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Original Research

Comparison of Correlations between Soil Physicochemical Properties and Diversity-Density of Soil Macrofauna in Juniper and Amygdalus Stands During the Growing and Resting Season (Case Study: Geno Protected Area, Hormozgan Province, Iran)

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Abstract

The present study was an attempt to compare the correlation between physicochemical properties of soil and diversity and density of soil macrofauna in Juniper and Amygdalus stands of Geno protected area during the growing and resting seasons. To this end, researchers field visited part of the forest at an altitude of 2200 m asl. and identified a half-hectare Juniper and a half-hectare Amygdalus stand. 10 points were randomly selected to place the sampling frame and measure the macrofauna and soil physicochemical properties. Soil samples were collected at 15 cm soil depth using a rectangular sampling frame (15 × 10. 10 cm) in growing and dormant seasons. Shannon-Wiener and Simpson diversity indices were used to evaluate the biodiversity of the identified macrofauna, and then Menhinick's and Margalef

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indices were used to evaluate the bio-richness of soil samples through Past3 software. The collected data were analyzed using SPSS26 software. The results showed that the coefficient of multiple correlation is significant for the linear combination of all research elements (5%) in Juniper and Amygdalus stands. In the Juniper and Amygdalus stands, specific weight account for 33% and 11% of the benchmark variables (the diversity and density of soil macrofauna) respectively. Biomass was also found to account for 43% of the diversity and density of soil macrofauna in Juniper and 31% of macrofauna diversity and density in the Amygdalus stands. PH accounted for 32% of macrofauna diversity and density in Juniper stand and 21% of macrofauna diversity and density in Amygdalus stand, EC accounted for 13% and 18% of macrofauna diversity and density in the Juniper and Amygdalus stands, respectively, nitrogen accounted for 12% and 23% of macrofauna diversity and density in the Juniper and Amygdalus stands, respectively, phosphorus accounted for 33% and 19% of macrofauna diversity and density in the Juniper and Amygdalus stands, respectively. Organic carbon accounted for 12% and 11% of macrofauna diversity and density in the Juniper and Amygdalus stands, respectively.

Keywords: flora families, geno protected area, growing and resting seasons, soil physical and chemical characteristics

Introduction

Soil is recognized as a critical component and the foundation of an ecosystem, as soil productivity determines what an ecosystem will look like in terms of the plant and animal life it can support. For example, in forest ecosystems, soils can determine species composition, timber productivity, and wildlife habitat, richness, and diversity. The role soil plays in forests is also critical to maintaining water quality and long-term site productivity [1-5]. Most natural, non-perturbated soils have three distinct layers of variable thickness. The physical properties of soil are characteristics that can be seen, felt, or measured. These include color, texture, structure, and water-holding capacity. Such properties usually determine the suitability of soil as a growth medium. Soil texture, which refers to the proportions of sand, silt, and clay, influences nearly every aspect of soil use and management. Sand is the largest particle (at 2.0 to 0.05 mm), silt is much smaller (0.05 to 0.002 mm), and clay is the smallest (less than 0.002 mm). Soil provides a variety of ecosystem services that benefit the human population and allow ecosystems to function properly [6]. In addition, soil is recognized as a globally important reservoir of biodiversity because macrofauna is an important component of soil biodiversity [7-10]. Macrofauna can be used as a biological indicator of the impacts on land use, for its relationship with the physical and chemical properties of the soil, and for its rapid variation over a short period of time that is a product of changes in cover and transformation in vegetation [3, 11-13]. Studies show that shifts in composition and structure of vegetation during secondary succession through natural regeneration and forest restoration are fairly well-known, but knowledge associated with changes

