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Spatial distribution of soil organic carbon stocks in Serbia

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Abstract
Spatial distribution of soil organic carbon (SOC) were investigated in the soils of Republic of Serbia. The database included a total of 1,140 soil profiles which corresponded to 4335 soil horizons. To establish the relationship 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). We calculated the SOC stock values 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 Chermozem 230.43 x 10^{12} g. Based on the size of the reference groups, total area of Republic of Serbia, and the mean SOC values for each reference group, we calculated the total SOC stocks. The obtained values for the soil layers 0-30 cm and 0-100 cm amounted to 695.31 x 10^{12} g and 1142.42 x 10^{12} g, respectively.

Key words: Organic carbon stocks, map unit, soil group, SOC content, Republic of Serbia

1. INTRODUCTION

This paper presents spatial distribution of organic carbon stocks in the soils in Republic of Serbia. The assessment was based on long-term research data and data from Soil Information System of Environmental Protection Agency (Vidojević & Manojlović, 2010). Estimation of organic carbon stocks in the soil is important for Republic of Serbia for several reasons. Of the total territory of Republic of Serbia, 65.6% are agricultural land and 32% are forest land (State of Soil in the Republic of Serbia for 2012, 2013). Considering the vital importance of organic carbon for the functioning of ecosystems, its effect on soil structure and soil water capacity, and its role in numerous chemical and physical soil properties, it is important to establish its baseline status in order to be able to monitor its variations over time. The assessment of organic carbon stocks was made in soil layers 0-30 cm and 0-100 cm and it was based on soil type.

2. METHODOLOGY

2.1. Study location

The assessment of organic carbon stocks in the soils in Republic of Serbia was carried out in the period 2009-2013.

Organic carbon stocks in the soils of Republic of Serbia were calculated on the basis of the mean values for each WRB reference soil group. Organic carbon stocks were calculated for the area of 77,474 km^2, i.e., for the territory of Republic of Serbia excluding Kosovo and Metohija Province (Statistical Yearbook of the Republic of Serbia, 2010). The territory of Kosovo and Metohija Province was excluded from calculation because of unavailable data.

2.2. 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 1140 soil profiles which involve 4335 horizons. Data that comprise the database for analytical study were 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%).

2.3. Calculation of organic carbon stocks per WRB reference groups

Using Soil Map of Serbia, areas of the main WRB reference soil groups were defined. Total values of organic carbon stocks for these reference groups were calculated on the basis of the mean values of organic carbon content at 0-30 cm and 0-100 cm and the area of each reference group. The database does not contain the results for organic carbon stocks in the following reference groups: Anthrosol, Calcisol, Histosol, Phaeozem, Podzol and Umbrisol. These groups cover a total area of 276,991 ha, which represents 3.57% of the territory of the country. For the calculation of organic carbon stocks in these groups, we used values which represented the arithmetic means for all reference group at 0- 30 cm and 0-100 cm expressed in t ha^{-1}. The mean values for the main reference groups were 89.59 t ha^{-1} and 145.69 t ha^{-1} for the depths of 0-30 cm and 0-100 cm, respectively.

Organic carbon stock at 0-30 cm per reference group was calculated according to the following formula:

SOC 30 cm (t) = Σ {(ẋ) mean value of organic carbon content per reference soil group at 0-30 cm (t ha^{-1}) x area occupied by reference group (ha)}

Organic carbon stock at 0-100 cm was calculated according to the following formula:

SOC 100 cm (t) = Σ {(ẋ) mean value of organic carbon content per reference soil group at 0-100 cm (t ha^{-1}) x area occupied by reference group (ha)}

3. RESULTS

The calculated data indicated that there existed a great variability in the content of organic carbon among the reference soil groups. The highest mean values of organic carbon content were found in the reference group Leptosol - 151.33 t ha^{-1} and 178.95 t ha^{-1} for the depths of 0-30 cm and 0-100 cm, respectively (Vidojević et al., 2012). The analysis of the coefficients of variation indicated that the mean values were not sufficiently representative for that group (CV > 50%). The lowest mean values of organic carbon content were found in the reference group Arenosol - 41.78 t ha^{-1} and 96.03 t ha^{-1} for the depths of 0-30 cm and 0-100 cm, respectively. The analysis of the coefficients of variation showed that the mean values were sufficiently representative for this group (CV <50%). The research showed that the values of organic carbon content had highest variability in the reference groups Leptosol and Regosol.

The result obtained on the basis of the compound area of the reference soil groups and the area of Republic of Serbia (77,474 km^2) indicated that the organic carbon stocks at 0-30 cm and 0-100 cm were 695.31 x 10^{12} g (Tg) and 1142.42 x 10^{12} g (Tg), respectively (Vidojević et al., 2015).

4. DISCUSSION

The map of organic carbon distribution per soil type, at 0-30 cm, showed that largest organic carbon stocks were present in Central Serbia (southern part), predominantly in the reference group Leptosol (Fig. 1). In that reference group, the content of organic carbon at 0-30 cm ranged from 11.06 to 527.22 t ha^{-1}, with the mean value of 151.33 t ha^{-1}. At 0-100 cm, the values ranged from 11.06 to 658.40 t ha^{-1}, with the mean value of 178.95 t ha^{-1}. The soils in this reference group are shallow, so that the values of organic carbon content to the depth of 100 cm represent in fact the value for the entire profile. The reference group Cambisol occupies the largest area in Central Serbia (37.76%). The values of organic carbon content for this reference group, at 0-30 cm, ranged from 20.44 to 347.62 t ha^{-1}, with a mean value of 89.81 t ha^{-1}. The coefficient of variation was 59.40%. The values of organic carbon content at 100 cm ranged from 25.74 to 398.43 tha^{-1}, with the mean value of 126.75 t ha^{-1}. The coefficient of variation was 49.54%. In the north of the country, in Vojvodina

