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Comparison of sub-canopy topsoil properties between three woody plant species, a case study of the Baladeh Watershed, Mazandaran Province, Iran

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ABSTRACT
Little information is available about the vegetation impact on soil, comparing the effects of different woody plant species on topsoil properties in subalpine degraded grasslands. Therefore, we studied the effects of three native woody plants with different structural canopies (evergreen needle-leaved vs. deciduous broad-leaved and cushion vs. free canopy) on the nutrient topsoil properties. We selected 20 sites as 20 replications in which all four woody species were found closed to each other in each site. Then soil samples were collected under the canopy of each woody species in June 2019 and transported to the laboratory for physico-chemical analyses. The results showed that generally, woody species differed in their effects on physico-chemical topsoil properties. So that, the needle-leaved evergreen *Juniperus sabina* exerted the most influence on soil properties compared to *Berberis integerrima* and *Onobrychis cornuta* ($p < 0.05$). Topsoil total organic carbon content was significantly highest under *J. sabina* and *B. integerrima* (3.30% and 3.07% respectively), while lowest under *O. cornuta* and herbaceous vegetation (2.61% and 2.23%, respectively). In addition, soil total nitrogen content was significantly highest under *J. sabina* and *B. integerrima* (0.18% and 0.17%, respectively), while lowest under *O. cornuta* and herbaceous vegetation (0.16% and 0.15%, respectively). The results of this study indicated that in sub-alpine grasslands, the presence and maintaining of woody species is important due to its positive role on substratum soil, considering in the rangeland improvement projects.

Keywords: Woody species, Cushion plants, Animal grazing, Soil nutrients, Haluposhteh.
Article type: Research Article.

INTRODUCTION
It has often been reported that vegetation composition, particularly woody plants, can influence soil properties, and that the nature and composition of the vegetation community are determinant of the soil properties (e.g. Jafarian Jeloudar *et al.* 2010). Urbina *et al.* (2020) highlighted the role of woody plants in the sequestration of soil C and nutrients through the allocation to the aboveground biomass. Ding *et al.* (2019) reported that woody plants shaped soil nutrient concentration and carbon storage in an abandoned subalpine grassland. However, none of the previous studies focused on the effect of different woody plant species with focusing on different feature and structure of woody plant species on soil properties in the subalpine mountainous grasslands. Woody plants, depending on the species, can strongly influence habitat condition. It is well known that the interaction between soil heterogeneity and woody plants induced the autogenic development of "fertile islands" in the grassland ecosystems (Kondo *et al.* 2012; Keesstra *et al.* 2017). The formation of fertile islands results from both biotic and abiotic processes including plant nutrient uptake, litter deposition and decomposition, burrowing animal activity, and Aeolian deposits (de Graaff *et al.* 2014; Johnson *et al.* 2016). The development of "fertile islands" around and adjacent to individual woody plants is important in ecology, since it could change the vegetation composition and

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structure, as well as the distribution patterns of soil resources, e.g. nitrogen and organic matter (Chen *et al.* 2003). Therefore, the study of the effect of individual woody plants on soil properties would help us to reach to natural potentials for conservation goals in the degraded areas. Indeed, woody plants modify the chemical properties of soil under their canopies with litter and root exudation (Sylvain & Wall 2011), improving soil microenvironments (over soil without vegetation), diminishing direct sunlight, increasing local moisture content, protecting the surface soil from hydric and eolic erosion, and adding fresh organic matter into the soil (Garcia-Sanchez *et al.* 2012; Mussa *et al.* 2016). However, depending on the structure and feature of woody plants (erect or recumbent, deciduous or evergreen, broad- or needle-leaved), they could play different roles in alteration of soil properties that we aimed to clarify these differences in this study. We believed that due to the inclemency of climate and the intense disturbance of human beings (overgrazing) in the subalpine grassland in Iran, the results of this study could help us in recovery and restoration of degraded areas with selecting a suitable woody plant species in restoration projects. The main purpose of this study was assessing the effects of three endemic woody species on physico-chemical soil properties for restoration goals. We hypothesized that evergreen woody plant species increased soil nutrients compared to deciduous woody plants and should be of priority for planting in the degraded areas.

