PAN
POLSKA AKADEMIA NAUK

JOURNAL OF WATER AND LAND DEVELOPMENT

e-ISSN 2083-4535

ITP-PIB

Polish Academy of Sciences (PAN) Institute of Technology and Life Sciences – National Research Institute (ITP – PIB)

JOURNAL OF WATER AND LAND DEVELOPMENT
DOI: 10.24425/jwld.2024.150278
2024, No. 62 (VII–IX): 29–36

Cultivation systems for winter wheat (*Triticum aestivum* L.) and soil susceptibility to erosion

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RECEIVED 13.01.2024 ACCEPTED 28.05.2024 AVAILABLE ONLINE –.–.2024

Abstract: The purpose of the research was to check whether the reduced cultivation system reduces the risk of soil water erosion compared to traditional ploughing. One of the good parameters (indicators) to check is the examination of soil properties, mainly the content of readily dispersible clay (*RDC*), bulk density (*BD*), and soil water content (*SWC*). The soil organic carbon (*SOC*) content plays an important role in the soil erosion process. The field experiment on silt loamy soils was carried out for 12 years on an area of 1 ha, arranged as a random block with four repetitions, a total of eight plots per year. Two tillage systems were used: traditional (TT – inversion) and reduced (RT – without inversion). Fertiliser doses were the same for both cultivation systems. Analyses included determinations of the available forms of K, P, and Mg, as well as pH, *SOC*, *SWC*, *BD*, and *RDC*. The experimental results indicate that the soil under reduced RT cultivation was characterised by better chemical and physical properties compared to the soil under traditional TT cultivation. RT cultivation reduces the risk of soil erosion without reducing the yield of winter wheat. The 12-year study showed that, RT tillage reduces the risk of soil erosion without reducing winter wheat yields. Lower *RDC* values were determined under RT tillage, indicating a reduction in the content of easily dispersible clay, reducing the risk of soil erosion.

Keywords: bulk density, readily dispersible clay, reduced tillage, traditional tillage, water content in soil

INTRODUCTION

One of the most significant and widespread forms of land degradation is soil erosion (Panagos *et al*., 2015). Soil erosion is commonly referred to as a natural process that can be accelerated by anthropogenic activities, especially agriculture. The phenomenon of erosion has a direct impact on the agricultural environment and food production (Lal, 2001). These processes include the separation, transport and deposition of soil particles. Rainfall and surface runoff are the main factors initiating the detachment of soil particles, and the rate of erosion processes increases when the soil surface is not covered with vegetation (Lal, 2001; Pimentel, 2006; Zuazo and Pleguezuelo, 2008; Žížala, Zádorová and Kapička, 2017).

In Poland, soil erosion of various types (water, wind and arable) is considered the most serious type of soil degradation, which has a negative impact on the physical and biological functions of the soil, as well as the production of agricultural crops and the quality of water resources. In our country, about 30% of arable land is threatened by soil degradation caused by water erosion. Water erosion is also an important threat to the quality of Poland's soils (Józefaciuk and Józefaciuk, 1996). Various edaphic, mechanical and vegetative conservation practices and management systems have been developed and implemented to reduce soil erosion (Powlson *et al*., 2011; Maetens, Poesen and Vanmaercke, 2012; Ruiz-Colmenero *et al*., 2013; Lima *et al*., 2018; Menšík *et al*., 2020). Balen van *et al*. 2023 point to a major global problem of soil quality deterioration due to agricultural intensification and reports (FAO, 2015) and Eurostat regional year book (Eurostat, 2021). The problem of soil erosion becomes even more important if we consider the increase in the frequency of extreme weather conditions, such as droughts and heavy rains caused by climate change (Podmanicky *et al*., 2011).

Soil erosion is a particular threat to agricultural productivity, especially, but not exclusively, in regions where agronomic inputs are low, the soil is not compact and resilient, and where heavy rains are frequent. Soil erosion is strongly influenced by human activity: as a result of agricultural activities, the rate of soil erosion in many areas with undulating topography is one to two orders of magnitude higher than under natural conditions (Powlson *et al*., 2011). The problem of soil erosion is closely related to recent changes in agricultural production, which is highlighted in the research by Žížala, Zádorová and Kapička (2017), by using large and heavy agricultural machinery.

