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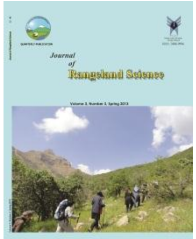

Full Length Article:

Effects of Shrub Canopy on the Microclimate and Soil Properties of Steppe Rangeland

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Abstract. In arid and semi-arid ecosystems, shrubs may act as fertility islands but their effect may vary depending on their morphology and ecological impacts. This research was aimed to study effect of three shrubs *Scariola orientalis, Astragalus heratensis,* and *Rosa persica* on soil properties and on the microclimate conditions (temperature, luminance, and soil moisture) of their understory in the steppe rangelands of Kakhek Gonabad, Iran**.** Along 50-m transects, flexible plot sizes were selected to measure the microclimate factors of understory species and the open spaces next to the shrubs based on the canopy diameters of each intercepted shrubs. Soil samples were taken from understory of shrubs. The microclimatic factors of understory and open spaces were compared using paired-t test. The soil properties were analyzed under 3 shrubs and open spaces and then comparison were made using Duncan's test. The results showed that temperature and luminance intensity were significantly lower in understory than the open spaces ($p<0.05$). Soil depth moistures (15-55 cm) were higher in understory than the open space while soil surface moistures (0-10 cm) did not vary. Among the investigated shrubs, *Astragalus heratensis* had the greatest facilitation effect on microclimatic factors. The soil criteria of EC (0.32 mS/cm), organic matter (1.6%), and nitrogen (0.08%) were significantly higher in understory of *Astragalus heratensis* than in the open space (0.15 mS/cm, 0.39%, and 0.028%), respectively. These effects can be related to the wider canopy cover, greater stature, and possibly nitrogen fixation for *Astragalus heratensis*.

Key words: Microclimate, Open space, Rangeland shrubs, Shrub canopy, Soil physical and chemical properties, Steppe rangeland

1. Introduction

Studying the relationship between vegetation and the soil is highly important in arid and semi-arid range ecosystems. Soil is one of the most important environmental factors that have close relationship with the vegetation. In fact, the soil properties are affected by root activities and litter which accumulates under canopy of perennial plants (Jafari *et al*., 2004; Naseri *et al*., 2012). So the soil properties and its nutrients have significant impact on the plant productivity and range ecosystem sustainability. The shrubs by their intensive canopy cover and root activity improve the quality of their understory soil. In addition, the improvement of soil properties have high correlation with soil stability (Jafari *et al*., 2009; Yang *et al*., 2011).

The soil under shrub plants of the fertile islands (King, 2008; Padilla and Pugnaire, 2009) commonly has a higher nutrient and humidity contents than the surrounding open areas, and thus increases the seedlings growth (Tirado and Pugnaire, 2005). In addition, the shade from shrubs reduces thermal amplitudes and decreases soil water evaporation (Flores and Jurado, 2003; Pugnaire *et al*., 2011). Shade also reduces thermal stress and transpiration of understory plants, thereby maintaining the soil moisture (Maestre *et al*., 2001; Armas and Pugnaire, 2005). Increasing these materials improve the quality and quantity of micro-habitats for other plants. (Tracol *et al*., 2011; Smit and Ruifrok, 2011; Berg and Steinberger, 2012).

The development is related to a number of factors influencing the redistribution of soil resources. These factors include shrub species, canopy shape, dust deposition under the canopy (Zheng *et al*., 2008; Howard *et al*., 2012), biomass, litter, nutrient concentration, mineralization, and nitrogen fixation by symbiotic bacteria (Duponnois *et al*., 2011).

Zheng *et al*., (2008) found that litter accumulation under canopy of shrubs led to higher soil fertility. Halvarson and Smith (1997) studying sagebrush habitats in Washington, USA found out that accumulation of organic carbon, nitrogen, and its recycling under these shrubs were higher as compared to the open spaces. Study of Huber-Sannwald and Pyke (2005) showed that the microclimate created by understory of *Artemisia tridentata* provide conditions of the initial establishment of perennial grasses.

The aim of this research was to assess the impact of three shrubs of *Scariola orientalis*, *Astragalus heratensis*, and *Rosa persica* on the chemical and physical soil properties and to investigate the effects of shrubs on the understory microclimate (temperature, luminance, and soil moisture). The findings of this paper can be used for the selection of best shrub species for rehabilitation of degraded rangelands and introducing species adaptable to the understory of rangeland shrubs.

