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Relationships Between Tree Species Composition, Soil Properties and Topographic Factors in a Temperate Deciduous Forest in Northern Iran

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Abstract: A study to establish relationships between tree species, soil properties and topographic factors was carried out in one section of the Caspian (Hyrcanian) forest in the north of Iran. Two-Way Indicator Species Analysis (TWINSPAN) classified basal areas of tree species from 325 tree plots and were ordinate using Detrended Correspondence Analysis (DCA). Several physical and chemical properties of soil, altitude, aspect and slope were determined for a sub-sample of 83 plots amongst 325 tree plots. Oriental beech (*Fagus orientalis* Lipsky.) and hornbeam (*Carpinus betulus* Linn.) were the two most important tree species in this forest, although 11 other tree species were also present. A majority of the plots at lower altitudes were dominated by hornbeam, while beech dominated in plots at higher altitude. C% and C/N in the soil surface were significantly associated with tree species composition and altitude. C/N and carbon storage increased at higher altitude, where beech tree is dominant, while those at low altitude or with low C/N ratio were dominated by hornbeam. Although the main gradient of tree species composition, *Fagus-Carpinus* gradient, described by C%, C/N and altitude, distribution of *Quercus castaneifolia*, *Acer* spp. *Tilia platyphyllos*, as the main other tree species in the study site, explained by the other soil properties, such as bulk density and soil texture.

Key words: Caspian (Hyrcanian) forest, temperate deciduous forest, *Fagus orientalis*, *Carpinus betulus*, multivariate analysis

INTRODUCTION

Temperate deciduous forests occur in climates with a marked but not prolonged cold season. Although forests of this type growing in North America, Europe and East Asia are well described in standard textbooks on biogeography and world vegetation (e.g., Walter, 1984; Archibold, 1995). Temperate deciduous forests growing under equivalent climates in central Asia and the Middle East are relatively less well described, particularly in English.

The Hyrcanian (Caspian) forest located in the north of Iran comprises a narrow band of temperate deciduous forests and is contiguous with a larger forest block extending across eastern Turkey and Caucasia. This forest covered the north-facing slopes of the Elborz mountain ranges extend from the Northwest to the Northeast of Iran with the area about 1.9 million hectares. About 60% of the forests within this range are managed for timber production and the remainders are degraded to varying degrees (Forest and Rangelands Organization of Iran, 1997). The forest incorporates various vegetation types and a wide range of environmental conditions. The flora of the Hyrcanian broad leaved temperate deciduous forest shows very little similarity to the Mediterranean flora and comprises a large number of central European species (Dawan and Famouri, 1964). *Fagus orientalis*, *Carpinus betulus*, *Acer velutinum*, *Quercus castaneifolia*, *Acer cappadocicum* and *Tilia platyphyllos* are the most important tree species and the *Fagus* and *Carpinus* are locally dominant. Although *Fagus orientalis* occurs in southern Europe, it does not extend into the forests of central Europe described by Ellenberg (1998), where its congener *Fagus sylvatica* is dominant in natural vegetation on a wide range of soil types and climates. *Carpinus betulus* does occur in central and western

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Europe, but it does not extend to such high altitudes as *Fagus sylvatica* in localities where the two species co-occur (Ellenberg, 1998).

The Hyrcanian forest is distinctly heterogeneous with respect to topography and it is likely that variation in these factors, especially altitude, slope and aspect influence vegetation and soil conditions. The forest has been classified into several vegetation belts on the basis of altitude (Dawan and Famouri, 1964; Mobayen and Tregubov, 1970; Sabeti, 1993) and many recent studies have been carried out to describe the vegetation of the Hyrcanian forest (Djavanshir, 1969; Mobayen and Tregubov, 1970; Assadi, 1985). Although these studies successfully identified different vegetation types, they did not consider how the distribution and composition of vegetation related to environmental conditions such as soil properties and topographic factors. Similarly, the majority of the studies of soils have been carried out independently of work on the vegetation and environment.

