Silva Balcanica, 20(Special issue 1)/2019

INFLUENCE OF SOIL TYPE AND LAND USE ON SOIL ORGANIC MATTER IN CLIMATE CONDITIONS OF WEST CARPATHIAN MTS. AND PANNONIAN BASIN

Gabriela Barančíková[1, 5], Erika Tobiašová[2], Erika Gömöryová[3], Jarka Makovníková[1], Ján Halas[1], Štefan Koco[1, 4], Rastislav Skalský[1]
[1]National Agricultural and Food Centre – Soil Science and Conservation Research Institute, Bratislava
[2]Department of Soil Science, Slovak University of Agriculture in Nitra
[3]Department of Natural Environment, Technical University in Zvolen
[4]Department of Geography and Applied Geoinformatics, Prešovská univerzita in Prešov
[5]Department of Environmental management, Prešovská univerzita in Prešov

Abstract

Objective of this study is to assess if the natural conditions (soil type) has greater effect on soil organic matter (SOM) than human activity (land use). Changes of SOM were studied on three experimental sites on different soil types (Haplic Chernozem, Eutric Cambisol, Luvic Stagnosol) and different ecosystems (forest FE), meadow (ME), arable land (AL). These parameters were selected in this study: soil organic carbon (SOC), labile carbon oxidized by $KMnO_4$ (C_L), hot water extractable organic carbon (HWEOC) and cold water extractable organic carbon (CWEOC). Mutual relationships between SOM parameters and biological parameter – carbon of microbial biomass (Cmic) were also determined. Obtained results show that land use had higher influence on SOC content and its forms compared to soil type. Between SOM, C_L, N_T and Cmic the significant correlations, confirmed also by cluster analysis, were determined.

Key words: soil types, land use, soil organic carbon, labile carbon, water extractable carbon

INTRODUCTION

Soil organic carbon (SOC) represents a key element in the global carbon cycle and terrestrial ecosystem and is one of the largest reservoirs of SOC (Chaopricha, Marin-Spiotta, 2014). It is very often considereded as a primary indicator of soil quality in relation to agricultural and environemental soil functions (Chevalier et al., 2016) and it is the principal factor in all classes of ecosystem services (Banwart et al., 2015). Important function of SOC in the soil ecosystem is taken into account also in fundamental soil functions defined by European Commission (EC 2006).

Baldock, Broos (2011) define SOM as a sum of all natural and thermally altered biologically derived organic material found in the soil or on stage of decomposition, irrespective of its source.

Lability of SOM depends on the chemical recalcitrance and physical protection against the decomposition activity of microorganisms (Silveria et al., 2008). Water-extractable organic carbon (CWEOC) is characterized as a soluble organic carbon, which is extracted with the aqueous solutions of weak ionization strength (Zsolnay, 2003). Hot water extractable organic carbon (HWEOC) is chemically more heterogeneous because hot water (>70°C) kills vegetative cells, thereby they are also extractable and simultaneously, substantially a higher amount of non-microbial organic matter are extracted (Sparling, 1998). Labile carbon (C_L) includes all organic components that are easily oxidizable with $KMnO_4$, including labile humus material and polysaccharides (Conteh et al., 1999).

Amount of SOM is influenced by soil microbial activity which is conditioned mainly by soil temperature, moisture, nutrient supply, particle size distribution, but also climatic factors (Poeplau, Don, 2013) and intensive use of agricultural soils (Abdalla et al., 2013; Sanford 2014; Coutinho et al., 2015). Microbial biomass carbon (Cmic) represents carbon contained within the cells of living soil organisms (bacteria, fungi, etc.). The amount of Cmic may be related to the total carbon content by the microbial quotient (Cmic/SOC) expressing the dynamics of SOM and can be used as an indicator of the net C loss or accumulation (Anderson, Domsch, 1986).

Direction of changes and conversion of SOC is in most of present-day ecosystems influenced by human activity – land use. This is especially true for agricultural land, where SOM represents more than 95% (pastures, meadows) or almost 100% (arable land) of the total organic carbon accumulated in man amended ecosystems (Stolbovoy, Montanarella, 2008). The changes in land use means changes in total stock of soil organic carbon. It is estimated that soil cultivation, mainly the conversion of pasture to AL, leads to significant organic carbon loses in the overall balance up to 50 Pg (Janzen, 2006). Guo, Gifford (2002) on the basis of meta analyse show that the conversion of pasture to AL decreased the SOC up to 59%.

Compared to agricultural soils, the forest soils are less influenced by human activity and are evolved under relatively natural conditions. Soils of the forest ecosystems exhibit a high input of SOM on the soil surface, exceeding several times the inputs in the agricultural ecosystems (Lukac, Godbold 2011).

