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Original Article

Effect of vegetation patch size on selected chemical properties of soils under semiarid climate conditions

Yarı kurak koşullarda bitki grubu büyüklüğünün bazı toprak kimyası parametrelerine etkisi

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ABSTRACT

This study aimed to investigate effects of vegetation patches of different sizes on selected chemical characteristics of soil. The study was carried out in a semiarid region of Central Anatolia. Based on average diameter of the canopy, vegetation patches in the site were divided into three groups: 0–4 meters (m) (small), 4–8 m (medium), and >8 m (large). Soil samples were collected from under the patch canopy and near the canopy at the topsoil. The soil samples were mixed, and one subsample was taken as a representative of each patch size. A total of 20 subsamples for the small, 14 for the medium-sized, and 14 for the large patches were collected. The soil samples were analyzed for electrical conductivity, pH, potassium, calcium, magnesium, phosphorus, total nitrogen, and total carbon. Results showed that patch size had a significant effect on the phosphorus and total nitrogen contents of the topsoil. Topsoil around the large patches had significantly greater phosphorus content 0.03 grams/liter (g/L) than small (0.01 g/L) and medium-sized (0.01 g/L) patches. Similar to phosphorus values, the topsoil around the large patches had significantly greater total nitrogen content (0.70%) than the topsoil around the small (0.62%) and medium-sized (0.60%) patches. Since both nitrogen and phosphorus nutrients are important elements for early plant growth and survival, large patches should not be cleared from the sites during the land rehabilitation works due to their positive impacts on the topsoil under fragile landscape conditions in the semiarid regions.

Keywords: Central Anatolia, fertility island, patch size, soil chemistry, soil nutrients

ÖZ

Bu çalışma, farklı büyüklükteki bitki örtüsü gruplarının toprak kimyası üzerindeki etkilerinin incelenmesi amacıyla İç Anadolu'nun yarıkurak özelliklerini temsil eden Çankırı bölgesinde gerçekleştirilmiştir. İncelenen toprak kimyası parametreleri, elektriksel iletkenlik, pH, potasyum, kalsiyum, magnezyum, fosfor, toplam azot ve toplam karbon'dur. Bitki örtüsü grupları, tepe tacı çapının büyüklüğüne göre 0-4 metre (m) (küçük), 4-8 m (orta) ve > 8 m (büyük) olmak üzere üç gruba ayrılmıştır. Toprak örnekleri tepe tacının hemen altından ve tepe tacının çapı kadar uzağından olmak üzere 10 cm derinliğinde üst topraktan üçer örnek olarak alınmış ve bu toprak örnekleri her bitki örtüsü büyüklüğünü temsil etmek üzere karıştırılarak tek bir genel örnek haline getirilmiştir. Toplamda, küçük bitki grupları için 20, orta ve büyük bitki grupları için 14'er adet genel toprak örneği oluşturulmuştur. Sonuçlar, bitki gruplarının büyüklüğünün üst topraktaki fosfor ve toplam azot üzerinde etkili olduğunu, diğer parametreler üzerinde ise istatistiki anlamda herhangi bir etkisinin olmadığını göstermiştir. Büyük bitki gruplarından alınan toprak örneklerindeki fosfor miktarı 0,03 gram/litre (g/L) ile orta (0,01 g/L) ve küçük (0,01 g/L) bitki gruplarından alınan örneklerden yüksek çıkmıştır. Toplam azot miktarı da büyük bitki gruplarından alınan örneklerde (%0,70), orta (%0,60) ve küçük (%0,62) bitki gruplarından alınan toprak örneklerindekinden önemli ölçüde yüksek çıkmıştır. Hem azot hem de fosfor bitki gelişiminde ve yaşamında önemli besin elementleri olduğundan, sonuçlar yarıkurak koşullarda yapılacak rehabilitasyon çalışmalarında büyük bitki gruplarının toprakların azot ve fostor içeriğine yaptıkları pozitif etkiden dolayı temizlenmeyerek sahada bırakılmalarının uygun olacağını göstermektedir.

