AGROKÉMIA ÉS TALAJTAN
(AGROCHEMISTRY AND SOIL SCIENCE)
71 (2022) 1, 119-134
DOI: 10.1556/0088.2021.00079

First published online: 29 Mar 2021

The response of soil physicochemical properties and soil microbial respiration to different land use types: A case of areas in Central-North Hungary region

*Tsedekech Gebremeskel WELDMICHAEL, Erika MICHÉLI, Barbara SIMON

Szent István University, Faculty of Agriculture and Environmental Science, Department of Soil Science, Páter Károly u. 1, 2100, Gödöllő, Hungary

Abstract

Land use change may modify key soil attributes, influencing the capacity of soil to maintain ecological functions. Understanding the effects of land use types (LUTs) on soil properties is, therefore, crucial for the sustainable utilization of soil resources. This study aims to investigate the impact of LUT on primary soil properties. Composite soil samples from eight sampling points per LUT (forest, grassland, and arable land) were taken from the top 25 cm of the soil in October 2019. The following soil physicochemical parameters were investigated according to standard protocols: soil organic matter (SOM), pH, soil moisture, NH_4^+–N, NO_3^-–N, AL-K_2O, AL-P_2O_5, $CaCO_3$, E_4/E_6, cation exchange capacity (CEC), base saturation (BS), and exchangeable bases (Ca^{2+}, Mg^{2+}, K^+, and Na^+). Furthermore, soil microbial respiration (SMR) was determined based on basal respiration method. The results indicated that most of the investigated soil properties showed significant difference across LUTs, among which NO_3^-–N, total N, and K_2O were profoundly affected by LUT ($p \leq 0.001$). On the other hand, CEC, soil moisture, and Na^+ did not greatly change among the LUTs ($p \geq 0.05$). Arable soils showed the lowest SOM content and available nitrogen but the highest content of P_2O_5 and $CaCO_3$. SMR was considerably higher in grassland compared to arable land and forest, respectively. The study found a positive correlation between soil moisture ($r = 0.67$; $p < 0.01$), Mg^{2+} ($r = 0.61$; $p < 0.01$), and K_2O ($r = 0.58$; $p < 0.05$) with SMR. Overall, the study highlighted that agricultural practices in the study area induced SOM and available nitrogen reduction. Grassland soils were more favorable for microbial activity.

Keywords: agricultural intensification, land use type, soil properties, soil microbial respiration, Central-North Hungary

*****Corresponding author*: TSEDEKECH GEBREMESKEL WELDMICHAEL, Szent István University, Faculty of Agriculture and Environmental Science, Department of Soil Science, Páter Károly u. 1, 2100, Gödöllő, Hungary.
E-mail: tsedyweld@gmail.com

Introduction

Land use change has been a global concern as it leads to soil degradation and soil nutrient cycles alteration. Land degradation is a growing concern for food security and ecosystem services in Europe and Central Asia. One of the major drivers of soil degradation in this region is agricultural intensification, which results in soil erosion, soil organic matter (SOM) loss, compaction, and soil pollution (FAO, 2015). Soil degradation decreases the capacity of the soil to supply primary production and its functional capacity to perform numerous critical ecosystem services (LEHMAN et al., 2015). In the last decade, the agricultural area in Hungary has declined; however, the country is among the leaders in terms of the proportion of agricultural land to the total area in the European Union (BOZSIK & KONCZ, 2018). Two third of the country is used for agriculture (JAKAB et al., 2015).