MATERIALS AND METHODS

Study area

The study was conducted in Baladeh Watershed in Mazandaran Province, Iran (36° 16′30″N - 36° 18′19″N; 51° 49′30″E -51° 51′17″E; Fig. 1). The elevation is between 2844 to 2963 m above sea level with an average annual rainfall of 394 mm. The average annual temperature is 5.5 °C with average annual maximum temperature 16.4 °C and average annual minimum temperature of 2.6 °C. Soil is shallow and mostly sandy in order of inceptisoil. The vegetation has been completely disappeared in some sites by intensive grazing (ca. five animals per hectare), emerging bare soil gaps. Sheep (Zel trace with average body weight of 27 kg) are the predominant grazers in the region, with a few goats during the end of April to September each year (Erfanzadeh *et al.* 2014). The area was excluded from grazing during the winter and few other months each year due to snowing and cold condition. The vegetation of the area is dominated by woody plant species of *Onobrychis cornuta* (12%), *Juniperus sabina* (10%) and *Berberis vulgaris* (5%) with a less density of *Rosa* sp. (1%) in a background of herbaceous species. The most dominant herbaceous species in the area are *Bromus tomentellus* (10%), *Festuca ovina* (5%), *Phlomis cancellata* (3%), *Thymus fedtschenkoi* (3%), *Erysimus elbrusense* (1%) and *Myosotis arvensis* (1%).

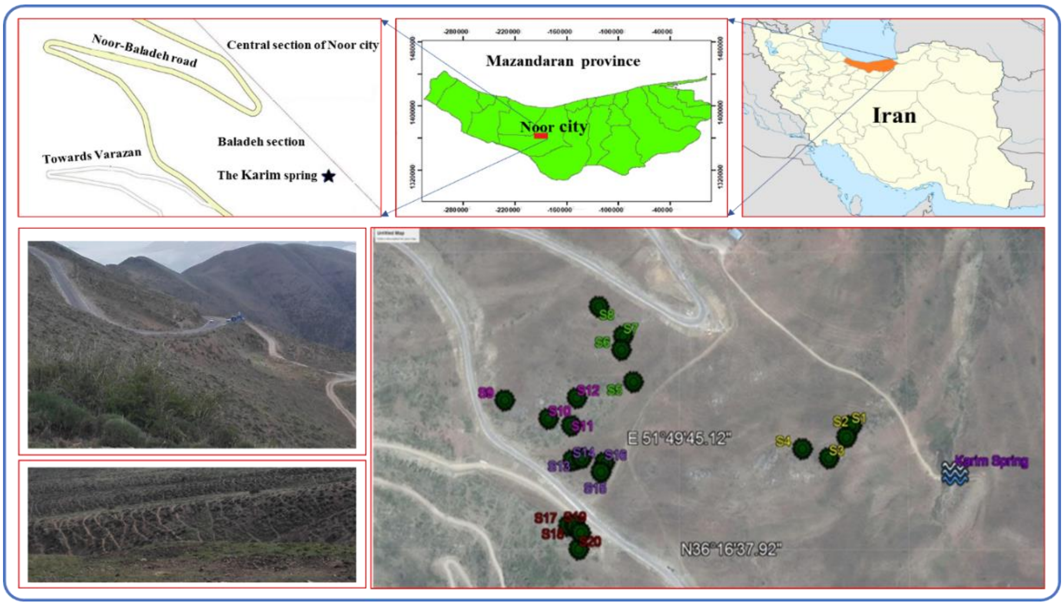

Fig. 1. The position of the study area in Mazandaran Province, Iran.

Woody plant selection

Three dominant woody species with different features and landforms together with herbaceous vegetation as control were selected in the study area. Since our study was focused on the variation of topsoil properties, depth rooting of the woody plants was not important for us. However, we did not find any information and data about depth rooting of the woody plants in the literature.

1) *Berberis vulgaris* L. (family Berberidaceae), also known as common barberry, is an upright deciduous woody plant with an average of 180 cm tall in the study area. The canopy structure is open with thorny branches (Erfanzadeh *et al.* 2020b).
2) *Juniperus sabina* L. (family Cupressaceae), commonly known as savin juniper, is a woody plant by evergreen dwarf conifer that is native to mountainous areas. It is usually seen as a wide-spreading woody plant to an average of 90 cm tall in the study area. The canopy structure is low stature and procumbent with uncompact form (Erfanzadeh *et al.* 2020b).
3) *Onobrychis cornuta* (L.) Desv. (family Fabaceae), commonly known as Holy clover, perennial, deciduous, branched spiny woody plant, forming cushions or tufts, up to 60 cm in height in the study area. The canopy structure is low stature with dense compact form (Erfanzadeh *et al.* 2020b).
4) Herbaceous vegetation dominated by perennial grasses such as *Festuca ovina* and *Bromus tomentellus* as control treatment.