2. Material and methods

2.1. Study area and plant species

The study area was located in 25 Km south of Gonabad, Iran,58° 31' 22" E, 34° 02' 25" N, and with average elevation 1800 m. The mean annual temperature is 12 °C, and the mean annual rainfall is 240 mm and considered as arid climate. The dominant native plant species in the study area were mainly perennial shrubs *Astragalus heratensis*, *Rosa persica*, *Scariola orientalis*, *Acanthophyllum* spp, *Artemisia aucheri* and *A. sieberi*, perennial grass of *Stipa barbata* and annual grass of *Bromus tectorum*. The following dominant shrub species were selected for this study.

***Scariola orientalis* (Boiss.) Sojack.** Species have long stems and branches with leaves on the branch (Jory and

Mahdavi, 2009). It is usually found in an area that has already been plowed for rain fed crop. Study of Pabot (1970) showed, species of *Scariola* are considered chamephytes and with medium palatability.

***Astragalus heratensis* Bunge.** A spiny shrub, with the leaves and stems, not being used by livestock (Paryab *et al*., 2007). It has a greater canopy structure and long branches as compared to *Scariola* and *Rosa*.

***Rosa persica* Mielx ex Juss.** A rhizomatous shrub, short stems and open canopy (porous) area, usually have small leave sand there are lots of spines on the stem (Ghahreman, 2001; Karimi, 2005). Moghadam (2007) mentioned that *Rosa persica* occurs in abandoned cultivated and grazed fields of arid and semi-arid regions and considered this species an weeds. Low palatability, spiny leaves and stems of three shrub were decrease value forage and more important preserve soil.

Five 50-m random-systemic transects were established. Canopy of shrubs that intercepted with transects were measured. Flexible plot size was used to measure canopy of dominant shrubs. Near surface, light and temperature were respectively measured by using a Light Meter and a Digital Timer Thermometer.

Length and width of each species was measured, on 20 random samples for estimating maximum canopy area (according to Cavieres *et al*., 2006). Further, to estimate maximum canopy height, the tallest branch of each species was measured.

To compare the effects of shrubs on the soil moisture paired soil samples were taken from understory of shrubs and open areas with 4 replications and with a total of 48 samples. Relative water content was measured in the soil surface (0-10 cm) and soil depth (15-55 cm) (Jankju, 2009). Soil moisture contents were calculated as a relative weight (Equation 1) : Equation 1.

$$W_m = \frac{Ww - Ws}{Ws} \times 100$$

W_m =Moisture %

W_w =Weight of wet soil

W_s =Weight of dry soil

To study effects of shrubs on the physical and chemical soil properties, four soil samples were taken from 0 to 20 cm depth in understory of shrubs and open spaces. In the laboratory, soil samples were air dried and hand-sieved via a 2 mm sieve to remove roots and other debris. Total Nitrogen (TN) was measured by Kjeltec method (Bao, 2000). Soil pH and Electrical Conductivity (EC) was measured respectively by a pH meter (Mclean, 1988) and hand-held conductivity meter (Rhoads, 1982). Organic Matter (OM) was measured by Walky and Bluak method (Nelson and Sommers, 1982). Soil texture was determined by Hydrometric method (Jafari-Haghighi, 2003).

2.2. Data analysis

Paired-t test was used tocompare the effects of shrubs and open spaces on the understory microclimatic (light, temperature, and relative humidity). Soil properties were analyzed under shrubs and in open spaces using ANOVA at α=0.05.

3. Results

Soil texture (sand, silt, and clay) did not significantly vary under shrubs as compared with the nearby open space. In terms of soil chemical properties of *Astragalus* under canopy, the organic mater, N and EC with average values of 1.6%, 0.08% and 0.32 mS/cm, were significantly higher than open areas with average values of 0.39%, 0.028% and 0.15 mS/cm, respectively ($p<0.05$, Table 1). Mean comparison of shrub species for canopy height and canopy area are shown in (Fig. 1). The canopy cover *Scariola* and *Astragalus* with average values of

1620 and 1600 cm^2 respectively, were wider than for the *Rosa* (500 cm^2). In addition, mean height of *Scariola* (35 cm) greatest compare with other shrubs (Fig. 1a).