In this study we present an analysis of tree species composition and environmental data from the Hyrcanian forest and compare trends in tree species composition according to gradients of topographic conditions and some soil properties. As many recent studies, such as Fu *et al.* (2004), Sebastia (2004) and Enright *et al.* (2005), have been used methods of classification and ordination to show relationships between vegetation and environmental factors, we also used these methods to evaluate these relationships.

MATERIALS AND METHODS

Study Site location and description: The study was conducted between 2002-2004 in the Kheirood-Kenar forest (51° 32’ N, 36° 27’ W) employed as education and research for Tehran University and is close to Nowshahr city in Mazandaran province in northern Iran. The area of the study site is about 1000 ha and the highest mean monthly temperatures of 29°C occur in June and July and the lowest of 7.1°C in February and the mean annual rainfall of 1354.5 mm at the Nowshahr meteorological station, which is 10 km from study area. The study site is classified as mountain forest with an altitudinal range from about 650 to 1400 m a.s.l. Although some parts of this area are underlined by sandstone, limestone forms the parent material across most of the site. The soils of the study site are *Inceptisols* and *Alfisols* on the base of soil survey taxonomy (Sarmadian and Jafari, 2001) and are described in detail below.

Sampling for determination of tree composition: 325 rectangular square plots of 50×50 m (2500 m^2) were chosen in the forest. A plot was established at every intersection of a 200×200 m grid and further samples were taken at every second midpoint between intersections. The position of the midpoint samples alternated with row and column of the grid.

In each plot, the diameter of all trees more than 7.5 cm diameter at breast height (1.3 m above the ground level) were measured and identified. Slope, elevation and aspect were recorded for each plot using clinometers, altimeter and compass, respectively (Suunto model).

Sampling of soil: For soil sampling, at the first, the landform map was produced on the base of altitude, slope and aspect with about 300 landform units. At the second stage, in each landform unit, each tree plot was compared with its two nearest neighbour plots on the base of their species compositions using the Sorenson index. If the Sorenson index had a value more than 75% similarity and the two plots fell within the same landform unit as defined above, one of the two plots was chosen at random for soil sampling. If two plots showed a Sorenson index less than 75% similarity or they fell within different landform units, they were both selected for soil sampling. In this way, 83 sample plots were selected for soil sampling from the original 325 tree plots.

In each selected plot, soil profile was dug, soil horizons were identified and characteristics of each horizon recorded on the standard description sheet. A soil sample was collected from each horizon and all of them air-dried and passed through a 2 mm mesh. For all of the soil samples, soil texture by hydrometer method, soil pH in 1:2.5 water suspensions and 1:2.5 KCl were identified. For soil samples collected from upper horizons (until about 40 cm), soil bulk density by clod method, total N by the Kjeldahl method, C% by Walkely and Black method and available P by Olson method were determined.

Numerical and statistical analyses: Basal area for each tree species in all of the plots and the total basal area for all of the trees species within each plot were calculated. These variables formed one matrix used for classification and ordination of all of the tree plots and tree species. Two-way indicator species analyses (TWINSPAN) (Hill *et al.*, 1976) method for classification and DCA (Deternded Correspondence Analysis) for ordination were used. For all of the above mentioned multivariate analyzing PC-ORD program version 3.17 was used.

One-way ANOVA (Analysis Of Variance) was used to analyze differences amongst tree groups identified by TWINSPAN. In ANOVA, the amount of basal area for each tree species was used as the response variable and the factors were tree groups (or forest types). For analyzing of soil properties and topographic variables differences among the tree groups, one-way ANOVA was also used. For ANOVA, Minitab version 13/1 was used.

Relationships between tree species composition with soil and topographic factors were examined in the output of DCA. For DCA analyzing, PC-ORD program version 3.17 were also used.

RESULTS

Classification and ordination of tree sample plots and tree species: The results of TWINSPAN for the 325-tree sample plots identified four tree groups at the second level of division and have been called A, B, C and D tree groups in this study (Fig. 1). Variations of basal area for each tree species amongst the tree groups from ANOVA have been also shown in Table 1.

