Research Article

Changes in some vegetation properties of the rangelands of the Palandöken Mountains, Erzurum, over two decades

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Abstract: Plant community responses to environmental changes depend upon management strategies, climate, topography, and time. The objective herein was to determine canopy coverage and botanical changes in Turkish highland rangelands with different topographical characteristics between 1993 and 2013. Trends in the plant composition changed depending on the slope aspect (compass direction) and topography. The contribution of the grasses to the canopy decreased, while that of legumes and the other families increased. The results indicated that rangeland degradation occurred under uncontrolled grazing conditions. Suitable range management changes are recommended for the conservation of natural resources in the highland rangelands of Turkey.

Key words: Botanical composition, grasses, legumes, long-term changes, rangeland

1. Introduction

Rangelands cover about half of the eastern Anatolian region surface area and have crucial importance for extensive animal raising enterprises. Almost all of the rangelands in the region, as in all of Turkey, are under common usage right with uncontrolled grazing, namely year-round heavy grazing, which is a major concern in those areas (Koç et al., 2014). These usages have substantial effects on the composition, richness, and successional trend of the rangeland vegetation (Beguin et al., 2011; Zhang et al., 2018). Understanding vegetation dynamics under current conditions should provide indispensable insight into rangeland condition trends that guide decision-making with respect to the sustainable use of natural resources in the highland rangelands of Turkey.

The plant composition of rangelands changes depending on the grazing pressure. In general, increasing grazing intensity in the shortgrass steppe reduces palatable plant presence and increases less palatable forbs (Zhang et al., 2018). Therefore, understanding the effect of grazing intensity on the botanical composition of rangelands is essential when designing a proper grazing management system in relation to the sustainable use of natural resources. Grazing timing, especially early- or late-season grazing, affects the composition, diversity, and frequency of rangeland plant communities. Early- and late-season

grazing, applied in experimental areas of Turkey, was reported to have physiologically harmful effects on palatable rangeland plants (Koç and Gökkuş, 1999; Koç et al., 2015). Grazing causes changes in the interspecific competition among plants (Graff et al., 2007), as overgrazed palatable species are replaced by unpalatable species (Wu et al., 2008). When rangeland is overgrazed, the palatable plant contribution to the botanical composition and rangeland conditions declines (Ateş, 2017). Heavy grazing is one of the main reasons for rangeland deterioration in Turkey when compared to other parts of the world (Koç et al., 2014).

Elevation, slope aspect (compass direction), and the degree of slope are the main topographic factors that cause variations in the vegetation structure, composition, and productivity of rangelands (Holechek et al., 2011). Changes in the solar radiation frequency and duration, which affect microclimatic conditions, are responsible for these variations (Rosenberg et al., 1983). Warmer aspects, to the south and west in the northern hemisphere, receive more grazing pressure, especially in spring and autumn due to warmer weather conditions (Ledgard et al., 1982), especially at high altitudes because spring growing begins earlier and winter conditions occur later in the growing season. Moreover, these aspects result in more severe erosion problems on south- and west-facing slopes due to

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more frequent freezing and thawing (Suckling, 1975). This situation causes severe soil degradation on warmer slopes and consequently, decreases plant density and increases undesirable plant populations (Suckling, 1975; Ledgard et al., 1982).

The objective of the current study was to determine the shift in canopy coverage and botanical composition over time under uncontrolled grazed pressure on highland shortgrass steppe rangelands located in topographically different positions of eastern Anatolia, Turkey, over 2 decades.

2. Materials and methods

2.1. Study area
This study was conducted on the shortgrass steppe rangelands of Palandöken Mountain, Erzurum, Turkey. The first vegetation survey was conducted in 1993 by Koç (1995) and a second survey was conducted 2 decades after that (2013) at the same sites. Selected were 9 study sites that represented the general conditions of highland mountain steppe rangelands. The experimental areas had similar grazing histories. Uncontrolled, early-, and late-season heavy grazing were practiced in the areas, as throughout the region.

The study sites had never been cultivated and encompassed slope aspects in the back and footslope position, and summit (S). Altitude, slope, and location information about the study sites are given in Table 1. The experimental plots were located on gentle to steep slopes on the Palandöken Mountains range and the altitudes of all of the sites were over 2000 m asl (between 2035 and 2420 m), as shown in Table 1. For the evaluation comparisons, 3 topographical positions, i.e. S, backslope, and footslope, and 4 slope aspects, such as north, south, east, and west were chosen, as: north footslope (NF), north backslope (NB), south footslope (SF), south backslope (SB), east footslope (EF), east backslope (EB), west footslope (WF), west backslope (WB). The slope gradient varied from 2% at the S, 40% to 43% on the backslopes, and 18% to 25% on the footslopes, and every slope position was repeated at every aspect (Table 1). The study sites were covered by shortgrass steppe vegetation, of which the dominant herbaceous and shrub species were sheep fescue (*Festuca ovina*) and astragale (*Astragalus microcephalus*), respectively.

