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Changes in Rangeland Condition and Health of Palandoken Mountain Rangelands Over Two Decades

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A B S T R A C T

Rangeland plant communities respond to environmental changes depending on management practices, climate, topography, and time. The objective of the study was to determine the changes in abundancy of functional plant groups, range condition score, class, and health with different topographical characteristics between 1993 and 2013. Trends in the investigated characteristics changed depending on aspect and topography. While the abundancy of decreaser and increaser plants decreased, invader plant abundancy increased over two decades. Similarly, range condition score, class, and health also declined in this period. The changes in investigated properties showed uneven distribution among the sites due to uncontrolled grazing practices and site characteristics. The results indicated that range degradation has been continued under current grazing practices. Therefore, sustainable range management strategies should be put urgently into practice for the conservation of natural resources in the highland hilly rangelands of Turkey.

1. Introduction

Due to rugged topography and short growing season, rangeland covers large areas in the eastern Anatolia region of Turkey and has a significant role for the animal husbandry in the region. As in all of Turkey, the main problem of these areas, which are under common usage right, is uncontrolled grazing (Koc et al., 2014). Overgrazing is the main reason for rangeland degradation all over the world, and it causes decrement of desired plants in botanical composition, serious increment of invasive plants and consequently, a decline in the range condition and health (Beguin et al., 2011). Understanding the trend of range conditions and health provides fundamental insight for decision-maker to improve undesirable usage practices.

For the assessment of range condition score, plants are separated into three categories which are a) decreaser, b) increaser and d) invader (Koc et al., 2003). Decreaser plants are desirable because they are ambitiously preferred by grazers, whereas

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increasers are less and invaders are rarely preferred by grazers. Hence, the contribution of decreaser plants to the botanical composition decrease, increasers and invaders increase as the grazing pressure increase. If grazing pressure continues in the same extend through degradation, firstly increasers thereafter invader plans begin to decline. Consequently, land degradation has become a serious problem in the area. This degradation process, especially soil degradation, is the main reason for decreasing of invader plants (Amiri et al., 2008).

Nowadays, rangeland health classifications are preferred in the ecological classification of rangeland resources rather than range condition classification. Rangeland health classification is based on the integration of soil, canopy, and other ecological units whereas rangeland conditions are based on botanical composition (Koc et al., 2003). Thus, the range condition is not a good reference for the sustainability of rangelands (Anonymous, 1994) because soil-plant integration is not considered. As is range condition classification, there is no standard method for rangeland health or ecological site classification, which are used worldwide. For example, Koc et al. (2003) suggested a range health classification method for Turkey rangelands based on canopy coverage, Anonymous (1994) suggested a method based on plant diversity for USA rangelands. According to the Turkish Rangeland Act Regulation, determining range condition class is necessary to decide on management plans without rangeland health, but rangeland health is necessary for sustainable use of rangeland and suggested method is consistent with the Turkish Rangeland Act.

Overgrazing cause not only changes in botanical composition but also decreases canopy coverage (Koc, 2001). As canopy coverage decrease, accelerate erosion becomes a serious problem, and rangelands lose ecological functions and sustainability (Koc, 1995). Hence, rangeland health considered canopy coverage is a more important property than range condition. As canopy coverage increase erosion risk decrease (Arnalds and Barkarson, 2003), therefore, the management plans considering to save and to improve canopy coverage has crucial importance for sustainable use of the rangelands. As grazing pressure increase plant mortality increase and canopy coverage decrease and consequently successional trend reverse. This situation is the main reason for range degradation. In rugged terrains, grazing never shows even distribution. Generally, herds spent more time and visit frequently bottom or ridge top than slope terrains (Greenwood and McKenzie, 2001). On the other hand, as the degree of slope increase, sensibility to erosion increase in the area. Therefore, determining range condition and health class considering terrain characteristics and making a flexible management plan considering terrain characteristics contribute to sustainable use of these natural areas.

The goal of the present study was to determine spatial and temporal changes in range condition and health class under uncontrolled grazing pressure on the highland rangeland, which has rugged topography, in eastern Anatolia, Turkey.

2. Materials and Methods

This study was carried out on steppe rangelands of Palandoken Mountain, Erzurum, Turkey. The first vegetation sampling was done in 1993 by Koc (1995) and the second sampling was done after 20 years (2013) on the same sites. Nine study sites, which represented the general characteristics of the region rangelands were selected. The area had similar grazing history which uncontrolled, early- and late-season heavy grazing application for decades.

