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ASSESSMENT OF THE RELATIONSHIP BETWEEN SOIL PROPERTIES IN AN OLD TREE LINE AND ITS RELATION TO TREE DENSITY AND TREE TRUNK CIRCUMFERENCE

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Abstract: Soil organic carbon (SOC) is known as a vital ecosystem service, resulting from interactions of ecological processes. It is important for its contributions to food production, mitigation, and adaptation to climate change. In this study, we investigated the relationship between tree density and tree trunk circumference with the soil chemical properties in the small tree line area located in Józsefmajor, Hungary. The interrelation between different chemical soil properties also was measured. For this purpose, samples were taken in 24 plots (6 m×13m) from 0–10 soil depths. Tree density and tree trunk circumference in each plot were measured. The Near-Infrared spectroscopy technique (Wavelength Range: 1300–2600nm MEMS (micro-electromechanical systems) technology) was used to estimate the chemical properties of the soil. Pearson and Spearman correlation analysis was applied to study the interrelationships between two multivariate data sets, tree density and trunk circumference were compared with soil properties. The results showed a significant relationship between some soil chemical parameters, especially between soil organic carbon (SOC) and total N and also the cation exchange capacity (CEC) with SOC and total N. Besides, this study shows that the plots containing more trees and with a higher trunk circumference provide higher SOC and total N concentrations. Trunk circumference has a slightly stronger correlation with these two soil properties compared to those of tree density.

Introduction

Soil is an important component of the biosphere which is formed by physical and/or chemical weathering due to the disintegration of parent materials (rock) (White et al. 2013). The quality of soil is a combination of stable and dynamic soil properties. Soil properties vary even in relatively small spatial scales (Ziadi et al. 2013, Centeri et al. 2012). Stable soil components (e.g. texture or mineral composition and dynamic characteristics (e.g. nutrient content, pH, humus) at a time scale are relevant to ecological processes (Oelmann et al. 2009, Goebes et al. 2019).

The dynamics of soil properties are affected by various factors including soil erosion (Centeri és Pataki 2003, Barczi és Centeri 2005, Barczi et al. 2006, Olson et al. 2011, Smith 2008, Edmondson et al. 2014, Kohlheb et al. 2014, Jakab et al. 2016), land use and land cover, climatic factors, topography (considered as main environmental controls of soil organic carbon (SOC) and total nitrogen (TN)) (Wang et al. 2012), landscape position and parent material texture (Osher and Buol 1998).

Among these factors, there is a broad agreement that land-use and land cover is a major altering force (Centeri 2002, Centeri és Császár 2005, Grónás et al. 2006) that affects soil dynamic properties, especially for SOC through altering soil carbon turnovers, decomposition, and soil erosion (Stumpf et al. 2018, Szalai et al. 2016, Jakab et al. 2018).

Therefore, vegetation, plant, and tree play an important role in controlling soil chemical /dynamic properties (Cha et al. 2019) on a small scale, for instance, trees play a significant role in the capture and preservation of atmospheric CO_2 in vegetation, soils, and biomass. Therefore, the presence of trees is likely to enhance soil C sequestration in the topsoil (Rhoades 1996, Tomlinson 2005, Casals et al. 2014, Hoosbeek et al. 2018, Rieder et al. 2018), on the other hand, soil properties have an impact on plant growth and composition of the species. As Londo et al 2006 showed soil pH can be used as a general guide for assessing nutrient availability and therefore the species that may grow on a given site. Also, Medinski (2007) found that soil infiltrability, clay, silt, EC, and pH influence the richness of life forms including plants. According to this research, heterogeneity of these properties produces niches with special conditions, which influences plant spatial distribution.

By the valuation and monitoring of soil properties that are sensitive to change by land use and management (Centeri et al. 2012), the sustainability of an ecosystem can be estimated. Identifying the relationships between soil properties, and their linkage with land cover and plants can be useful in long-term restoration programs (Boecker et al. 2015) in degraded areas and provides an important tool for monitoring the quality of conservation in natural ecosystems because they allow the current situation to be identified, and risky situations to be alerted (Novak et al. 2019).

The objective of the present case study is to describe the effect of tree density and tree trunk circumference on the heterogeneity and distribution of soil properties in a small scale of woodland.

