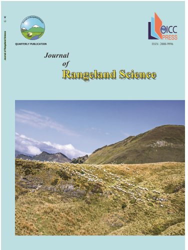

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# Effects of fire on vegetation cover and forage production of Solan rangeland in Hamadan Province, Iran

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**Abstract:**
Fire causes extensive damage to rangelands' ecosystems in arid and semi-arid regions. The purpose of this study was to investigate the effects of rangeland fire on vegetation and forage production in mountainous rangelands of the Solan area in Hamadan province, Iran. A burnt area and a homogeneous area without fire (control) were selected for this study. In the burnt area, the fire has occurred in July 2018. In each site, data were collected in the months July to October using four linear transects with a length of 200 m using a systematic random sampling method. In each transect at a distance of 20 m, 10 plots of 1 $m^2$ were considered. Vegetation sampling was done during (July to October) three years of 2018, 2019, and 2020. Some factors such as forage production, percentage of bare soil, stones and gravels, litter, survival rate, canopy cover, and percentage of shrubs, perennial and annual forbs, perennial and annual grasses were measured. The results showed that there were significant differences between the two areas for all variables except perennial forbs cover, shrubs cover, and stone and gravels percent in the first year. Fire reduced the litter percent, forage production, canopy cover, survival, and increased bare soil, soil erosion, and sediment. The geophytes life forms of the species in the study areas had the highest coverage percentage (38.66%) in both areas. Some species such as: Astragalus verus, Astragalus gossypinus, Acantholimon bromifolium, Acantholimon olivieri, and Acanthophyllum crassifolium were sensitive to fire. On the other hand, species such as Rosa persica due to having rhizomes and extensive underground roots were resistant to fire.

**Keywords:** Fire; Life form; Rangeland; Vegetation

## 1. Introduction

All areas of the world that are not barren deserts, farmed, or covered by solid rock, ice, or concrete can be classified as rangelands. Therefore, rangelands include deserts, forests and all natural grasslands . Rangelands is defined as uncultivated land that will provide the necessities of life for grazing and browsing animals [1]. Most of the rangelands in the world are located in semi-dry landscapes where agricultural activities may not be dominant land use due to either low or variable rainfall. In Iran, rangelands occupy nearly 54.6% of the total land area and 65% of natural resources [2]. Rangelands are the largest terrestrial ecosystem in the Iran, thus playing an important role in the economy of the country by providing ecological goods.

Drought, urban activities, agriculture, and fire are the main factors destroying natural ecosystems [3]. The vast majority of 30–46 million $km^2$ of the global land surface are burnt by fires every year (approx. 4% of the global land surface) [4]. Globally, fires are a critical driver of the carbon cycle because they consume biomass through combustion resulting in an immediate release of greenhouse gases including $CO_2$, CO, and $CH_4$ [5]. Also, fires eliminate or reduce aboveground plant biomass [6]. However, in the long term; the effects of fire are more complex. For example, plants that are exposed to fire at different phenological stages are affected differently [7]. Fire has played a key role in the formation of most rangeland ecosystems and

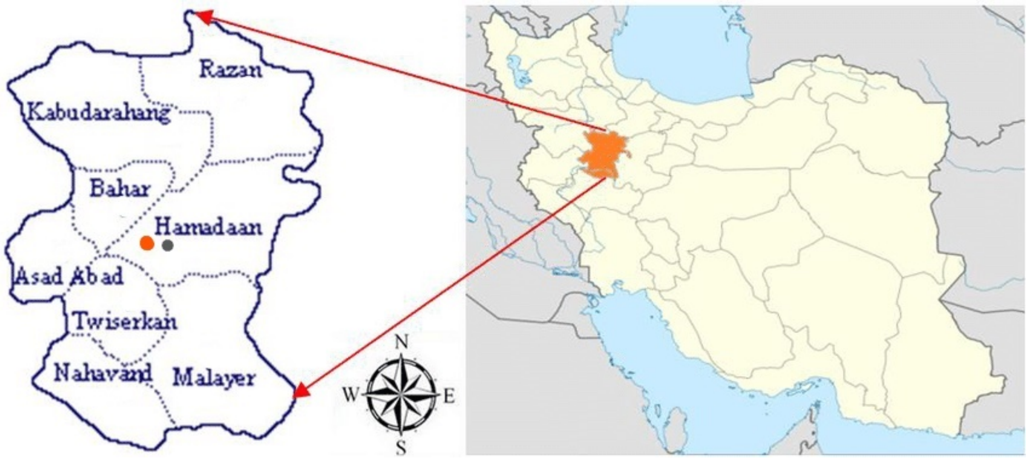


**Figure 1.** Map of study area in Hamedan province, Iran (Red spot).

it is one of the major factors that affect rangeland vegetation (grasslands and shrub lands) [8, 9]. Some studies consider wildfires as disturbance; however, fires are the most important ecological factor that fulfills crucial roles and functions in grasslands and rangelands [10]. Fire influences the species composition, vegetation structure and dynamics, habitat values, and ecosystem functioning, as well as being potentially both beneficial and damaging to people and property [11]. For example, increasing production and diversity, the richness of species, increasing perennial grasses, and plants with high palatability are the positive effects of fire [12]. It is necessary to mention that plant productivity, plant nutrient content, plant diversity, and plant mortality responses to fire are highly variable [13]. On the other hand, wildfires have devastating effects on the environment, ecology, and economy. A loss of vegetation after fire reduces biodiversity, promotes the invasion of exotic species, enhances soil erosion, and even increases the potential for flooding and debris flows overall, wildfires create disturbances that remove vegetation and litter, making soils vulnerable to both wind and water erosion and leaving gaps within vegetation that are susceptible to invasive species [14–16]. Numerous studies have been conducted on the rangelands fires effects. For example, Moreira et al. reported the growth of herbaceous species in the burnt area after one year [17]. Gholami et al. showed that the fire significantly increases the canopy cover percent of annuals, perennials, grasses, forbs, Throphytes, Cryptophytes, Hemicryptophytes, Chamaephytes, Asteraceae, Caryophyllaceae, Fabaceae, Rubiaceae, and Poaceaeto as compared to control [18].