The experimental area consisted of sloping aspects in the back, footslope position, and summit and had never been cultivated. The information about the topographical characteristics of the experimental sites is given in Table 1. The plots were located gently to steep slopes on the area and the altitude of the sites were changed between 2035 and 2420 m. the experimental plots were covered by shortgrass steppe species of which common species were sheep fescue (*Festuca ovina*), astragales (*Astragalus* spp.) thymes (*Thymus* spp.), etc.

In the experimental sites, 3 composite soil samples were taken from surface to depth of 20 cm during both vegetation sampling years and analyzed for physical and chemical properties using the methods described by the Soil Survey Laboratory Staff (1992). The analysis results showed that there were no significant differences between the sampling years and the average values were given in Table 1. While the soil of S site had a loamy-sand texture class, the other sites' soils had a sandy-loam texture class. Soil organic matter content varied between 2.66 and 4.21% among sites soils and it was the highest in WF and the lowest SF soils. Soil pH was about neutral in all sites (Table 1). There were problems with respect to lime and salt contents of the soils. The study sites soils' were deficient in Olsen P content, which changed between 17.19 and 28.22 kg ha^{-1} (Table 1).

The general climatic characteristics of the study site are a semi-arid, continental climate with long, cold winters and short, arid summers. The nearest meteorological station to the study site is in Erzurum city, located at 1850 m altitude and about 10 km far from the sites. According to the station records, long-term average annual temperature and total precipitation were 5.6 ^oC and 432 mm, respectively. Annual total precipitation in 1993 and 2013 were 343 and 284 mm, and annual temperature in 1993 and 2013 were 3.8 and 5.3 ^oC, respectively. Total annual precipitation and average temperature were lower than long-term averages during the experimental years.

Vegetation surveys were performed in the second half of June, when the common species reached the flowering stage in both years, using the line-intercept method developed by Canfield (1941). A total of 8000 points were observed in each site in eight 10-m line-intercept transects considering the basal area. After determining the botanical composition of each site, the plants were grouped into decreaser, increaser, and invader classes considering their properties to determine the rangeland condition and the rangeland health classes calculated considering basal coverage. Range condition degree and classes, and health classes were determined considering the method suggested by Koc et al. (2003) for Turkey rangelands. According to the methods, range condition classes rated considering decreaser and increaser percentage as poor (1-25%), fair (26-50%), good (51-75%) and excellent (76-100%), and health classes rated considering canopy coverage as healthy (>40%), at-risk (30-40%) and unhealthy (<30%).

An arc-sin transformation was performed on the functional plant group data and then, the data belong to functional plant groups and range condition scores were subjected to analyses of variance based on a general linear model for repeated measurements using the StatView package (SAS Institute, 1998) and means were separated using TUKEY Multiple Range Test.

Table 1. Aspect, altitude, slope and soil properties information at the experimental plots.

Site	Altitude (m)	Slope (%)	Texture class	Organic matter (%)	P_2O_5 (kg/ha)	$CaCO_3$ (%)	pH	Salt
Summit (S)	2420	2	Loamy Sand	3.85	17.19	0.33	6.80	0.06
South Footslope (SF)	2276	25	Sandy Loam	2.66	17.49	0.45	6.95	0.05
South Backslope (SB)	2321	40	Sandy Loam	3.52	21.59	0.44	7.03	0.05
North Footslope (NF)	2035	21	Sandy Loam	3.87	21.69	0.38	6.89	0.04
North Backslope (NB)	2210	43	Sandy Loam	3.30	27.35	0.40	6.79	0.05
West Footslope (WF)	2191	18	Sandy Loam	4.21	21.62	0.33	6.83	0.08
West Backslope (WB)	2249	42	Sandy Loam	4.13	28.22	0.39	6.87	0.05
East Footslope (EF)	2113	20	Sandy Loam	4.13	23.72	0.37	6.65	0.10
East Backslope (EB)	2293	43	Sandy Loam	4.18	26.03	0.47	6.95	0.09

3. Results

The results of the analysis of variance are given in Table 2. As is seen in Table 2, site, year and site year interaction were significant at $p<0.01$ level for analyzed parameters. Since the study was aimed to determine changes over time, the changes between two sampling periods and their spatial distribution will be criticized in this paper.

