Cíl 3/Cel 3
2007-2013

EVROPSKÁ UNIE / UNIA EUROPEJSKA
EVROPSKÝ FOND PRO REGIONÁLNÍ ROZVOJ / EUROPEJSKI FUNDUSZ ROZWOJU REGIONALNEGO
PŘEKRAČUJEME HRANICE / PRZEKRACZAMY GRANICE

Assessment of Soil Organic Carbon Status and Changes in Soils of Polish-Czech Borderland

Radoslaw Kaczynski, Grzegorz Siebielec, Rafal Galazka, Jacek Niedzwiecki, Sarka Polakova

IUNG

ÚKZÚZ

Cíl 3/Cel 3
2007-2013

EVROPSKÁ UNIE / UNIA EUROPEJSKA
EVROPSKÝ FOND PRO REGIONÁLNÍ ROZVOJ / EUROPEJSKI FUNDUSZ ROZWOJU REGIONALNEGO
PŘEKRAČUJEME HRANICE / PRZEKRACZAMY GRANICE

ASSESSMENT OF SOIL ORGANIC CARBON STATUS AND CHANGES IN SOILS OF POLISH-CZECH BORDERLAND

Partner responsible: Institute of Soil Science and Plant Cultivation – State Research Institute, Pulawy (IUNG)

Partner contributing: Central Institute for Supervising and Testing in Agriculture (UKZUZ)

Authors:

Radoslaw Kaczynski, Grzegorz Siebielec, Rafal Galazka, Jacek Niedzwiecki, Sarka Polakova

December 2013

CONTENT

1. INTRODUCTION

In the proposal of European Commission on Soil Framework Directive (COM(2006) 232 final) – soil organic matter is explicitly defined as "the organic fraction of the soil, excluding undecayed plant and animal residues, their partial decomposition products, and without the living soil biomass". Other papers define SOM as all organic materials found in soils irrespective of their origin or state of decomposition[1].

Soil organic matter (SOM) content is probably the most useful single indicator of the sustainability of the soil resources, and can therefore be potentially used as an indicator of changes in the ability of soils to maintain current crop yields and other non-productional functions. It is associated with key functions in both chemical and physical aspects of a soil's overall function[2].

SOM is essential to many soil functions:

- production potential - major source of plant nutrients,
- physical - retention, structure, susceptibility to erosion and condensation,
- chemical - sorption capacity, buffering properties, stabilization of pH, filtration of contaminants,
- biological - biodiversity provision, strengthening of soil and plant health status.

Soil organic matter (SOM) decline was defined by the EU Strategy for Soil Protection as the major threat to soil quality. Balance of SOM is the main criterion of sustainability of farming system. Regional assessments indicate that SOM levels might be decreasing. The introduction of a market economy and the integration of Poland and the Czech Republic into the European Union resulted in multi-directional changes in agriculture. They are highlighted in the organization and intensity of plant and animal production and specialization of farms. Simplification of crop rotations and specialization in agriculture have led to limited input of organic matter to soil. Intensive farming system combined with the simplification of crop rotation (decrease in share of perennial forage crops, legumes in favor of cereals and maize) can lead to a decrease in input of crop residues, and consequently, to a decrease in soil organic matter content. The observations in recent years show that there is an increasing number of farms without animal production and thus, deprived of manure or slurry supply, which are an extremely important part of soil fertility formation. What cannot be overlooked is the fact that increasingly larger part of straw is allocated to heating plants as fuel. Activities aimed at protection of SOC (soil organic carbon) and the new possibilities of introducing exogenous organic matter become so extremely important challenge. Key exercise which is needed is the assessment of current status and changes in SOC content as response to agronomic

---

[1] Baldock, J. A., Skjemstad, J. O., (1999), Soil organic carbon/soil organic matter. In 'Soil Analysis: an Interpretation Manual. (Eds K. I. Peverill, L. A. Sparrow, and D. J. Reuter.) CSIRO Publishing, Collingwood, pp. 159-170,

[2] King, J.A., Bradley, R.I. and Harrison, R. (2005), Current trends of soil organic carbon in English arable soils. Soil Use and Management, 21: pp. 189–195.

and climatic conditions. Such information is required for proposals and implementation of agricultural and legal measures for protection of SOC.

The objective of this task was to evaluate status and trends in soil organic carbon in agricultural soils of Polish – Czech borderland.

2. MATERIAL AND METHODS

2.1. Study area

The study area covers Polish - Czech borderland with the area of 46 320 km^2 (Fig. 1).

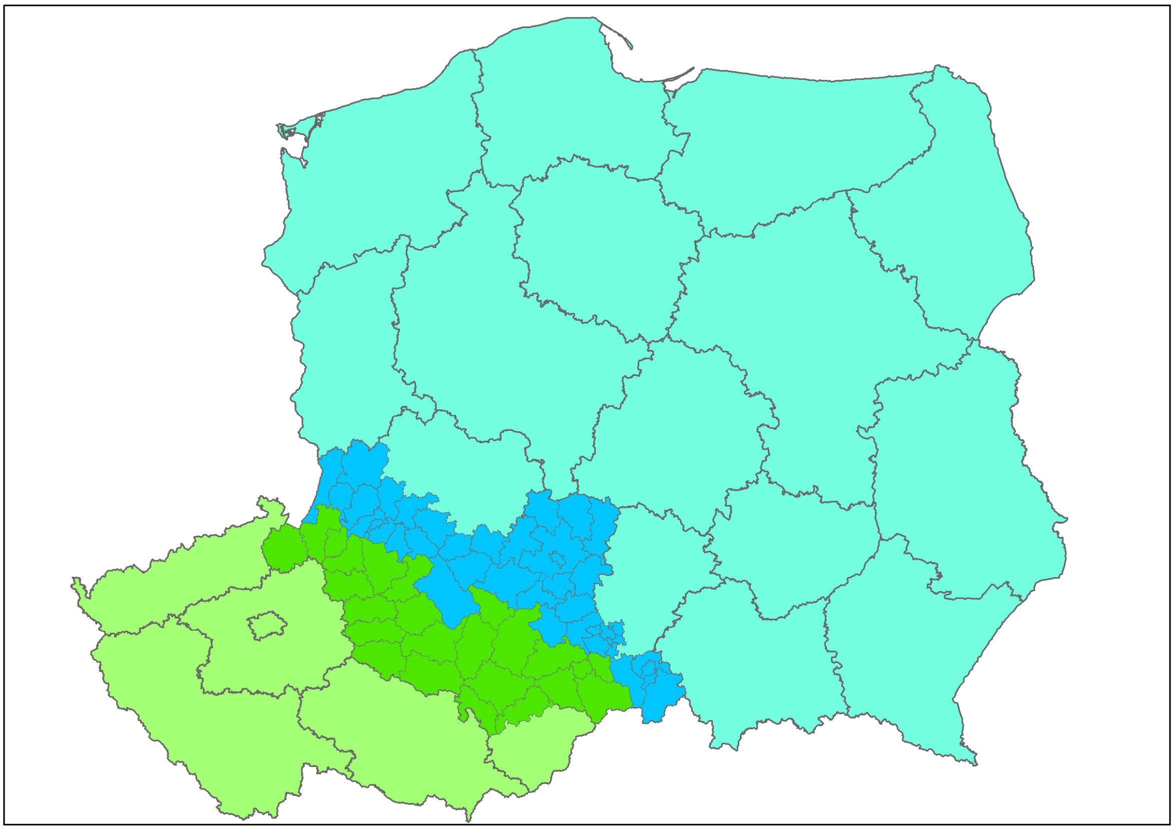

Figure 1. Area covered by soil sampling

Rysunek 1. Obszar objęty badaniem próbek glebowych
Obrázek 1. Území pokryté odběry půdních vzorků

The area is quite diverse both in terms of natural conditions (elevation, climate, soil) and agronomic factors. The borderland contains mountainous land in Sudetes and Beskids with low annual temperature (<3°C) and high precipitation rate (>1000 mm), and lower parts on the north and south of them with higher temperature (about 7°C) and lower annual precipitation (<600 mm). Prevailing soil type is cambisol and the texture is mostly silt on the Polish side and clay on the Czech side. Agricultural land is used mostly as arable land. Pastures and permanent grassland are located mainly in the mountainous parts due to natural factors (elevation and slopes). Main part of borderland is occupied by high intensive, large scale commercial crop production with short crop rotation, large share of intensive crops like wheat, corn, rape and low livestock population.

2.2 Data

The studies aimed at soil organic matter evaluation in the borderland are based on two national soil inventory systems:

1- Czech "Basal Soil Monitoring System (BSMS)",
2- Polish soil survey and monitoring system database consisting of historical data that represents soil reference profiles sampled in 1960-1984 and resampled in 2013.

Basal Soil Monitoring System (BSMS) which covers three distinct classes of land uses i.e. agricultural, forestry and protected areas was performed in the Czech Republic. In each class, individual subsystem is implemented on the basis of the same main principles and methods set out by the Czech Ministries of Agriculture and Environment along with three agricultural, forestry and environmental research institutes. The monitoring plots on agricultural land were established in 1992, when also the first samples were taken in basal net of 190 monitoring plots. In 1995 samples were taken again by application of optimized sampling method. Five years later, in 1997, the subsystem of contaminated areas was established. In total, 27 monitoring plots were created on the sites characterized by inorganic contamination of both anthropogenic and geogenic origin. [3,4]

Starting point for the Polish study is the database of reference profiles described and analyzed in order to produce the soil agricultural map of Poland in 1960 - 1984 period. The database of 5700 profiles has been digitalized and contains results for soil horizons up to a depth of 1,5 m for each profile. A set of information describing profiles contains: land use, location of the profile within the landscape, complex of soil suitability, soil type, texture, organic matter content, pH, available nutrients. This database was developed at the IUNG in Puławy. Many properties of soils recorded in this database are now out-of-date, but the database itself is a reference point for investigations concerning changes in soil properties (for example SOM changes) and relationships between various soil properties.