The soils of the experimental areas comprised fine-textured basaltic material. During the 1993 and 2013 vegetation surveys, 3 composite soil samples were collected from the surface level down to a depth of 20 cm at each site, and analyzed for some physical and chemical properties using the methods described by the Soil Survey

Table 1. Altitude, slope, and location information of the experimental sites.

Sites	Altitude (m)	Slope (%)
NF	2035	21
NB	2210	43
SF	2276	25
SB	2321	40
EF	2113	20
EB	2293	43
WF	2191	18
WB	2249	42
S	2420	2

Laboratory Staff (1992). A comparison of the soil analyses between the sampling years did not show significant differences. The 2 sampling results were averaged and are given in Table 2. Soils of all of the research sites had sandy-loam texture classes, except at the S, which had loamy-sand. Organic matter contents changed between 2.66% and 4.21% among soils of the sites. The highest soil organic matter content was determined in WB soils while the lowest was determined in SF soils. Soil pH was neutral at all of the sites (between 6.65 and 7.03) (Table 2). There were no problems with the lime and salt contents of the soils of the research sites (Table 2). The total salt and $CaCO_3$ content ranged between 0.04% and 0.1%, and 0.33% and 0.47%, respectively (Table 2). The soils were deficient in Olsen P content, which ranged between 17.49 and 28.22 kg ha^{-1} (Table 2).

The study sites had a semi-arid, continental climates with long, cold winters and short, arid summers. The nearest meteorological station to the study sites was in the city of Erzurum, located at an altitude of 1850 m and was about 10 km from the sites. According to the Meteorological Records of Erzurum[1], the long-term mean annual temperature and total precipitation were 5.6 °C and 432 mm, respectively. The yearly total precipitation in 1993 and 2013 was 343 and 284 mm, respectively. The average annual temperatures in 1993 and 2013 were 3.8 and 5.3 °C, respectively. The total annual precipitation and average temperatures were below the long-term averages during the sampling years.

2.2. Sampling methods
Vegetation surveys were conducted in the last part of June in both years, when common species reached the flowering stage, using the line-intercept method developed by Canfield (1941). Eight 10-m line-intercept transects were

Table 2. Physical and chemical properties of different geographical landscape position soils.

	NF	NB	SF	SB	EF	EB	WF	WB	S
Texture class	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Loamy sand
OM (%)	3.87	3.30	2.66	3.52	4.13	4.18	4.21	4.13	3.85
P_2O_5 kg/ha	21.69	27.35	17.49	21.59	23.72	26.03	21.62	28.22	17.19
$CaCO_3$ (%)	0.38	0.40	0.45	0.44	0.37	0.47	0.33	0.39	0.33
pH	6.89	6.79	6.95	7.03	6.65	6.95	6.83	6.87	6.80
Salt (%)	0.04	0.05	0.05	0.05	0.10	0.09	0.08	0.05	0.06

used and a total of 8000 points were observed considering the basal area in each site. The canopy coverage and botanical composition were calculated. The results were sorted into *Agropyron intermedium*, *Bromus tomentellus*, *Catabrosella parviflora*, *Festuca ovina*, *Koeleria cristata*, total grasses, *Astragalus microcephalus*, *Medicago* spp., total legumes, *Artemisia spicigera*, *Thymus parviflorus*, and the other family categories to compare with 20 year differences. Species with an abundance value higher than 5% were included in the sorting procedure.

2.3. Univariate statistical analyses
The hypothesis that the canopy coverage, common species, and plant groups had changed over the 2 decades was tested and to what extent the changes depended on the landscape position under uncontrolled grazing conditions was determined. An arc-sin transformation was performed on the data regarding the canopy coverage and botanical composition. Thereafter, the data were subject to analyses of variance based on a general linear model for repeated measurements using the StatView package (SAS Institute Inc., Cary, NC, USA; 1998). Means were separated using the Tukey multiple range test.

2.4. Multivariate statistical analyses
Detrended correspondence analysis (DCA) was used to determine the relationships between plant species and if their changes depended on the geographical landscape position and time using CANOCO, v.4.5 for windows (Leps and Smilauer, 2003). Due to the presence of many zero species, data were transformed using the transformation $\ln (10 \times X + 1)$, where X is the number of species in the species score (ter Braak and Smilauer, 2002). Automatic selection was used to determine the analyses of variance explained by the individual variables. Monte Carlo permutation tests were used for testing each variable. Differences were considered significant at $P \leq 0.05$.

