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Relationship of soil physical and chemical properties with ecological species groups in *Pinus taeda* plantation in northern Iran

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Abstract. *Adel MN, Daryaei MG, Pashaki MS, Jalali J, Kuhestani JS, Jiroudnezhad R. 2017. Relationship of soil physical and chemical properties with ecological species groups in* Pinus taeda *plantation in northern Iran. Biodiversitas 18: 422-426.* The aim of this study was to investigate the relationship of physical and chemical properties of soils with ecological species groups in *Pinus taeda* plantation forests in Guilan province, Iran. For this purpose, a random systematic 100 m × 200 m grid sampling plan was used to establish 75 sampling plots. In each plot, soil factors and percent cover of each herbaceous species were recorded. Sub-plots of 32 m^2 were used for herbaceous species measurements. At each sampling plot, soil samples were collected in depth of 0-30cm. The result of TWINSPAN analysis revealed five dictinct groups. Multivariate analysis was performed through CANOCO 4.5 to explore the relationship between soil factors and plant community. Results showed that the most important soil factors in these communities were N, P, K, OC, Ca, Mg, TNV, pH, SP, soil texture (clay, sand, silt) and EC. The results indicated that the physical and chemical soil characteristics have a significant role in the growth and distribution of plant communities in the study area.

Keywords: *Pinus taeda,* plantation, soil properties, vegetation

INTRODUCTION

Much evidence has indicated that soil factors have greater impact on distribution and diversity of plant species and communities compared with climatic factors (Griffiths 2006). Soil factors directly affect survival and growth of different plant species and control distribution of these species (Erfanzade & Alemzade Gorji 2011). Vegetation structure is formed based on the effect of various factors (e.g. climate, topography, parent rock and biological agents) on vegetation and soil and based on a certain relationship between these factors in a particular environment. Therefore, understanding the trend of changes in an ecosystem and its components, especially plants and soil, is an important tool for proper management in terms of conservation, restoration, modification, development and sustainable exploitation of natural resources, which allows access to optimal scientific and practical strategies for implementation of more systematic and accurate management practices in natural resources (Tatian et al. 2011).

Description and analysis of vegetation rely on ecological aspects within an ecological framework, which allow proper understanding of changes in vegetation and distribution of plant species. Therefore, vegetation is discussed as an integral part of any ecosystem (Jafarian et al. 2011). Plant sociology is essential for identification and detection of an environment, uniformity and non-uniformity of that environment, identification of plant communities and the relationships between plant species (Taghipour et al. 2011). Each plant community encompasses a set of species with similar ecological aspects and needs, which is influenced by complex environmental conditions. Each community selects a certain habitat. The presence of indicator species are significantly dependent on soil properties. Herbaceous species are used as indicators to determine the quality of ecosystems (Mataji et al. 2009).

Since the plants coexist in a community and plants and other components are closely interrelated in an ecosystem, it is inevitable to understand the relationship between vegetation and environmental factors due to important role of plants in balance of an ecosystem as well as direct and indirect exploitation of plant species by human populations (Moradi & Ahmadipour 2006). Plant communities are not randomly created. There is a high correlation between plant communities and their surrounding environment. Structure and composition of plant communities are greatly influenced by environmental factors (Garcia et al. 2007).

Several studies have been conducted in this context which some are mentioned here. A study was conducted on the reaction of pine, spruce and Douglas-fir to soil nutrients in southern Germany. It was found out that nitrogen, phosphorus, potassium and calcium play an important role in growth of the above species (George et al. 1997). Another study was conducted on biomass and soil nutrients of stands of pine, spruce and fir in Minnesota in USA. It was found that soil nutrients had similar effects on the three masses of soil (Perala and Alban 1982). Another study was conducted on the relationship between ecological species and soil factors in a Ponderosa Pine Forest in Arizona. It was found out that total nitrogen, organic carbon and soil texture were the most important soil factors that affect the twelve ecological species (Abella and Covington 2006). Aghaei et al 2013) examined the relationship between ecological species and environmental factors in forests in Yasouj. It was found out that the percentage of litter, altitude and slope affect both separation and distribution of ecological groups in the study area. Pourbabaei et al. (2010) conducted a study in Qalarang forest in Ilam. It was found out that nitrogen, phosphorus, potassium, bulk density, acidity, altitude and clay percent are effective in development of five ecological groups. Another study was conducted in China where humidity, salinity, acidity and nutrients were the most important factors in control of plant communities (Yibing2008). Study area includes plantation of pure non-native species in a loblolly pine forest in Rasht Town. However, no similar study was conducted on its understory species. The present study aimed to determine ecological species groups and their relation with soil physical and chemical properties in *Pinus taeda* plantation in Saravan forest at northern Iran.