Anahtar Kelimeler: Besin zengini alanlar, bitki grubu büyüklüğü, İç Anadolu, toprak besin maddeleri, toprak kimyası

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INTRODUCTION

Plant covers in the arid and semiarid ecosystems are sparsely distributed due to water deficit (Aguiar and Sala, 1999; Maestre and Cortina, 2002). As seen in many dryland environments, patchy vegetation covers are common in the semiarid areas of Mediterranean region and have different soil characteristics beneath the patches such as infiltration rates, water storage capacities, soil moisture content, aggregate stability, and nutrient content from adjacent bare soils (Boer and Puigdefábregas, 2005). Maestre and Escudero (2009) indicated that dryland desertification adversely affects nearly 250 million people worldwide. They tried to find a power law to use vegetation patches as an "early warning" systems for desertification process in Mediterranean drylands.

Therefore, patches can play important role on the soil and water conservation in the watersheds with poor soil conditions under arid and semiarid climatic conditions. Accumulation of plant debris and their decomposition on the topsoil beneath the patches can increase biological activity and productivity in the soil. This phenomenon also affects the plant diversity around the patches by creating island of fertility, influencing soil hydrology and erodibility (Puigdefábregas, 2005; Schade and Hobbie, 2005). Additionally, patch canopies can serve as an efficient trap for interception of atmospheric dust and chemical compounds. For example, Lequy et al. (2014) reported a large interception of atmospheric particulate deposition by canopy of beech stands in Northeastern France. Muvengwi et al. (2015) also suggested that nutrient enrichment in patches can increase resource heterogeneity, and it can have a significant impact on determining ecosystem structure and function in semiarid savanna ecosystems. Vegetation patches can not only alter soil chemistry beneath the patch canopies through dry deposition and litter turnover but also influence runoff and sediment fluxes in drylands. Boer and Puigdefábregas (2005) compared runoff and sediment yield of an area having patchy vegetation distribution with another area having uniform vegetation cover. They found that the area with patchy vegetation structure had a greater soil loss and storm discharge than the area with evenly vegetation distribution. Furthermore, distribution and pattern of vegetation types can change because of global warming. This expected natural phenomenon can cause permanent soil and vegetation losses and alter soil chemistry. Therefore, clearance or protection of existing patches with respect to their influence on soil nutrient content is an important issue during the land rehabilitation works in semiarid regions.