Decreaser plants are good indicator for range condition. According to results, decreaser plants declined significantly (p<0.01) in the botanical composition over 20 years in the experimental area but these decreases did not show a similar trend in all sites (Table 2 and 3). The highest decreases were recorded on NF and NB and the least decreases were recorded on EF, EB, and S sites between the sampling years (Fig. 1).

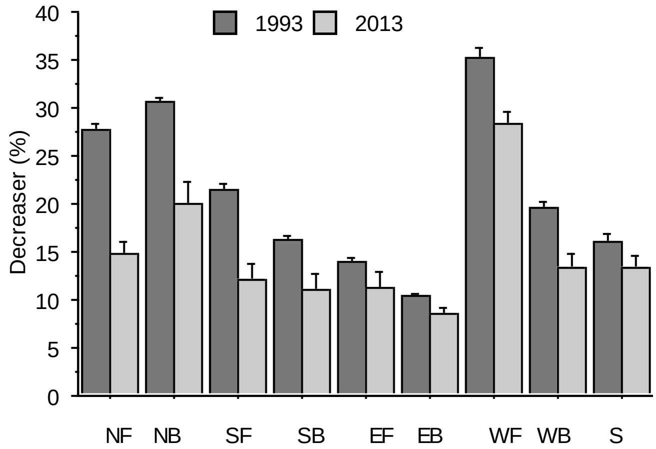

Fig. 1 Changes in decreaser plant abundance among the sites over the time

Table 2. The results of analysis of variance

	D.F.	Decreaser		Increaser		Invader		Range Condition	
		F	p	F	p	F	p	F	p
Site (S)	8	74.097	0.000	40.311	0.000	38.488	0.000	60.375	0.000
Year (Y)	1	145.596	0.000	56.641	0.000	192.021	0.000	149.115	0.000
S x Y	8	5.539	0.000	24.970	0.000	10.543	0.000	2.458	0.017

Table 3. Changes in functional plant groups, range condition score and health class depend on years and sites.

	Year	**NF**	**NB**	**SF**	**SB**	**EF**	**EB**	**WF**	**WB**	**S**	**Mean**
Decreaser	1993	27.72	30.66	21.37	16.29	14.05	10.46	35.29	19.56	15.97	21,26 A
	2013	14.78	20.09	12.12	11.03	11.21	8.54	28.24	13.37	13.29	14,74 B
	Mean	**21,25 C**	**25,38 B**	**16,75 D**	**13,66 DF**	**12,63 F**	**9,50 G**	**31,77 A**	**16,47 D**	**14,63 DF**	**18,00**
Increaser	1993	11.14	19.24	31.38	40.22	43.45	36.83	23.09	21.03	32.03	28,71 A
	2013	16.60	20.32	30.33	22.63	26.85	23.95	35.31	18.35	13.82	23,13 B
	Mean	**13,87 D**	**19,78 C**	**30,86 AB**	**31,43 AB**	**35,15 A**	**30,39 B**	**29,20 B**	**19,69 C**	**22,93 C**	**25,92**
Invader	1993	61.15	50.10	47.25	43.29	42.51	52.72	41.62	59.41	52.00	50,01 B
	2013	68.63	59.60	57.56	65.92	61.86	67.51	36.45	68.29	70.59	61,82 A
	Mean	**64,89 A**	**54,85 B**	**52,41 B**	**54,61 B**	**52,19 B**	**60,12 A**	**39,04 C**	**63,85 A**	**61,30 A**	**55,92**
Range Condition	1993	38.85	49.90	41.37	36.29	34.05	30.46	55.29	39.56	35.97	40,19 A
	2013	31.04	38.72	31.23	29.55	30.57	27.78	48.24	30.10	27.11	32,70 B
	Mean	**34,95 CD**	**44,31 B**	**36,30 C**	**32,92 CD**	**32,31 D**	**29,12 E**	**51,77 A**	**34,83 CD**	**31,54 D**	**36,45**
Range Condition and Health Class	1993	F-H	F-H	F-H	F-H	F-R	F-H	G-H	F-R	F-H	F-H
	2013	F-R	F-R	F-U	F-U	F-R	F-R	F-H	F-R	F-R	F-R
	Mean	F-R	F-R	F-R	F-R	F-R	F-R	G-H	F-R	F-R	F-R

H: healthy, R: risk and U: unhealthy.

