Research Paper

Volume : 3 | Issue : 7 | July 2014 • ISSN No 2277 - 8179

# Determination of Organic Carbon Stability in Grassland Soils Using The Method of Chemo-Destructive Fractionation

Agriculture

**KEYWORDS :** Soil organic carbon, Legume swards, Carbon stability, Chemo-destructive fractionation

**Dr. Inga Liaudanskiene** — Chemical Research Laboratory, Institute of Agriculture, Lithuanian Research Centre for Agriculture and Forestry, LT 58344 Akademija, Kedainiai distr., Lithuania

**Dr. Jonas SLEPETYS** — Department of Plant Nutrition and Agroecology, Institute of Agriculture, Lithuanian Research Centre for Agriculture and Forestry, LT 58344 Akademija, Kedainiai distr., Lithuania

**Dr. Alvyra SLEPETIENE** — Chemical Research Laboratory, Institute of Agriculture, Lithuanian Research Centre for Agriculture and Forestry, LT 58344 Akademija, Kedainiai distr., Lithuania

## ABSTRACT

*Plant species can influence soil organic carbon (SOC) quantity and qualitative composition. This research determined total SOC content and carbon distribution in SOC fractions of different stability in grassland soils in Central Lithuania by ap-plying chemo-destructive fractionation in order to investigate SOC reliance on herbaceous plant species. The pure legume swards and mixture with other legumes and with Festulolium was grown under organic management on Endocalcari-Endohypo-gleyic Cambisol. For comparison, the old semi-natural pasture has been used. The highest amount of SOC accumulated in the soil under four-component sward (Galega orientalis + Medicago sativa + Trifolium pratense + Festulolium). This sward also determined the increase of carbon content in residual F4 fraction, which can be de-fined as strengthening of SOC stability. The most sustainable was the soil of old semi-natural pasture, whereas the compara-ble amount of labile and recalcitrant SOC fractions determines the soil fertility and SOC sequestration and protection from de-composition simultaneously.*

## INTRODUCTION

Grasslands are one of the most common ecosystem types in the world, covering about 40% of the ice-free terrestrial surface. It has been estimated that about 30% of the global C pool is stored in grasslands, much of it below-ground (Smith, 2008). Soil, which is a complex and continuously developing part of many ecosystems, including grassland, plays an especially important role in the protection of natural environment and use of its resources. The main functions of the soil – biomass production and biodiversity, source of raw materials, storing, filtering and transforming nutrients, substances and water, physical and cultural environment for humans – are directly dependent on carbon pool. Soil organic matter (SOM), including C – the key element, is derived from complicated mixture of fresh organic materials from plants, soil fauna, root exudates, microbial residues and chemically or physically protected substrates, which generally consist of labile and recalcitrant pools (von Lützow et al., 2007). To be sequestrated, SOC should be converted from the active pools to less reactive intermediate or passive pools, and, consequently, sustained in the soil for decades or longer (Silveira et al., 2008). Total SOC is not always useful indicator for monitoring purposes, where the changes in land-use are not drastic. In the last decades more attention has been paid to the SOC of various lability (Kolář et al., 2009), which has been acknowledged as a good indicator of soil quality and environmental health (Strosser, 2010). Popov and Tcyplenkov (1994) modified the SOM oxidation method, dividing SOM into 11 pools with different degrees of carbon oxidizability/stability, and called the method "chemo-destructive fractionation". Later Chan et al. (2001) and Strosser (2010) has proposed a similar method by which SOM is divided into 4 fractions, and called the method "sequential oxidation". Insufficiently is known about the distribution of organic carbon in grassland soils and how it is affected by the composition of the vegetation within these environments. The aim of this research was to estimate the influence of legume swards in a pure crop and in mixture with other legumes on soil organic carbon distribution in SOC fractions of different stability.

