

Influence of scattered Greek juniper trees on soil properties in semi-arid woodlands in the northwest of Iran

YOUNES ROSTAMIKIA^{1*}, MOHAMMAD MATINIZADEH², SOHRAB MOHTARAM ANBARAN³

¹Natural Resources Department, Ardabil Agricultural and Natural Resources Research and Education Center, AREEO, Ardabil, Iran

²Forest Research Division, Research Institute of Forests and Rangelands, AREEO, Tehran, Iran

³Department of Natural Resources, Faculty of Agriculture and Natural Resources, University of Mohaghegh Ardabili, Ardabil, Iran

*Corresponding author: younesrostamikia@gmail.com

Citation: Rostamikia Y., Matinizadeh M., Mohtaram Anbaran S. (2024): Influence of scattered Greek juniper trees on soil properties in semi-arid woodlands in the northwest of Iran. J. For. Sci., 70: 560–573.

Abstract: Scattered Greek juniper (*Juniperus excelsa* M. Bieb.) trees have ecological values, such as soil protection and soil erosion reduction in the Irano-Turanian region; however, intensive exploitation puts their habitats at risk. Therefore, knowing the soil characteristics of these habitats plays an important role in their management. The aim of this study was to investigate the soil quality of semi-arid woodlands dominated by a pure *Juniperus excelsa* community. At three sites in the Irano-Turanian region, soil samples were randomly taken from a depth of 0–20 cm in the eastern direction under the crowns of Greek juniper trees and from bare soil. The evaluated physical properties included bulk density (*Bd*), moisture, sand percentage, silt percentage and clay. Chemical properties included pH, electrical conductivity (*EC*), organic carbon (*SOC*), total nitrogen (*TN*), and nutrient concentrations of bare soil compared to the below-crown soil. Additionally, we investigated basal respiration (*BR*) and microbial biomass carbon (*MBC*) to evaluate the influence of Greek juniper trees on soil microbial activity. The bulk density value in samples taken under crowns was significantly lower by 42% compared to bare soil; however, significantly higher soil moisture (+39.8%) was obtained under tree crowns. Although clay and sand content under tree crowns was significantly higher than that of bare soil, sand content under tree crowns was significantly lower than in bare soil. According to our findings, soil pH under tree crowns and in bare soil was 7.13, which increased to 7.67 in bare soil. Soil *EC* (+15%), *SOC* (+76%), and *TN* (+29%) were significantly higher under tree crowns. The concentrations of magnesium and sodium were similar between bare and below-crown soils, but significantly higher phosphorus (+46%), potassium (+41%), calcium (+31.1%), iron (43.3), and zinc (+56.6%) were observed under Greek juniper crowns. Soil microbial activity was higher under tree crowns compared to bare soil, as evidenced by significantly increased *BR* (+49.1%) and *MBC* (+43.5%). Our findings indicate that scattered Greek juniper trees can improve soil properties, and their destruction leads to a significant decrease in soil quality. Generally, planting Greek juniper seedlings in degraded areas can help restore the soil quality.

Keywords: *Juniperus excelsa*; organic matter; soil quality; tree crown

Supported by the Research Institute of Forests and Rangelands, Tehran, Iran, under project No. 01-09-09-035-00022-000431.

© The authors. This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0).

<https://doi.org/10.17221/60/2024-JFS>

In many arid and semi-arid biomes, including woodlands, harsh ecological conditions such as water shortages, little and irregular rainfall, high temperatures and nutrient deficiencies limit tree and shrub density (Sardans, Peñuelas 2013). In these conditions, scattered trees provide a mosaic of fertile spots beneath their canopies in often nutrient-poor soils (Ogunkunle, Awotoye 2010). However, the scattered trees that are able to grow and survive in these critical conditions play an important ecological and preservative role in the soil (Manning et al. 2006). The process of soil modification depends significantly on tree species, particularly litter quantity and quality (Getaneh et al. 2022). On the other hand, the stability of forest ecosystems relies on the variability of soil characteristics influenced by different species. Trees have varying effects on soil microbial activity by altering the soil characteristics through litter production, organic matter accumulation, humidity retention, and C:N ratio changes (Keller et al. 2012).

In arid and semi-arid ecosystems, scattered trees significantly affect the soil properties and can greatly impact soil fertility as well as conservation and improvement of soil quality (Manning et al. 2006). Individual trees that can grow and adapt themselves in adverse conditions play an essential ecological and protective role within these ecosystems (Casals et al. 2014). The canopy of scattered single trees prevents light penetration to lower parts by creating shade; this reduces evaporation and transpiration while maintaining soil moisture, facilitating many physicochemical and biological processes in forest soils (Zhukov et al. 2019; Yang et al. 2022). Under these conditions, the fall and accumulation of dead leaves beneath canopies increase nutrient availability to plants under crowns, consequently, conditions are provided for the survival, establishment and growth of seedlings beneath tree crowns (Aponte et al. 2011). Single trees in woodlands create changes in microclimate, floral composition, fungal communities, and other ecosystem components through biological recycling of mineral elements as well as environmental changes including thermal regimes and moisture levels (Manjur et al. 2014). Trees can increase the nutrient balance of soil by reducing nutrient losses from erosion and leaching while increasing nutrient inputs through nitrogen fixation along with enhanced biological activities via biomass pro-

vision and suitable microclimates (Ogunkunle, Awotoye 2010).

Greek juniper (*Juniperus excelsa*), belonging to the family Cupressaceae, is one of the main species found in the semi-arid woodlands of the Irano-Turanian zone; its natural habitats cover extensive areas in western and central Iran (Mozaffarian 2004). This species plays an important ecological and economic role, especially in woodlands (Pirani et al. 2011). Nevertheless, human disturbances such as overexploitation for wood, land-use intensity, trampling effects from livestock grazing, fire incidents, and prevailing harsh environmental conditions hinder the natural regeneration of Greek juniper (Khoshnevis et al. 2019). This low regeneration rate threatens the survival of this species. Therefore, considering its importance for soil and water conservation is crucial for restoring its habitats. A better understanding of how individual trees affect soil properties, both physicochemical and biological, will aid management decisions aimed at restoring the habitats of this species (Rostamikia, Zobeire 2012). There is limited information regarding the influence of Greek juniper tree canopies on the soil characteristics, especially on microbial activities, within soils. Microbial respiration represents biological activity within soils and is one of the main processes controlling carbon dynamics within ecosystems. Changes in the microbial community structure beneath tree canopies can affect both carbon and nitrogen levels within soils (Gartzia-Bengoetxea et al. 2016).

In this study, we aimed to quantify the effect of *Juniperus excelsa* on soil quality in noticeably threatened semi-arid woodlands located in Khalkhal. Specific objectives included (i) determining the effect of crown cover on physicochemical and biological properties of soils; and (ii) comparing physicochemical properties related to soil quality along with microbial properties between soils beneath *J. excelsa* crowns versus bare soils.

