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Assessment of plant biological diversity and soil characteristics in the pure ash tree stand and in mixture with beech (a case study of Lavij-Noor, Iran)

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Abstract

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The present study has been done to evaluate the impact of pure ash stand and mixed stand with beech on the herb layer biodiversity and soil properties in the forests of Noor city. There is a unique stand of ash in the forests of Noor city and at 1,900–2,100 m a.s.l., which is rarely seen like that in the northern forests of Iran. Shannon-Wiener diversity indices (H'), Simpson index of dominance (D), Margalef richness (R_1) and Pielou's evenness were used to analyse biodiversity. Sampling was also conducted to investigate physical and chemical properties of soil (bulk density, acidity, electrical conductivity, soil moisture, soil lime, nitrogen and organic carbon) in each sample plot and at two depths (10 and 20 cm). The total number of 26 soil samples (13 soil samples at either depth) in pure ash stand and 24 soil samples (12 soil samples at either depth) from this type of stand mixed with beech were taken. The results of plant species biodiversity showed that between the pure ash stand and the stand mixed with beech there is a significant difference at the 99% probability level in Shannon-Wiener diversity, Margalef richness, and Simpson dominance. There is also a significant difference at the 95% probability level between the two stands under study in Pielou's evenness index. The results of soil factors also showed that at the depth of 10–20 cm acidity factor showed a significant difference from its adjacent stand at the 99% probability level. There is also a significant difference at the 99% probability level in acidity (0–10 cm) and soil moisture at the depth of 10–20 cm between the two areas, but there is not any significant difference between the areas under study in electrical conductivity and lime factors at the two depths and also in moisture content at the depth of 0–10 cm. It should be noted that between the stand and soil nitrogen, organic carbon and bulk density parameters at both depths (0–10 and 10–20 cm) a significant difference at the 95% confidence level is shown.

Keywords: Hyrcanian forest; mixed stand; biodiversity; Shannon-Wiener; soil chemical properties

Currently, there is a sharpened debate about the importance of preserving biological diversity. Along with the degradation of natural resources, so many animal and plant species undergo the risk of extinction which could adversely affect global biodiversity as well. Environment protection measures could not be realized until the vegetation cover and biological diversity of the region of interest are completely evaluated. Identification of plant species, assessment of biological forms and plant geography of the region are not only of fundamental importance for environmental studies, but also they determine the regional capacity for multiple purposes for the current and upcoming periods (Mesdaghi 2000).

The term biodiversity includes biodiversity and ecosystem diversity, but at the local and regional scale, species diversity makes up the main part of biodiversity. The species diversity can be expressed by two indices of species richness and evenness index. The first indicator is the number of species and the second indicator is concerned with the distribution of the species abundance. So as a practical measure, estimating species diversity is often based on sampling (Bakhshi Khaniki 2011). Habitats that have more biodiversity are considered to be more fertile, dynamic and ecologically sustainable in response to temporal changes (Smith 1996).

Soil is among the most important factors in determining and assessing the status of biodiversity. In fact, soil is known as an important part of the ecosystem which plays an important role in the development of forest vegetation and the improvement in the quality of biodiversity (Kooch et al. 2009). Soil and vegetation development is a complex process resulting in changes and differences in soil characteristics, which *per se* affect the composition of forest vegetation and its growth rate (Crowley et al. 2003). In fact, what affects the absence or presence of species, are the physical and chemical soil and topography factors (Habibi Kaseb 1992). Thus for evaluation and classification of habitat fertility, understanding physical, chemical and biological characteristics of soil is essential (Enright et al. 2005).

On account of discussions on the management of sustainability of forest ecosystem products, the need to evaluate soil properties has risen (Fisher, Binkley 2000). To examine the habitat fertility and its classification, understanding the physical, chemical and biological soil quality criteria is obligatory (Schoenholtz et al. 2000) because these features are often spatially and temporally significantly different (Hale et al. 2005).

Ash (*Fraxinus excelsior* Linnaeus) tree is basically a heliophyte, a mesophyte with high nutrient demand which is characterized by a large canopy. However, beech (*Fagus orientalis* Lipsky) trees are sciophytic with a dense broad crown. On account of the differences in the structure and amount of light passing through the canopy and reaching the forest floor, which is an important determinant of understorey vegetation growth, and given the differences in soil characteristics in the two stands, this study set out to identify the biological diversity in the forest conservation project in Lavij, Mazandaran province.

Since the establishment and growth of plant species depend on the soil and plant composition, this study aims at finding answers to the following questions:

(*i*) Whether the soil under the ash stand is richer compared with the beech stand;

(*ii*) Whether the biological diversity in the ash stand is richer compared with the beech stand.