Under the natural conditions SOM is influenced mainly by parent material, climate and geographical parameters. However in disturbed ecosystems (intensive agriculture) SOM can be also strongly affected by land use and soil management.

Objective of this study is to assess whether the total SOC content and its labile forms are affected more by natural conditions (soil type) or human activity (land use). Differences in SOC, C_L, CWEOC, HWEOC of different soil types and soil ecosystems are evaluated and it is further analysed which of these parameters are more affected by soil type and land use. Relationship between SOM parameters and microbial parameter Cmic is also evaluated.

MATERIALS AND METHODS

Study sites and soil sampling

Experimental sites were chosen to represent natural conditions of Western Carpathian Mts. and Pannonian basin parts of Slovakia, which are characterized by high heterogeneity of climatic, geographic, and soil characteristics. For this reason, the individual experimental sites were located in different altitude and different soil types (Haplic Chernozem, Eutric Cambisol, Luvic Stagnosol). On each experimental site, the sampling locations were placed in three different ecosystems (arable land – AL, meadow – ME, forest – FE) with minimal distances between them.

Haplic Chernozem (HC) developed from calcareous loess represents experimental site Močenok in the south-west Slovakia (Pannonian basin). Altitude is 138-173 m, slope 0-3°. On AL corn was harvested at the time of soil sampling. ME exhibited high density of roots in the top 0.1 m. Ash (*Fraxinus excelsior*, 80%) and oak (*Quercus petraea* L., 20%) with admixture of black locust (*Robinia pseudoacacia*) dominated the tree layer of FE ecosystem.

On the experimental site Tŕnie located in central Slovakia (Carpathian Mountains) soil type is Eutric Cambisol (EC) developed from volcanic agglomerates and epi-clastic rocks. Altitude is 550-554 m, and slope is 3-7°. Soil at the AL was after S*orghum* harvest at the time of soil sampling. On the ME, unlike the Chernozem locality, more herbaceous species occur and this ME has been mowed. Mixed FE is formed of hornbeam (*Carpinus betulus* L., 75%), oak (*Quercus robur* L., 10%), lime (*Tilia cordata*, 10%) and wild cherry (*Prunus avium*, 5%).

Luvic Stagnosol (LS) developed from polygenetic loam represents soil type at experimental site Hanušovce nad Topľou in the north-east Slovakia (Carpathian Mountains). Altitude of this locality is 258-308 m. On AL wheat was cultivated and ME was actively grazed. FE is formed mainly of hornbeam (*Carpinus betulus* L., 90%) and pine (*Pinus sylvestris*, 5%) with the admixture of beech (*Fagus sylvatica* L.), birch (*Betula pendula*) and wild cherry (*Prunus avium*). Topsoil samples were collected at all experimental sites from depth 0-0.1 m during October and November 2015. Samples were immediately transported to the laboratory and subsamples intended for the determination of microbial properties were stored at 4°C until the analyses were performed. Soils samples for the analyses of microbial properties were not sieved to preserve natural conditions for microorganisms. All visible roots and fresh litter material as well as rocks were manually removed. Soil samples for all other analyses were dried out at constant laboratory temperature 25°C (+/-2°C). Soil samples were crushed to 2 mm to separate non-decayed or only slightly decayed plant debris.

Soil analyses

SOC and total nitrogen (N_T) were analysed by Euro EA 3000 elemental analyser in CN configuration (Kobza et al., 2011) in all soil samples.

C_L was determined by $KMnO_4$ oxidation according Loginow with modification, water extractable organic carbon was determined in cold (CWEOC) and hot water (HWEOC) water according Ghani with modification (Tobiašová et al., 2018).

Microbial biomass carbon (Cmic) was determined using the microwave-irradiation procedure described by Islam and Weil (1998).

The STATGRAPHICS CENTURION XV program was used for statistical analysis, Spearmann correlation analysis, and cluster classification.

RESULTS AND DISCUSSION

Organic carbon in the soil ecosystem is influenced mainly by natural conditions and human activity (Eckelman et al., 2006). Natural factors affecting SOC dynamics include soil properties (parent material, soil type, clay and stone contents), climate characteristics (temperature, precipitation, solar radiation) and geographic factors (altitude, slope, topographical wetness index, etc.) (Poeplau, Don, 2013). Impact of human activities on SOC content is mainly driven by land use (AL, ME, FE) and in case of intensively used agricultural soils the most important is soil management (Kheir at al., 2010; Xu et al., 2011, Abdalla et al., 2013; Gollany et al., 2010). Our previous results (Barančíková, 2016) also confirm a strong effect of land use on SOC content. It is mainly demonstrated by significant differences in the topsoil SOC concentration of different ecosystems, but soil type still plays an important role.