Materials and methods

Location of the study area

The study site is located at the Józsefmajor (Fenyőharaszt) experimental and training Farm (JETF) of Szent István University (47° 41′ 30.6″ latitude N, 19° 36′ 46.1″ longitude E; 110m above sea level) with of a clay-loam texture, Endocalcic Chernozems, Loamic (WRB 2015). This small tree line (312m length and 6 m width) is covered with perennials and bushes whereas the predominant tree species of the strip is *Robinia pseudoacacia* (Black Locust). The area is flat (Elevation: 110 m above sea level) and the climate is continental with an average annual temperature of 10.3 and 15 °C. The average amount of precipitation is 520–570 mm/year of which 395mm falls in the vegetation period. The yearly number of sunny hours in the area is 1920–1980, and the main direction of the wind is NW-SE. Figure 1 shows the location of the case study in Hungary and Figure 2 shows a view of the tree line where the samples had taken.

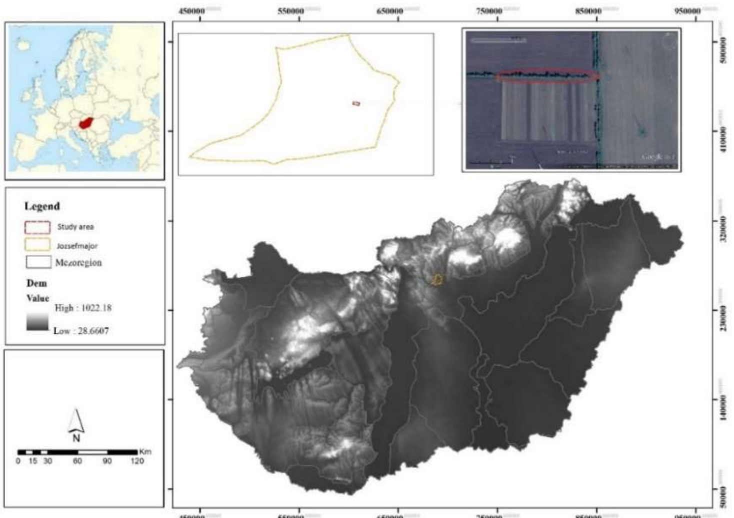

Figure 1. Location of the study area at Fenyőharaszt, Hungary
1. ábra A fenyőharaszti kísérleti terület elhelyezkedése

Figure 2. Tree line at Fenyőharaszt in between two arable fields, Hungary
2. ábra A fasor a két szántóföld között Fenyőharaszton

Methodology

To estimate the effect of tree density and tree trunk circumference on the heterogeneity and distribution of soil properties an experiment was arranged in a randomized sampling in a block design (Dekemati et al. 2019). This experiment included 2 steps: (1) soil sampling and tree measurement, (2) the measurement of soil properties. As the case study is small tree line with a size of 312m length and 6m width, it is divided into 24 plots (13×6) with different tree densities.

The sampling was performed in 24 plots with a size of 6m×13m and a soil depth of 0–10 cm (figure 3). For this purpose, 3 points were selected randomly under or near the trees on each plot, the 3 soil cores per plot were combined into a mixed sample so that finally 24 soil samples were available for the whole area, the roots were picked out of the soil by hand. Also, we measured tree number and tree trunk circumference on each plot. Here we considered plants with the height more than 6 m as a tree.

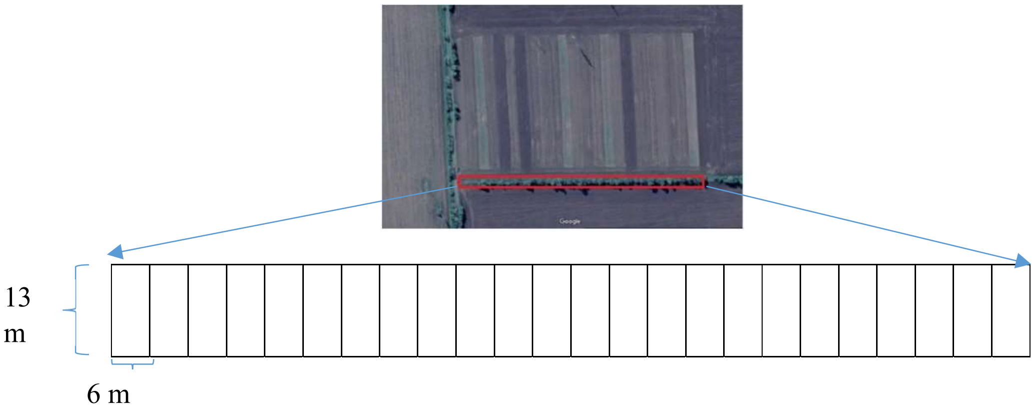

Figure 3. Location of sampling and 24 plots at Fenyőharaszt, Hungary
3. ábra A mintavétel és a 24 parcella helye Fenyőharaszton, Magyarország

