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ASSESSMENT OF SOIL ORGANIC MATTER MANAGEMENT IN POLISH AGRICULTURE¹

Key words: soil organic matter (SOM), reproduction, degradation, structure of sown area, animals stock

ABSTRACT. The subject of this study was the analysis of the soil organic matter (SOM) management in Polish agriculture in 2017-2019. The comparative analysis in spatial arrangement was carried out at the level of polish voivodeships. SOM balance was prepared in a simplified way, using its degradation and reproduction coefficients proposed by Eich and Kundler. During 2017-2019, the balance of SOM was at level of 0.07 t DM/ha arable land (ArL). Positive balance of SOM was found in most voivodeships of Poland, and by far the highest in two voivodeships: Podlaskie and Warmińsko-Mazurskie, where manure and slurry resources were the largest. The negative SOM balance ranged from -0.02 t DM/ha ArL in Lubuskie to -0.14 t DM/ha ArL in Dolnośląskie, and the main reason for this was low natural fertilizer supply. In those voivodships the amount of ploughed-in plant material was insufficient to cover the losses of SOM caused by plant cultivation. The analysis of SOM management confirmed high polarisation between individual voivodships, together with the processes of extensification of production organisation (specialisation), with a simultaneous increase in its intensity and scale of concentration.

INTRODUCTION

From the perspective of sustainable development and maintenance of the production potential of agriculture, it is reasonable to maintain soil fertility and to obtain satisfactory production and economic effects at an appropriate level, minimizing environmental burdens. The importance of these issues has been emphasized in the European Commission [EC 2020] set goals for European agriculture in the “farm to fork” strategy, which is the centerpiece of European Green Deal (EGD) concept [Wrzaszcz, Prandecki 2020].

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Soil fertility, commonly defined as its ability to transfer nutrients, water, air and heat to plants growing on it, is determined by a set of physical, chemical and biological soil properties [Mazur 1995].

One of the basic elements affecting the maintenance of soil fertility is proper fertilizer management, adapted to specific crop rotations, cropping systems, nutrient needs of plants and the agrochemical status of soils. Specific crop rotations, favorable sowing structure, applied natural fertilizers, as well as ploughed intercrops or by-products of main crop plants (most often straw), positively affect the balance of SOM and maintain soil fertility [Zimny et al. 2015]. It is also important to note that decreasing the content (degradation) of SOM increases greenhouse gas emissions, while increasing its amount in the soil (reproduction) is a limiting factor for the greenhouse effect (CO₂ fixation – sequestration) [Kopiński, Kuś 2011, Kuś, Kopiński 2012].

In the last several years in European and Polish agriculture there have been rapid organizational changes, generally leading to simplifications and increased directional specialisation of production. Also traditional elements of agrotechnology, such as crop rotation, balanced natural-mineral fertilization, traditional tillage or animal husbandry systems, have lost their practical meaning [Kuś 2010]. There is also a progressive regional differentiation of directions and intensity of agricultural production [Kopiński 2020, Kopiński, Wrzaszcz 2020, Matyka et al. 2020], often insufficiently adapted to natural soil and climatic conditions [Krasowicz et al. 2009].

The aim of this study was to assess SOM management in Poland, at the regional level (NUTS-2).

MATERIAL AND METHODS

The research and analysis had an intimate character. The determination of the size of the balance of SOM on the surface of 1 ha of arable land (ArL) concerned the period of 2017-2019. The comparative analysis in the spatial system was conducted at the level of voivodeships (NUTS-2), where the reference point was the average values for Poland.

The balance of SOM was prepared in a simplified way, using its degradation and reproduction coefficients proposed by Eich and Kundler [Fotyma, Mercik 1995], which are given in Table 1. These coefficients determine how much organic matter was accumulated or decomposed in the soil on the area of 1 ha under the cultivation of a given crop or how much of it accumulated as a result of applying 1 ton of natural and organic fertilizers, side crops and intercrops on the area of 1 ha of arable land (ArL). A positive result indicates proper management of SOM and, in the long term, ensures stabilisation of humus content at the optimum level for a given soil. In the case of negative balance it is necessary to undertake organizational changes in agricultural production. The average

Table 1. Coefficient of reproduction (+) and degradation (-) of soil organic matter

Specification	Coefficient [t/ha]
Cereals and oils crops	- 0.53
Maize and vegetables	- 1.15
Fodder root crops	- 1.40
Pulses	+ 0.35
Fodder legumes with grasses on ArL	+ 1.96
Other crops	0.00
Intercrops for green manure	+ 0.70
Manure fertilizers (DM)*	+ 0.35
Slurry fertilizers (DM)**	+ 0.28
Plowed straw (DM)***	+ 0.21
Plowed leaves (DM)****	+ 0.14

