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RESEARCH ARTICLE

PLANT SPECIES DIVERSITY AND LIFE –FORM SPECTRA ALONG AN ELEVATIONAL GRADIENT IN EASTERN BLACK SEA REGION OF TURKEY

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ABSTRACT

Alpha and beta diversity and evenness were investigated along an elevational gradient in a mountainous region in East Black Sea Region of Turkey. Alpha and beta diversity indexes and Shannon's evenness were significantly changed along the elevational gradient. The highest Shannon_Wiener and Margalef were found in *Festuca lazistanica* subsp. *giresunica* community. The highest Simpson's index was found in *Acantholimon acerosum* community. Alpine grasslands represented by *Festuca lazistanica* subsp. *giresunica* community had the lowest evenness, while forest communities represented by *P. orientalis-Rh. luteum* community had the highest evenness. The highest beta diversity was found in *Picea orientalis-Rhododendron luteum* forest community, while the lowest beta diversity was found in *Festuca lazistanica* subsp. *giresunica* community. Organic matter, elevation and aspect were found to be the most significant factors by CCA analysis. While hemicryptophytes was found to be the dominant life form in studied in all different plant communities, therophytes was found to be lowest.

INTRODUCTION

Plant biodiversity patterns and their underlying mechanisms are constitute to the main goals of macroecology and species diversity is defined one of the most remarkable concept which are used for the evaluation of ecosystems at different scales. It means the variety of species in a given region, area or in the whole world. Changes in species diversity are related to many ecological gradients (Grime, 2001). It has been proposed that elevation is one of the most notable factors which effect plant biodiversity patterns (Magurran, 1988; Isık and Ugurlu 2011; Tang *et al.* 2012). Species diversity, as a component of biodiversity is closely related to other parameters of ecosystem functioning such as productivity. It has been reported that species diversity enhanced ecosystem productivity and stability (Buba 2015; Lee and Chun 2016). The composition, structure and function of species are significant in protecting the ecosystem integrity. Pausas and Austin (2001) stated that plants with a similar life form are assumed to have a similar effect on the dominant ecosystem processes. The diversity of plant life forms reflect the species richness patterns in relation to environmental gradients (Tierney *et al.* 2009; Mahdavi *et al.* 2013). Alpha and beta diversity are two main components of plant biodiversity.

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Alpha diversity is measured in habitat level, while beta diversity showed the difference in species composition and changes of diversity from a habitat/community to another one (Ghilishli *et al*., 2015). Relations between evenness and richness of species provide important information in the understanding of the model and mechanisms of biodiversity. Species evenness is the key measurement of community structure and some ecological processes like competition can change species evenness (Wang *et al.* 2004; Zhang *et al*., 2012; Chang *et al.* 2012). It has been emphasized that the vegetation pattern is closely related to the pattern of micro-topography in mountainous areas and an altitude gradient is formed and this gradient affects the community patterns. Biodiversity is subjected to spatial variation and abiotic factors such as heterogeneity of the environment contribute to levels of biodiversity in addition to biotic factors such as competition and facilitation at the local scale (Lee and Chun, 2016). Biological diversity and Evenness were studied along an elevational gradient in North of Anatolia because this area has a transitional character between Euxine and Irano-Turanian Phytogeographical Region and influenced by both oceanic and arid climates and include several communities like mixed coniferous forests, alpine shrubs, alpine meadows, and steppe communities. This study is aimed to determine (i) whether species diversity and evenness are changed along the elevational gradient or not (ii) the probable relationships between the distribution of life forms and species diversity (ii) the relationships among environmental factors and plant communities along the elevational gradient.