Conventional agricultural practices in many parts of the world have and continue to have negative consequences in terms of soil and water conservation, as well as the protection of the environment as a whole. This is due to improper use of the soil, monoculture and the use of cultivation tools, which leave the soil without vegetation and excessively loosened. In this condition, heavy rains easily remove the most valuable particles from the soil (Raczkowski *et al*., 2009; Lipiec, 2021). The use of inappropriate technologies that are not adapted to site-specific conditions (slopes, intensity of rainfall) causes runoff, soil erosion, and degradation. Therefore, the consequence of traditional farming methods, based on the mouldboard plough (to 25–30 cm depth) is a gradual loss of soil and its fertility until the land becomes unproductive (Rosa de la *et al*., 2005; Simota *et al*., 2005; Xiong, Sun and Chen, 2018; Zhao, Yang and Govers, 2019). Many soil parameters influence soil erosion, including: texture, stoniness, organic matter, carbonate content, structure, bulk density, degree of infiltration, water retention, surface crust, workability status, subgrade compaction (Rosa de la *et al*., 2004).The organic matter content also plays a significant role in soil stability with respect to erosion (Dexter and Czyż, 2007; Czyż *et al*., 2017).

Soil erosion is a gradual slow and sometimes rapid process that occurs when the impact of water or wind separates and removes soil particles, causing soil degradation. Deterioration of soil quality and low water content due to erosion and increased surface runoff have become serious problems worldwide (Lv *et al*., 2023). Often the problem becomes so severe that the land is unsuitable for farming and must be abandoned. Many agricultural civilisations have perished due to mismanagement of land and natural resources, and the history of such civilisations is a good reminder to take special care of natural resources (Lal, 2001).

Agricultural activities aim to create the most favourable conditions for plants to grow and develop. Most often, soil cultivation involves turning, crushing, or mixing the soil (Cannell *et al*., 1985; Gajri, Arora and Prihar, 2002; Gajda *et al*., 2017). There is a constant development of new cultivation techniques and agricultural machinery to meet the wide variability of soil, climate, and plant requirements.

Modern soil cultivation technologies are being introduced more and more frequently around the world. Cultivation simplifications are an alternative to traditional cultivation in terms of reducing costs and labour inputs. Replacing traditional cultivation methods with other less energy-intensive ones also brings benefits in the form of reducing the risk of soil erosion, as well as improving the physical and chemical properties of soils (Lal, 2001; Stanek-Tarkowska *et al*., 2018).

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The aim of the investigation was to check whether the reduced cultivation system reduces the risk of soil water erosion in the temperate climate, compared to traditional plough cultivation. In our opinion, one of the good parameters (indicators) to check is the examination of soil properties, mainly the content of readily dispersible clay (*RDC*), bulk density (*BD*), soil water content (*SWC*), and the soil organic carbon (*SOC*) content plays an important role in the soil erosion process.

MATERIALS AND METHODS

A field experiment with an area of 1 ha was established in 2008 at the experimental station of the University of Rzeszów in Krasne, latitude 50°03' N; longitude 22°06' E. The experiment was carried out for 12 years (2008–2020). The field was divided into two parts: 0.5 ha under traditional tillage (TT) and 0.5 ha under reduced tillage (RT). Winter wheat (cultivar 'Bogatka') was grown in both plots throughout the duration of the experiment. The winter wheat was grown in monoculture, and yield was determined each year. The granulometric composition of the soil was determined based on the following (the division of soils into the granulometric subgroups was based on the recommendations of the United States Department of Agriculture (USDA) (Ditzler, Scheffe and Monger, 2017) as a silty loam texture (sand: 2–0.05 mm, 22 $g \cdot (100\ g)^{-1}$; silt: 0.05–0.002 mm, 65 $g \cdot (100\ g)^{-1}$; clay: <0.002 mm, 13 $g \cdot (100\ g)^{-1}$). Before starting the experiment in 2008, soil samples were taken from an arable soil layer (0–35 cm) and the following were determined: pH in KCl, soil water content (*SWC*), soil bulk density (*BD*) and readily dispersible clay content (*RDC*), content of available P, K, and Mg, and soil organic carbon (*SOC*) content. The results of the soil analysis are presented in Table 1.

In 2020, after 12 years of conducting the experiment in the period just before harvesting the plants, samples were collected for chemical and physical analyses of the soil in order to check whether the use of simplified cultivation compared to traditional cultivation improves the chemical and physical properties of the soil in a winter wheat monoculture.