Province, the region with the most intensive agricultural production, the organic carbon content at 30 cm was mostly low, amounting to 1.93%. The most common soil type in this part of the country is Chernozem, which covers 57.9% of the area. The values of organic carbon content for this reference group, at 30 cm, ranged from 7.89 to 133.51 t ha^{-1}, with the mean value of 73.82 t ha^{-1} (Vidojević et al., 2016). The organic carbon content at 100 cm ranged from 24.21 to 341.37 t ha^{-1}, with the mean value of 168.20 t ha^{-1}. The obtained values indicated that chernozems have a greater depth of the humus horizon (Ah), which went up to 100 cm, then Cambisols with the humus horizon up to the depth of 60 cm.

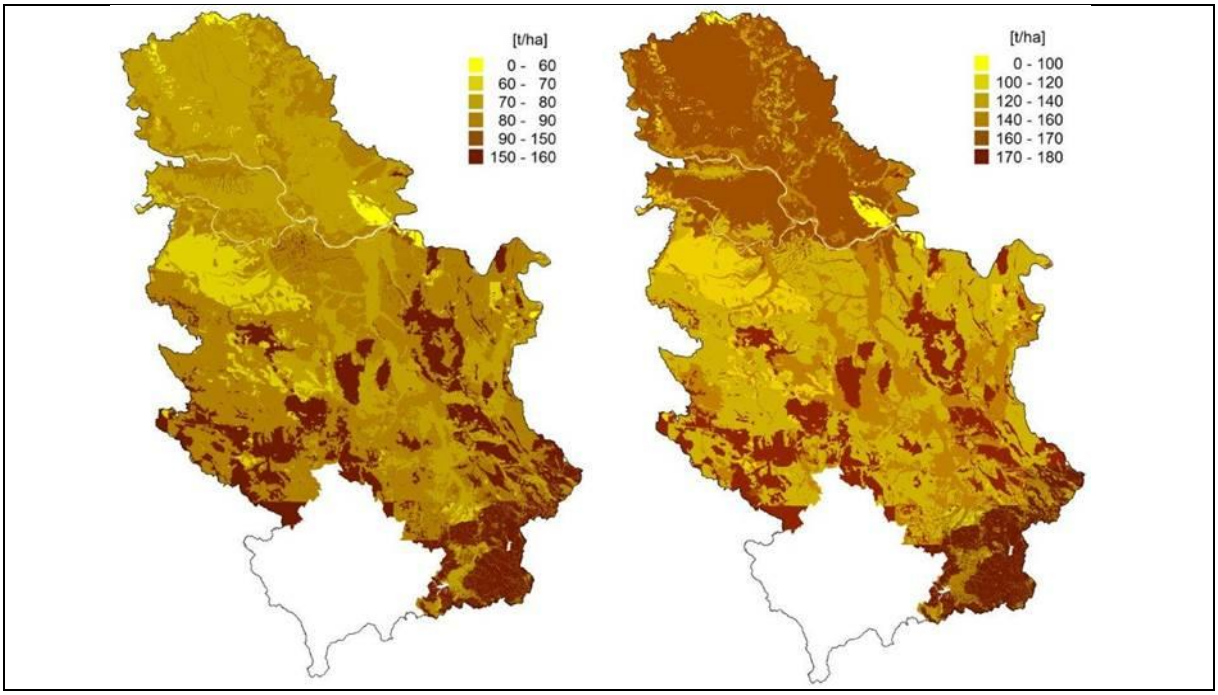

Fig. 1. SOC stocks distribution by soil type, to the depths of a) 0-30 cm and b) 0-100 cm (Vidojević et al., 2015)

Chernozem and Gleysol, the two most common soil reference groups in Vojvodina Province, which occupy 76.03% of the area, were found to have larger organic carbon stocks than Cambisol, the most common soil reference group in Central Serbia. The Chernozem soil in Russia was reported to contain 290 t ha^{-1} of organic carbon at 0-100 cm (Mikhailova & Post, 2006), while a study in Bulgaria showed 142 t ha^{-1} (Filcheva et al., 2002). Chernozem in Vojvodina Province, which had developed on loess terraces, has the mean organic carbon content of 151 t ha^{-1} at 0-100 cm (Belić et al., 2013).

5. CONCLUSION

According to the analysis of the soil map, the soils of Serbia were found to store 695.31 x 10^{12}g (Tg) of organic carbon at 0-30 cm and 1142.42 x 10^{12} g (Tg) at 0-100 cm. The spatial distribution of organic carbon stocks and its variability is caused by various factors, such as clay content, land use pattern, altitude, and climate. In general, the distribution of the content of organic carbon at 0-30 cm showed higher values in Central Serbia, where forestland occupied a larger area than agricultural land.

Republic of Serbia has a variety of soils which differ in profile structure and depth. In the case of the reference soil groups with the profile depth less than 100 cm, the content of organic carbon was still presented for the depth of 0-100 cm although it was not true for the actual situation.

As the data for organic carbon content come from a total of 1140 soil profiles, we believe that the results of the this study are accurate and reliable. This study is the first comprehensive assessment of organic carbon stocks in the soils layers 0-30 cm and 0-100 cm done in Republic of Serbia. The compilation of data on organic carbon stocks and its distribution in the different soil reference groups is the first step in the evaluation and monitoring of changes of organic carbon stocks in the soils of Republic of Serbia.

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