MATERIALS AND METHODS

Study area

Study area was located on Saravan forest between Rasht and Roodbar at 37°5′35″ north and 49°24′29″ east in Guilan Province in northern Iran. Non-native conifer species of loblolly pine were planted in this area. This was a pure peer forest to the old forest in terms of topography (e.g. slope, direction of slope and elevation). Native broadleaf species of *Pterocarya fraxinifolia, Parrotia persica, Gleditschia caspica, Prunus divaricata, Alnus glutinosa* and *Quercus castaneifolia* were found in this area in the past, which were destroyed due to indiscriminate exploitation. Elevation varied from 50m to 250m. Mean slope was 5% at northern direction in the study area. Total annual precipitation was 1374.4mm and mean annual temperature was 15.9°C. The highest amount of precipitation was recorded at October (218.6mm) and the lowest precipitation was recorded at June (39.5mm). The highest temperature was recorded at July (20.38°C) and the lowest temperature was recorded at February (2.34°C). According to Emberger climate index, this was locality belongs to a highly humid land. Siltstone and sandstone were parent rock materials. Depth of plant root varied from 60cm to 70cm (Sedighi Pashaki2011).

Data collection

An area consisting of hand-planted conifer forests (150 hectares) was selected. In addition, 75 plots with 100 x 200 meter grid sampling were implemented to determine coverage percent of plant species. Minimum area was used to determine the size of sample plots in an herbaceous layer (minimum area = 32m^2). Domin criteria was calculated to estimate coverage percent. Three soil sample were collected from the center and surrounding area of each plot at a depth of 0-30cm after removing litter from the plots. The combined sample as a soil sample was transferred to a laboratory where organic carbon was measured based on Walkley-Black Method (Walkley and Black 1934). Absorbable phosphorus was measured using Olsen method with a spectrophotometer (Olsen et al. 1954). Exchangeable calcium and magnesium were determined using Complexometry Method. The extracts were prepared using normal ammonium acetate (Ali Ehyayi and Behbahani Zadeh 1993). Soil total nitrogen was determined using Kjeldahl Method (Bremner 1996). Available potassium was measured with ammonium acetate extraction methods using flame photometer (Soil Survey Staff 1984). Soil texture was determined using a Bouyoucos Hydrometer (Bouyoucos 1962). Based on the theory of changes in bulk density (weight per unit volume) of mixture of soil and distilled water during deposition (Gharavi Manjili et al. 2009). Also, the percent of saturated humidity of each sample was measured. Soil acidity was determined using electrical pH meter with a mixture of soil and distilled water at a ratio of 1 to 2.5. The percentage of total neutralizing value known as TNV was measured by titration. Soil electrical conductivity was determined using electrical conductivity meter in the mixture of soil and distilled water at a ratio of 1 to 2.5 (Gharavi Manjili et al. 2009).

Data analysis

Two-way indicator species analysis with the computer program known as TWINSPAN based on default cross-section of the program was used to classify 75 plots and determine ecological species groups. Indicator species of each ecological species group were determined by Indicator Species Analysis known as the ISA. ISA and TWINSPAN analysis were performed using PC-ORD for win. Version 5 (McCune & Mefford2006). DCA analysis was used to calculate the gradient to determine whether to use linear or non-linear methods. RDA method was used to examine the relationship between vegetation and soil variables. DCA and RDA were performed using CANOCO 4.5 (Ter Braak1998). ONE-WAY ANOVA and Tukey test were used to compare the ecological groups in terms of physical and chemical properties of the soil. Data normality was examined using Kolmogorov - Smirnov test. For this purpose, IBM SPSS version 22 was used.

