SOIL EROSION DURING SECONDARY TILLAGE

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Abstract
Today's agriculture faces many challenges, the greatest is providing enough food on an ever decreasing amount of farmland for an ever-increasing population. In addition, other influences such as climate change, changes in cropping practices, and land degradation must be taken into account. Much of the research on soil degradation in the Czech Republic has focused on water and wind erosion. More than 50 % of the soil in the Czech Republic is threatened by water erosion, with wind erosion affecting almost 25 %. The research carried out in this paper focused on the shifting of soil particles due to secondary tillage during contour tillage. The experiment was based on the "tracer" method at different values of the slope of the experimental plot (2°,6°, and 11°). The results show that the shift of soil particles is significantly influenced by the slope on which the agronomic tillage is carried out. Statistical significance of the data was observed for tracers placed at the depth of tillage between 2° and 11° slope. In secondary tillage, working tools hurt soil erosion. It is necessary to observe these undesirable effects and minimize soil erodibility in the context of sustainable management.

Key words: *soil, soil translocation, soil tillage, cultivator, degradation, sustainability, monitoring.*

INTRODUCTION

Soil is one of the most precious resources on Earth. Soil resources are essential for humans and ecosystems (*Turner et al., 2007*). Currently, soil degradation is a major global environmental problem. Globally, about 30 % of the Earth's landmass is degraded. The importance of the problem is evidenced by the fact that 3.2 billion people are affected by land degradation. Soil erosion is usually referred to as the primary cause of land degradation. Soil erosion is recognized as an environmental problem in many regions (*Xin and Xiangzheng, 2020*). In the Czech Republic, much of the research has focused on water and wind erosion. These types of erosion are among the most discussed factors affecting soil degradation, both at the professional level and at the level of the general public. The current state of knowledge of this issue allows monitoring and subsequent analysis of the impacts of erosion. This subsequent evaluation provides a valuable basis for designing sustainable management practices (*Sklenička et al., 2022*). Although erosion caused by tillage is currently not as well studied as the above-mentioned erosion processes, it also contributes significantly to soil degradation (*Fiener et al., 2018*). *Novara. et al.* (*2022*) state that the effects of soil erosion resulting from tillage are more significant than soil erosion resulting from water erosion. Soil tillage on very sloping land can even involve up to six times more soil particle transport compared to water erosion (*Richter, 1999*). This fact confirms that erosion during tillage is one of the major processes of soil degradation and this issue needs to be investigated. The average rate of soil loss on soils in the Czech Republic was found to be 2.52 $t \cdot ha^{-1} \cdot year^{-1}$ (*Panagos. et al., 2015*). This soil loss can be estimated at approximately 4.3 billion CZK per year (*Podhrázská et al., 2016*). The susceptibility of a plot of land to soil erosion is influenced by, among other things, agricultural mechanization or the size of the soil block. *Žížala et al., (2021)* state that erosion phenomena most often affect land plots of 20-50 ha in size and 500-750 m slope length. Considering the history of soil block formation in the Czech Republic, when smaller plots of land were merged into larger soil blocks, the phenomenon of soil degradation has gained in intensity. Currently, the average size of soil blocks in the Czech Republic is one of the largest in Europe.

Žížala et al., (2021) point out the dangers of simultaneous water erosion and soil erosion due to tillage. It also highlights that the area at risk of erosion from tillage is almost 1.5 times larger than the area at risk from water erosion alone. The average contribution of tillage erosion to total soil erosion is between 20 % and 30 %. In the past, water erosion was considered the dominant soil degradation process in Central Europe, often with extreme impacts that are easily visible. Erosion by tillage is not so visible. The shift of soil particles only becomes apparent after the soil has been worked several times. Due to gravity and the kinetic energy generated by the movement of the working tools, the soil particles do not fall back to their original location but are transported slightly down the slope. This processing causes soil erosion leading to the gradual removal of soil particles from the soil horizon and the accumulation of soil sediments and nutrients at the bottom of the slope (*Wilken et al., 2020*). Convex and concave eroded soil sections are described, for example, by *Govers et al., (1994); Hrabalikova et al., (2016); Lobb et al., (1995); Novák and Hůla (2018)*. Tillage erosion is a relevant soil redistribution process in sloping cropland (*Gristina. et al., 2022*). According to the available literature, the effect of agricultural machinery acting in the longitudinal direction has been resolved.