3. Results
In the experimental area, the canopy coverage had increased from 1993 to 2013. The south slope aspect had

lower canopy coverage than the others. There were general increases in the canopy coverage, but this increase showed different shifts among the sites; therefore, the year × site interaction was apparent for the canopy coverage (P < 0.0004), as shown in Figure 1.

Observations between the 2 sampling dates showed changes in the botanical composition. The extent of the changes depended on geomorphological positions. Therefore, the all year × site interactions were significant (P < 0.0005). Changes depended on the landscape position, year, and their interaction. The total grass percentage decreased over the 2 decades. In the first sampling year, the sites had a similar grass percentage, but this similarity disappeared after 2 decades, except at the S. In general, the decreasing ratio was greater on the footslopes for all of the aspects, whereas there was no change in the grass percentage at the S over the 2 decades (Figure 2). This difference in the decreasing trend of the grass percentage in the botanical composition was responsible for the year × position interaction (P < 0.0036), as shown in Figure 2.

While *Agropyron intermedium*, *Bromus tomentellus*, and *Catebrosella parviflora* increased in contribution to the
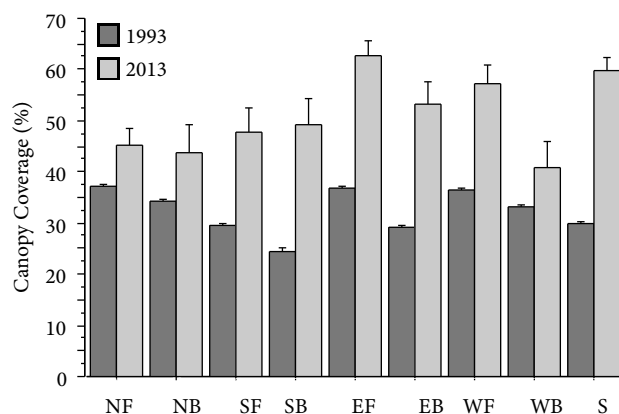
Figure 1. Mean (se ± 1) canopy coverage score for the rangeland site plots pre- and postsampling dates.
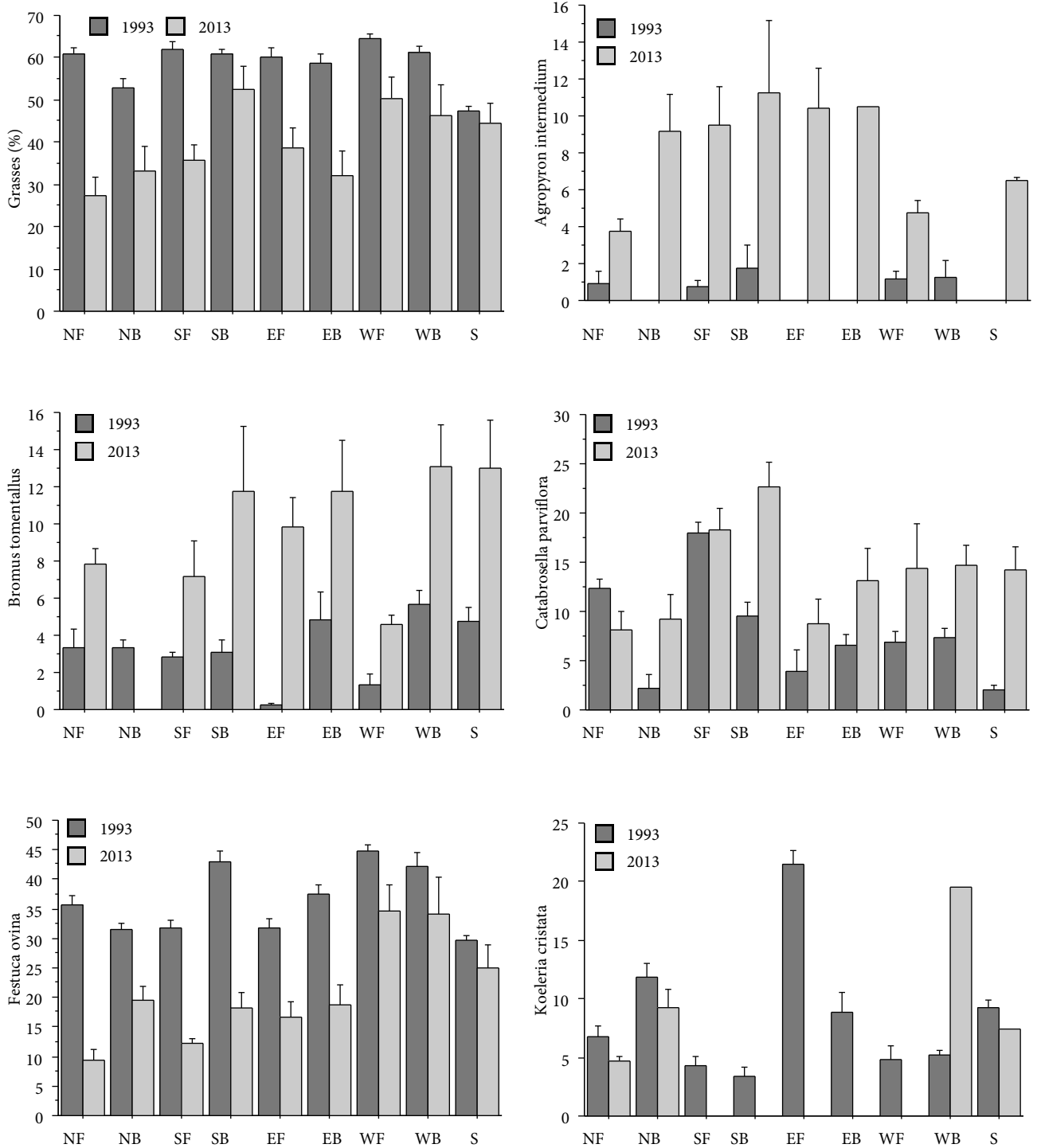
Figure 2. Mean (se ± 1) grass species and total grasses score for the rangeland site plots pre- and postsampling dates.

