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Effects of Fire on Some Vegetation and Soil Properties in a Semi-Arid Shrubland (Case Study: Kachaleh Rangelands, Kamyaran Region)

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ABSTRACT

Aim: Fire is one of the most critical ecological disturbances in rangelands that change vegetation and soil characteristics. Up to now, few studies have been conducted to study the short-term effects of fire on soil and vegetation in a semi-arid shrubland. The positive or negative effects of fire on soil and vegetation of rangeland have been investigated in this research.

Materials and Methods: Soil pH, electrical conductivity (EC), total potassium (K), calcium (Ca), sodium (Na), and magnesium (Mg) content were selected as soil attributes and vegetation richness, diversity, and density (percent ground cover) as vegetation properties. Vegetation and soil sampling was performed based on a systematic randomized method along three transects (The length of transects in control and the burnt area was 100 m and the distance between each plot was 10 m). Information about vegetation traits (production, density, diversity, richness, and evenness) was recorded in a 1 m^2 plot. Soil samples were taken at two depths of 0-15 and 15-30 cm by an auger.

Findings: Compared to unburnt rangeland, the percentage of vegetation (16.30 %), production (20.47 $Kg.ha^{-1}$), and density of vegetation (6.74 %) in the burnt region have been decreased significantly ($P<0.05$). The results showed that there was a significant difference between the burned and unburnt areas in terms of diversity and richness indices and the average values obtained in the unburnt area (1.66, 0.79, 2.44, 1.99, and 0.14 for Shanon-Wiener, Simpson, Margalef, Menhinick, and Simpson, respectively) was significantly ($P<0.05$) higher than the burned area (1.36, 0.77, 1.92, 1.73 and 0.19 for Shanon- Wiener, Simpson, Margalef, Menhinick, and Simpson, respectively) ($P<0.05$). In the Simpson evenness index, no significant difference was observed between control and burned areas.

Conclusion: The present study results had shown a significant decrease in species diversity and richness in burnt rangeland. There were not any positive effects of fire on soil or vegetation cover in the studied area. Therefore, to manage fire hazards, it is necessary to hold various training and extension classes by experts from the Department of Natural Resources, to involve watershed residents in firefighting, increase indigenous awareness and provide firefighting equipment.

Keywords: Rangelands, Fire, Vegetation diversity, Soil pH, Soil calcium.

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Introduction

Rangelands, as one of the most important renewable natural resources, have an essential role in the conservation and sustainability of ecosystems. This issue is especially important in Iran, which is one of the driest countries in the world and suffers from severe vegetation limitations [1]. After urbanization and agricultural activities, fire is the most pervasive factor in destroying natural ecosystems in arid and semi-arid regions [2]. Fire is a harmful phenomenon in arid and semi-arid regions that adversely affect the production, reproduction of woody species, vegetation, and soil properties [2].

Fire impacts the competition ability and sequencing stages in vegetation community and changes vegetation biodiversity in natural ecosystems [3]. As one of the most important ecological disturbances in many habitats and natural ecosystems, conflagration can significantly affect the composition of vegetation communities and their dynamics. Fire is a significant disturbance in shrublands in arid and semi-arid areas [4]. Fire is one of the main factors for the destruction of shrublands and changes in their structure and diversity [5]. In addition, the conflagration regime has an important effect on the rate of vegetation change and population sequence after fire [6]. Burn occurrence is one of the main factors changing the composition and structure of natural ecosystems [4].

Severe rangeland fires may negatively impact the soil's physical and chemical properties [7]. The amount and intensity of heat generated by conflagration will negatively influence the soil [8], destroy the soil surface horizons [9]. In this regard, burning affects the mineral and biological properties of soil and changes the vegetation community. In contrast to various reports and studies on the adverse effects of fire, some researchers have reported the positive effects of conflagration on soil and vegetation. Based on Certini [7], the fire had a significant positive effect on annual grasses. Alcaniz et al. [10] indicated that the physiochemical properties of natural rangeland soils improved after using controlled fire. However, Magomani and Tol [11] indicated that burning could have a significant negative impact on aggregate stability and bulk density as soil physical properties in semi-arid savannah. Crotteau et al. [12] and Reinhart [13] reported that controlled conflagration could manage the quality of vegetation and soil in natural resources.