The mean microclimate factors of temperature and luminance in the understory of shrubs, 22.74 ˚c and 10050 lux, were significantly lower than open spaces of 24 ˚c and 70000 lux, respectively (Fig. 2). In addition, mean temperature (22.07˚c) and Light intensity (6860 Lux) under *Astragalus* canopy was lower than that of *Rosa*, with average values of 23.68 ˚c and 24784 lux, respectively (Fig. 3).

The relative soil moisture in the understory (W_m:0.75 %) and open spaces (W_m : 0.68%) were not significantly different at 0-10 cm ($p>0.05$), but significantly different at 15-55 cm (W_m: 1.44 and 0.88% respectively, Fig. 4). These results indicate, soil moisture depths of 15-55 cm in the shrub understory were higher than the open spaces ($p<0.05$). Furthermore, this factor was different for soil surfaces, but not different in depth (Fig. 5). So that in the comparison between three shrub, soil moisture value was high in the depths of 0-10 cm, under canopy cover of *Astragalus* (W_m:0.95%) and had greater impact on conservation soil surface moisture compared to *Scariola* and *Rosa* (W_m: 0.72% and 0.58% respectively).

Table 1. Comparing the mean and SE of soil properties at understory and open spaces for three shrubs

Treatments	OM(%)	N (%)	pH	EC(mS/cm)	Sand (%)	Clay (%)	Sit (%)
Open space	$0.39^b \pm 0.10$	$0.028^b \pm 0.001$	$8.67^a \pm 0.01$	$0.15^b \pm 0.003$	$63.56^a \pm 1.49$	$4.35^a \pm 1.18$	$32.09^a \pm 0.44$
R. persica	$0.57^b \pm 0.23$	$0.041^b \pm 0.01$	$8.25^a \pm 0.31$	$0.17^{ab} \pm 0.01$	$69.17^a \pm 3.49$	$7.26^a \pm 1.14$	$23.57^a \pm 3.51$
A. heratensis	$1.60^a \pm 0.40$	$0.080^a \pm 0.01$	$8.25^a \pm 0.12$	$0.32^a \pm 0.05$	$64.45^a \pm 4.10$	$7.55^a \pm 1.48$	$28.0^a \pm 3.16$
S. orientalis	$1.26^a \pm 0.52$	$0.031^b \pm 0.008$	$8.42^a \pm 0.05$	$0.23^{ab} \pm 0.04$	$73.59^a \pm 3.83$	$5.49^a \pm 1.64$	$20.91^a \pm 4.87$

Means followed by the same letters in each column are not significant ($P<0.05$).

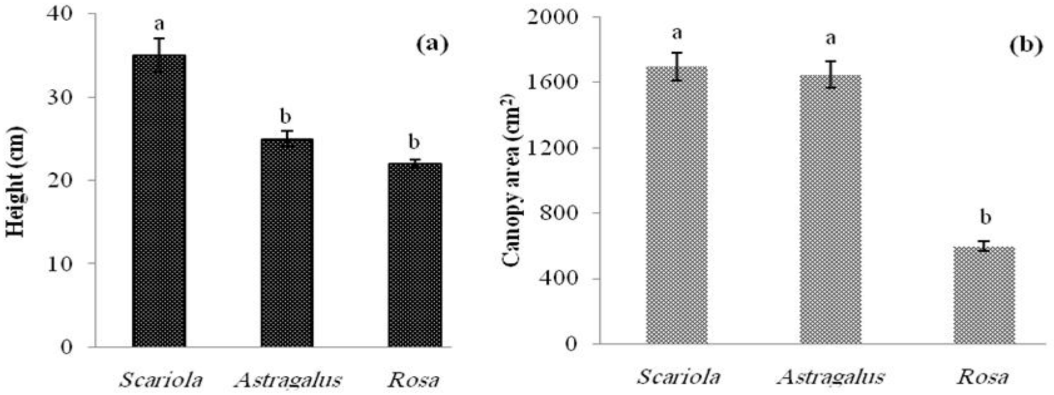

Fig. 1. Canopy height and canopy area of shrub species. Mean values ± standard errors are shown. Different effects (a, b) indicate significant differences ($P< 0.05$)