botanical composition, *Festuca ovina* and *Koeleria cristata* decreased over time in the experimental areas (Figure 2). The frequency of *Agropyron intermedium* was less than 2% in 1993, but it increased to over 6% over the 2 decades in the experimental areas. Increases were more pronounced on the

NB, SF, SB, EF, EB, WF, and S than at the other sites; thus, a year x position interaction was apparent for *A. intermedium* (P < 0.0001), as shown in Figure 2. The botanical composition of *B. tomentellus* increased over time, but this increase was not similar at all of the sites (Figure 2). The

increases in frequency were more pronounced on the SB, EF, EB WB, and S when compared to the other sites; hence, a year x position interaction was apparent for *B. tomentellus* (P < 0.0002), as indicated in Figure 2. The frequency of C. *parviflora* was about 5% in 1993 and its overall frequency did not increased over the following 2 decades (Figure 2). The percentage of C. *parviflora* in the botanical composition did not change on the SF and decreased slightly on the NF, but this percentage increased at the other sites. Thus, the year × position interaction was measured for *C. parviflora* (P < 0.0003), as shown in Figure 2. *F. ovina* was a dominant species in the botanical composition of the experimental sites. The coverage of this species decreased over the 2 decades, but this decrease did not show similar trends at all of the sites. The decreasing ratio was more obvious on the NF, SF, EF, and EB than at the other sites (Figure 2). These differences in the decreasing trends among the sites were responsible for the year x position interaction for F. *ovina* (P < 0.0003), as shown in Figure 2. Overall, the means of *K. cristata* in the botanical composition decreased sharply over the 2 decades, while its percentage increased on the WB, and it became nearly extinct on the SF, SB, EF, EB, and WF. Thus, a year x position interaction existed for *K.*

cristata (P < 0.0001), as shown in Figure 2.