RESULTS AND DISCUSSION

Results

TWINSPAN analysis was closed on the three level. In the first level, 75 sample plots with eigenvalue of 0.282 were divided into two groups, one consisting of 40 individuals with indicator species of *Asplenium adianthum-nigrom* L. and *Urtica dioica* as negative group and another one consisting of 35 individuals with indicator species of *Pteridium aquilinum* (L.) Kuhn and *Erigeron hyrcanicus* as positive group. At the second level, 40 sample plots with eigenvalue of 0.301 were divided into two groups, one consisting of 24 individuals with indicator species of *Helianthus annus* as negative group and another one consisting of 16 individuals with indicator species of *Crataegus microphylla* as positive group. In addition, 35 sample plots with eigenvalue of 0.247 were divided into two groups, one consisting of 22 individuals with indicator species of *Coix lacryma-jobi* L. and *Fragaria vesca* as negative group and another one consisting of 13 individuals with indicator species of *Pteris dentate* Forssk as positive group. In the third level, only 24 sample plots with eigenvalue of 0.351 were divided into two groups, each consisting of 13 individuals with indicator species of *Smilax excelsa* as negative group and another one consisting of 11 individuals with indicator species *Viola odorata* as positive group. As a result, five groups can be distinguished based on TWINSPAN classification.

The first group included 13 sample plots with indicator species of *Carex* sp., *Viola odorata* and *Asplenium adianthum-nigrom* L. The second group included 11 sample plots with indicator species of *Oxalis acetocella*, *Pteris dentate*, *Pteridium aquilinum* (L.) Kuhn and *Polygonum hyrcanicum*. The third group included 16 sample plots with indicator species of *Smilax excelsa* and *Urtica dioica*. The fourth group includes 22 sample plot with indicator species of *Helianthus annus* and *Fragaria vesca*. The fifth group included 13 sample plots with indicator species of *Oplismenus undulatifolius, Crataegus microphylla* and *Ruscus hyrcanus* (Figure 1).

DCA analysis showed that the gradient is less than 3. Thus, ordination method based on linear relations known as RDA was used. For this purpose, the first and the second axes of RDA with the highest eigenvalues (0.483 and 0.307 respectively) were used. In total, 70.6% of total variance was explained by the first and the second axes. The results of RDA analysis revealed that calcium, magnesium, acidity and total neutralizing value were the most important and effective factors in the first group. Nitrogen, phosphorus, potassium, organic matter content, magnesium and gravel were the most important and effective factors in the second group. The third group is highly correlated with soil salinity and saturated humidity percent. The fourth group is highly correlated with clay soil and the fifth group is highly correlated with silty soil (Figure 2).

The results of comparison between the groups showed that the highest pH and TNV belonged to the first group and the lowest pH and TNV belonged to the fourth group. The highest amount of calcium belonged to the first group and the lowest amount of calcium belonged to the third group. The highest amounts of N, P, K and organic carbon belonged to the second group and the lowest amounts belonged to the fifth group. The highest amount of magnesium belonged to the first and second groups and the lowest amount of magnesium belonged to the fifth group. The highest values of EC and SP belonged to the third group and the lowest values of EC belonged to fourth and fifth and the lowest values of SP belonged to the first, fourth and fifth groups. The highest amount of silt belonged to the fifth groups and the lowest amount belonged to the second group. The highest amount of clay belonged to the fourth group and the lowest amount belonged to the first, second and fifth groups. The highest

