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Variability of soil physical indicators imposed by beech and hornbeam individual trees in a local scale

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ABSTRACT

Kooch Y, SM Hosseini, Hojjati SM, Fallah A. 2013. Variability of soil physical indicators imposed by beech and hornbeam individual trees in a local scale. Biodiversitas 14: 25-30. The objective of our study was to determine if soil physical indicators could be related to the influence of the individual trees in stands of mixed species growing on steep slopes in the Hyrcanian forests of Iran. Research was conducted in a forest dominated by beech (*Fagus orientalis* Lipsky) and hornbeam (*Carpinus betulus* L.) interspread with the other deciduous tree species. Due to, twenty hectare areas of Experimental Forest Station of Tarbiat Modares University was considered in northern Iran. The positions of trees with diameter at breast height more than 45cm were recorded by Geographical Position System (GPS). Three single-trees (trees with canopy cover separated from other trees and covered distinguished space) considered for soil sampling from every tree species and diameter class as three replications. All of soil samples were excavated in north aspect and at the nearest point to tree collar for more precision. Soil samples were taken at 0-15, 15-30 and 30-45cm depths using auger soil sampler with 81cm^2 cross section. The result of this research showed that bulk density was significantly greater under beech than under hornbeam. This character tends to be less in 0-15cm depth than in 15-30cm and 30-45cm depths. Variable amounts of this character were found among diameter classes of beech and hornbeam also. Silt and clay were significantly greater under hornbeam than under beech. Moisture was significantly higher under beech than under hornbeam, whereas soil depths and diameter classes did not show any significant difference. Current research has shown that the influence of individual trees with different diameter classes can be detected in forest floors and upper minerals soil layers even under mixed stands in steepy sloping landscapes. This subject should be considered in natural forests management.

Key words: Bulk density, Hyrcanian forest, moisture, old trees, soil texture

INTRODUCTION

Tree-soil interactions and their influence on tree fitness and forest community dynamics are complex. Many current theories on spatial heterogeneity and species diversity of forest communities are based on the premise that species interaction is controlled by competition for resources such as light, water, nutrients (Binkley and Menyailo 2005). Although these resources are largely constrained by the physical environment, the influence of canopy trees on resources can be of significant importance in forest ecosystem dynamics. This biotic control over resources has received little attention until recently in understanding forest ecosystem dynamics. Several authors have demonstrated the existence of a close interaction between plant and soil (Lovett et al. 2002; Compton et al. 2003; Templer et al. 2005). The evidence above suggests that tree-soil feedbacks need to be incorporated into the concept of species diversity and spatial heterogeneity in forest ecosystems in order to gain more insight in long-term forest dynamics. The soil under the influence of a forest develops properties that vary spatially with relation to the location of the trees. This variation in soil properties is frequently reflected in the distribution of the various species of the ground flora. The amelioration or degradation of the forest soil takes place with each tree as a center of influence (Kooch et al. 2011). Individual species are an important control on soil properties such as structure, water availability, and biota, as well as nutrient cycling. Tree species may influence soil nutrient cycling directly, via nutrient uptake (Turner et al. 1993), litter inputs (Prescott 2002), and induced leaching losses (Compton et al. 2003; Templer et al. 2005), and indirectly, via alteration of microclimate and disturbance regime (Chapin et al. 2002), precipitation chemistry and floral and faunal activities (Smolander and Kitunen 2002).