MATERIAL AND METHODS

Covering an area of about 17 ha, the study site is situated between 36°17’19” and 36°17’52”N and from 52°04’09” to 52°04’58”E at an elevation ranging from 1,900 to 2,100 m a.s.l. in Noor urban district in Mazandaran province. The two stands cover an area of about 10 and 7 ha, respectively. It should be noted that both adjoining stands are totally the same in terms of elevation, slope, and aspect.

Sampling was carried out in a grid with the dimensions of 50 × 100 m on each row every 50 m using rectangular plots with dimensions of 30 × 20 m. Totally 28 plots in the homogeneous ash tree stand and 24 plots in heterogeneous stand with beech were established. To measure biodiversity in each of these segments, the percentage of herbaceous species in both stands was calculated. Soil sampling in each plot was carried out at two depths of 10 and 20 cm by using a cylinder core (8 cm in diameter). Soil samples were then transferred to the lab for further analysis including: bulk density by the cylinder (ring) technique, moisture content by weighing and drying, chemical properties of the soil such as total nitrogen content according to the Kjeldahl method, soil organic carbon according to the Walkley-Black method, carbonate content according to the calcimeter method, pH was measured by the potentiometer method using an 827 pH lab meter (Metrohm, Switzerland). Soil to water ratio 1:2.5, and conductivity of a water-saturated soil extract were measured at 20°C using an electrical conductivity (EC) meter (CC-501, Hotek Technologies, USA) (Ghazanshahi 1997).

Data analysis. To compare biodiversity in the two stands, the percentage coverage of herbaceous species per plot and each stand was introduced into the Past software (Version 2.5, 2006) and the diversity, richness and evenness were measured by Shannon-Wiener, Simpson, Margalef and Pielou index, respectively. The SAS software (Version 9.1, 2004) was used to analyse the plant biodiversity and soil data. Mean comparison was done by MS Excel (Version 2007) based on the Student-Newman-Keuls (SNK) method.

RESULTS

Biodiversity of grass

The results showed that the Shannon-Wiener diversity, Margalef, and Simpson dominance indices were significantly different between the two

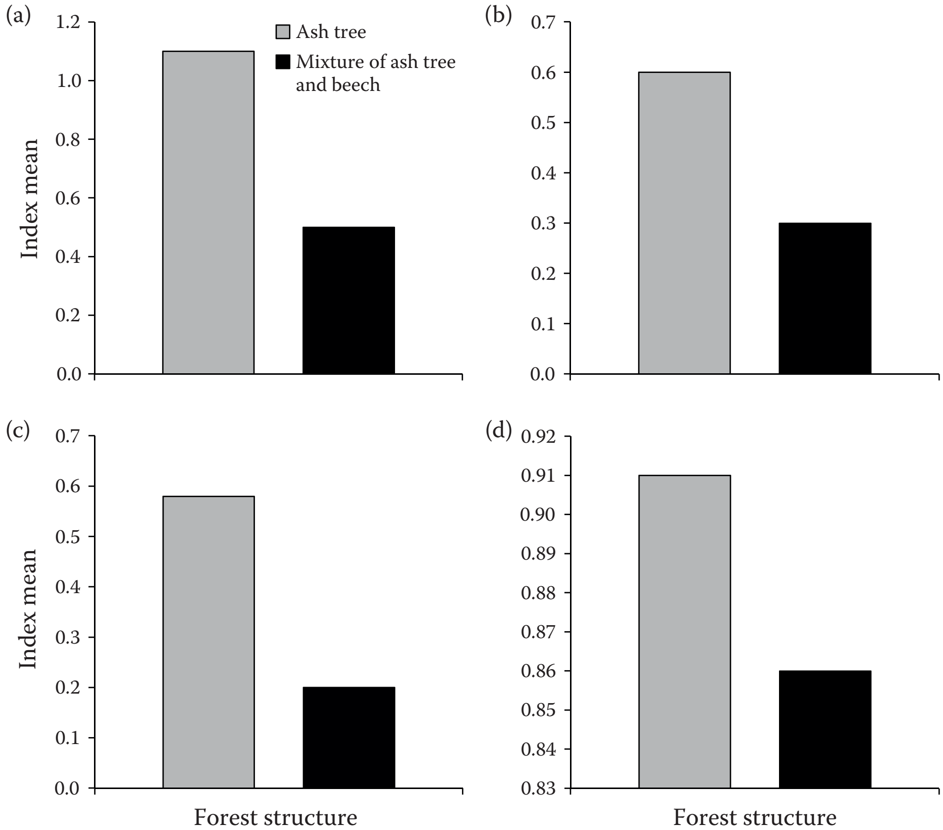

Fig. 1. The biodiversity indices in the homogeneous ash tree stand compared to the heterogeneous stand: Shannon-Wiener (a), Simpson (b), Margalef (c), Pielou (d)

populations at the 99% probability level. In Pielou's evenness index there was a significant difference between the two populations at the probability of 95% so that the values of all indices were higher in the homogeneous ash tree stand compared to the heterogeneous stand (Fig. 1).