Land use and management practices influence the physical, chemical, and biological properties of soils. In most of the lands used for agricultural activities, soil organic matter and nutrients availability have shown decline compared to undisturbed land use types such as forest and grasslands (CELIK, 2005). The changes in soil physicochemical properties affect soil microbial diversity, abundance, and activity (PAULA et al., 2014). Land use type also affects soil microbes by modifying the type of litter input, root depth, and turnover rates (VAN LEEUWEN et al., 2017). Soil microorganisms govern ecosystem functioning through decomposition and nutrient cycling (CREAMER et al., 2016). Therefore, the ability to reverse soil degradation and improve soil functions is closely linked to the ability to promote the biological functioning or health of the soil (LEHMAN et al., 2015). Soil microbial respiration (SMR), a process by which soil microbes decompose organic matter, is considered a reliable ecological indicator to assess soil microorganisms overall metabolic activity (MOSCATELLI et al., 2018). In Europe, CREAMER et al. (2016) noted that soil respiration rate was greatly influenced by soil properties, such as pH, SOM, total nitrogen (TN), and cation exchange capacity (CEC). Temperature and water content were also found to be critical variables influencing SMR in soils from Hungary (TÓTH & FARKAS, 2010).

The influence of various land use and soil management systems on soil microbial communities and activities is well examined; however, in Hungary only a few studies are available , which deal primarily with the effects on soil microbial activity (GANGWAR et al., 2018). Although the general relationship between land use type (LUT) and its effects on soil properties is well understood, the extreme spatial and temporal heterogeneity of soils and the complex interaction among biological, physical, and chemical components of the soil make the prediction of land use effects challenging. Hence, site specific information is needed for their interpretation in a local context. Thus, the objective of the present study was to investigate the effect of LUT on physicochemical properties and SMR to provide site-specific information important to support the development of management alternatives to maximize and sustain soil functions in the study area.

Materials and Methods

Description of the study area

The study was carried out on the experimental farm of Szent István University at Gödöllő hill and Száritópuszta in Gödöllő town (47° 35’ 47.65” N, 19° 21’ 18.54” E) and Hort city (47° 41′ 24″ N, 19° 46′ 48″), in Hungary. The sites encompassed three LUTs (forest, grassland, and arable land) and four reference soil groups (RSGs) (Luvisols, Chernozems, Arenosols, Phaeozems) (IUSS WORKING GROUP WRB, 2015).

The Gödöllő sites belong to the Gödöllő-Monori hilly region, which is part of Northern Hungarian Mountain. The mean annual temperature ranges from 9.5–10°C, and the yearly precipitation is about 600 mm (DÖVÉNYI et al., 2008). The Gödöllő forest soils have been classified as Luvisols and are mostly under oak trees (*Quercus cerris and Quercus robur*) grown more than 50 years. The grassland site of Száritópuszta was classified as Phaeozem and the arable site as Arenosol. The grassy vegetation has been left undisturbed for more than 20 years and predominantly consisted of *Echinochloa crus*, *Echinochloa galli*, *Setaria pumila*, *Chenopodium album*, *Fallopia convolvulus*, and *Ambrosia artemisiifolia.* The arable field was tilled with cultivator and complex fertilizer (NPK (15/15/15), 100 kg ha^{-1} Calcium ammonium nitrate (NH_4NO_3 + $CaMg(CO_3)_2$) was applied. During the sampling, winter oat was grown on the field.

The research sites in Hort are located in Heves County, which belong to North Great Hungarian Plain. The average annual temperature ranges from 10–11°C, and the mean rainfall is between 550–600 mm (DÖVÉNYI et al., 2008). The soil belongs to Chernozem soil type. The grassland site has not been cultivated for 6 years and dominated by *Elymus repens*. The arable site was subjected to intensive tillage by harrowing with heavy disc and 150 kg N ha^{-1} was applied in the form of 34% ammonium nitrate . Earlier, the field was used to grow wheat and during the sampling oilseed rape (*Brassica napus*) was grown. The general description of the sampling sites is presented in *Table 1*.

Soil sampling and preparation

The soil sampling was conducted on six sites (two replication of each LUT) in October 2019. At each site, eight points around the main soil profile in a 10 m radius were designated as sampling points. Eight soil subsamples, from a depth of 0–25 cm, were collected from each site, compiled, and mixed thoroughly to make a composite sample. In total, six composite soil samples (two from each LUT) were collected. From the composite sample, two subsamples were taken for: a) physiochemical and for b) SMR analyses. Soils for SMR were stored in a refrigerator at 4°C, while soils for physicochemical analyses were air dried and sieved through 2 mm mesh and kept at room temperature until the analyses.