MATERIALS AND METHODS

Study Area

The study area is situated in southern parts of Ordu city with an average altitude of 1350-3107 m. The studied localities are Mesudiye (40° 34'15.80"N and 37°45'44.27" E; 1350 m), Turnalik (40°42'58.82"N and 37°55'52.90"E; 1670 m), Cambasi (40°37'2.99"N and 37°56'56.03"E; 1850 m) and Karagol Mountain (40°31'41.71"N and 38°8'26.44"E; 3107 m) (Figure 1). Climatic data showed that mean annual temperature is decreased, while mean annual precipitation is increased along the elevational gradient (Table 1). Mesudiye is characterized by steppic communities dominated by *Acantholimon acerosum* (Wild.) Boiss. *Picea orientalis-Rhododendron luteum* forest communities is very widespread in Turnalık. Cambası and Karagöl are characterized by alpine meadows characterized by *Thymus praecox* subp. *alpina* and *Festuca lazistanica* subsp. *giresunica* communities, respectively. *Acantholimon acerosum* (Wild.) Boiss community is usually occurred in dry and unproductive and stony soils. Codominant species in that community were *Ranunculus arvensis*, *Prunus mahaleb*, *Chelidonium majus*, *Juniperus excelsa*, *Ranunculus oreophilus*, *Lathyrus laxiflorus. Picea orientalis – Rhododendron luteum* community occurred in north and northwest slopes on acidic and silty-loam soils. *Rhododendron ponticum*, *Saxifraga sibirica L. subsp. mollis* (Sm) Mathews, *Salvia forskahlei*, *Cardamine bulbifera*, *Galium rotundifolium*, *Rosa cannina*, *Ajuga eupotaria* L. were accompanied species. *Thymus praecox subsp. jankae* community occurred acidic and organic soils. *Saxifraga sibirica* L. subsp. *mollis* (Sm) Mathews, *Fagus orientalis* Lipsky, *Aster alpinus* L.,*Coryllus avellana* were also found in that community. *Festuca lazistanica* Alexeev subsp. *giresunica* community occurred in azonal soils and codominant species in that community were *Epilobium montanum*, *Colchicum kotschyi* Boiss., Diagn, *Cardamine bulbifera*L., *Stellaria holostea, Colchicum speciosum* Steven, *Helichrysum arenarium*(L.), *Symphytum sylvaticum* subsp. *sylvaticum*, *Allium djimilense* Boissex. Regel, *Legousia pentagonia* (L.) Thellung.

Sampling

All study areas covered 100 quadrats consisting quadrats of 20mx20m for trees, 10mx10m subplot for shrubs and 1mx1m for grass. Percent cover was recorded for each species within continuous sampling plots (Blanquet, 1934). The cover-abundance symbols of the Braun-Blanquet scale (r, +, 1, 2, 3, 4 and 5) were replaced by values according to van der Maarel: 1, 2, 3, 5, 7, 8, and 9, respectively (Yalcin *et al.* 2004; Agır *et al.* 2016). Raunkiaer's life forms of plants were classified according to Ellenberg & Mueller-Dombois (1967). The Shannon, Simpson, and Margalef diversity indexes have been widely used to determine alpha diversity in biodiversity studies (Magurran 2004). The Shannon-Wiener index standardizes the percentage abundance of species in a proportionate way and it expresses the proportion of the coverage of a given species in the total sample (Gülsoy and Özkan, 2008; Zhang *et al.* 2012).

$$H' = \sum_{i=1}^{s} p_i ln p_i \quad (1)$$

Simpson's biodiversity index is focused on concentration of dominance of a particular species in a particular ecosystem (Rahman *et al.* 2009). Simpson index is defined with the formula stated in equation.

$$D = 1/(\sum_{i=1}^{s} p_i{}^2) \quad (2)$$

Margalef index represents the number of species in the total number of individuals of the species and it is calculated with the formula stated in equation (Rahman, 2009).

$$Da = (S-1)/ \log_e N \quad (3)$$

Evenness value shows the percentage of presence of plant species in comparison to one another in a plant unity or in a sample plot (Kılınç *et al*., 2006) and evenness was calculated by using Shannon equitability (E_H) with H'/H'_{max} ratio (where H'_{max} =ln S). (Agır *et al.* 2016).

$$E_H = \sum_{i=1}^{s} p_i ln p_i \ / \ \ln S \quad (4)$$

Beta diversity is defined as spatial heterogeneity or pattern diversity index and calculated by using Whittaker's formula (Magurran 2004; Agır *et al.* 2016).

$$\beta w = S/\alpha - 1 \quad (5)$$

Where; S: total number of species and α: average species richness in the samples.