---

[3] Sanka M., Petrus J., Kalus C., et al., (1995), Basal soil monitoring scheme in the protected areas of the Czech Republic. Environ Monit. Assess., 34 pp. 167–174,

[4] Metodika monitorování zemědělských a lesních půd a půd chráněných území České republiky. (1993) Praha: MŽP ČR, odbor ochrany lesa a půdy ve spolupráci s Ústředním kontrolním a zkušebním ústavem zemědělským,. 39 p.

Current and historical data describing characteristics of agriculture were obtained from Central Statistical Office of Poland and Czech Statistical Office. Climatic data were derived from the IPCC model. [5]

2.2.1. Field survey and soil sampling

In the study area, 80 soil samples (40 PL and 40 CZ) were taken and analyzed for organic matter - its current state and changes over time (Fig. 2, 3). Monitoring points were localized by using Global Positioning System with sub-meter precision (<3 m). Nevertheless, it was checked in the field that the geographical coordinates are in accordance with the original description of local topography (slope gradient, position on the slope, landmarks, soil profile characteristics). Samples were taken in spring 2013 from topsoil horizon (0 - 20 cm) of arable land. In each sampled field, 20 individual samples from 10-m radius were taken with a hand auger and the extracted soil was mixed to provide composite, homogenous samples. Samples were stored in cool, dark conditions and immediately transported to laboratory. The same procedure refers to both Polish and Czech samples.

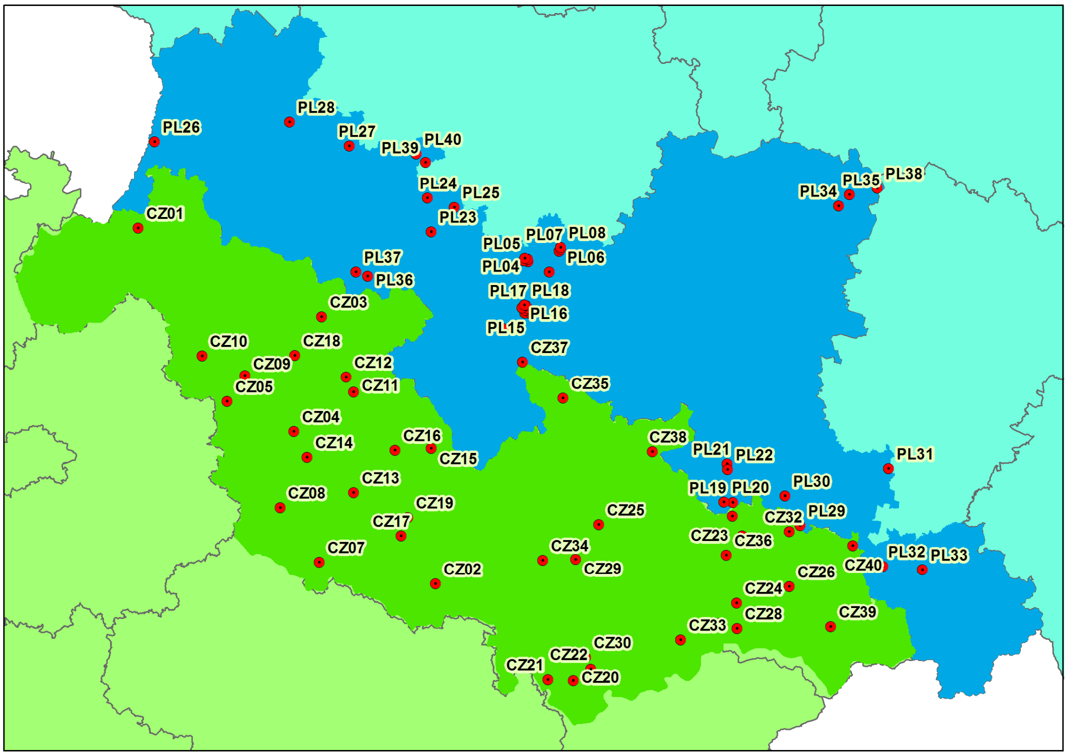

Figure 2. Location of sampling points in the borderland area

Rysunek 2. Lokalizacja punktów poboru próbek w obszarze przygranicznym
Obrázek 2. Lokalizace odběrových bodů v příhraniční oblasti

---

[5] http://www.ipcc-data.org/obs/get_30yr_means.html

Figure 3. Example locations of sampling points

Rysunek 3. Przykłady miejsc poboru próbek
Obrázek 3. Příklad umístění odběrových bodů

2.2.2. Laboratory analyses

Each bulk sample of soil has been divided into two subsamples - bigger was air dried, sieved through 2 mm mesh and subsequently grinded for the analysis of total organic matter content (modified Tiurin method for Polish samples and Walkley - Black method for Czech samples), and then transferred to standard physical and chemical analyzes in laboratory. Second part (smaller) was kept in natural state for the analyses of soil organic matter labile fraction. Before the analysis, this subsample was also sieved through 2 mm mesh to separate the skeletal parts from the soil. Organic matter content was set to be the most important soil parameter for determination. In 2013, organic matter content in soil samples was analyzed by identical methods as in the historical measurements, so that the analytical results would be comparable to make the determination of changes in SOC content realistic. The set of analysis of collected samples included:

- Soil texture was determined by the hydrometer method, modified by Casagrande and Prószyński, based on measurement of the density of soil suspension during progressive sedimentation, and the sieving method to fractionate sand. The content of particle size classes (sand, 2.0 - 0.05 mm; silt, 0.05 - 0.002 mm; clay, <0.002 mm) is determined according to the FAO/USDA classification system.[6]
- Soil pH was measured by potentiometric method - using a glass electrode in a 1:2,5 (volume ratio) suspension of soil in water (pH in H_2O) and in 1 mol/l potassium chloride solution (pH in KCl).
- Soil organic carbon was determined by different methods in each country, as mentioned above. In Polish samples SOC content was determined by the Tiurin method in which organic carbon is oxidized to CO_2 by mixture of potassium dichromate and sulphuric acid. Excess of dichromate is titrated with a solution of Mohr's salt. [7] In the Czech samples, Walkley - Black method was used. It's very similar to Tiurin's method with the same main reagent, but the reaction occurs in slightly different conditions - it is heated for 45 minutes at 125 °C. [8]
- The analysis of the soluble organic matter was performed by determination of dissolved organic carbon. This is the fraction of the total organic carbon soluble in water, which passes through a filter having a pore diameter of 0.45 microns. DOC analysis was performed by extraction with hot water (hot water extraction HWE) at temperature of 80 °C. Using this method it was assumed that, if the labile fraction can be readily degraded by enzymes of microorganisms, it is also the aqueous solution. For the analysis, a sample of

---

[6] Lityński T., Jurkowska H., Gorlach E. (1976), Chemico- Agricultural Analyzes, Soil and Fertilizers. PWN ,

[7] Ostrowska A., Gawliński S., Szczubiałka Z. (1991), Methods for analyzing and assessing the properties of soil and plants. Instytut Ochrony Środowiska,

[8] Walkley Allan., (1947), A critical examination of a rapid method for determining organic carbon in soils- effect of variations in digestion conditions and of inorganic soil constituents. *Soil Science* 63.4 pp. 251-264,

soil was weighed (9 g) to 100 ml centrifuge tube, and was treated with water (90 ml), so as to maintain the ratio of soil / solution 1:10. The tube was inserted into a water bath and was heated at 80 °C for 16h. The sample was cooled, centrifuged (20 min, 4500 rpm), the solution was decanted and filtered through a Buchner funnel equipped with a membrane filter with a pore size of 45 microns. The supernatant was analyzed for C_{org} using CN analyzer (Analytik Jena Multi N / C 2100/2100S).[9]

- Total C and total N was also determined by dry high temperature combustion in elemental analyzer – about 0,2 g of grinded soil is wrapped in tin foil and used for the analysis on VarioMacro Cube Elemental Analyzer by Elementar Analysensysteme GmbH.

3. RESULTS AND DISCUSSION

3.1. Level of SOC in borderland area

The soil organic content in the sampling area was highly diversified; however, no spatial regularity was observed (Fig. 4). The range of total SOC was 0.76 - 3.02 %. Slightly higher contents of total SOC were observed in the Czech locations – median contents in Czech and Polish samples were 1.30 and 1.11, respectively (Table 1, Fig. 5). Variability of labile SOC was much lower than that of total SOC (Tab. 2). Average contents of labile SOC were not much different in Polish and Czech samples; however, much higher maximum contents were measured in Czech locations (Tab. 2, Fig. 6).

Most of samples had total SOC contents within the range of 0.75 - 1.75 % of soil (Fig. 7). Few samples (less than 5 %) exhibited SOC contents considered as high in mineral soils, according to Polish agronomic criteria (SOC > 2 % of soil) (Fig. 7). This observation indicates that SOC content in agricultural soils of the borderland is generally medium or low; therefore there is a risk in the area for soil functioning due to depletion of SOC.

