simpson index and 3.64 according to the Shannon index. In terms of gamma diversity, the lowest Simpson index was measured as 0.93 in the GB stands and the highest as 0.96 in the GC stands. While the average Shannon diversity index value was 3.41, the lowest value was determined in GB stands with 3.21 and the highest was determined in GC stands with 3.57 (Table 9).

While the highest number of taxa was observed in July with 82, the lowest number was seen in September with 54. In terms of observation period, the highest diversity according to the Shannon index for fir stands was in June (3.51), and this decreased gradually towards August and started to rise again in September (3.31). The Simpson diversity index shows a similar trend to the Shannon index (Table 10).

The number of taxa and individuals were higher on the south aspects. Shannon diversity index values were also higher in the south than in the north. The Shannon value was 3.59 on the south aspect and 3.58 on the north aspect, while the Simpson diversity index values were determined as 0.96 for both aspects (Table 11).

When the stand type-observation period interaction was examined, the highest diversity according to the Shannon index was observed in July and September in GC stands with a value of 3.22. The lowest value of 2.62 was observed in GB stands in August. According to the Simpson diversity index, the highest value of 0.95 was observed in GA stands in July and in GC stands in September. The lowest value of 0.89 was observed in GD stands in August. Evenness values ranged between 0.40 and 0.68 (Table 12).

According to the Shannon index, the highest diversity was observed in GC stands with a value of 3.41 on the south aspect. The lowest value, with 2.73, was observed in the GB stands again on the south aspect. Only for this stand type,

Table 9. Variation of diversity indices according to stand types
Tablica 9. Varijabilnost različitih indeksa s obzirom na tipove sastojina

Stand Type (Tip stalka)	Number of Quadrates (Kvadratni broj)	Number of Taxa (Broj svojti)	Dominance (Dominacija)	Simpson	Shannon	Evenness (Ujednačenost)
GA	160	70	0,05	0,95	3,45	0,45
GB	160	63	0,07	0,93	3,21	0,39
GC	160	84	0,04	0,96	3,57	0,42
GD	160	78	0,05	0,95	3,40	0,38

Table 10. Variation of diversity indices according to observation time
Tablica 10. Varijacija indeksa raznolikosti prema vremenu promatranja

Observation time (Vrijeme promatranja)	Number of Quadrates (Kvadratni broj)	Number of Taxa (Broj svojti)	Dominance (Dominacija)	Simpson	Shannon	Evenness (Ujednačenost)
June (Lipanj)	160	77	0,04	0,96	3,51	0,43
July (Srpanj)	160	82	0,05	0,95	3,43	0,38
August (Kolovoz)	160	61	0,06	0,94	3,21	0,40
September (Rujan)	160	54	0,05	0,95	3,31	0,51

Table 11. Variation of diversity indices according to aspects
Tablica 11. Varijacija indeksa raznolikosti prema aspektima

Aspect (Izgled)	Number of Quadrates (Kvadratni broj)	Number of Taxa (Broj svojti)	Dominance (Dominacija)	Simpson	Shannon	Evenness (Ujednačenost)
South	320	100	0,04	0,96	3,59	0,36
North	320	89	0,04	0,96	3,58	0,40

Table 12. Diversity indices by stand type and observation time
Tablica 12. Indeksi raznolikosti prema vrsti sastojine i vremenu promatranja

Stand Type (Tip staništa)	Observation Time (Vrijeme promatranja)	Number of Taxa (Broj svojti)	Dominance (Dominacija)	Simpson	Shannon	Evenness (Ujednačenost)
GA	June (Lipanj)	42	0,07	0,93	3,00	0,48
	July (Srpanj)	41	0,05	0,95	3,19	0,59
	August (Kolovoz)	35	0,10	0,90	2,71	0,43
	September (Rujan)	34	0,07	0,93	2,98	0,58
GB	June (Lipanj)	36	0,07	0,93	2,96	0,54
	July (Srpanj)	32	0,10	0,90	2,70	0,47
	August (Kolovoz)	30	0,10	0,90	2,62	0,46
	September (Rujan)	35	0,07	0,93	2,98	0,56
GC	June (Lipanj)	41	0,07	0,93	3,08	0,53
	July (Srpanj)	50	0,06	0,94	3,22	0,50
	August (Kolovoz)	47	0,06	0,94	3,15	0,50
	September (Rujan)	37	0,05	0,95	3,22	0,68
GD	June (Lipanj)	47	0,07	0,93	3,12	0,48
	July (Srpanj)	41	0,07	0,93	2,99	0,49
	August (Kolovoz)	37	0,11	0,89	2,69	0,40
	September (Rujan)	36	0,09	0,91	2,85	0,48

the Shannon value in the south was lower than in the north. In other fir stands, the Shannon diversity index for the south aspect was either equal to or higher than the north. According to the Simpson diversity index, the highest value was 0.95 and this value was seen on the southern aspects of fir stands, except GB. The Simpson diversity index for