* – average content of dry matter in manure 25%

** – average content of dry matter in slurry above 7%

*** – average content of dry matter in straw 75%

**** – average content of dry matter in leaves 17%

Source: own study based on [Fotyła, Mercik [1995]

coefficient values for the country and individual voivodeships were calculated according to the formula [Kopiński, Kuś 2011]:

$$\text{Coefficient of reproduction and degradation} = \frac{\sum(\% \text{ cereal area} \times -0.53) + (\% \text{ root crops area} \times -1.40) + (\dots)}{\text{sown area} (\%)}$$

The analyses were based on CSO data [2018-2020 a, b, c, d] on: the area of cultivation of individual plants, the structure of sowings, crop by-product yields (straw, sugar beet and fodder beet leaves), the area of green manures and natural fertilizer consumption resources (manure, poultry manure, slurry) in individual voivodeships of Poland.

The amount of ploughed mass of beet leaves and straw were determined by own (expert) method on the basis of its distribution taking into account in relation to the harvest, the demand for litter, animal feed according to the SFOM model [Jadczyzsyn et al. 2000] and the amounts allocated for other purposes (sales, energetic, etc.).

RESEARCH RESULTS AND DISCUSSION

The calculations show that there is a considerable variation in the sowing structure in individual voivodships of Poland. As a result, the magnitude of SOM degradation index ranges from about -0.27 t DM/ha ArL in the Warmińsko-Mazurskie Voivodeship, to -0.61 t DM/ha ArL in the Opolskie Voivodeship, with the national average of -0.51 t DM/ha ArL (Table 2). According to previous studies by Jerzy Kopiński and Jan Kuś [2011, 2012], such a level of degradation was already present in Poland at the beginning of this

Table 2. Value of degradation (-) of soil organic matter for voivodships of Poland calculating for sown area; average years 2017-2019

Voivodships	Share of sown area (%) and value of degradation of soil organic matter						Value of degradation SOM [t DM/ha ArL]
	cereals. oil crops (-0.53)	fodder root crops (-1.40)	maize (-1.15)	pulses (+0.35)	fodder legumes with grasses on ArL (+1.96)	other (0)	
Dolnośląskie	78.5	5.4	10.9	1.3	1.8	2.0	-0.58
Kujawsko-Pomorskie	68.1	7.7	14.7	2.0	3.6	3.9	-0.56
Lubelskie	80.7	5.4	5.3	4.3	1.8	2.5	-0.51
Lubuskie	77.1	1.7	9.9	5.9	4.0	1.4	-0.45
Łódzkie	78.3	5.3	9.0	2.6	2.4	2.3	-0.54
Małopolskie	69.6	8.5	9.8	2.7	3.2	6.2	-0.53
Mazowieckie	72.5	4.4	14.6	2.4	3.1	3.1	-0.54
Opolskie	79.3	5.0	13.0	1.1	1.1	0.5	-0.61
Podkarpackie	73.9	9.9	9.4	2.5	3.1	1.2	-0.57
Podlaskie	64.7	1.9	19.7	1.8	11.5	0.4	-0.36
Pomorskie	79.5	5.0	4.8	5.0	4.2	1.4	-0.45
Śląskie	79.7	3.6	10.5	2.3	3.1	0.8	-0.52
Świętokrzyskie	77.0	6.0	3.9	4.9	3.6	4.6	-0.45
Warmińsko-Mazurskie	73.0	1.9	8.0	5.0	11.1	0.9	-0.27
Wielkopolskie	70.3	6.0	16.8	1.9	3.5	1.6	-0.57
Zachodniopomorskie	79.0	4.2	5.7	4.8	5.1	1.2	-0.43
Poland	74.5	5.1	11.3	2.9	4.0	2.1	-0.51

Source: own study based on SP data [GUS 2018-2020 a, c]

century, when as a result of plant cultivation, about 0.4 t DM/ha ArL were mineralized on average per year. The lowest degradation of SOM, apart from the Warmińsko-Mazurskie Voivodeship, occurred in the Podlaskie Voivodeship (-0.36 t DM/ha ArL), where over 10% of the crop structure consists of perennial legumes with grasses and grasses in field cultivation. On the other hand, in the voivodeships: Dolnośląskie, Kujawsko-Pomorskie, Podkarpackie, Opolskie and Wielkopolskie an increased degradation of SOM was observed, above the level of 0.55 t DM/ha ArL. It was influenced by a considerably larger share of crops leading to humus degradation, i.e. maize and root crops including sugar beet (about 20%) in the sowing structure, at the same time with a negligible area of perennial plants.