In this study, forest soils can be considered as natural and our data on SOC well support this statement because the highest content of SOC was found in Chernozem under FE with the deepest topsoil humus horizon. In FE ecosystems the observed SOC content decreased in order HC>EC>LS. Across all evaluated ecosystems the highest SOC content was found in HC, whereas the lowest one in LS (Table 1). The reason of the highest content of SOC in HC across all ecosystems can be explained by pedogenetic conditions which formed this soil type.

After soil cultivation, the topsoil SOC content decreases rapidly and therefore in the intensively managed agroecosystems the content of topsoil SOC is lower compared to less affected ecosystems. This is also visible from the results of our study, where the highest content of SOC was found in the forest soils and it then decreased in order FE>ME>AL. The same pattern was found also for labile forms of SOC (C_L, HWEOC) and carbon of microbial biomass (Table 1). Moreover, significant correlations were found in the results between SOC, C_L, HWEOC and Cmic (Table 2).

The SOM is also an important source of nitrogen and it contains more than 95% of nitrogen from the total nitrogen pool in the soil (Knops, Bradley, 2009). Similar to topsoil SOC, the highest content of N_T was found in Chernozem and the lowest in LS. When compared across the ecosystems, N_T decreased in order FE>ME>AL which is similar to SOC, C_L, HWEOC, Cmic.

Higher inputs of plant and root residues to the FE and grassland ecosystems have stabilizing effect on the SOC in the topsoil (Sanford et al., 2014; Barančíková et al., 2016). FE can be considered as natural ecosystem with the highest input of plant and root residues. Therefore also in this ecosystem was found the highest content of SOC, C_L, HWEOC, Cmic (Table 1). MEs (or pastures) are in generally more influenced by human activity (mowing, biomass removal, cattle grazing) and therefore the topsoil SOC content and its forms in this ecosystem are lower when compared to FE ecosystem. The lowest topsoil SOC content among the ecosystems was found in the AL, the reason of which is, that this ecosystem is the most strongly affected by human activity. Dawson Smith (2007) reported decrease of SOC stock due to

Table 1. Basic parameters of soil organic matter

Soil type/use	SOC (%)	N_T (%)	C_L (mg/kg)	CWEOC (mg/kg)	HWEOC (mg/kg)	Cmic (μg/g)
HC FE	6.37	0.620	9322	656	1563	693
HC ME	5.78	0.611	6629	365	895	443
HC AL	2.79	0.270	3252	477	1110	389
EC FE	3.4	0.225	4556	585	6328	290
EC ME	2.46	0.278	2340	468	491	235
EC AL	1.94	0.184	1431	515	491	227
LS FE	4.56	0.393	3636	668	1324	181
LS ME	3.1	0.310	2895	406	839	182
LS AL	1.86	0.193	1748	382	686	134

HC Haplic Chernozem FE forest SOC soil organic carbon CWEOC cold water extractable organic carbon
EC Eutric Cambisol ME meadow N_t total nitrogen HWEOC hot water extractable organic carbon
LS Luvic Stagnosol AL arable land C_L labile carbon oxidizable with $KMnO_4$ Cmic microbial biomass carbon

Table 2. Correlations between soil organic matter parameters

	SOC	N_T	C_L	CWEOC	HWEOC	Cmic
SOC		**0.972*** **	**0.960*** **	0.297	**0.749*** **	**0.846*** **
N_T	**0.972*** **		0.932***	0.115	0.433	0.856***
C_L	**0.9602*** **	**0.932*** **		0.375	**0.700** **	**0.904*** **
CWEOC	0.297	0.115	0.375		0.550	0.319
HWEOC	**0.749*** **	0.433	**0.700** **	0.550		0.629
Cmic	**0.846*** **	**0.856*** **	0.6285	0.319	0.6285	

SOC soil organic carbon
CWEOC cold water extractable organic carbon
HWEOC hot water extractable organic carbon
C_L labile carbon oxidizable with $KMnO_4$
Cmic microbial biomass carbon
Correlation.- significance labels: *** p<0.001,** p<0.01

conversion of FE or ME to AL. The next important factor of the increased SOC loss from agricultural soils is inappropriate soil management, mainly low input of organic material (residues) into the soil (Janzen, 2006). On the basis of these data, it can be concluded that topsoil SOC content and its forms is more controlled by land use than by soil type, but impact of pedogenetic factors (deep humus horizon on HC) can also affect total SOC content.