The frequency of total leguminous plants in the botanical composition increased over time in the experimental areas (Figure 3). There were considerable differences among the investigated sites with respect to the total leguminous coverage. The increasing trend of the percentage of leguminous species in the botanical composition between the sampling dates differed among the sites. Therefore, a year x position interaction existed for the total leguminous plant coverage. The percentage of *A. microcephalus*, a shrub with spines, in the botanical composition increased after the first sampling. The EB had the highest *A. microcephalus* coverage, while the S had the least coverage among the sites. The increasing trend in *A. microcephalus* coverage among the sites over time differed; therefore, the year × position interaction was significant (P < 0.0032), as indicated in Figure 3. The total coverage of perennial *Medicago* species (mainly *M. varia* and *M. papillosa*) increased over time, but differed among the sites (Figure 3). While their coverage increased on the NB and SF, they became nearly extirpated on the EF and EB; thus, the year x position interaction was significant (P < 0.0001), as shown in Figure 3.
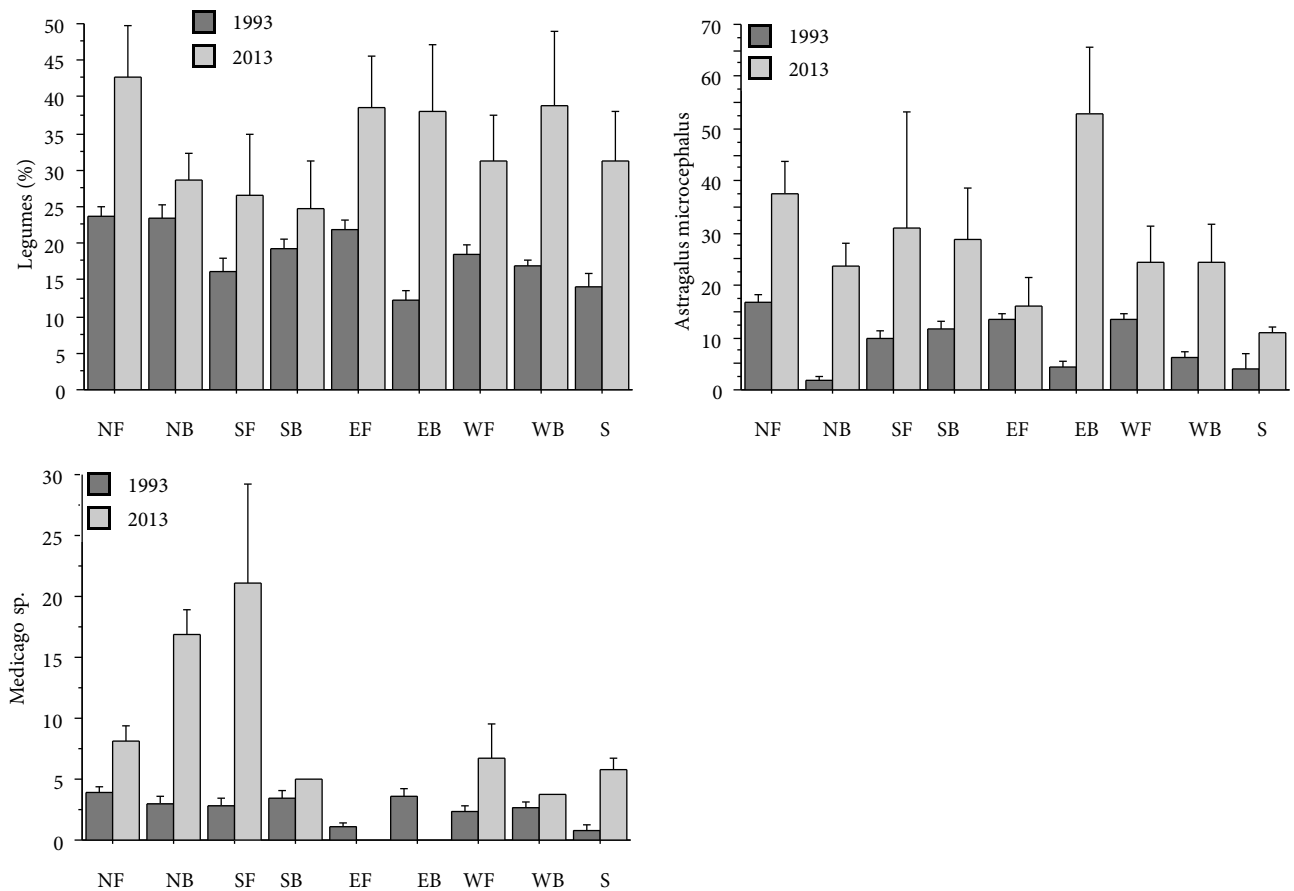

Figure 3. Mean (se ± 1) legume species and total legumes score for the rangeland site plots pre- and postsampling dates.

Plants other than grasses or legumes contributed slightly more to the botanical composition over the 2 decades after the first sampling (Figure 4). The coverage of other families among the sites also changed. Other species on the NB, SF, EB, and S contributed more to the botanical composition. The percentage of other families increased on the NF, NB, and SF, but decreased at the S. This different trend of the coverage of the other families among the sites over time was responsible for the year × site interactions (P < 0.0043). The composition contribution of *A. spicigera* and *Thymus parviflorus* increased over time in the experimental areas. While there was a higher percentage of *A. spicigera* in the botanical composition on the NB, the same was true for *T. parviflorus* on the NB, SF EB, and S. The percentage of both species in the botanical composition increased over time, but this increasing trend differed among the sites; hence, a year × site interaction was apparent for both species (P < 0.0001), as shown in Figure 4.