Natural resources such as rangelands are the main and most valuable assets of any country. Conservation and expansion of these resources due to their important role in the economic and social life of human beings are necessities of planning [19]. If the effects of fire are not considered in the management for sustainable utilization of the rangeland ecosystem, it could disturb the rangeland condition and speed up further degradation of the ecosystem [20]. Studying the effects of rangeland fires determines which plant species are resistant or sensitive and which species survive in natural ecosystems and continue to grow. The natural regeneration of species after a fire also determines the tendency and condition of the rangeland. By recognizing resistant and semi-sensitive species, damaged rangeland can be repaired and rehabilitated. Resistant and semi-resistant species show sequence and frequency in the rangeland. Therefore, the objective of this study was to estimate the short-term (three-year) effect of fire on vegetation cover and forage production indicators of the rangeland in mountainous rangelands of Solan area in Hamadan province, Iran.

## 2. Materials and methods

### 2.1 The study area

The Solan area is located in the northeast of Hamadan city in Hamadan province, Iran between 48°41′5″ E to 48°43′17″ E and 34°41′34″ N to 34°42′16″ N (Fig. 1). The absolute maximum and minimum temperatures are 41 °C and -30 °C, respectively. In this region, the precipitation usually occurs

**Table 1.** Some climatic variables of the studied years in 2018, 2019 and 2020.

| Year | Annual Average temperature (°C) | Annual Precipitation (mm) | Annual average Relative Humidity % |
|---|---|---|---|
| 2018 | 13.4 | 335.8 | 46.2 |
| 2019 | 12.3 | 507.1 | 50.8 |
| 2020 | 12.0 | 389.4 | 49.2 |


**Figure 2.** The study areas in the Solan region (control site: A photo and burnt site: B photo).

for 8 months from October to May and the average annual rainfall is 320 mm.

### 2.2 Sampling method

The fire occurred in July 2018. Vegetation sampling was performed in the July to October of 2018, 2019, and 2020. The study area was selected at two sites: A: burnt area and B: unburnt area (control) that were close to each other (Fig. 2). In each site, four transects and on each transect, 10 plots with an area of 1 $m^2$ in the direction of the dominant slope were selected using a systematic random sampling method. The location of each plot was recorded and marked using GPS device. Generally, 40 plots were measured in the burnt site and 40 plots in the control area. The plant species were identified using the flora of Iranica and the Raunkiaer classification method was used to determine the biological form of plants. To determine the susceptibility of species to fire based on the qualitative classification of the Likert scale, the sensitivity was determined as resistant, semi-resistant, semi-sensitive and sensitive, and the criterion for being in each class was considered as regrowth in autumn and spring. In addition, to determine the extent of resistance of each species in the burnt area, the number of semi-burnt, living, and dead species in sample plots were recorded. Moreover, in each plot, the parameters of canopy cover percentage, litter percentage, dry matter forage production (cutting and weighing method), percentage of annual and perennial grass and forbs covers, percentage of shrubs cover, percentage of


**Figure 3.** Regeneration of plant species in the burnt area (up picture of Astragalus verus and down picture of Astragalus gossypinus).

stones and gravels, bare soil percent, and plants palatability classes were recorded.
Table 1 shows the annual precipitation, annual average temperature and annual relative humidity of the sampling years (2018, 2019 and 2020).

### 2.3 Statistical analysis

Statistical data were analyzed using SAS9.4 software. The normality of data distribution was tested using the Kolmogorov-Smirnov test. The T-test was used to compare the means of variables between control and burnt site for individual year and average over two years.

## 3. Results

### 3.1 Vegetation forms and information

The results showed that the predominant type of vegetation in the study area is Astragalus verus- Annual grass. On the other hand, based on field surveys, it was determined that there were 75 species in the study area. So, there were 9 species of shrubs, 33 species of perennial forbs, 16 species of annual forbs, 12 species of perennial grasses, and 5 species of annual grasses. Also, examination of the number of species related to the Raunkiaer classification method revealed that 1 species was Phanerophytes, 29 species were Geophytes, 8 species were Chamaephytes, 14 species were Hemicryptophytes, 2 species were Cryptophytes, and 21 species were Theophytes. So,there were 7 species (9.33%) of Resistant, 46 species (61.33%) of semi-resistant, 10 species (13.33%) of semi-sensitive, 11