Rangeland conflagration is an important destructive phenomenon in arid and semi-arid rangelands [14]. Nevertheless, the responses of soil and vegetation to fire occurrence are highly variable [15, 16]. The soil organic matter [17, 18], vegetation diversity [19, 20, 21], plant community composition [22], the forage production potential of rangeland plants [23], and the content of soil nutrition [24, 25, 26] affected significantly after the occurrence of rangelands fire.

Based on the previous reports, the response of soil and vegetation of rangelands to fire may vary according to all environmental characteristics and fire intensity. There have been several fires in the natural rangelands of the study area in recent years. However, the reliable scientific results of these fires on soil and vegetation characteristics have been unknown.

Zagros vegetation in western parts of Iran has an important role in protecting water and soil and the livelihood of the native people. The effect of fire on soil properties depends on the intensity, frequency, duration of the fire, soil moisture, and climatic conditions. Therefore, there is always uncertainty about fire's positive or negative effects on soil properties and rangeland vegetation. So, this study aims to investigate the effects of fire on the soil and vegetation of Kachleh Rangelands in Kamyaran City. This study was conducted with two hypotheses

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1) vegetation, 2) soil properties of Kachleh Rangelands in the Kamyaran region affected significantly after fire occurrences.

Materials and Methods

Study area and data collection

The study area is 20 km north of Kamyaran City in the south of Kurdistan Province (44° 55’ 34” N, 50° 58’ 46” E) (Figure1). The maximum altitude of the region is 2085 m (a.s.l.), the minimum is 2030 m, and the general slope of the region is south to north. The common precipitation is snow, and the mean annual rainfall is 540 mm.y^{-1}.

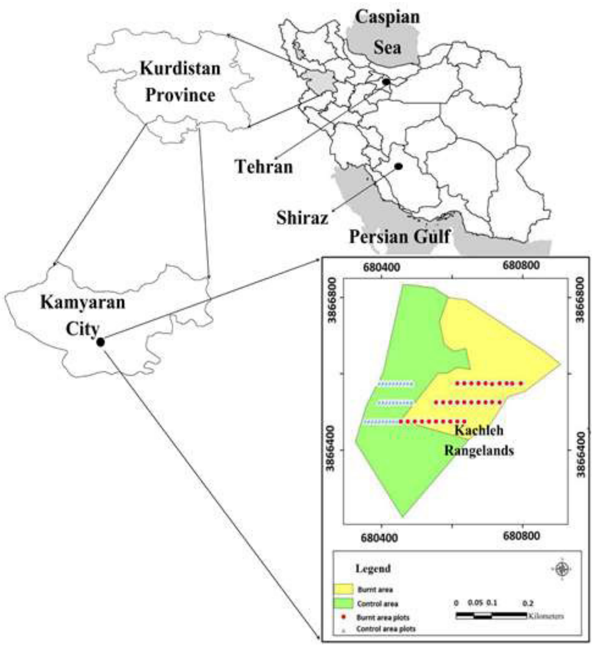

Figure 1) Location of the study area in Iran and Kurdistan Province, Iran.

In this study, the measured traits include soil properties [(pH, EC, total nutrient concentrations of Na, K, Ca, and Mg) and vegetation characteristics (richness, diversity, evenness, density, and vegetation production)] were performed in two fire and control sites with an area of 88.7 and 67.9 ha, respectively. The fire in the Kacheleh Rangeland area had occurred one year before the sampling time in June 2019. Vegetation and soil sampling was performed based on a systematic randomized method along three transects. The length of each transects in the control area and fire zone was 100 m, and the distance between the plots was 10 m. Vegetation and soil sampling was done based on a systematic randomized method. In this research, three transects were established in the burnt region, and three transects were performed in unburnt rangeland. Along each transect, ten soil samples were taken by auger at two depths (based on the type of vegetation in which is shrubland with herbaceous species) of 0-15 and 15-30 cm at both control and fire sites, and vegetation sampling was performed in May 2019 based on systematic manner. Information about vegetation traits (production, density, diversity, and richness) was recorded in a 1 m^2 plot.

Vegetation Sampling and Analysis

Vegetation measurement characteristics in this study included determining the percentage of bare soil, rocks, and pebbles, litter, percentage of vegetation, vegetation density, and production. Afterward, the Shannon-Wiener and Simpson as diversity indices, Margalef and Menhinick as richness, and Simpson as evenness indices were used to estimate species diversity, richness, and evenness in two burnet and control regions. Equations for calculating Shannon-Wiener (Eq. 1) and Simpson (Eq. 2) as diversity indices, Margalef (Eq. 3) and Menhinick (Eq. 4) as richness and Simpson (Eq. 5) as evenness indices were shown in Table 1[3, 23, 27].