Studies of trees grown in monocultures effectively isolate species effects on soils, but may not adequately capture species effects in mixed stands (Rothe and Binkley 2001). Despite continued research into tree species effects on soil nutrient cycles, the generality of these effects remains unknown (Binkley and Menyailo 2005). For example, leaf litter decomposition experiments have shown that mixtures of litter of different species can exhibit additive, neutral, and antagonistic effects on overall decomposition that are not easily predicted from the characteristics of the individual litters alone (Gartner and Cardon 2004). More generally, experimental studies of grasslands have shown that species diversity and functional characteristics can impact a range of ecosystem processes that serve as the context for individual species effects on soils (Tilman et al. 2001). Thus, plants can shape long-term patterns of soil and ecosystem development (Jenny 1941) in ways that may affect subsequent interspecific interactions and plant-soil relationships. Old-growth forests of northern Iran provide a unique opportunity to examine tree species-soils relationships in a wide range of mixed-species ecosystems that developed with minimal anthropogenic disturbance. Northern forests of Iran stretch up to an altitude of 2800 m asl. and comprise different forest types with 80 species of trees and shrubs. There is 1.9×106 ha of hardwood forests in the north of Iran, which is called Hyrcanian ecosystem (Hosseini et al. 2007; Rouhi-Moghaddam et al. 2008; Poorbabaei and Poorrostam 2009). The Hyrcanian forests are one of the last remnants of natural deciduous forests in the world (Sagheb Talebi 2000).

Beech (*Fagus orientalis* Lipsky) is one of the most important elements of forests in the temperate broad-leaf forest biome and represents an outstanding example of the re-colonization and development of terrestrial ecosystems and communities after the last ice age, a process which is still ongoing (Mosadegh 2000; Marvie Mohadjer 2007). In the north of Iran, pure and mixed oriental beech forests cover 17.6 per cent of the surface land area and represent 30 per cent of the standing volume. Beech is the most valuable wood-producing species in the Caspian forests (Resaneh et al. 2001). The beech trees are found in small groups up to 500m asl. while individuals have been reported from 110m up to 2650m. At low altitudes, they occur mixed with hornbeam (*Carpinus betulus* L.) (Marvie Mohadjer 2007). In spite the important of Hyrcanian forests, but earlier study that has evaluated the effects of dominated individual trees on soil characters at the stand level wasn't considered. The objective of this study is to quantify the effects of beech and hornbeam single tree species on soil physical indicators in an old-growth hardwood forest of Iran that is the first survey in these forests.

MATERIALS AND METHODS

Site description

This research was conducted in Experimental Forest Station of Tarbiat Modares University located in a temperate forest of Mazandaran province in the north of Iran, between 36˚ 31’ 56˝ N and 36˚ 32‘ 11˝ N latitudes and 51˚ 47‘ 49˝ E and 51˚ 47‘ 56˝ E longitudes (Figure 1). The maximum elevation is 1700m and the minimum is 100m. Minimum temperature in December (6.6˚C) and the highest temperature in June (25˚C) are recorded, respectively. Mean annual precipitation of the study area were from 280.4 to 37.4 mm at the Noushahr city metrological station, which is 10Km far from the study area. For performing this research, a limited area of reserve parcel (relatively undisturbed) considered that was covered by *Fagus orientalis* and *Carpinus betulus* dominant stands. This limitation had an inclination 60-70 percent with northeast exposure at 546-648 m asl. Bedrock is limestone-dolomite with silty-clay-loam soil texture. Presence of logged and bare roots of trees is indicating rooting restrictions and soil heavy texture (Kooch et al. 2010).