**Table 2.** Species of Solan site.
(∗: Presence, -: Absence)

| Species name | Family | Species Form | Life Form | Palatability Class | Species in Control | Species in Fire | Fire Resistance |
|---|---|---|---|---|---|---|---|
| Berula angustifolia (L.) Koch. | Apiaceae | Perennial- Forb | Geophytes | class III | ∗ | ∗ | Semi-sensitive |
| Bupleurum falcatumL. | Apiaceae | Perennial - Forb | Geophytes | class III | ∗ | ∗ | Semi-resistant |
| Carthamus oxyacantha M. Bieb. | Apiaceae | Annual - Forb | Theophytes | class III | ∗ | ∗ | Semi-sensitive |
| Echinophora platyloba DC. | Apiaceae | Perennial - Forb | Hemicryptophyes | class III | ∗ | ∗ | Semi-resistant |
| Eryngium billardieri Delar. | Apiaceae | Perennial - Forb | Hemicryptophyes | class III | ∗ | ∗ | Semi-resistant |
| Gundelia tournefortii L. | Apiaceae | Perennial - Forb | Geophytes | class III | ∗ | ∗ | Resistant |
| Rhabdosciadium aucheri Boiss. | Apiaceae | Perennial - Forb | Geophytes | class III | ∗ | ∗ | Semi-resistant |
| Siumsi sarum L. | Apiaceae | Perennial - Forb | Geophytes | class III | ∗ | ∗ | Resistant |
| Centaurea virgate Lam. | Asteraceae | Perennial - Forb | Hemicryptophyes | class III | ∗ | ∗ | Semi-resistant |
| Centaurea solstitialis L. | Asteraceae | Annual - Forb | Theophytes | class III | ∗ | ∗ | Semi-resistant |
| Cirsium arvense L. | Asteraceae | Perennial - Forb | Hemicryptophyes | class III | ∗ | ∗ | Semi-resistant |
| Cirsium leucocephallum (M. Bieb.) Fisch. | Asteraceae | Perennial - Forb | Hemicryptophyes | class III | ∗ | ∗ | Semi-resistant |
| Cousiniade cipiens Boiss. and Buhse | Asteraceae | Perennial - Forb | Hemicryptophyes | class III | ∗ | ∗ | Semi-resistant |
| Scorzonera hispanica L. | Asteraceae | Annual - Forb | Theophytes | class III | ∗ | ∗ | Resistant |
| Tanacetum parthenium (L.) Sch. Bip. | Asteraceae | Perennial - Forb | Geophytes | class III | ∗ | ∗ | Semi-resistant |
| Tanacetum polycephalum Sch. Bip. | Asteraceae | Perennial - Forb | Geophytes | class III | ∗ | ∗ | Semi-resistant |
| Anchusa italica Retz. var. Kurdicagusuleac | Boraginaceae | Perennial - Forb | Hemicryptophyes | class III | ∗ | ∗ | Semi-sensitive |
| Myosotis alpestris Schmidt. | Boraginaceae | Perennial - Forb | Geophytes | class III | ∗ | ∗ | Semi-resistant |
| Myosotis palustris (L.) Nath. | Boraginaceae | Perennial - Forb | Geophytes | class III | ∗ | ∗ | Semi-resistant |
| Solenanthus stamineus (Desf.) Wettst. | Boraginaceae | Perennial - Forb | Geophytes | class III | ∗ | ∗ | Resistant |
| Alyssum lanigerum DC. | Brassicaceae | Annual -Forb | Theophytes | class III | ∗ | ∗ | Semi-sensitive |
| Cardamine uliginosa M.B. | Brassicaceae | Annual - Forb | Theophytes | class III | ∗ | ∗ | Semi-sensitive |
| Cardaria draba (L.) Desv. | Brassicaceae | Perennial - Forb | Geophytes | class III | ∗ | ∗ | Semi-resistant |
| Sisymbrium loeselii L. | Brassicaceae | Annual - Forb | Theophytes | class III | ∗ | - | Sensitive |
| Asyneuma persicum (A.DC.) Bornm. | Campanulaceae | Perennial - Forb | Geophytes | class III | ∗ | ∗ | Semi-resistant |
| Acanthophyllum crassifolium Boiss. | Caryophyllaceae | Shrub | Chamaephytes | class III | ∗ | ∗ | Semi-sensitive |
| Stellaria media (L.) Vill. | Caryophyllaceae | Annual - Forb | Theophytes | class III | ∗ | - | Sensitive |
| Hypericum scabrum L. | Clusiaceae | Perennial - Forb | Geophytes | class III | ∗ | ∗ | Semi-resistant |
| Euphorbia cheiradenia Boiss. and Hohen. | Euphorbiaceae | Perennial - Forb | Geophytes | class III | ∗ | ∗ | Semi-resistant |
| Astragalus verus Olivier. | Fabaceae | Shrub | Chamaephytes | class III | ∗ | - | Sensitive |
| Astragalus gossypinus Fisch. | Fabaceae | Shrub | Chamaephytes | class III | ∗ | - | Sensitive |
| Lathyrus pratensis Burkart. | Fabaceae | Annual - Forb | Theophytes | class I | ∗ | ∗ | Semi-resistant |
| Lotus corniculatus L. | Fabaceae | Perennial - Forb | Geophytes | class I | ∗ | ∗ | Semi-resistant |
| Trifolium pratense L. | Fabaceae | A- Forb | Theophytes | class I | ∗ | ∗ | Semi-resistant |
| Lophanthus laxiflorus (Benth.) Levin. | Lamiaceae | Perennial - Forb | Geophytes | class II | ∗ | ∗ | Semi-resistant |
| Marrubium astracanicum Jacq. | Lamiaceae | Perennial - Forb | Geophytes | class III | ∗ | ∗ | Semi-resistant |
| Mentha longifolia (L.) Hudson. | Lamiaceae | Perennial - Forb | Geophytes | class III | ∗ | ∗ | Resistant |