Table 13. Diversity indices by stand type and aspect
Tablica 13. Indeksi raznolikosti s obzirom na tip sastojine i izloženost

Stand Type (Tip stalka)	Aspects (Izgled)	Number of Taxa (Broj svojti)	Dominance (Dominacija)	Simpson	Shannon	Evenness (Ujednačenost)
GA	South	56	0,05	0,95	3,34	0,50
	North	51	0,05	0,95	3,34	0,55
GB	South	43	0,10	0,90	2,73	0,36
	North	50	0,05	0,95	3,34	0,56
GC	South	64	0,05	0,95	3,41	0,47
	North	54	0,06	0,94	3,13	0,42
GD	South	61	0,05	0,95	3,28	0,43
	North	53	0,05	0,95	3,19	0,46

Table 14. Diversity indices in fir stands by aspect and observation period
Tablica 14. Indeksi raznolikosti u sastojinama jele s obzirom na izloženost i razdoblje promatranja

Aspects (Izgled)	Observation Time (Vrijeme promatranja)	Number of Quadrates (Kvadratni broj)	Number of Taxa (Broj svojti)	Dominance (Dominacija)	Simpson	Shannon	Evenness (Ujednačenost)
South (Jug)	June (Lipanj)	80	60	0,05	0,95	3,36	0,48
	July (Srpanj)	80	61	0,05	0,95	3,31	0,45
	August (Kolovoz)	80	55	0,07	0,93	3,11	0,41
	September (Rujan)	80	44	0,06	0,94	3,19	0,55
North (Sjeverne)	June (Lipanj)	80	53	0,06	0,94	3,29	0,51
	July (Srpanj)	80	59	0,05	0,95	3,33	0,47
	August (Kolovoz)	80	47	0,06	0,94	3,10	0,47
	September (Rujan)	80	45	0,05	0,95	3,25	0,57

GB on the south aspect was 0.90, which was the lowest level for fir stands. Also, the evenness value (0.36) of GB stands on the south aspect was the lowest. Interestingly, the north aspects of these stands had the highest evenness value with 0.56 (Table 13).

Among the fir stands, the highest diversity by aspect and observation period according to the Shannon index was seen in June on the southern slopes with a value of 3.36. The lowest value was 3.10 in August in the north. While the lowest evenness value was observed in August with 0.41 on the south aspect, the highest value in the north was observed in September with 0.57 (Table 14).

DISCUSSION
RASPRAVA

With this study, taxa were determined by sampling in 640 quadrate samples in GA, GB, GC and GD stands of fir forests on north and south aspects from June to September. Shannon and Simpson diversity index values were calculated at alpha and gamma diversity levels in these stands.

122 taxa were determined at the level of variety, subspecies, species, genus and family. However, in a situation of whole stand area survey, it could be expected that the number of taxa would be higher for this region. Beus and Vojniković (2005) identified 56 plant species in mixed fir and beech species in Bosnia and Herzegovina. Although our study was realized in pure stands of Trojan fir, their value is less than half of our results. There can be many factors effecting floristic composition. Also, there are mixed stands of fir with pine around our study area, but we did not focus on them. By carrying out the diversity analysis in different forest stands with step-by-step researches, it can be possible to compare similar areas in terms of diversity and make a classification. Redowan (2015) made a classification of diversity indices for Majella National Park (Italy) by arranging the index values and classifying them from low to high to compare different forest areas in the national park. A similar global system can be developed by carrying out the diversity index analyses for different regions.

Among 122 taxa, some, like *Calamintha grandiflora*, *Fragaria vesca*, *Helleborus orientalis*, and *Rubus sanctus* were registered in all stand types (GA, GB, GB, SE) from June to September. However, considering the aspect conditions, it was determined that only *Fragaria vesca* was seen in quadrates in all cases. *Fragaria vesca* is an important taxon for wildlife, as well as for cultivation for its fruits. It is an important product that should be evaluated as a non-wood forest product in terms of planning. It can also be used as an income-generating product for the local people.

Graae and Heskjaer (1997) did not observe the effect of stand structure on species diversity in their study to determine the differences between managed and non-managed forests. However, they stated that there is less species rich-

ness in older stands. Also, Behera and Misra (2006) did not find a significant difference among the stands in terms of the Shannon diversity index in their study on the analysis of herbaceous vegetation in four different stands consisting of broad-leaved species. On the other hand, Pitkanen (1997) reported that species richness is higher in young stands and in the fertile areas, and also, albeit at a lesser level, the basal area, crown cover and species mixing ratio in trees are also influential on this. Contrary to this, Zhu et al. (2009) indicated that species diversity was greatest in the mid-successional stage, which appears similar to our results. This can be interpreted as a peaked (n-shaped) diversity - age (or diameter) class relationship, while Gosper et al. (2013) found a U-shaped relationship between diversity and time since fire. In this study, based on the gamma diversity level, relatively young stands (GB) have the poorest diversity in terms of the Simpson and Shannon indices. They peak in GC stands and then decrease in GA stands, which represent the older (thicker) areas.