At the first level of TWINSPAN high basal areas of *Fagus orientalis* and *Carpinus betulus* are the key features for the division (Fig. 1). *Carpinus betulus* in tree groups A and B and *Fagus orientalis* in tree groups C and D are as dominant tree species in these groups. *Acer cappadocicum* and *Quercus castaneifolia* is the other abundant tree species placed in group A. The main tree species distinguishes group B from the other groups is *Alnus subcordata*. Inside group C, although there are several tree species, *Fagus orientalis* is the dominant species within this tree group. Although *Fagus orientalis* is also dominant within group D, *Tilia platyphyllos* is as a co-dominant tree species and distinguish this group from the other groups.

The results of ordination of tree plots by DCA were used to prove the distribution of the plots of the tree groups around the DCA axes (Fig. 2). As have been shown, tree group C and D located on the left hand side of the diagram and the right side of the diagram is covered by A and B tree groups. Meanwhile *Carpinus betulus*, *Quercus castaneifolia*, *Acer cappadocicum*, *Alnus subcordata* and *Ulmus glabra* have been distributed on the right side of diagram. The top left of diagram including group C include *Fagus orientalis* and

Table 1: Mean of the basal area for each tree species (m^2) in each tree groups and significant level of them among tree group identified by ANOVA

Tree species	Group A	Group B	Group C	Group D	F-value	(p-value)
Fagus orientalis	1.72a*	2.12a	6.24c	5.09c	100.90	(0.00)
Carpinus betulus	5.52a	4.00b	1.43c	0.64c	118.72	(0.00)
Acer velutinum	0.40	0.63	0.59	0.38	ns	
Acer cappaducicum	0.33a	0.08b	0.02b	0.09b	34.95	(0.00)
Alnus subcordata	0.01a	0.80b	0.19a	0.01a	49.35	(0.00)
Tilia platyphyllos	0.04a	0.11a	0.03a	1.02d	39.08	(0.00)
Quecus castaneifolia	0.57a	0.20b	0.02b	0.00b	16.93	(0.00)
Ulmus glabra	0.06a	0.01b	0.02ab	0.04ab	2.98	(0.03)
Diospyros lotus	0.04	0.05	0.00	0.00	ns	
Parrotia persica	0.01	0.03	0.00	0.00	ns	
Fraxinus excelsior	0.01	0.01	0.00	0.00	ns	
Cerasus avium	0.00	0.00	0.01	0.00	ns	
Sorbus torminalis	0.00	0.00	0.02	0.01	ns	

*Means sharing the same superscript letter are not significantly different

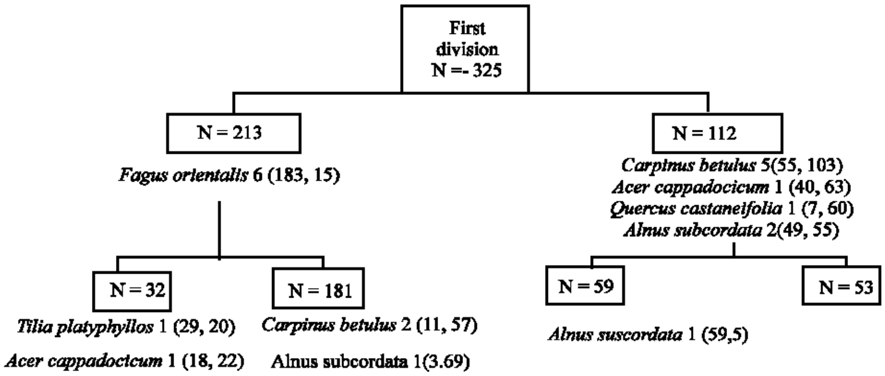

Fig. 1: Four tree Groups (forest types) formed at the second level of TWINSPAN. At the first level, high basal areas of *Fagus orientalis* and *Carpinus betulus* are the key features for the division