---

[9] Strosser E., (2010), Methods for determination of labile soil organic matter: an overview. Journal of Agrobiology 27(2),

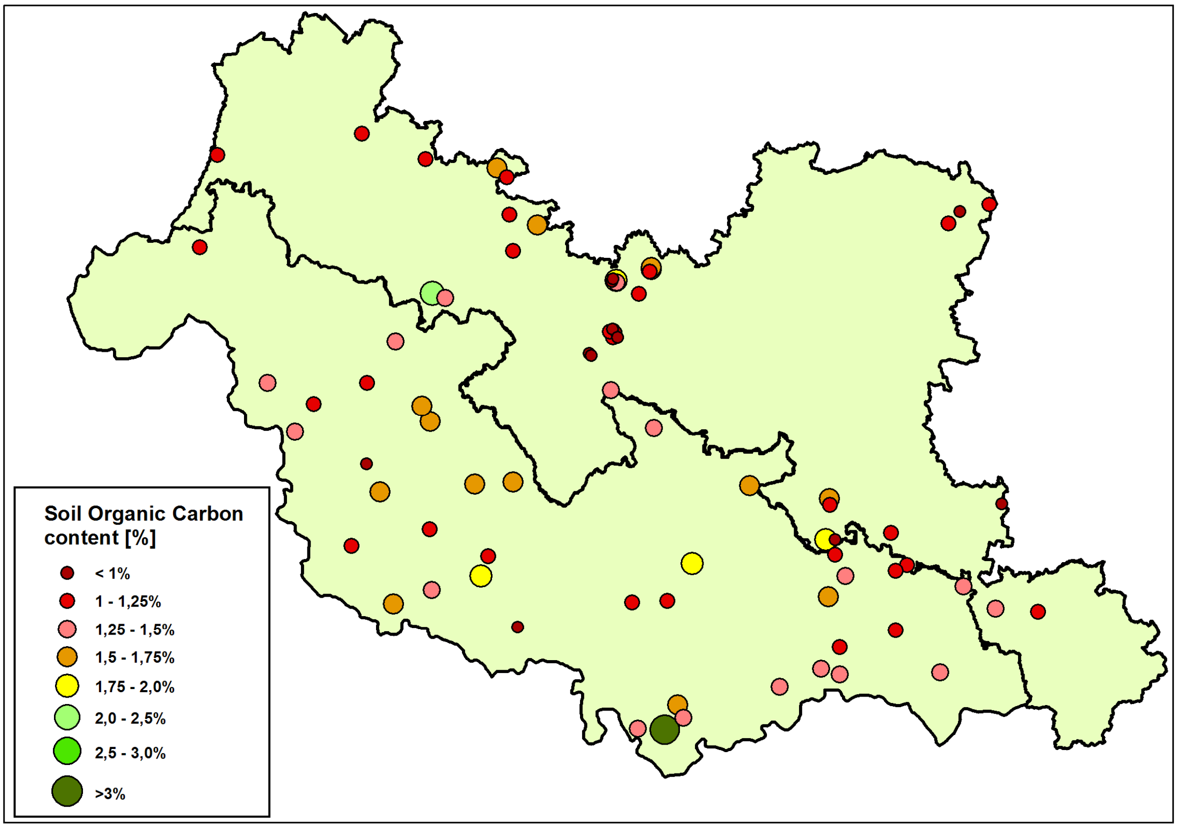

Figure 4. Current soil organic carbon content in sampling points

Rysunek 4. Aktualny stan zawartości węgla organicznego w badanych próbkach
Obrázek 4. Aktuální obsah organického uhlíku na odběrových lokalitách

Table 1. Basic statistics for total soil organic carbon content in the study area

Tabela 1. Podstawowe statystyki dla zawartości węgla organicznego na badanym obszarze
Tabulka 1. Základní statistika obsahu celkového organického uhlíku v zájmovém území

	SOIL ORGANIC CARBON CONTENT [%]					
	MIN	MAX	MEAN	MEDIAN	ST DEV	VARIANCE
ALL	0.76	3.02	1.30	1.23	0.36	0.13
PL	0.76	2.31	1.21	1.11	0.33	0.11
CZ	0.81	3.02	1.39	1.30	0.36	0.13

Table 2. Basic statistics for dissolved soil organic carbon content in the study area

Tabela 2. Podstawowe statystyki dla zawartości rozpuszczalnego węgla organicznego na badanym obszarze
Tabulka 2. Základní statistika obsahu rozpuštěného organického uhlíku (DOC) v zájmovém území

	DISSOLVED ORGANIC CARBON CONTENT [%]					
	MIN	MAX	MEAN	MEDIAN	ST DEV	VARIANCE
ALL	0.05	0.32	0.10	0.09	0.04	0.002
PL	0.05	0.13	0.08	0.08	0.02	0.0003
CZ	0.06	0.32	0.11	0.11	0.05	0.002

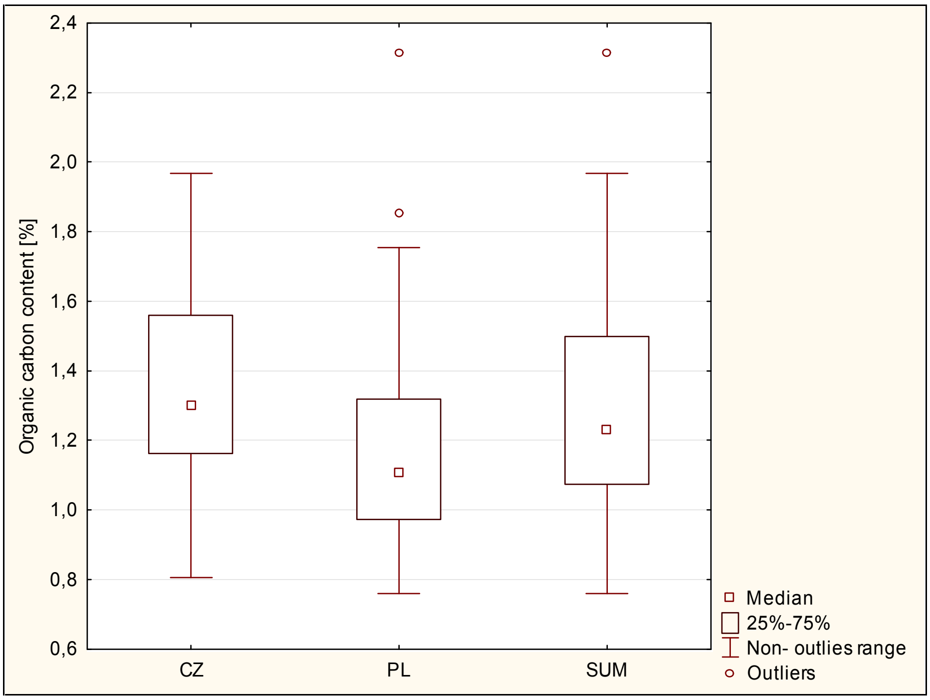

Figure 5. Ranges of total SOC content in the study area

Rysunek 5. Zakres zawartości węgla organicznego w badanych próbkach
Obrázek 5. Rozsah obsahů celkového SOC v zájmovém území

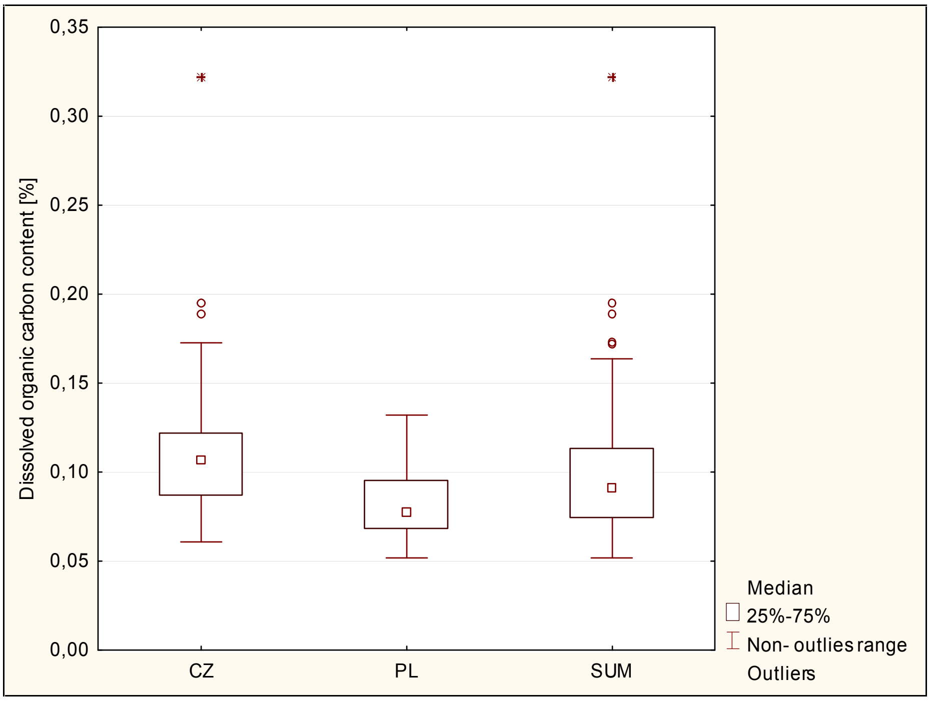

Figure 6. Ranges of dissolved SOC content in the study area

Rysunek 6. Zakres zawartości rozpuszczalnego węgla organicznego w badanych próbkach
Obrázek 6. Rozsah obsahů rozpuštěného SOC v zájmovém území