The alpha and beta diversity indices values are defined by using Biodiversity Pro 2 Programme (McAllece *et al.* 1997). Aspect was recorded as the azimuth (ɵ) measured from true north and transformed to a relative measure for heat load (HL) using the equation HL = [1 _ cos(u)]/2 (Fontaine *et al.* 2007). Twenty soil samples of 0-30 cm depth were collected from each community using an auger and they were air-dried and sieved to pass through a 2-mm screen. pH was determined in deionized water (1:2.5) and the samples were thoroughly mixed by a shaker and then filtered through Whatman No. 42 filter paper and measured by using an Expandomatic IV digital pH meter. Soil nitrogen concentration was determined by the micro Kjeldahl method. Soil phosphorus concentration was determined spectrophotometrically following the extraction by ammonium acetate. Soil potassium was determined by using a Petracourt PFP-7 flame photometer after ammonium acetate-acetic acid extraction. Organic matter concentration was determined by Walkley-Black method (Kacar, 2012).

Statistical Analysis

SSPSS v.22.0 program was used to determine significant difference and correlation between species diversity and ecological traits. ANOVA was used to assess statistical differences in various parameters between plant data and ecological parameters. To show the relationships among environmental variables and plant communities Canonical Correlational Analysis (CCA) is employed by using the CAP 1.5 version (Community Analysis Package, 1999) and ECOM 1.33 version (Environmental Community Analysis, 2001). Data were also analyzed by using the Plymouth Routines in Multivariate Ecological Research (PRIMER) version 5.0, software package for the determination of Bray-Curtis similarity (Clarke and Gorley 2001).

Figure 1. Map of the study area

Table 1. Climatic data of the study area

Locality	Climatic data	1	2	3	4	5	6	7	8	9	10	11	12	Total
Mesudiye	Temperature (°C)	-2.8	-0.7	2.9	8.0	11.6	14.6	17.2	16.9	14.1	9.8	4.7	0.2	8.04
	Precipitation (mm)	46.7	39.2	41.3	74.2	82.8	47.9	11.6	8.0	21.4	42.9	52.5	60.9	529.4
Turnalik	Temperature (°C)	0.8	0.4	-1.6	-1.6	3.6	8.2	12.0	16.2	16.6	12.0	7.0	2.8	6.45
	Precipitation (mm)	105.1	106.5	105.8	92.73	90.42	112.3	99.2	108.0	110.2	143.5	141.0	105.0	1231.5
Cambasi	Temperature (°C)	-2.1	-1.6	-3.6	-3.4	1.6	6.6	10.0	14.2	14.4	10.0	5.0	0.8	4.32
	Precipitation (mm)	123.1	124.5	123.8	110.7	108.4	130.3	117.2	126.2	128.5	161.2	159.0	122.5	1534.7
Karagol	Temperature (°C)	-3.8	-2.6	-4.6	0.6	5.2	9.0	13.2	13.6	9.0	4.0	-3.8	-2.0	3.15
	Precipitation (mm)	132.1	133.5	132.8	119.7	117.4	139.3	126.2	135.0	137.2	170.5	168.0	131.5	1643.0

RESULTS

Alpha and beta diversity indexes and Shannon's evenness were significantly changed along the elevational gradient. The lowest ShannonWiener and Margalef were found in *Festuca lazistanica* subsp. *giresunica* community. Simpson index indicate that the bigger the value of D, the lower the diversity and the highest Simpson's index was found in *Acantholimon acerosum* community (Figure 2). Alpine grasslands represented by *Festuca lazistanica* subsp. *giresunica* community had the lowest evenness, while forest communities represented by *P. orientalis-Rh. luteum* community had the highest evenness (Table 2).

The highest beta diversity was found in *Picea orientalis-Rhododendron luteum* forest community, while the lowest beta diversity was found in *Festuca lazistanica* subsp. *giresunica* community (Table 2). Rarefaction diagram was coincided with the biodiversity indexes (Figure 3). Bray-Curtis similarity diagram showed that four different groups were separated and *Festuca lazistanica* subsp. *giresunica* community was found to be different from the other communities (Figure 4). Only Margalef index was significantly correlated with elevation. The other correlations were not significant (Figure 5). Organic matter, elevation and aspect were found to be the most significant factors by CCA analysis. *Acantholimon acerosum* and *Festuca lazistanica* subsp. *giresunica* communities were associated with elevation and aspect, while *Picea orientalis*