Besides the distribution and coverage area of vegetation patches, vegetation composition of the patches has also great impacts on soil erosion and runoff. In fact, a study carried out in semiarid Central Mexico showed that vegetation patches with different dominant species had significantly different impacts on runoff and soil loss (Vásquez-Meéndez et al., 2010). Vegetation patches in dry environments also creates island of fertility due to organic matter accumulation from decomposition of plant litter, and hence positively influences nutrient availability in the soils beneath the patches (Cerdán et al., 2016; Ridolfi et al., 2008). Schade and Hobbie (2005) investigated effects of velvet mesquite trees (*Prosopis velutina*) on soil moisture and biochemistry of nitrogen in the soils of Sonoran Desert in Arizona. They reported that *Prosopis velutina* had a positive impact on the soil by creating islands of fertility compared to the outside of the patches. In another study carried out in the northern Chihuahuan Desert in USA, Cross and Schlesinger (1999) found that all elements were homogenously distributed in the grassland soils while the plant-essential elements including nitrogen, phosphorus, and potassium were concentrated in the soils under the shrub (*Larrea tridentata*) patches. Besides above-mentioned positive impacts of patches on the soil under their canopies, especially woody vegetation patches create negative effects on the diversity and composition of understory vegetation. Schade et al. (2003) found declines in the species diversity and changes in the vegetation composition for understory vegetation growing under *Prosopis* canopies in the Sonoran Desert. In addition, Aguiar and Sala (1994) showed that emergence and survival of grass seedlings increased as the distance from the shrub patches increased due to decreased root competition between shrubs and grasses. On the other hand, despite some positive influences of vegetation patches on the soil nutrient status especially under the patch canopies, vegetation patches are removed from entire area in the rehabilitation of degraded lands in Turkey. Even though numerous plant species within the patches can have little forage value for grazing animals, they may be useful for watershed protection (Roundy and Call, 1988). Additionally, clearance of vegetation patches from the sites can expose soil surface directly to atmospheric events and can make organic matter poor soils much more vulnerable to erosion in the arid and semiarid lands. Moreover, revegetation of arid and semiarid ecosystems may not be successful due to limitations in growing conditions. Although complete eradication of patchy vegetation from entire land in site preparation can be time- and cost-saving compared to partial soil preparation with conserving existing vegetation this type of treatment may not be a promising strategy in terms of watershed protection in a dry environment. Therefore, regardless of vegetation type and desirability for livestock grazing, existing patches should be maintained in the areas where clearance of patches can increase erosion risk and vegetation manipulation is not necessary to increase composition of desirable forage plants. Thus, these existing patches can serve as a nucleus for seed production and future of seed for surrounding areas. A number of studies have been conducted worldwide to investigate effects of vegetation patches on soil beneath them. In the majority of these studies, researchers compared the chemical content of the soils under patches with those in the open spaces (Cerdán et al., 2016; Puigdefábregas, 2005) and the effects of patches composed of only certain shrub species (Cerdán et al., 2016, Erickson et al., 2005; Vásquez-Meéndez et al., 2010). Contrary, we examined effect of patches composed of more than one plant species including tree, shrub, grass, and forb species on the soils in the surrounding area of the patch canopy. In Turkey, forest service generally removes all existing patches regardless of patch size and use mechanical methods for revegetation of disturbed lands to save time and cost for a better soil tillage. This approach can have a high potential for failure especially in semiarid areas. Removal of all patch sizes can increase erosion potential and even accelerate it. Moreover, it can take time for rehabilitated lands to recover due to moisture deficit and become costly because of intensive land preparation works. Soil chemical characteristics directly influence the growth performances of the plants, and deficiencies of nutrients such as potassium, calcium, phosphorus, nitrogen, and magnesium stunt plant growth (Fenn et al., 2006; Uchida, 2000; Zhao et al., 2005). Therefore, the soil samples were analyzed for electrical conductivity (EC), pH, potassium (K^+), calcium (Ca^{+2}), magnesium (Mg^{+2}), phosphorus ($P\text{-}PO_4^{-3}$), total nitrogen (N), and total carbon (C). If patches with larger sizes have positive impacts on soil nutrients around the patches, then they can be kept in the site and function as a seed source for surrounding area. Hence, this study aimed to determine if some selected soil chemical properties around the patches change depending on patch size. If all patch sizes have similar effect on soil chemistry around the patches, then it can be concluded that all patches can be removed from the site to prepare the land for the revegetation.

MATERIAL AND METHODS

Study site

This study was carried out in Tatlıçay watershed in Çankırı (40° 33′–40° 51′ N latitudes and 33° 17′–33° 46′E longitudes). Size of the area is 67000 hectare (ha), and its elevation ranges from 720 m to 1820 m. About 50% of the area has steep or very steep