However, there are very few studies dealing with longitudinal and lateral soil translocation with variable slope angle magnitude and focusing on secondary tillage. The lack of research conducted on this issue may bias the overall assessment of soil erosion on sloping farmland. This paper aims to assess the effect of slope angle on the longitudinal and lateral translocation of soil particles during secondary tillage.

MATERIALS AND METHODS

The experiment took place at Nesperská Lhota near Vlašim (GPS 49.690435 N";14.815578 E") on a plot with sandy loam, particles < 0.01 mm: 29 % by weight. The average slope of the plot is 4.2°, and the elevation is 461 meters above sea level. Parcel size of 4.74 ha was measured in LPIS using GIS as the total area. The area of moderate and severe erosion-prone land is 3.64 ha. The experimental plot is classified as standard arable land with conventional management. At the same time as the soil displacement measurements, intact soil samples were collected on the plot for laboratory determination of the soil's physical properties. The sampling was carried out using the Kopecky Physical Roller Kit method to collect 100 cm^3 physical cylinders from depths of 0.1, 0.15, and 0.2 m and calculate selected soil hydro-physical parameters such as reduced bulk density and porosity. Soil samples were collected before and after the measurements. The rolls were evaluated in the laboratories of the Czech University of Agriculture in Prague according to the ISO EN 17989-2 standard. Samples for the determination of physical properties should be taken in at least three repetitions (*Pokorný et al., 2007*). The results of the averages are recorded in Tab. 1 and 2.

Tab. 1 Soil bulk density and porosity before secondary tillage

Depth m	Bulk Density $g.cm^{-3}$	Porosity %
0.1	1.49	43.8
0.15	1.52	43.3
0.2	1.51	43.2

Tab. 2 Soil bulk density and porosity after secondary tillage

Depth m	Bulk Density $g.cm^{-3}$	Porosity %
0.1	1.37	50.2
0.15	1.39	48.2
0.2	1.39	47.2

The soil experiment was started after harvesting winter wheat with an average yield of 5.5 $t \cdot ha^{-1}$. The post-harvest residues were crushed and a subsoiling to a depth of 0.1 m was carried out for the initial incorporation of biomass. The land was plowed at the beginning of September. A Ross plow was used for plowing. The plowing depth was 0.22 m. Immediately after plowing, the land was leveled using a skid and harrow. The land was left at this stage until the end of September. Natural subsidence was therefore taking place. The three most suitable experimental plots for the measurements were then located and marked. The first measurement area was on the relative plane. The slope of the plane was 2°. The second area was selected on a higher slope with a value of 6°. The third area had the highest slope of the plot, 11°, which is the maximum allowed range of slope for a secondary tillage machine. The slope was measured using a digital inclinometer (BMI, Germany).

A Saturn combination cultivator was used for secondary tillage. The cultivator is used to cultivate the soil before sowing and to create the seedbed. The machine used for the measurements was a trailer-mounted machine with a working width of 6 m, divided into 4 sections, so each section has a working width of 1.5 m. The cultivator levels loosen, crumble, and back compact the soil. The Saturn cultivator has been reattached to a Zetor 130 HSX 16V tractor. The power of the tractor is slightly undersized which reduces the possibility of selecting the working speed. The working speed of the machine was 9 ± 0.2 $km \cdot h^{-1}$.