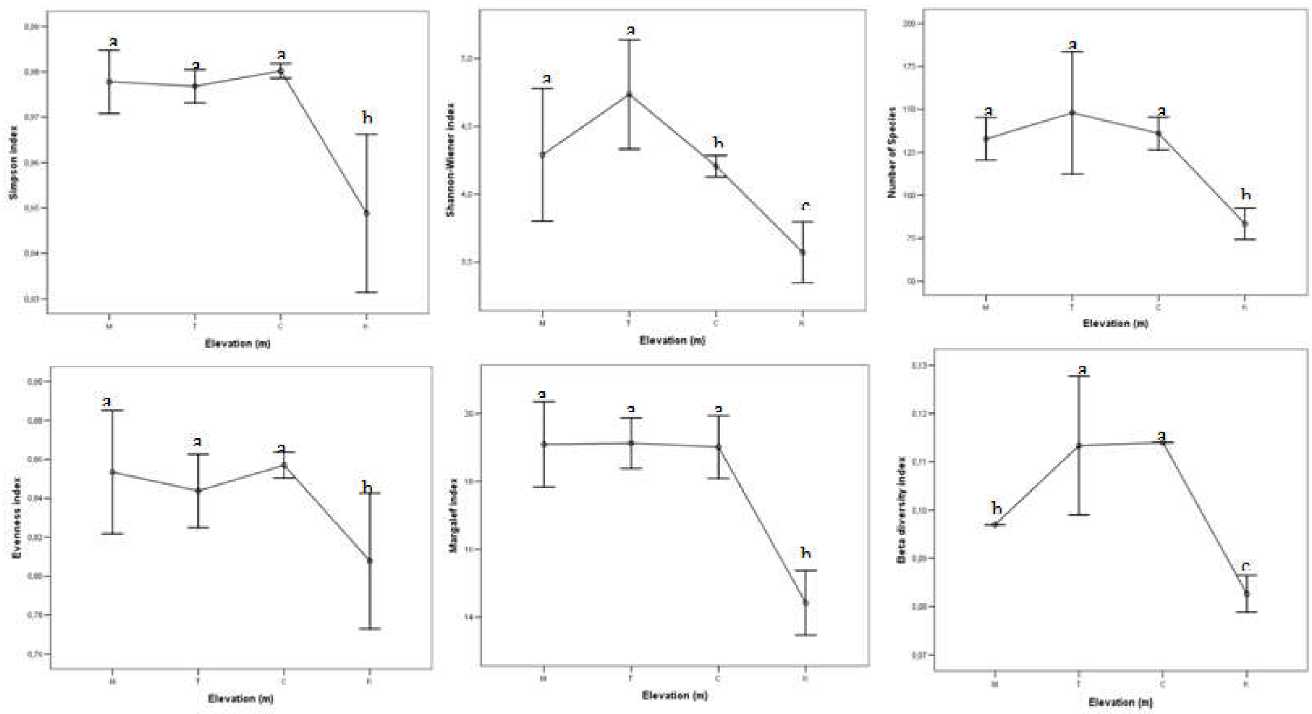

Figure 2. Alpha and beta diversityalong the elevational gradient

Table 2. Alpha and beta diversity indexes in the study area

Diversity index	Locality	Mean ±Standard error	F-value
Shannon-Wiener	C	4.29±0.17	15.56**
	T	4.74±0.14	
	M	4.20±0.02	
	K	3.57±0.08	
Simpson	C	0.98±0.01	18.38**
	T	0.98±0.01	
	M	0.99±0.02	
	K	0.95±0.02	
Margalef	C	19.09±0.45	42.96**
	T	19.13±0.26	
	M	19.02±0.33	
	K	14.42±0.34	
Shannon eveness	C	0.85±0.02	5.96*
	T	0.84±0.01	
	M	0.86±0.01	
	K	0.81±0.02	
Species richness	C	132.80±4.46	15.73**
	T	148.00±1.28	
	M	136.00±3.40	
	K	83.40±3.24	
Beta diversity	C	0.097±0.002	75.24**
	T	0.117±0.002	
	M	0.114±0.002	
	K	0.084±0.002	

**p <0.01 * p<0.05 Localities: C. Cambasi T: Turnalik M: Mesudiye K: Karagol

Table 3. Eigenvalues and intraset correlation coeffients for CCA. Significant values were indicated in bold.