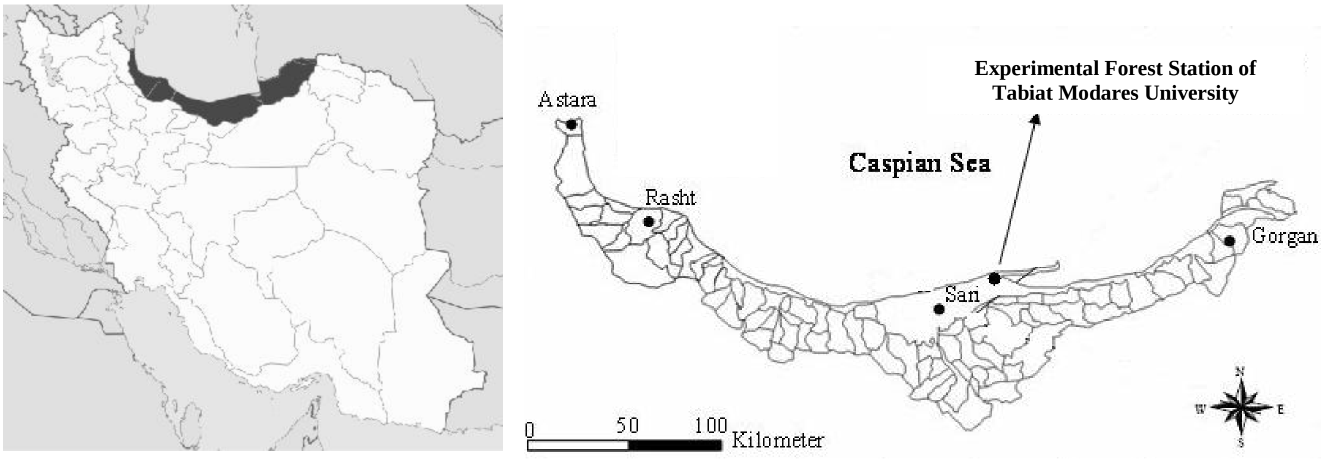

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Figure 1. Location of the study site inside the Hyrcanian zone, the Central Caspian region of northern Iran.

Soil sampling

Due to examine the influence of forest individual trees on soil physical indicators, twenty hectare areas of Experimental Forest Station of Tarbiat Modares University was considered. The positions of trees with diameter at breast height (DBH) (1.3 m) more than 45 cm (Goodburn and Lorimer 1999; Scahrenbroch and Bockheim 2007; Kooch et al. 2011) were recorded by Geographical Position System (GPS). Three single-trees (was defined as trees with canopy cover separated from other trees and covered distinguished space) considered for soil sampling from every tree species and diameter class as three replications. All of soil samples were excavated in north aspect and at the nearest point to tree collar for more precision. Soil samples were taken at 0-15, 15-30 and 30-45cm depths using auger soil sampler with 81cm^2 cross section (Kooch et al. 2011).

Laboratory analyses

For this purpose, large live plant material (root and shoots) and pebbles in each sample were separated by hand and discarded. The air-dried soil samples were sieved (aggregates were crushed to pass through a 2 mm sieve) to remove roots prior to analysis. Bulk density at air dried moisture content was measured by Plaster (1985) method (clod method). Soil texture was determined by the Bouyoucos hydrometer method (Bouyoucos 1962). Soil moisture was measured by drying soil samples at 105° C for 24 hours (Ghazanshahi 1997).

Statistical analyses

Normality of the variables was checked by Kolmogrov-Smirnov test and Levene test was used to examine the equality of the variances. Differences between diameter classes and depths in soil properties were tested with two-way analysis (ANOVA) using GLM procedure, with diameter classes (45-55, 55-65, 65-75, 75-85, 85-95, 95-105cm) and depth (0-15, 15-30 and 30-45 cm) as independent factor. Interactions between independent factors were tested also. Duncan test was used to separate the averages of the dependent variables which were significantly affected by treatment. Independent sample t-test carried out for compare means of soil properties between beech and hornbeam single trees. Significant differences among treatment averages for different parameters were tested at P ≤ 0.05. SPSS v. 11.5 software was used for all the statistical analysis.

RESULTS AND DISCUSSION

Analysis of variance of studied characters is indicating that in relation to beech single trees, the greater amounts of bulk density belong to 45-55cm diameter class and the least was detected in 65-75cm class (Table 1). This character showed the maximum and minimum in 45-55cm and 75-85cm diameter classes, respectively under hornbeam trees (Table 2). Bulk density was significantly greater under beech than under hornbeam (Figure 2). This character tends to be less in 0-15cm depth than in 15-30cm and 30-45cm depths (Tables 1 and 2). Soil texture components showed no significantly difference among diameter classes of beech trees, but the greater amounts of silt content was found in 30-45cm depth (Table 1). Under hornbeam, the higher values of silt, clay and lower amounts of sand were considered in 75-85 diameter class (Table 2). Sand content was significantly higher in 0-15cm, whereas the greater amounts of silt detected in 30-45cm depth. Clay amounts did not show any significant difference between depths (Table 2). Silt and clay were significantly greater under hornbeam than under beech (Figure 2). Moisture was significantly higher under beech than under hornbeam (Figure 2), whereas soil depths and diameter classes did not show any significant difference (Tables 1 and 2).