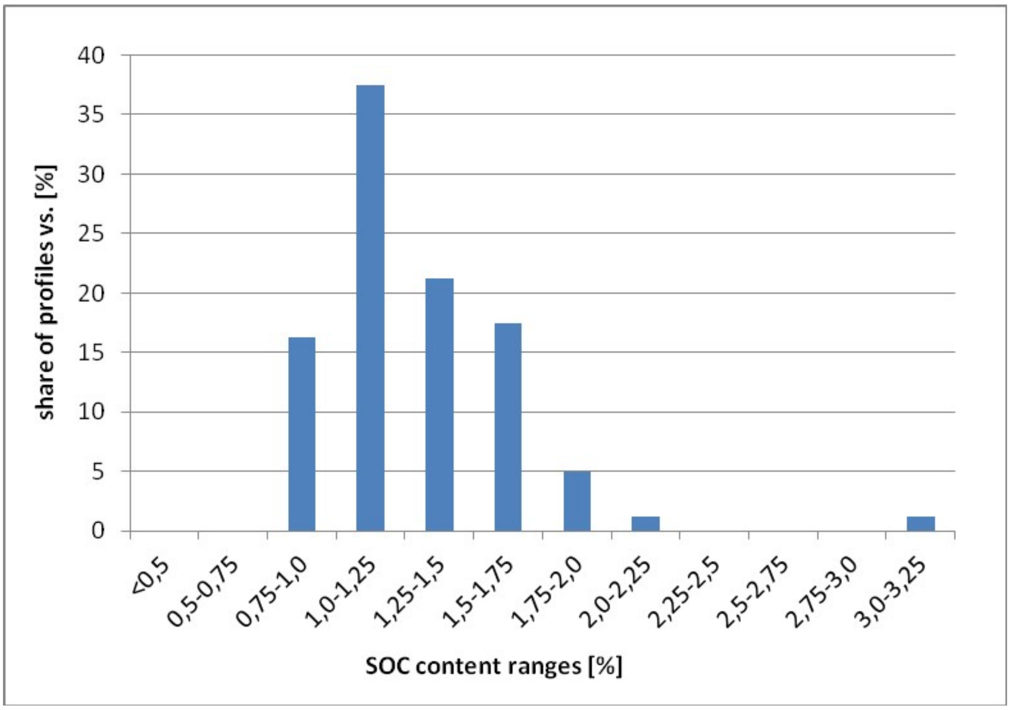

Figure 7. Share of soil profiles [%] in SOC content ranges

Rysunek 7. Udział profili w poszczególnym przedziałach zawartości węgla organicznego
Obrázek 7. Zastoupení lokalit [%] v jednotlivých intervalech obsahů SOC

3.1.1. Main factors determining organic matter content in soils

The amount of SOC present in a particular soil is determined by the balance between the rates of organic carbon input (vegetation, roots) and output (carbon dioxide release from microbial decomposition). However, soil type, climate, management, soil texture, topography and the interactions between each of these are modifying factors that will affect the total amount of SOC in a profile.

Pearson correlation was used to determine relationships between SOC content in 2013 and biophysical and agricultural factors. Factors considered as affecting SOC level were: mean annual temperature, mean annual precipitation, soil texture (sand, silt and clay content), soil pH and agricultural factors. Agricultural factors were available only for the Czech region which had a quite detailed information on crop rotation and fertilization (organic and mineral) for the monitoring plots. Information describing crop rotation and fertilizers are available for all plots for the last 20 years. Carbon input from crops and manure and the annual balance of C_{org} was calculated on the basis of the type of crop in each year and type and quantity of added organic fertilizer using VDLUFA method[10]. A significant correlation was observed only for organic carbon content and soil texture in both Polish and Czech soils (Tab. 3, 4). The clay content is known to improve bindings

---

[10] Körschens, M., Rogasik, J., Schulz, E., Böning, H., Eich, D.,Ellerbrock, R., Franko, U., Hülsbergen, K.-J., Köppen, D., Kolbe, H., Leithold, G., Merbach, I., Peschke, H., Prystav, W., Reinhold, J., Zimmer, J. (2004), Humusbilanzierung – Methode zur Beurteilung und Bemessung der Humusversorgung von Ackerland. Verband Deutscher Landwirtschaftlicher Untersuchungs- und Forschungsanstalten (VDLUFA) (ed.): 12 p.

between organic matter and soil particles through the protection of the soil aggregates (Figure 8).

No statistically significant correlations were observed between total soil carbon or SOC and carbon input to soil calculated by the VDLUFA method in the Czech dataset (Table 4). It is likely that variability of soil conditions affects the carbon accumulation more than crop rotation.

Table 3. Correlation matrix for relationships between total and organic carbon and physico-chemical factors

Tabela 3. Tabela korelacji opisująca zależność pomiędzy zawartością węgla całkowitego oraz organicznego a czynnikami środowiskowymi
Tabulka 3. Korelační matice vztahů mezi obsahy celkového a organického uhlíku a fyzikálně-chemickými faktory

	Total carbon	Organic carbon
mean annual temperature	-0.019	-0.047
mean annual precipitation	0.105	0.104
silt content	-0.123	-0.108
clay content	0.533*	0.457*
pH KCl	0.189	0.103
pH H_2O	0.222*	0.135

* significant at $p < 0,05$

Table 4. Correlation matrix for relationships between total and organic carbon and all considered factors (natural and agronomic) for Czech soils

Tabela 4. Tabela korelacji opisująca zależność pomiędzy zawartością węgla całkowitego oraz organicznego a wszystkimi badanymi czynnikami (naturalnymi oraz antropogenicznymi)
Tabulka 4. Korelační matice vztahů mezi obsahy celkového a organického uhlíku a všemi uvažovanými faktory (přírodními a agronomickými) - české půdy

	Total carbon	Organic carbon
mean annual temperature	0.037	0.018
mean annual precipitation	-0.034	-0.049
silt content	-0.391*	-0.359*
clay content	0.612*	0.504*
pH KCl	-0.057	-0.199
pH H_2O	-0.004	-0.145
C-balance VDLUFA	0.174	0.138
C_{org} from fertilizers	-0.222	-0.194

* significant at $p < 0,05$

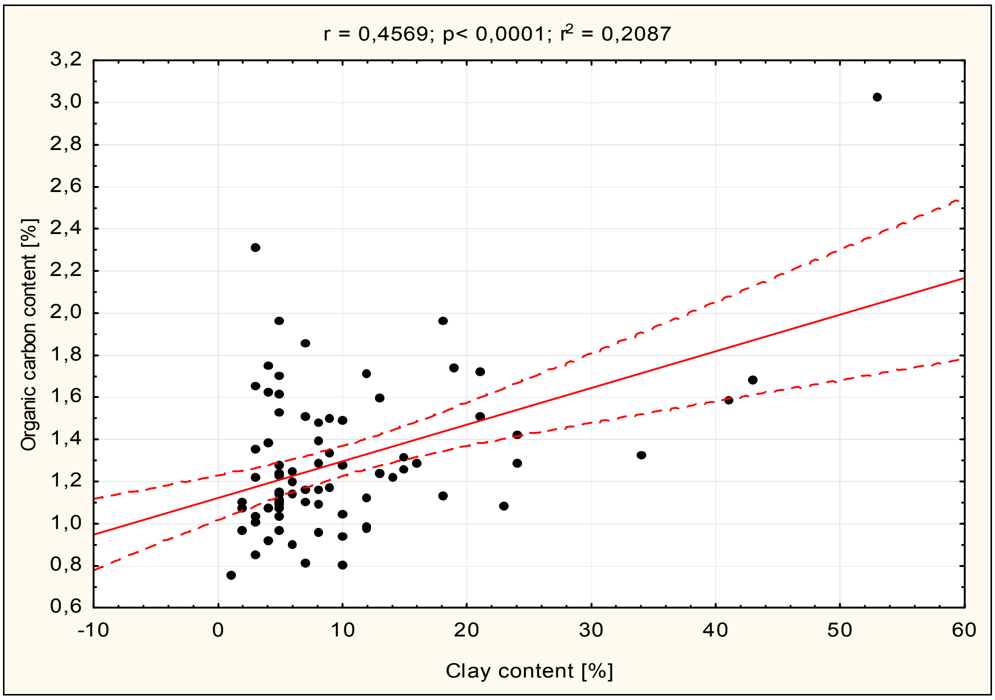

Figure 8. Relationship between SOC content and clay content for all soils

Rysunek 8. Zależność pomiędzy zawartością węgla organicznego a zawartością iłu w badanych próbkach
Obrázek 8. Vztah mezi obsahem SOC a obsahem jílu - všechny půdy

As complementary information to total carbon and organic carbon, amount of labile fraction of organic carbon (expressed as dissolved organic carbon - DOC) was measured. DOC is an important indication in studies on organic carbon in soil because the amount of dissolved organic carbon in water represents the fraction of bioavailable and chemically active carbon. The DOC content and the ratio of labile fraction to the total organic matter content are considered as parameters very sensitive to land use and agronomy changes, responding even in a relatively short period of time. As shown in figure 9 only 23 % of labile OC variability can be explained by total SOC content. It means that other soil, climatic and agronomic conditions play important roles for the DOC. Labile fractions of SOC were positively correlated with clay content (Fig. 10).