Site selection

We selected 20 sites as 20 replications in which all four woody species were found close to each other in each site (Fig. 2). Therefore, the effect of climatological and topographical factors could be ignored in the data analyses. All sites were selected in northern slope. The distance between each two closed sites was 100 m to maximum 600 m. Soil sampling was performed in June 2019 during the peak of plant biomass production (Sun *et al.* 2017). Under each individual woody species, 10 soil cores were collected at random to a depth of 20 cm (Baskan *et al.* 2016), with a 5 cm diameter auger. Then the soil cores pooled per each woody species (totally 80 soil samples). All of the soil samples were transported to the laboratory and stored at 4 ºC until they were processed. The samples were sieved, the roots and coarse gravel (> 2 mm) were removed by sieving, and the < 2-mm soil was used to examine the effects of vegetation composition on soil properties (Liu *et al.* 2014).

Fig. 2. Positions of the four woody plant species, *Juniperus sabina*, *Berberis. integerrima*, *Onobrichis cornuta* and herbaceous vegetation (as control). They were selected close to each other in each site (replication).

Wet aggregate stability (WAS) was measured using a modification of the wet-sieving method. Then, 50 g of air-dried 2.0-2.8 mm soil aggregates were pre-wet with an atomizer spray before being transferred to the uppermost of a set of three sieves of 2.0, 1.2 and 0.5 mm in diameter. The water level was adjusted, so that the aggregates on the 2.0 mm- sieve were just submerged at the highest point of the oscillation. The soil remaining on each sieve after 4 min (200 oscillations) was dried at 105 °C and weighed. Soil pH and electrical conductivity (EC) were determined in soil–water suspension in the ratio of 1:2.5 (weight/volume). Soil pH was measured using a glass-electrode pH meter, while EC using a conductivity meter. Total organic carbon (TOC) was determined by the Loss of Ignition method, while the total nitrogen (TN) content using a Kjeldahl Apparatus Nitrogen Analyzer (FOSS2200; Zandi *et al.* 2017). We also calculated C/N as an acceptable index for the litter quality (Wang *et al.* 2010). The particulate organic carbon (POC) was determined by physical fractionation (Zandi *et al.* 2017).

Twenty-five grams of air-dried soil samples were dispersed with 100 mL of 5 g L^{-1} of sodium hexametaphosphate $(NaPO_3)_6$. The soil solution mixture was shaken for 1 h at high speed (= 500 rpm) on an end-to-end shaker and poured over a 0.053-mm sieve with several deionized water rinses. The soil remaining on the sieve was back washed into a pre-weighed aluminum dish and dried at 60 ºC for 24 h, then ground and analyzed for C. Soil moisture was estimated gravimetrically, by drying the samples during 48 h at 75 ºC (Curiel Yuste *et al.* 2007). Wet aggregate stability was measured using a modification of the wet-sieving method (Chancy & Swift *et al.* 1984). To evaluate the effect of woody plant species on soil properties, One-Way ANOVA following post-hoc tests (LSD test) were used with woody species as fixed factor and the soil properties as dependent factors. Kolmogrove-Smirnov test was used to test the normal distribution of data before using ANOVA test. These statistical analyses were conducted using SPSS 23.0.

RESULTS

Some measured topsoil physico-chemical properties significantly varied between the woody plants (Table 1), increasing from grassland (woody plant interspace) to woody plant base:

Soil physical properties under woody plant canopies

There were no significant differences of WAS values between four woody plant species (Table 1, Fig. 3). Soil moisture content was highest understory the *B. integerrima* and *J. sabina* with 5.91% and 5.78%, respectively (Table 1, Fig. 3). The lowest amount of soil moisture content was observed in the control area (3.88%).

Soil chemical properties under woody plant canopies

Electrical conductivity and pH exhibited a non-significance differences between different species of woody plants. Soil TOC content was significantly highest under *J. sabina* and *B. integerrima* (3.30% and 3.07% respectively), while lowest under *O. conuta* and herbaceous vegetation (2.61% and 2.23%, respectively; Table 1, Fig. 4). Similarly, the highest values of POC were found under *J. sabina* and *B. integerrima* (both 4.99 g kg^{-1}), while lowest under herbaceous vegetation (3.14 g kg^{-1}; Table 1, Fig. 4). Soil TN content was significantly highest under *J. sabina* and *B. integerrima* (0.18% and 0.17%, respectively), while lowest under *O. conuta* and herbaceous vegetation (0.16% and 0.15%, respectively; Table 1, Fig. 4). There were no significant differences of C/N values between four woody species (Table 1).

Table 1. Effect of woody plant species on some physico-chemical soil properties (One-Way ANOVA).