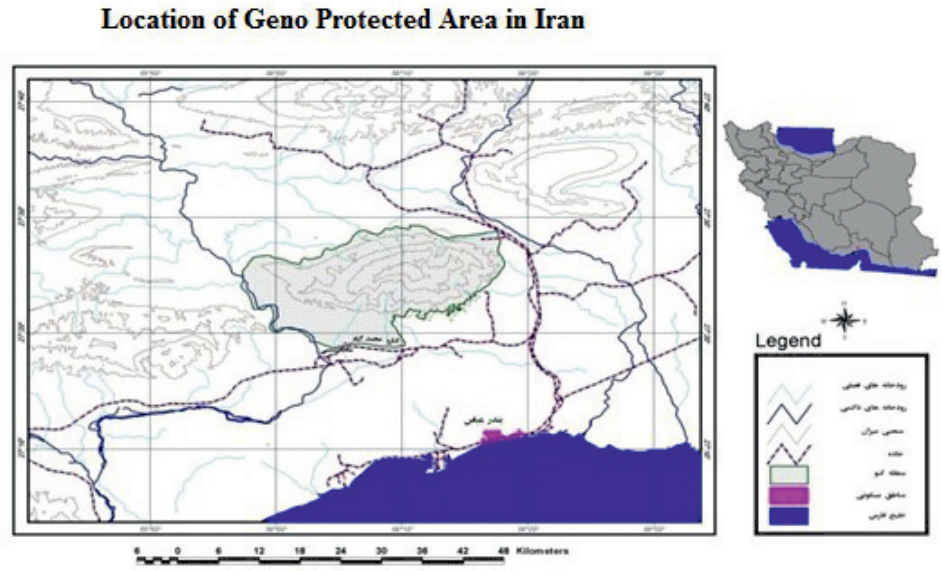

Fig. 1. Location of the Geno Biosphere Reserve in Iran.

in soil macrofauna is still limited. [4, 10, 14-17]. Amazonas et al. [18] evaluated the density and diversity of soil macrofauna during the tropical forest restoration period in southeastern Brazil. The results of this study indicate patterns of transformation in soil macrophages along the chronological order. Density did not increase along secondary succession, but was correlated with canopy cover. Diversity was characterized by high dominance of social insects and evenness among other groups [13]. We conclude soil macrofauna has a high capacity to recolonize young forests and that its recovery is considerably fast compared to other ecosystem transformations. In another study, Suárez et al. [19] examined soil macrofauna under various land uses in the Columbian Amazon. The objective of this work was to evaluate the soil macrofauna and the bioindicator taxonomic groups associated with different land uses in the Colombian Amazon. For each land use, six monoliths were randomly selected and divided into four layers (litter, and 0-10, 10-20, and 20-30 cm soil depths). The variables considered in the analysis of land use effects were: individuals per square meter, order richness, Shannon's diversity index, and Pielou's evenness index. The greatest values for soil macrofauna density and diversity occurred in the forest, in contrast with the pasture. The principal component analysis distinguished land use according to macrofauna diversity, separating the native forest from the other land uses. The cluster analysis indicated the potential of some agroforestry systems to conserve the values of soil macrofauna density and diversity similar to those of the forest. According to the analysis of indicator value, five taxonomic groups (Diplura, Pseudoscorpionida, Araneae, Chilopoda, and Gastropoda), identified as bioindicators, are associated with preserved sites because of the sensitivity of their populations., Laossi et al. [20] investigated the effects of plant diversity on plant biomass production and soil macrofauna in the Amazon rangelands. The results of this study showed that Fauna diversity increased significantly with shoot biomass. Root biomass did not affect fauna density and diversity. The results suggest that fauna density is affected by titter quality and that it is more affected by resource quantity than quality. Our results also confirm the importance of nitrogen fixers to ecosystem function. In another study, Tsufac et al. [21] found that t increasing tree species diversity and density leads to increasing soil macro-fauna diversity and density in cocoa-based agroforestry systems [22, 23]. Sembiring et al. [12] investigated soil macrofauna diversity after eight years of Mount Sinabong eruption in Sumatra, Indonesia. The results of this study showed that the thicker the volcanic ash covering the soil surface, it would reduce soil moisture, soil water content, organic C, and soil pH, but on the other hand, increase the soil temperature [24, 11]. A total of 20 species were able to live on the Andisols affected by the eruption of Mount Sinabung. The present study also is an attempt to compare the correlation between soil physicochemical properties and diversity and density of soil macrofauna in Juniper and Amygdalus during the growing and resting season in Geno Protected Area, Hormozgan, Iran.