MATERIAL AND METHODS

Site description. This study was conducted in Ardabil province located in northwestern Iran. The province spans approximately 1.75 million ha; about 1.2 million ha fall within the Irano-Turanian zone (including mountainous regions as well as plains). The current research was conducted across three different semi-arid *Juniperus excelsa*

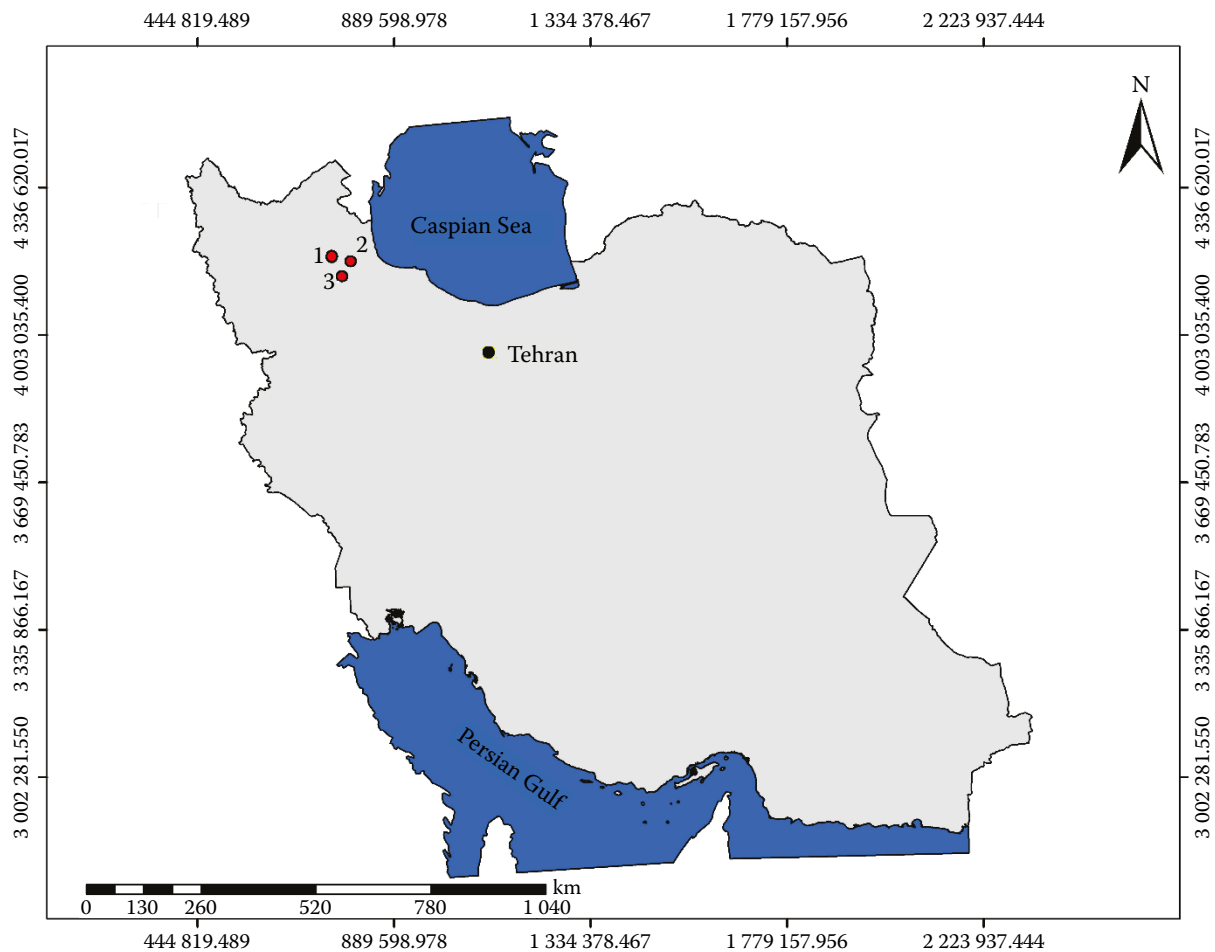


Figure 1. Location of the study sites in Iran, indicated by the three red circles

The sites represent the main semi-arid woodland type dominated by a *Juniperus excelsa* community; these sites are located in the Irano-Turanian zone

woodlands (Figure 1, Table 1). According to Emberger's climatic classification system, this region has a cold semi-arid climate characterised by a mean annual temperature of 10.1 °C with average annual precipitation amounting to approximately 290 mm (Figure 2). Arid conditions persist from mid-June until late October each year. The dominant herbaceous plant species occurring in *Juniperus* communities include *Bromus dantho-*

niae Trin., *Astragalus gossypinus* Fisch., *Artemisia aucheri* Boiss., and *Agropyron repens* (L.).

Sampling design. In June 2022, ten individuals of *Juniperus excelsa* were randomly selected within a sample plot measuring 3 ha at each study site (Table 1) to assess how individual trees influence soil properties within semi-arid woodlands. Crown diameters for selected trees ranged between 5–7 m while diameters at breast height (DBH) ranged be-

Table 1. Properties of the studied sites dominated by the semi-arid woodlands of *Juniperus excelsa*

Site	Latitude	Longitude	Elevation (m a.s.l.)	Slope (%)	Mean annual precipitation (mm)	Mean annual temperature (°C)
Dostloo	37°27'01"N	48°23'12"E	1 575	18	332.4	22.4
Manamin	37°17'06"N	48°20'47"E	1 530	22	313.8	23.9
Sejahrood	37°10'08"N	48°34'12"E	1 525	19	303.5	24.5

<https://doi.org/10.17221/60/2024-JFS>

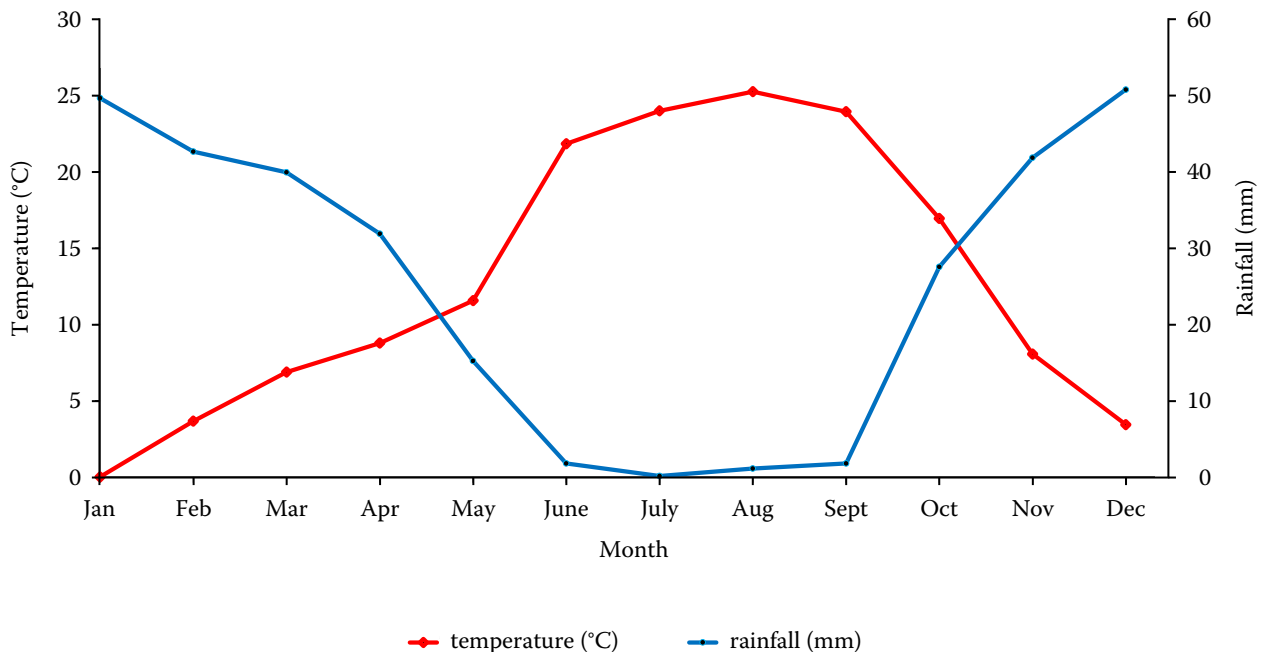


Figure 2. Ambrothermic diagram for the study area based on data from the weather station at Khakhal city from 1995 to 2022 (this is the only weather station in the wider area, which is 37 km, 61 km, and 89 km away from sites 1, 2, and 3, respectively)