Table 1. Dominant plant species and their composition in the patches

Dominant plant species in the patches	Life forms	Overall composition (%)
Quercus macranthera Fisch. & Mey. Ex Hohen subsp. *syspirensis* (C. Koch) Menitsky	Tree, 1–2 m in diameter, 3–6 m in canopy diameter	25
Quercus pubescens Willd.	Tree, 5–10 m in height, 4–10 m in canopy diameter	15
Astragalus gossypinus Fischer *Astragalus anthylloides* Lam. *Astragalus emarginatus* Lab.	Herbaceous, 15–30 cm in height, 20–30 cm in canopy diameter	15
Pinus nigra Arn. subsp. *pallasiana* (Lamb.) Holmboe	Tree, 20–25 m in height, 10–20 m in canopy diameter	10
Gypsophila simulatrix Bornm. & Woron.	Herbaceous, 20–50 cm in height, 30–60 cm in canopy diameter	7
Juniperus oxycedrus L. subsp. *oxycedrus* *Juniperus* nana *Willd*.	Tree, 1–4 m in height, 2–4 m in canopy diameter	5
Amygdalus orientalis Miller.	Shrub, 0.5–1.5 m in diameter, 1–3 m in canopy diameter	5
Rosa dumalis Bechst. *Rosa canina* L. *Rosa gallica* L.	0.5–1.5 m in diameter, 1–1.5 m in canopy diameter	5
Grasses	Herbaceous, 3–7 cm in height, 3–5 cm in vegetative cover diameter	5
Paliurus spina-christi Mill.	Shrub, 1–1.5 m in diameter, 1–2 m in canopy diameter	3
Genista sessilifolia DC.	Herbaceous, 10–30 cm in height, 20–40 cm in canopy diameter	2
Hedysarum nitidum Willd.	Herbaceous, 5–10 cm in height, 10–20 cm in canopy diameter	2
Crataegus orientalis Pallas ex Bieb. *Rumex crispus* L. *Berberis vulgaris* L. *Melilotus officinalis* (L.) Pall. *Glycyrrhiza glabra* var. *glandulifera*. *Pyrus amygdaliformis* Vill. var. *amygdaliformis* *Jasminum fruticans* L. *Verbascum* sp. *Tamarix smyrnensis* Bunge. *Rhus coriaria* L. *Eryngium billardieri* Delar.	Some shrub and herbaceous plants with very small portions	Less than 1%

cm: centimeters; m: meters

slope greater than 12%. Mean annual precipitation is around 402.1 milimeters (mm), and over 60% of it falls during the dormant season. Average annual temperature is about 11.1°C and varies between 23°C in July and -0.6°C in January. Prevailing wind direction is southeast and originates from hot and dry air masses coming from Persian Gulf. The site has a semiarid continental climate with water deficit during the summer months according to Thornthwaite classification method. Soil of the study site is mainly composed of limestone and sedimentary rocks such as conglomerate and marl with gypsum. Soil texture is sandy silt with high lime content. The study site located in Central Anatolia under semiarid climatic conditions experiences severe soil erosion for decades due to degradation of vegetation cover as a result of human intervention. Because of land disturbance, the area has an unevenly distributed patchy vegetation cover and nutrient poor bare soil conditions in inter patches. Vegetation is mainly composed of dwarfed woody species like oak trees due to grazing and browsing, and spiny and noxious shrub species like *Astragalus* spp., with a small portion of herbaceous species that left ungrazed under the spiny shrubs patches or have relatively little forage value. Dominant plant species in the patches were identified, and their average composition was determined as a percent of total number of plant species in the patches (Table 1) (Gökbulak, 2013).

Soil sampling and analyses

Four transect lines with a minimum distance of 200 m from each other were established parallel to slope gradient at the same altitude, aspect, and similar slope in the study site where distribution of patches were almost uniform, topography and soil conditions were homogenous. Forty-eight vegetation patches that intercepted the transect lines were selected within 100 ha area. Based on mean diameter of canopy cover, vegetation patches were divided into three groups: 0–4 m, 4–8 m, and >8 m. To avoid influences of neighboring patches, distances between patches were kept with minimum that soil sampling points of two neighboring patches did not overlap each other. One soil sample from the beneath the approximate center of patch canopy and two samples from the near the patch with a half distance of canopy longest diameter were collected in the opposite direction on straight line through the patch canopy center (Figure 1). Thus, the soil sampling locations around the patches varied for each patch size depending on the longest diameters of the canopies. A total of three soil samples from the top soil (0–10 cm soil depth) under, and surrounding area of the patch canopy were collected for each patch intercepted the transect line (Figure 1). To prevent sampling errors and to decrease the effect of heterogeneity, soil samples were mixed and a subsample was taken as a representative of each patch sampled. A total of 20 samples for the small (0–4 m in diameter), 14 for the medium-sized (4–8 m in diameter), and 14 for the large (>8 m in diameter) patches were collected. The soil samples were analyzed according to the methods briefly described in Gülçur (1974) as below. Firstly, samples were air-dried and sieved through a 2 mm mesh for chemical analysis. EC and pH (soil/water ratio of 1/5) were determined using a WTW Multiline P4 (WTW; Weilheim, Germany) universal meter. K^+, Ca^{+2}, and Mg^{+2} were extracted from the samples using 1 N ammonium acetate solution. P-PO_4^{-3} was determined according to the molibdophosphoric blue color method using a PerkinElmer 2100 DV (Perkin Elmer; Waltham, Massachusetts, USA) atomic absorption spectrophotometer equipment (APHA-AWWA-WPCF 1975). Total N and total C were measured using a Leco Truspec CN 2000 (Leco; Michigan, USA) device as explained in its instructions manual. Data were analyzed using one-way variance analyses (ANOVA) to determine a statistically significant difference between data values. Since data should have a normal distribution to apply one-way ANOVA, Kolmogorov–Smirnov test was