Materials and Methods

Study Area

The Geno Biosphere Reserve, covering an area of about 43,000 hectares, is one of the thirteen UNESCO Biosphere Reserves in Iran, which is located in the northwest of Bandar Abbas (Location: 27°24'10"N – 56°37'41"E). The average annual temperature of the area is 26.8ºC, the average annual rainfall varies from 290.3 mm to 348.75 mm, in the altitude range of 50 to 2347 meters. The soils of the study fall within the category of sandy and loamy soils and are classified, in terms of lime percentage, into groups of soils with very large amounts of lime (more than 30%). As for salinity, the soil of the study area falls within the category of ordinary soils. As for flora geography, the flora of Mount Geno belongs to the Sahara-Sandi and Irano-Turanian vegetation zones. At a glance, one can easily pinpoint three distinct vegetative layers including acacia and porkh on the slopes, Amygdalus in the middle altitudes and Juniper in the peaks and upper altitudes. The vegetation of the region covers more than 360 species of vascular plants, with the smaller proportion being ferns and reptiles and the larger proportion being flowering plants. As is the case in arid and desert areas, two groups of woody shrubs and short-lived annuals have the greatest diversity in this region. Prosopis, Christ's thorn jujube, acacia and salt cedar trees grow on low slopes and plains and are often accompanied by woody shrubs and porkh, Dodonaea, Salvadora persica, and Calotropis procera shrubs. Olea europaea, Amygdalus, turpentine, and Pistacia atlantica trees along with woody shrubs such as Spongiforme and Convolvulus as well as a large number of Semi-woody and herbaceous plants grow in the middle of the highlands, sometimes forming dense groves. Amygdalus and Montpellier maple trees, along with Cotoneaster shrubs and beautiful Dionysia revoluta bushes and a number of other woody plants and small and large shrubs, accompany Juniper trees in the highlands [25].

Methodology

After touring through the forests at an altitude of 2200 m a.s.l.,, researchers detected a half-hectare Juniper stand and a half-hectare Amygdalus stand. In the next step, the canopy of the trees was measured. Once the tree canopies were measured, 10 points in each stand were randomly selected in order to measure the macrofauna and soil chemical properties using a sampling frame. Soil samples were collected from

Table 1. Flora families identified in the Amygdalus stands in the Geno Biosphere reserve.

Cydnidae	Scolopocryptoidae	Thomisidae	Larva of Nymphalidae
Embiidae	Tingidae	Scutelleridae	Carabidae
Coccinellidae	Staphylinidae	Linyphiidae	Lepismatidae
Formicidae	Syrphidae	Lygaidae	Anthocoridae
Clubionidae	Miridae	Pompilidae	Olpiidae
Gryllidae	Tenebrionidae	Ixodidae	Pentatomidae
Hydrometridae			

Table 2. Flora families identified in the Juniper stands in the Geno Biosphere reserve.

Platygastridea	Coccinellidae	Alydidae	Pompilidae	Pentatomidae
Tenebrionidae	Clubionidae	Embiidae	Lycosidae	Miridae
Syrphidae	Cydnidae	Larva of Papilionoidea	Lepismatidae	Myrmeleontidae
Carabidae	Cynidnae	Elateridae Larve	Ixodidae	Scolopocryptoidae
Gryllidae	Cicadellidae	Lepismtidae	Hydrometridae	Rhagodidae
Armadillidiidae	Thomisidae	Formicidae	Linyphidae	Lygaidae

15 cm soil depths using a rectangular sampling frame (15 × 10. 10 cm) in two seasons of growth and rest. Macrofuna were separated manually. Soil temperature was measured and recorded at the sampling site. In this process, the electrodes of a digital thermometer were placed at 15 cm soil depth. Soil samples were collected from the same points and soil depths. The samples were subjected to chemical analysis in a lab. Percentage of soil moisture was determined by collecting samples from 15 cm soil depth and measuring the dry and wet weight of the sample [2], Percentage of matter and organic carbon was measured using Walky-black method, Electrical conductivity was measured using soil saturated extract [8], Nitrogen was measured using Kjeldahl's measurement technique, Phosphorus was calculated using the technique proposed by Olsen Ribeiro et al. [26], potentiometric acidity was measured using a pH meter [12], soil texture was calculated using Bukas hydrometry method, and bulk density was measured using the agglomeration method). In order separate macrofauna, a soil sample collected by the sampling frame was dumped on the surface of a nylon, then the macrofauna was carefully separated, and placed in 70% alcohol for identification. Digital Mecroscop Eei camera was used to capture images of the macrofauna isolated from the soil.