Soil sampling and analysis

After air-drying the soil samples and passing through a 2 mm sieve, soil tests were performed. After preparing the saturated soil sample, pH and EC were measured with a pH meter and electric conductivity meter (EC meter), respectively. The total sodium and potassium content after extraction was measured using a flame photometer, and the amount of calcium and magnesium in the soil was determined by the titration method.

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Table 1) The equation for calculating Shannon-Wiener and Simpson as diversity indices, Margalef and Menhinick as richness, and Simpson as evenness indices.

Indicator	Equation	Equation no.	Descriptions
Shannon-Wiener	$H = -\sum_{i=1}^{s}(pi * Lnpi)$	Eq. (1)	H = the Shannon-Wiener diversity index Pi = fraction of the entire population made up of species i S = numbers of species encountered ∑ = sum from species 1 to species S
Simpson	$\sigma = 1 - \sum_{i=1}^{s}\left[\frac{ni\ (ni-1)}{Ni\ (Ni-1)}\right]$	Eq. (2)	P: the proportion ($n.N^{-1}$) of individuals of one particular species found (n) divided by the total number of individuals found (N) Σ: still the sum of the calculations S: the number of species
Margalef	$R_1 = \frac{S-1}{ln\ (N)}$	Eq. (3)	S: the number of species N: the total number of individuals in the sample
Menhinick	$R_2 = \frac{S}{\sqrt{N}}$	Eq. (4)	S: the number of species N: the total number of individuals in the sample
Simpson	$E_D = \frac{D}{S}$	Eq. (5)	S: Number of gathered species in the sampling

Data Analysis

The Kolmogorov-Smirnov test was used to evaluate the normality of the data. Since the study area is natural rangeland with uncontrollable properties, comparison of means of soil and vegetation properties were performed by two-way analysis of variance (ANOVA) ($p<0.05$), using SPSS 13. Soil properties in the burnt and control areas at two depths (0-15 and 15-30 cm) were also statistically compared ($p<0.05$).

Findings

Vegetation characteristics

According to the ANOVA results (Table 2), bare soil, pebbles, and litter were higher in the burned rangeland. In the case of bare soil, rock and gravel, there is a significant difference between the two study areas due to the presence of standing litter. Based on the ANOVA results, remarkable differences were seen in vegetation density between the burnt rangelands (10.3%) and control areas (14.23%) ($P<0.05$). The total production of rangeland in the burnt region was reported as 84.07 $Kg.ha^{-1}$ which is significantly ($P<0.05$) higher than the total production of control rangeland (20.47 $Kg.ha^{-1}$) (Table 2). Compared to the control region, a significantly lower percentage of total vegetation has been observed in the burnt rangelands. ANOVA results showed significant differences between the percentage of various forms of vegetation (i.e., forb, shrubs, grasses, and annuals) in burnt and control rangelands (Table 3).

There were no significant differences between vegetative density and shrub, forb, and grass production in burnt and unburnt rangeland (Table 4).

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Table 2) Results of ANOVA on the soil surface characteristics in burnt and control rangelands.

	Production (Kg.ha^{-1})	Litter (%)	Pebbles (%)	Bare soil (%)	Total density (%)
Burnt rangeland	20.47±15.10 ^{b}	63.13 ± 2.22 ^{b}	19.31±0.68 ^{a}	13.88±2.57 ^{a}	6.74±0.03 ^{a}
Control area	84.07±63.74 ^{a}	88.6 ±1.46 ^{a}	9.95±1.32 ^{b}	9.53±1.36 ^{b}	6.65±0.82 ^{a}

* indicates a significant difference at 5%, ns: indicates the no significant difference at 5%, different letters in the same column indicate a significant difference (P<0.05).

Table 3) Results of ANOVA values of vegetation cover percentage in burnt and control rangelands.

	Shrubs cover (%)	Forbs cover (%)	Grass cover (%)	Annual cover (%)	Total vegetation cover (%)
Burnt rangeland	0.36±0.01 ^{b}	7.55±0.40 ^{b}	4.33±0.87 ^{b}	8±0.47 ^{b}	16.30±0.69 ^{b}
Control area	13.15±0.02 ^{a}	13.90±0.25 ^{a}	15.93±0.52 ^{a}	32.80±2.03 ^{a}	49.85±0.66 ^{a}

* indicates a significant difference at 5%, ns: indicates the no significant difference at 5%, different letters in the same column indicate a significant difference (P<0.05).