Table 1
General description of sampling sites

Site	Location	Land use	RSG (WRB, 2015)	Elevation (m)	Texture class
GUF	Gödöllő hill	Forest	Luvisol	245	Sandy loam
GBG	Gödöllő hill	Forest	Luvisol	248	Sandy loam
SZP1	Szárítópuszta	Grassland	Phaeozem	222	Sandy loam
SZP2	Szárítópuszta	Arable	Arenosol	232	Sandy
CSGY	Hort	Grassland	Chernozem	160	Heavy clay
CSSZ	Hort	Arable	Chernozem	160	Clay loam

Abbreviations: Reference soil group (RSG), Gödöllő university forest (GUF), Gödöllő botanical garden (GBG), Szárítópuszta 1 (SZP1), Szárítópuszta 2 (SZP2), Hort 1 (CSGY), Hort 2 (CSSZ)

Physicochemical analyses

Soil pH was determined potentiometrically in a soil to water suspension (1:2.5) (BUZÁS, 1988). Soil moisture was estimated by gravimetric method at 105°C for 24 h (BUZÁS, 1993). Available nitrogen (NH_4^+–N and NO_3^-–N) was measured using Parnas-Wagner apparatus (EGNÉR et al., 1969), while AL (ammonium-lactate)- P_2O_5 and K_2O were extracted according to EGNÉR et al. (1960) and measured using flame photometer and UV-VIS spectrophotometer, respectively. SOM was determined using Walkley-Black method (WALKLEY & BLACK, 1934). The quality of humic substances (E_4/E_6) was determined using spectrometer based on PAGE et al. (1982). $CaCO_3$ content was measured using Scheibler calcimeter (BUZÁS, 1988). CEC and exchangeable basic cations (Ca^{2+}, Mg^{2+}, K^+, and Na^+) were extracted following the Mehlich 3 extraction (MEHLICH, 1953), and the base cations were measured using ICP-spectrometer. All laboratory analyses were performed in triplicates.

Determination of SMR

The analysis of SMR followed the ISO 16072:2002(E) guideline and CHENG et al. (2013) with minor modification. In short, fifty grams of moist field soil was measured and placed in an airtight jar with a suspended conical flask containing 10 mL of 1.0 M NaOH. The jars were flushed with clean air with low CO_2 content, tightly closed and incubated at 22°C for ten days. After ten days, the conical flask was removed and 1 ml $BaCl_2$ was added in the NaOH solution to precipitate the trapped CO_2. Three drops of phenolphthalein were added and titrated against 0.5 M HCl. The determination was carried out in triplicates. Controls (triplicate flasks without soil) were also prepared.

Statistical analyses

One-way ANOVA for parametric data or Kruskal-Wallis test for non-parametric data was applied to determine significant differences between the land uses analyzed. Tukey's test was applied at 5% significance for multiple comparisons of means of soil properties across LUTs. Pearson's correlation analyses were employed to examine the relationship between various physicochemical parameters and SMR (correlation was assumed significant when $p < 0.05$). All statistical analyses were performed in R software (R DEVELOPMENT CORE TEAM, 2017).