Ordination analysis results indicated that the percentage of the species and plant family groups in the botanical composition and canopy coverage showed a different dynamic at the sites over time. The results of the DCA showed that the 4 axes explained 51.2, 66.5, 69.0, and 70.5% of the cumulative percentage of variance of species data, respectively (Figure 5). *A. intermedium* and *A. spicigera* exhibited a distinct change in botanical composition over time (Figure 5). The abundance of these species showed a tremendous increase between the first and second sampling dates at the sites. The abundance of *B. tomentellus*, *C. parviflora*, *A. microcephalus*, and *Medicago* spp., as well as the canopy coverage ratio, showed small positive changes over the 20-year period (Figure 5). *F. ovina*, *T. parviflorus*, the total grasses, total legumes and the other families also showed changes in the botanical composition, but the changes were not as pronounced throughout the sampling period when compared to the canopy coverage of *B. tomentellus*, *C. parviflora*, *A. microcephalus*, and *Medicago* spp. (Figure 5). The rangeland site position effect on the composition was more stable in 1993 than in 2013 (Figure 5). Divergence of the rangeland site position in 1993 was apparent throughout the sampling periods and an approximately more similar rangeland site position, but no convergence, was detected in 2013 (Figure 5).
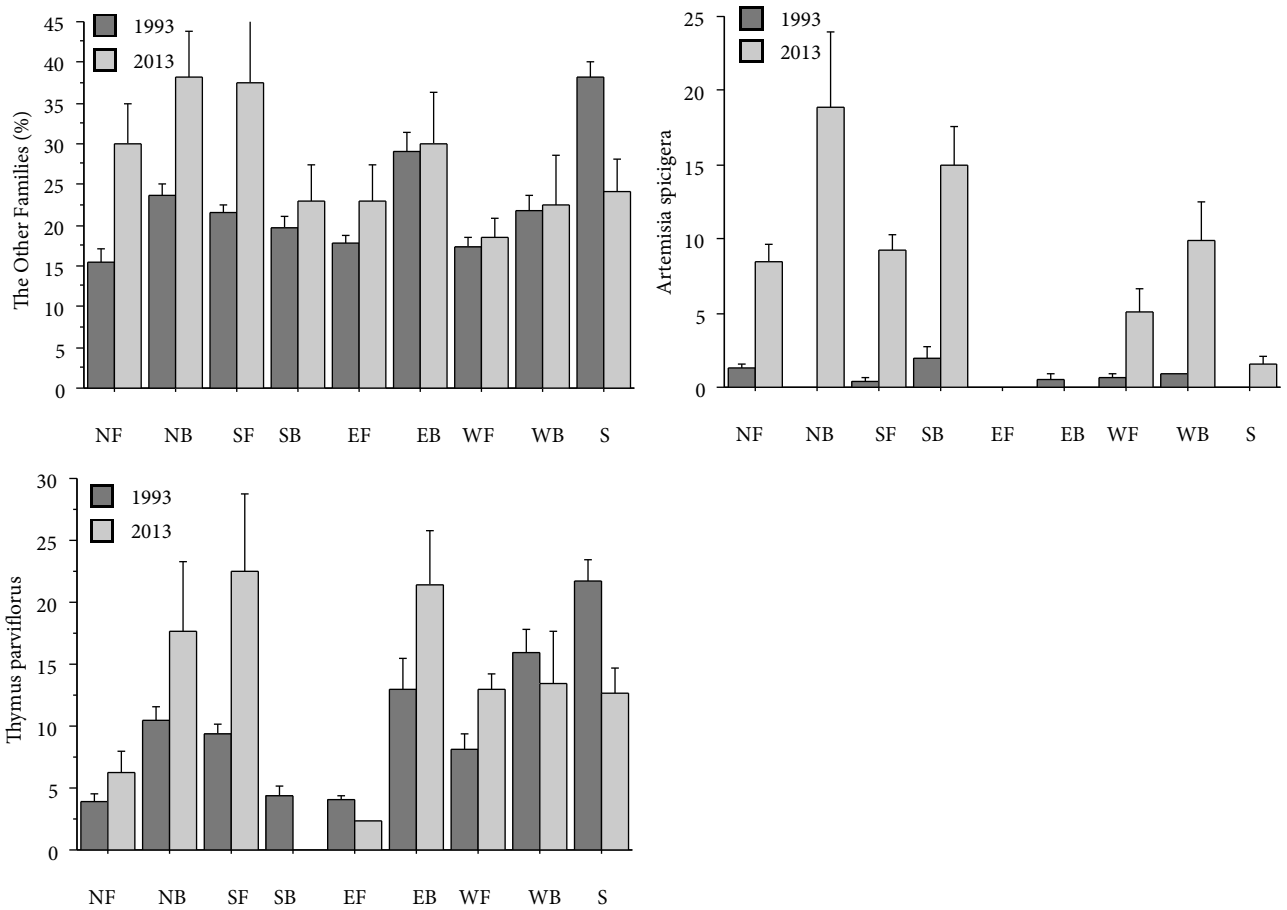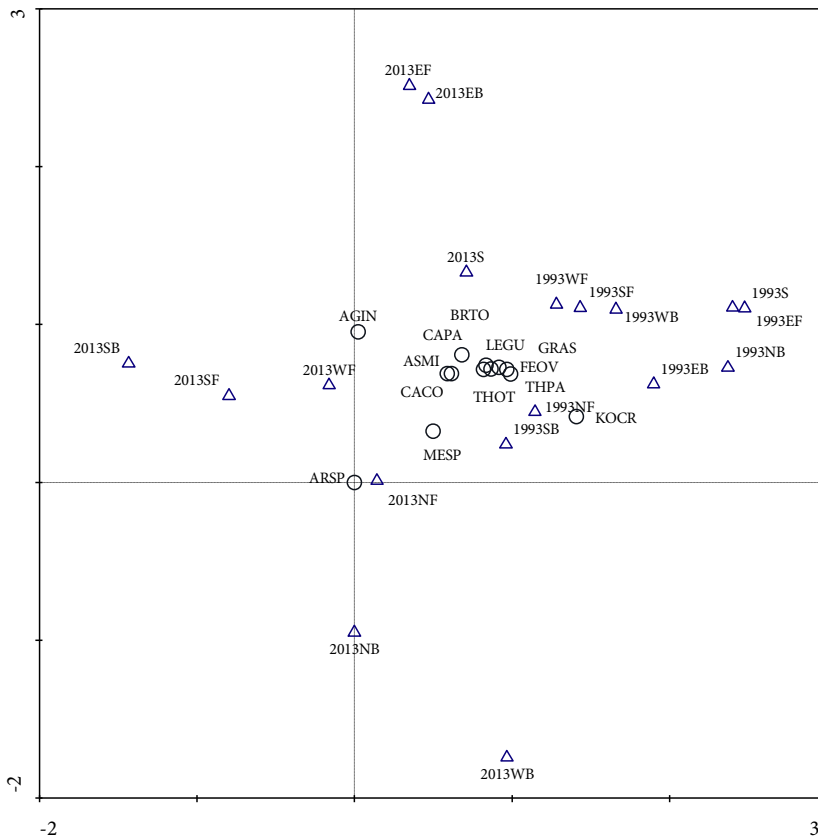