Soil properties	df	F-value	P-value
Total organic carbon	3	5.15	0.003**
Particulate organic carbon	3	4.96	0.003**
Total nitrogen	3	2.65	0.048*
C/N	3	0.59	0.623ns
pH	3	0.21	0.88ns
EC	3	0.14	0.93ns
Moisture	3	2.90	0.046*
Wet aggregate stability	3	0.377	0.770ns

** significant at $p < 0.01$; * significant at $p < 0.05$; ns: not significant

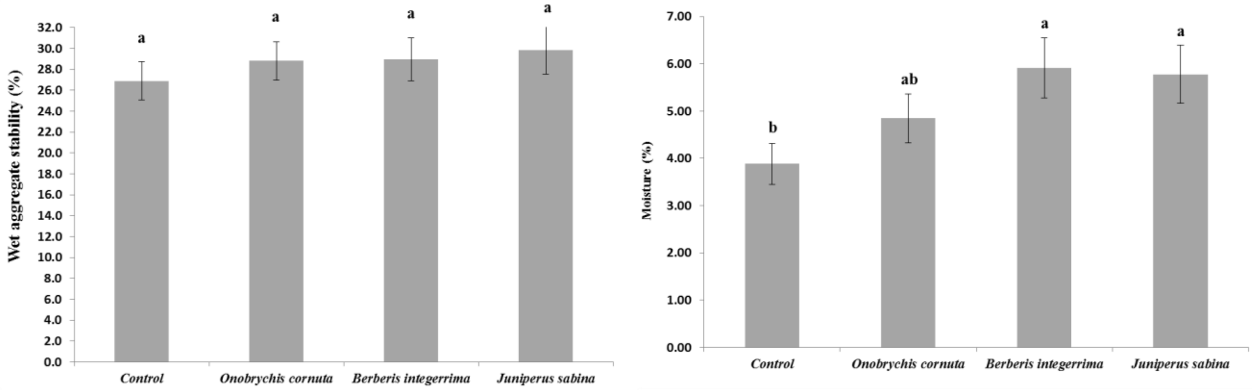

Fig. 3. Differences in the studied soil physical properties between woody plant species and control. Small letters showed the differences of soil properties between woody plant species and control.