| Nepeta macrosiphon Boiss. | Lamiaceae | Perennial - Forb | Geophytes | class III | ∗ | ∗ | Resistant |
| Nepeta straussii Hausskn. and Bornm. | Lamiaceae | Perennial - Forb | Geophytes | class III | ∗ | ∗ | Resistant |
| Phlomisanis odontha Boiss. | Lamiaceae | Perennial - Forb | Hemicryptophyes | class II | ∗ | ∗ | Semi-resistant |
| Scutellaria nepetifolia Benth. | Lamiaceae | Annual - Forb | Theophytes | class III | ∗ | ∗ | Semi-resistant |
| Starchys setifera C.A. Mey. | Lamiaceae | Annual - Forb | Theophytes | class III | ∗ | ∗ | Semi-resistant |
| Teucrium orientale L. | Lamiaceae | Perennial - Forb | Geophytes | class III | ∗ | ∗ | Semi-resistant |
| Thymus fallax Fisch. and C. A. Mey. | Lamiaceae | Shrub | Chamaephytes | class III | ∗ | ∗ | Semi-resistant |
| Acantholimon bromifolium Boiss. ex Bge. var. bromifolium | Plumbaginaceae | Shrub | Chamaephytes | class III | ∗ | - | Sensitive |
| Acantholimon olivieri (Jaub. and Spach) Boiss. | Plumbaginaceae | Shrub | Chamaephytes | class III | ∗ | - | Sensitive |
| Agrostis gigantean (Roth) | Poaceae | Perennial - Grasse | Geophytes | class III | ∗ | ∗ | Semi-resistant |
| Bothriochloa ischaemum (L.) Keng. | Poaceae | Perennial - Grasse | Geophytes | class I | ∗ | ∗ | Resistant |
| Brachypodium sylvaticum (Huds.) P.Beauv. | Poaceae | Perennial - Grasse | Geophytes | class I | ∗ | ∗ | Semi-resistant |
| Bromus pumilio (Trin.) P.M. Sm. | Poaceae | Annual - Grasse | Theophytes | class II | ∗ | - | Sensitive |
| Bromus tectorum L. | Poaceae | Annual - Grasse | Theophytes | class II | ∗ | - | Sensitive |
| Bromus dantonia Trin. | Poaceae | Annual - Grasse | Theophytes | class II | ∗ | - | Sensitive |
| Bromus tomentellus Boiss. | Poaceae | Perennial - Grasse | Hemicryptophyes | class I | ∗ | ∗ | Semi-sensitive |
| Elymus hispidus (Opiz) Melderis var. podperae (Nabelk) Assadi | Poaceae | Perennial - Grasse | Geophytes | class II | ∗ | ∗ | Semi-resistant |
| Elymus repens subsp. Elongatiformis (Drobow) Melderis | Poaceae | Perennial - Grasse | Geophytes | class II | ∗ | ∗ | Semi-resistant |
| Festuca ovina L. | Poaceae | Perennial - Grasse | Hemicryptophyes | class I | ∗ | ∗ | Semi-resistant |
| Heteranthelium piliferum (Sol.) Hochst. exJaub. and Spach. | Poaceae | Annual - Grasse | Theophytes | class II | ∗ | - | Sensitive |
| Hordeum bulbosum L. | Poaceae | Perennial - Grasse | Hemicryptophyes | class I | ∗ | ∗ | Semi-resistant |
| Melica persica Kunth. | Poaceae | Perennial - Grasse | Geophytes | class II | ∗ | ∗ | Semi-resistant |
| Phragmites australis (Cav.) Trin. exSteud. | Poaceae | Perennial - Grasse | Hemicryptophyes | class II | ∗ | ∗ | Semi-resistant |
| Poa bulbosa L. | Poaceae | Perennial - Grasse | Hemicryptophyes | class II | ∗ | ∗ | Semi-resistant |
| Stipa barbata Desf. | Poaceae | Perennial - Grasse | Cryptophytes | class I | ∗ | ∗ | Semi-resistant |
| Taeniatherum caput-medusae (L.) Nevski | Poaceae | Annual - Grasse | Theophytes | class II | ∗ | - | Sensitive |
| Rumex angustifolius Campd. | Polygonaceae | Perennial - Forb | Cryptophytes | class III | ∗ | ∗ | Semi-resistant |
| Ranunculus constantinopolitanus (DC.) d'Urv | Ranunculaceae | Annual - Forb | Theophytes | class III | ∗ | ∗ | Semi-resistant |
| Amygdalus lycioides Spach var. horrida | Rosaceae | Shrub | Phanerophytes | class III | ∗ | ∗ | Semi-sensitive |
| Cerasus microcarpa (C. A. Mey.) Boiss. | Rosaceae | Shrub | Chamaephytes | class III | ∗ | ∗ | Semi-sensitive |
| Geumur banum L. | Rosaceae | Annual - Forb | Theophytes | class II | ∗ | ∗ | Semi-sensitive |
| Potentilla reptans L. | Rosaceae | Perennial - Forb | Geophytes | class I | ∗ | ∗ | Semi-resistant |
| Rosa persica J.F. Gmel. | Rosaceae | Shrub | Chamaephytes | class III | ∗ ∗ | High-resistant | |
| Galium verum L. | Rubiaceae | Annual - Forb | Theophytes | class III | ∗ | ∗ | Semi-resistant |
| Pedicularis sibthorpii Boiss. | Scrophulariaceae | Annual - Forb | Theophytes | class III | ∗ | ∗ | Semi-resistant |
| Veronica anagalis-aquatica L. | Scrophulariaceae | Annual - Forb | Theophytes | class III | ∗ | ∗ | Semi-resistant |
| Verbascum Thapsus L. | Scrophulariaceae | Perennial - Forb | Hemicryptophyes | class III | ∗ | ∗ | Semi-resistant |
| Urtica dioica L. | Urticaceae | Perennial - Forb | Geophytes | class III | ∗ | ∗ | Semi-resistant |