## MATERIALS AND METHODS

Field experiment was carried out on an Endocalcari-Endohypogleyic Cambisol in the central part of Lithuania (55°24′ N, 23°52′ E). The soil characteristics were as follows: pHKCl 7.0, available phosphorus (P2O5) 128 mg kg-1 and available potassium (K2O) 211 mg kg-1 determined by (A–L) Egner–Riem–Domingo method. The experiment examined the effects of swards grown under organic management on the accumulation of organic carbon in different soil layers. The following long-lived legume swards and their mixtures were investigated: 1) Galega orientalis 100%, 2) Medicago sativa 100%, 3) Galega orientalis 40% + Medicago sativa 40% + Festulolium 20%, 4) Galega orientalis 40% + Medicago sativa 20% + Trifolium pratense 20% + Festulolium 20%. The pure or mixtures of herb species were sown under barley in certified ecological area. The experiment was laid out as a randomized complete block with four replications and a plot size of 35 m2. No mineral or organic fertilisers and pesticides were used. The swards were used 11 y. and cut either two or three times per season. We have used the old semi-natural pasture for comparison, which sward was not renewed up to present day in the paddock occupying area of 2.1 ha where the soil samples were taken. This is one of the oldest (66 y.) semi-natural pastures in Lithuania. For many years the sward has been used for grazing and forage, but currently, since the cattle for pasturing is no longer, this sward is only cut for silage making. Soil samples were taken in three replications in each investigated site in 2012. Six sub-samples per plot were taken randomly by using a steel auger. Each soil sample core was separated into 0–10, 10–20 and 20–30 cm depth, and combined across sub-samples by depth for each plot. All samples were air-dried, visible roots and plant residues were manually removed. Then the samples were crushed, sieved through a 2-mm sieve and homogeneously mixed. For the SOC determination and chemo-destructive fractionation an aliquot of the air-dried soil samples was passed through a 0.25-mm sieve. SOC content was determined by dry combustion method using fully automatic analyzer Vario EL III (Elementar, Germany). Chemo-destructive fractionation is based on different resistance of SOC to the action of oxidant solutions with the identical concentration of oxidizer K2Cr2O7 with growing oxidizing ability which depends on the concentration of H+, provided with the different amount of H2SO4. The method allows determining up to 11 SOC pools differing in resistance to oxidation (Popov & Tcyplenkov, 1994). Popov et al. (2004) combined the isolated 11 pools of SOC into three fractions: labile fraction F1 (1–4 pools), moderately labile fraction F2 (5–7 pools), and stable fraction F3 (8–11 pools). The fourth residual fraction of organic carbon (F4) is defined as the difference between the total SOC determined by dry combustion method and organic carbon after reaction with 98% H2SO4.The detailed description of the procedure of chemo-destruction of SOC can be found in Liaudanskiene et al. (2013). Experimental data of SOC chemical analyses were processed ($P<0.05$) by the statistical programme STAT ENG for EXCEL vers. 1.55 (Tarakanovas & Raudonius, 2003).

## RESULTS AND DISCUSSION

In recent years in Lithuania the attention was given to estimate the influence of swards on SOC accumulation and stabilization (Slepetys & Slepetiene, 2012; Liaudanskiene et al., 2013). At the beginning of

the field experiment the SOC content was 13.1, 12.9 and 9.74 g kg-1 in 0–10, 10–20 and 20–30 cm soil layers, respectively (Slepetys & Slepetiene, 2012). Our research data suggest that during the investigation period all swards increased SOC content in 0–30 cm layer by 15–17% (in relative values) compared with the amount of SOC at the beginning of experiment (Table 1). The 0–10 cm layer was the richest in SOC (17.4–18.4 g kg-1), but SOC content in old semi-natural pasture upper soil layer was higher by more than 2.5 times compared with sown legume swards. Herbaceous plants have a well-developed root system which is densely distributed in topsoil, therefore the greatest amounts of SOC accumulated in the upper soil layer, but cultivated soils generally have low SOC content compared to native or semi-natural ecosystems. In order to identify in which carbon fraction the SOC was accumulated, we applied the method of SOC chemo-destructive fractionating. It is well established that organic materials with a high C:N ratio (>30:1) are slow to mineralize and may cause some accumulation of SOC, whereas materials with a low C:N ratio (<20:1) usually rapidly mineralize (Christopher & Lal, 2007). Whereas the majority of aboveground biomass was removed with harvest therefore the belowground plant residues had an appreciable impact on the SOM and SOC content increase. Legumes have a low C:N ratio in both above- and belowground biomass – 10–30 and 20–50, respectively (Nemeikšiene et al., 2010). Meanwhile C:N ratio of the grass biomass is more than 2-fold higher. The legumes C:N ratio is more favourable for the further micro-biochemical transformations, compared with grasses. It is well known that vegetation is a major factor in regulating soil labile organic C (Fissore et al., 2008). The different plants such as legumes and grasses with different litter properties have an observable influence on the SOC dynamics in soil. The plant materials that form the immediate source of soil organic C vary widely in composition, and consequently in the extent to which their C accumulates in the soil.