Results of the soil per depth in the homogeneous ash tree stand and heterogeneous stand as the mixture of ash tree and beech

The results of the comparison of soil factors in relation to the SNK test showed that the pH factor at a depth of 10–20 cm was significantly different between the stands at the level of 99%. In nitrogen, organic carbon and soil bulk density there was a significant difference between the two populations at both depths (0–10 and 10–20 cm) at the probability of 95%. In acidity (0–10 cm) there was a significant difference between the two stands at the probability of 95%, but in EC and carbonates, no significant difference was observed at the two depths between the stands. The results of carbon to nitrogen ratio show a significant difference at 99% at the depth of 0–10 cm and at 99% at the depth of 10–20 cm (Fig. 2).

DISCUSSION AND CONCLUSIONS

In an ecosystem, plants and other parts are closely interrelated and each plays a crucial role in the ecosystem (Hoffmann 1998).

By observing the appearance of ground vegetation it becomes clear that these species choose their habitat based on their ecological nature (Rahimi 2005). The soil is one of the main factors influencing the distribution of plant communities (Jafari et al. 2008). Assessment of the soil characteristics is one of the basic principles of forest ecology management that influence many silvicultural and ecological options. In other words, the presence of a species in the plant community is associated with soil characteristics of the area (Zas, Alonso 2002).

What adds importance to the biodiversity is its role in maintaining the stability of ecosystems because the presence of more species in a region enhances the structure of the ecosystem, which improves ecosystem stability in response to changes. Diversity and species richness indices are changed by environmental factors (Heydari, Mahdavi 2009). Typically as the local biological diversity increases, so does the ecological sustainability and ecosystem fertility which result in a more developed soil (Pourbabaei et al. 2000). Generally speaking, attempts to comprehend the interrelations of in-