tween 15–20 cm across selected specimens; each sample tree had its nearest conspecific neighbour located approximately 25–30 m away. Soil samples were taken at depths ranging from 0 cm to 15 cm under each canopy halfway along the crown radii toward an eastern direction using an auger tool; similarly, collected samples were obtained from outside of each canopy area, located at least around 30 m away from the nearest tree crowns to serve as controls. Ten bare soils plus ten below-crown samples per site resulted in a total of sixty samples collected overall across all sites studied. Some samples were preserved under cold conditions ($\sim 4^{\circ}\text{C}$) until biological characteristics measurements could be performed later during experimentation phases while the remaining samples underwent air-drying prior to transport into laboratories designated for physical/chemical analyses.

Laboratory analyses. We measured physical characteristics including moisture content levels along with bulk density via the lump method while determining the texture using hydrometric techniques according to Gee and Bauder (1982). Soil pH values were assessed by a suspension method using deionised water at ratios equalling one part of the sample against two point five parts of water; electrical conductivity readings were obtained

via saturated extract methods. Organic carbon content along with total nitrogen levels were recorded following Walkley-Black protocols outlined by Haluschak (2006) while Kjeldahl acid-digestion methods described by Sun et al. (2022) provided TN data points. Available phosphorus concentrations were determined using Olsen's method per Haluschak's guidelines while potassium levels underwent evaluation by the normal ammonium acetate techniques. Soluble Ca and Mg contents underwent determination using EDTA (ethylenediaminetetraacetic acid) titrimetric methods established by Tucker and Kurtz (1961); additionally, atomic absorption spectrophotometry facilitated micronutrient content measurements including Fe and Zn directly extracted from solutions using atomic absorption spectrometry techniques described by Krzebietke et al. (2023).

Basal respiration rates were calculated based upon closed container methodologies measuring CO_2 released due to solely microbial respiration quantified per mg CO_2 per g DM (DM – dry matter) over twenty-four-hour periods following Schinner et al. (1996). The fumigation-extraction method was used for microbial biomass carbon assessments whereby chloroform-treated samples underwent twenty-four-hour exposure before

measuring the resultant organic carbon post-extraction via potassium sulphate employing Walkley-Black protocols outlined previously.

Data processing. We checked the normality across collected datasets using Kolmogorov-Smirnov tests before performing linear mixed-effects models analysing all traits concerning 'scattered tree effects' across both bare and below-crown soils using SPSS software (Version 19, 2010), developed by SPSS Inc., USA. To ascertain 'scattered tree effects,' averages derived from data collected across all three sites constituted parameters of our models while the principal component analysis enabled us to investigate the relationships between various variables present in the datasets analysed by multivariate correlation analyses; further, relationships between variables and principal components established during principal component analysis (PCA) were identified and evaluations were conducted subsequently.

RESULTS

Soil physical properties. Results indicated significant differences in all measured physical properties between bare soils and those located beneath Greek juniper tree crowns (Table 2). The bulk density value recorded in the samples taken directly underneath tree crowns exhibited a notable reduction of 42% relative to the corresponding values observed in bare soils depicted graphically (Figure 2). Soil moisture levels recorded beneath the Greek juniper tree canopy revealed statistically significant increases totalling 39.8% when compared to those found within exposed/bare patches surrounding sampled areas, thus corroborating the findings illustrated previously therein. Average pH measurements recorded in bare patches reached 7.67, which decreased to 7.13 once taken directly below the respective tree canopies, providing further evidence supporting the aforementioned claims outlined

Table 2. Results of linear mixed models testing scattered tree effect on soil characteristics

Variable	Estimate	SE	df	t	P-value
Physical properties					
Bulk density	0.21	0.03	56	1.21	< 0.001
Soil moisture	0.88	0.07	56	12.54	< 0.001
Sand (%)	7.24	0.11	56	10.18	< 0.001
Clay (%)	10.11	0.89	56	20.12	< 0.001
Silt (%)	23.05	0.16	56	4.21	< 0.001
Chemical properties					
EC	0.19	0.02	56	4.02	< 0.001
pH	1.44	0.03	56	−0.04	< 0.001
SOC (%)	1.11	0.09	56	5.58	< 0.001
TN (%)	0.15	0.00	56	16.54	< 0.001
Phosphorus	11.25	1.25	56	10.25	< 0.001
Potassium	85.14	7.89	56	8.21	< 0.001
Calcium	1.98	0.21	56	3.54	< 0.001
Magnesium	−0.18	0.02	56	0.41	0.109
Sodium	−0.59	0.61	56	−0.19	0.210
Iron	3.21	0.38	56	6.41	< 0.001
Zinc	0.51	0.04	56	8.45	< 0.001
Biological properties					
Basal respiration	0.24	0.03	56	−5.09	< 0.001
Microbial biomass carbon	−1.14	0.14	56	−7.21	< 0.001

Bold – statistically significant effects ($P < 0.05$); *df* – degrees of freedom; *EC* – electrical conductivity; *SE* – standard error; *SOC* – soil organic carbon; *t* – *t*-statistic; *TN* – total nitrogen

<https://doi.org/10.17221/60/2024-JFS>

earlier throughout this section. While clay/silt compositions measured below the respective canopies exhibited statistically significant elevations exceeding those recorded in the exposed/bare patches surrounding sampled areas, sand compositions observed beneath the respective crowns

remained comparatively lower than those found in the exposed/bare patches surrounding sampled areas (Table 2, Figure 3).

Soil chemical properties. Results showed that, apart from average soil magnesium and sodium concentrations, all soil chemical proper-