	First axis	Second axis
Eigenvalues	0.332	0.180
Percent of restricted cumulative	15.8	24.4
Species-environment correlation	0.923	0.844
Intra-set correlation	32.9	50.9
K	-0.199	0.163
N	-0.089	0.008
pH	-0.226	0.006
Organic matter	-0.526	-0.001
P	-0.112	0.392
Elevation	0.680	-0.358
Slope	-0.011	-0.116
Aspect	0.046	0.533

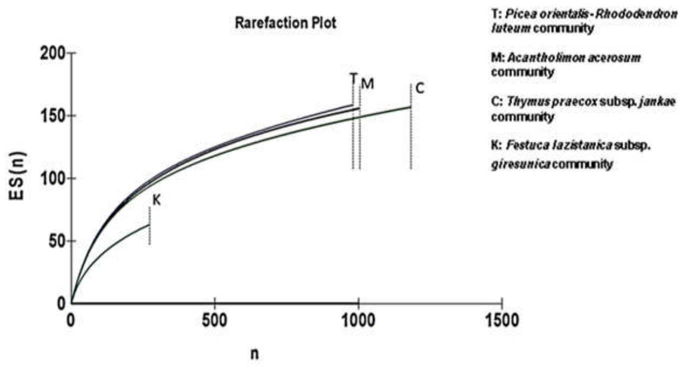

Figure 3. Rarefaction diagram of the studied localities (T: *Picea orientalis- Rhododendron luteum* community; M: *Acantholimon acerosum* community; C: *Thymus praecox* subsp. *jankae* community; K: *Festuca lazistanica* subsp. *giresunica* community).