Our research data show that the relative share of labile carbon in SOC (F1 fraction) was from 48.9 to 52.3, from 47.4 to 53.6, and from 49.4 to 52% in 0–10, 10–20 and 20–30 cm soil layer, respectively.

**Table 1. The influence of swards on SOC, soil C:N ratio and distribution of organic C in chemo-destructive fractions, mean data 2012**

| Sward | Depth, cm | SOC, g kg$^{-1}$ | Soil C:N | Chemo-destructive fractions | | | |
|---|---|---|---|---|---|---|---|
| | | | | F1 | F2 | F3 | F4 |
| | | | | % from SOC | | | |
| 1) Galega orientalis | 0–10 | 17.8 | 11.2 | 51.1 | 11.4 | 20.4 | 17.1 |
| | 10–20 | 13.2 | 8.98 | 52.4 | 16.4 | 21.9 | 9.36 |
| | 20–30 | 10.5 | 8.93 | 50.6 | 15.8 | 25.0 | 8.68 |
| | 0–30 | 13.8 | 9.71 | 51.3 | 14.5 | 22.4 | 11.7 |
| 2) Medicago sativa | 0–10 | 17.5 | 10.0 | 52.3 | 11.0 | 20.5 | 16.2 |
| | 10–20 | 13.0 | 9.37 | 53.6 | 15.3 | 20.7 | 10.4 |
| | 20–30 | 11.0 | 9.09 | 51.3 | 15.1 | 24.4 | 9.18 |
| | 0–30 | 13.8 | 9.49 | 52.4 | 13.8 | 21.9 | 11.9 |
| 3) Galega orientalis + Medicago sativa + Festulolium | 0–10 | 17.4 | 11.0 | 50.4 | 11.5 | 20.2 | 17.9 |
| | 10–20 | 13.0 | 9.71 | 47.4 | 18.3 | 19.9 | 14.4 |
| | 20–30 | 10.8 | 9.52 | 52.0 | 15.7 | 20.3 | 12.0 |
| | 0–30 | 13.7 | 10.1 | 50.0 | 15.2 | 20.1 | 14.8 |
| 4) Galega orientalis + Medicago sativa + Trifolium pratense + Festulolium | 0–10 | 18.4 | 11.6 | 48.9 | 13.2 | 18.5 | 19.5 |
| | 10–20 | 12.6 | 10.1 | 49.3 | 16.3 | 20.1 | 14.4 |
| | 20–30 | 10.4 | 9.54 | 49.4 | 16.4 | 21.4 | 12.8 |
| | 0–30 | 13.9 | 10.4 | 49.8 | 15.3 | 20.0 | 15.6 |
| 5) Old semi-natural pasture | 0–10 | 49.5 | 14.0 | 40.1 | 8.06 | 19.0 | 32.8 |
| | 10–20 | 24.6 | 11.1 | 47.1 | 12.6 | 24.9 | 15.5 |
| | 20–30 | 14.8 | 10.6 | 40.1 | 12.0 | 28.0 | 19.9 |
| | 0–30 | 29.6 | 11.9 | 42.4 | 32.6 | 24.0 | 22.7 |

**Note: F1 – labile fraction, F2 – moderately labile fraction, F3 – stable fraction, F4 –residual fraction.**

The compounds that are part of the labile SOC fraction are biochemically active; they are related to material and energy transformations in the soil, as well as appreciable affect soil fertility (Popov et al., 2004). The relative share of moderately labile (F2 fraction) and stable (F3 fraction) carbon in SOC increased with depth. The soil of legume mixtures with Festulolium (treatments 3 and 4) had a higher residual organic C content in SOC. The less favourable for decomposition lignin:N ratio of legumes root biomass and Festulolium C:N ratio led to slower mineralization of residues. The increase of hardly oxidizable organic C fraction content in SOC suggest that following organic matter destruction processes prevailing in soil when organic substances are stabilized biochemically and physico-chemically, and soil organic C is sequestrated. The more even distribution of organic C in fractions of different stability in soil of four-component sward, compared with mono-component sward, can be linked to the highest root mass determined in the mentioned treatment (Slepetys & Slepetiene, 2012). The root mass of multi-component swards in total was higher than that of pure swards.