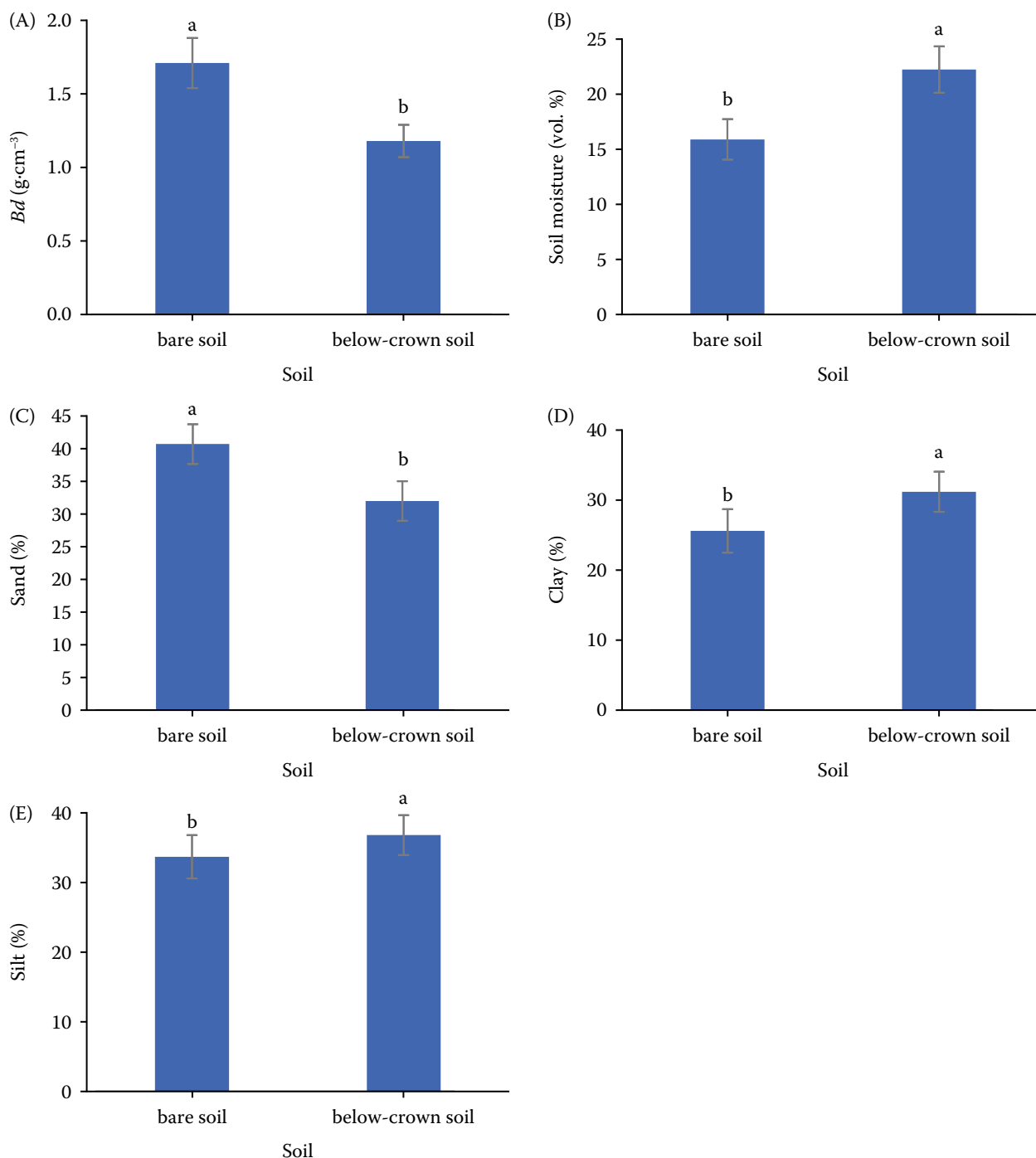


Figure 3. The mean percentage (data from the three sites) of bulk density (Bd), volumetric moisture, sand, clay, and silt of soil from bare soil and from under the Greek juniper tree crowns

a, b – significant differences at $\alpha = 0.05$ (see Table 2)

ties differed significantly between bare patches and the soil below Persian juniper tree crowns (Table 2). The electrical conductivity (EC) was significantly higher by 15% in the below-crown soil, while soil pH (average of three sites) under the crowns of trees (7.13) was significantly lower than that of bare soil (7.67) (Figure 4). Significant increases in SOC (+76%) were observed in soils under the crown (Figure 3). Average soil TN, P, and K concentrations were 29%, 46%, and 41% higher under the Greek juniper crowns compared to bare soil, respectively (Figure 4). Soil Ca, Fe, and Zn concentrations were also higher under the Greek juniper crowns compared to bare soil (Ca +33.1%, Fe +42.3%, Zn +55.6%). However, Mg and Na concentrations were not significantly affected by the tree crowns (Figure 4).

Soil biological properties. Results of the analysis indicated that basal respiration (BR) and microbial biomass carbon (MBC) of soil were sig-

nificantly positively influenced by the presence of Greek juniper trees ($P < 0.001$; Table 2). Basal respiration was significantly higher by 49.1% under the crown compared to the soil outside the crown (Figure 5). Similarly, microbial biomass carbon rates obtained from soil samples taken under Greek juniper trees exceeded those from bare soil by 43.5% (Figure 5).

The PCA summarised approximately 62.8% of the total data variability in the first two components (Table 3). The first component ($PC1$) had an eigenvalue of 4.16, accounting for 40.20% of the variability, and was negatively correlated with bulk density, silt, pH, and phosphorus. The second main component ($PC2$) accounted for 22.60% of the variability, with an eigenvalue of 2.05, and was negatively associated with bulk density (Bd), soil moisture, sand, TN (%), potassium, iron, basal respiration, and microbial biomass carbon (Table 3, Figure 6). In general, biological variables

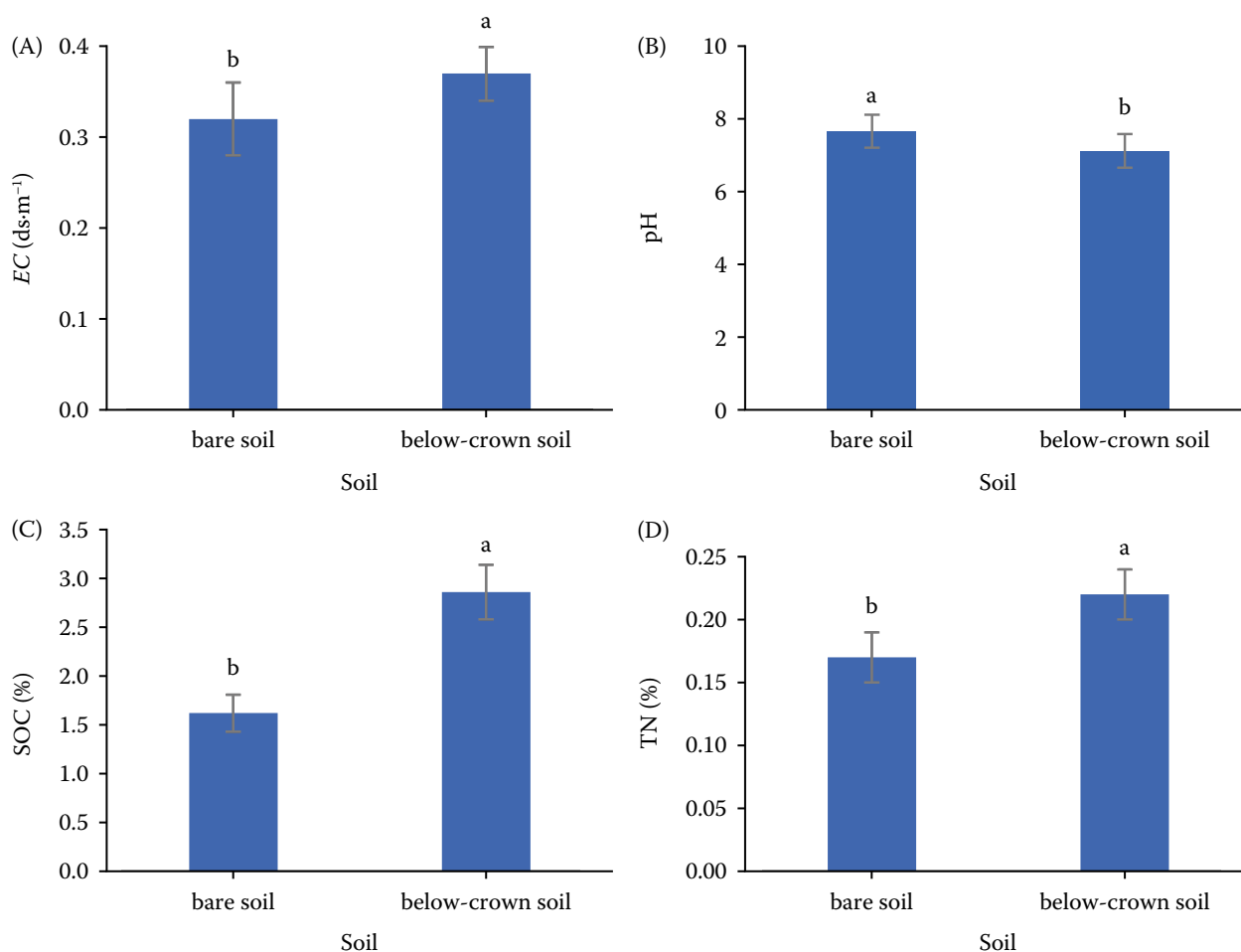


Figure 4. The mean (data from the three sites) pH, electrical conductivity (EC), soil organic carbon (SOC), total nitrogen (TN) and nutrient concentrations of soil from bare patches and from under the Greek juniper tree crowns