Analyses of basic soil properties

We used the Near-infrared spectrometry (Wavelength Range: 1300–2600 nm MEMS (micro-electromechanical systems) technology) to measure soil properties with an agro-care scanner device. Near-Infrared spectroscopy is a robust method that requires little soil preparation (e.g removing roots and stones) (Sharififar et al. 2019). In this study, an agro scanner was used to estimate soil parameters including (OC (%), total N (g/kg), total P (g/kg), cation exchange capacity (CEC), exchangeable K (mmol/kg), clay content (%), pH (KCl). Figure 4 shows the agro scanner used for measurement in this study.

Figure 4. The Soil Cares soil scanner and its use during soil measurement
4. ábra A Soil Cares talajszkenner és használata talajvizsgálat közben

Data Analysis

A variable analysis illustrates the important features of the measured soil parameters and tree properties (Table 1). According to Table 1, the measured data show a normal distribution except for tree density and tree trunk circumference. Pearson's linear correlation coefficient was used as a measure for the relationship between soil parameters. To investigate the correlation between soil parameters and a- tree density and b- trunk circumference, the non-parametric analysis of the Spearman correlation (ρ) was used because of the abnormal distribution of the data. Also, P-value is used to test the statistical significance of the estimated correlations. P-values below 0.05 indicate statistically significant non-zero correlations at the 95.0% confidence level. Statgraphics 18 software was used for the statistical analysis.

Result

Table 1 shows the important characteristics of all measurements, in terms of chemical properties, the chernozem from the study area is well supplied by organic matter, with a humus content of over 4%. This chernozem is also well-supplied with nutrients, with a total nitrogen content of 3.1 ppm on average. The phosphorus content is about 83 ppm and the potassium content is around 7.5 mmol/kg. The soil reaction is low acidic, as the average of pH value is 5.8. In conclusion, there can be said that the chernozem from studied area has a high productivity potential for sure yields. Distribution of this data is normal as here the standardized skewness value and standardized kurtosis value are within the range expected for data from a normal distribution (-2, +2).

Table 3 shows the result of spearman analysis for soil parameters and tree density and tree trunk circumference. The correlations between SOC, Total-N, and CEC, SOC, Total-N were highly significant and strong (Table 2), and it can also be observed that there are significant correlations between other soil properties, including: CEC and Clay, clay and pH, exchangeable K and pH and total P, SOC and total P, Total N and total P. Table 3 summarizes the correlation coefficient for tree density and tree trunk circumference.

Table1. Summary of statistics for soil chemical and main tree properties
1. táblázat A talajkémiai tulajdonságok általános statisztikai értékelése és a fő fa tulajdonságai

Static	OC (%)	Total N (ppm)	Total P (g/kg)	Cation exchange capacity (mmol/kg)	Exchangea-ble K (mmol/kg)	Clay (%)-	pH (KCl)	Tree den-sity (tree/area)	Treetrunk cir-cumference (cm)
Count	24	24	24	24	24	24	24		
Average	5.77	3.10	0.83	214.47	7.50	18.80	5.81	5.83	278.05
Median	5.6	3.2	0.8	223.55	7.7	19.05	5.7	4.5	248.1
Mode	-	3.3	0.8	-	7.7	19.4	5.5	2.0	
Standard deviation	1.39	0.57	0.09	37.68	1.23	3.61	0.44	5.25	153.16
Coeff. of variation	24.21	18.61	11.002	17.57	16.42	19.22	7.59	90.099	55.0836
Minimum	3.8	2.2	0.7	155.3	4.6	12.2	4.8	1.0	50
Maximum	8.5	4.2	1.0	270.6	10.1	26.6	6.5	26.0	700.7
Range	4.7	2.0	0.3	115.3	5.5	14.4	1.7	25.0	650.7
Lower quartile	4.65	2.75	0.8	182.2	6.75	15.8	5.5	2.0	199.25
Upper quartile	6.4	3.35	0.9	245.55	8.45	21.4	6.25	7.0	318.15
Interquartile range	1.75	0.6	0.1	63.35	1.7	5.6	0.75	5.0	118.9
Stnd. skewness	1.168	0.168	0.711	-0.650	-0.909	0.401	-0.056	5.301	2.229
Stnd. kurtosis	-0.43	-0.64	-0.47	-1.16	0.64	-0.55	-0.42	9.11	1.94

This table shows that SOC and total N have a significant positive correlation with tree density and tree trunk circumference, while other parameters - including total P, CEC, exchangeable K, clay (%) - have not.