Figure 4. Mean (se ± 1) other species score for the rangeland site plots pre- and postsampling dates.

Figure 5. Ordination showing that the species composition varied with respect to geographical landscape position and over time was grouped according to plant species, functional groups, and canopy coverage.

Abbreviation key: D-mark represents rangeland site and sampling time and O-mark represents canopy coverage, plant species and families. (CACO) canopy coverage, (AGIN) *Agropyron intermedium*, (BRTO) *Bromus tomentellus,* (CAPA) *Catebrosella parviflora,* (FEOV), *Festuca ovina,* (KOCR), *Koeleria cristata,* (GRAS) Grasses, (ASMI) *Astragalus microcephalus*, (MESP) *Medicago* spp. (LEGU) Legumes, (ARSP) *Artemisia spicigera*, (THPA) *Thymus parviflorus* and (THOT) the other families.

4. Discussion

Soil erosion is a common natural phenomenon in arid and semiarid ecosystems. About 80% of accelerated erosion on terrestrial ecosystems occurs in rangelands ecosystems (Thurow, 1991). Rolling topography and erratic rainfall are the major factors. In rangelands, as the canopy coverage decreases, the severity of erosion increases. Therefore, it is essential to encourage canopy coverage on rangelands for sustainable use. In the experimental areas, the canopy coverage had increased over the 2 decades. This increase originated mainly from higher *A. microcephalus* coverage, an undesired shrub for grazing management. As the percentage of this species increased in the botanical composition, the desirable plant percentage then decreased (Figure 3).

Variations in the increasing ratio of canopy coverage among the sites might have been a result of differences in the grazing pressure and soil moisture regimes due to increasing gazing pressure (Sürmen et al., 2012; Koç et al., 2013; Faria et al., 2018). Decreasing moisture contents (Koç, 2001) cause decreases in the canopy coverage in steppe rangelands. In the study areas, the number of sheep had decreased over the 2 decades and sheep herds had not grazed uniformly in all of the areas. Grazing occurred more frequently around human settlements because the herds returned regularly to the settlement at midday for milking during the summer. Northern parts of the areas were close to settlements; thus, these sites were exposed to more grazing pressure than the other sites. Consequently, the increasing rates of canopy coverage were slower than at the other parts of the rangeland over the 2 decades.