The experiment involved the use of two tillage systems: traditional (inversion) tillage (TT) and reduced tillage (RT – without inversion). The TT was based on a mouldboard plough (up to a depth of 25 cm). In TT, the straw was chopped and ploughed after harvest, while in RT it was based on a rigid

Table 1. Soil chemical properties at depth of 0–35 cm, before setting up the experiment in 2008

Soil layer (cm)	pH_{KCl}	P	K	Mg	*SOC* g·(100 g)$^{-1}$ of soil	*BD* g·cm^{-3}	*RDC* g·(100 g)$^{-1}$ of soil	*SWC* vol. %
		mg·kg^{-1} of soil						
0–5	5.2	98	141	54	0.78	1.27	2.75	33.5
5–10	5.2	98	141	54	0.78	1.30	2.70	32.6
10–15	5.2	98	141	53	0.77	1.34	2.68	31.7
15–20	5.1	97	140	53	0.75	1.37	2.62	29.8
20–25	5.1	97	140	52	0.62	1.41	2.65	29.1
30–35	5.1	96	140	51	0.31	1.45	2.80	28.3

Explanations: *SOC* = soil organic carbon, *BD* = bulk density, *RDC* = readily dispersible clay, *SWC* = soil water content
Source: own study.

cultivator (to a depth of 10 cm) and equipment that crushed and loosened the soil; after harvest, the straw was chopped and left on the surface. The experiment was carried out on an area of 1 ha, arranged as a random block with 4 repetitions, a total of 8 plots per year. Winter wheat was seeded between 19 and 30 September, at a density of 400 seeds per m^2 and a sowing depth of 3–4 cm. Mineral fertilisers were the same for both tillage systems and in each experimental year. Autumn fertiliser (Polifoska) was used at a dose of 18 kg N·ha^{-1}, 55 kg P·ha^{-1} and 90 kg K·ha^{-1}. Each spring, nitrogen fertiliser in the form of ammonium nitrate 120 kg N·ha^{-1} was applied in three doses: at the beginning of spring growth – 60 kg·ha^{-1} (26–27 BBCH[1]), during shoot elongation – 30 kg·ha^{-1} (32–33 BBCH), and when creating ears – 30 kg·ha^{-1} (55–56 BBCH). To control weeds in the growing and postemergence period, Chwastox Turbo 340 SL was used at a dose of 2.0 dm^3·ha^{-1}. Juwell TT 483 SE 1.2 dm^3·ha^{-1} was used to combat fungal pathogens in the phase of shoot sprouting and ear formation.

After 12 years, soil samples were collected for physico-chemical analyses, just before harvest, in four repetitions, from six depths: 0–5, 5–10, 10–15, 15–20, 20–25, and 30–35 cm deep. To measure: soil bulk density (*BD*), volumetric water content (*SWC*), samples were collected in 100 cm^3 cylinders and weighed before and after drying at a temperature of 105°C (Czyż and Dexter, 2008). *BD* was calculated as the mass of dry soil mass per unit volume of moist soil. Soil stability in water was measured in terms of readily dispersible clay content (*RDC*) (g·100 g^{-1} of soil) using a Hach 2100AN turbidimeter (Czyż and Dexter, 2009). Ten replicas were used for each year and depth in each field. The organic carbon (*SOC*) content was determined by wet oxidation using the Tiurin method (Ostrowska, Gawliński and Szczubiałka, 1991). The soil pH in KCl was measured potentiometrically in a volumetric system of 1:2.5, the suspension ratio in 1.0 mol·dm^{-3} of KCl solution (International Organization for Standardization, 2005). The content of available P and K were determined by the Egner-Rhiem and the available Mg by the Schachtschabel method (Page, Miller and Keeney, 1982). Each year in the period from 2009 to 2020, the grain yield of winter wheat yield was determined to compare whether the cultivation differentiates the yield. The grain yield per ha was calculated at 15% humidity.

[1] BBCH-scale (Ger.: BBCH – **B**iologische Bundesanstalt, **B**undessortenamt und **CH**emische Industrie).

Statistical analysis was performed using the Statistica 13.3.0 programme. To verify the normality of the distribution, the Shapiro–Wilk test was performed at $p < 0.05$. The homogeneity of the variances was also checked. Then, a one-way ANOVA test was used for each depth measurement. To determine and verify the relationship, Tukey's post hoc test was performed with a significance level of $p \leq 0.05$.