All diversity, richness, and evenness indices in burnt and control rangelands differed significantly (P<0.05). The maximum values of these indices were seen in the control region. Nevertheless, no significant difference was observed between control and burnt areas (Table 5).

Soil characteristics

The ANOVA results indicated the main and interactions effects of burning and soil depth (burning × soil depth) on some soil properties (Table 6).

There were not any significant differences between burning × soil depth of investigated soil properties. Moreover, based on ANOVA analysis results (Table 7), there were not any significant differences (P<0.05) between soil pH and EC in both soil depths. The content of Ca, Mg, Na, and K also differed significantly (P<0.05) in the burnt and control region.

Discussion

Compared to the control region, a significantly lower percentage of vegetation has been observed in burnt rangeland. In contrast, a significantly higher percentage of bare soil, rocks, gravel, and litter were seen in burnt burned regions (Tables 2 and 3). These results are consistent with the results of Treble et al. [12] that stated the increase in litter in the burnt area is due to the presence of standing litter.

The average vegetation density and production in the rangelands of the unburnt region is remarkably higher than the rangelands of the burnt area (Table 4), which is in contrast with the findings of Javadi and Maamun [13], who reported that due to fire in rangelands, the percentage of vegetation in the burnt region increased significantly.

In this study, a significant difference was observed between burnt and control rangeland in Shannon-Wiener (as diversity index) and Margalef and Minhinkenic (as richness indices) (Table 5). The results of this section are consistent with the results of Javadi and Maamun [13] and in contrast with the results of [14]. The reports of Rafiei et al. [15] about significant differences in the diversity of species in burnt and control areas are inconsistent

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Table 4) Results of ANOVA values of vegetative density and production in burnt and control rangelands.

Vegetation form	Indicator	Studied region	Mean
Grass	Production	Burnt Rangeland	6.13±0.07 [b]
		Control region	24.36±0.04 [a]
	Density	Burnt Rangeland	5.20±0.06 [a]
		Control region	7.43±0.05 [a]
Forb	Production	Burnt Rangeland	12.93±0.56 [a]
		Control region	20.66±0.13 [a]
	Density	Burnt Rangeland	5.56±0.15 [a]
		Control region	6.20±0.27 [a]
Shrub	Production	Burnt Rangeland	1.40±0.11 [b]
		Control region	39.03±0.1 [a]
	Density	Burnt Rangeland	0.13±0.1 [b]
		Control region	0.60±0.03 [a]

* indicates a significant difference at 5%, ns: indicates the no significant difference at 5%, different letters in the same column indicate a significant difference (P<0.05).

Table 5) Results of ANOVA values of vegetative diversity, richness, and evenness in burnt and control rangelands.

Vegetation properties	Indicator	Studied region	Mean
Diversity	Shannon-Wiener	Burnt Rangeland	1.36±0.62 [b]
		Control region	1.66±0.6 [a]
	Simpson	Burnt Rangeland	0.77±0.02 [a]
		Control region	0.79±0.07 [a]
Richness	Margalef	Burnt Rangeland	1.92±0.18 [b]
		Control region	2.44±0.11 [a]
	Menhinick	Burnt Rangeland	1.73±0.09 [b]
		Control region	1.99±0.08 [a]
Evenness	Simpson	Burnt Rangeland	0.19±0.01 [a]
		Control region	0.14±0.03 [a]

* indicates a significant difference at 5%, ns: indicates the no significant difference at 5%, different letters in the same column indicate a significant difference (P<0.05).

Table 6) Results of the analysis of variance (ANOVA) of the main and interactions effects of different burning and soil depth on some soil properties.

Studied region	df	pH	EC ($dS.m^{-1}$)	Ca ($g.kg^{-1}$)	Mg ($g.kg^{-1}$)	Na ($g.kg^{-1}$)	K ($g.kg^{-1}$)
Burnt Rangeland	1	0.106 [ns]	0.055 [ns]	0.184 [ns]	0.519 [ns]	0.231 [ns]	0.101 [ns]
Control region	1	0.583 [ns]	0.357 [ns]	0.067 [ns]	0.725 [ns]	0.065 [ns]	0.529 [ns]
Burning × soil depth	1	0.321 [ns]	0.241 [ns]	0.072 [ns]	0.082[ns]	0.112 [ns]	0.324 [ns]

* indicates a significant difference at 5%, ns: indicates the no significant difference at 5%, df: indicates the degree of freedom.