The,"tracer" method was used to assess soil particle displacement (*Govers et al., 1999*). These methods are based on placing tracers in the soil and noting their initial position (in this case in two axes). Once the tracers have been placed and recorded, the soil is processed by the machine and the position of the tracers is again detected. An M6 metal detector (Whites Devices) was used to determine the position. The numbered aluminum cube method was used in the experiment. The aluminum cubes were numbered from 1 to 20. The numbered "tracers" were divided into two groups. The color was used to divide the tracers. The yellow marked tracers were located on the soil surface. The tracers marked in silver were placed in the soil treatment depth, which was 0.8 m. The cube edge length was 16 mm. As reported by *Kouselou et al., (2018)*, the high recovery rate of the applied tracers is essential for accurate quantification of soil movement. The larger the more accurate and representative the approximation of soil movement. In this research, 120 indicators were applied to measure soil movement and all 120 indicators were found and recorded. The recovery rate is 100 %. Data were processed using MS Excel (Microsoft Corp., Redmond, WA, USA), Statistica 12 (Statsoft Inc., Tulsa, OK, USA), and Oriana (Kovach Computing Services, Pentraeth, UK).

RESULTS AND DISCUSSION

The data were evaluated with respect to the length of the marker offset and the directional angle of the markers. The length of the directional vector represents the length of the translocation of a particular tracer from its original location. The directional vector is the angle of the vector that indicates the difference from the direction of movement of the device. A positive value of this angle represents a translocation in the direction of the gradient line (perpendicular to the direction of device movement). Tukey's HSD test was applied to the measured data. The results of the Tukey HSD test are recorded in Table 3. Table 3 shows the statistical significance of the tracer data located at the depth of tillage. Columns 1 and 2 indicate with asterisks groups containing factor levels that are not significantly different from each other in their means.

Tab. 3 Statistical significance table for tracers located at processing depth (alfa=,0500)

Velikost svahu °	Průměr m	1	2
2	1,03707111	****	
6	1,53578592	****	****
11	2,66079882		****

The results of the measurements are further illustrated in Figure 1. The results show the effect of slope on the displacement of particles in the slope direction. The longest measured marker distance was 10.52 m and was measured in the experimental plot with a slope of 6°. The effect of slope and the magnitude of the directional angle vector were also observed. These results were recorded for both sets of tracers. It was found that the values of the angles in both sets of tracers increased as the slope increased. These results are recorded in Figure 2.