Results

Soil physicochemical properties

Table 2

Physicochemical characteristics among land use types

Parameter	Land use type			p-value
	Forest	Grassland	Arable	
SOM (%)	4.85b (0.280)	5.06b (0.58)	2.83a (1.19)	0.031 *
pH (H_2O)	5.08a (0.38)	7.62b (0.08)	7.83b (0.13)	0.002**
pH (KCl)	4.03a (0.33)	6.58b (0.08)	6.67b (0.16)	0.003**
$CaCO_3$ (%)	0.00a (0.00)	0.23ab (0.11)	1.14b (0.51)	0.112
Soil moisture (%)	21.58a (2.89)	31.20a (4.85)	21.98a (4.44)	0.241
NH_4^+–N (mg kg^{-1})	9.00b (0.47)	7.81ab (0.57)	5.96a (0.58)	0.004 **
NO_3^-–N (mg kg^{-1})	30.08b (3.66)	8.779a (2.62)	0.44a (0.20)	0.000***
Total N (mg kg^{-1})	39.08c (3.22)	16.57b (2.22)	6.40a (0.39)	0.000***
AL-K_2O (mg kg^{-1})	143.00a (12.92)	199.00b (8.19)	135.75a (8.07)	0.000 ***
AL-P_2O_5 (mg kg^{-1})	34.15a (3.99)	58.27a (21.14)	104.17a (32.82)	0.281
Ca^{2+} (cmol kg^{-1})	5.75a (1.24)	13.56b (2.15)	14.99b (2.06)	0.002**
Mg^{2+} (cmol kg^{-1})	0.92a (0.24)	7.38b (2.87)	2.46ab (0.02)	0.150
K^+ (cmol kg^{-1})	0.25a (0.04)	0.35a (0.02)	0.45b (0.05)	0.003 **
Na^+ (cmol kg^{-1})	0.08a (0.02)	0.64a (0.28)	0.20a (0.03)	0.430
CEC (cmol kg^{-1})	33.77ab (0.60)	35.88b (4.42)	30.71a (5.31)	0.750
BS (%)	20.61a (4.09)	56.55b (7.94)	60.12b (3.88)	0.003
E_4/E_6	6.31b (0.10)	3.57ab (0.68)	4.58a (0.39)	0.044

Values are the means (SE) of six replicates; different letters across the rows indicate significant differences among the variables at $p < 0.05$ (ANOVA). p-values show significant levels among the LUTs. *, **, ***: Significant at the 0.05, 0.01, and 0.001 levels, respectively. Land use type (LUT), soil organic matter (SOM), cation exchange capacity (CEC), base saturation (BS)

Considerable variability was observed among the LUTs with respect to most physicochemical properties (*Table 2*). Soils from the arable land showed significantly lower SOM content with a mean of 2.83% compared to soils collected from forest (4.85%) and grassland (5.06%), respectively. The ratio of E_4/E_6 was higher (6.31) in forest compared to arable (4.58) and grassland (3.75). The differences between LUT in K_2O was significant ($p = 0.0007$), ranging from 135 mg kg^{-1} in arable land to 199 mg kg^{-1} in grassland. The available nitrogen content of soils under cultivation was lower compared to levels in forest and grasslands. Forest soils exhibited significantly lower soil pH as compared to grassland and arable soils. However, the difference in pH between the grassland and arable soils was not statistically significant. Compared with grassland and forest soils, there was a high content of $CaCO_3$ and P_2O_5 in arable soils. Soil moisture did not show a significant difference among the land use types, whereby the highest value was recorded in grassland soils compared to arable land and forest soils.

Among the base cations, Ca^{2+} and K^+ were significantly higher in arable soils, followed by grassland and forest soils, whereas the amount of Mg^{2+} and Na^+ were highest in grassland and lowest in forest. The CEC did not show a significant difference between the LUT and ranged from 30.7 cmol kg^{-1} to 35.8 cmol kg^{-1} in arable and grassland soils, respectively. The forest soils were significantly different in base saturation (BS) from both the grassland and arable soils; however, there was no significant difference in BS between arable and grassland soils.