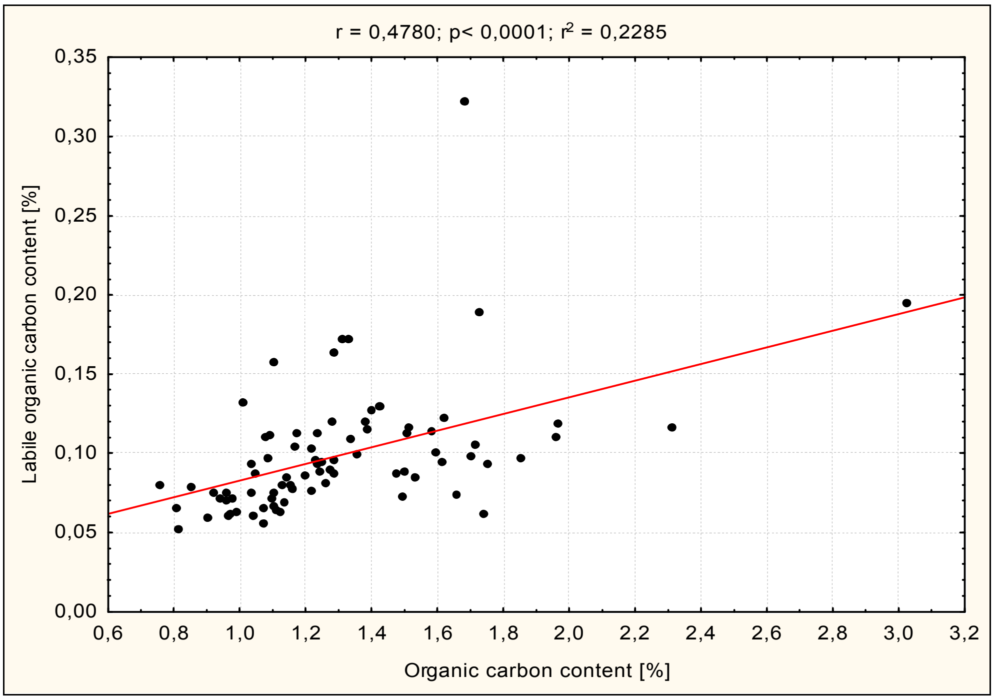

Figure 9. Relationship between labile fraction of C_{org} and total organic carbon content in soils

Rysunek 9. Zależność pomiędzy zawartością rozpuszczalnego węgla organicznego a zawartością całkowitego węgla organicznego w badanych próbkach
Obrázek 9. Vztah mezi obsahem labilní frakce organického uhlíku a obsahem celkového organického uhlíku v půdách

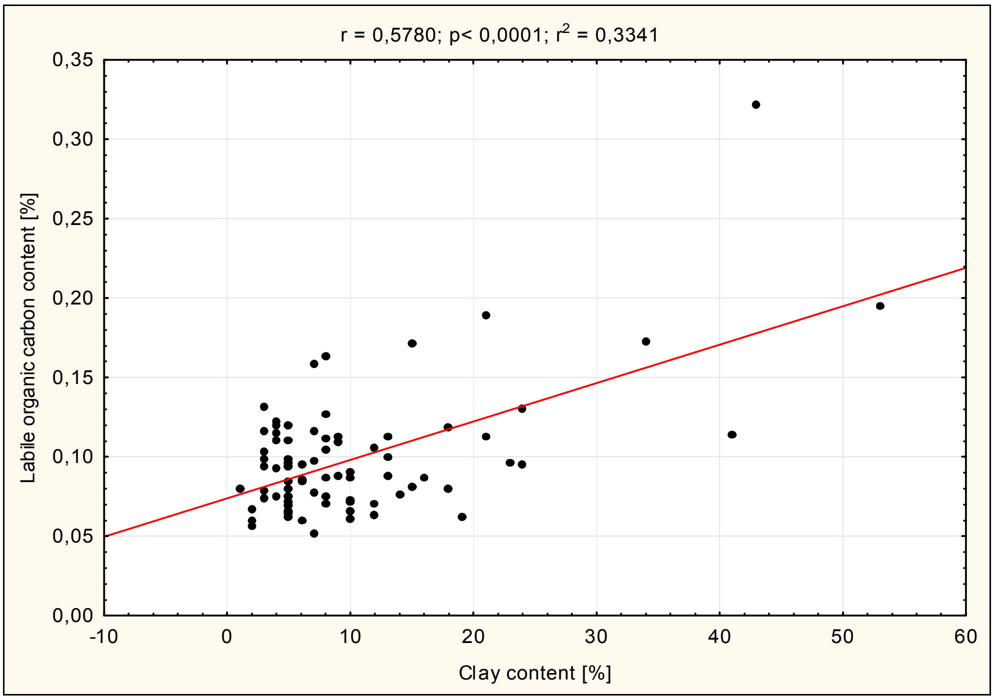

Figure 10. Relationship between clay content and labile soil organic carbon in all soils

Rysunek 10. Zależność pomiędzy zawartością rozpuszczalnego węgla organicznego a zawartością iłu
Obrázek 10. Vztah mezi obsahem jílu a labilním organickým uhlíkem - všechny půdy

3.2. SOC changes

3.2.1. Scale and direction of SOC changes

Interestingly, soils with initial low content of SOC exhibited accumulation of carbon within the assessment period. These are mostly light texture soils that were subjected to relatively intensive crop production (Fig. 11). For soils with initial SOC content ranged between 1 and 2 %, an equal number of soils showed loss and accumulation of SOC. Decline of SOC was measured in most of soils with initial high content of carbon; however, such soils represented only 7 sampling locations (Fig. 11).

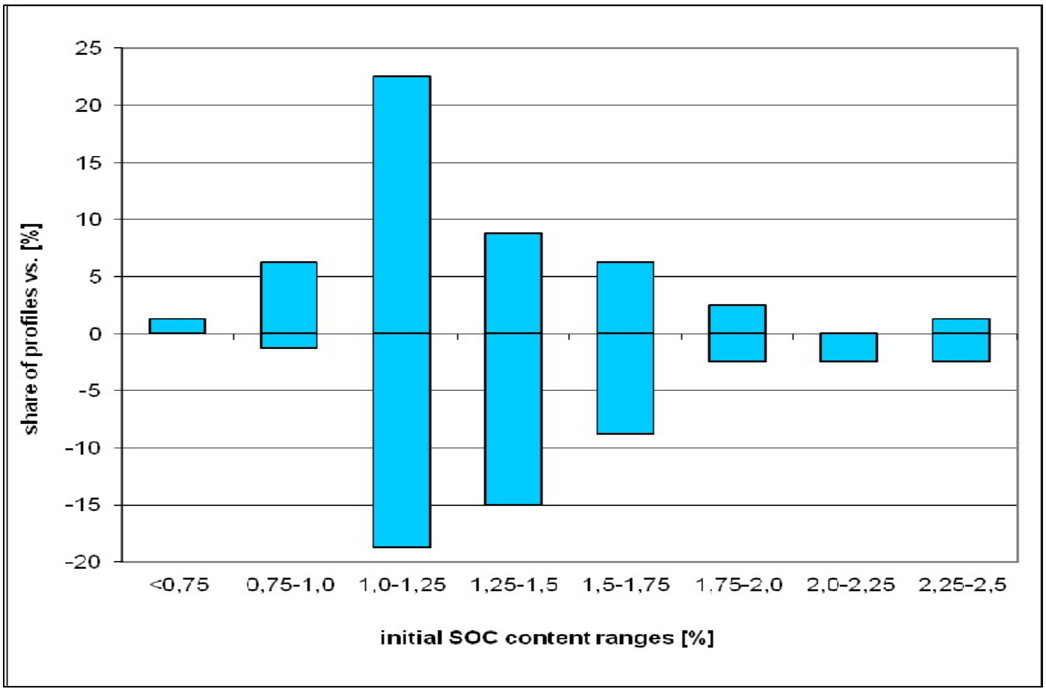

Figure 11. Share of soil profiles in which an increase or decrease in SOC content was observed (without correction for soil depth in Polish soils)

Rysunek 11. Udział profili [%] w których wystąpił wzrost lub spadek zawartości węgla organicznego w poszczególnych zakresach zawartości początkowej (bez współczynnika korekcji głębokości)
Obrázek 11. Procento lokalit [%], na kterých byl pozorován nárůst nebo pokles obsahu SOC (bez korekce hloubky odběru u polských půd)

Figure 12 contains similar information; however, the initial SOC content was corrected in Polish soils for change in plowing depth. The historical SOC data represent 60s and 70s of the last century when the depth of soil conversion was smaller than presently. Because in the 70s, an average depth of plowing has increased, which was associated with intensive mechanization of agriculture, organic matter content has been diluted as a result of mixing humus horizon of the subsoil. The change concerned plowing depth of 25-30 cm. It was assumed that, prior to commingling of 0 – 25 cm and 25 – 30 cm layers, organic matter content in the layer of 25-30 cm was half of the content in the top layer.[11]

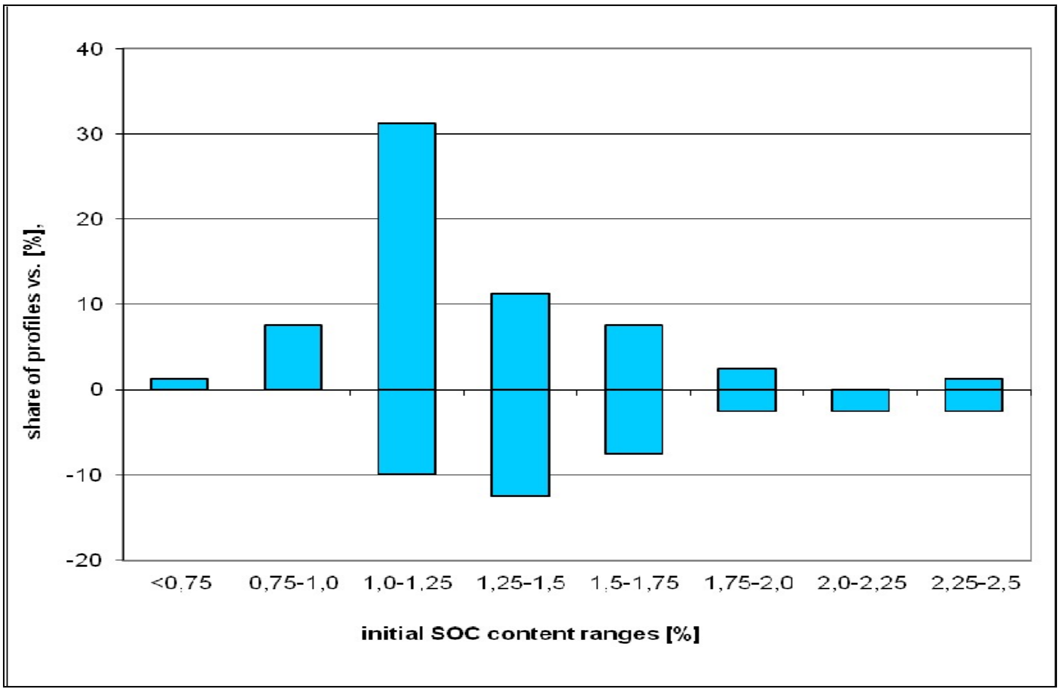

Figure 12. Share of soil profiles in which an increase or decrease in SOC content was observed

