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*Dragana D. VIDOJEVIĆ*[1*], *Maja S. MANOJLOVIĆ*[2], *Aleksandar R. ĐORĐEVIĆ*[3], *Ljiljana M. NEŠIĆ*[2], *Tihomir M. PREDIĆ*[4]

[1] Ministry of Environmental Protection of the Republic of Serbia,
Environmental Protection Agency,
Ruže Jovanović 27a, Belgrade 11160, Serbia
[2] University of Novi Sad, Faculty of Agriculture, Department of Field and Vegetable Crops,
Trg Dositeja Obradović 8, Novi Sad 21000, Serbia
[3] University of Belgrade, Faculty of Agriculture, Department of Pedology and Geology,
Nemanjina 6, Zemun–Belgrade 11080, Serbia
[4] Agricultural Institute of Republic of Srpska, Department of Agroecology,
Knjaza Miloša 17, Banja Luka, Republic of Srpska

# CORRELATIONS BETWEEN SOIL ORGANIC CARBON, LAND USE AND SOIL TYPE IN SERBIA

ABSTRACT: Correlation between soil organic carbon (SOC) and land use and soil type were investigated in the soils of the Republic of Serbia. The database included a total of 1,140 soil profiles. To establish the correlation between organic carbon content and soil type, a soil map of Serbia was adapted to the WRB classification and divided into 15,437 polygons (map units). The SOC stock values were calculated for each reference soil group based on mean values of SOC at 0–30 and 0–100 cm and their areas. The largest SOC stocks for the soil layers 0–30 cm were found in Cambisol 194.76 x $10^{12}$ g and Leptosol 186.43 x $10^{12}$ g and for the soil layers 0–100 cm in Cambisol 274.87 x $10^{12}$ g and Chernozem 230.43 x $10^{12}$ g. Using the Corine Land Cover (CLC) database, the major categories of land use were defined. Based on the obtained mean values of organic carbon content for the soil layers 0–30 and 0–100 cm and the areas indicated by Corine Land Cover categories of land use, the organic carbon stocks in agricultural soil, forest soil, semi-natural areas, and artificial areas were calculated. The correlation of organic carbon stocks and the different land use categories, soil reference group, and soil depth was studied for reference groups that occupy the major part of central Serbia, such as Cambisol (taking up 37.76% of the territory) and Leptosol (22.22% of the territory), and have a sufficient number of sites that were required for this type of analysis.

KEYWORDS: correlation, land use, organic carbon stocks, reference group

[*] Corresponding author. E-mail: dragana.vidojevic@sepa.gov.rs

## INTRODUCTION

Soil is a natural resource with accumulated large organic carbon stocks (Lal, 2004; Manojlović, 2008). Appropriate land use aimed at increasing the level of organic carbon can increase the productivity and sustainability of agricultural ecosystems (Cole et al., 1997). Also, appropriate land use has a role in alleviating greenhouse gas effects, given that the soil is capable of either releasing or absorbing carbon. The total content of organic matter in the soil is higher in the conservation tillage as compared to plowing in winter wheat and sunflower production (Šeremešić et al., 2016). Statistical analysis has shown that there is a significant effect of the tillage system and the crop on the change of the total content of organic matter. Increasing organic matter in the soils is an important strategy of biological immobilization of carbon (Manojlović and Aćin, 2007; Manojlović et al., 2008). To ensure sustainable land use, the organic matter in the soils must be kept at a satisfactory level. The content of organic matter in specific layers of the soil is a basis for the calculation of organic matter up to a meter depth (Gobin et al., 2011; Vidojević and Manojlović, 2010). In this manner, organic carbon stocks can be assessed against the soil type and its specific use. Identifying parameters influencing the reduction of organic carbon stocks in the soil, as well as interconnectedness of these parameters lays the foundation for mapping the areas at risk of organic matter reduction. Organic carbon stocks in the soils of the Republic of Serbia have not been assessed consistently. The results of the assessment done so far have shown that a universal approach that would apply to a large area is not possible and that more detailed analyses will require more precise and reliable data at both regional and national levels.

## MATERIAL AND METHODS

### Soil database

In the period 2009–2011, a database was established which served as the basis for further research. Its objective was to collate all available data and to adapt them to fit the base. Presently, the database includes a total of 1,140 soil profiles which involve 4,335 horizons. The database comprises the data for analytical study collected in the period 1962–2010. The soil map of Serbia shows that the reference groups Histosol, Anthrosol, Calcisol, Podzol, Phaeozem, and Umbrisol are distributed over a limited area in the country, totaling 3.58%. The most extensive groups are Cambisols (27.99%), Chernozems (17.68%) and Leptosols (15.9%) (Vidojević et al., 2015).