Shannon-Wiener and Simpson diversity index was used to evaluate the biodiversity of the identified macrofauna. Richness was measured using Menhinick's and. Margalef's richness indice through Past3 software. Soil macrofauna were identified using the taxonomic classification keys proposed by Borror [27]. Once identified, the soil macrofauna were oven dried at 60ºC for 72 hours, and then their dry weight was measured with precision 0.001. Data were analyzed using SPSS 26 software. The normality of the data was checked using the Kolmograph-Smirnov test and the result showed that all the data are normal. the correlation between diversity and density of soil macrofauna and the physical and chemical properties of soil was measured and compared in growing and resting seasons using Pearson correlation coefficient test (p = 95%). Also, repeated measure multiple regression test was used to investigate the correlation between predictor variables and the diversity and density of soil macrofauna in the growing and resting seasons.

Formula:

Diversity indices	Formula	Description
Shannon's diversity index (H')	$H' = -\sum_{i=1}^{R} pi \cdot \ln pi$	ni, the number of clones in the ith OTU
Simpson's index of diversity (1-D)	$D = \sum_{i=1}^{R} \frac{ni(ni-1)}{N(N-1)}$	N, total number of the individuals in each sample
Menhinick's index (Dmn)	$Dmn = \frac{S}{\sqrt{N}}$	pi, ni over N
Margalef's index (Dmg)	$Dmg = \frac{(S-1)}{\ln(N)}$	

Table 3. Pearson correlation test results for the correlation between physicochemical properties of soil and diversity and density of soil macrofauna in Juniper stand during the growing season.

	Specific weight	Biomass	pH	EC	Nitrogen	Phosphorus	Organic carbon	Temperature	Moisture	Soil texture
Simpson's index	0.003	0.023	0.442	0.72	0.62	0.002	0.003	0.000	0.65	0.003
Shannon-Wiener	0.001	0.287	0.000	0.000	0.004	0.543	0.003	0.000	0.000	0.000
Evenness	0.03	0.664	0.006	0.000	0.003	0.003	0.006	0.403	0.003	0.006
Menhinick	0.001	0.001	0.001	0.006	0.000	0.000	0.000	0.000	0.003	0.002
Margalef	0.006	0.001	0.001	0.001	0.000	0.000	0.001	0.000	0.001	0.001

Table 4. Pearson correlation test results for correlation between physicochemical properties of soil and diversity and density of soil macrofauna in Juniper stand during the resting season.

	Specific weight	Biomass	pH	EC	Nitrogen	Phosphorus	Organic carbon	Temperature	Moisture	Soil texture
Simpson's index	0.004	0.000	0.000	0.008	0.008	0.1	0.103	0.000	0.000	0.008
Shannon-Wiener	0.01	0.003	0.000	0.3	0.004	0.002	0.008	0.008	0.002	0.312
Evenness	0.002	0.002	0.000	0.007	0.000	0.002	0.9	0.004	0.004	0.008
Menhinick	0.008	0.004	0.000	0.000	0.12	0.66	0.333	0.007	0.008	0.002
Margalef	0.007	0.000	0.000	0.000	0.000	0.000	0.44	0.51	0.17	0.002

Table 5. Pearson correlation test results for correlation between physicochemical properties of soil and diversity and density of soil macrofauna in Amygdalus stand during the growing season.

	Specific weight	Biomass	pPH	EC	Nitrogen	Phosphorus	Organic carbon	Temperature	Moisture	Soil texture
Simpson's index	0.002	0.001	0.002	0.000	0.007	0.001	0.000	0.000	0.002	0.001
Shannon-Wiener	0.002	0.000	0.000	0.000	0.002	0.005	0.000	0.3	0.009	0.002
Evenness	0.000	0.003	0.213	0.661	0.002	0.19	0.002	0.002	0.9	0.000
Menhinick	0.000	0.005	0.000	0.000	0.41	0.32	0.15	0.000	0.02	0.01
Margalef	0.001	0.000		0.000	0.002	0.000	0.000	0.000	0.000	0.000