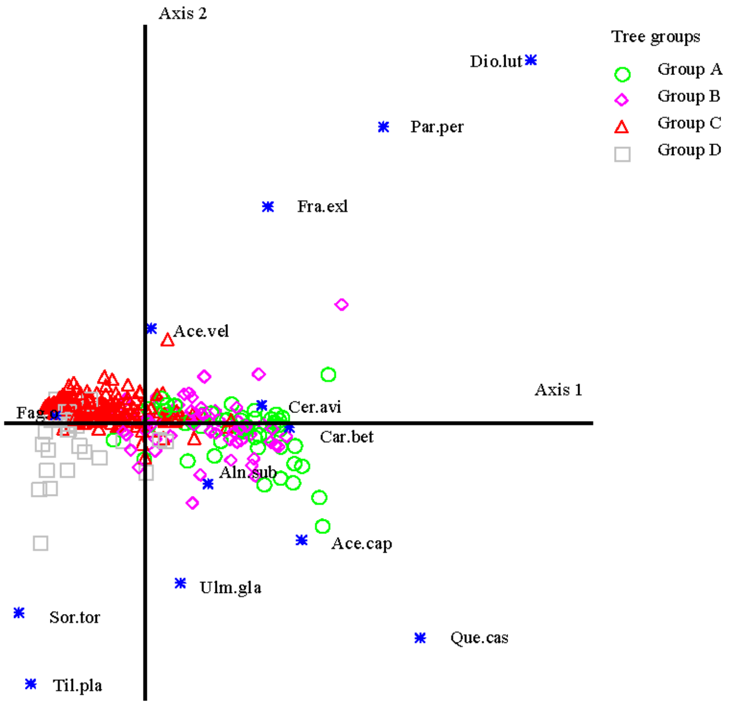

Fig. 2: Distribution of tree species and sample plots of each tree groups along with two axes of DCA. Location of each tree species and the plots show some relationships between them. For example *Fagus orientalis* and *Carpinus betulus* covered two points against to each other

Table 2: The Pearson Correlation coefficient between tree species and the axes of DCA Among the tree species, *Fagus orientalis* show negative significant correlation and *Carpinus betulus*, *Acer cappadocicum*, *Quercus castaneifolia* demonstrate positive significant correlation to the first axes of DCA

Tree species	r (Axis 1)	r-5q (Axis 1)	r (Axis 2)	r-5q (Axis 2)
Fagus orientalis	-0.847	0.717	0.231	0.054
Carpinus betulus	0.879	0.773	-0.218	0.048
Acer velutinum	-0.018	0.000	0.415	0.173
Acer cappadocicum	0.352	0.124	-0.222	0.049
Alnus subcordata	0.197	0.039	-0.132	0.018
Tilia platyphyllos	-0.165	0.027	-0.533	0.284
Quercus castaneifolia	0.403	0.163	-0.528	0.279
Ulmus glabra	0.047	0.002	-0.180	0.032
Diospyrus lotus	0.230	0.053	0.294	0.086
Parrotia persica	0.106	0.011	0.124	0.015
Fraxinus excelsior	0.073	0.005	0.048	0.002
Cerasus avium	0.054	0.003	-0.020	0.000
Sorbus torminalis	-0.055	0.003	-0.066	0.004

the lower left-hand side is covered by tree group D containing *Tilia platyphyllos* and *Sorbus torminalis*. The Pearson correlation coefficient between tree species and two axes of DCA identifies relationship between tree species and the axes of DCA (Table 2).

Variations of environmental factors among the tree groups: The variations of environmental factors, included soil properties and topography factors, tested by ANOVA showed that some of them varied significantly among the tree groups (Table 3). Percentage of organic carbon (C%) in A and B horizons, available P and bulk density in A horizon, follow by altitude demonstrate significant differences amongst the tree groups (Fig. 3). C% is low in tree group A compared to the other tree groups and the amount of bulk density is also lower in tree group B and significantly differs among the tree groups. The maximum amount of P observes in tree group D, where *Tilia platyphyllos* follow *Fagus orientalis* were dominant tree species. Furthermore, there are obvious differences in

Table 3: Mean of the variables that differ significantly amongst the tree groups, F-value and probability identified by ANOVA. Differences of soil texture among the tree groups have been also shown in this table