To establish the relationship between organic carbon content and land use and soil type, a soil map of Serbia was adapted to the WRB classification and divided into 15,437 polygons (map units). The assessment was based on long-term research data and data from the Soil Information System of Environmental

Protection Agency (Vidojević and Manojlović, 2010). The assessment of organic carbon stocks in the soils of the Republic of Serbia was carried out in the period 2009–2013 and it was made in soil layers 0–30 cm and 0–100 cm and based on soil type and land use category.

### Calculation of organic carbon stocks per land use categories

Using the Corine Land Cover (CLC) database for 2006, the areas of the major categories of land use were defined. Based on the obtained mean values of organic carbon content in soil layers 0–30 and 0–100 cm and the areas indicated by Corine Land Cover categories of land use, the organic carbon stocks in agricultural land, forest land, semi-natural areas, and artificial areas were calculated. The last category includes mostly the urban green areas and recreational areas. The database does not contain organic carbon data for other categories of land use.

Organic carbon stock for the soil layer 0–30 cm per land use category was calculated according to the following formula:

SOC 30 cm (t) = Σ {(ẋ) mean value of organic carbon content per category of land use for the soil layer 0–30 cm (t $ha^{-1}$) x area occupied by land use category (ha)}

Organic carbon stock for the soil layer 0–100 cm was calculated according to the following formula:

SOC 100 cm (t) = Σ {(ẋ) mean value of organic carbon content per category of land use for the soil layer 0–100 cm (t $ha^{-1}$) x area occupied by land use category (ha)}

### Statistics

Statistical data analysis was used to identify and establish the correlation between the organic carbon stocks from the most represented soil reference group and the land use category.

The correlation of the organic carbon stocks and the different land use categories (agricultural land and forest land), soil reference group, and soil depth was studied for reference groups that occupy the major part of central Serbia, such as Cambisol (taking up 37.76% of the territory) and Leptosol (22.22% of the territory), and have a sufficient number of sites that were required for this type of analysis. The Cambisol reference group included 90 sites in agricultural land and 64 sites in forest land. The Leptosol reference group included 35 sites in agricultural land and 71 sites in forest land.

The analysis of soil organic carbon stocks was performed with a package IBM SPSS statistics 20. Indicators of descriptive statistics were obtained to identify a general trend in the variability of organic carbon stocks in different extreme conditions. The analysis of the variance during a three-factor experiment showed the importance of land use impacts, reference soil group, and soil depth for the organic carbon content – for 5% and 1% risk levels. Relative interdependence of characteristics was measured with the Pearson correlation coefficient, tested at the 5% and 1% level of significance.

## RESULTS

Organic carbon stocks broken down by different land use categories were identified by examining the soils at 1,140 sites for assessment of soil organic carbon stocks in t/ha. The analysis of the share of land use category at investigated sites has shown that 6.5% of sites are classified as artificial areas for assessment of soil organic carbon stocks in t/ha, 50.6 % of sites are classified as agricultural land, and 42.9% of sites are classified as forests and semi-natural areas. Distribution of soil organic carbon was shown in relation to land use category as defined by the Corine Land Cover categories. In the Republic of Serbia, artificial areas, agricultural land, forests, and semi-natural areas, and wetlands and water surfaces cover 257,070 ha, 4,395,186 ha, 2,967,453 ha, and 127,691 ha, respectively. The respective percentages are 3.32%, 56.73%, 38.30%, and 1.65%.

The analysis of organic carbon content in agricultural land showed that in layer 0–30 cm the values ranged from 3.72 t $ha^{-1}$ to 328.23 t $ha^{-1}$ (Table 1). The mean value was 68.99 t $ha^{-1}$. In layer 0–100 cm the values ranged from 18.25 t $ha^{-1}$ to 658.40 t $ha^{-1}$, with the mean value of 136.57 t $ha^{-1}$. The analysis of variation coefficients indicated that the mean values for this land use category were not sufficiently representative (CV > 50%) (Vidojević et al., 2015).

The analysis of organic carbon content in the category of forests and semi-natural areas showed that in the layer 0–30 cm the values ranged from 4.93 t $ha^{-1}$ to 527.22 t $ha^{-1}$. The mean value was 116.35 t $ha^{-1}$. In layer 0–100 cm, the values ranged from 10.06 t $ha^{-1}$ to 646.98 t $ha^{-1}$, with the mean value of 154.19 t $ha^{-1}$. The analysis of variation coefficients indicated that the mean values for this land use category were not sufficiently representative (CV > 50%).