species (14.66%) of sensitive and 1 species (1.33%) of high-resistant. So that there were 10 species of palatability class I (13.33%), 13 species of palatability class II (17.33%) and 52 species of palatability class III (69.33%) (Table 2).

### 3.2 Canopy and vegetation covers

The results of the means comparison of canopy cover and vegetation cover in two areas showed that in the first year, there were significant differences between control and burnt area for canopy cover, annual and perennial grasses, and annual forbs covers percentage ($P \leq 0.01$). In the burnt site, the frequency of annual forbs, annual grasses, perennial grasses, and canopy cover were significantly lower than control area (Table 3). So, the canopy cover percentage decreased up to 50% compared to the control area. In the second and the third year after the fire, there was no significant difference between two areas for canopy cover (Table 3). However, the result showed that in the second year, there was a significant difference between the two areas in the annual forbs cover ($P \leq 0.01$). For perennial grasses covers, the lower value was observed in the third year after the fire ($P \leq 0.05$).

In the burnt area, the highest annual and perennial forbs cover was observed in the third year of sampling. Also, in the burnt area, the highest percentage of annual and perennial grasses cover was observed in the first and second years, respectively. Moreover, in the burnt area, the highest canopy cover and shrubs cover were observed in the third year of sampling (Table 3). In the burnt area, the highest annual and perennial forbs cover were observed in the third year of sampling. Also, in the burnt area, the highest annual grass cover was observed in the second and third years,

**Table 3.** The results of independent two samples T test to compare the variables of burnt and control areas in 2018, 2019, and 2020 and three years in the Solan area.
(ns, ∗, ∗∗ = non-significant and significant at 5% and 1% probability level, respectively.
Means of traits with different letters are significantly different using independent two samples T test)

| Year | Treatment | Canopy Cover (%) Cover (%) | Annual grass Cover (%) | Perennial grass Cover (%) | Annual forbs Cover (%) | Perennial forbs Cover (%) | Shrubs Cover (%) |
|---|---|---|---|---|---|---|---|
| 2018 | Control | 43.25 a | 12.97 a | 13.35 a | 3.92 a | 4.67 | 8.85 |
| | Fire | 20.85 b | 3.12 b | 9.30 b | 0.70 b | 3.05 | 4.62 |
| | T test | ∗∗ | ∗∗ | ∗∗ | ∗∗ | ns | ns |
| 2019 | Control | 42.90 | 17.62 | 6.97 | 6.92 a | 5.45 | 5.80 |
| | Fire | 39.20 | 22.35 | 8.77 | 4.35 b | 4.35 | 5.25 |
| | T test | ns | ns | ns | ∗∗ | ns | ns |
| 2020 | Control | 42.12 a | 20.00 | 4.17 a | 5.80 a | 6.37 | 6.02 |
| | Fire | 41.50 b | 18.92 | 2.50 b | 6.70 b | 8.00 | 5.37 |
| | T test | ∗ | ns | ∗∗ | ∗ | ns | ns |
| Mean 3 years | Control | 42.75 a | 16.86 | 8.16 a | 5.55 a | 5.50 | 6.89 a |
| | Fire | 33.85 b | 14.80 | 6.85 b | 3.91 b | 5.13 | 8.08 b |
| | T test | ∗∗ | ns | ∗ | ∗∗ | ns | ∗ |

respectively. Moreover, in the burnt area, the highest value of canopy cover was observed in the third year of sampling. The shrub cover was stable in the second and third years with no significant differences with control (Table 3). Also, in the control and burnt site in the mean 3 years, there were significant differences between control and burnt area for canopy cover, annual forbs cover ($P \leq 0.01$), perennial grass cover and shrubs cover ($P \leq 0.05$) (Table 3).

### 3.3 Forage production

The fire reduced the forage production. The results showed that there were significant differences between the control and burnt area in terms of forage production in all years after the fire ($P \leq 0.01$) (Table 4). The highest forage production (Kg/ha) was always observed in the control area. In the burnt area, the highest forage production (218.7 Kg/ha) was achieved in the third year (Table 4). In the control area, forage production increased from 183.5 to 312.7 and 310 Kg/ha, in the first, second and third years, respectively. In the burnt area, forage production increased from 05.5 to 41.7 and 218.7 Kg/ha, in the first, second and third years, respectively, indicating the highest forage production (218.7 Kg/ha) in the third year. Also, the results of means comparison for 3 years of forage production showed a significant difference between the two areas ($P \leq 0.01$) (Table 4).

### 3.4 Litter, stones, gravels, and bare soil percentage

The results showed that the fire reduced the litter percentages in all years after the fire. In the first and third years after the fire, there was a significant difference between the control area and burnt area in terms of litter percentage ($P \leq 0.01$) (Table 4). The highest litter percentage was observed in both regions in the third year (Table 4).
The fire increased bare soil percentage. The results showed that there was a significant difference between the control and burnt area for bare soil in the first and third years after the fire ($P \leq 0.01$). The highest percentage of bare soil was observed in the first year with values of 22.05 and 39.8% for control and burnt area, respectively. On the other hand, the mean 3-year bare soil percentage was higher in the burnt area. Comparison of mean percentage of stone and gravels did not show a significant difference between the two areas (Table 4).

### 3.5 Survival rate

Fire reduced plant survival. The results showed that the plant survival was significantly different between the two areas in all years of sampling ($P \leq 0.01$) (Table 4).

## 4. Discussion

Fire can have positive or negative effects on ecosystem components. Changes in the structure and composition of vegetation are the most obvious effects of fire on natural ecosystems, including rangelands [21]. In other words, most rangeland communities are resilient to fire but significant changes in their structures and compositions may occur [22]. The results showed that Geophytes had the highest species in the two areas. Long-term relationships with fire influence the life of many plant species; this led to the evolution of many mechanisms and plant morphologies in response to frequent fire, including obligate seeders, resprouters, fire ephemerals, regular ephemerals, and geophytes [23]. These strategies enable plants to survive fire disturbance and to rapidly recolonize burnt areas [24]. The geophytes species have some forms of underground storage organs (bulb, tuber, thick rhizome, etc.), which provides rapid growth with the return of favorable climatic conditions [25]. The largest plant species in the study sites was Amygdalus lycioides with an average canopy diameter of 70 cm, an average height of 75 cm, and a frequency less than 5%. The widespread and open canopy of this species causes it to burn. Parts of this species that remain healthy

**Table 4.** The results of independent two samples T test to compare the variables of burnt and control areas in 2018, 2019, and 2020 and three years in the Solan area.
(ns, ∗, ∗∗ = non-significant and significant at 5% and 1% probability level, respectively.
Means of traits with different letters are significantly different using independent two samples T test.)

| Year | Treatment | Litter % | Forage production (Kg/ha) | Survival Rate% | Stone and gravels% | Bare soil % |
|---|---|---|---|---|---|---|
| 2018 | Control | 8.87 a | 183.5 a | 100.00 a | 27.27 | 22.05 b |
| | Fire | 4.70 b | 05.5 b | 40.50 b | 34.52 | 39.80 a |
| | T test | ∗∗ | ∗∗ | ∗∗ | ns | ∗∗ |
| 2019 | Control | 9.47 | 312.7 a | 100.00 a | 31.75 | 16.12 b |
| | Fire | 8.80 | 41.7 b | 40.50 b | 27.12 | 25.25 a |
| | T test | ns | ∗∗ | ∗∗ | ns | ∗∗ |
| 2020 | Control | 16.75 a | 310.0 a | 100.00 a | 23.62 | 17.50 b |
| | Fire | 12.37 b | 218.7 b | 35.50 b | 25.50 | 25.87 a |
| | T test | ∗∗ | ∗∗ | ∗∗ | ns | ∗ |
| Mean | Control | 11.70 a | 268.7 a | 100.00 a | 27.55 | 18.55 b |
| 3 years | Fire | 8.62 b | 88.6 b | 38.83 b | 29.05 | 30.30 a |
| | T test | ∗∗ | ∗∗ | ∗∗ | ns | ∗∗ |