Changes in livestock density strongly affect the final balance of SOM. It is related to the possibility of reproduction of humus loss by natural fertilizers (farmyard manure

Table 3. Level of livestock load, use of manure and slurry, plowed straw, leaves beet and area of crops for green manure for voivodeships of Poland in 2017-2019 years

Voivodeships	Livestock load	Use of manure	Use of slurry	Plowed straw	Plowed leaves beet	Crops for green manure
	LU/ha ArL	tonnes/ha ArL				thousand ha
Dolnośląskie	17.9	1.2	0.3	1.6	1.4	2.7
Kujawsko-pomorskie	53.5	3.7	1.2	0.9	2.4	1.4
Lubelskie	30.4	4.5	0.6	1.2	1.5	0.8
Lubuskie	39.5	2.6	0.8	1.0	0.3	1.3
Łódzkie	57.6	5.4	1.5	0.8	0.4	3.6
Małopolskie	35.1	4.3	0.7	0.9	0.3	0.9
Mazowieckie	63.6	4.7	1.6	0.2	0.6	4.7
Opolskie	31.7	1.8	0.8	1.8	1.8	2.4
Podkarpackie	20.6	2.9	0.3	1.1	0.7	1.5
Podlaskie	85.6	11.5	5.0	0.0	0.0	0.2
Pomorskie	38.2	2.5	0.9	1.1	0.9	1.4
Śląskie	46.0	3.2	0.9	1.2	0.4	0.7
Świętokrzyskie	38.3	3.5	0.5	0.9	0.6	0.9
Warmińsko-mazurskie	62.5	4.6	2.0	0.4	0.2	0.8
Wielkopolskie	83.0	5.5	1.5	0.5	1.6	4.5
Zachodniopomorskie	21.2	1.0	0.4	1.4	1.0	1.9
Poland	50.9	4.3	1.3	0.8	1.0	29.9

Source: own study based on SP data [GUS 2018-2020 a, b, d]

and slurry) and the amount of ploughed-in by-products of plants and crops grown for green manure (Table 3). In voivodships with the highest animal density in the country, respectively, higher production and consumption of manure and slurry was recorded, and these were (in order) such voivodships as: Podlaskie, Wielkopolskie, Mazowieckie and Warmińsko-Mazurskie (Table 3). In those voivodships small amounts of straw are ploughed in and it is usually used for litter or fodder for livestock. Differentiation of the level of consumption of the two aforementioned types of natural fertilizers depends on the size and structure of animal stock [Kopiński, Witorożec 2021].

The low stocking rate in such voivodships as: Dolnośląskie, Podkarpackie, Zachodniopomorskie, Lubelskie, Opolskie and Małopolskie is concerning, because this limits possibilities of reproduction of SOM from natural fertilizers.

Table 4. Value of degradation and reproduction of soil organic matter (SOM) for voivodships of Poland in 2017-2019 years

Voivodships	Reproduction of SOM with			Value of reproduction SOM	Value of degradation SOM	Balance of SOM
	manure	slurry	plowed crop residues			
	tonnes DM/ha ArL					
Dolnośląskie	0.10	0.01	0.33	0.44	-0.58	-0.14
Kujawsko-Pomorskie	0.32	0.02	0.23	0.57	-0.56	0.01
Lubelskie	0.39	0.01	0.25	0.65	-0.51	0.14
Lubuskie	0.23	0.02	0.18	0.43	-0.45	-0.02
Łódzkie	0.47	0.03	0.15	0.65	-0.54	0.11
Małopolskie	0.38	0.01	0.17	0.56	-0.53	0.03
Mazowieckie	0.41	0.03	0.06	0.51	-0.54	-0.03
Opolskie	0.16	0.02	0.36	0.54	-0.61	-0.07
Podkarpackie	0.26	0.01	0.22	0.48	-0.57	-0.09
Podlaskie	1.01	0.10	0.00	1.11	-0.36	0.75
Pomorskie	0.22	0.02	0.21	0.45	-0.45	0.00
Śląskie	0.28	0.02	0.23	0.53	-0.52	0.01
Świętokrzyskie	0.31	0.01	0.18	0.50	-0.45	0.05
Warmińsko-Mazurskie	0.40	0.04	0.07	0.51	-0.27	0.24
Wielkopolskie	0.48	0.03	0.13	0.64	-0.57	0.07
Zachodniopomorskie	0.09	0.01	0.27	0.37	-0.43	-0.06
Poland	0.37	0.03	0.18	0.58	-0.51	0.07