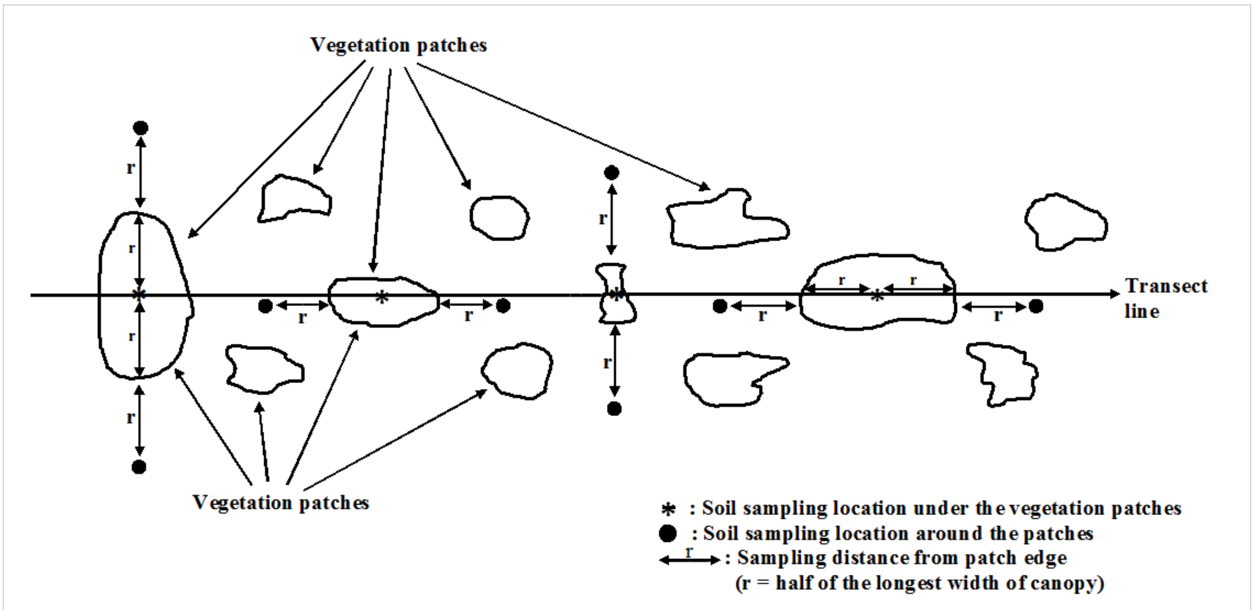

Figure 1. Schematic sketch of soil sampling location under and around the patch canopies

used. The variables that did not show normal distribution were approached to normal by logarithmic transformations. Means were separated with Tukey test ($p<0.05$) (Zar 1996). To all over statistical analyses, Statistical Package for the Social Sciences 21.0 was applied 2012 (SPSS IBM Corp.; Armonk, NY, USA).