will be able to regrow. So, in the study area, about 40% of Amygdalus lycioides had regrown. Cerasus microcarpa is a genus of Rosaceae and did not completely disappear and regrow after the fire. Moradi et al. stated that Cerasus microcarpa tolerated fire well and grew after the fire, immediately. Also, Astragalus gossypinus in the first year and Astragalus verus in the second year after fire revived itself. Tahmasebi (2013) reported that in the rangelands of Chaharmahal and Bakhtiari province, Iran, species of Astragalus such as Astragalus verus are not able to significantly regenerate themselves one year after the fire. This is due to the dense canopy of this species and the resulting greater severity of the burn. Species such as Acantholimon bromifolium, Acantholimon olivieri, and Acanthophyllum crassifolium were completely burnt and destroyed by fire. Rosa persica burns easily and completely. However, due to its extensive rhizome and underground roots, it grew in autumn and spring and did not disappear. Continuation of reproduction of this species using underground germination (geophyte) and to some extent, fire reduces their competition and growth. In other words, Rosa persica due to the presence of rhizome and extensive underground roots are very resistant to fire. Although the R. persica species is resistant, the fire reduced the frequency of this species. In a similar way, Mirdavoodi and Azdoo reported that the fire reduced the Rosa persica frequency [26]. R. persica is weaker in competition with other forbs and grasses species and if the rangeland ecosystem is managed and protected, this species will not have the ability and competitiveness to grow and regenerate and over time, its density will decrease. Perennial forbs species such as Anchusa italica Retz. var. Kurdica gusuleac, Berula angustifolia, Asyneuma persicum, Bupleurum falcatum, Cardaria draba, Scutellari anepetifolia, Myosotis alpestris, Hypericum scabrum, Euphrbia cheiradenia, Mentha longifolia, Marrubium astracanicum, Eryngium billardieri, Phlomis anisodontha, Teucrium orientale, Tanacetum polycephalum, Tanacetum parthenium, Myosotis palustris, Nepetam acrosiphon, Lotus corniculatus, Rumex angustifolius, Solenanthus stamineus, Galium verum, Ranunculus constantinopolitanus, Potentilla reptans, Starchys setifera, Verbascum thapsus, Echinophora platyloba, Rhabdoscia diumaucheri, Cousinia sp.,Utica dioica, Siumsi sarum, Cirsium leucocephallum, Cirsium arvense, Lophanthus laxiflora, Centaura virgatei, and Gundelia tournefortii have 40 to 85% water and do not burn easily [27]. The presence of extensive underground organs of these plants makes them have an acceptable 80% survival rate after the fire. However, perennial forbs species have limited natural regeneration in the first year after the fire and when the fire is intense, they have no natural regeneration with seeds. Also, the annual forbs species such as Scorzonera sp., Pedicularis sibthorpii, Scutellariane petifolia, Alyssum lanigerum, Cardamine uliginosa, Geumur banum, Stellari amedia, Veronica anagalis-aquatica, and Sisymbriumloesell are destroyed by fire. Seeds of these species that are dropped on the ground, especially seeds that are small are more durable and as a result, less damaged. These seeds start to grow in the following year. In other words, plants that can germinate after a fire are annual species with fine seeds and survival seed banks [28]. The results showed that perennial grasses such as Agrostics gigantean, Bothriochloai schaemum, Elymus hispidus, Poa bulbosa, Festuca ovina, Melica persica, Brachypodium sylvaticum, Elymus repens, Bromus tomentellus, Bromus pumilio, Phragmites australis, Hordeum bulbosum, and Stipa barbata severely burn. However, seeds that have not been completely burned can grow. These seeds have a cover and if the embryo and part of the endosperm stay healthy, they will grow in autumn. In general, studies have shown that the number of perennials due to the location of the buds (above or below ground) and asexual propagation by rhizome or stolons will increase in the years after the fire [29, 30]. Also, annual grasses such as Bromus dantonia, Bromus tectorum, Taeniatherum caput-medusa, and Heteranthelium pilliferum burn completely due to fire and their density and frequency are severely reduced after the fire.

The result showed that in the first year after the fire, there was a significant difference between the two areas, for annual forbs and annual and perennial grasses species. The percentage of perennial forbs and shrubs covers did not show a significant difference, which indicates the regrowth of these plants one year after the fire. Many species in the burnt site were able to regenerate themselves in the second year. However, the fire caused an increase in annual plants. Patten and Cave in the upper Sonoran desert (Southern Arizona grasslands) stated that the abundance of annual plants species decreased after the fire [31]. Similar to our results, Kahmen and Poschlod showed an increase in annual plants species [32]. This study showed that the fire significantly reduced the litter percentage such that in the first year after the fire in the burnt area compared to the control area, litter percentage decreased by 50% although it was gradually increased. The fire induced removal of litter and standing old or dead plant material [33]. Many researchers stated that fire removes litter [30]. In this study, the most important factor in increasing litter is improving and increasing the percentage of cover, density, and production of annual grasses and forbs. The fire increased the bare soil area. In many studies, researchers stated that fire increases the bare soil [22, 34]. Shahlaei et al. found that due to fire, the percentage of bare soil increased. After the fire, plants litter, and the plants that cover most of the bare soil are removed [30]. The result showed that forage production, which is mostly related to annual forbs and grasses species, was decreased in the burnt area compared to the control area in all years after fire; however, it showed an upward trend. Our findings were similar to those of some researchers [34, 35]. By reducing the litter and vegetation, and increasing the bare soil surface due to the fire, the radiance of sunlight to the soil and its surface radiance increase. Increasing the ambient temperature stimulates biological activities so that the organic minerals and nutrients become available and as a result, the growth of grasses will be faster . Numerous studies have shown that after fire, suitable conditions are provided for the development of grasses species [29]. Plant species having their buds under the bark or having thick bark can protect their vegetative buds from fire damage and therefore, they are resistant to fire. Most forbs and grasses species have terminal buds that are located on the ground and this is the cause of their resistance to fire [36]. For example, after the fire, perennial grasses will grow because they can resist fire due to the position of bud growth on or below the soil surface [37]. In general, the role of plant species and their vegetative form in returning to the process of succession and their stability, and change in the vegetation composition is important and effective [38]. According to the obtained results, the canopy cover in the burnt area compared to the control site was decreased although it showed an upward trend. Fattahi and Tahmasebi reported results similar to the results of the present study.