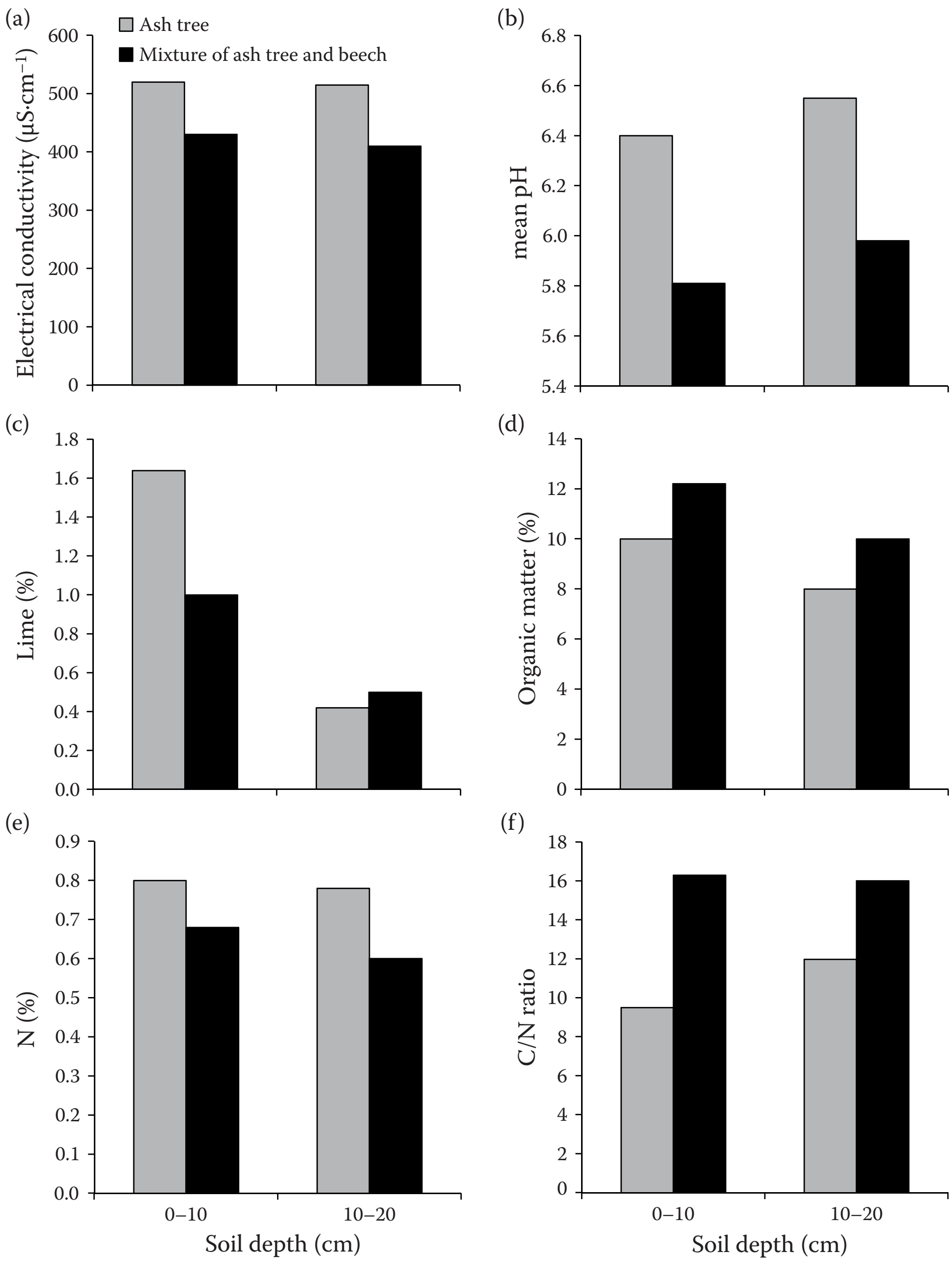

Fig. 2. The soil properties in the homogeneous ash tree stand compared to the heterogeneous stand: electrical conductivity (a), mean pH (b), lime content (c), organic matter content (d), nitrogen content (e), C/N ratio (f)

dices could lead to a better understanding of the ecosystem itself (Rahimi 2005). The species of the forest floor are more sensitive in comparison with changes in environmental conditions, in particular in the soil. These species could be considered as proxies of biological conditions which indicate general soil characteristics (Wilson et al. 2001).

Indicators of richness, biological diversity and evenness

Lower biological diversity in the beech stand could be explained by reduced light, acidic soil and accumulation of litter which restrict plant growth. On the contrary, in the ash tree stand, high soil nitrogen content because of rapid litter decomposition, being located in the lower parts and due to better moisture, has resulted in an improved species diversity, which agrees with the findings of Collins and Picket (1988) and Felton et al. (2006).

Physical and chemical properties of soil

In the present study the physical and chemical characteristics of soil showed significant differences between the two populations. Tree species can affect soil properties in different ways; for example, prompting differences in the chemical composition of above- and below-ground litter, differences in root activity and changes in microclimate under the tree cover, changing the understorey vegetation (Hansson et al. 2011). The lowest and the highest pH values were measured in the beech and ash tree stands, respectively. This is attributable to the slow rate of litter decomposition as a result of high lignin content, high C/N ratio, and high stem flow rates compared with the ash tree stand (Kooch, Hosseini 2012) which result in soil acidification. Obviously, changes in soil pH could lead to alterations in nitrogen uptake and microorganism activity, and nutrient availability at different depths (Hagen-Thorn et al. 2004).

The C/N ratio is an important indicator of the transformation of soil organic matter (Schua et al. 2015). According to the observations C/N ratios were generally lower in ash stand. Material with a lower C/N ratio can be decomposed by microorganisms much more readily.

Soil moisture should primarily control litter decomposition, with a possible positive feedback and hence soil organic matter in a sense that with higher soil organic matter, soil moisture also increases (Silveira et al. 2010).

Results suggest that soil bulk density is comparatively lower in the homogeneous ash tree stand at both depths. Soil bulk density is a determinant of plant species distribution. This factor is inversely related to soil organic matter. Soils with higher bulk densities are more compact with less organic matter, which restrains the establishment of new plant species (Bajtala 1999).

Carbon and organic matter deeply influence chemo-physical and biological properties of soil. The results of this study indicated that soil organic carbon differs at both depths between the two stands at the probability of 95%. Soil organic carbon decreases from the upper soil layer (0–10 cm) to the deeper one (10–20 cm). Higher soil organic carbon at the first depth contributes to the buildup of litter which ameliorates soil physical and biological properties.

The most significant determinant of soil mineral content is EC. Higher soil minerals result in higher EC values. Lower EC values in the heterogeneous stand could be attributed to the higher slope gradient and the existence of a parent material with proper drainage.

The soil of the ash tree stand was comparatively richer because of the abundance of understorey vegetation cover. Nitrogen is the most significant determinant of plant growth which is used in the organic compounds in the soil. Organic matter decomposition and humification depend on the factors like temperature, moisture, its origin, and nitrogen content in the litter (Zarrinkafsh 2002). Cannel and Dewar (1995) studied the changes of C/N ratio as the proxy of litter decomposition. Fu et al. (2004) in his study evaluated the relationships between soil, topography and species diversity in the broadleaved forest of Beijing region in China. Their study revealed that among soil properties, organic matter and total nitrogen have the greatest influence on vegetation.

The findings of the present study showed that species diversity indices are not good proxies alone for the maintenance of ecosystem stability and health. To attain a stable and healthy ecosystem, species nature, demands and biological conditions have to be identified.

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