RESULTS AND DISCUSSION

Results showed that patch size did not have significant effect on selected soil chemical characteristics except for nitrogen and phosphorus (Table 2). The soils around all patch sizes had similar pH values. Soil reaction was alkaline and varied between 7.10 and 7.55. EC values of the soils decreased from 0.55 µS/cm for the small patch to 0.35 µS/cm for the large patch, but these decreases were not statistically significant. Phosphorus was one of the two soil chemical characteristics that showed changes depending on patch size. Soils around the small and medium-sized patches had similar phosphorus values, whereas soils around the large patch had significantly almost two fold greater phosphorus content (0.03 g/L). Potassium content of the soils from surrounding of different patch size varied between 0.18 g/L and 0.34 g/L and did not show significant differences (Table 2). Calcium values decreased from 8.24 g/L to 4.06 g/L and magnesium values from 1.38 g/L to 0.43 g/L as patch size decreased, but the decreases were not great enough to be statistically significant among the patches ($p>0.05$). Total nitrogen was another soil chemical parameter that was significantly affected by patch size. Soils around the small and medium-sized patches had similar nitrogen content, whereas that around the large patches had significantly the greatest total nitrogen content ($p<0.05$) (Table 2). Similar to total nitrogen content, the large patches had the greatest total carbon content than soils around the small and medium-sized patches. However, the differences between the soil carbon contents were not statistically significant, and they varied between 3.11% and 4.83%.

Similar studies showed that it is very difficult to make generalization about effect of patch size on soil chemical properties. The differences between results of various studies can be attributed to the differences in the plant composition of the patches and the location of the soil sampling around the patches. For instance, Fraser and Carlyle (2011) investigated impacts of patches dominated only by spotted knapweed (*Centaurea stoebe* L.) with various sizes. They found that spotted knapweed patch size had significant influence on soil chemical properties. In contrast to results of our study, they stated that as patch size increased, soil carbon and nitrogen contents decreased and phosphate increased. In some studies, chemical contents of the soils under the patches were compared with those of the soils in the interspaces. There is no study available considering the soil characteristics under the patches and patch neighbors together. Cross and Schlesinger (1999) examined soil chemical characteristics under two shrubs, creosote bush and broom snakeweed dominated patches, and compared them with the soil properties in interspaces. In that study, researchers found that concentrations of phosphorus, nitrogen, and potassium were higher in the soils under the shrub canopy than those in the inter-patch spaces. Similarly, Cerdán et al. (2016) also investigated effects of woody patches dominated by some shrub species including *Pistacia lentiscus* L., *Quercus coccifera* L., *Ephedra fragilis* Desf., *Juniperus oxycedrus* L., and *Rhamnus lycioides* L. on the soils under the shrub canopies and compared these soil characteristics with those from interspaces in Southern Spain. They reported higher dissolved organic matter under the patches than inter-patch spaces. As seen from the literature, results can vary depending on differences in plant species, climate and soil conditions, and soil sampling location.

Even though most of the soil chemical characteristics were not significantly affected by patch size, phosphorus and nitrogen contents of the soils significantly increased with patch size. Since both nutrients are essential elements for plant growth (Firmansyah et al., 2017), and their deficiencies retard or stunt plant growth together with other nutrients (Fan et al., 2016; Li et al., 2016; Uchida 2000), impact of large patches on soil phos-

Table 2. Mean values (mean ± SEM) of selected chemical parameters in the soils around the vegetation patches with different diameters. Means with different superscript letters are significantly different between patch sizes at the same row (p<0.05)

	Patch diameter range (m)			
Soil chemical parameters	0–4 (n=20)	4–8 (n=14)	>8 (n=14)	Significance
pH	7.40±0.13	7.55±0.11	7.10±0.16	$p>0.05$
Electrical conductivity (µS/cm)	0.55±0.08	0.52±0.09	0.35±0.04	$p>0.05$
Phosphorus (g/L)	$0.01^{a}\pm0.002$	$0.01^{a}\pm0.002$	$0.03^{b}\pm0.01$	$p<0.05$
Potassium (g/L)	0.23±0.03	0.18±0.02	0.34±0.07	$p>0.05$
Calcium (g/L)	8.24±1.94	7.02±1.94	4.06±0.52	$p>0.05$
Magnesium (g/L)	1.38±1.02	0.51±0.13	0.43±0.05	$p>0.05$
Nitrogen (%)	$0.62^{a}\pm0.02$	$0.60^{a}\pm0.01$	$0.70^{b}\pm0.04$	$p<0.05$
Carbon (%)	$3.55^{a}\pm0.43$	$3.11^{a}\pm0.37$	$4.83^{a}\pm0.76$	$p>0.05$

g: grams; L: liter; m: meters; n: number of sub-samples; p: level of significance phorus and nitrogen content should be considered before land preparation in the poor nutrient conditions such as the study sites in this study.