The result showed that soil erosion and sedimentation increased after the fire. Similar to this result, Johansen et al. have done some experiments in New Mexico, USA, and observed almost 25 times higher sediment in the burned plots than unburned plots [39]. Parlak found that the runoff, maximum runoff, runoff percentage, sediment concentration, the peak of sediment, and total soil loss values of the burned plots were significantly higher than the unburned plots [40]. The amount of surface cover is an important control of infiltration, runoff, and soil erosion in both burned and unburned areas. In unburned areas, surface cover increases infiltration, decreases runoff and decreases soil erosion with several mechanisms. These include rainfall interception, maintaining high porosity by increasing soil organic matter and facilitating biological activity, preventing soil sealing, and increasing surface roughness.

The results showed that the composition of vegetative forms of plant species was affected by fire and their aerial parts were destroyed and damaged. So, production, litter, and survival are significantly different after three years of fire and the rangeland ecosystem has not been able to survive yet. Plants species differ in terms of vegetative forms, location of productive buds, root depth, amount of seeds, and seed bank. Also, the intensity and duration of fires and the abundance of plant species are different. Annual plant species are severely damaged by fire. These species may die after the fire if they do not have seeds in places far from the fire such as the rocks and pebbles. Perennial species and shrubs with vegetative buds on the surface of the soil or underground can regrow after the fire.

## 5. Conclusion

According to the results of this study, fire in the study area reduced the density and abundance of prickly and invasive species in the area. Therefore, controlled fire can be a management factor in controlling invasive species that are not part of the climax of the area. On the other hand, the presence of a natural seed bank in the rangeland ecosystem of the study area has caused these seeds to be protected from fire and can start growing and increasing density after rain due to reduced competition and removal of upper floors and opening of suitable space. In general, fire rejuvenates and increases the quality and quantity of suitable plant species and has a positive role for some plants that are constantly grazed and exploited. Therefore, with a managed fire, it is possible to give the pasture a chance and to improve its condition by applying biological management.

**Conflict of interest statement:**
The authors declare that they have no conflict of interest.

## References


[1] J. L. Holechek, R. D. Pieper, and C. H. Herbel. *Range Management Principles and Practices*. Pearson, 2004.

[2] H. Badripour, N. Eskandari, and S. A. Rezaei. *Rangelands of Iran, an Overview*. Pooneh, 1th edition, 2006.

[3] M. Reinhard, M. Rebetezl, and R. Schlaepfer. "Recent climate change: Rethinking drought in the context of Forest Fire research in Ticino, South of Switzerland". *Journal of Theoretical and Applied Climatology*, **82**:17–25, 2005.

[4] J. T. Randerson, Y. Chen, G. R. Van Der Werf, B. M. Rogers, and D. C. Morton. "Global burned area and biomass burning emissions from small fires". *Journal of Geophysical Research: Biogeosciences*, **117**:G04012, 2012.

[5] W. Seiler and P. J. Crutzen. "Estimates of gross and net fluxes of carbon between the biosphere and the atmosphere from biomass burning". *Climatic Change*, **2**:207–247, 1980.

[6] L. M. Zavala, R. de Celis, and A. Jordán. "Fire in rangelands and its role in management". *Range and Animal Sciences and Resources Management*, **2**:146–170, 2014.

[7] E. M. Ruckman, S. Schwinning, and K. G. Lyons. "Effects of phenology at burn time on post-fire recovery in an invasive C4 grass". *Restoration Ecology*, **20**:756–763, 2012.

[8] J. E. Keeley and P. W. Rundel. "Fire and Miocene expansion of C4 grasslands". *Ecology Letters*, **8**:683–690, 2005.

[9] W. M. Jolly, M. A. Cochrane, P. H. Freeborn, Z. A. Holden, T. J. Brown, G. J. Williamson, and D. M. J. S. Bowman. "Climate-induced variations in global wildfire danger from 1979 to 2013". *Nature Communications*, **6**:7537, 2015.

[10] J. M. Carroll, T. J. Hovicka, C. A. Davis, R. D. Elmore, and S. D. Fuhlendorf. "Reproductive plasticity and landscape heterogeneity benefit a ground-nesting bird in a fire-prone ecosystem". *Journal of Applied Ecology*, **27**:2234–2244, 2017.

[11] E. J. Van Etten. "Fire in rangelands and its role in management". *Range and Animal Sciences and Resources Management*, **2**:146–170, 2010.

[12] A. Mirzaei Mossivand, F. Keivan Behjou, E. Zandi Esfahan, and A. Ghorbani. "Assessment of fire effects on surface cover changes and forage production (Case study: Delfan County, Lorestan Province, Iran)". *Journal of Rangeland Science*, **5**:60–71, 2015.

[13] P. B. Reich, P. Bakken, D. Carlson, L. E. Frelich, S.K. Friedman, and D. F. Grigal. "Influence of logging, fire and forest type on biodiversity and productivity in southern boreal forests". *Journal of Ecology*, **82**:2731–2748, 2001.

[14] E. J. Davis, C. Moseley, P. Jakes, and M. Nielsen-Pincus. "The lost summer: Community experiences of large wildfires in Trinity County, California". *Scientific Journal (JRNL) Forest Service U.S. Department of Agriculture*, :363–381, 2011.