Soil factors	Group A	Group B	Group C	Group D	F-value	(p-value)
C% (A Horizon)	4.6a*	5.6ad	6.1ad	7.5d	4.28	(0.008)
B.D (A Horizon)	1.8a	1.4b	1.5b	1.7ab	5.32	(0.002)
C% (B1 Horizon)	0.8a	1.4b	1.1ab	0.9ab	2.90	(0.041)
P (A Horizon)	14.8a	16.3a	12.3b	19.7c	3.94	(0.049)
Altitude	876.9a	994.3b	1057.4b	1036.7b	11.30	(0.000)
ST (A Horizon)	C-L	S-C-L	S-L	S-C-L		
S T (B1 Horizon)	C	C-L	C-L	C-L		

*Means sharing the same superscript letter are not significantly different, C% = Percentage of organic carbon, BD = Bulk Density, P = Available Phosphorus C-L= Clay Loam, S-C-L= Silty Clay Loam, S-L= Silty Loam, C = Clay, ST = Soil Texture

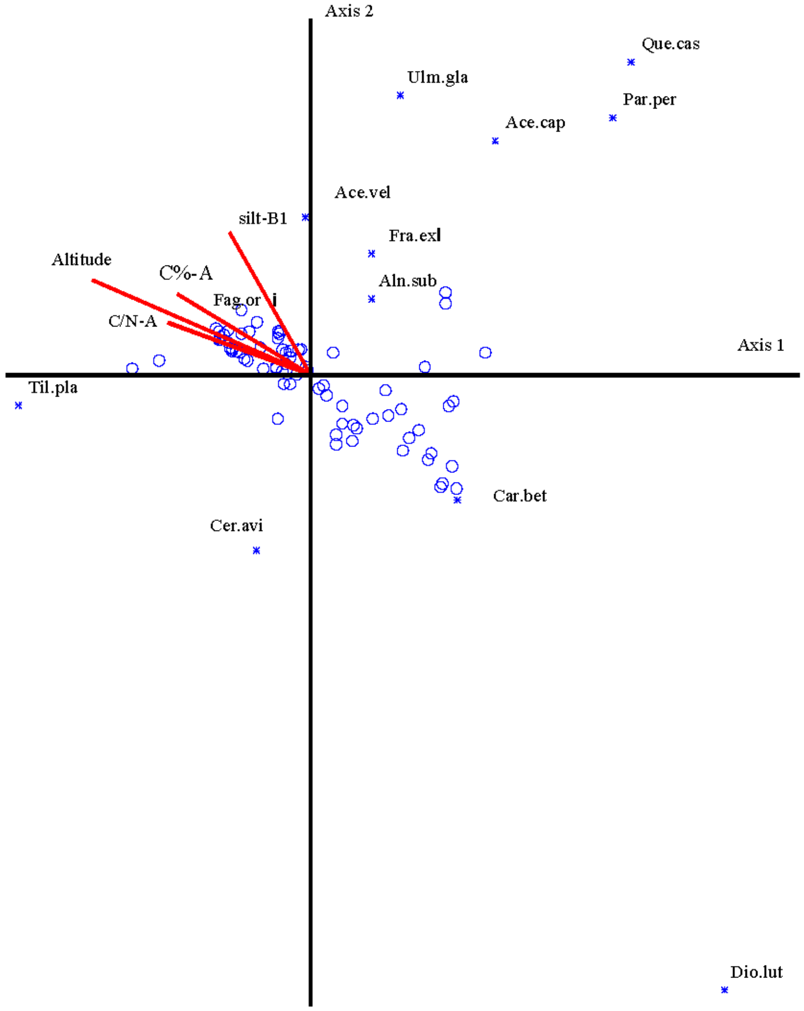

Fig. 3: Joint plots between environmental variables and tree species as well as tree samples. The direction of the arrows illustrate significant increasing of environmental variables toward to the left side of the first axes of DCA where pointed by domination of *Fagus orientalis* and against to place of domination of *Carpinus betulus*

altitude gradient amongst the tree groups, with *Carpinus*-dominating at the lower altitudes (Group A and B) compared to other tree groups, especially with the *Fagus*-dominating in the tree groups C and D.