CONCLUSION

Results of this study showed that phosphorus and nitrogen content of the soil were influenced by patch size. Since both chemicals are macronutrients for plant growth, their deficiencies negatively affect plant growth in addition to other nutrients. Under poor nutrient conditions, large patches can be protected from vegetation clearance in the sites where the lands are rehabilitated. Based on results of this study, it can be said that small and medium-sized patches can be cleared from the land in the revegetation studies in this semiarid regions to manage a better soil preparation and to save time and cost. To have a clear picture, we need more studies to reach a conclusion about if patch sizes play important role on soil chemical content and if it is necessary to keep or remove all existing vegetation patches prior to revegetation of degraded lands during the soil preparation processes in the arid and semiarid regions.

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REFERENCES

- Aguiar, M.R., Sala, O.E., 1994. Competition, facilitation, seed distribution and the origin of patches in a Patagonian steppe. *Oikos*, 70, 26-34. **[CrossRef]**
- Aguiar, M.R., Sala, O.E., 1999. Patch structure, dynamics and implications for the functioning of arid ecosystems. *Trends in Ecology and Evolution* 14(7): 273-277. **[CrossRef]**
- APHA, AWWA, WPCF., 1975. Standard Methods for the Examination of Water and Wastewater. 14th edition, Washington, DC.
- Boer, M., Puigdefábregas, J., 2005. Effects of spatially structured vegetation patterns on hillslope erosion in a semiarid Mediterranean environment: a simulation study. *Earth Surface Processes and Land Forms* 30: 149-167. **[CrossRef]**
- Cerdán, M., Sánchez-Sánchez, A., Jordá, J.D., Amat, B., Cortina, J., Ruiz-Vicedo, N., El-Khattabi, M., 2016. Characterization of water dissolved organic matter under woody vegetation patches in semi-arid Mediterranean soils. *Science of the Total Environment* 553: 340-348. **[CrossRef]**
- Cross, A.F., Schlesinger, W.H., 1999. Plant regulation of soil nutrient distribution in the northern Chihuahuan Desert. *Plant Ecolology* 145: 11-25. **[CrossRef]**
- Erickson, H.E., Soto, P., Johnson, D.W., Roath, B., Hunsaker, C., 2005. Effects of vegetation patches on soil nutrient pools and fluxes within a mixed-conifer forest. *Forest Science* 51(3): 211-220.
- Fan, J.W., Du, Y.L., Wang, B.R., Turner, N.C., Wang, T., Abbott, L.K., Stefanova, K., Siddique, K.H.M., Li, F.M., 2016. Forage yield, soil water depletion, shoot nitrogen and phosphorus uptake and concentration, of young and old stands of alfalfa in response to nitrogen and phosphorus fertilisation in a semiarid environment. *Field Crops Research* 198: 247-257. **[CrossRef]**
- Fenn, M.E., Perea-Estrada, V.M., de Bauer, L.I., Perez-Suarez, M., Parker, D.R., Cetina-Alcala, V.M., 2006. Nutrient status and plant growth effects of forest soils in the Basin of Mexico. *Environmental Pollution* 140: 187-199. **[CrossRef]**
- Firmansyah, I., Spiller M., de Ruijter, F.J., Carjens, G.J., Zeeman, G., 2017. Assessment of nitrogen and phosphorus flows in agricultural and urban systems in a small island under limited data availability. *Science of the Total Environment* 574: 1521-1532. **[CrossRef]**
- Fraser, L.H., & Carlyle, C.N., 2011. Is spotted knapweed (*Centaurea stoebe* L.) patch size related to the effect on soil and vegetation properties? *Plant Ecology* 212: 975-983. **[CrossRef]**
- Gökbulak, F., 2013. Vegetation Analyses in Rangelands. Istanbul University publication no: 5151, Faculty of Forestry publication no: 503. Yazın Basın Matbaacılık TRZ. Tic. Ltd. Şti: Istanbul-Turkey.
- Gülçur, F., 1974. Toprağın fiziksel ve kimyasal analiz metodları. İstanbul Üniversitesi Orman Fakültesi Yayınları, İ.Ü. Yayın No: 1970, OF Yayın No: 201, Kutulmuş Matbaası, İstanbul (In Turkish).
- IBM, 2012. IBM Corp. Released IBM SPSS statistics for Windows, version 21.0. Armonk: IBM Corp.
- Lequy, E., Calvaruso, C., Conil, S., Turpault, M.P., 2014. Atmospheric particulate deposition in temperate deciduous forest ecosystems: Interactions with the canopy and nutrient inputs in two beech stands of Northeastern France. *Science of the Total Environment* 48: 206-215. **[CrossRef]**
- Li, J., Guo, Q., Zhang, J., Korpelainen, H., Li, C., 2016. Effects of nitrogen and phosphorus supply on growth and physiological traits of two Larix species. *Environmental and Experimental Botany* 130: 206-215. **[CrossRef]**
- Maestre, F.T., Cortina, J., 2002. Spatial patterns of surface soil properties and vegetation in a Mediterranean semi-arid steppe. *Plant and Soil* 241: 279-291. **[CrossRef]**
- Maestre, F.T., Escudero, A., 2009. Is the patch size distribution of vegetation a suitable indicator of desertification processes? *Ecology* 90(7): 1729-1735. **[CrossRef]**
- Muvengwi, J., Ndagurwa, H.G.T., Nyenda, T., 2015. Enhanced soil nutrient concentrations beneath-canopy of savanna trees infected by mistletoes in a southern African savanna. *Journal of Arid Environments* 116: 25-28. **[CrossRef]**
- Puigdefábregas, J., 2005. The role of vegetation patterns in structuring runoff and sediment fluxes in drylands. *Earth Surface Processes and Landforms* 30: 133-147. **[CrossRef]**
- Ridolfi, L., Laio, F., D'Odorico, P., 2008. Fertility island formation and evolution in dryland ecosystems. *Ecology and Society* 13(1): 5. Online document. **[CrossRef]**
- Available from: http://www.ecologyandsociety.org/vol13/iss1/art5/. Accessed 13 October 2017.
- Roundy, B.A, Call, C.A., 1988. Revegetation of arid and semiarid rangelands, in: P.T. Tueller (ed.), Vegetation Science Applications for Rangeland Analysis and Management. Kluwer Academic Publishers, Dordrecht, Boston. **[CrossRef]**