Rysunek 12. Udział profili [%] w których wystąpił wzrost lub spadek zawartości węgla organicznego w poszczególnych zakresach zawartości początkowej (po użyciu współczynnika korekcji głębokości)
Obrázek 12. Procento lokalit [%], na kterých byl pozorován nárůst nebo pokles obsahu SOC

The following equation was used for the correction:

$$OC_i = \frac{25 \cdot OC_i^m + 5 \cdot 0{,}5 \cdot OC_i^m \cdot Max\left(0; Min\left(1; \frac{1982 - sampl.year}{1982 - 1972}\right)\right)}{30},$$

Where :

OC_i - organic carbon content diluted,

OC_i^m - measured organic carbon content

25 - historical depth of plowing [cm]

5 – size of enlargement of plowing horizon [cm] between 1972 and 1982

---

[11] Stuczyński T. i in., (2007). Przyrodnicze uwarunkowania produkcji rolniczej w Polsce. W: Współczesne uwarunkowania organizacji produkcji w gospodarstwach rolniczych. Studia i Raporty IUNG-PIB, Puławy, 7,pp. 77-115

Such correction was not needed for Czech soils since, in this case, the starting date is year 1992 when the tillage is similar to nowadays soil management. After the correction more soils with initial SOC content 1 - 1.25 % exhibited carbon sequestration within the period covered by the assessment (Fig. 12).

There is a clear relationship between an initial SOC level in soil and its current content measured in 2013 in the same locations (Fig. 13). Such trends of carbon accumulation in soils with low initial content and carbon decline in soil initially rich in carbon have been previously observed by Bellamy et al. (2005)[12] and have been summarized by Kuikman[13] et al. (2008).

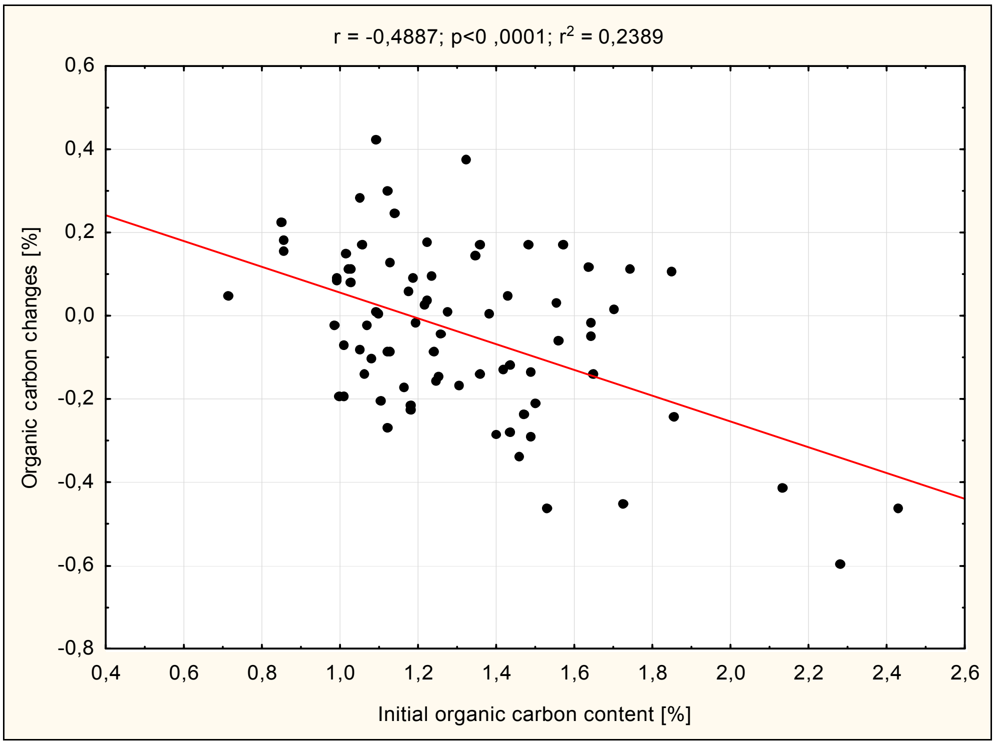

Figure 13. Relationship between initial SOC content and rate of SOC change in soils of the borderland

Rysunek 13. Zależność pomiędzy zmianami zawartości węgla organicznego a jego początkową zawartością w badanych próbkach
Obrázek 13. Vztah mezi původním obsahem SOC a změnami SOC v půdách příhraniční oblasti

The changes of SOC content in soils of the border region did not exhibit any clear spatial regularity besides that loss of SOC was recorded for soil profiles located in

---

[12] Bellamy, P.H., Loveland, P.J., (2005), Bradley, R.I., Lark, R.M. and Kirk, G.J.D. . Carbon losses from all soils across England and Wales 1978-2003. *Nature* 437 pp. 245-248,

[13] Kuikman, P.J, Ehlert, P.A.I., Chardon, W.J., van Beek, C.L., Tóth, G. & Oenema, O., (2008), *Current status of risk assessment methodologies for soil organic matter decline* RAMSOIL report 2.5.

northern-west of the borderland (Fig. 14). On the other hand accumulation of SOC was observed in most of soil profiles in the Kralovehradecky region (CZ) and in all locations in northern part of Opolskie region (PL).

Generally, magnitude and range of SOC changes in Czech soils were slightly higher than on Polish side of the region (Fig. 15).

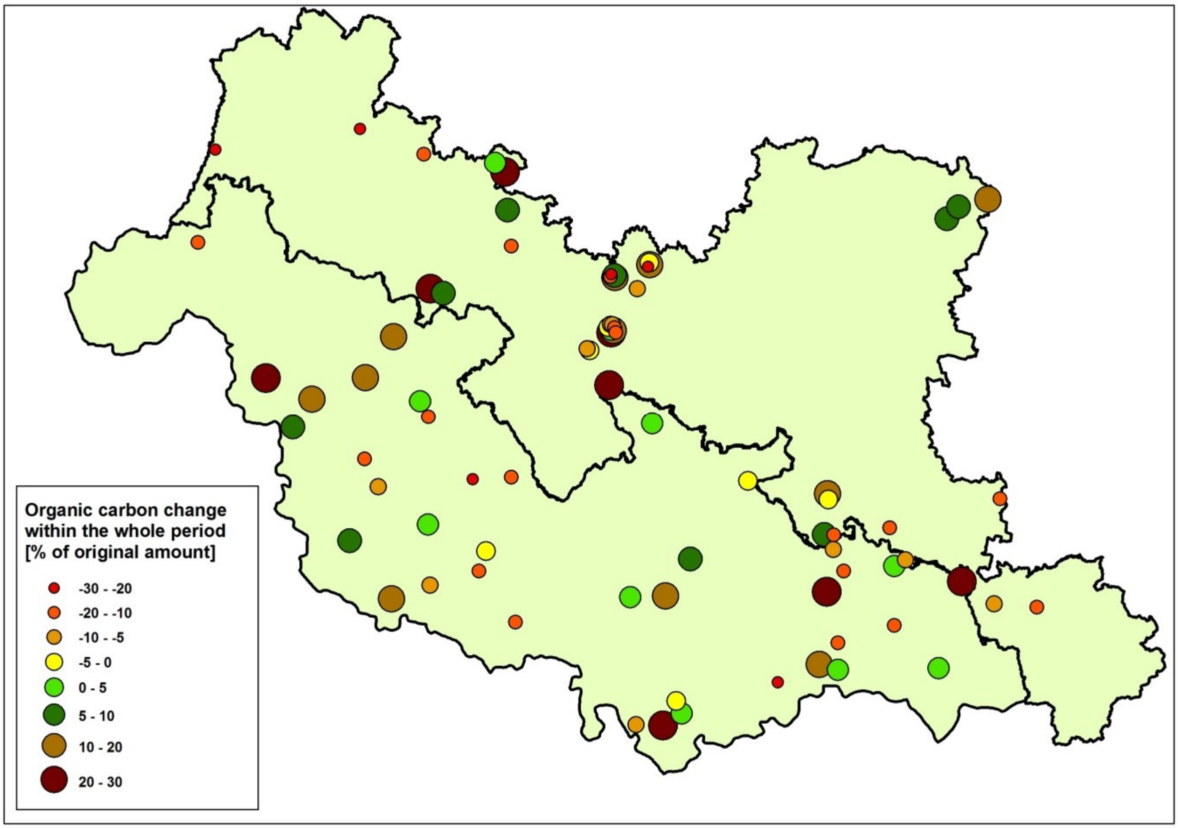

Figure 14. Spatial distribution of soil profiles with the observed increase and decrease in SOC content (negative values represent loss of SOC)