Relationships between tree composition and measured environmental factors were also studied by using of DCA. On the basis of DCA method, all of the soil characteristics and topographic variables were used as

Table 4: Pearson and Kendall correlations between environmental variables and the axes of DCA. The environmental variables used as the second matrix of DCA to describe variations of tree composition in the forest stand

	Axis			
	1		2	
Soil factors	R	R^2	R	R^2
pH.H_2O-A	-0.229	0.053	0.173	0.030
Clay-A	0.184	0.034	-0.267	0.071
Silt-A	-0.114	0.013	0.147	0.022
Sand-A	-0.085	0.007	0.151	0.023
C%-A	-0.310	0.096	0.239	0.057
BD-A	0.147	0.022	-0.206	0.043
N%-A	-0.117	0.041	0.155	0.024
C/N-A	-0.319	0.101	0.190	0.036
P-A	-0.220	0.000	0.106	0.011
pH.H_2O-B1	-0.120	0.014	-0.001	0.000
Clay-B1	0.135	0.018	-0.309	0.095
Silt-B1	-0.239	0.057	0.320	0.102
Sand-B1	0.032	0.001	0.102	0.010
C%-B1	0.135	0.018	-0.161	0.026
BD-B1	0.135	0.018	-0.161	0.026
N%-B1	0.220	0.049	0.058	0.003
C/N-B1	0.018	0.000	-0.115	0.013
P-B1	-0.20	0.000	0.053	0.003
Depth	0.051	0.003	0.007	0.000
Altitude	-0.396	0.157	0.264	0.070

the second matrix to evaluate their relationships to tree composition. Correlation coefficient between the environmental variables and two axes of DCA showed that C% (r = -0.310) and C/N in A horizon (r = -0.319), content of silt in B1 horizon (r = -0.239) and altitude (r = -0.396) demonstrate a significant relationship to the first axis of DCA (Table 4). Content of clay (r = -0.309) and silt (r = 0.320) in B1 horizon showed a significant relationship to the second axis of DCA. The other environmental variables had not a significant relationship to the axes of DCA. The direction of the arrows of C%, C/N and altitude and correlation coefficient between these variables and the first axes of DCA show that these variables trend toward the left side of the first axis of DCA, where *Fagus orientalis* is dominant and in contrast to *Carpinus betulus* domination. Correlation coefficient and direction of arrows for silt in B1 horizon demonstrate that the trend of this arrow is to the first and second axes of DCA. This result can explain both distributions of *Fagus orientalis* and *Acer velutinum*, although it is more significant in relation to the second axes of DCA where *Acer velutinum* is located.

DISCUSSION

The results showed that *Fagus orientalis/Carpinus betulus* gradient is the main fraction of tree species composition in the study site, although in different places of this forest the other tree species appear with them. The distribution form of *Fagus orientalis* and *Carpinus betulus* along the forest stands is in contrary to each other, as *Carpinus betulus* being dominant in the forest stands located at low altitude and gradually replaced by *Fagus orientalis* at high altitude. As mentioned before, the majority of the Caspian forests are classified as mountain forests and variations of topographic condition especially altitude influence on variations of vegetation and tree compositions. Precipitation and temperature are factors, varied to altitude and can influence tree species composition directly and indirectly through other environmental factors, notably soil conditions. The results of different analyses in this study defined except the altitude, C% and C/N in A horizon are significantly correlated with the forest composition compared to other soil variables and they referred to organic materials and the rate of their decompositions. The results of the study confirmed that by increasing of altitude and domination of beech in the forest, content of these soil factors is getting higher. C% and C/N in the soil depend on decomposition of organic materials and then obviously these factors in the soil alter to the altitude-induced climatic differences. Basically climatic conditions especially temperature and rainfall is the key factors controlled the accumulation of nitrogen and organic materials and the rate of decomposition of it (Brady and Weil, 1999). Lorphelin and Kichi (1987) reported that as the altitude increases, the activity of soil organisms and decomposition of organic matter decline. Bonito *et al.* (2003) in their research in broad-leaved forest in United State described mineralization of nitrogen significantly affected by altitude. On the other hand although several environmental factors influence on the rate of litter decomposition, the amount of litter fall is remarkably uniform among tree species growing under similar soil and climatic conditions (Fisher and Binkley, 2000). Finzi *et al.* (1998) showed that there are differences in the size and distribution of C and N pools at varying soil depths beneath six different tree species in temperate forests. Edwards *et al.* (1970) reported that the rate of decomposition of beech leaves is lower than oak, elm, birch and ash leaves. In the comparison of leaf decomposition rates among different tree species recognized that litter of *Carpinus betulus* decomposed more rapidly than *Fagus orientalis* (Cornelissen, 1996), so that the presence of beech in this study may augment the content of nitrogen and carbon in higher altitude. Overall there are complex relationships between tree compositions; altitude and soil organic matter in the study site and obviously the main gradient of tree species composition in this forest is associated to this complex soil/climate gradient.