The analysis of organic carbon content in the category of artificial areas showed that in layer 0–30 cm the values ranged from 30.71 t $ha^{-1}$ to 133.51 t $ha^{-1}$. The mean value was 74.74 t $ha^{-1}$. In the layer 0–100 cm, the values ranged from 45.68 t $ha^{-1}$ to 342.66 t $ha^{-1}$, with the mean value of 161.43 t $ha^{-1}$. The analysis of variation coefficients indicated that these mean values were representative (CV < 50%) for this land use category.

Based on the areas of the different land use categories, the values of organic carbon stocks for these categories were obtained. The results showed that the organic carbon stocks in the category of agricultural land were 303.22 x $10^{12}$ g (Tg) and 600.25 x $10^{12}$ g (Tg) for the soil layers 0–30 cm and 0–100 cm, respectively. In the category of forests and semi-natural areas, the organic carbon stocks were 345.26 x $10^{12}$ g (Tg) and 457.55 x $10^{12}$ g (Tg) for the layers 0–30 cm and 0–100 cm, respectively. In the category of artificial areas, which mainly included sites within urban green areas and recreational areas, the organic carbon stocks were 19.21 x $10^{12}$ g (Tg) and 41.50 x $10^{12}$ g (Tg) for the soil layers 0–30 cm and 0–100 cm, respectively. The category of wetlands was not investigated in this study.

*Table 1.* Soil organic carbon (SOC) content and SOC stocks by CLC categories in the Republic of Serbia

| | | | | 0–30cm | | | | | 0–100 cm | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | SOC content ($t\ ha^{-1}$) | | | | | SOC content ($t\ ha^{-1}$) | | | | |
| | Area (ha) | Area (%) | n | Mean | Min | Max | SD | SOC stock (Tg) | Mean | Min | Max | SD | SOC stock (Tg) |
| **Agricultural areas** | 4,395,186 | 56.73 | 577 | 68.99 | 3.72 | 328.23 | 36.68 | 303.22 | 136.57 | 18.25 | 658.40 | 72.86 | 600.25 |
| **Forestland and semi-natural areas** | 2,967,453 | 38.30 | 489 | 116.35 | 4.93 | 527.22 | 79.60 | 345.26 | 154.19 | 10.06 | 646.98 | 93.22 | 457.55 |
| **Artificial areas** | 257,070 | 3.32 | 74 | 74.74 | 30.71 | 133.51 | 22.61 | 19.21 | 161.43 | 45.68 | 342.66 | 65.71 | 41.50 |

**n**: Number of soil profiles in the database. **SD**: Standard deviation

The obtained data indicated that there existed a great variability in the content of organic carbon among the reference soil groups. The largest SOC stocks for the soil layers 0–30 cm were found in Cambisol 194.76 x $10^{12}$ g and Leptosol 186.43 x $10^{12}$ g and for the soil layers 0–100 cm in Cambisol 274.87 x $10^{12}$ g and Chernozem 230.43 x $10^{12}$ g.

## Multi-regression and correlation analysis

Table 2 shows the results of descriptive statistics of the content of organic carbon in the soil as related to different land use categories and WRB groups, measured up to 30 cm and 100 cm depth. The lowest variability of the content of soil organic carbon, measured in two layers of the soil, was found in Cambisol in agricultural land (28.75% and 39.30% respectively), while Leptosol in agricultural land showed most variability (64.24% and 86.67% respectively). With increasing depth of agricultural land, the dispersion of the organic carbon stocks increases as well. When it comes to forest land, for both groups the variability of organic carbon content is almost regular. Generally speaking, the variability of soil organic carbon stocks is outstanding (Cv>30%), which means that the concentration of the observed element is impacted to a great extent by external factors.

*Table 2.* Descriptive statistics of the content of soil organic carbon for the soil layers 0–30 cm and 0–100 cm as related to different WRB groups and land use categories (t/ha)

| Land use category | WRB group | n | $\bar{x} \pm S_{\bar{x}}$ | **Xmax–Xmin** | **Cv (%)** |
|---|---|---|---|---|---|
| | | | | 0–30 cm | |
| Agricultural land | **Cambisol** | 90 | 63.49 ± 1.94 | 134.68–20.44 | 28.75 |
| | **Leptosol** | 35 | 117.26 ± 12.73 | 328.23–18.25 | 64.24 |
| **Forestland** | **Cambisol** | 64 | 124.99 ± 9.18 | 347.62–40.50 | 58.27 |
| | **Leptosol** | 71 | 184.75 ± 12.75 | 471.70–32.48 | 58.05 |
| | | | | 0–100 cm | |
| Agricultural land | **Cambisol** | 90 | 102.72 ± 4.26 | 250.72–25.74 | 39.30 |
| | **Leptosol** | 35 | 162.10 ± 23.74 | 658.40–18.25 | 86.67 |
| **Forestland** | **Cambisol** | 64 | 154.73 ± 10.05 | 398.43–59.96 | 51.55 |
| | **Leptosol** | 71 | 217.43 ± 16.41 | 646.98– 32.48 | 63.60 |