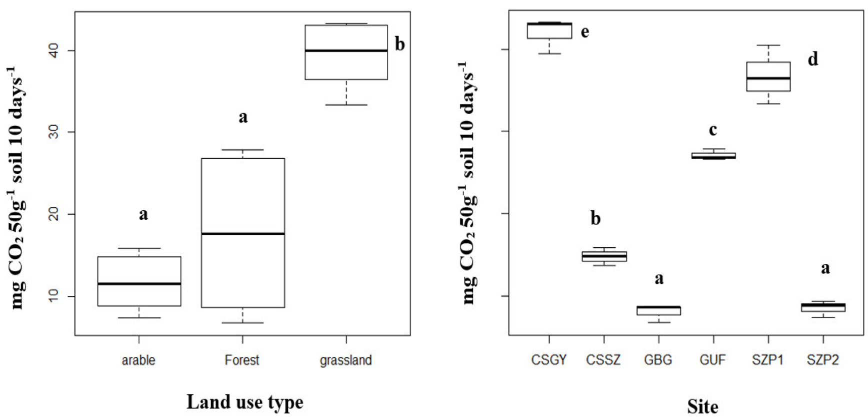

Figure 1

SMR across LUTs (left) and site (right). Different letters indicate significant differences at $p < 0.05$ (n =6). Hort 1 (CSGY), Hort 2 (CSSZ), Gödöllő botanical garden (GBG), Gödöllő university forest (GUF), Szárítópuszta 1 (SZP1) Szárítópuszta 2 (SZP2)

Soil microbial respiration

The grassland showed significantly higher SMR compared to forest and arable land (*Figure 1*). The present study found a positive correlation of SMR with soil moisture ($r = 0.67$; $p < 0.01$), Mg^{2+} ($r = 0.61$; $p < 0.01$), K_2O ($r = 0.58$; $p < 0.05$), SOM ($r = 0.56$; $p < 0.05$), and Na+ ($r = 0.52$; $p < 0.05$), However, no statistically significant correlation of SMR with pH ($r = 0.33$; $p > 0.05$) was observed (*Table 3*).

Table 3
Pearson's correlation matrix of the investigated soil properties

	SOM	pH (H_2O)	Soil moisture	$CaCO_3$	NH_4^+–N	NO_3^-–N	AL-K_2O	AL-P_2O_5	Ca^{2+}	Mg^{2+}	K^+	Na^+	CEC	BS	E_4/E_6	SMR
SOM	1															
pH (H_2O)	–0.32	1														
Soil mois.	0.70**	0.29	1													
$CaCO_3$	–0.79***	0.47*	–0.61**	1												
NH_4^+–N	0.45	–0.60**	–0.11	–0.13	1											
NO_3^-–N	0.32	0.71***	–0.12	–0.42	0.41	1										
AL-K_2O	0.53*	0.07	0.45	–0.43	0.21	–0.29	1									
AL-P_2O_5	0.85***	0.4	–0.75***	0.93***	–0.16	–0.34	–0.36	1								
Ca^{2+}	0.16	0.71***	0.76***	–0.11	–0.55	–0.64**	0.26	–0.27	1							
Mg^{2+}	0.63**	0.38	0,87***	–0.34	0.09	–0.4*	0.63	–0.52*	0.72	1						
K^+	–0.52*	0.46	–0.22	0.45	–0.47	–0.83***	0.12	0.47	0.38	–0.01	1					
Na^+	0.58*	0.33	0.45	–0.22	0.22	–0.42	0.63	–0.41*	0.63	0.04	0.04	1				
CEC	0.77***	–0.07	0.87***	–0.79***	0.03	–0.04	0.45	–0.91***	0.58	0.74	–0.2	0.62	1			
BS	–0.07	0.87***	0.5	0.31	–0.41	–0.75***	0.21	0.13	0.86***	0.66	0.49	0.66	0.2	1		
E_4/E_6	–0.13	–0.4	0.58**	0.09	0.28	0.66	–0.21	0.31	–0.81***	–0.65**	–0.4	–0.60**	–0.61**	–0.65	1	
SMR	0.56*	0.33	0.66**	–0.39	0.06	0.08	0.57*	–0.34	0.33	0.60**	–0.38	0.52*	0.36	0.36	0.03	1

*, **, ***: Significant at the 0.05, 0.01, and 0.001 levels, respectively. Soil organic matter (SOM), cation exchange capacity (CEC), base saturation (BS), soil microbial respiration (SMR).