In the statistical analyses based on the diversity indices calculated at the alpha diversity level, there were no significant differences in terms of the Simpson diversity index in fir stands according to stand type, aspect and observation period. However, stand type-aspect interaction had a significant effect on diversity. Since the fir stands have a vertically layered structure, it is assumed that the more stable and similar microclimatic conditions in the stand are responsible for this. On the other hand, while there were no significant differences in terms of stand type and aspect among the diversity values found according to the Shannon index, it was seen that observation period was effective and that the diversity decreased periodically from June to September. It is thought that with the beginning of the vegetation period, a large number of plants began to appear, but that later on, due to both the climatic conditions and the life span of the plants, they disappeared from the area. The Shannon diversity indices in fir stands (except GB) on the southern aspects had higher values than the northern aspects. Graae and Heskjaer (1997) stated that soil moisture is influential on vegetation. Although no soil moisture measurements were carried out in this study, it is thought that favorable site conditions for diversified species under the vertical and thick crown layer of fir stands can be formed on south aspects with more sunlight. Since the study area is adjacent to the steppe transition zone and the partial drought seen in the summer months affects the distribution of plants in terms of species and quantity, the decrease in diversity from June to September can be explained by the fact that some species disappear due to summer drought or their short vegetation period.

Periodic differences in vegetative diversity indices or plant richness may also have resulted from the sampling method used. As a matter of fact, the quadrate (frame) samples taken from the stands were not at the same place in every period of observation, and conscious systematic shifts were made in order to better represent the stands. For this reason, since the plants are not homogeneously distributed in the forest stand area, the plants observed in one place in the stand might not be seen in other areas around. So, some plants may not have coincided with the quadrates and may have not been evaluated as to whether they exist in the area. Although this type of sampling is advantageous in terms of revealing the plant richness of the stands, it may lead to the fact that sparse plants in the area cannot be sampled every time, and that therefore, they are considered as dried out and lost from the environment.

CONCLUSION
ZAKLJUČAK

Only the developmental stages of stand types change under normal conditions while forests are being managed. Therefore, knowing the plant diversity in terms of stand types will help to predict the future vegetative diversity depending on the change of stand types over time. With the present study, the vegetative diversity values of the stands for fir were revealed. From this, diversity can be calculated for different forest areas and for the entire forest. In this way, vegetative diversity can be determined numerically and steps can be taken towards its integration into forest planning and management.

Since fully stocked stands (having a closure of more than 70%) will be formed under successful forest management conditions, this study has been limited to this type of stand. It is necessary to present the vegetative diversity numerically for different closure situations, even for different site and elevation situations and in different tree species. In this way, comparisons can be made in terms of tree species and stand types by using vegetative diversity indices such as site class, which expresses the wood yield strength of a habitat.

ACKNOWLEDGEMENTS: This work was supported by The Scientific and Technological Research Council of Turkey (TUBITAK), with Project ID: TOVAG-115O958. We also thank to Ahmet Ayteğin and Yusuf Ercan for their collaboration on field.

DECLARATIONS: We confirm that the manuscript is the authors' original work and it has not received prior publication and is not under consideration for publication elsewhere.

FUNDING: This work was supported by the Scientific and Technological Research Council of Turkey (TUBITAK, Project ID: TOVAG-115O958).

CONFLICTS OF INTEREST/COMPETING INTERESTS: The authors declare that they have no known competing or conflicts of interests.

AVAILABILITY OF DATA AND MATERIAL: The data that support the findings of this study are available from the corresponding author upon reasonable request.

CODE AVAILABILITY: Not applicable.

AUTHORS' CONTRIBUTIONS: All authors equally contributed to different parts of the manuscript.

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SAŽETAK

Procijenjeno je 640 uzoraka 0,5x0,5 m dobivenih metodom sustavnog uzorkovanja. Uzorkovanje je obavljeno u dva ponavljanja u GA (staroj), GB (mladoj), GC (srednjedobnoj), GD (nepravilnoj) sastojini, na sjevernim i južnim izloženostima. Terenska istraživanja provedena su tijekom 4 različita razdoblja (lipanj, srpanj, kolovoz, rujan) unutar vegetacijskog razdoblja. Određene su 122 biljne svojte na razini vrsta i infraspecifičnih svojti. U samo jednoj sastojini jele zabilježeno je 48 biljnih svojti, 41 svojta zabilježena je u svim sastojinama. 5 svojti biljaka viđeno je samo u GA sastojinama, 7 u GB, 15 u GC i 13 samo u GD sastojinama. Najbogatiji tip sastojine po broju svojti utvrđen je kao GC tip sastojine sa 84 biljne svojte, ali je više jedinki po ha izbrojano u GA i GD sastojinama.

KLJUČNE RIJEČI: Trojanska jela, Raznolikost biljaka, Indeksi raznolikosti, Sastojina, Aladağ, Turska.