Results

The flora families identified in the Amygdalus and Juniper stands in the Geno Biosphere reserve are described in Tables 1 and 2. Pearson correlation coefficient (with a significance of 5%) was used to test the correlation between soil physicochemical properties and diversity and density of soil macrofauna in Juniper and Amygdalus stands during the growing and resting seasons. In this test, if the significance level is lower than the error rate (0.05%), the existence of a significant correlation between the two variables is proved. And if the significance level is greater than the error rate, it can be concluded that there is no significant correlation between the two variables. The results of Pearson correlation coefficient test used to check the correlation between physicochemical properties of soil and diversity and density of soil macrofauna in Juniper stand during the growing season are presented in Table 3. As the table shows, there is a significant positive correlation between Simpson's diversity index, specific weight, phosphorus, organic carbon, and temperature and soil texture during the growing season. Because the significance level for these variables is less than 5% and is statistically significant. There is also a significant positive correlation between Shannon-Wiener diversity index and specific weight, pH, EC, nitrogen, organic carbon, temperature, moisture and soil texture. Study of the correlation between evenness index and physicochemical properties of soil shows that there is a significant positive correlation between evenness index, specific weight, pH, EC, nitrogen, phosphorus, organic carbon, temperature, moisture and soil texture. The results also show that there is a significant positive correlation between evenness index and specific weight, pH, EC, nitrogen, phosphorus, organic carbon, soil moisture and texture. Menhinick and. Margalef's richness index was also found to be positively correlated with all physicochemical properties of soil in the Juniper stand during the growing season.

According to Table 4, there is a significant positive correlation between Simpson index and specific weight, biomass, pH, EC, nitrogen, temperature, moisture, and soil texture in the Juniper stand during the resting season. Shannon-Wiener index was also found to be positively correlated with all physicochemical properties of soil except for soil texture. The results also showed that, the evenness index has a positive and significant correlation with all physicochemical properties (p = 5%) in the Junipers stand during the resting season. The Menhinick index was also found to have a significant positive correlation with specific weight, biomass, pH, EC, temperature, moisture and soil texture. Margalef index for the Juniper stand was also found to be positively correlated with specific weight, biomass, pH, EC, nitrogen, phosphorus and soil texture during the resting season.

The results of the correlation between physicochemical properties of soil and the diversity and

Table 6. Pearson correlation test results for correlation between physicochemical properties of soil and diversity and density of soil macrofauna in Amygdalus stand during the resting season.

	Specific weight	Biomass	pH	EC	Nitrogen	Phosphorus	Organic carbon	Temperature	Moisture	Soil texture
Simpson's index	0.008	0.001	0.000	0.06	0.008	0.001	0.000	0.003	0.008	0.001
Shannon-Wiener	0.000	0.001	0.008	0.09	0.001	0.665	0.000	0.000	0.000	0.991
Evenness	0.000	0.001	0.49	0.111	0.000	0.001	0.008	0.91	0.006	0.008
Menhinick	0.001	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.1	0.000
Margalef	0.000	0.001	0.11	0.000	0.000	0.008	0.008	0.003	0.000	0.000

Table 7. Repeated measure multiple regression between predictor variables and the diversity and density of soil macrofauna.

Predictor variable	Juniper			Amygdalus		
	Multiple correlation	Coefficient of determination	Sig	Multiple correlation	Coefficient of determination	Sig
Specific weight	0.21	0.33	0.001	0.331	0.11	0.000
Biomass	0.28	0.43	0.001	0.64	0.31	0.003
PH	0.16	0.32	0.000	0.543	0.21	0.003
EC	0.112	0.13	0.000	0.663	0.18	0.001
Nitrogen	0.664	0.12	0.002	0.504	0.23	0.000
Phosphorus	0.324	0.33	0.000	0.981	0.19	0.000
Organic carbon	0.652	0.12	0.001	0.408	0.11	0.000
Temperature	0.221	0.11	0.001	0.384	0.35	0.000
Moisture	0.766	0.17	0.000	0.66	0.15	0.000
Soil texture	0.604	0.31	0.005	0.54	0.11	0.000

density of soil macrophytes in the Amygdalus stand during the growing and resting seasons are presented in Tables 5 and 6, respectively. As Table 5 shows, there is a significant positive correlation between Simpson and Margalef and Shannon-Wiener indices and the soil physicochemical properties in the Amygdalus stand during the growing season. The evenness index was also found to have a significant positive correlation with specific weight, biomass, nitrogen, organic carbon, temperature and soil texture. The results also showed that Menhinick index has a positive correlation with all physicochemical properties of soil except for nitrogen, phosphorus and organic carbon.