Discussion

Variability of important physicochemical properties among LUTs

Previous studies showed that soils under the same LUT most probably have similar physicochemical properties (JOHNSON et al., 2003). We found that soils under relatively undisturbed systems (grassland and forest) had advantages in good soil attributes over disturbed systems (arable land). Particularly, SOM and available nitrogen had shown significant decrement in arable soils, implying that agricultural practices in arable lands could negatively influence the soil's organic and nutrient content. Non plowing and continuous plant coverage in forest and grassland could result in a high content of SOM and nutrients in these soils. N and SOC are being depleted on cultivated land mostly by similar processes because organic matter is a source for both (ZAJÍCOVÁ & CHUMAN, 2019). As RODRIGUES et al. (2017) discussed, tillage practices in arable land may result in losses of carbon from the soil due to decomposition, erosion, and leaching. Consistence to our finding, CELIK (2005) found that compared to forest and pasture soils, SOM in cultivated soils decreased by 44% and 48%, respectively, for the top 0–10 cm layer soil. Similarly, KUNLANIT et al. (2019) investigated the influence of land use change on SOC stock and their quality in Northeast Thailand. They found that the conversion of forest to cultivated land significantly reduced both SOC and humic acid stock.

The finding of a substantially higher content of the available form of N (NH_4^+–N, NO_{3^-} –N, and total N) in forest soils collaborated with previous work of GOL (2009), who reported that conversion of forest to cultivated land significantly decreased both the content and stock of SOM and total N. Higher litter production and N fixation by the different tree and shrub species within forest probably contributed to higher available N content in forest soils. Equally, loss of available N through the faster decomposition of organic matter associated with continuous tilling of soils could also be why the low available N content in cultivated soils. Grassland soils had higher K_2O than forest and arable land, possibly due to high SOM content and little soil disturbance, resulting in high nutrient adsorption and low leaching rate. RODRIGUES et al. (2017) recorded that potassium content in minimum tillage was significantly higher than that of the conventional tillage system.

Among soil attributes, pH is considered "master soil variable" since it influences soil biological, chemical, and physical properties, thereby determining plant growth and biomass yield (NEINA, 2019). Soil pH influences the solubility and mobility of SOM and nutrients. It was reported that solubility of organic matter in the soil inclines with an increase in soil pH, causing the leaching of organic matter and nutrients in alkaline soils (CURTIN et al., 2016). The finding of a significantly low pH level in forest soils in this study is consistent with the previous studies by RODRIGUES et al. (2017) and WELDMICHAEL et al. (2020). The low pH in forest soils could be attributed to low base cations in the soil or the type of litter residues of forest vegetation (RODRIGUES et al., 2017). The arable soils were characterized by a high content of available P, $CaCO_3$, and Ca^{2+}, while forest soils showed the lowest content of these parameters. A similar result was noted by MAHARJAN et al. (2018), who reported a significant increment of P stock by 64% and 36% at 0–10 cm and 10–20 cm depth, respectively, in conventional farming compared to forest. The relatively higher P and $CaCO_3$ in arable soils might be due to the application of inorganic fertilizers and liming. Conversely, the significant low content of P in forest soils was probably related to low pH in forest soils. Various studies documented that P could be fixed with Al or Fe under low pH, thus became unavailable (e.g., MORI et al., 2018), and base cations and calcium carbonate leached from the soil (CURTIN et al., 2016).

Several previous studies have shown that land use change dramatically influences the soil's hydrological process (e.g., QIU et al., 2001). In most cases, soil moisture substantially declines in arable soils compared to grassland and forest soils (QIU et al., 2001). Tillage could aerate and expose soils to sunlight, thereby increases water loss from the soil through evaporation. The relatively high content of SOM and improved surface cover that resulted in increased water infiltration and decreased water loss through surface evaporation could explain the high soil moisture in grasslands. It has been shown that SOM increases water holding capacity and infiltration of the soil by improving soil porosity and reduce soil compactability (MCCAULEY et al., 2005). In this study, this was evidenced by the positive association of SOM with soil moisture (*Table 3*).