RESULTS AND DISCUSSION

Before establishing the experiment in 2008, samples were taken from the results of the experimental field, and the analysis is presented in Table 1. The soil was characterised by an acidic reaction in the profile of 5.1–5.2, the content of nutrients (P, K, Mg) was at an average level for soils used for agriculture. The organic carbon (*SOC*) content was low, ranging from 0.78 to 0.31 (g·100 g^{-1} of soil) and decreased with depth. The bulk density (*BD*) was the lowest in the upper layers of the profile, and with depth, the *BD* value increased, which is a normal phenomenon because the plough reached a depth of 20–25 cm. Analysing the initial values of readily dispersible clay content (*RDC*), it is found that they are high, indicating the instability of soils in water and their susceptibility to water erosion. It is important to note that the soil was traditionally cultivated with a plough (TT) for many years before the experiment was established. In the case analysed, the soil water content (*SWC*) decreased with depth, which is a normal phenomenon when plough cultivation is used.

Two cultivation systems were carried out for 12 years (2008–2020), but soil samples were not deliberately taken so that the soil under cultivation, and especially under reduced cultivation, could rest and stabilise its properties. After 12 years, in 2020, soil samples were taken from both treatments of TT and TR crops before the harvest of winter wheat. The results after 12 years are shown in Figure 1.

After analysing the results obtained after 12 years, there is a significant increase in soil reaction at a depth of 0–5 cm from 5.3 (TT) to 5.9 (RT) with 0.5 pH. Differences decreased with depth and at a depth of 30–35 cm the difference between RT and TT was 0.2 pH. The differences between TT and RT cultivation are also visible at other depths. Similar researches were conducted by Zuber *et al.* (2015), Li *et al.* (2019), and Malvezi *et al.* (2019), pointing to the benefits that soil receives under the influence of

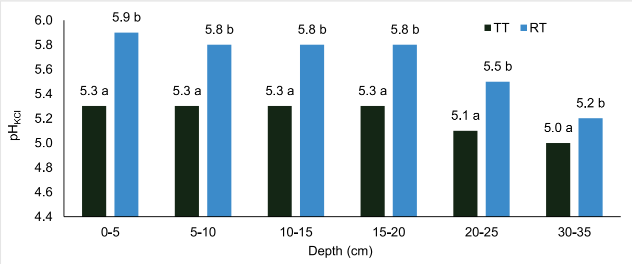

Fig. 1. The effect of traditional tillage (TT) and reduced tillage (RT) on soil pH at different depths after 12 years experiment; values marked with different letters are statistically significant at $p \leq 0.05$; source: own study

reduced tillage. Our research is consistent with the results of the cited authors. The increase in pH in the topsoil layers is caused by the decomposition of the organic matter (that was left behind) in the topsoil layer in RT. Its decomposition increased the release of hydrogen ions associated with organic anions.

The increase in the content of available forms of K, P, and Mg at all depths under RT (Fig. 2) is, according to the authors, related to the leaving of crop residues and their slow decomposition, which favoured a greater accumulation of available forms compared to TT. Yuan (2020) in his research points to a similar phenomenon that has a positive effect on soil properties and plant development in reduced tillage (RT). In addition, in the case of available forms of K, P, and Mg, it can be concluded that the increase in the content of the elements is related to the leaving of crop residues and their slow decomposition. The study by Małecka *et al.* (2015), Gajda, Czyż and Dexter (2016), Gajda *et al.*

Fig. 2. The effect of traditional tillage (TT) and reduced tillage (RT) on soil, the available forms at different depths after 12 years of the experiment: a) K, b) P, c) Mg; values marked with different letters are statistically significant at $p \leq 0.05$; source: own study

(2017), and Stanek-Tarkowska *et al.* (2018) also confirms that the use of reduced cultivation increases the content of available forms of K from 25 to 38 $mg \cdot kg^{-1}$ of soil, P – from 25 to 28 $mg \cdot kg^{-1}$ of soil, and Mg – from 28 to 29 $mg \cdot kg^{-1}$ of soil in the soil at all depths (0–35 cm) compared to traditional plough cultivation.

Franzluebbers (2002) also showed higher contents of available K, P, and Mg in reduced cultivation. He claims that the higher content of K, P and Mg on the soil surface in reduced cultivation was directly related to the area where crop residues left in the field were accumulated.