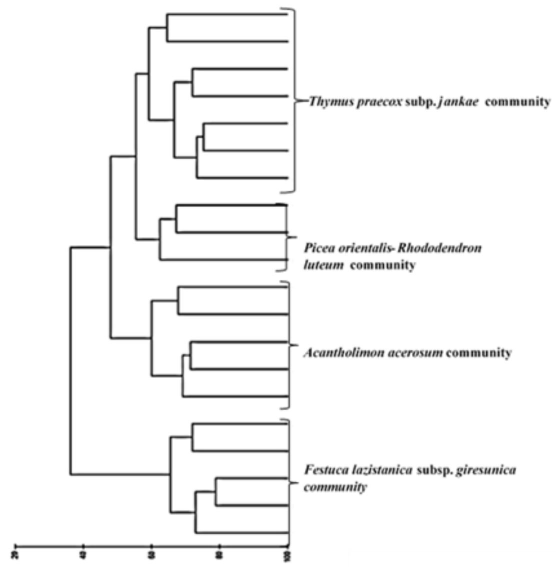

Figure 4. Bray-Curtis diagram of the studied localities

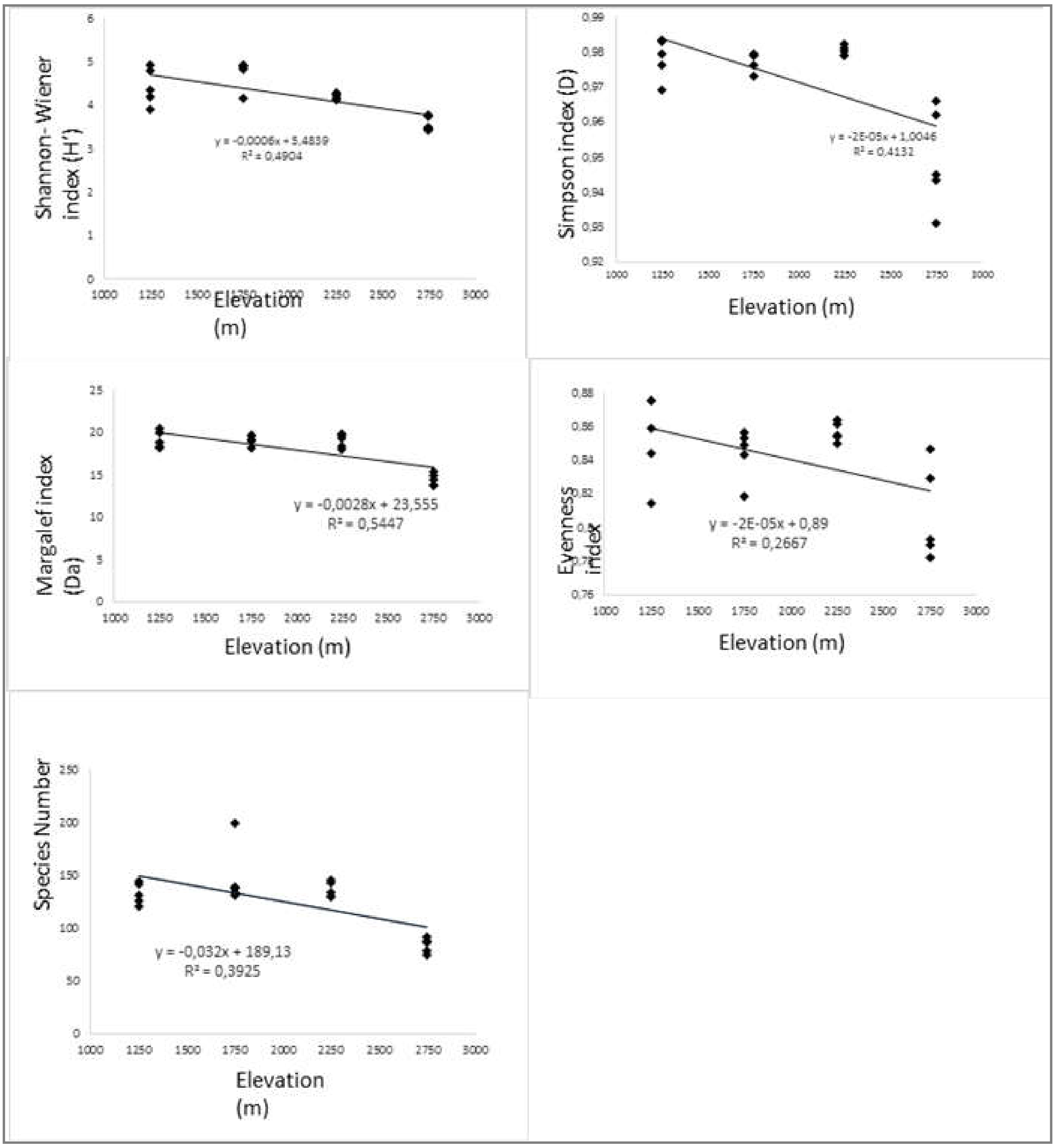

Figure 5. Relationship between diversity indexes and elevation (P<0.001)