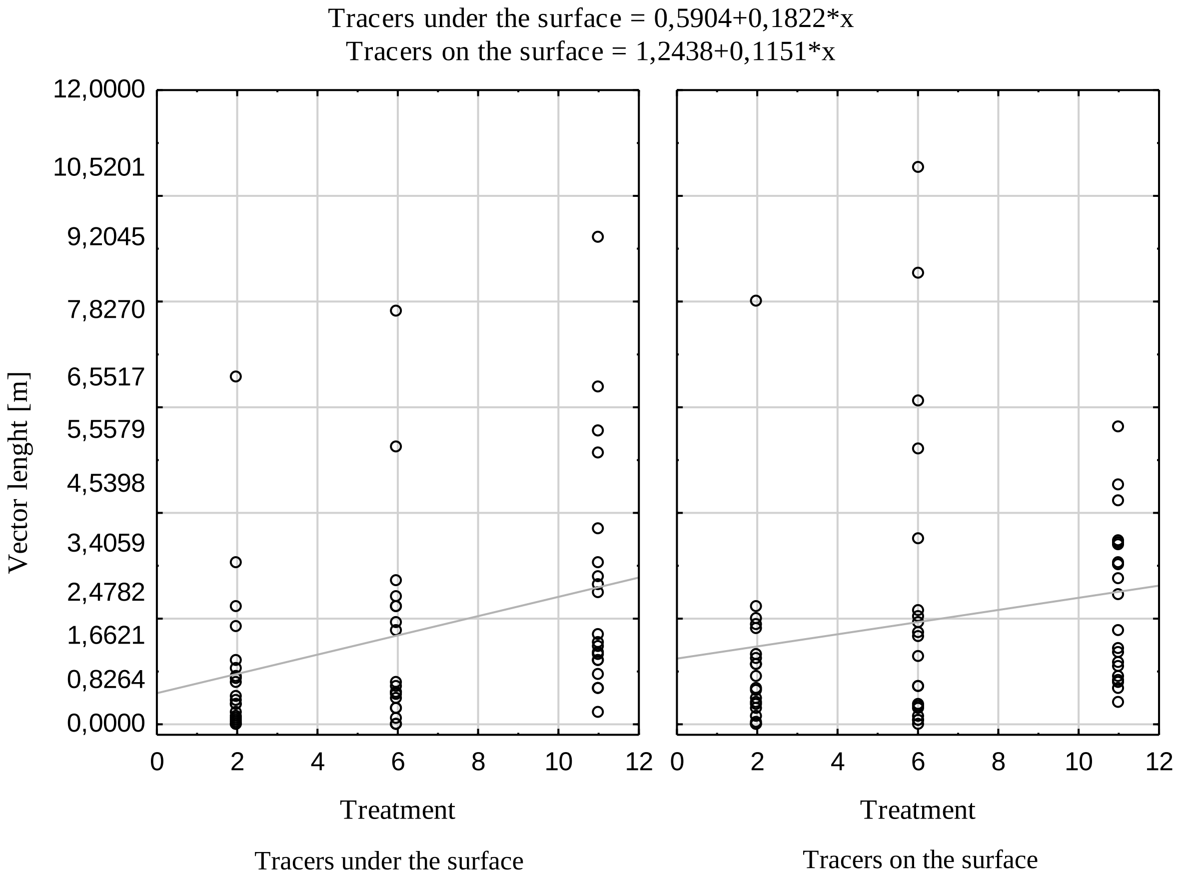

Fig. 1 Length of travel of soil markers

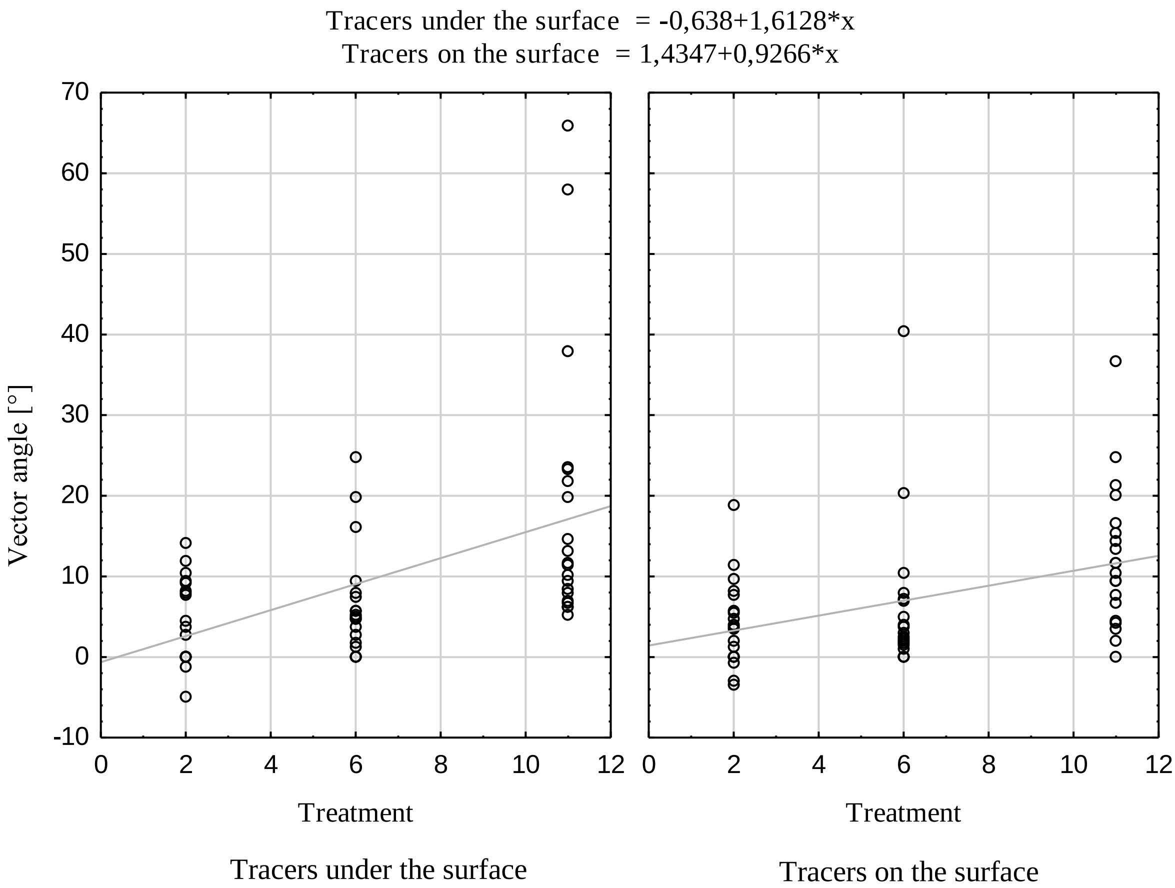

Fig. 2 Shift angle size

In the last two decades, a number of studies have been conducted that report different soil translocation rates for different soils (properties, conditions) and tillage techniques (speed, direction, depth, tool type, etc.) determined from different measurement techniques (*e.g., Loob et al., 1999; Kouselou et al., 2018; Turkelboom et al., 1999; Novara et al., 2019; Novara et al., 2022; Logsdon, 2013*). These aforementioned studies show that there are substantial differences for similar categories of tillage (e.g., secondary tillage), which have mostly been interpreted as differences resulting from differences in soil properties (bulk density) and tillage techniques (in particular, tillage depth, tillage rate, and tillage direction). *Lobb et al., (1999)* looked at soil translocation in Ontario, Canada. He used a field cultivator for secondary tillage with a processing speed of 6.48 km·h^{-1} and values with an average displacement of 0.321 m were measured. *Kouselou et al., (2018)* also used a cultivator with a working speed of 8 km·h^{-1} for measurements and measured a soil displacement of only 0.152 m. The measured values published in this study do not fully confirm these results. Much higher values of displacement occur in the study of *Turkelboom et al., (1999),* who recorded displacement in a plot with a 16 % slope of 2.88 m, and in a plot with a 22 % slope of 3.81 m. The measured values in this paper do not differ significantly from those of *Turkelboom et al., Novara et al., (2019)* observed the translocation of soil particles in the area of Santa Margherita del Belice, Sicily, using a cultivator with a working speed of 4 km·h^{-1} for soil processing. The slope on which the experiment