Results of present research are indicating that individual trees can be effective on soil physical indicators. The weight of a tree, combined with the movement of structural roots during windy conditions, can compress soils over centimeter-scales (Chappell et al. 1996). With considering to mountainous position of Hyrcanian forests in Iran and presence of trees with high diameters (old trees), therefore, it is imagined that many of trees are influenced by

Table 1. Mean of soil physical indicators in relation to diameter classes and soil depth in beech site

Variable / soil character		Bulk density (g/cm^3)	Sand (%)	Silt (%)	Clay (%)	Moisture (%)
Diameter class (cm)	45-55	1.13 (0.00)a	33.19 (0.59)	37.66 (0.31)	29.15 (0.28)	40.30 (0.27)
	55-65	1.11 (0.00)bc	32.04 (0.63)	38.72 (0.41)	29.23 (0.29)	39.54 (0.29)
	65-75	1.10 (0.00)c	32.11 (0.67)	38.61 (0.41)	29.27 (0.28)	41.82 (0.26)
	75-85	1.12 (0.00)b	32.00 (0.64)	38.72 (0.41)	29.27 (0.28)	39.93 (0.30)
	85-95	1.11 (0.00)bc	32.11 (0.67)	38.61 (0.41)	29.27 (0.28)	39.24 (0.29)
	95-105	1.12 (0.00)ab	33.18 (0.58)	37.66 (0.31)	29.15 (0.28)	39.88 (0.30)
	F-value	7.60**	0.70ns	2.14ns	0.02ns	2.23ns
Soil depth (cm)	0-15	1.11 (0.00)b	32.94 (0.41)	37.78 (0.22)b	29.27 (0.19)	40.21 (0.21)
	15-30	1.12 (0.00)a	32.71 (0.39)	38.07 (0.20)b	29.21 (0.19)	39.89 (0.22)
	30-45	1.12 (0.00)a	31.68 (0.48)	39.13 (0.31)a	29.18 (0.19)	40.26 (0.70)
	F-value	10.50**	1.90ns	7.86**	0.03ns	0.21ns
	Interaction	0.70ns	0.09ns	0.38ns	0.00ns	0.77ns

Note: ** Different is significant at the 0.01 level. (ns): Non significant differences ($P > 0.05$). Values are the means ±St. error of the mean (in parenthesis). Within the same column the means followed by different letters are statistically different ($P < 0.05$).

Table 2. Mean of soil physical indicators in relation to diameter classes and soil depth in hornbeam site

Variable / soil character		Bulk density (g/cm^3)	Sand (%)	Silt (%)	Clay (%)	Moisture (%)
Diameter class (cm)	45-55	1.13 (0.00)a	33.18 (0.58)a	37.26 (0.31)c	29.15 (0.28)b	39.40 (0.33)
	55-65	1.12 (0.00)a	32.04 (0.63)ab	38.73 (0.41)b	29.23 (0.29)b	39.18 (0.30)
	65-75	1.09 (0.00)b	30.31 (0.66)b	39.57 (0.45)b	30.11 (0.28)b	39.76 (0.28)
	75-85	1.05 (0.00)c	25.34 (1.89)c	42.53 (1.85)a	32.07 (0.29)a	39.89 (0.32)
	85-95	1.11 (0.01)ab	30.27 (0.67)b	39.57 (0.45)b	30.16 (0.28)b	39.41 (0.29)
	95-105	1.11 (0.00)ab	32.00 (0.64)ab	38.73 (0.41)b	29.27 (0.28)b	39.32 (0.27)
	F-value	13.89**	17.08**	24.79**	11.10**	0.70ns
Soil depth (cm)	0-15	1.09 (0.00)c	31.92 (0.51)a	37.97 (0.21)c	30.07 (0.32)	39.85 (0.21)
	15-30	1.10 (0.00)b	30.97 (0.58)a	39.02 (0.30)b	29.99 (0.31)	39.42 (0.19)
	30-45	1.11 (0.00)a	28.68 (1.23)b	41.38 (0.95)a	29.93 (0.31)	39.21 (0.20)
	F-value	4.43*	12.34**	54.87**	0.08ns	2.07ns
	Interaction	0.35ns	3.95**	16.39**	0.00ns	0.27ns

Note: ** Different is significant at the 0.01 level. *Different is significant at the 0.05 level. (ns): Non significant differences (P > 0.05). Values are the means ±St. error of the mean (in parenthesis). Within the same column the means followed by different letters are statistically different (P < 0.05).