Both the variance and ordination analyses showed that the botanical composition changed over time in the areas. In general, while the grasses decreased, the forbs (legumes plus the other families) increased. The main reason for this general trend was uncontrolled grazing in the area over the 2 decades. Studies conducted on other grasslands/ rangelands types have shown that overgrazing was the

main reason for decreasing coverage and abundance of grasses, and consequently land degradation (Koç and Gökkuş, 1994; Gibbens et al., 2005; Öztaş et al., 2003; Amiri et al., 2008; Gamoun, 2014; Mirzabaev et al., 2016; Zhang et al., 2018). Grass species contribution to the botanical composition varied over time. While *F. ovina* and *K. cristata* decreased, *A. intermedium*, *B. tomentellus*, and *C. parviflora* increased to varying degrees over the 2 decades (Figure 2). This different trend among the species likely originated from seasonal changes in sheep grazing preferences. Because fine-textured plants, such as *F. ovina* and *K. cristata*, are preferred by sheep at all growing stages, coarse plants, such as *A. intermedium* and *B. tomentellus*, are less preferred after reaching reproductive stages (Rashvand et al., 2017). The stems of these plants become dry and spiny to the touch. These species keep only minimum photosynthetic tissue to replenish reserves and maintain themselves. Consequently, their abundance might increase in the botanical composition over the time. Similar results were also reported by Shewmaker et al. (1989) and Gamoun (2014). The changes in grass species abundance in the botanical composition over time showed different trends among the sites. This variation mainly originated from the differences in landscape position of the sites, because the slope aspect and degree affect the plant composition due to their effects on hydrological properties (runoff and snowdrift), light intensity, drought severity, and grazer behavior (Patridge et al., 1991; Amezaga et al., 2004; Gong et al., 2008; Holechek et al., 2011). A decreasing number of sheep in the areas might have contributed to uneven grazing pressure on the sites. This situation may also have contributed to differences in the uneven distribution of grasses among the sites.

Under uncontrolled heavy grazing conditions, palatable plants are replaced by those lower in palatability (Holechek et al., 2011). *A. microcephalus* is not preferred by grazers due to its spines; thus, the abundance of this plant increased on the sites over time. This increase also contributed to increases in the total legumes in the botanical composition on the rangeland sites. Similarly, *Medicago* spp. increased over time. These plants have a prostrate growth under grazing (Patridge et al., 1991; Holechek et al., 2011) and grazers tend to graze them less because they do not like their tongues touching the soil while collecting low-growing forage (Koç and Gökkuş, 1993; Arnalds and Barkarson, 2003). These plant properties probably caused

increases of these plants in the botanical composition over time at the sites. Uneven grazing distribution and changes in the landscape positions, resulting from grazer distribution and microclimates, caused uneven increases of these plants in the botanical composition. These different trends were also responsible for the site x time interaction on this species contribution in the botanical composition.

Overall, the other plant groups increased in the botanical composition of the areas over time, but this increase was not consistent at all of the sites. These differing trends also caused time x site interactions. Differences likely originated from the distribution of grazing and uneven effects of the landscape position on the microclimates in the areas. Similar effects were also observed for the grass and legume distribution at the study sites over time. The increases in contribution of *A. spicigera* and *T. parviflorus* to the botanical composition were the most pronounced at the sites over time. Both of these species have aromatic contents (Patridge et al., 1991; Holechek et al., 2011) and are never preferred by grazers until more palatable grazable plants dry and their aromatic content declines (Aygün et al., 2018). Thus, these plants achieve resistance to grazing due to grazing-resistant life cycles. Consequently, this type of plant increases in botanical composition under heavy grazing conditions. Uncontrolled grazing always causes increases in unwanted plant distribution; thus, increases in the other plant species contents in the botanical composition over time is a natural phenomenon.

Ordination analysis demonstrated that plant species and site characteristics did not show consistent trends among the experimental sites over time. The sites exhibited partly similar canopy properties on the first sampling date, while they distinctly different on the second. This situation was mainly caused by differences in the grazing distribution over the intervening years that originated from landscape characteristics.

In conclusion, the results indicated that retrogressive succession on the experimental sites was due to rangeland mismanagement. Rangeland deterioration continued because undesired plant proportions increased in the botanical composition over time at the experimental areas. These results can also be generalized for the region around the experimental area. Thus, it is essential to establish sustainable range management plans that govern the grazing period, duration, carrying capacity, and distribution.

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