One of the most important aspects of our work was to find out whether the risk of soil erosion could be reduced after 12 years of using two different cultivation systems, TT and RT. For this purpose, we used soil parameters such as *SOC*, *SWC*, *RDC*, and *BD*, which, according to the authors, can be used as an indicator to obtain an answer to what contributes to soil water erosion. The test results with soil organic carbon are presented in Figure 3. In studies by Rawls *et al.* (2003), Dexter *et al.* (2008), and Lal (2020), the authors indicate a close relationship between an increase in organic matter content and an increase in soil water retention. Therefore, it can be assumed that as *SOC* increases, *SWC* increases. Organic carbon is hydrophilic, so higher water content is observed in soils with high *SOC*.

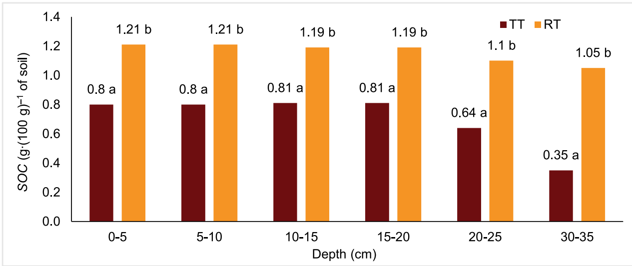

Fig. 3. The effect of traditional tillage (TT) and reduced tillage (RT) on soil organic carbon (*SOC*) at different depths after 12 years of the experiment; values marked with different letters are statistically significant at $p \leq 0.05$; source: own study

Soil data from a depth of 0–35 cm (Fig. 3), show a significant increase in organic matter (*SOC*) content at RT after 12 years. Similar results were presented by Małecka *et al.* (2015) and Stanek-Tarkowska *et al.* (2018). The top layer of soil 0–5 cm was characterised by a higher *SOC* content, which is related to the leaving of crop residues; similar observations can be found in the works of Franzluebbers (2002), Dexter *et al.* (2008), Gajda, Czyż and Dexter (2016), Lobsey and Viscarra Rossel (2016), and Gajda *et al.* (2017).

Cultivation practices influence both physical and chemical properties. The research by Stanek-Tarkowska *et al.* (2018) showed high correlations between soil parameters – *SOC* and *SWC*. In these studies, a relationship is also visible between the increase in *SOC* and the increase in *SWC* (Fig. 4), especially under reduced cultivation. The greatest differences in water content in RT compared to TT were recorded in layers from 0 to 20 cm. In the deeper layers, the differences were small. Our research indicates that the use of reduced tillage positively improved soil moisture, especially in the 0–20 cm layer, which is most exposed to water and wind erosion processes.

An important parameter of soil physical properties is bulk density (*BD*), which is widely regarded as an indicator of soil

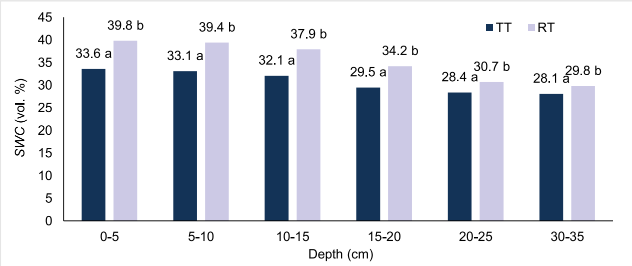

Fig. 4. The effect of traditional tillage (TT) and reduced tillage (RT) on soil water content (*SWC*) at different depths after 12 years of the experiment; values marked with different letters are statistically significant at $p \leq 0.05$; source: own study

compaction. *BD* determines the amount of infiltration and influences the rooting depth of plants, available water capacity, porosity, soil aeration, availability of plant nutrients, and soil microbial activity. All these parameters affect key soil processes. Soils with lower bulk density have good structure, greater surface area and the ability to retain water and nutrients. Bulk density impacts the transport of water and gases in the soil and their interactions with the environment.

In the world literature there are studies by Franzluebbers (2002), Podmanicky *et al.* (2011), Małecka *et al.* (2015), Gajda *et al.* (2017), Nandan *et al.* (2019) on the use of various cultivation practices and their impact on the chemical and physical properties of work; these authors state that as a result of abandoning deep ploughing, beneficial changes occur in the soil.