Source: own study based on SP data [GUS 2018-2020 a, b, c, d]

The analysis of Table 4, shows that the level of degradation and reproduction and thus the balance of SOM are quite clearly regionally differentiated, they result from different crop structure and stocking rate. It should be noted that the reproduction of SOM from natural fertilizers is on average in Poland twice higher than the reproduction from ploughed straw, beet leaves and plant material as green manure. However, in the case of Podlaskie and Warmińsko-Mazurskie voivodeships, fertilisation with manure and liquid manure fully covers losses of SOM caused by plant cultivation. In those voivodeships the highest

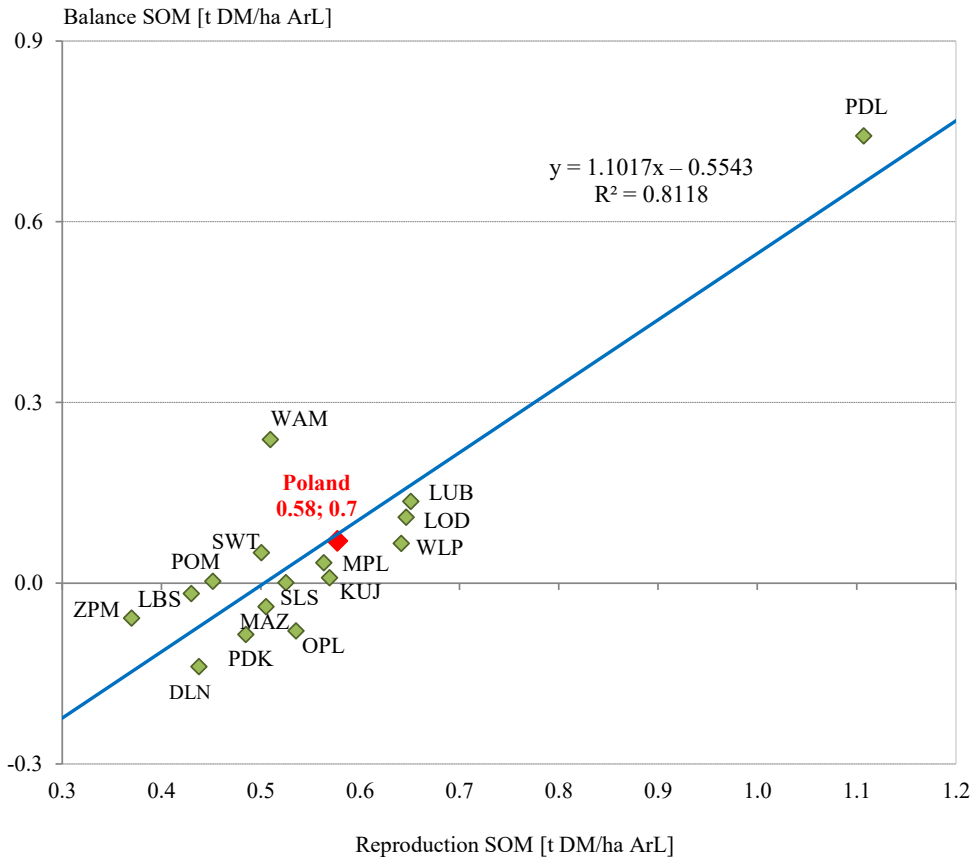


Figure 1. Correlation between reproduction index (X-axis) and balance (Y-axis) of SOM in voivodeships of Poland in 2017-2019

Shortcuts: Dolnośląskie (DLN), Kujawsko-Pomorskie (KUJ), Lubelskie (LUB), Lubuskie (LUS), Łódzkie (LOD), Małopolskie (MLP), Mazowieckie (MAZ), Opolskie (OPL), Podkarpackie (PDK), Podlaskie (PDL), Pomorskie (POM), Śląskie (SLS), Świętokrzyskie (SWT), Warmińsko-Mazurskie (WAM), Wielkopolskie (WLP), Zachodniopomorskie (ZAP)

Source: own calculation

in the country SOM balances were recorded, amounting in Podlaskie and Warmińsko-Mazurskie to 0.75 and 0.24 t DM/ha ArL, respectively.