The frequency of increaser plants showed decreases (p<0.01) in the botanical composition over 20 years (Table 3) but the trend in increaser plants frequency did not show a similar trend in all sites. While increaser plants frequency increase slightly on NF and NB, it did not show any significant changes on SF but it decreased on the other sites (Fig. 2).

The frequency of invader plants is an easy indicator of range degradation. In the area, invader plant frequency increased significantly (p<0.01) over 20 years but these increases did not show a similar trend among the sites (Fig. 3). While invader plant frequency decreases slightly on WF, it was increased on the other sites. The increases were the highest on S, EF, and SB than the others.

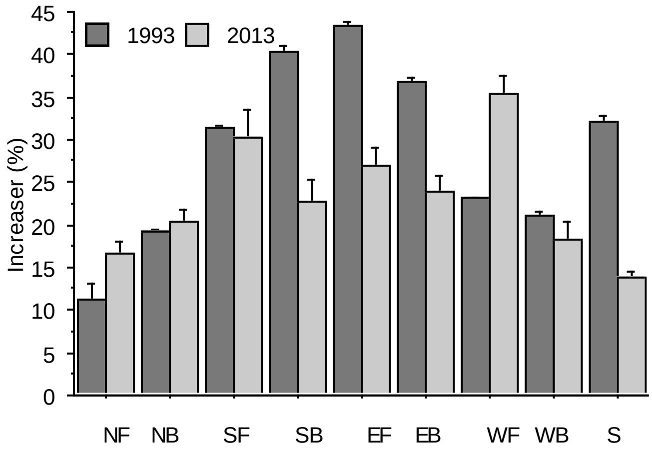

Fig. 2 Changes in increaser plant abundance among the sites over the time

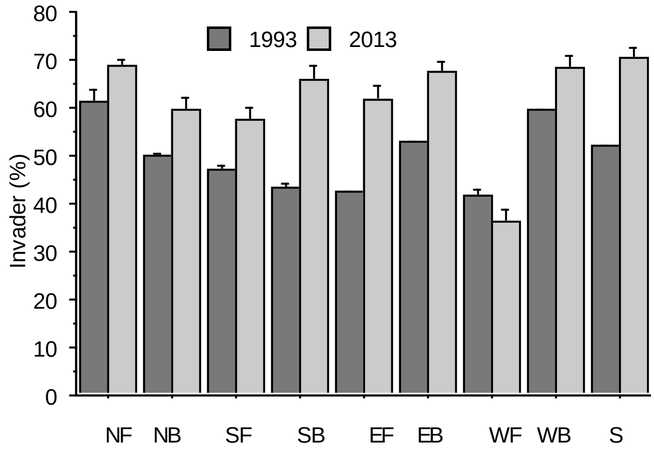

Fig. 3 Changes in invader plant abundance among the sites over the time

The range condition scores were decreased over 20 years (Table 2). These decreases showed a different trend among the sites (Fig. 4). The highest decrease in range condition score was observed on NB and SF, it was the least on EB. Expect for WF, all range sites were at the fair condition and healthy health class in the first sampling date. The fair range condition class retained but health class declined some sites, for example, rangeland health class drop-down unhealthy on south aspect. In general, both range condition class and health class declined over 20 years in the experimental area.