Table 2. Correlations coefficient of soil properties, significant correlations at the >95% probability level are bold
2. táblázat A talajtulajdonságok korrelációs együtthatói

Soil parameters	CEC	Clay	Exchangeable K	SOC	pH	Total N	Total P)
CEC		**0.47**	0.06	**0.60**	0.23	**0.67**	0.16
P-value		*		**		**	
Clay	**0.47**		0.13	-0.05	**0.55**	0.12	-0.05
P-value	*				**		
Exchangeable K	0.06	0.12		0.21	**0.44**	0.30	**0.40**
P-value							*
SOC	**0.60**	-0.05	0.21		-0.05	**0.94**	**0.55**
P-value	**					***	**
pH	0.23	**0.55**	**0.44**	-0.05		0.07	0.30
P-value		**	*			0.72	0.15
Total N	**0.67**	0.12	0.30	**0.94**	0.07		**0.52**
P-value	**			***			**
Total P	0.16	-0.05	**0.40**	**0.55**	0.30	**0.52**	
P-value			**0.048**	**0.0053**		**0.0087**	

Only the pH shows significant negative correlations with the tree trunk circumference in this study. The research area's soil pH range (4.8-6.5) is classified as highly acidic to neutral soil (NRCS 1998), so this finding can show that the current tree species (Robinia pseudoacacia) are acidic soil-resistant.

Table 3. Correlations of soil properties with tree trunk circumference and tree density
3. táblázat A fa mellmagassági körméretek és a fasűrűség összefüggései a talajtulajdonságokkal

Parameter	SOC (%)	Total N (ppm)	Total P (g/kg)	Cation exchange capacity (mmol/kg)	Exchangeable K (mmol/kg)	Clay (%)	pH (KCl)
Tree density	**0.47**	**0.42**	0.27	0.06	-0.12	-0.18	-0.2
P-value	*	*					
Tree trunk circumference	**0.50**	**0.46**	0.09	0.19	-0.14	-0.19	**-0.40**
P-value	*	*					*

Discussion

Soil is a diverse form of the physical, chemical, and biological process that occurs over spatial and temporal scales. Soil properties integrate and reflect both past and present conditions at a given location (Jhariya et al. 2019). In this study, we investigated the interaction between soil properties and also the influence of trees on soil properties with a focus on soil organic carbon. In general, the presence of trees caused larger concentrations of C, N, and P in the topsoil compared to the grassland (Hoosbeek et al 2018).

One of the main benefits of agroforestry is the potential contribution of trees to soil improvement. Therefore, in this study, we focus on finding a correlation between soil properties (in particular SOC) and tree density and trunk circumference in a natural ecosystem where located on the opposite side of arable land nearby. As soil fertility, plant growth, and reproduction all depend on the chemical properties of the soil, so it's important to consider the soil's chemical properties and their interaction which influence the soil's ability to retain and release nutrients.

Earlier research has already shown that there is a significant correlation between the chemical properties of the soil (Kamprath and Welch 1962, Syers et al 1970, Fang et al.2007, Solly et al. 2020, Fu et al. 2010, Liu et al. 2016). Kamprath and Welch (1962) and Syers et al (1970) show, the cation exchange capacity (CEC) of soil is closely related to organic carbon and clay content, which is consistent with the results of this study. The reason for this might be that clay particles have negatively charged sites that allow them to adsorb and adhere to cations so that increasing the clay content of soil would further increase its CEC (Efretuei 2016). As this study shows, there is a significant correlation between the clay content and pH. This could be due to the influence of pH through its effect on the net negative charge of the clay particles.

We observed that the content of SOC is significantly correlated with the CEC, which confirms the results of previous studies (Fang et al. 2007, Solly et al. 2020). The increase in cation exchange sites provided by soil organic matter may partly explain this phenomenon and it is because the organic matter colloids have large quantities of negative charges.