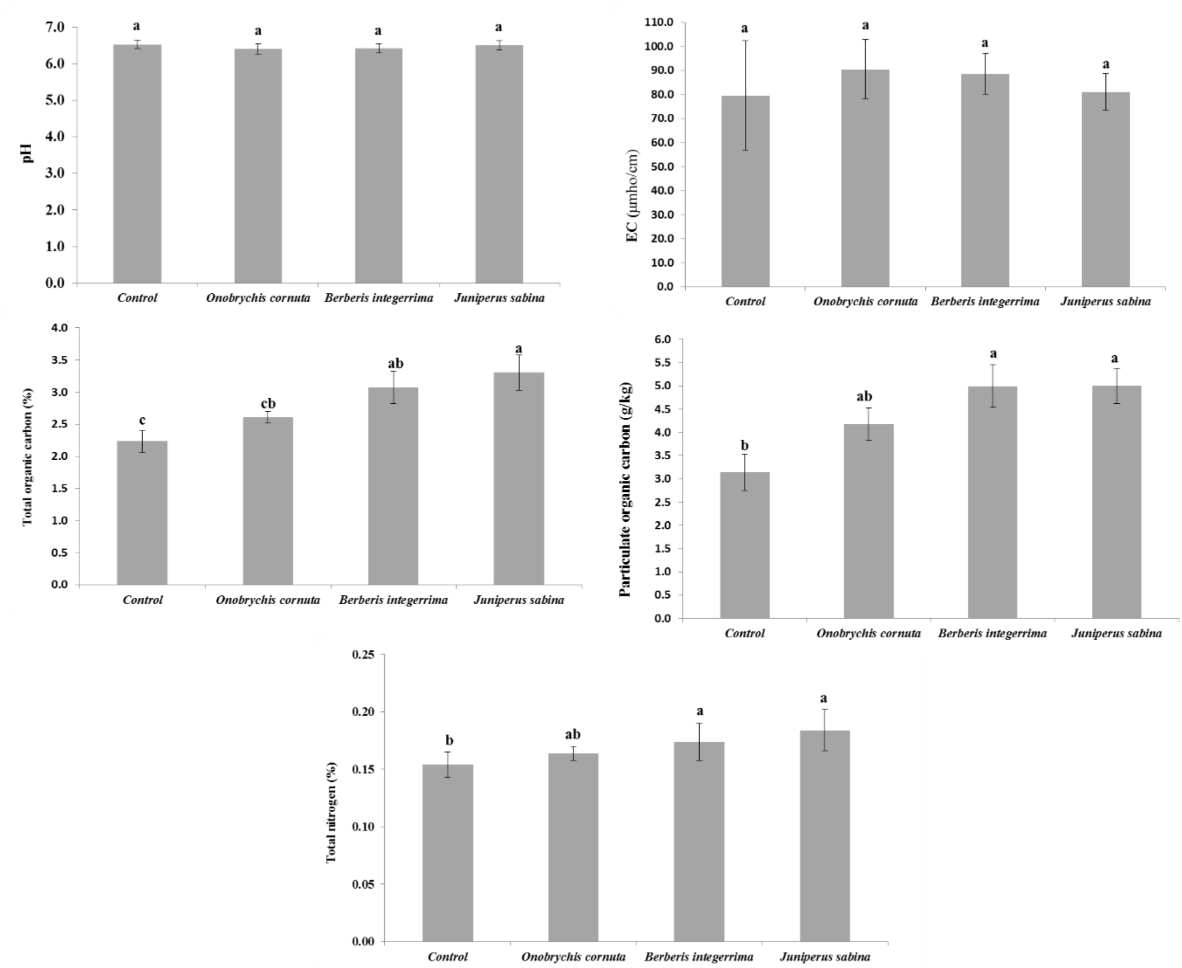

Fig. 4. Differences in the studied soil chemical properties between woody plant species and control. Small letters showed the differences of soil properties between woody plant species and control.

DISCUSSION

Species composition, the type of plant species and the spatial patterns of plant distribution can influence vegetation heterogeneity characteristics such as plant diversity and species richness (Omidipour *et al.* 2020) and resource availability and topsoil heterogeneity, as well as the rates of physical and biochemical processes that control C and N balance in grasslands (Erfanzadeh *et al.* 2014). Our study has presented the topsoil differences and heterogeneity under the woody plants in subalpine grasslands. Overall, our results exhibited that the presence of woody plants improves the values of understory topsoil nutrient. Previous studies reported that nutrient accumulation beneath woody plants in the grasslands is common and provides opportunities for carbon and nitrogen sequestration (Jackson *et al.* 2002). McClaran *et al.* (2008) reported that the TOC and TN accumulation was ca. 80-750% greater beneath *Prosopis velutina* than in open grassland. Soils under woody canopies are more fertile than soils from the surrounding grassland (Naumi *et al.* 2012; Noumi 2015). A likely mechanism is that nutrient enrichment of soil under woody plants canopy is a common phenomenon in the habitats with harsh condition (in our study area low temperature together with grazing; Titus *et al.* 2002). The upraised nutrient content in soil can be a result of an elevation in the plant litter amount, on the one hand, and an enhancement in soil microorganisms, on the other hand (Xie & Wittig 2004). However, among the three woody plants, *J. sabina* and *B. integerrima* displayed a stronger effect with the higher values of topsoil N and C contents, compared to the other woody plant and control, respectively. The first species with the highest soil carbon and nitrogen amount in the understory compared with the two other species and open areas is a needle-leaved and evergreen one. Probably, the high litter production due to being ever green resulted to the highest C storage in the understory. Coniferous species are able to increase the content of carbon in soil (Bu *et al.* 2012). Moreover, organic carbon accumulation may be mainly a result of not only higher organic matter production by the woody plant (Arekhi *et al.* 2010;