**n**: Number of soil profiles

What is also worth noting is that organic carbon stocks for the Leptosol reference group are larger in comparison to the Cambisol reference group; the same applies to forest land when compared with agricultural land. Measured differences in the content of organic carbon stocks for different reference soil groups and land use categories for the soil layers 0–30 cm and 0–100 cm have been statistically tested (Table 3). The co-occurring influence of the three factors (reference soil group, land use category, and depth of soil layers) on the variability of organic carbon stocks has been examined. The variance analysis test has shown that individual factors have a very significant statistical impact on the change of organic carbon concentrations in the soil ($p<0.01$), while their interaction (on both levels) is not statistically significant ($p>0.05$).

*Table 3.* The analysis of variance (ANOVA) of tested factors and their influence on the variability of soil organic carbon

| **Test** | **Land use (A)** | **Reference soil group (B)** | **Depth (C)** | **AxB** | **AxC** | **BxC** | **AxBxC** |
|---|---|---|---|---|---|---|---|
| **F** | 52.212** | 51.907** | 20.063** | $0.081^{NS}$ | $0.438^{NS}$ | $0.069^{NS}$ | $0.007^{NS}$ |
| **p-level** | 0.000 | 0.000 | 0.000 | 0.776 | 0.508 | 0.794 | 0.935 |
| **Partial eta-squared coef.** | 0.093 | 0.092 | 0.038 | 0.0001 | 0.0009 | 0.0001 | 0.0000 |

$^{NS}$ >0,05 **<0,01

Apart from statistical importance, based on partial eta-squared coefficients, the effects of each factor were measured. The measurement has shown that land use category (agricultural or forest), as well as reference soil group (Cambisol and Leptosol) have nearly identical effects on the variability of organic carbon stocks: the land use category influences variability by 9.3%, and the reference group by 9.2%. The measured depth of soil layers modifies the values of SOC by 3.8%.

## DISCUSSION

The map of organic carbon distribution depending on land use category showed that organic carbon stocks were higher in forests and semi-natural areas than in agricultural land, up to 40.71% and 11.43% for the soil layers 0–30 cm and 0–100 cm, respectively (Vidojević, 2016). Organic carbon content was found to be higher in artificial areas than in agricultural land, forestland, and semi-natural areas. The reasons for this are manifold, but the most probable explanation is that the samples for this category were taken from urban green areas and recreational areas which are intensively fertilized and the removal of organic carbon is reduced. This study showed that there occurred a great variability in results when categories of land use were analyzed. Only the sites belonging to the category of artificial areas, at 0-30 cm, produced sufficiently representative values of the mean content of organic carbon. It appears that organic carbon content depends more on other factors, such as soil type, climatic conditions, and altitude than on land use category.

The distribution of organic carbon stocks in the soil layer 0–30 cm has shown higher values in central Serbia, with larger areas of forested land in comparison to the Province of Vojvodina in the north of the country consisting of mostly agricultural fields (Vidojević et al., 2017). The distribution of stocks in the soil layer 0–100 cm has shown larger carbon content in the Province of Vojvodina in comparison to central Serbia. These are mostly the reference groups of Chernozem and Gleysol, occupying 76.03% of the area of the Province of Vojvodina, which has larger organic carbon stocks in comparison to the most prevalent referent group in central Serbia – Cambisol (Vidojević et al., 2016).

Analysis of the organic carbon content in the surface layer (0–20 cm) in the most prevalent soils of forest ecosystems in central Serbia: eutric Ranker, eutric Cambisol, and dystric Cambisol has shown that the mean value of organic carbon for all the tested soils amounts to 5.77 kg $m^{-2}$ (Kadović et al., 2012).

The research done by Freibauer et al. (2004) has pointed out that average organic carbon stocks in European arable land are at the level of mean organic carbon stocks in European mineral soils (around 53 t/h) at a 0–30 cm depth when different soil types are taken into consideration. Consequently, it is likely that European soils vary to a great deal across climate regions and soil types.