Rysunek 14. Przestrzenne rozmieszczenie profili, w których wystąpił wzrost lub spadek zawartości węgla organicznego (ujemne wartości oznaczają spadek w badanym okresie)
Obrázek 14. Prostorové rozložení lokallit s pozorovaným zvýšením či poklesem obsahu SOC (záporné hodnoty reprezentují ztrátu SOC)

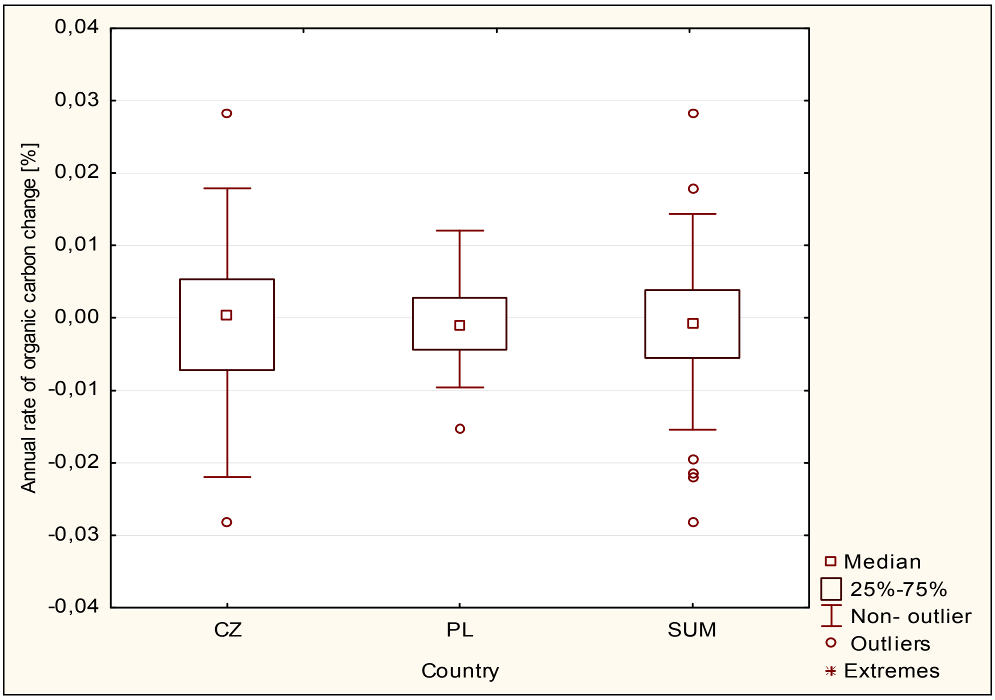

Figure 15. Annual change of SOC expressed in actual values (negative values mean loss of SOC, positive values mean accumulation of SOC)

Rysunek 15. Roczna wielkość zmiany zawartości węgla organicznego wyrażona w % zawartości (wartości ujemne oznaczają spadek, dodatnie przyrost)
Obrázek 15. Roční změny SOC vyjádřené v reálných hodnotách (záporné hodnoty představují ztrátu SOC, kladné hodnoty akumulaci SOC)

3.2.2. Impact of environmental and agricultural factors on changes in the content of SOC

Multiple regression models were developed by using a step-wise selection of variables in order to explain the observed changes in SOC content in soils of the borderland. The input variables to the models were all available soil and climatic indicators.

For the dataset without the depth correction the following variables went into the model:

initial SOC, mean temperature, clay content and carbon lability calculated as

lability of C = $\frac{C\ labile}{C\ stable}$

The regression model was:

Annual rate of C_{org} changes [% of original value]= 3,02-0,89*C_{org} initial-0,27* mean annual temperature -5,15*lability of C^{*} +0,018*clay content ; p<0,001

The model explained only 33 % of the observed variability of the SOC change in the region (Fig. 16).

The quality of regression equations that account for the SOC change was improved by using the depth corrected data – the model explained 42 % of SOC change trends (Fig. 17). In this case clay content did not enter the model. The other model variables remained in the equation:

Annual rate of C_{org} changes [% of original value]= 3,95-1,18*C_{org} initial-0,33* mean annual temperature -5,69*lability of C; P<0,001

Importance of initial SOC for the SOC trends likely accounts for interference of agriculture with natural soil conditions and processes. Intensive agriculture caused mineralization of SOC in soil types initially rich in organic substances. On the other hand converting soils with initial low SOC content and relatively low productivity to intensive crop production increased carbon input and subsequent SOC accumulation.

Higher temperature induces SOC mineralization and therefore this variable appears negative in the equation. Carbon lability also had negative coefficient in the equation which might mean that higher values of this variable can be indicative of carbon mineralization processes in soil.

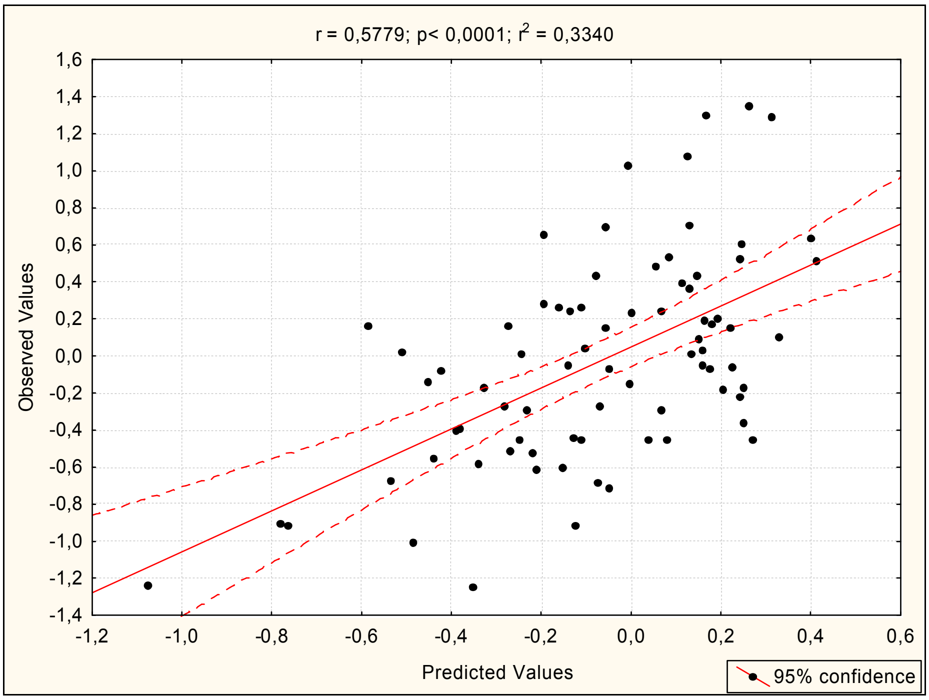

Figure 16. Relationship between SOC changes measured and estimated by the multiple regression model using the database without the depth correction

Rysunek 16. Zależność pomiędzy obserwowaną i przewidywaną za pomocą regresji wielorakiej wielkością zmian zawartości węgla organicznego. Użyto danych bez korekcji na głębokość.
Obrázek 16. Vztah mezi změnami SOC měřenými a odhadnutými pomocí vícenásobného regresního modelu s využitím dat bez korekce hloubky

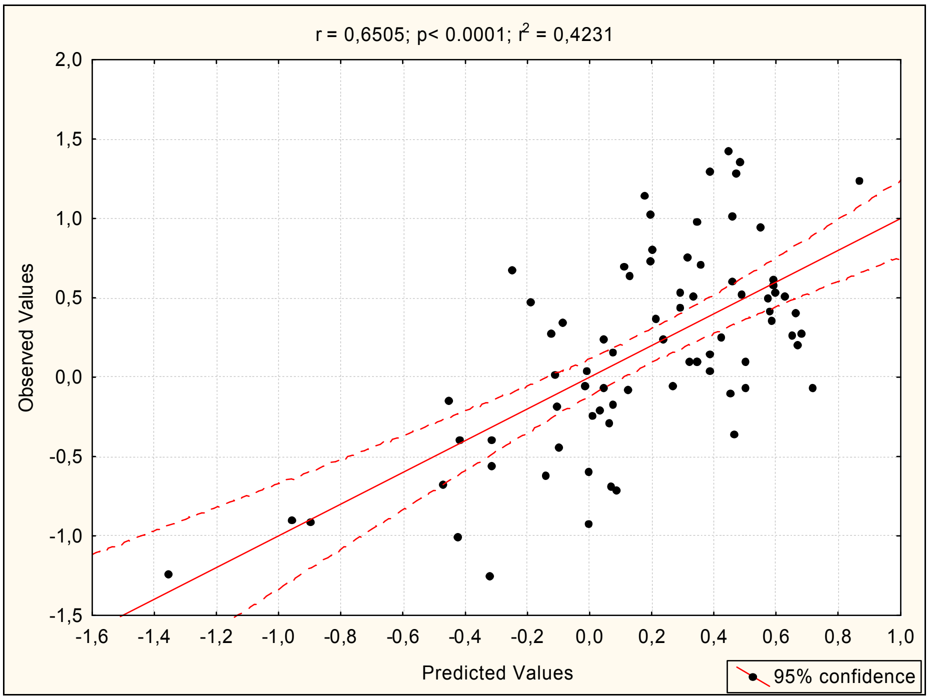

Figure 17. Relationship between SOC changes measured and estimated by the multiple regression model using the dataset with the depth correction

Rysunek 17. Zależność pomiędzy obserwowaną i modelowaną za pomocą regresji wielorakiej wielkością zmian zawartości węgla organicznego. Użyto danych po zastosowaniu współczynnika korekcji

Obrázek 17. Vztah mezi změnami SOC měřenými a odhadnutými pomocí vícenásobného regresního modelu s využitím dat po korekci hloubky

4. SUMMARY

The changes in agriculture such as specialization and simplification of crop rotation lead to reduction of organic carbon input to soil, which in consequence can result in soil organic carbon decline. The study was aimed at evaluating status and trends in soil organic carbon (SOC) in agricultural soils of Polish – Czech borderland. The work involved two sources of historical SOC data: Czech "Basal Soil Monitoring System (BSM)" containing SOC data from 1992 and Polish soil survey containing soil reference profiles sampled in 1960 - 1984. Eighty locations, 40 in each country, were resampled in 2013 and samples were analyzed for SOC with the same methods as in the past.