In conclusion, differences in plant communities lead to alterations in soil microclimate, quality and quantity of carbon input, and the content, transformation and decomposition of organic carbon. It is evident that the SOC in soil exists as a continuum from labile to strongly stabilized forms. The higher plant diversity in semi-natural pasture leads to larger plant biomass, both aboveground and belowground (Davidson & Jenssens, 2006), and therefore a larger biomass input in long-time scale into the soil compared with legume swards. The research data show that the most sustainable was the soil of old semi-natural pasture, whereas the comparable amount of labile and recalcitrant SOC fractions determines the soil fertility as well as sequestration and protection of SOC from decomposition.

**ACKNOWLEDGEMENTS**

This research was funded by the grant of the Research Council of Lithuania No. MIP-039/2012 (CARBOSTABILIS).

## REFERENCE

Chan, K.Y., Bowman, A. & Oates, A. 2001. Oxidizible organic carbon fractions and soil quality changes in an Oxic Paleustalf under different pasture leys. Soil Science 166: 61–67 | Christopher, S.F & Lal, R. 2007. Nitrogen management affects carbon sequestration in North American cropland soils. Critical Reviews in Plant Sciences 26: 45–64 | Davidson, E.A. & Janssens, I.A. 2006. Temperature sensitivity of soil carbon decomposition and feedbacks to climate change. Nature 440: 165–173 | Fissore, C., Giardina, C.P., Kolka, R.K., Trettin, C.C., King, G.M., Jurgensen, M.F., Barton, C.D. & McDowell, S.D. 2008. Temperature and vegetation effects on soil organic carbon quality along a forested mean annual temperature gradient in North America. Global Change Biology 14: 193–205 | Kolář, L., Kužel, S., Horáček, J., Čechová, V., Borová-Batt, J. & Peterka, J. 2009. Labile fractions of soil organic matter, their quantity and quality. Plant, Soil and Environment 55 (6): 245–251 | Liaudanskienė, I., Šlepetienė, A., Šlepetys, J. & Stukonis, V. 2013. Evaluation of soil organic carbon stability in grasslads of protected areas and arable lands applying chemo-destructive fractionation. Zemdirbyste-Agriculture 100 (4): 339–348 | Lützow von, M., Kögel-Knabner, I., Ekschmitt, K., Flessa, H., Guggenberger, G., Matzner, E. & Marschner, B. 2007. SOM fractionation methods: relevance to functional pools and to stabilization mechanisms. Soil Biology and Biochemistry 39: 2183–2207 | Nemeikšienė, D., Arlauskienė, A., Šlepetienė, A., Cesevičienė, J. & Maikštėnienė, S. 2010. Mineral nitrogen content in the soil and winter wheat productivity as infuenced by the pre-crop grass species and their man-agement. Zemdirbyste-Agriculture 97 (4): 23–36 | Popov, A.I. & Tcyplenkov, V.P., Sankt-Peterburg State University. 1994. Method of determination of humus forms. Patent of Rus-sian Federation No. 2020481 (in Russian) | Popov, A.I., Rusakov, A.V., Nadporozhskaja, M.A. & Yakovleva, V.V. 2004. The use of the chemodestruction fractionating for the estima-tion of quantitative – qualitative composition of soil organic matter. Humus and soil-forming: collection of scientific works of St. Petersburg State Agrarian University, p. 63–72 (in Rus-sian) | Silveira, M.L., Comerford, N.B., Reddy, K.R., Cooper, W.T. & El-Rifai, H. 2008. Characterization of soil organic carbon pools by acid hydrolysis. Geoderma 144: 405–414 | Slepetys, J. & Slepetiene, A. 2012. Response of soil nitrogen and carbon to organic management of legume swards. Zemdirbyste-Agriculture 99 (1): 9–16 | Smith, P. 2008. Land use change and soil organic carbon dynamics. Nutrient Cycling in Agroecosystems 81: 169–178 | Strosser, E. 2010. Methods for determination of labile soil organic matter: an overview. Journal of Agrobiology 27: 49–60 | Tarakanovas, P. & Raudonius, S. (2003). The statistical analysis of agronomic research data using the software programs ANOVA, STAT, SPLIT-PLOT from package Selekcija and Irristat. Akademija, Kedainių r. (in Lithuanian)