<https://doi.org/10.17221/60/2024-JFS>

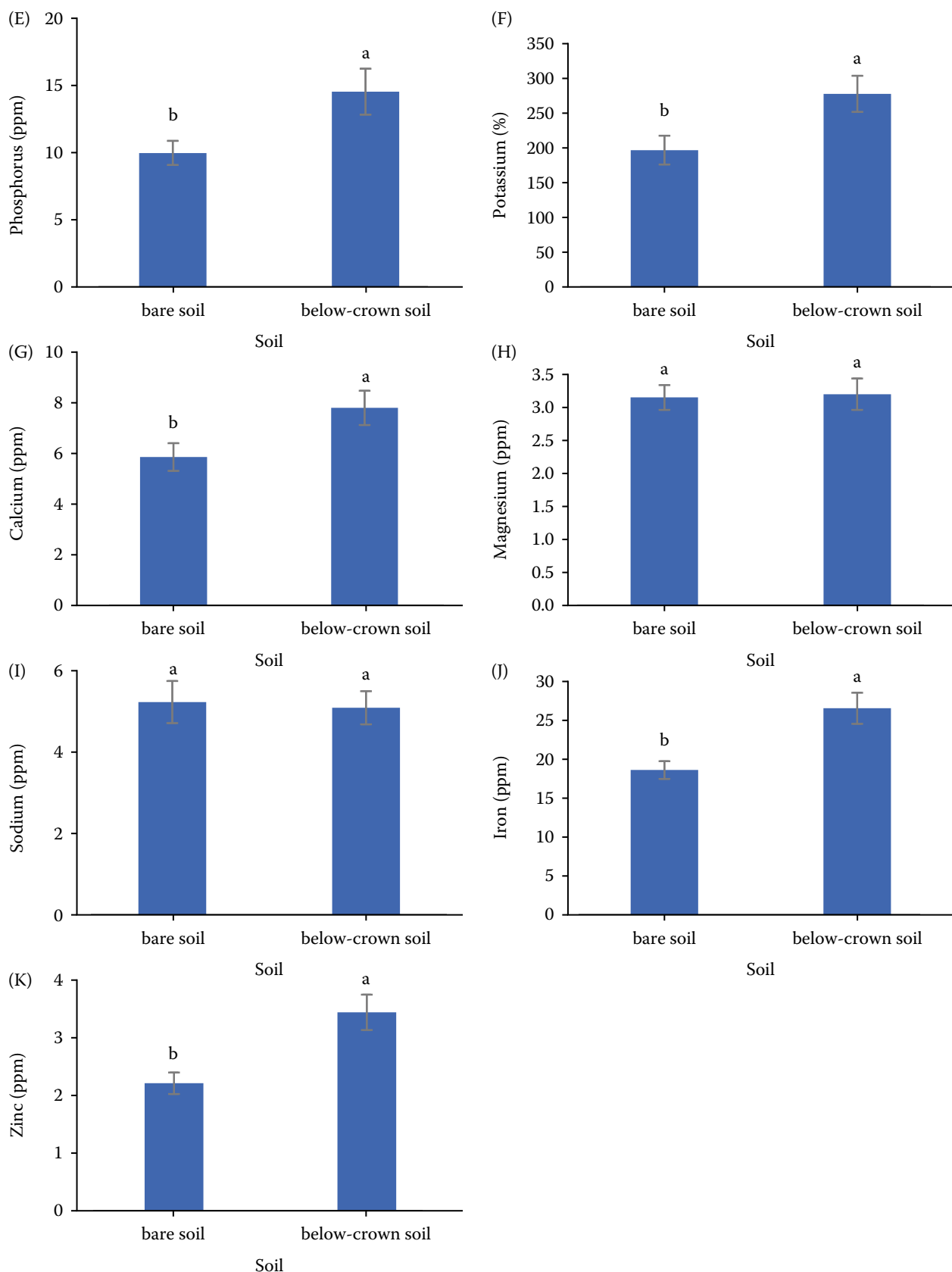


Figure 4. To be continued

a, b – significant differences at $\alpha = 0.05$ (see Table 2)

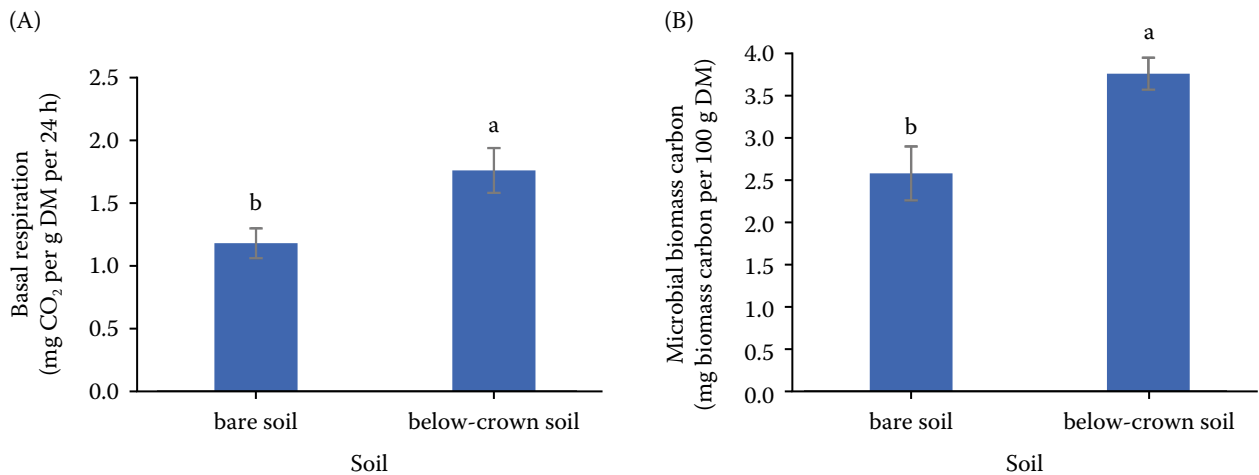


Figure 5. The mean (data from the three sites) basal respiration (*BR*) and microbial biomass carbon (*MBC*) of soil from bare patches and from under the Greek juniper tree crowns

a, b – significant differences at $\alpha = 0.05$ (see Table 2); DM – dry matter

(positive PC1 values) and soil physical variables (negative PC2 values) oppose each other in PC2 (Figure 6). The score plot of the soil variables

clearly indicated that the soils under Greek juniper trees differed increasingly from the bare soils (Figure 6).