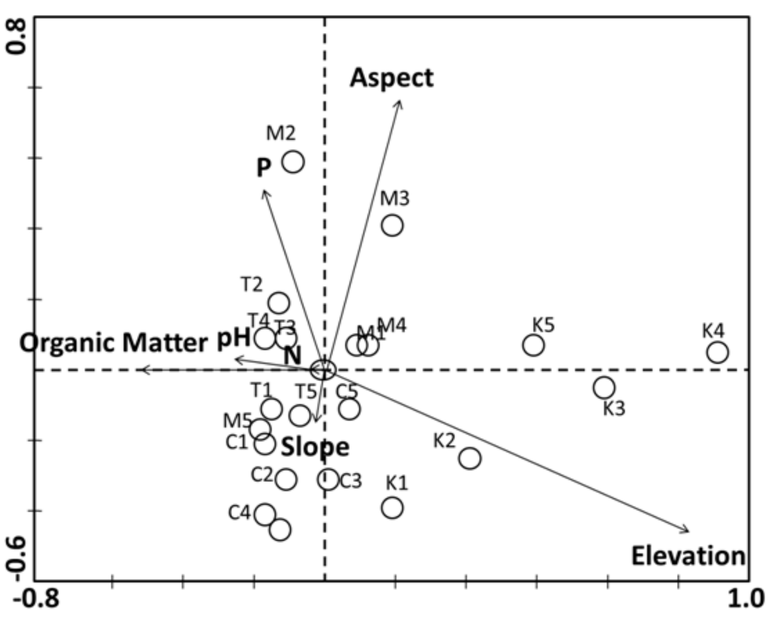

Figure 6.CCA ordination of the studied communities

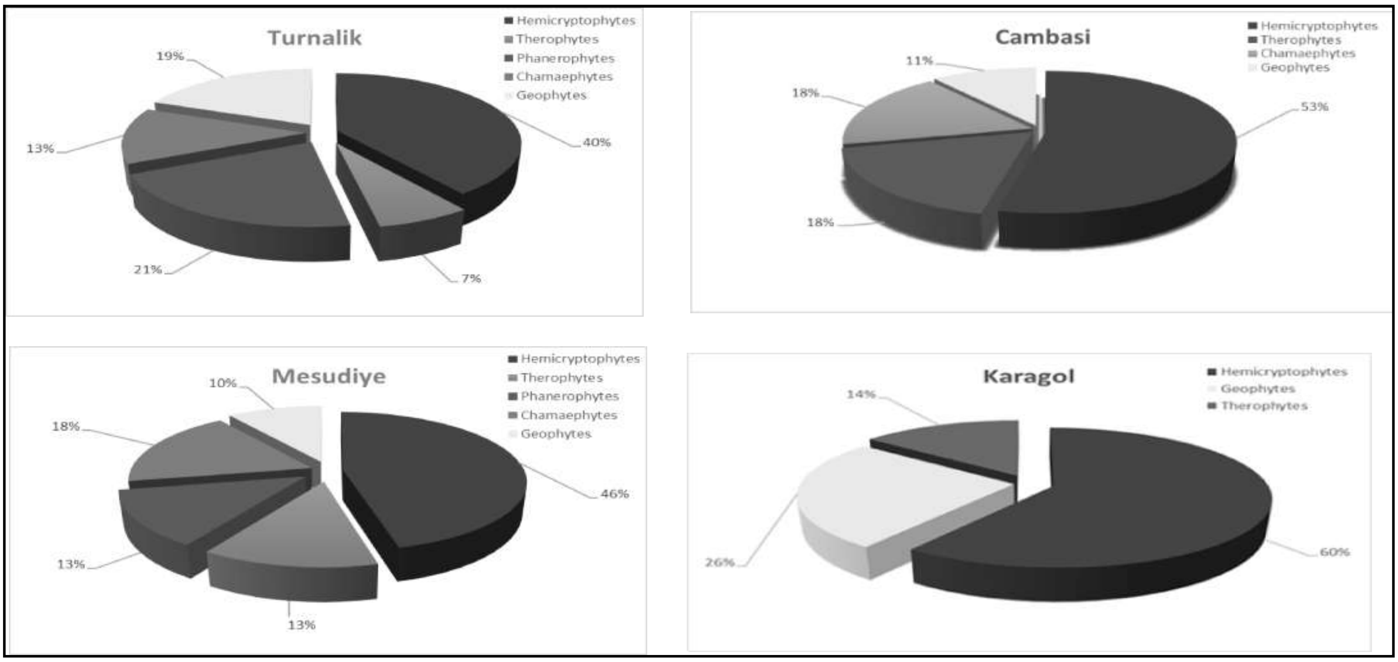

Figure 7. The distribution of life forms in studied localities

community was negatively associated with soil organic matter content (Table 3; Figure 6). Hemicryptophytes was found to be the dominant life form in studied plant communities. In *Festuca lazistanica* subsp.*giresunica* community, hemicryptophytes were followed by geophytes. In *Acantholimon acerosum* community hemicryptophytes were followed by chamephytes. In *Thymus praecox* subp. *alpina* community, hemicryptophytes were followed by chamephytes and therophytes (Figure 7).