Influence of LUT on SMR and major drivers for its variability

Based on the Kruskal-Wallis test, SMR significantly differed among the LUTs ($p < 0.01$). The grassland showed significantly higher SMR compared to forest and arable land. This finding agrees with CREAMER et al. (2016), who reported that grassland soils had a remarkably high amount of SMR than arable soils; however, it was in contrast with LIU et al. (2018), who found that farmland had higher basal respiration compared to orchard, grassland, and abandoned land. As highlighted by LIEBIG (1996), SMR is an important indicator of soil health since it indicates the level of microbial activity, SOM content, and its decomposition. Usually, higher SMR reflects high belowground microbial activity (RYAN & LAW, 2005). One of the possible reasons for the high SMR in grassland soils could be a high level of labile C in the grassland system. SOM/SOC has been well documented to affect soil respiration as it is the primary energy source for microbes (CREAMER et al., 2014). In line with that, this study also found a significant positive correlation of SMR with SOM ($r = 0.56$; $p < 0.01$) (*Table 3*). In their study, LIU, et al. (2018) discussed that soil respiration rate was related to SOC among all fertilizer treatments, implying the strong influence of SOM on soil microbial activity. MURUGAN et al. (2014) investigated variations of the catabolic function of different land use in Germany using MicroResp^{TM} method, showed significant lower organic C content, biomass C, and residue C in the maize monoculture compared to the grassland treatments, suggesting higher labile C present in the grassland systems promoted microbial activity. Generally, the availability of SOM is known to greatly influence soil microbial activity. However, certain organic matter pools such as water extractable organic carbon (WEOC) and dissolved organic carbon (DOC) correlate with microbial activity more closely than others (GREGORICH et al., 2003; KALBITZ et al., 2003). Conversely, others have observed little or no relationship between WEOC and potential microbial activity (e.g., SCHNABEL et al., 2002).

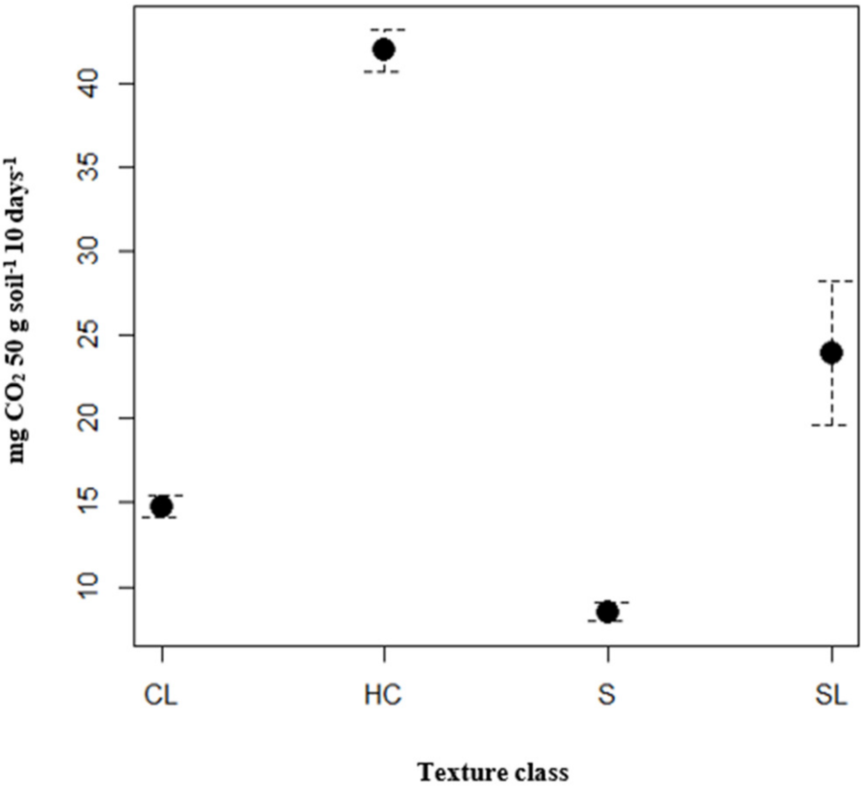

Figure 2
Plot of means with standard error showing the rate of SMR across texture classes. Sandy loam (SL), sandy (S), clay loam (CL), heavy clay (HC)