Table 3. Results of the principal component analysis (PCA) for soil variables

Variable	PC1	PC2
Bulk density	–0.144	–0.201
Soil moisture	0.188	–0.092
Sand (%)	0.276	–0.118
Clay (%)	0.151	0.289
Silt (%)	–0.159	0.162
<i>EC</i>	0.215	0.095
pH	–0.118	0.123
SOC (%)	0.162	0.109
TN (%)	0.104	–0.111
Phosphorus	–0.201	0.205
Potassium	0.324	–0.219
Calcium	0.213	0.121
Magnesium	0.118	0.130
Sodium	0.092	0.161
Iron	0.098	–0.138
Zinc	0.104	0.204
Basal respiration	0.194	–0.212
Microbial biomass carbon	0.309	–0.201
Eigenvalues	4.160	2.050
Percent of total variance	40.200	22.600

Bold – statistically significant effects ($P < 0.05$); *EC* – electrical conductivity; PC – principal component; SOC – soil organic carbon; TN – total nitrogen

<https://doi.org/10.17221/60/2024-JFS>

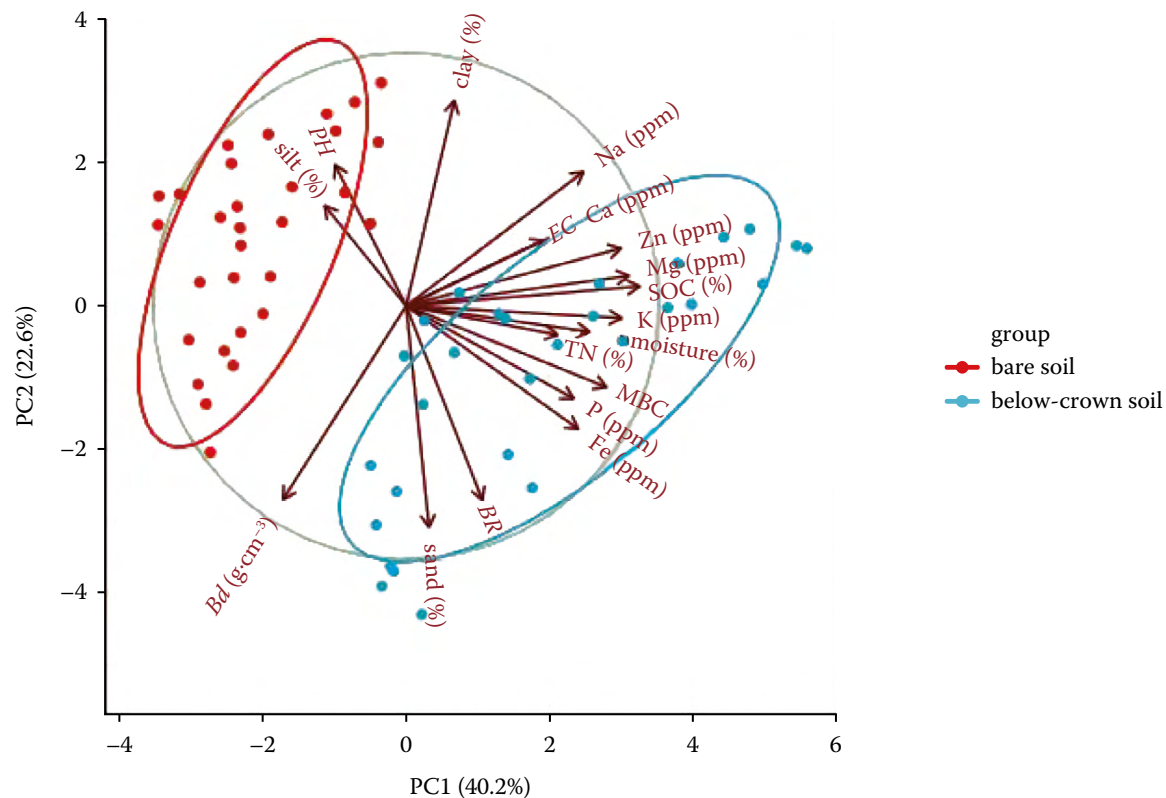


Figure 6. Principal component analysis (PCA) for soil variables

Bd – bulk density; *BR* – basal respiration; *EC* – electrical conductivity; *MBC* – microbial biomass carbon; *SOC* – soil organic carbon; *PC* – principal component; *PH* – potential of hydrogen; *TN* – total nitrogen

DISCUSSION

Soil is one of the important components of the forest ecosystem, which, along with other ecological factors, determines the distribution pattern of vegetation. On the other hand, trees and their canopy can also provide different amounts of organic matter, with chemical compounds affecting the chemical, physical, and biological characteristics of the soil in different ways (Murray et al. 2023). In this study, we evaluated the impact of scattered Greek juniper trees on soil physical, chemical, and biological properties in the fragile semi-arid woodland ecosystems of the Irano-Turanian region. Our findings show that scattered Greek juniper trees have an extremely positive influence on soil quality, especially on the soil biological population through increasing the amount of soil organic carbon.

Examining the physical characteristics of the soil showed that the bulk density under the crowns of Greek juniper trees was significantly lower than that of bare soil. The reason for this can be the ac-

cumulation of litter and plant remains under tree crowns, which causes an increase in porosity and improves the soil structure (Yelenik et al. 2022). It has been proved that the accumulation of organic matter in the soil increases its physical and chemical variables (Bashir et al. 2021). Similarly to the present study, lower bulk density was obtained under the crowns of *Pistacia atlantica* (Rostamizad et al. 2018) trees in Iran.

Our study also confirmed that the soil moisture content under crowns was about 40% higher than in bare soil. This difference in the soil moisture content compared to bare soil may be attributed to improved soil structure as a result of better porosity and permeability and higher organic matter content, which helps hold more soil moisture under tree crowns. Organic matter enables the soil to retain water by increasing its surface area and improving its structure for better porosity (Álvarez et al. 2021). Similar findings were reported by Zarafshar et al. (2023) under wild pistachio trees. According to Rostamizad et al. (2018), the

soil moisture content decreased significantly with an increasing distance from Persian turpentine (*Pistacia atlantica* Desf.) trees to open areas. The shading from single trees reduces soil temperature and evaporation, thereby creating a microclimate with higher humidity for soil biological communities (El-Keblawy, Abdelfatah 2014).

Our findings indicate significantly higher clay and silt content in the tree crown zone than in bare soil; however, the sand content under tree crowns is lower than in bare soil. The findings of this study are consistent with results from other related studies that indicated the clay and sand content was slightly higher under *Faidherbia albida* and *Croton macrostachyus* crowns than in open areas (Manjur et al. 2014). In fact, it can be stated that the positive effect of tree canopies in preventing soil erosion has caused a higher percentage of clay beneath tree crowns than outside them (Yücesan et al. 2019).

According to the results of our study, electrical conductivity (*EC*) under the crown was higher than in bare soil. Studies show that the main source of soil ions comes from chemical degradation of soil minerals, decomposition of plant residues, and ion release from them (Rostamiazad et al. 2018). Therefore, it can be expected that *EC* will increase due to factors like dead leaf presence, sufficient humidity creating suitable conditions for microbial activity, and litter decomposition.