was conducted was 15° and the particle displacement was 1.2 m. *Novara et al., (2022)* further compared the effect of a disc cultivator with a working speed of 2 to 5 km·h^{-1} and a slope of 6°. The results showed that the mean soil translocation distance was up to 1.14 m. These results agree with the measured results for a slope of 6°. The authors *Novák and Hůla (2018),* concluded that at a working speed of 7 km·h^{-1}, the maximum particle displacement occurs up to 10 m. The authors further observe the vector direction of the displacement. They conclude that on a slope of 11°, a vector displacement of up to 60° occurs. This was only partially confirmed. The vector displacement of the markers was observed up to 76° on a slope with a slope of 6°.

CONCLUSIONS

In this experiment, the impact of secondary tillage on the longitudinal and lateral transport effect was evaluated. High variability of values was found, but the expected trend was confirmed, and a direct relationship was found between the lateral displacement of particles downslope when the machine moved along the contour. The transport effect was significantly influenced by the value of the lateral tilt of the machine. Slope values from very low values of 2° to maximum values for safe machine operation of 11° were evaluated in this work. A statistically significant difference in the results of the tracer data was found between the data obtained at slope gradients of 2° and 11°. On the basis of the measured and evaluated results, we conclude that soil degradation occurs by soil processing on sloping land in the conditions of the Czech Republic. The study of soil erosion by tillage should be intensively continued, because it is a phenomenon with significance for the preservation of soil fertility during intensive soil management.

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