In this study, we also found a significant relationship between SOC and nitrogen contents, which is consistent with other findings (Fu et al. 2010, Liu et al. 2016). It is because, in areas, with perennial vegetation, the source of organic carbon and nitrogen is the same, and most often it is the decomposition of litter (Xue and An 2018).

Besides, this study showed a significant relationship between total P, SOC, and total N contents, which was also obtained from other authors (Lemanowicz 2018, Singh et al. 2015, Hou et al. 2014) and exchangeable K content. This positive relationship between soil organic carbon and N with P can be explained by considering this point that, soil organic matter promotes soil microflora biological activity, so the intensity of activity of soil microflora promotes P solubilization and resulting increases available- P amounts. Also, nitrogen could provide the necessary element for the production of phosphatase catalyzing biochemical phosphorus mineralization (Liu et al. 2014).

There is a rather weak relationship between exchangeable potassium and total P with other soil properties studied. The correlation between the exchangeable potassium and soil acidification is explained by the fact that leaching of basic soil cations causes soil acidification. This means that a positive correlation between soil pH and exchangeable K, which is a basic cation, should be identified (Kozak et al. 2005).

In this study, we also investigate the relationship between tree density and tree trunk circumference with soil properties. As the results show (Tab.3), both tree density and trunk circumference have a positive effect on SOC and total N, which was also reported by Hoosbeek et al (2018), possibly by influencing the litter dynamics (Edmondson et al. 2014) root density and completeness of resource utilization (Islam et al. 2015). Trees influence the input into the soil system by increasing the capture of wetfall and dryfall and adding N_2 fixation to the soil (Rhoades 1996). Soil carbon is slowly absorbed into the soil when plant material dies and is deposited in the soil (Rhoades 1996). Even after the significant coefficient value, where tree trunk circumference is more important than tree density, it is concluded that plots with larger and older trees can increase the amount of SOC.

Conclusions

In conclusion, considering that trees and plants, with increasing litterfall and increasing supply of soil with organic matter, lead to an increase in the organic content and total N content of the soil, thus increasing soil fertility in soils, understanding this fact about the interactions between tree and soil is an important and essential interest of farmers and foresters involved in maintaining or increasing the productivity of sites. From an ecological point of view, the soil patches under the treetops are valuable local and regional reserves of nutrients and carbon that influence community structure and ecosystem functioning.

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EGY IDŐS FASOR TALAJTULAJDONSÁGAI KÖZÖTTI KAPCSOLATOK ÉRTÉKELÉSE, ÉS ÖSSZEFÜGGÉSE A FA ÁLLOMÁNYSŰRŰSÉGÉVEL ÉS TÖRZSKERÜLETÉVEL

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Kulcsszavak: szerves szén, művelés nélküli talaj összes nitrogén-tartalma, talaj-növény összefüggés

Besides, this study shows that the plots containing more trees and with a higher trunk circumference have more soil organic carbon and total N, and it is shown that the tree trunk circumference has a more significant correlation with these two soil properties. Egy józsefmajori fasorban vizsgáltuk a fasűrűség és a törzskerület közötti összefüggését a talaj kémiai tulajdonságaival. Mértük a talaj különböző kémiai tulajdonságai közötti összefüggést. Az összehasonlítás érdekében 24 parcellán (6m×13m) vettünk mintát 0–10 cm talajmélységből. Minden parcellán megmértük a fasűrűséget és a törzskerületeket. A talaj kémiai tulajdonságainak becslésére Near-Infrared spektrométer technikát (Wavelength Range: 1300–2600nm MEMS (Micro-ElectroMechanical Systems) technológia) alkalmaztunk. Lineáris regressziót (Pearson és Spearman korrelációs analízis) alkalmaztunk két, többváltozós adatsor közötti összefüggések vizsgálatára, fa sűrűsége és a törzskerülete került összehasonlításra a talaj tulajdonságaival. Az eredmények szignifikáns kapcsolatot mutattak ki a talaj egyes kémiai paraméterei között, különösen a talaj szerves szén- (SOC) és az összes nitrogén-tartalma között, valamint a kationcsere-kapacitás (CEC) és a SOC és az összes N között, ami nincs összhangban a korábbi tanulmányokkal. Ezen túlmenően ez a vizsgálat azt mutatja, hogy a több fát tartalmazó és nagyobb törzskerületű parcellákban több a talaj szerves szén- és össz-N-tartalma, és kimutatható, hogy a fatörzs kerülete szignifikánsabb összefüggésben van ezzel a két talajtulajdonsággal.