Classification methods applied to quantitative parameters of SOM (cluster procedure) resulted in 3 clusters with similar characteristics. The results of the analysis (dendrogram on Fig. 1) also indicates more pronounced impact of the ecosystem compared to soil type, especially in the case of agroecosystem of arable soils and MEs.

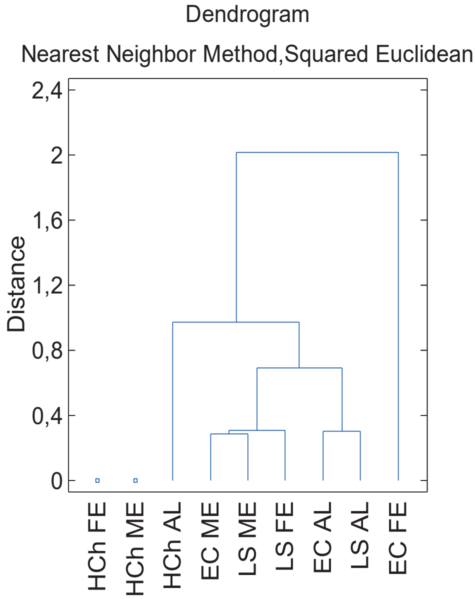

Fig.1. Cluster analysis of SOC in individual soil types (HCh-Haplic Chernozem, EC-Eutric Cambisol, LS-Luvic Stagnosol) according to ecosystems (FE, ME, AL)

CONCLUSION

Impact of soil types and land use on soil organic carbon and its forms was analysed in this study. From the results it can be concluded that in climate conditions of Western Carpathian Mts. and Pannonia basin the topsoil SOC content is more affected by land use then by soil type. In case of total SOC content, the pedogenetic conditions can more pronounce the impact of soil type (deep humus horizon on Haplic Chernozem). The results were also confirmed by significant correlations found between total topsoil organic carbon content and its forms, and microbial soil parameter (Cmic). Higher content of topsoil SOC and its fractions in natural ecosystem (FE) compared to ecosystems more affected by human activity (MEs, arable soils) were confirmed also by cluster analysis.

Acknowledgements: This work was supported by the Slovak Research and Development Agency under the contract APVV-14-0087.

REFERENCES

Abdalla, M., Osborne, B., Lanigan, G., Forristal, D., Williams, M., Smith, P., Jones, M.B. 2013. Conservation tillage systems: a review of its consequences for gas emissions. Soil Use and Management, 29, 199-209.

Anderson, T. H., Domsch, K. H. 1986. Carbon assimilation and microbial activity in soil. Zeitschrift für Pflanzenernärung und Bodenkunde, 149, 457-468.

Baldock, J. A., Broos, K. 2011. Soil organic matter. – In: Huang, P. M., Li, Y. C., Sumner, M. I. (Eds.). Handbook of soil sciences: properties and processes, Second Edition. Taylor et Francis/CRC press, Boca Raton, 11-52.

Banwart, S.A., Black, H., Cai, Z., Gicheru, P.T., Joosten, H., Victoria, R.L., Milne, E., Noellemeyer, E., Pascual, U. 2015. The global challenge for soil carbon. – In: Banwart, S.A., Noellemeyer, E., Milne, E. (Eds.). Soil Carbon. Scope Series volume 71, CAB International, Boston, 1-9.

Barančíková, G**.,** Makovníková, J., Halas, J. 2016. Effect of land use change on soil organic carbon. Agriculture, 62, 10-18.

Coutinho, H.L.C., Noellemeyer, E., De Carvalho Balieiro, F., Piňeiro, G., Fidalgo, E. C. C., Martius, C., Da Silva, C. F. 2015. Impacts of land use change on carbon stocks and dynamics in Central-southern South American biomes: Cerrado, Atlantic forest and Southern grasslands. – In: Banwart, S.A., Noellemeyer, E., Milne, E. (Eds.). Soil carbon. Science, management and policy for multiple benefits. Oxfordshire, CAB International*,* 243-264.

Conteh, A., Blair, G.T., Lefroy, R.D.B., Whitbread, A.M. 1999. Labile organic carbon determined by permanganate oxidation and its relationships to other measurements of soil organic carbon. Humic Substances in the Environment, 1, 3-15.

Dawson, J.J.C., Smith, P. 2007. Carbon losses from soil and its consequences for land-use management. Review Science of the Total Environment, 382, 165−190.