The analysis revealed that current SOC content in agricultural soils of the borderland is generally medium or low, therefore there is a threat to proper soil functioning due to depletion of SOC. A significant correlation was observed only for relationships between SOC content and soil texture in both Polish and Czech soils. No statistically significant relationship between modelled carbon input from agriculture and SOC content was recorded.

Soils with initial low content of SOC exhibited accumulation of carbon within the assessment period whereas in the group of soils with initial SOC content between 1 and 2 %, an equal number of soils showed loss and accumulation of SOC. Decline of SOC was measured in most of the soils with initial high content of carbon. Such phenomenon can be probably attributed to the impact of agriculture: increased mineralization in intensively used soils rich in SOC and increased input of crop residues to soils with initial low SOC level. Initial SOC content and mean annual temperature had most significant impact on the trends of SOC changes in the region.

STRESZCZENIE

Zmiany w rolnictwie polegające na zaawansowanej specjalizacji i uproszczeniach w płodozmianie prowadzą do zmniejszenie dopływu resztek pożniwnych do gleby a w konsekwencji do spadku zawartości węgla organicznego (OC) w glebie. Celem badań była ocena poziomu i zmian zawartości OC w glebach regionu nadgranicznego Polski i Republiki Czeskiej. W badaniach wykorzystano dwa źródła danych historycznych: system monitoringu gleb w Rep. Czeskiej zawierający najstarsze dane z roku 1992 oraz baza danych profili wzorcowych w Polsce posiadająca dane z lat 1960 - 1984. W roku 2013 ponownie pobrano próbki glebowe w 80 lokalizacjach (po 40 w obu krajach) i zmierzono w nich zawartość OC za pomocą metod stosowanych w przeszłości.

Badania wykazały, że zawartość OC w glebach regionu nadgranicznego jest z reguły niska lub średnia co wskazuje na potencjalne zagrożenie dla funkcjonalności gleb z powodu ubytku próchnicy. Istotną korelację stwierdzono wyłącznie dla zależności pomiędzy zawartością OC i zawartością iłu koloidalnego. Nie stwierdzono natomiast istotnej zależności pomiędzy modelowanym dopływem węgla do gleby a jego zawartością w glebie.

Gleby o niskiej początkowej zawartości węgla wykazały wzrost zawartości OC w okresie objętym ewaluacją, podczas gdy w grupie gleb o początkowej zawartości OC w zakresie 1 - 2% w zbliżonej liczbie profili odnotowano spadek i wzrost jego poziomu. Spadek zawartości OC został zaobserwowany w niemal wszystkich lokalizacjach o wysokiej zawartości początkowej. Zjawiska te mogą być powiązane z wpływem rolnictwa: zwiększona mineralizacja w intensywnie użytkowanych glebach bogatych w węgiel oraz podwyższony dopływ resztek pożniwnych do gleb z niską zawartością początkową OC. Zawartość początkowa OC oraz średnia roczna temperatura miały największy wpływ na kierunki zmian zawartości OC w glebach regionu nadgranicznego.

SHRNUTÍ

Změny v zemědělství, např. specializace a zjednodušené střídání plodin, vedou ke snížení vstupu organického uhlíku do půdy, což se v důsledku může projevit poklesem obsahu půdního organického uhlíku. Tato studie byla zaměřena na hodnocení stavu a trendů v oblasti obsahu organického uhlíku v půdě (SOC) v zemědělských půdách polsko-české příhraniční oblasti. Práce využívá dva zdroje historických dat týkajících se SOC: český "Bazální monitoring půd (BSM)" obsahující data z roku 1992 a výsledky polského průzkumu půd obsahující referenční půdní profily vzorkované v letech 1960 - 1984. V roce 2013 bylo převzorkováno osmdesát lokalit, 40 v každé zemi, a ve vzorcích byl stanoven obsah SOC stejnými metodami jako v minulosti.

Analýza ukázala, že současný obsah SOC v zemědělských půdách v příhraniční oblasti je obecně střední, nebo nízký a vyčerpání SOC je pro řádné fungování půdy hrozbou. Významná korelace byla pozorována pouze pro vztahy mezi obsahem SOC a strukturou půdy a to jak v polských, tak v českých půdách. Nebyl zaznamenán žádný statisticky významný vztah mezi modelovaným vstupem uhlíku ze zemědělství a obsahem SOC.

V rámci posuzovaného období se v půdách s nízkým počátečním obsahem SOC projevila akumulace uhlíku, zatímco ve skupině půd s počátečním obsahem SOC mezi 1 a 2 %, vykázal stejný podíl půd ztrátu a akumulace SOC. Snížení obsahu SOC bylo zjištěno u většiny půd s počátečním vysokým obsahem uhlíku. Tento jev lze pravděpodobně přičíst vlivu zemědělství: zvýšená mineralizace v intenzívně obhospodařovaných půdách bohatých na SOC a zvýšený vstup rostlinných zbytků do půd s počáteční nízkou hladinou SOC. Nejvýznamnější vliv na trendy změn obsahů SOC v regionu měly počáteční obsah SOC a průměrná roční teplota.

5. REFERENCES

Baldock, J. A., Skjemstad, J. O., (1999), Soil organic carbon/soil organic matter. In 'Soil Analysis: an Interpretation Manual. (Eds K. I. Peverill, L. A. Sparrow, and D. J. Reuter.) CSIRO Publishing, Collingwood, pp. 159-170,

King, J.A., Bradley, R.I. and Harrison, R., (2005), Current trends of soil organic carbon in English arable soils. Soil Use and Management, 21 pp. 189–195, Sanka M., Petrus J., Kalus C., et al., (1995), Basal soil monitoring scheme in the protected areas of the Czech Republic. Environ Monit. Assess., 34 pp. 167–174,

Sanka M., Petrus J., Kalus C., et al., (1995), Basal soil monitoring scheme in the protected areas of the Czech Republic. Environ Monit. Assess., 34 pp. 167–174,

Metodika monitorování zemědělských a lesních půd a půd chráněných území České republiky. (1993) Praha: MŽP ČR, odbor ochrany lesa a půdy ve spolupráci s Ústředním kontrolním a zkušebním ústavem zemědělským,. 39 p.

http://www.ipcc-data.org/obs/get_30yr_means.html

Lityński T., Jurkowska H., Gorlach E., (1976), Chemico- Agricultural Analyzes, Soil and Fertilizers. PWN,

Ostrowska A., Gawliński S., Szczubiałka Z., (1991), Methods for analyzing and assessing the properties of soil and plants. Instytut Ochrony Środowiska, Warszawa,

Walkley Allan., (1947), A critical examination of a rapid method for determining organic carbon in soils-effect of variations in digestion conditions and of inorganic soil constituents. *Soil Science* 63.4 pp. 251-264,

Strosser E., (2010), Methods for determination of labile soil organic matter: an overview. Journal of Agrobiology 27(2),

Körschens, M., Rogasik, J., Schulz, E., Böning, H., Eich, D.,Ellerbrock, R., Franko, U., Hülsbergen, K.-J., Köppen, D., Kolbe, H., Leithold, G., Merbach, I., Peschke, H., Prystav, W., Reinhold, J., Zimmer, J., (2004), Humusbilanzierung – Methode zur Beurteilung und Bemessung der Humusversorgung von Ackerland. Verband Deutscher Landwirtschaftlicher Untersuchungs- und Forschungsanstalten (VDLUFA) (ed.): 12 p.

Stuczyński T. i in., (2007), Przyrodnicze uwarunkowania produkcji rolniczej w Polsce. W: Współczesne uwarunkowania organizacji produkcji w gospodarstwach rolniczych. Studia i Raporty IUNG-PIB, Puławy, 7 pp. 77-115

Bellamy, P.H., Loveland, P.J., (2005), Bradley, R.I., Lark, R.M. and Kirk, G.J.D. . Carbon losses from all soils across England and Wales 1978-2003. *Nature* 437 pp. 245-248,

Kuikman, P.J, Ehlert, P.A.I., Chardon, W.J., van Beek, C.L., Tóth, G. & Oenema, O., (2008), *Current status of risk assessment methodologies for soil organic matter decline* RAMSOIL report 2.5.

Cíl 3 / Cel 3
2007-2013

EVROPSKÁ UNIE / UNIA EUROPEJSKA
EVROPSKÝ FOND PRO REGIONÁLNÍ ROZVOJ / EUROPEJSKI FUNDUSZ ROZWOJU REGIONALNEGO
PŘEKRAČUJEME HRANICE / PRZEKRACZAMY GRANICE

ASSESSMENT OF SOIL ORGANIC CARBON STATUS AND CHANGES IN SOILS OF POLISH-CZECH BORDERLAND

Processed by: Radoslaw Kaczynski, Grzegorz Siebielec, Rafal Galazka, Jacek Niedzwiecki, Sarka Polakova
Published by: Central Institute for Supervising and Testing in Agriculture (ÚKZÚZ), Institute for Soil Science and Plant Cultivation (IUNG)
Reprint: 140
Year: 2015
Number of pages: 28
Printed by: Central Institute for Supervising and Testing in Agriculture (ÚKZÚZ), Hroznová 2, 656 06 Brno