Although the national average SOM balance in 2017-2019, was 0.07 t DM/ha ArL, the coefficient of reproduction and degradation was negative in six voivodeships indicating increased mineralization. The negative balance of SOM ranged from -0.02 t DM/ha ArL in Lubuskie to -0.14 t DM/ha ArL in Dolnośląskie. A negative balance occurred also in Mazowieckie, Opolskie, Podkarpackie and Zachodniopomorskie voivodships. While in Mazowieckie Voivodship a very low level of ploughed-in by-products and catch crops on arable land could be indicated as the reason for such a low coefficient, in the remaining voivodships the main reason was, first of all, low stocking rate of animals and small resources of natural fertilizers; moreover, the amount of ploughed-in plant material was insufficient to cover SOM losses caused by plant cultivation. This was confirmed by the results of the analyses by Jerzy Kopiński and Wioletta Wrzaszcz [2020] which showed that in those voivodeships, as well as in the Pomorskie Voivodship, only from 9 to 16% of cropland was subjected to natural fertilisation and the share of farms applying such fertilisation did not exceed 1/3 of the total.

There is a very high correlation between possibilities of reproduction of SOM compensating for it is degradation caused by mineralisation processes in the circulation of mineral components, including carbon, in agriculture and the amount of the balance (Figure 1). In this respect, in comparison with the majority of voivodships, Podlaskie Voivodship definitely stands out as it has a very high level of reproduction and balance of SOM. At the same time this voivodship was a leader in animal husbandry, especially in dairy cows [Kopiński 2020]. Unfortunately, due to logistic difficulties it is very difficult to transfer these surpluses to other regions of the country, which are dominated by inventory-free plant production [Kuś, Kopiński 2012]. The analysis of these data confirms the existence, also in this respect, of high polarization between individual voivodeships, together with processes of extensification of production organization (specialisation) with a simultaneous increase in its intensity and scale of concentration [Wrzaszcz, Kopiński 2019].

CONCLUSIONS

1. In Poland there was a slight positive balance of SOM: reached 0.07 t DM/ha ArL in 2017-2019.
2. Positive balance of SOM was found in most voivodeships of Poland, and by far the highest in two voivodeships: Podlaskie and Warmińsko-Mazurskie, amounting to 0.75 and 0.24 t DM/ha ArL, respectively, i.e. generally having high manure and slurry resources.

3. Voivodeships with the highest content of SOM were distinguished by the lowest degradation of SOM (above -0.4 t DM/ha ArL).
4. The negative SOM balance ranged from -0.02 t DM/ha ArL in the Lubuskie Voivodeship to -0.14 t DM/ha ArL in the Dolnośląskie Voivodeship, and the main reason of this were low animal stocking rate and low amount of natural fertilisers, as ploughed-in plant material is insufficient to cover SOM losses caused by plant cultivation.
5. A high correlation was observed between SOM reproduction of compensating for its degradation, caused by mineralisation processes in the mineral cycle and the amount of the balance.
6. Analysis of SOM management confirmed high polarisation between individual voivodships, together with the processes of extensification of production organisation (specialisation) in it is intensity and scale concentration.

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OCENA GOSPODARKI GLEBOWĄ MATERIAŁ ORGANICZNĄ POLSKIEGO ROLNICTWA

Słowa kluczowe: bilans glebowej materii organicznej, reprodukcja, degradacja, struktura zasiewów, obsada zwierząt

ABSTRAKT

W artykule przeanalizowano sposób gospodarowania glebową materią organiczną w polskim rolnictwie w latach 2017-2019. Analizę porównawczą w układzie przestrzennym prowadzono na poziomie województw. Bilans substancji organicznej gleby sporządzano w uproszczony sposób, wykorzystując współczynniki jej degradacji i reprodukcji zaproponowane przez Eicha i Kundlera. W latach 2017-2019 saldo bilansu glebowej substancji organicznej było na poziomie 0,07 t s.m./ha GO. Dodatkowo saldo glebowej substancji organicznej stwierdzono w większości województw Polski, a zdecydowanie najwyższe w dwóch, tj. w podlaskim i warmińsko-mazurskim, w których zasoby obornika i gnojowicy były największe. Ujemne saldo bilansu glebowej materii organicznej mieściło się w przedziale od -0,02 t s.m./ha GO w lubuskim, do -0,14 t s.m./ha GO w dolnośląskim, a głównym tego powodem były małe zasoby nawozów naturalnych. W tych województwach ilość przyorywanego materiału roślinnego była niewystarczająca do pokrycia ubytków glebowej substancji organicznej powodowanych uprawą roślin. Przeprowadzona analiza, względem oceny gospodarowania glebową substancją organiczną, potwierdziła występowanie wysokiej polaryzacji pomiędzy poszczególnymi województwami, łącznie z procesami ekstensyfikacji organizacji produkcji (specjalizacja), z jednoczesnym wzrostem jej intensywności i skali koncentracji.

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