Eckelmann, W., Baritz, R., Bialousc, S., Bielek, P., Carré, F., Houšková, B., Jones, R.J.A., Kibblewhite, M., Kozak,J., Le Bas,C., Tóth,G.,Ttóth,T. Vátallyay,G., Halla,M.Y., Zupan,M. 2006. Common Criteria for Risk Area Identification according to Soil Threats. European Bureau Research Report No.20, Office for Official Publications of the European Communities, Luxemburg, EUR 22185 EN, 94.

European Commission (EC). 2006. Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions. Thematic Strategy for Soil Protection. COM 231 Final Brussels.

Gollany, H. T., Novak, J. M., Liang, Y., Albrecht, S. L., Rickman, R. W., Follet, R. F., Wilhelm, W.W., Hunt, P.G. 2010. Simulating soil organic carbon dynamics with residue removal using the CQESTR model. Soil Science Society of America J. 74, 372-383.

Guo, L. B., Gifford, R. M. 2002. Soil carbon stocks and land use change: a meta analysis. – In Global Change Biology, 8(4), 345−360.

Chaopricha, N.T., Martin-Spiotta, E. 2014. Soil burial contributes to deep soil organic carbon storage. Soil Biology and Biochemistry, 69, 251-264.

Chevallier,T., Hamdi,S., Gallali,T., Brahim,N., Cardinel,R., Bounouara, Z., Cournac, L., Chenu, C., Bernoux, M. 2016. Soil carbon as an indicator of Mediterranean soil quality. The Mediterranean Region under Climate Change: A scientific update, Sub-chapter 3.5.3., Marseile, 627-636.

Islam, K. R., Weil, R. R. 1998. Microwave irradiation of soil for routine measurements of microbial biomass carbon. Biology and Fertility of Soils, 27, 408–416.

Janzen, H. H. 2006. The soil carbon dilemma: shall we hoard it or use it. Soil Biology and Biochemistry, 38, 419-424.

Kheir, R. B., Greve, M. H.,Bocher, P. K., Greve, M. B., Larsen, R., Mccloy, K. 2010. Predictive mapping of soil organic carbon in wet cultivated lands using classification-tree based models: The case study of Denmark. J. of Environtal Management, 91, 1150-1160.

Knops, J.M.H., Bradley, K.L. 2009. Soil carbon and nitrogen accumulation and vertical distribution across a 74-year chronosequence*.* Soil Science Society of America J., 73, 2096-2104.

Kobza, J., Hrivňáková, K., Makovníková, J., Barančíková, G., Bezák, P., Bezáková, Z., Dodok, R., Grečo, V., Chlpík, J., Lištjak, M., Mališ, J., Píš, V., Scglosserová, J., Slávik, O., Styk, J., Širáň, M. 2011. Jednotné pracovné postupy rozborov pôd (Uniform working procedures of soil analysis). Bratislava, 51−117.

Lukac, M., Goldbold, D. L. 2011. Soil Ecology in Northern Forests. Cambridge University Press, 256.

Poeplau, C., Don, A. 2013. Sensitivity of soil organic carbon stocks and fractions to different land-use changes across Europe. Geoderma, 192, 189-201.

Sanfrord, G.R. 2014. Perennial grasslands are essential for long term SOC storage in the Mollisols of

the North Central USA. – In: Hartemink, A., McSweeney, K. (Eds.): Soil Carbon. Springer Cham Heildelberg, 281-288.
Silveria, M. L., Comerford, N. M., Reddy, K. R., Cooper, W. T., El-Rifai, H. 2008. Characterization of soil organic carbon pools by acid hydrolysis. Geoderma, 144, 405-414.
Sparling, G., Vojvodič-Vukovič, M., Schipper, L.A. 1998. Hot-water-soluble C as a simple measure of labile soil organic matter: the relationship with microbial biomass C. Soil Biology and Biochemistry, 30, 1469-1472.
Stolbovoy, V. Montanarella, L. 2008. Application of Soil organic carbon status indicators for policy-decision making in the EU. Threats to soil quality in Europe. – In: Toth, G., Montanarella, L., Rusco, E. (Eds.) JRC Scientific and Technical Reports, 87-99.
Tobiašová, E., Barančíková, E., Gömöryová, E. 2018. Metodiky stanovenia parametrov pôdnej organickej hmoty (Methods of the determination of soil organic matter parameters). SPU, Nitra, 86.
Zsolnay, A. 2003. Dissolved organic matter: artefacts, definitions, and functions. Geoderma, 113 (3-4), 187-209.
Xu, X., Liu, W., Kiely, g. 2011. Modelling the change in soil organic carbon of grassland in response to climate change: Effects of measures versus modelled carbon pool for initializing Rothamsted Carbon model. Agriculture, Ecosystems and Environment, 140 (3-4), 372-381.

E-mail: gabriela.barancikova@nppc.sk