Ruwanza & Shackleton 2016), but also by the slower rate of litter mineralization. The second species with the highest values of carbon and nitrogen under the canopy was *B. integerrima*. These high values of TN, TOC and POC might be a result of litter input by this species as well as by herbaceous species growing in the understory of the woody plant. The positive interactions or facilitation, among plants is common in habitats with harsh conditions (Xu *et al.* 2015), where the landscape often consists of patches of woody plants embedded in a bare soil background that is sparsely populated with herbaceous species. Numerous studies have shown that the establishment and fecundity of herbaceous plants are higher in the woody plant patch than in the surrounding areas (Maestre *et al.* 2005; Badano *et al.* 2009). Such facilitation is mainly attributed to the engineering effect of woody plants, which improves the physical, chemical and hydrological conditions for herbaceous vegetation growing in woody plant patches, compared to conditions in open patches (Noumi 2015). Patches of woody vegetation can also modify plant community composition and dynamics by trapping seeds and creating suitable microhabitats (Erfanzadeh *et al.* 2014; Aerts *et al.* 2016). More precisely, woody plants accumulated large and diverse soil seed banks beneath their canopy, which were higher in the density and richness from seed banks of the open matrix (Dreber & Esler 2011; Erfanzadeh *et al.* 2016). These differences could be related to a very high seed input under the woody plant canopies that increases above-ground vegetation production (Erfanzadeh *et al.* 2020a), and to the capability of patches to trap seeds from surrounding environment (Niknam *et al.* 2018). However, the role of woody plants in facilitation for herbaceous species could less pronounce by *O. cornuta* due to high compact of canopy and less open space between the branches compared to *B. integerrima* with open erect canopy. In our study, woody plant species varied from evergreen needle leaves to deciduous broadleaves species growing closed to each other. These vegetation alterations might result in different litter types and qualities (Wang *et al.* 2013). It has been showed that a low C/N ratio generally represents good quality litter and a high transfer rate of C from litter fall to mineral soils (Wang *et al.* 2010). In our results, however, soil C/N ratios showed a highest value in understory of *J. Sabina*, while lowest value in herbaceous vegetation. Although, high soil C/N ratios in mountainious areas, in general, were reported (Du *et al.* 2014) due to low temperatures and low transfer rates of C, we believe that the rate of C/N could be different among plant species, resulted in different quality and decomposition of litter. So, we could consider the litter chemical analyses in the future studies. Bu *et al.* (2012) observed that the C/N ratio in density fractions were higher in coniferous areas than alpine meadow. Although soil moisture measurements showed that water is less available under canopy areas of woody plants than open patches in arid ecosystems (Facelli & Temby 2002), conversely, in our study the moisture contents was higher under canopies of all measured woody plants, compared to the open grassland. Moisture was lower in the bare soil, because of the increased exposure to sunlight and air currents, which led to the elevated evaporation and desiccation (Ruwanza & Shackleton 2016). In contrast to previous studies (Carrizo *et al.* 2015) the results of our study exhibited a non-significant differences in the aggregate stability between the four woody species. The elevated aggregate stability in soil under forest has been reported due to the upraised organic matter (Mainuri & Owino 2013). Soil nutrients are influenced not only by plant community (Zhao *et al.* 2020), but also by plant population and the species of woody plants. As a result, knowledge of the effects of the species of woody plants on soil quality properties such as TOC status is essential in natural habitats, when considering conservation strategies based on higher carbon sequestration of each woody plant species in these habitats. These studies could be more important to be conducted when some researchers reported converse results and stated that in terms of soil C accumulation, planting or recovery of woody plant species might not be an effective choice for land degradation control. In the vegetation conservation projects based on higher carbon accumulation, the manager should consequently identify the plant species which can absorb and add carbon into soil at a higher rate and try to improve their spatial extent. Therefore, it would strongly suggest that the managers consider the conservation of these woody plants. Sometimes, it has been observed that people use the fire to replace the woody plantlands into the grasslands, while the presence of woody plants is very important for soil conservation.

CONCLUSIONS

The results of this study indicated that in sub-alpine grasslands, the presence and maintaining of woody plant species is important due to its positive role on substratum soil. Moreover, before improvement and recovery of the degraded areas using planting of native woody plants, different roles of various woody plants on soil properties could be considered in the projects.

REFERENCES

Aerts, R, Maes, W, November, E, Behailu, M, Poesen, J, Deckers, J, Hermy, M & Muys, B 2006, Surface runoff and seed trapping efficiency of woody plants in a regenerating semiarid woodland in northern Ethiopia. *Catena*, 65: 61-70.

Arekhi, S, Heydari, M, Pourbabaei, H 2010, Vegetation-Environmental Relationships and Ecological Species Groups of the Ilam Oak Forest Landscape, Iran. *Caspian Journal of Environmental Sciences*, 8: 115-125.

Badano, EI, Pérez, D & Vergara, CH 2009, Love of nurse plants is not enough for restoring oak forests in a seasonally dry tropical environment. *Restoration Ecology*, 17: 571-576.

Baskan, O, Dengiz, O & Gunturk, A 2016, Effects of toposequence and land use-land cover on the spatial distribution of soil properties. Environmental *Earth Sciences*, 75: 1-10.

Bu, X, Ruan, H, Wang, L, Ma, W, Ding, J & Yu, X 2012, Soil organic matter in density fractions as related to vegetation changes along an altitude gradient in the Wuyi Mountains, southeastern China. *Applied Soil Ecology*, 52: 42-47.

Carrizo, ME, Alesso, CA, Cosentino, D & Imhoff, S 2015, Aggregation agents and structural stability in soils with different texture and organic carbon contents. *Scientia Agricola*, 72: 75-82.

Chaney, K & Swift, R 1984, The influence of organic matter on aggregate stability in some British soils. *Eurasian Journal of Soil Sciences*, 35: 223-230.

Chen, G, Zeng, D, Chen, F, Fan, Z & Geng, H 2003, A research review on" fertile islands" of soils under woody plant canopy in arid and semi-arid regions. *Journal of Applied Ecology*, 14: 2295-2300.