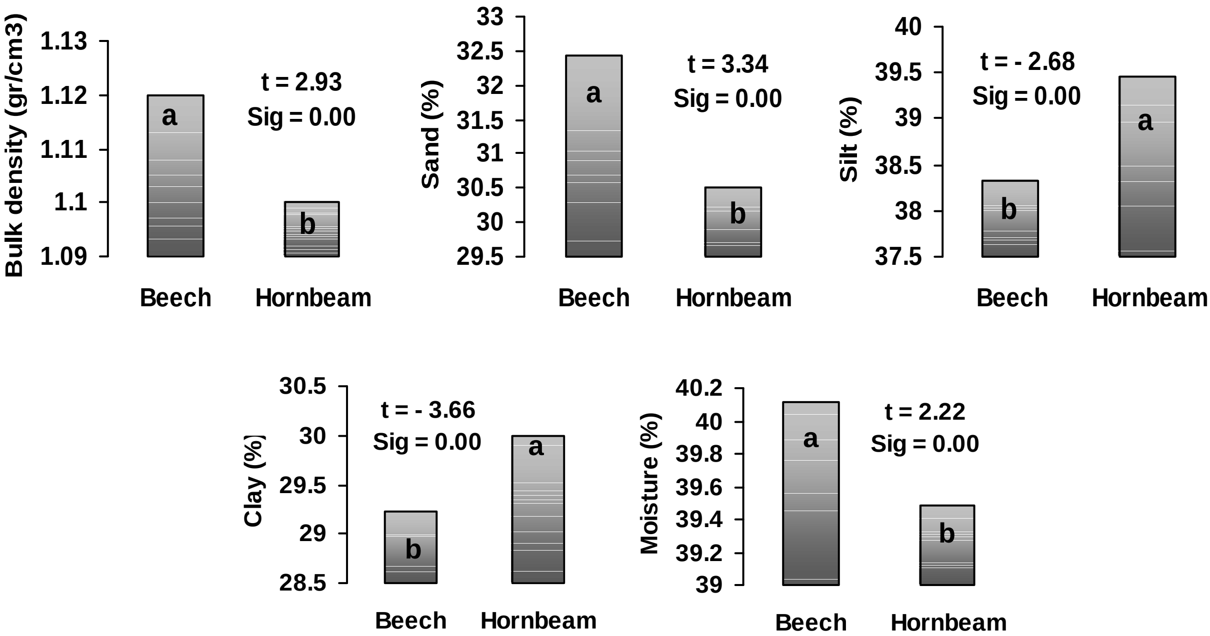

Figure 2. Mean of soil physical indicators in relation to beech and hornbeam individual trees

windthrow event. Old trees in study area (beech and hornbeam) with high diameters and intensive crown covering are similar to sail in front of windthrow, therefore, are more impacted of heavy windthrow. The factors collection together including large crowns and full foliage, rooting form, the higher height and high diameters of these trees making theirs vulnerable to windrthrow (Kooch et al. 2008). Thus, heavy windthrow can be imposed on these trees and are due to theirs movement in small scale that this subject is effective on variability of bulk density. At the millimetre scale, the growth of tree roots can locally increase the density of soil and have a localized impact on bulk density (Blevins et al. 1970; Whalley et al. 2004). Thus, mentioned factors can be effective on variability of bulk density under individual trees. In this research, bulk density increased in soil deeper layers. Both living and decayed roots can create well-connected pores in the topsoil called ‘macropores’ (Chandler and Chappell 2008). Pay attention to upper soils have more density of fine roots, thus these pores occurred in superficial soils that are due to decreasing of bulk density, finally. Bulk density showed significantly increasing under beech than hornbeam.