Also, research by Polláková *et al.* (2020) indicates the benefits that can be obtained for the soil and crops by using reduced tillage.

Bulk density (*BD*) is not an intrinsic property of the soil but is dependent on the agronomic and natural systems used (Zeng *et al.*, 2013). The *BD* is a major factor in soil compaction and changes relatively quickly after the response caused by soil tillage. The use of heavy machinery and agricultural tools on agricultural land leads to soil compaction. Bulk density is an inherent physical property of soil and depends on mineral composition, organic matter and water content (Czyż and Dexter, 2015; Gajda, Czyż and Dexter, 2016).

Our research showed a significant decrease ($p \leq 0.05$ in the value of *BD* under RT compared to TT over 12 years. Lower *BD* values under RT were recorded throughout the profile analysed from 0 to 35 cm depth. Figure 5 shows the largest significant decrease in *BD* content found in the 0–5 cm layer by 0.21 g·cm^{-3}; even at a depth of 30–35 cm after 12 years of reduced cultivation, a *BD* decrease of 0.12 g·cm^{-3} was observed. It might seem that these values are small, but in the case of *BD*, they are of great importance.

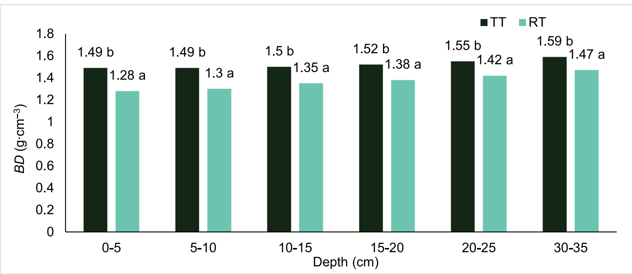

Fig. 5. The effect of traditional tillage (TT) and reduced tillage (RT) on soil bulk density (*BD*) at different depths after 12 years of the experiment; values marked with different letters are statistically significant at $p \leq 0.05$; source: own study

The main goal of human activity should be to protect soils against erosion. Water erosion is largely caused by the deterioration of the physical properties of the soil, especially a parameter that is underestimated and rarely researched, such as the content of readily dispersible clay (*RDC*). The clay content is a key component of any soil. When the soil contains a small amount of *RDC* bound to the soil, its particles are bound together and stick close together, constituting a component of other soil aggregate particles; then the soil is stable when wet or exposed to water. Stable soils are characterised by low *RDC* content. However, when the soil contains large amounts of *RDC* in contact with water, clay dispersion occurs – a phenomenon that involves the repulsion and movement of clay particles in suspension between larger soil particles. Hence, the high content of *RDC* in the soil causes two phenomena: the weakening and blurring of wet soils under the action of water, and the excessive hardness and cementation of soils under drought conditions (Dexter *et al.*, 2011; Czyż *et al.*, 2017).

Our research has shown that the use of RT compared to TT for 12 years resulted in a decrease in the content of *RDC* in the entire soil profile (Fig. 6).

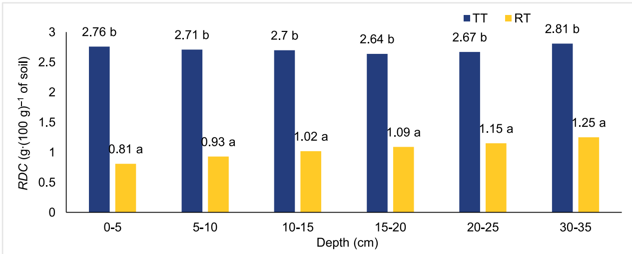

Fig. 6. The effect of traditional tillage (TT) and reduced tillage (RT) on readily dispersible clay (*RDC*) at different depths after 12 years of the experiment; values marked with different letters are statistically significant at $p \leq 0.05$; source: own study

Our research has shown that the use of reduced tillage compared to traditional tillage for 12 years resulted in a decrease in the content of *RDC* in the entire soil profile (Fig. 6). However, taking into account water erosion and heavy rains, the top layer of soil is the most important because it is exposed to raindrop impact and surface runoff. The long-term field experiment showed a beneficial reduction in the *RDC* content in RT by 1.95 g·(100 g)$^{-1}$ of soil, especially in the upper layer of soil (0–5 cm) compared to TT, and at a depth of 5–10 cm – by 1.78 g·(100 g)$^{-1}$ soil compared to TT. Reducing the *RDC* content in the soil improves its stability in water, making it more resistant to water erosion.