- Schade, J.D, Sponseller, R., Collins, S.L., Stiles, A., 2003. The influence of *Prosopis* canopies on understorey vegetation: Effects of landscape position. *Journal of Vegetation Science* 14: 743-750. **[CrossRef]**
- Schade, J.D., Hobbie, S.E., 2005. Spatial and temporal variation in islands of fertility in the Sonoran Desert. *Biogeochemistry* 73: 541-553. **[CrossRef]**
- Uchida, R., 2000. Essential Nutrients for Plant Growth: Nutrient Functions and Deficiency Symptoms. In: Silva A.J., and Uchida, R. (Eds.), Plant Nutrient Management in Hawaii's Soils, Approaches for Tropical and Subtropical Agriculture, College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa, Honolulu.
- Vásquez-Méndez, R., Ventura-Ramos, E., Oleschko, K., Hernández-Sandoval, L., Parrot, J.F., Nearing, M.A., 2010. Soil erosion and runoff in different vegetation patches from semiarid Central Mexico. *Catena* 80: 162-169. **[CrossRef]**
- Zar, J.H. 1996. Biostatistical Analysis. 3rd ed. Prentice-Hall, Upper Saddle River.
- Zhao, D., Reddy, K.R., Kakani V.G., Reddy V.R., 2005. Nitrogen deficiency effects on plant growth, leaf photosynthesis, and hyperspectral reflectance properties of sorghum. *European Journal of Agronomy* 22: 391-403. **[CrossRef]**