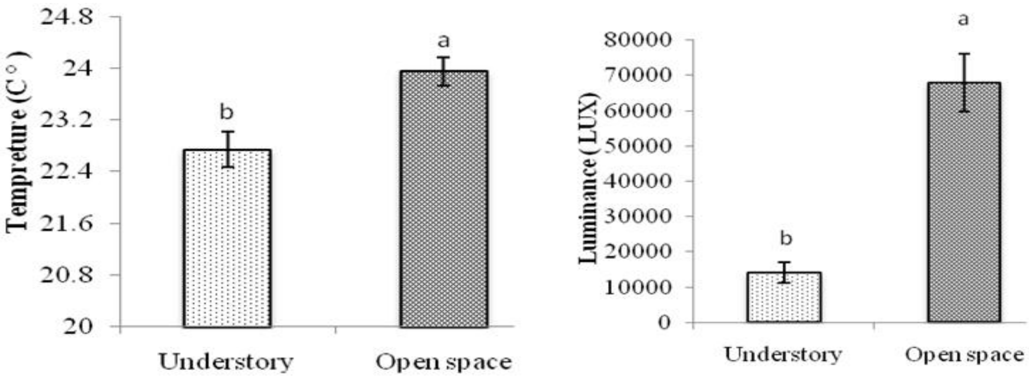

Fig. 2. Tempreture (°C) and luminance (LUX), under canopy of shrubs and in open areas. Column with the same letters are not significant ($P<0.05$).

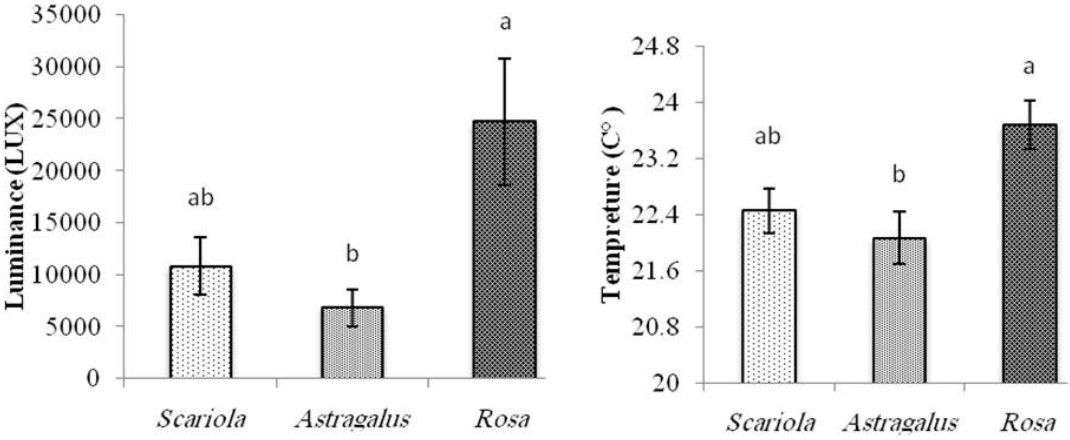

Fig. 3. Tempreture (°C) and luminance (LUX) under canopy of shrubs. Column with the same letters are not significant (P<0.05).

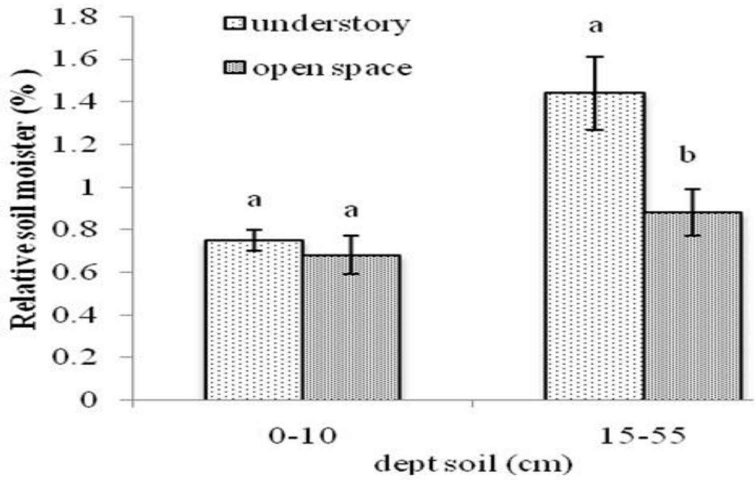

Fig. 4. Surface soil moisture (0-10 cm and 15-55cm) under canopy of shrubs and open spaces. Column with the same letters are not significant (P<0.05).