Of course, to prevent water erosion of soils and improve their water retention, it is necessary to carry out agrotechnical treatments that support increased *SOC* content and reduce the *BD* value (Lal, 2001).

Soil water retention is a major soil hydraulic property that regulates soil functioning in ecosystems and has a huge impact on soil management. Minasny and McBratney (2018) reported that soil water retention capacity is an important component of the water and energy balance of the terrestrial biosphere. It affects the rate of evapotranspiration and is important for crop production.

It is generally accepted that the water capacity available in the soil can be enhanced by increasing the organic matter content. Our study shows a clear trend that as the soil *SOC* content increased, the water content of RT crops increased relative to TT crops. The beneficial effect of reduced tillage compared to conventional tillage is undoubtedly undeniable if we compare the values of easily dispersible clay, which contributes to soil erosion. Dexter *et al.* (2008) state that when the content of *RDC* in water is lower, the higher the organic carbon content in the soil. When the *RDC* values are higher during the analyses, the soils are less stable in water and, therefore, more susceptible to water erosion. This relationship was presented in their research by Czyż and Dexter (2008), Czyż *et al.* (2008), Czyż and Dexter (2009), and Czyż *et al.* (2017).

From an agricultural point of view, the crop yield that can be obtained using different cultivation systems, which often differ in terms of cost, is important. But will the grain yield obtained from other than traditional cultivation systems be comparable to traditional cultivation? The results of the winter wheat grain yield included in Table 2 from 12 years of research show that in the case of RT, the yields were similar or even slightly higher than in TT, however, they were statistically not significant.

Table 2. Grain yield (Mg·ha^{-1}) of winter wheat under conventional (TT) and reduced tillage (RT) over the 12 years of the experiment

Tillage systems	Years												12-years average
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
TT	7.31^{a}	6.15^{a}	6.26^{a}	7.23^{a}	7.41^{a}	7.20^{a}	6.11^{a}	6.23^{a}	6.24^{a}	6.21^{a}	6.22^{a}	7.12^{a}	6.64
RT	6.62^{b}	6.04^{b}	6.11^{b}	7.25^{a}	7.43^{a}	7.27^{a}	6.55^{a}	6.28^{a}	6.26^{a}	6.24^{a}	6.26^{a}	7.15^{a}	6.62

Explanations: values marked with different letters are statistically significant at $p \leq 0.05$.
Source: own study.

Analysing the yield in our experiment, it is found that reduced tillage (RT) was characterised by higher yields after just three years of using reduced tillage in comparison to traditional tillage (TT). Balen van *et al.* (2023) found in their research that the yield from reduced cultivation was higher than from traditional cultivation. This was influenced by a number of parameters considered, such as reaction, an increase in the amount of available K, P, and Mg, an increase in the content of *SOC*, *SWC*, and a decrease in the content of *BD* and *RDC*, which, according to the authors, had a beneficial effect on plants and soil. Gajda *et al.* (2017) also reported similar results in the study of the 4-year field experiment mean values of grain winter wheat yield under reduced tillage which was 0.3 Mg·ha^{-1} less than under conventional tillage, but this difference was not statistically significant.

CONCLUSIONS

Erosion processes are generally considered natural, but in recent years there has been a significant acceleration, which is most often correlated with improper agricultural practices. Preference for large-scale farms that use heavy machinery to minimise production costs. Often without considering how it affects the properties of the soil and whether it can accelerate or slow down erosion processes.

Our task is to protect the soil as a part of the Earth's ecosystem, especially in the future, due to environmental changes across the globe. Soil is one of the most valuable natural resources without which the production of plants and animals, and subsequently food, is impossible. Therefore, it is an important factor in maintaining food quality and safety, human health and the sustainability of entire ecosystems.

Our years of research have shown that the use of RT significantly improves the chemical and physical properties of soil without reducing yields, which is very important.

It has been shown that RT after 12 years, decreases the values of *BD* and amounts of *RDC*, has a beneficial effect on the soil, preventing the loss of organic matter and nutrients of elements necessary for plant growth. Leaving crop residues in RT significantly improved the content of *SOC*, *SWC* and available forms of K, P and Mg in the soil.

CONFLICT OF INTERESTS

All authors declare that they have no conflict of interests.

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