DISCUSSION

Negative regressions were found among diversity indices and elevation and it has been found that Margalef index was significantly correlated with elevation. These significant changes may be attributed to the climatic differences, substrate discontinuities and mountainous escarpment along the elevational gradient (Hegazy *et al.* 1998). A linear relationship was also reported among species richness, diversity, and maturity values and ecological factors such as altitude, and aspect etc (Schuster and Diekmann 2005; Shaheen *et al.* 2011). Treberg and Turkington (2014) stated that evenness expresses how equally abundant species are in a particular community the lowest evenness indicated some species become much more abundant relative to others in that particular community, and as density and competition increased, these species were more affected than other species. *T. praecox* subsp. *alpina* community had the highest evenness due to a more balanced species composition, while *F. lazistanica* subsp. *giresunica* community had the lowest evenness due to high coverage of this species (Giupponi *et al.* 2015; Agır *et al.* 2016). It has been found that alpine grasslands and steppe communities had lowest species diversity. The alpine regions are characterized by low productivity, high intensity of solar radiation, and high degree of resource seasonality because of high ultraviolet (UV) radiation, high wind velocity, blizzards, low temperature, and snowstorms (Nautiyal *et al.,* 2004). The vegetation of this fragile zone is adapted to the extreme conditions occurring with sparse populations; is generally dwarfed, stunted, or spiny; and develops a mosaic patch of different forms. Some ecophysiological stress factors (especially temperature) explain the low species richness in alpine environments (Mahdavi *et al.* 2013). Ecological relations and structure of communities can only be explained if the relationships between species diversity and environmental values are examined (Odat *et al.* 2010). Elevation was found to be a very significant factor by CCA analysis. Soil organic matter content and aspect were also found to be significant. Soil organic matter was associated with *Picea orientalis* communities, while *A.acerosum* and *F. lazistanica* subsp. *giresunica* communities were associated with elevation and aspect. Elevation was classified as the variable which best explains variations in species diversity and local variables such as soil organic matter and the degree of slope play a secondary role in species diversity. Several studies have demonstrated the importance of topography and soils in regulating vegetation patterns across mountainous regions (Sánchez-González and López-Mata 2005; Sherman *et al.* 2008; Kopeč *et al.* 2010; Ozkan and Berger 2014). In addition to elevation, aspect is also significant in main vegetation distributions, because they have an impact on the isolation of communities affecting the water in the soil. Soil organic matter content is affected by microclimate, soil structure, and nutrient cycle etc in arid and semi-arid regions (Binkley and Giardina, 1998; Mirzaei and Karami 2015).

Beta diversity values were found to be low in studied communities. Szymura *et al.* (2016) stated that relatively few species dominated in alpine regions with high ground cover values and as a result of this beta diversity was generally low in alpine regions due to various factors such as large total area of grasslands, low geological but high land-cover diversity. The highest beta diversity was found in *Picea orientalis–Rhododendron luteum* community**,** while the lowest beta diversity was found in *Festuca lazistanica* subsp.*giresunica* community. The number of species is low in *Festuca lazistanica* subsp.*giresunica* community and if the species in different sample areas are persistent and the same species are repeated, beta diversity is low, while if different species co-occurred beta diversity will be high (Kılınc *et al.* 2006).

Gulsoy and Ozkan (2008) stated that high beta diversity values indicate high level of exchange in the number of species and showed the exchange amount of the species throughout the environmental gradient (Hashemi, 2010). As a result of this, beta diversity was found to be low at high elevations due to harsh environmental conditions like low temperatures, short growing season, high solar radiation, wind velocity etc and this shows that *Festuca lazistanica* subsp.*giresunica* community had the lowest heterogeneity. The studied communities were dominated by hemicryptophytes. The survival of hemicryptophytes is strongly related to the soil moisture in the upper soil layers. It has been stated that the large representation of hemicryptophytes confirms the preponderance of steppe vegetation. For example, in Mesudiye *Acantholimon acerosum* (Wild.) Boiss exhibits chamaephytic and strumous form. Wind-swept habitats at high altitudes are mainly characterized by thorny-cushion vegetation and this species is able to survive under heavy grazing and unsuitable climatic and edaphic conditions such as snow cover and soil erosion. This species has some superiorities in terms of resilience to drought for a long time and tolerance to topographic and edaphic extreme conditions (Yücel, 2002; Mahdavi *et al.* 2013). It has also been found that the ratio of hemicryptophytes in *Festuca lazistanica* subsp.*giresunica* community which occurred at high elevations were the highest. Baumann *et al.* (2016) stated that the much more pronounced summer drought causes to increase the number of hemicryptophytes with elevation. In *Festuca lazistanica* subsp.*giresunica* community, hemicryptophytes were followed by geophytes. Geophytes have some advantages with respect to high mucilage content which lowered freezing point and able to survive shallow soils (Jacquemyn *et al.* 2009; Mahdavi *et al.* 2013). In Mesudiye which characterized by *Acantholimon acerosum*, hemicryptophytes were followed by chamephytes and the lowest annual rainfall was found in Mesudiye region. Chamaephytes are better adapted to drought as compared to the other life forms (Senni *et al.* 2013). Biological diversity in mountainous areas has a particular importance because they are harbour for endemic species and the protection of such areas is a vital importance for maintain ecosystem balance (Shaeen *et al.* 2011). More detailed studies should be done to explain which factors are more significant for biodiversity patterns in mountainous areas along the elevational gradient.

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