Soil acidification due to an increase in the rate of dissolution of soil minerals beneath trees (Augusto et al. 2000), acidic litter-fall (Chappell et al. 2006) or acidic exudates (Chappell et al. 2007) has been shown to reduce soil structural stability. This reduced stability can lead to a reduction in soil porosity. High rates of leaching by infiltrating stem-flow can exacerbate the acidification effect (Augusto et al. 2002). Regarding to low acid under beech than hornbeam, thus instability is more considered in soils imposed by beech trees. By this reason, porosity is decreased under beech and bulk density will be increased that is according to obtained result in this research. The soil acidity also affects the presence and abundance of soil fauna, such as earthworms (Neirynck et al. 2000). As earthworm activity creates more stable soil aggregates and adds macro-porosity, reduced abundance would be expected to increase of bulk density. In general, soil pH detected as the most important effective factor on earthworms abundance (Boettcher and Kalisz 1991; Neirynck et al. 2000). Research results of Kooch et al. (2011) in study area showed that soil pH was significantly less under beech than hornbeam and earthworm's abundance were fewer also. Thus bulk density showed significantly increasing under beech than hornbeam. This result also can be related to more activity of earthworm's population under hornbeam individual trees. The composition of the over story has an impact on soil structure (Read and Walker 1950). Graham and Wood (1991), Graham et al. (1995) have shown that the soil structure and its stability were tree species dependent, probably because of differential effects on worm activity.

Furthermore, wild and domesticated animals use isolated trees for shelter during rainstorms or for shade from intense solar radiation. This congregation of animals, particularly at times when the soil is wet, can compact the soil and thereby increase the bulk density of the soil horizon (Drewry et al. 2000). Regarding to more amounts of moisture under beech than hornbeam, soil compaction was more occurred, thus increasing of bulk density is more considered. Silt and clay were more gathered under hornbeam than beech that can be related to earthworm's greater densities as with creation of macropores they are due to changes in the components of soil texture. Earthworms are able to transferring of smaller components of soil (i.e. clay and silt) to different layers. Beech individual trees with superficial rooting system have more ability for preservation of soil moisture in upper soil. Thus, moisture was significantly higher under beech than under hornbeam, whereas soil depths did not show any significant difference. In total, compared to open areas, the reduced precipitation received beneath tree canopies due to enhanced wet-canopy evaporation (David et al. 2006) combined with greater root abstraction to support transpiration can lead to considerably greater topsoil drying during rain-free periods (Ziemer 1968; Katul et al. 1997).

The study has shown that the influence of individual trees with different diameter classes can be detected in forest floors and upper minerals soil layers even under mixed stands in steepy sloping landscapes. The magnitude of the differences observed depends to some degree on the nature of the forest stand and under story vegetation and on climatically and topographically controlled processes such as litter redistribution and soil creep. In any case, the soil landscape may be viewed as a mosaic, with properties of the individual pedons composing the mosaic reflecting the occurrence and physical characteristics of the tree species present. Differences in substrate properties beneath the crown of juxtaposed tree species may in some cases be large enough to result in short-range variations in soil properties and plant growth (Kooch et al. 2011). Present research was the first survey to quantify the local effect of individual trees on soil physical indicators in Hyrcanian forests of Iran. However, the effect of over story species is strongly influenced by forest management (e.g. low density stands or mixed stands) that, further researches should address this point.

CONCLUSION

The forest soils can be strongly influenced by tree species. Many studies have addressed the effects of monocultures on forest soil physical, but few have examined the effects of varying ratios of species within stands. In current research, the validity of the concept of "single-tree influence circles" was tested in a forest dominated by beech (*Fagus orientalis* Lipsky) and hornbeam (*Carpinus betulus* L.) on steep slopes in the Alborz Mountain, Hyrcanian forest of Iran. In this paper, we presented data on and discussed the effects of individual species trees on soil physical indicators in a single soil map unit in an old-growth northern hardwood forest. Soil bulk density and moisture were significantly greater under beech than under hornbeam. Whereas, silt and clay were significantly greater under hornbeam than under beech. We propose that soil diversity in this old-growth northern hardwood forest is substantial and suggest that it be considered in soil survey and forest management.

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