Trees can either increase or decrease soil acidity depending on litter composition and soil pH buffering capacity related to texture and geological substrate (Augusto et al. 2015). The lower *EC* values obtained in soils under canopy may be directly related to changes in base cation concentrations in litterfall (Stefanowicz et al. 2021). Organic matter (OM) has an important effect on the physical and chemical properties of soil, fertility status, plant nutrition, and microbial activity in soil (Brady, Weil 2002). Our results indicate that organic carbon (+76%), total nitrogen (+29.4%), available phosphorus (+45.7%), and available potassium (+41%) were higher under tree crowns than in bare soil. In line with this study, Zarafshar et al. (2023) reported significant variations in total nitrogen, organic carbon, and available phosphorus under wild pistachio tree canopies compared to open areas. The higher amount of organic carbon under tree crowns may be due to Greek juniper leaves containing materials with a higher C:N ratio, decomposing at a slower rate in the soil environment

and remaining longer in the soil; this makes this tree cover show higher amounts of carbon (Rahman et al. 2013). Additionally, phenolic materials, lignin, and gums in the needle leaves of these trees slow down their decomposition process, causing organic carbon accumulation beneath tree crowns (Atashnama et al. 2018). Similarly, the distribution relationship of nitrogen is similar to that of organic carbon; trees significantly impact organic matter properties and nitrogen levels (Shukla et al. 2006).

The results indicate that available potassium (+41%) was also higher under tree crowns compared to bare soil. This may be due to the accumulation of more organic matter such as foliage and roots under tree crowns, which increases microbial activities, organic matter decomposition, and subsequent mineralisation. Generally, findings from this study align with those reported by Saeed et al. (2020), who noted potassium accumulation beneath *Vachellia nilotica* tree crowns compared to open areas in the Sahara Desert. Mamo and Asfaw (2017) found higher levels of available potassium under *Croton macrostachyus* tree canopies than outside them in the West Hararghe Zone, Ethiopia. Similarly, Zarafshar et al. (2023) reported a significant increase in available potassium under canopies of scattered wild pistachio trees compared to the open land.

Our study showed that concentrations of Mg and Na were similar in both bare soil and below-crown soils. Similarly, Gea-Izquierdo et al. (2010) observed no significant differences in Mg and Na concentrations beneath holm oak trees compared to open areas in Mediterranean grasslands. The results revealed that Greek juniper tree crowns positively affected nutrient concentrations such as calcium, iron, and zinc when calcium increased by 33%, iron by 34%, and zinc by 55% compared to bare soil. In agreement with our results, levels of Ca, iron, and zinc were significantly higher beneath *Pistacia atlantica* and *Prunus orientalis* crowns in Tang Khoshk, Semirom, Iran; these nutrients were largely supplied by higher litter from tree crowns (Khanmohammadi, Matinizadeh 2023). Zinc is an essential microelement for plant growth; its deficiency leads to reduced plant growth (Ahmad et al. 2012). Therefore, protecting Greek juniper trees and planting seedlings in overexploited areas within semi-arid woodlands on calcareous soils may help increase this element's availability.

<https://doi.org/10.17221/60/2024-JFS>

Quantitative measurement of soil biological characteristics is fundamental for understanding ecosystem functions since soil microbes play an important role in the biogeochemical cycling of nutrients in arid and semi-arid ecosystems (Wu et al. 2024). Our findings on microbial processes indicate a strong stimulation of microbial activity by trees; Greek juniper trees increased litter input and higher SOM storage under their crowns, as indicated by significantly higher SOC contents compared to bare soil. Our results indicated that basal respiration rates and microbial biomass carbon rates in soils beneath Greek juniper trees exceeded those from bare soils. These findings are consistent with results from Khanmohammadi and Matinizadeh (2023), showing increased basal respiration rates and microbial biomass carbon beneath *Pistacia atlantica* and *Prunus orientalis* compared to soils outside their canopies due to the increased presence of organic matter there. Thus, it can be stated that moisture levels and high organic carbon content in soils under Greek juniper crowns compared to bare soils have increased basal respiration rates stimulated by respiration under tree crowns; microbial activity such as respiration has a direct relationship with the microbial population size – higher microbial biomass correlates with a higher basal respiration rate (Gebrewahid et al. 2019).

CONCLUSION

The above discussion justifies that the presence of scattered juniper trees has improved the physical, chemical and biological characteristics of soil by adding organic matter to the soil. It seems that preserving Greek juniper trees in semi-arid woodlands of the Irano-Turanian region is essential for soil quality by providing habitats for fauna and flora in arid and semi-arid ecosystems. Therefore, by planting seedlings of these species in empty spaces, it is possible to help restore the quality and performance of the soil in destroyed areas. Of course, by identifying the structure and composition of the soil microbial community under the crowns of these species and inoculating rhizosphere microorganisms (mycorrhizal fungi and symbiotic growth-promoting bacteria) to Greek juniper seedlings in the nursery, it is possible to help increase the percentage of survival, establishment and growth of seedlings in the field.

REFERENCES

- Ahmad W., Watts M.J., Imtiaz M., Ahmed I., Zia M.H. (2012): Zinc deficiency in soils, crops and humans. *Agrochimica*, 56: 65–97.
- Álvarez F., Casanoves F., Suárez J.C. (2021): Influence of scattered trees in grazing areas on soil properties in the Piedmont region of the Colombian Amazon. *PLoS One*, 16: e0261612.
- Aponte C., García L.V., Pérez-Ramos I.M., Gutierrez E., Maranon T. (2011): Oak trees and soil interactions in Mediterranean forests: A positive feedback model. *Journal of Vegetation Science*, 22: 856–867.
- Atashnama K., Golchin A., Mousavi Koupar A. (2018): Soil properties, labile pools of soil organic carbon and their variations under broadleaf and coniferous plantation in Hyrcanian forest, northern Iran. *Environmental Resources Research*, 6: 118–138.
- Augusto L., De Schrijver A., Vesterdal L., Smolander A., Prescott C., Ranger J. (2015): Influences of evergreen gymnosperm and deciduous angiosperm tree species on the functioning of temperate and boreal forests. *Biological Reviews*, 90: 444–466.
- Bashir O., Ali T., Baba Z.A., Rather G.H., Bangroo S.A., Mukhtar S.D., Naik N., Mohiuddin R., Bharati V., Bhat R.A. (2021): Soil organic matter and its impact on soil properties and nutrient status. In: Dar G.H., Bhat R.A., Mehmood M.A., Hakeem K.R. (eds): *Microbiota and Biofertilizers*. Cham, Springer: 129–159.
- Casals P., Romero J., Rusch G.M., Ibrahim M. (2014): Soil organic C and nutrient contents under trees with different functional characteristics in seasonally dry tropical silvopastures. *Plant Soil*, 374: 643–659.
- El-Keblawy A., Abdelfatah M.A. (2014): Impacts of native and invasive exotic *Prosopis congeners* on soil properties and associated flora in the arid United Arab Emirates. *Journal of Arid Environments*, 100: 1–8.
- Gartzia-Bengoetxea N., Kandeler E., de Arano I.M., Arias-González A. (2016): Soil microbial functional activity is governed by a combination of tree species composition and soil properties in temperate forests. *Applied Soil Ecology*, 100: 57–64.
- Gea-Izquierdo G., Allen-Díaz B., San Miguel A., Cañellas I. (2010): How do trees affect spatio-temporal heterogeneity of nutrient cycling in Mediterranean annual grasslands? *Annals of Forest Science*, 67: 112–123.
- Gebrewahid Y., Tekla K., Gebre-Egziabhier T.B., Tewolde-Berhan S., Birhane E., Eyasu G., Meresa E. (2019): Dispersed trees on smallholder farms enhance soil fertility in semi-arid Ethiopia. *Ecological Processes*, 8: 1–8.
- Gee G.W., Bauder J.W. (1982): Particle size analysis. In: Page A.L., Miller R.H., Keeney D.R. (eds): *Methods*