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Table 7) Results of ANOVA values of selected soil properties in burnt and control rangelands.

Studied region	Soil depth	pH	EC ($dS.m^{-1}$)	Ca ($g.kg^{-1}$)	Mg ($g.kg^{-1}$)	Na ($g.kg^{-1}$)	K ($g.kg^{-1}$)
Burnt Rangeland	0-15	7.42±1.11 [a]	0.15±0.01 [a]	5.06±0.27 [a]	0.08±0.01 [a]	14.87±1.29 [a]	39.23±2.98 [a]
	15-30	7.47±1.23 [a]	0.12±0.03 [a]	5.17±0.19 [a]	0.09±0.01 [a]	15.12±0.11 [a]	40.22±3.11 [a]
Control region	0-15	7.50±1.32 [a]	0.12±0.01 [a]	5.32±1.01 [a]	0.06±0.03 [a]	15.04±2.03 [a]	38.89±3.09 [a]
	15-30	7.55±1.57 [a]	0.11±0.01 [a]	5.13±1.07 [a]	0.11±0.01 [a]	14.95±2.07 [a]	41.01±3.32 [a]

* indicates a significant difference at 5%, ns: indicates the no significant difference at 5%, different letters in the same column indicate a significant difference ($P<0.05$).

with the present study results, but in terms of higher values of diversity index in the burnt zone is in contrast with the results of this study. The present study results showed that there was no significant difference in the Simpson evenness index between the control and burnt rangeland. Similar results were reported by Rafiei et al. [15]. Pourbabaei [16], in the study about the long-term effects of fire on the diversity of herbaceous species in humid areas, concluded that the average percentage of cover, diversity, richness, and evenness had increased significantly in the burnt regions, which is consistent with the results of this study. This disagreement can be explained by the difference between the study period (our research was conducted based on a short period) and the climatological type (our research has been performed in a semi-arid region) differences between the two studies. In another study conducted in semi-arid rangelands by Ghorbani [17], the results showed that the effect of fire on all plant species was significant due to increment the richness and diversity indices in contrast with the results of the present study. Sanghoon et al. [18] also reported that after the fire in the burned regions, the richness and evenness have increased, agreeing with the present research findings. The decrease in species richness in the burnt rangeland in the present study may be attributed to low rainfall and soil fertility [36, 37, 38].

The results showed that no significant differences were observed between fire-affected rangelands and control areas at the two studied depths (Table 6). The study of soil properties by Javadi and Maamun [13] in semi-arid rangeland in the short term showed no significant difference between soil nutrients in the control and burnt areas, which is consistent with the results of this study. Granged et al. [19] in the Mediterranean region stated that after the fire, the acidity and electrical conductivity of the topsoil decreased remarkably compared to the control, which is not consistent with the present study results. In contrast with the present study, Neff et al. [9] showed that the burnt rangelands K and Ca content of soil have leached by rainwater and decreased significantly in soil. The pH, electrical conductivity, potassium, calcium, and magnesium were examined in Girona, Spain. Another report by Alcaniz et al. [10] indicated all parameters except acidity increased significantly after the fire occurrence in natural rangeland, which is not in agreement with the results of this study. In coincident with the present study results, Badia and Marti [8], in investigating the effect of fire heat on soil chemical properties, reported an increase in soil pH. This study showed that the K content of the soil was not significantly affected after fire

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occurrence (Table 6). These results contrast with the results of Hemtboland et al. [35] that stated K content of topsoil significantly increased in burnt regions. The increase in K values is probably due to the release of K ions from minerals or organic matter affected by the fire. Moreover, a significant increase in the Mg content of topsoil in the burnt region was previously reported by Castelli and Lazzari [21], which contrasts with the results of the present study (Table 7).

Conclusion

The effect of fire on soil properties depends on the frequency, duration of the fire, soil moisture, and climatic conditions. Therefore, there is always uncertainty about the positive or negative effects of fire on rangelands' soil and vegetation properties. So, the research results about the effect of fire on rangelands can only be utilizable in certain regions. The present study results indicate a significant decrease in species diversity and richness in the burnt region. The results of the present research did not show any positive effect of fire on soil or vegetation. Therefore, to manage fire hazards, it is necessary to hold various training and extension classes by experts from the Department of Natural Resources, to involve watershed residents in firefighting, increase indigenous awareness and provide firefighting equipment. The effects of fires, firefighting methods in natural resources, and how to prevent fires should be evaluated and planned locally.

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