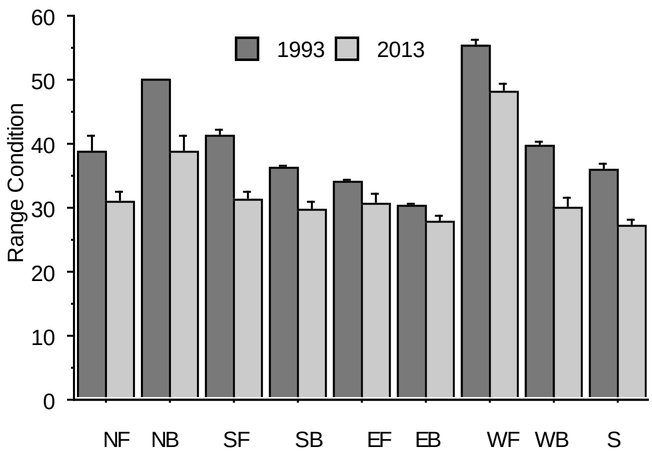

Fig. 4 Changes in range condition score among the sites over the time

4. Discussion

Range condition classification is made by considering the botanical composition and it provides basic information for decision-maker. While making the classification, the plants are grouped in three categories which are decreaser, increaser, and invader. The decreaser category consists of highly palatable plants that decline in abundance with increasing grazing pressure (Zhang et al., 2018). In the experimental area, decreaser plant percentage in the botanical composition declined about 21.26% due to overgrazing pressure, which has been continuing in the region for decades (Koc et al., 2020). This decline did not show a similar trend among the experimental sites. The plant begins to grow earlier in the spring on the south aspect due to receiving of more solar radiation, thus, herds are driven earlier and grazed heavily in this period. On the other hand, the plants the dry later than the others and the environment is cooler on the north aspect due to less solar radiation and therefore, north aspect provides more nutritious feed and comfortable climatic condition for herds during hot summer period. This situation causes overgrazing on these aspects in early spring and summer, respectively. Hence, the decreaser plant declined more on these aspects than the others during the experimental periods.

The increaser plants are preferred lesser by grazers because they provide less palatable feed. Although their frequency increase under moderate grazing pressure, it decreases under heavy grazing pressure (Altın et al., 2011). General decreases in increaser plant frequency are a result of continued heavy grazing pressure during the experimental period. The increaser plants increased significantly on WF and NF over two decades period. These increases and the serious decreases on the sites such as SB, EF and S probably originated from uneven grazing distribution (Altın et al., 2011). Apart from the differences of site characteristics, competition ability of these plants might also be responsible for this variation because competition ability changes depending on the plant. Consequently, both site characteristics and competition affect the successional trend in the community (Yunusbaev et al., 2003).

Invader plants are generally unpreferred by grazers due to low palatability or secondary metabolites/anatomical properties. Hence, their frequency increases under mismanagement conditions (Holechek et al., 2011). As opposed to decreaser and increaser, the invader plants' frequency increased in the experimental area over two decades. The main reason for this increase is overgrazing pressure, which continues in the region for decades. The spatial distribution of this increase was uneven because seasonal distributions of grazing and site characteristics are different among the sites. The differences in site characteristics affect the competition ability of the plants. In general, adverse site characteristics trigger undesired plant invasion (Altın et al., 2011; Holechek et al., 2011). Thus, invasive plants showed higher increases in back slope position in the experimental area over two decades. As is well known that as sloppiness increase the availability of site characteristics gets down on the rough topographic areas (Oztas et al., 2003).

Due to continued mismanagement practices, mainly early and overgrazing, the range condition score declined significantly over two decades. This is an expected result because there is no example in the world that a rangeland saves its condition under continued mismanagement practices (Holechek et al., 2011). As is in plant functional groups distribution, spatial distribution in the changes at range condition was uneven. The factors such as seasonal distribution of heavy grazing and site factors, which affect decreaser plant abundance also affected similarly range condition score.

Rangeland health is a simple indicator of the sustainability of rangeland functions. The method which was used in this experiment was based on canopy coverage to classify rangeland health class (Koc et al., 2003). Rangeland health mainly focuses on the integrity of the soil and natural vegetation and its sustainability (Gullap et al., 2020). Under accelerated erosion condition, to save sustainability of soil and consequently, vegetation is not possible, therefore, saving soil against accelerated erosion has to be the priority on the rangelands. Marshall (1973) explained that as the canopy coverage increase, accelerated erosion risk decrease on the rangeland. In the experimental area, since mismanagement, early and overgrazing, continue for decades, range deterioration continues because rangeland health declined over two decades due to decreasing plant density. Declining in rangeland health classes are not even all sites. The sites exposed to heavy grazing and harsh environmental factors exposed to more decreasing. Especially south aspects, which exposed to early grazing, freezing, and thawing, and seriously moisture stress due to more solar radiation showed serious rangeland health loss and the health class dropped to unhealthy over two decades. This situation is an early warning of seriously accelerated erosion on this aspect under current management practices.

In conclusion, the experimental results showed that range deterioration still continues in the region due to mismanagement practices. There has not been any regulation about mismanagement practices in the region as is country-wide up to now. Since south aspects received more solar radiation, snow melting earlier, and grazing started earlier. This practice has a detrimental effect on plant cover. Consequently, the rangeland health class drops down to a critical threshold against accelerated erosion. According to results, grazing distribution is not uniform in the areas so range degradation shift uneven on the area. Therefore, to stop range deterioration and improve current condition has crucial importance to sustainable use of natural rangeland. For this purpose, it is important regulating suitable grazing season, grazing capacity, and grazing distribution considering site characteristics.

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