According to Table 6 there is a significant positive correlation between Simpson index and physicochemical properties of soil in the Amygdalus stand during the resting season. The results also showed that Shannon-Wiener index is positively correlated with specific weight, biomass, PH, PC, nitrogen, organic carbon, temperature, moisture. The evenness index was also found to be positively correlated with specific weight, biomass, nitrogen, phosphorus, organic carbon, soil moisture and texture. A significant positive correlation was also observed between all physicochemical properties of soil and Menhinick-Margalef indices.

In the next step, the multiple correlations between soil physicochemical properties and the diversity and density of soil macrofauna in Juniper and Amygdalus stands was obtained. As Table 7 shows, the multiple correlation coefficient is significant for the linear composition of all research components (p = 5%) in Juniper and Amygdalus stands. In the Juniper and Amygdalus stands, specific weight accounts for 33% and 11% of the criterion variables, i.e. the diversity and density of soil macrofauna. Biomass accounts for 43% and 31% of the diversity and density of soil macrofauna in Juniper and Amygdalus stands, respectively. In addition pH accounts for 32% and 21% of diversity and density in Juniper and Amygdalus stands, EC accounts for 13% and 18% of criterion variables in Juniper and Amygdalus stands, nitrogen accounts for 12% and 23% of the criterion variables in Juniper and Amygdalus stands, phosphorus accounts for 33% and 19% of criterion variables criterion variables in Juniper and Amygdalus stands, and finally organic carbon accounts for 12% and 11% of criterion variables criterion variables in Juniper and Amygdalus stands explain the criterion variables.

Discussion and Conclusion

Biodiversity of soil macrofauna can significantly contribute to preservation of health of ecosystems and habitats of other flora and fauna species. Variations in soil quality and diversity indices are proportional to soil characteristics and forest habitat fertility [6, 28]. Macrofauna populations represent the ability to create habitat in the future and can serve as a suitable criterion to evaluate the performance of forest management in terms of ecosystem protection and sustainability. Amazonas et al. [18] showed patterns of transformation in soil macrofauna along chronological succession. The results of the present study also indicate transformations in the diversity and density of the macrofauna during the growing and resting seasons, which is consistent with the results of Amazonas et al. Suárez et al. [19] also showed that forests account for the highest proportion of soil macrofauna density and diversity [29, 17]. The results of the present study are also indicative of high diversity and density of soil macrofauna. Laossi et al. [20] investigated the effects of plant diversity on biomass production and soil macrofauna in the Amazon rangelands [30]. The results of this study

showed significant increases in soil macrofauna and biomass. The results of the present study also showed a significant positive correlation between soil biomass and Menhink and Margalef indices in Juniper stands during the growing season [31]. A significant positive correlation was also observed between Simpson index, Menhinick index, evenness and biomass in the Juniper stand during the resting season [22]. Margalef index was found to be positively correlated with biomass in Juniper stand during the resting season. Simpson, Menhink, Margalef and Shannon-Wiener index as well as evenness index were also found to be positively correlated biomass in the Amygdalus stand, during the growing season of. A significant positive correlation was also observed between biomass and some indices such as Simpson index, Shannon-Wiener index, evenness index, Menhink and Margalef index in Amygdalus stand during the resting season [32]. This finding is consistent with the results of Laossi et al. [20]. Since there is a significant positive correlation between physicochemical properties and diversity and density of soil macrofauna, it can be argued that both Amygdalus and Juniper stands have provided suitable conditions for soil macrofauna [33]. Therefore, Amygdalus and Juniper species can be recognized as one of the most suitable species for afforestation and development of forest lands and providing the ground for enhancement of soil's physical and chemical properties [34].

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Conflict of Interest

The authors declare no conflict of interest.

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