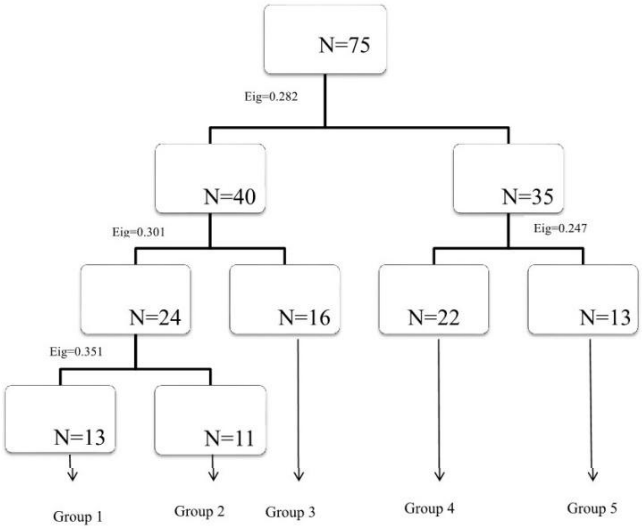

Figure 1. Determination of ecological species group using TWINSPAN method

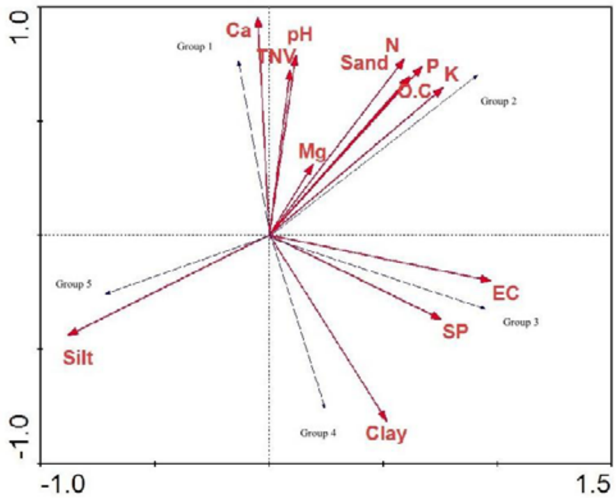

Figure 2. Relationship between ecological species groups and soil factors using RDA ordination

Table 1. Comparison of soil physical and chemical characteristics between ecological species groups

Unit	Group 1	Group 2	Group 3	Group 4	Group 5
pH	6.63[a]	6.06[b]	5.45[c]	5.17[d]	5.55[c]
EC (ds.m)	0.025[b]	0.031[b]	0.067[a]	0.014[c]	0.014[c]
OC (%)	5.09[b]	6.95[a]	3.49[c]	3.59[c]	2.96[d]
N (%)	0.43[b]	0.63[a]	0.29[c]	0.3[c]	0.25[d]
P (mg/kg)	65.49[b]	70.97[a]	32.63[c]	27.87[c]	24.24[d]
K (mg/kg)	194.96[b]	202.48[a]	94.67[c]	85.06[c]	79.51[d]
Ca (mg/kg)	19.35[a]	15.9[b]	7.75[e]	8.95[d]	10.45[c]
Mg (mg/kg)	7.03[a]	7.25[a]	2.17[b]	3.6[b]	1.7[c]
TNV (%)	5.75[a]	4.5[b]	0.25[d]	0.12[e]	1.62[c]
Sand (%)	41[b]	51[a]	27.5[c]	24.5[c]	25.75[c]
Silt (%)	34[c]	24[e]	40.5[b]	29.5[d]	48.75[a]
Clay (%)	25[c]	25[c]	32[b]	46[a]	25.5[c]
S.P. (%)	48.65[c]	49.52[c]	62.46[a]	55.47[b]	49.15[c]

amount of sand belonged to the second group and the lowest amount belonged to the third, fourth and fifth groups (Table 1).