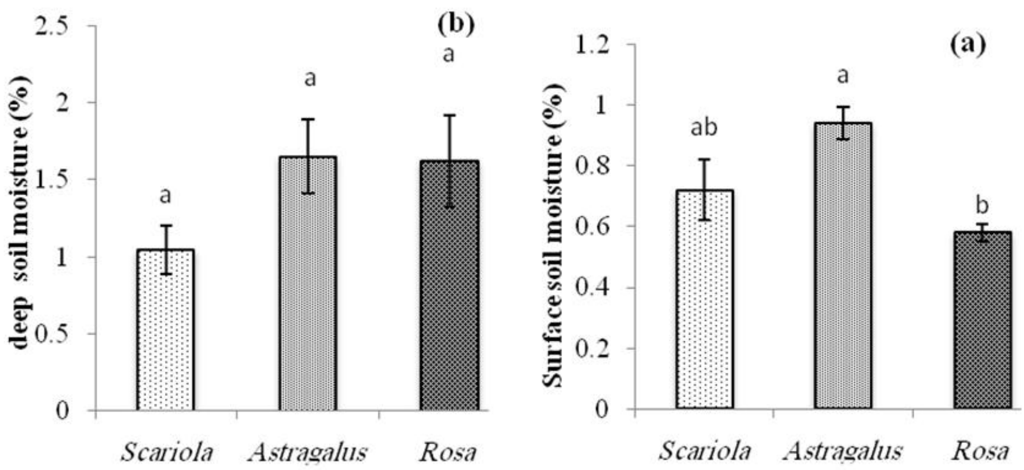

Fig. 5. Effects of shrubs on relative soil moisture. a) surface soil (0-10) and b) deep soil (15-55). Column with the same letters are not significant (P<0.05).

4. Discussion and Conclusion

4.1. Effects of shrubs on microclimate

We found ameliorative effects by shrubs on their canopy light and temperature were lower, but moisture was higher under canopy of shrubs than in the nearby open areas. These results confirm results by other researchers (Padilla and Pugnaire, 2009; Rodriguez-Garcia *et al.*, 2011), who found milder microclimate under shrubs. In another study in the steppe rangelands of Nadooshan, Jankju (2009) found that the higher soil moisture and lower temperature under canopy of shrubs may facilitate establishment of annual grasses under their canopy, as compared to open area.

Here we found positive effects of shrub canopy on soil moisture being more pronounced on the deep than surface soil layer. That is because the surface soil moisture is more influenced by the air temperature and humidity, whereas soil moisture at deep layers is mostly influenced by winter rainfalls and plant biological activities (Jafari, 2005). Competition among the nurse and understory plants may be responsible for the depletion from soil moisture of soil layers (Jankju, 2009; Maghamnia *et al*., 2010).

Effects of shrub on the microclimate of their understory were influenced by their canopy structure and dimensions. *Astragalus* with a dense canopy and wide crown had more effects on the modification of temperature and light intensity as compared to *Rosa*, which had a wide but highly porous canopy. Lopez and Valdivia (2007) and Howard *et al.,* (2012) also reported that increasing the size of shrubs' canopy increased their positive effects on the understory of their microclimate.

4.2. Effect of shrubs on soil texture and chemistry

The shrubs as 'fertile islands' were improved microclimate and soil conditions and their positive effects on chemical properties were more pronounced than their physical properties. Shrub species had significantly increased soil nitrogen and carbon, but they did not affected soil texture, EC and pH. None significant differences in pH between soils understory of shrubs and the nearby open space may be due to no significant effect of shrub biomass (Moro *et al*., 1997; Liu *et al*., 2011). Studies of Naseri *et al*. (2010) showed that presence of shrubs in rangeland led to increase soil nutrients and fertility. The amount of EC was under 4 mµ so the soil of understory and open space considered as none saline and alkaline soils. The mean of clay, silt, and sand percentages were none significantly different between the understory and open space, as was already reported by Moro *et al.* (1997). Padilla *et al*. (2009) found that shrubs also may affect the spatial distribution of soil resources and improve the water contents of soil.

The effects of shrubs on soil texture and chemistry were varied based on the species types. *Astragalus* had more influences on the chemical and physical properties soil and microclimate modification as compared to *Scariola* and *Rosa*. *Astragalus* increased organic matter and nitrogen of soil understory. These properties are indicators of soil fertility and vegetation productivity. The higher organic matter and nitrogen can be related to higher biomass, litter, moisture and lower light intensity under canopy of *Astragalus* (see also West and Dovovan, 2004; Yang *et al*., 2011). The higher amount of nitrogen may also be related to higher root turnover and microorganism activities (Su *et al*., 2002; Flores and Jurado, 2003). Greater impact of *Astragalus* on the soil properties can due to its greater stature and a possible micro organism symbiosis for this species, being known as a Leguminosae shrub.