In this study, SMR was found positively correlated with soil moisture ($r = 0.67$; $p < 0.01$). Various studies documented that soil moisture, among others, has important effects on soil microbial diversity and function (e.g., CONANT et al., 2004; LIU et al., 2009). Soil moisture influences other physicochemical properties, such as pH, redox potential, O_2, and CO_2, which affects soil microbial communities and their activities (BARROS et al., 1995). Soil moisture can decrease soil respiration by minimizing microbial contact with available substrate and dormancy and death of microorganisms at low soil water potentials (CONANT et al., 2004). The significant effect of soil moisture in SMR was detected by LIU et al. (2009), who reported that decreased soil moisture caused a significant reduction of SMR, suggesting that soil water availability was an important variable in regulating SMR in semiarid temperate grassland of China. Generally, soil respiration increases with soil moisture, and the ideal soil moisture to microbial activity is near field capacity (LIEBIG, 1996). In this study, the variation of SMR was greatly affected by soil moisture, evidenced by a strong positive correlation between these variables (*Table 3*). The relationship between soil moisture and SMR varies with soil type and characteristics. For instance, soil microbial activity is higher in fine textured soil due to a large surface area which enhances water holding capacity and nutrient availability of the soil (HAMARASHID et al., 2010; YAN et al., 2018). Likewise, this study found that the rate of SMR was highest in fine textured soils compared to coarser texture soils (*Figure 2*). Earlier studies also revealed that water potential (WILSON & GRIFFIN, 1975), water filled pore space (TORBERT and WOOD, 1992), and soil moisture level (GUNTIÑAS et al., 2013) highly influenced the soil microbial respiration.

Among the base cations, Mg^{2+} showed a significant positive correlation with SMR ($r = 0.61$; $p < 0.01$). It is well known that Mg^{2+}, together with other base cations, is an important soil nutrient that greatly influences the soil microbial population and their activity since it is required for microbial growth and protein synthesis (RUTGERS et al., 2009). The finding of a strong positive correlation between SMR and Mg^{2+} was also detected by RICHTER et al. (2018), who assessed the effect of diagnostic features, land use, and soil type on microbial biomass and microbial indices in Irish grassland. This study also found a positive correlation of K_2O with SMR ($r = 0.58$; $p < 0.05$). Our finding contrasts with MORI (2018), who conducted an incubation experiment to examine the effects of K addition on SMR and soil microbial biomass in a condition of sufficient labile C supply in China's tropical soils and found no significant effect of K addition on SMR. Various studies reported the significant effect of pH on SMR (WAKELIN et al., 2008; ANDRUSCHKEWITSCH et al., 2014); however, this study did not find a statistically significant correlation of SMR with pH ($r = 0.33$; $p = 0.1678$). The neutral correlation between pH and SMR was also noted (EBRAHIMI et al., 2019).

Conclusions

The present study highlighted that, among the investigated soil physicochemical parameters, SOM and available nitrogen were significantly influenced by LUT. The agricultural practices in arable land resulted in organic matter and nutrient availability depletion in the soil. The soil's catabolic capacity was substantially higher in grassland than forest and arable land, suggesting that the overall soil microbial activity in the investigated soils was enhanced by grassland system. The strong correlation of SMR with soil moisture, SOM, and Mg^{2+} implies that these parameters probably were key drivers for the variation of SMR in the study area.

Acknowledgments

The research is funded by Stipendium Hungaricum Scholarship Program (SHE-935-1/2016) and it was supported by the Ministry of Innovation and Technology within the framework of the Thematic Excellence Program 2020, Institutional Excellence Sub-Program (TKP2020-IKA-12) in the topic of water-related researches of Szent István University.

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Received: 19 Oct 2020
Accepted: 26 Feb 2021