[15] F. B. Pierson, C. J. Williams, S. P. Hardegree, M. A. Weltz, J. J. Stone, and P. E. Clark. "Fire, plant invasions, and erosion events on western rangelands". *Rangeland Ecology and Management*, **64**:439–449, 2011.

[16] G. Peterson, C. R. Allen, and C. S. Holling. "Ecological resilience, biodiversity, and scale. Journal of Ecosystems". *Journal of Rangeland Science*, **1**:6–18, 1998.

[17] F. Moreira, A. Delgado, S. Ferreira, R. Borralho, N. Oliveira, M. Inàcio, J. S. Silva, and F. Rego. " Effects of prescribed fire on vegetation structure and breeding birds in young Pinuspinaster stands of northern Portugal". *Journal of Forest Ecology and Management*, **184**:225–237, 2003.

[18] P. Gholami, M. R. Mirzaei, E. Zandi Esfahan, and A. Eftekhari. "Effects of Fire on Composition, Biodiversity, and Functional Groups Changes in Semi-Steppe Rangelands of Southern Zagros, Iran". *Journal of Rangeland Science*, **10**:39–48, 2020.

[19] J. L. Beverly and D. L. Martell. "Characterizing extreme fire and weather events in the boreal shield Ecozone of Ontario". *Agricultural and Forest Meteorology*, **133**:5–16, 2005.

[20] C. S. Everson. *Veld burning in different vegetation types*. Veld management in South Africa. University of Natal Press, 1999.

[21] L. F. DeBano, D. G. Neary, and P. F. Ffolliott. *Fire effect on ecosystems*. Wiley and Sons, 1th edition, 1998.

[22] J. C. Guevara, C. R. Stasi, C. F. Wuilloud, and O. R. Estevez. "Effects of fire on rangeland vegetation in south-western Mendoza plains (Argentina): composition, frequency, biomass, productivity, and carrying capacity". *Journal of Arid Environments*, **41**:27–35, 1999.

[23] G. W. Wardell-Johnson. "Response of forest eucalypts to moderate and high-intensity fire in the Tingle Mosaic, south-western Australia: comparisons between locally endemic and regionally distributed species". *Journal of Austral Ecology*, **25**:409–421, 2000.

[24] A. M. Gill, R. H. Groves, and I. R. Noble. *Fire and the Australian Biota*. Australian Academy of Science, 1th edition, 1981.

[25] K. J. Niklas. "Life forms, plants". *Encyclopedia of Ecology*, :2160–2167, 2008.

[26] H. Mirdavoodi and Z. Azdoo. “Impact of Rosa persica Controlling Methods on Species Richness and Diversity in Steppe Vegetation, Arak, Iran”. *Journal of Rangeland Science*, **11**:89–102, 2021.

[27] Gh. Assadian, Z. Azimnejad, and R. Bahramloo. “The effect of fire on some biodiversity indicators and determining fire-resistant plant species in Solan rangelands in Hamedan”. *Iran Nature*, **6**:61–74, 2021.

[28] S. Gonzalez and L. Ghermandi. “Postfire seed bank dynamics in a semiarid grassland”. *Journal of Plant Ecology*, **199**:175–185, 2008.

[29] K. Haubensak C. D. Antonio and D. Wixon. “Effect of fire and environmental variables and composition in grazed salt desert shrub lands of the Great Basin (USA)”. *Journal of Arid Environments*, **73**:643–650, 2009.

[30] S. Erkovan, A. Koc, M. K. Gullap, H. I. Erkovan, and S. Bilen. “The effect of fire on the vegetation and soil properties of ungrazedShortgrass steppe rangeland of the eastern Anatolia region of Turkey”. *Turkish Journal of Agriculture and Forestry*, **40**:290–299, 2016.

[31] D. T. Patten, , and G. H. Cave. “Fire temperatures and physical characteristics of a controlled burn in the Upper Sonoran Desert”. *Journal of Range Management*, **37**:277–280, 1984.

[32] S. Kahmen and P. Poschlod. “Does germination success differ with respect to seed mass and germination season? Experimental testing of plant functional trait responses to grassland management”. *Annals of Botany*, **101**:541–548, 2008.

[33] J. R. Weir, S. D. Fuhlendorf, D. M. Engle, T. G. Bidwell, D. C. Cummings, D. Elmore, R. F. Limb, B. W. Allred, J. D. Scasta, and S. L. Winter. *Patch Burning: Integrating Fire and Grazing to Promote Heterogeneity*. Department of Natural Resource Ecology and Management, Oklahoma Cooperative Extension Service, Oklahoma State University, 2019.

[34] G. Dale, R. G. Brockway, R. Gatewood, and R. B. Paris. “Restoring fire as an ecological process in short grass prairie ecosystems: initial effects of prescribed burning during the dormant and growing seasons”. *Journal of Environmental Management*, **65**:135–152, 2002.

[35] R. B. Kristofor. “Soil physiochemical changes following 12 years of annual burning in humid-subtropical tall grass prairie. A hypothesis”. *Journal of ActaEcologica*, **30**:407–413, 2006.

[36] R. G. Bailey. *Ecoregions map of North America: Explanatory Note.* USDA Forest Service, 1998.

[37] J. Ortman and D. D. Beran. “Grassland management with prescribed fire”. *Nebraska cooperative extension, EC*, **148**:122–132, 2008.

[38] M. Goodarzi, M. Azimi, A. Zandi Isfahan, Gh. Karimi, and A. A. Shahmoradi. “Investigation of the effect of fire on wheatgrass cover”. *Iranian Journal of Range and Desert Research*, **22**:545–537, 2015.

[39] M. P. Johansen, T. E. Hakonson, and D. D. Breshears. “Post-fire runoff and erosion from rainfall simulation: contrasting forests with shrublands and grasslands”. *Journal of Hydrological Processes*, **15**:2953–2965, 2001.

[40] M. Parlak. “Effects of wildfire on runoff and soil erosion in the southeastern Marmara Region, Turkey”. *Journal of Ekoloji*, **24**:43–48, 2015.