5. Conclusions

The three shrubs in this research had significantly affected their understory. However their influence seemed to be more important on the function than the structure of the micro-habitat under their canopy. A significant change in microclimate conditions (temperature, light and luminance) had possibly affected the microbial activity, which subsequently led to the higher carbon and nitrogen concentration (Su *et al*., 2002; Flores and Jurado, 2003). In contrast, shrubs did not affect the more stable ecosystem indices, e.g. soil texture, EC and pH, which are mainly dependent on the abiotic (erosion, and evapotranspiration) rather than biotic (plant competition and resource uptake) factors (Goldberg and Novoplansky, 1997). Furthermore, among the three shrubs, the greatest effect on soil parameters were found for *Astragalus*, which also had greater effect on the microclimate conditions.

Astragalus with a greater canopy structure had greater impact on its microclimate understory, which subsequently led to higher biological activity, soil and carbon concentration. Therefore, it can be a suitable plant to be used as a nurse in the restoration projects. Finally, a greater impact of arid land shrubs on the functional rather than structure of microclimate suggest that the shrub canopy may provide temporarily favorite conditions under their canopy, which can be used a chance for establishment of other plants.

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تأثیر تاج پوشش بوته‌ها بر شرایط میکروکلیمایی و خصوصیات خاک در مرتع استپی

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چکیده

در اکوسیستم‌های مناطق خشک و نیمه‌خشک، گیاهان بوته‌ای ممکن است به‌عنوان جزایر حاصلخیزی در نظر گرفته شوند، اما اثرات آنها با توجه به خصوصیات مرفولوژیکی و اکولوژیکی متفاوت است. این تحقیق با هدف بررسی تاثیر سه بوته مرتعی کاهوی بیابانی، گون و ورک بر خصوصیات خاک و شرایط میکروکلیمایی (دما، درجه روشنایی و درصد رطوبت نسبی) محیط در مراتع استپی کاخک گناباد صورت گرفت. در طول ترانسکت‌های ۵۰ متری از پلات‌های انعطاف‌پذیر برای اندازه‌گیری خصوصیات میکروکلیمایی از زیر اشکوب بوته‌ها و فضای هر بوته استفاده شد. اندازه پلات‌ها متناسب با تاج هر یک از بوته‌های برخوردی به ترانسکت بود. نمونه‌های خاک نیز از زیر اشکوب هر یک از بوته‌ها و فضای باز مجاور آنها گرفته شد. برای مقایسه فاکتورهای میکروکلیمایی در زیر اشکوب بوته‌ها با فضای باز مجاور آنها از آزمون t جفتی استفاده شد. خصوصیات خاک در زیراشکوب سه بوته و فضای باز مجاور با کمک آزمون دانکن مقایسه شدند. بر اساس نتایج، دما و نور زیراشکوب بوته‌های مرتعی به طور معنی‌داری کمتر از فضای بیرون بود ($p<0/05$). درصد رطوبت نسبی عمقی خاک (cm ۱۵- ۵۵) در زیراشکوب بوته‌ها بیشتر از فضای مجاور بود اما مقدار رطوبت نسبی خاک در لایه‌های سطحی (۰ - cm۱۰) با هم اختلافی نداشتند. در بین سه بوته مرتعی مورد مطالعه، بوته‌های گون تاثیر بیشتری بر شرایط میکروکلیما داشت. میزان هدایت الکتریکی (۰/۳۲ mS/cm)، ماده آلی (۱/۶٪) و نیتروژن خاک (۰/۰۸٪) در زیراشکوب بوته گون به طور معنی‌داری بیشتر از فضای بدون پوشش بود (به ترتیب، ۰/۱۵ mS/cm ، ۰/۳۹ ٪ و ۰/۰۲۸٪). تأثیر بیشتر گون به عواملی از قبیل پوشش تاجی گسترده‌تر، بیومس بیشتر و احتمالا توانایی آن در تثبیت نیتروژن نسبت داده شد.

کلمات کلیدی: میکروکلیما، فضای باز، بوته‌های مرتعی، تاج بوته‌ها، خصوصیات فیزیکی و شیمیایی خاک، مرتع استپی