- of Soil Analysis, Part 2: Chemical and Microbiological Properties. Madison, American Society of Agronomy and Soil Science Society of America: 404–408.
- Getaneh S., Honnay O., Desie E., Helsen K., Couck L., Shibru S., Muys B. (2022): Impact of tree litter identity, litter diversity and habitat quality on litter decomposition rates in tropical moist evergreen forest. *Forest Ecosystems*, 9: 1–9.
- Haluschak P. (2006): Laboratory Methods of Soil Analysis. Canada-Manitoba Soil Survey: 132.
- Keller A.B., Reed S.C., Townsend A.R., Cleveland C.C. (2012): Effects of canopy tree species on belowground biogeochemistry in a lowland wet tropical forest. *Soil Biology and Biochemistry*, 58: 61–69.
- Khanmohammadi Z., Matinizadeh M. (2023): Evaluation of soil properties under the canopy of wild pistachio (*Pistacia atlantica* Desf.) and wild almond (*Prunus orientalis* (Mill.) Koehne) (Case study: Tang Khoshk, Semirum). *Journal of Soil and Plant Interactions*, 14: 93–108.
- Khoshnevis M., Teimouri M., Sadegzadeh Hallaj M.H., Matinizadeh M., Shirvany A. (2019): The effect of canopy and its geographic orientation on seeds germination and survival of *Juniperus excelsa* seedlings. *Iranian Journal of Forest*, 11: 363–371.
- Krzebietke S., Daszykowski M., Czarnik-Matusiewicz H., Stanimirova I., Pieszczyk L., Sienkiewicz S., Wierzbowska J. (2023): Monitoring the concentrations of Cd, Cu, Pb, Ni, Cr, Zn, Mn and Fe in cultivated Haplic Luvisol soils using near-infrared reflectance spectroscopy and chemometrics. *Talanta*, 251: 123749.
- Mamo D., Asfaw Z. (2017): Status of selected soil properties under *Croton macrostachyus* tree at Gemechis district, West Hararghe zone, Oromia. *Journal of Resources Development and Management*, 31: 31–39.
- Manjur B., Abebe T., Abdulkadir A. (2014): Effects of scattered *F. albida* (Del.) and *C. macrostachyus* (Lam.) tree species on key soil physicochemical properties and grain yield of Maize (*Zea mays*): A case study at Umbulo Wacho watershed, southern Ethiopia. *Egyptian Journal of Agricultural Research*, 3: 63–73.
- Manning A.D., Fischer J., Lindenmayer D.B. (2006): Scattered trees are keystone structures – Implications for conservation. *Biological Conservation*, 132: 311–321.
- Mozaffarian V. (2004): Trees and Shrubs of Iran. Tehran, Farhang Moaser Press: 1120.
- Murray J., Smith A.P., Simpson M., Elizondo K.M., Aitkenhead-Peterson J.A., Waring B. (2023): Climate, as well as branch-level processes, drive canopy soil abundance and chemistry. *Geoderma*, 438: 116609.
- Ogunkunle C.O., Awotoye O.O. (2010): Soil fertility status under different tree cropping system in a southwestern zone of Nigeria. *Notulae Scientia Biologicae*, 3: 123–128.
- Pirani A., Moazzeni H., Mirinejad S., Naghibi F., Mosaddegh M. (2011): Ethnobotany of *Juniperus excelsa* M. Bieb. (Cupressaceae) in Iran. *Ethnobotany Research and Applications*, 9: 335–341.
- Rahman M.M., Tsukamoto J., Rahman M.D., Yoneyama M., Mostafa K.M. (2013): Lignin and its effects on litter decomposition in forest ecosystems. *Chemistry and Ecology*, 29: 540–553.
- Rostamikia Y., Zobeire M. (2012): Study on the structure of *Juniperus excelsa* Beib. stand in Khakhal protected forests. *Journal of Wood and Forest Science and Technology*, 19: 151–162.
- Rostamizad P., Hosseini V., Samani K.M. (2018): The effects of wild pistachio (*Pistacia atlantica* Desf.) single-trees crown on the amount of nutrients in the forest soil (Sarvabad region in Kurdistan province). *Journal of Water and Soil Science*, 22: 383–393.
- Saaed M., Alshareef B.B., Fadel B.A. (2020): The ability of indigenous legume trees to create islands of fertility in extremely arid and degraded ecosystems: Case study, Al-Kufra oasis, Libya. *Libyan Journal of Environmental Science and Technology*, 22: 33–47.
- Sardans J., Peñuelas J. (2013): Plant-soil interactions in Mediterranean forest and shrublands: Impacts of climatic change. *Plant and Soil*, 365: 1–33.
- Schinner F., Öhlinger R., Kandeler E., Margesin R. (1996): *Methods in Soil Biology*. Berlin, Springer: 425.
- Shukla M.K., Lal R., Ebinger M., Meyer C. (2006): Physical and chemical properties of soils under some piñon-juniper-oak canopies in a semi-arid ecosystem in New Mexico. *Journal of Arid Environments*, 66: 673–685.
- Stefanowicz A.M., Rozek K., Stanek M., Rola K., Zubek S. (2021): Moderate effects of tree species identity on soil microbial communities and soil chemical properties in a common garden experiment. *Forest Ecology and Management*, 55: 482–502.
- Sun M., Zhai B.C., Chen Q.W., Li G., Du S. (2022): Response of density-related fine root production to soil and leaf traits in coniferous and broad-leaved plantations in the semiarid loess hilly region of China. *The Journal of Forestry Research*, 33: 1071–1082.
- Tucker B.B., Kurtz L.T. (1961): Calcium and magnesium determinations by EDTA titrations. *Soil Science Society of America Journal*, 25: 27–29.
- Wu H., Cui H., Fu C., Li R., Qi F., Liu Z., Yang G., Xiao K., Qiao M. (2024): Unveiling the crucial role of soil microorganisms in carbon cycling: A review. *Science of the Total Environment*, 909: 168627.
- Yang L., Zhang Q., Ma Z., Jin H., Chang X., Marchenko S.S., Spektor V.V. (2022): Seasonal variations in temperature sensitivity of soil respiration in a larch forest in the North-

<https://doi.org/10.17221/60/2024-JFS>

- ern Daxing'an Mountains in Northeast China. The Journal of Forestry Research, 33: 1061–1070.
- Yelenik S.G., Rehm E.M., D'Antonio C.M. (2022): Can the impact of canopy trees on soil and understory be altered using litter additions? Ecological Applications, 32: e02477.
- Yücesan Z., Hacısalıhoğlu S., Kezik U., Karadag H. (2019): Effects of canopy on soil erosion and carbon sequestration in a Pedunculate Oak (*Quercus robur* L. subsp. *robur* L.) coppice stand during the conversion process into high forest. Austrian Journal of Forest Science, 136: 45–66.
- Zarafshar M., Rousta M.J., Matinizadeh M., Talebi K.S., Bordbar S.K., Alizadeh T., Nouri E., Bader M.K.F. (2023): Scattered wild pistachio trees profoundly modify soil quality in semi-arid woodlands. Catena, 224: 106983.
- Zhukov O.V., Kunah O.M., Dubinina M.Y., Fedushko M.P., Kotsun V.I., Zhukova Y.O., Potapenko O.V. (2019): Tree canopy affects soil macrofauna spatial patterns on broad- and meso-scale levels in an Eastern European poplar-willow forest in the flood plain of the River Dnipro. Folia Oecologica, 46: 101–114.

Received: August 19, 2024

Accepted: October 2, 2024

Published online: November 22, 2024