Curiel, Yuste J, Baldocchi, D, Gershenson, A, Goldstein, A, Misson, L & Wong, S 2007, Microbial soil respiration and its dependency on carbon inputs, soil temperature and moisture. Glob. *Change Biological Bioenergy*, 13: 2018-2035.

de Graaff, MA, Throop, HL, Verburg, PS, Arnone, JA Campos, X 2014, A synthesis of climate and vegetation cover effects on biogeochemical cycling in woody plant-dominated drylands. *Ecosystems*, 17: 931-945.

Ding, L, Wang, P, Zhang, W, Zhang, Y, Li, S, Wei, X, Chen, X, Zhang, Y & Yang, F 2019, Woody plant encroachment shapes soil nutrient concentration, stoichiometry and carbon storage in an abandoned subalpine grassland. *Sustainability*, 11: 1732.

Dreber, N & Esler, K 2011, Spatio-temporal variation in soil seed banks under contrasting grazing regimes following low and high seasonal rainfall in arid Namibia. *Journal of Arid Environment*, 75: 174-184.

Du, B, Kang, H, Pumpanen, J, Zhu, P, Yin, S, Zou, Q, Wang, Z, Kong, F & Liu, C 2014, Soil organic carbon stock and chemical composition along an altitude gradient in the Lushan Mountain, subtropical China. *Ecological Restoration*, 29: 433-439.

Erfanzadeh, R, Bahrami, B, Motamedi, J & Petillon, J 2014, Changes in soil organic matter driven by shifts in co-dominant plant species in a grassland. *Geoderma*, 213: 74-78.

Erfanzadeh, R, Daneshgar, M & Ghelichnia, H 2020a, Improvement of the seedling emergence method in soil seed bank studies using chemical treatments. *Community Ecology*, 21: 183-190.

Erfanzadeh, R, Kamali, P, Ghelichnia, H & Pétillon, J 2016, Effect of grazing removal on aboveground vegetation and soil seed bank composition in sub-alpine grasslands of northern Iran. *Plant Ecology*, 9: 309-320.

Erfanzadeh, R, Shahbazian, R & Zali, H 2014, Role of plant patches in preserving flora from the soil seed bank in an overgrazed high-mountain habitat in northern Iran. *Journal of Agricultural Sciences and Technology*, 16: 229-238.

Erfanzadeh, R, Shayesteh Palaye, AA & Ghelichnia, H 2020b, Shrub effects on germinable soil seed bank in overgrazed rangelands. *Plant Ecology and Diversity*, 13: 199-208.

Facelli, JM & Temby, AM 2002, Multiple effects of woody plants on annual plant communities in arid lands of South Australia. *Austral Ecology*, 27: 422-432.

García-Sánchez, R, Camargo-Ricalde, SL, García-Moya, E, Luna-Cavazos, M, Romero-Manzanares, A & Manuel Montaño, N 2012, *Prosopis laevigata* and *Mimosa biuncifera* (Leguminosae), jointly influence plant diversity and soil fertility of a Mexican semiarid ecosystem. *Revista de Biología Tropical*, 60: 87-103.

Jackson, RB, Banner, JL, Jobbágy, EG Pockman, WT, Wall, DH 2002, Ecosystem carbon loss with woody plant invasion of grasslands. *Nature*, 418(6898): 623-626.

Jafarian Jeloudar, Z, Arzani, H, Jafari, M, Kavian, A, Zahedi, Gh, Azarnivand, H 2010, Vegetation community in relation to the soil characteristics of Rineh rangeland, Iran. *Caspian Journal of Environmental Sciences*, 8: 141-150.

Johnson, BG, Verburg, PS & Arnone, JA 2016, Plant species effects on soil nutrients and chemistry in arid ecological zones. *Oecologia*, 182: 299-317.

Keesstra, S, Wittenberg, L, Maroulis, J, Sambalino, F, Malkinson, D, Cerdà, A & Pereira P, 2017, The influence of fire history, plant species and post-fire management on soil water repellency in a Mediterranean catchment: The Mount Carmel range, Israel. *Catena*, 149: 857-866.

Kondo, J, Hirobe, M, Yamada, Y, Undarmaa, J, Sakamoto, K & Yoshikawa, K 2012, Effects of *Caragana microphylla* patch and its canopy size on "islands of fertility" in a Mongolian grassland ecosystem. Landsc. *Ecological Engineering*, 8: 1-8.