Although the variations of altitude, C/N and C% make clear the main gradient of tree composition *(Fagus/Carpinus* gradient), some other independent variations of tree species composition in this area are not explained by above mentioned factors. As the results of this study show, *Alnus subcordata* was the indicator tree species in tree group B and amongst the measured variables, bulk density and soil texture, especially in A horizon, are the factors separated tree group B from the other tree groups. On the base of these results, *Alnus subcordata* found on light texture soil with low bulk density. *Alnus subcordat* and its Conger *Alnus glutinosa* as two important tree species in north of Iran covered high and low altitude in this area, respectively. Zareh and Habashi (2000) demonstrated that the roots of *Alnus subcordat* distribute on soil surface and showed that this species prefer to grow on light texture soil with a high-quality humus form. Fakhari (2006) declared that *Alnus glutinosa* compared to some deciduous and evergreen tree species prefer to grow on soils with low bulk density. Sedigi (2002) also mentioned that *Alnus glutinosa* prefer deep and moistly soil with low bulk density. Herault *et al.* (2004) in comparison of the regeneration patterns of woody species between Norway spruce plantations and deciduous forests on alluvium soils declared that *Alnus glutinosa* is a hydrophilous species favoured by light-textured soils.

Distribution of *Acer cappadocicum*, *Quercus castaneifolia* and *Tilia platyphyllos*, amongst the tree species groups also show differences to central gradient in study site. Although *Acer cappadocicum* and *Quercus castaneifolia* found in the other tree groups, they are as co-dominated tree species associated to *Carpinus betulus* in tree group A. Amongst measured variables, it seems that soil texture is the main factor described distribution of them in this group. Soil texture in tree group A, compare to the other tree groups, classified as heavy soil texture class and several studies in different places in north of Iran have been shown that both *Carpinus betulus* and *Quercus castaneifolia* grow on heavy soil texture (Habibi, 1984a, b). Gorji-Bahri (1988) also showed that, *Quercus castaneifolia* located in the forest sites with heavy soil and sufficient content of water.

In the study site, *Tilia platyphyllos* is as indicator tree species appear significantly in tree group D, where the key factor distinguished it from the other tree groups was available P, as the content of P in this group is higher than the other tree groups. The general knowledge on different tree species influence on the soil's P status is quite limited and it is likely that different species may have different or even contradictory effects on various components of the P cycle and P pools in different soil layers (Hagen-Thorn *et al.*, 2004).

Although the results of this study could describe distribution of main tree species in study site, we are unable to explain the distribution of the less common species, for example, *Parrotia pesica*, *Diospyros lotus*, *Fraxinus excelsior*, *Sorbus torminalis* and *Cerasus avium.* This difficulty is partly due to their rarity in the forest, but we may note that they are found mostly at lower altitudes and that they are perhaps more typical of forest of lower altitudes than those studied here.

As mentioned before, topographic condition in north of Iran is very complex and also important. We expected to have several relationships between soil properties, tree composition and topographic conditions, but among the topographic factors we only found relationship between altitude and the other mentioned factors. It seems that the other topographic and physiographic factors such as land form and also parent material can effect on soil properties and tree composition in this area, so more studies can be so important in next researches.

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