Discussion

Soil pH was one of the effective factors in distribution of the first ecological species group. The results showed that this group is established in the soils with high and close to neutral acidity. This is mostly important due to presence of such elements as calcium, magnesium and total neutralizing value, which greatly increase soil acidity. On the other hand, saturated humidity percentage in this group was less than other groups. Mohtasham Nia et al. (2007) reported that acidity is one of the most important factors affecting establishment and distribution of ecological species groups. Monier et al. (2006) classified 25 stands of plants using soil properties in Egypt. They reported that acidity is the most Important factor in this classification. Gharavi Manjil et al. (2009) reported that calcium content and acidity are the main factors in classification of plant groups in forests of Guilan. Mehrdadi (2001) also studied the relationship between plant groups and soil factors in Qom. He showed that distribution of plant species is a function of the amount of soil acidity. Zarei (2010) studied plant species distribution in Qom and highlighted the role of magnesium in classification of plant communities. Virtanen et al. (2006) performed large-scale studies in Eurasia and highlighted the role of acidity in classification of plant species. The soil in this group was less humid than other groups.

The correlation of the second ecological group with soil chemical properties and abundant (macro) nutrients was positive. Nitrogen, phosphorus and potassium were the most important macro nutrients, which greatly contribute to growth of plant species. The amount of soil organic carbon in this group was higher than other groups. The second species group was established in the soils with high sand. Shokri et al. (2003) studied ecological vegetation of Hezar Jarib region in Behshahr and reported that such soil factors as percentage of sand are effective in distribution of plant communities. Mataji et al. (2009) studied Kheyrud Forest in Noshahr and highlighted the role of sand, nitrogen and phosphorus in development of plant communities in the north of Iran. Eshaghi Rad et al. (2009) also studied Kheyroud forest in Noshahr and reported that nitrogen, phosphorus, organic carbon and potassium are the most important factors in development of plant communities in northern forests. Similar study was conducted in Taleghan where potassium and sandy soil were the most important factors in classification of plant communities (Piry Sahragard et al. (2011). Mohsennezhad et al. (2010) studied Haraz highlands in Amol and showed that phosphorus, potassium, and sand contribute to classification of plant groups. Sandy soil is less prone to salinity due to easier leaching and larger pores (Shokri et al. 2003). Jafarian et al. (2011) studied the role of nitrogen, phosphorus, carbon and potassium in classification of plant communities in Semnan.

The third group was established in the regions with higher electrical conductivity than other regions. The third plant species group fitted this soil characteristic. On the other hand, saturated humidity percentage was higher in this group than other groups. Toranjzar et al. (2011) showed that electrical conductivity plays an important role in determining ecological groups in Arak. Roody et al (2012) showed that saturated humidity percent and electrical conductivity were the most important and effective soil factors in determining ecological species groups in northern Sisangan forests in Noshahr. Schoenholtz et al. (2000) showed that electrical conductivity plays an important role in determining plant communities. Zare Chahooki et al. (2008) showed that humidity and electrical conductivity are effective factors in distribution of plants in Yazd Province. Jafari et al. (2009) showed that percent of SP is an important and effective factor in ecological species groups in Qom.

The fourth group was established in clay soils and the fifth group was established in silty soils. Acidity and nutrients in these two groups were less than other groups. Liu et al. (2005) showed that clay soil is an important factor in classification of plant communities in conifer forests in China. Gavili Kilaneh & Vahabi (2012) highlighted the role of clay in classification of plant communities in Fereydunshahr Highlands of Iran. Gorgin Karaji et al. (2006) showed that some plant species select the areas with high clay or silt contents and less acidity compared to other areas in Saral in Kurdistan, west of Iran. Eshaghi Rad et al. (2009) introduced clay along with macro nutrients as the important factors in development of plant communities in northern forests in Kheyroudkenar, Noshahr. Zolfaghari et al. (2010) reported that clay and silt are the most important and effective factors in classification of plant communities in Plour in Amol of Iran. Soil texture is effective in plant distribution due to humidity, soil water holding capacity, the cycle of nutrients, aeration and depth of roots (El-Ghani 2003).

In general, the results of this study showed that physical and chemical properties of the soil are effective in growth and distribution of plant communities in the study area. It is important to identify effective factor in plant growth for accurate and systematic management of afforestation in the study area with the purpose of successful growth and proper ecological compatibility of the plant species. It is essential to include identification of the effective factors in plant growth in future plans and objectives in addition to soil properties.

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