Liu, M-Y, Chang, Q-R, Qi, Y-B, Liu, J & Chen, T 2014, Aggregation and soil organic carbon fractions under different land uses on the tableland of the Loess Plateau of China. *Catena*, 115: 19-28.

Maestre, FT, Valladares, F, Reynolds, JFI 2005, the change of plant-plant interactions with abiotic stress predictable? A meta-analysis of field results in arid environments. *Journal of Ecology*, 93: 748-757.

Mainuri, ZG & Owino, JO 2013. Effects of land use and management on aggregate stability and hydraulic conductivity of soils within River Njoro Watershed in Kenya. *International Soil Water Conservation and Restoration*, 1: 80-87.

McClaran, MP, Moore-Kucera, J, Martens, DA, van Haren, J & Marsh, SE 2008, Soil carbon and nitrogen in relation to woody plant size and death in a semi-arid grassland. *Geoderma*, 145: 60-68.

Mussa, M, Ebro, A & Nigatu, L 2016, Impact of woody plants species on soil physic-chemical properties along grazing gradients in rangelands of Eastern Ethiopia. Trop. *Subtropical Agroecosystems*, 19: 343-355.

Niknam, P, Erfanzadeh, R, Ghelichnia, H & Cerda, A 2018, Spatial variation of soil seed bank under cushion plants in a subalpine degraded grassland. *Land Degradation and Development*, 29: 4-14.

Noum,i Z 2015, Effects of exotic and endogenous woody plants on understory vegetation and soil nutrients in the south of Tunisia. *Journal of Arid Land*, 7: 481-487.

Noumi, Z, Abdallah, L, Touzard, B & Chaieb, M 2012, *Acacia tortilis* (Forssk.) subsp. *raddiana* (Savi) Brenan as a foundation species: A test from the arid zone of Tunisia. *Rangeland Journal*, 34: 17-25.

Omidipour, R, Erfanzadeh, R, Faramarzi, M 2020, Climatic condition effects on the components of plant diversity in the western Iran grasslands using multiplicative partitioning methods. *Caspian Journal of Environmental Sciences*, 19: 1-10.

Ruwanza, S & Shackleton, CM 2016, Effects of the invasive woody plant, Lantana camara, on soil properties in the Eastern Cape, South Africa. *Weed Biological Management*, 16: 67-79.

Sun, Y, Zhang, Y, Feng, W, Qin, S, Liu, Z, Bai, Y, Yan, R & Fa, K 2017, Effects of xeric woody plants on soil microbial communities in a desert in northern China. *Plant and Soil*, 414: 281-294.

Sylvain, ZA & Wall, DH. 2011, Linking soil biodiversity and vegetation: implications for a changing planet. *American Journal of Botany*, 98: 517-527.

Titus, JH, Nowak, RS & Smith, SD 2002, Soil resource heterogeneity in the Mojave Desert. *Journal of Arid Environments*, 52: 269-292.

Urbina, I, Grau O, Sardans, J, Ninot, JM & Peñuelas, J 2020, Encroachment of woody plants into subalpine grasslands in the Pyrenees changes the plant-soil stoichiometry spectrum. *Plant and Soil*, 448: 37-53.

Wang, H, Liu, S, Wang, J, Shi, Z, Lu, L, Zeng, J, Ming, A, Tang, J & Yu, H 2013, Effects of tree species mixture on soil organic carbon stocks and greenhouse gas fluxes in subtropical plantations in China. *Forest Ecology and Management*, 300: 4-13.

Wang, H, Liu, SR, Mo J-M, Wang JX, Makeschin F & Wolff, M 2010, Soil organic carbon stock and chemical composition in four plantations of indigenous tree species in subtropical China. *Ecological Restoration*, 25: 1071-1079.

Xie, Y & Wittig, R 2004, The impact of grazing intensity on soil characteristics of *Stipa grandis* and *Stipa bungeana* steppe in northern China (autonomous region of Ningxia). *Acta Oecologia*, 25(3): 197-204.

Xu C, Holmgren M, Van Nes, EH, Maestre, FT, Soliveres, S, Berdugo, M, Kéfi, S, Marquet, PA, Abades, S & Scheffer, M 2015, Can we infer plant facilitation from remote sensing? A test across global drylands. *Applied Ecology*, 25: 1456-1462.

Zandi, L, Erfanzadeh, R & Joneidi Jafari, H 2017, Rangeland use change to agriculture has different effects on soil organic matter fractions depending on the type of cultivation. *Land Degradation and Development*, 28: 175-180.

Zhao, Q, Ding, S, Liu Q, Wang, S, Jing, Y & Lu, M 2020, Vegetation influences soil properties along riparian zones of the Beijiang River in Southern China. *PeerJ* 8: e9699

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