Based on a research study of organic carbon stocks in agricultural land of Europe conducted using a CENTURY model (Lugato et al., 2014), a value of 17.63 Gt for a 0–30 cm layer was obtained. The model included the EU and non-EU countries (Serbia, Bosnia and Herzegovina, Croatia, Albania, Macedonia, and Norway). The results obtained by the model were tested against the European Environment and Observation Network (EIONET) results, as well as against approximately 20,000 soil samples from LUCAS 2009 study.

The organic carbon stocks in agricultural land were identified and measured based on the surface of agricultural land in the Republic of Serbia. The value shown in Gt is 0.35 Gt of organic carbon stocks at a 0–30 cm depth in arable land of the Republic of Serbia, or else 1.98% of total content for the agricultural soils of Europe tested with the CENTURY model (Vidojević et al., 2014).

## CONCLUSION

The spatial distribution of organic carbon stocks and its variability in the Republic of Serbia is caused by various factors.

The co-occurring influence of reference soil group, land use category, and depth of soil layer on the variability of organic carbon stocks has been examined. The variance analysis test has shown that individual factors have a very significant statistical impact on the change of organic carbon concentrations in the soil, while their interaction (on both levels) is not statistically significant.

The research has shown a high variability of results for different categories of land use. The measurements have shown that land use category (agricultural or forest), as well as reference soil group Cambisol and Leptosol have nearly identical effects on the variability of organic carbon stocks.

The obtained results have shown that an inventory of the land cover provides essential information in a world that is quickly becoming aware of the environmental limitations and lack of natural resources. The compilation of data on organic carbon stocks and its distribution in the different soil reference groups and land use categories is the first step in the evaluation and monitoring of changes of organic carbon stocks in the soils of the Republic of Serbia.

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# КОРЕЛАЦИЈА ИЗМЕЂУ ОРГАНСКОГ УГЉЕНИКА У ЗЕМЉИ, КОРИШЋЕЊА ЗЕМЉИШТА И ВРСТЕ ОБРАДИВОГ ЗЕМЉИШТА У СРБИЈИ

Драгана Д. ВИДОЈЕВИЋ[1], Маја С. МАНОЈЛОВИЋ[2],
Александар Р. ЂОРЂЕВИЋ[3], Љиљана М. НЕШИЋ[2], Тихомир М. ПРЕДИЋ[4]

[1] Министарство заштите животне средине,
Агенција за заштиту животне средине,
Руже Јовановић 27а, Београд 11160, Република Србија
[2] Универзитет у Новом Саду, Пољопривредни факултет,
Департман за ратарство и повртарство,
Трг Доситеја Обрадовића 8, Нови Сад 21000, Република Србија
[3] Универзитет у Београду, Пољопривредни факултет,
Катедра за педологију и геологију
Немањина 6, Земун–Београд 11080, Република Србија
[4] Пољопривредни институт Републике Српске,
Завод за агроекологију,
Књаза Милоша 17, Бања Лука 78000, Република Српска

РЕЗИМЕ: У раду су представљени резултати истраживања које је имало за циљ утврђивање зависности садржаја органског угљеника у земљишту, начина коришћења земљишта и референтне групе земљишта у Републици Србији. База података је укључила укупно 1.140 профила земљишта. За потребе утврђивања зависности садржаја органског угљеника и типа земљишта педолошка карта Србије прилагођена је WRB класификацији и садржи 15.437 полигона. Урађена је калкулација за сваку референтну групу земљишта на основу резултата средњих вредности садржаја органског угљеника у слоју земљишта 0–30 cm и 0–100 cm за главне референтне групе и њихових површина. На основу средње вредности садржаја органског угљеника у земљишту и површине референтне групе утврђено је да највећу резерву органског угљеника у земљишту у слоју 0–30 cm има камбисол 194,76 x 1012 g и лептосол 186,43 x 1012 g, и у слоју 0–100 cm дубине камбисол 274,87 x 1012 g и чернозем 230,43 x 1012 g. На основу резултата средњих вредности садржаја органског угљеника у слоју 0–30 cm и 0–100 cm дубине и површине коју заузима Corine Land Cover категорија начина коришћења земљишта, израчуната је укупна вредност резерви органског угљеника за пољопривредна земљишта, шуме и полуприродна подручја и вештачке површине. Статистичка зависност садржаја органског угљеника у земљишту од начина коришћења земљишта, референтне групе земљишта и дубине слоја, рађена је за референтне групе које заузимају највећу површину посматрајући територију централне Србије и то за референтну групу камбисол (која заузима 37,76% територије), затим лептосол (која заузима 22,22% територије) и довољног броја локалитета који су били потребни за анализу.

КЉУЧНЕ РЕЧИ: резерве органског угљеника у земљишту, коришћење земљишта, зависност, референтна група