Acta fytotechnica et zootechnica 1
Nitra, Slovaca Universitas Agriculturae Nitriae, 2011, s. 27–28

# SOIL STRUCTURE OF HAPLIC LUVISOL AS INFLUENCED BY TILLAGE AND THE PLOUGHING OF CROP RESIDUES

# VPLYV OBRÁBANIA PÔDY A ZAPRACOVÁVANIA POZBEROVÝCH ZVYŠKOV NA PÔDNU ŠTRUKTÚRU HNEDOZEME

Vladimír ŠIMANSKÝ

Slovak University of Agriculture in Nitra, Slovakia

In this field experiment (experimental base of SUA in Nitra) the structural state of Haplic Luvisol and its susceptibility to potential erosion due to the differences in tillage practices and the ploughing of crop residues were evaluated. Two tillage systems (conventional and minimal) and two treatments of fertilization (control and with added crop residues) were appraised. In the study of Haplic Luvisol, the conventional tillage and ploughing of crop residues had a positive effect by increasing the favourable structural macroaggregates, values of structure coefficient and also water-stable macroaggregates. In contrast, in the conventional or minimal tillage study of Haplic Luvisols, it was by about 42% potentially more vulnerable to wind erosion.

**Key words:** water-stable macroaggregates, structural coefficient, Haplic Luvisol, soil tillage, crop residues

The stability of soil structure is one of the most important indicators of soil quality. Soil structure has a direct impact on the complex processes affecting plant growth and the sustainability of production. Plant growth primarily depends on soil structure and the size, distribution and stability of aggregates. The resulting state of the soil structure depends on the impact of different soil properties, farming systems and environmental factors (Six et al., 2000). In addition, the stability of aggregates determines soil resistance to erosion (Barthès and Roose, 2002). Erosion not only has serious effects on crop yields but also negatively affects the soil functions, as it reduces plant rooting depth, removes nutrients and organic matter, reduces infiltration rates and limits soil water available to plants (Pimentel et al., 1995; Lupwayi et al., 2001). In Slovakia, the most important degradation processes include water and wind erosion, which has a direct impact on soil structure. Water erosion presents a potential threat to 46% of agricultural land (1 087 839 hectares) and wind erosion processes potentially threaten 9% of agricultural land which amounts to 202 429 hectares.

The aim of this study was to assess the structural state of Haplic Luvisol and its susceptibility to potential erosion due to the differences in tillage practices and ploughing crop residues.

## Material and methods

In 1999 a field experiment was carried out by the Department of Plant Production (SAU in Nitra) in the locality of Dolná Malanta [lat. 48° 19' 00''; lon. 18° 09' 00'']. The mean temperature of this location is 9.8 °C and average rainfall is 573 mm. Soil, according to FAO classification, is silt loam Haplic Luvisol (WRB, 2006). The soil carbon content was 12.6 $g.kg^{-1}$, while the cation exchange capacity was 154.6 $mmol.kg^{-1}$ and the base saturation percentage was 90.3 %. On average, the soil active pH was 6.71. More detailed information about the experimental base of SUA in Nitra (climate, geological, pedological conditions) is published in Tobiašová and Šimanský (2009).

The field experiment included two tillage systems as well as two fertilization treatments.

The variants of tillage were:

- B1 – conventional tillage (medium tilth to a depth 0.22 – 0.25 m),
- B2 – minimal tillage (disking to a depth 0.10 – 0.12 m).

The variants of fertilization were:

- 0 – control (without fertilization),
- CR – crop residues ploughing to soil.

During 2007 – 2010, soil samples were taken from the depths 0 – 0.2 m. These soil samples were dried at laboratory temperature and hand divided by the sieve (dry and wet sieve) to 7 size fractions (Hraško et al., 1962). In fractions of aggregates, the coefficient of structure and content of water-stable macro-aggregates were calculated (Zaujec and Šimanský, 2006). The obtained results were statistically evaluated. Mean values of all variables were compared using an analysis of variance and were separated by the LSD multiple-range test at the 95% confidence level.

## Results and discussion

During the years 2007 – 2010 the climatic conditions had contributed to the major share of the structural changes found in the portion of aggregates within soil tillage systems and the ploughing of crop residues (Fig. 1). Climate is one of the most important factors that influence structural changes through the repeated cycles of drying and wetting or freezing and thawing, which produce the shrinking and swelling that leads to the formation of aggregates (Lal and Shukla, 2004; Šimanský et al., 2006). Tillage and fertilization are very important factors affecting the aggregation processes (Šimanský et al., 2008). A statistical evaluation of the results depending on soil tillage and fertilization is presented in Table 1. Conventional tillage, when compared to the minimal tillage, has a positive effect on the increase of the structural aggregates portion within the

**Table 1** Statistical evaluation of parameters of soil structure stability in Haplic Luvisol (Dolná Malanta) according to LSD multiple-range test

| Parameters (1) | Size fractions of aggregates in mm (2) | Tillage system (3) | | Fertilization (4) | | ± Limits (5) | |
|---|---|---|---|---|---|---|---|
| | | B1 | B2 | 0 | CR | $LSD_{0.05}$ | $LSD_{0.01}$ |
| Content of structural aggregates in % (6) | <0.25 | 4.56 | 3.21 | 4.28 | 3.49 | 0.93 | 1.32 |
| | 0.25 – 0.50 | 4.34 | 3.04 | 4.22 | 3.16 | 1.35 | 1.92 |
| | 0.50 – 1 | 13.16 | 9.04 | 9.54 | 12.65 | 3.63 | 5.16 |
| | 1 – 3 | 21.85 | 18.38 | 18.82 | 21.42 | 3.35 | 4.76 |
| | 3 – 5 | 15.27 | 16.38 | 16.26 | 15.39 | 1.47 | 2.10 |
| | 5 – 7 | 13.30 | 15.77 | 15.70 | 13.37 | 2.05 | 2.92 |
| | >7 | 27.53 | 34.19 | 33.04 | 28.67 | 7.93 | 11.27 |
| Water-stable macroaggregates (7) | | 75.66 | 73.6 | 70.89 | 78.37 | 13.73 | 19.52 |
| Structure coefficient (8) | | 2.66 | 1.98 | 2.01 | 2.62 | 0.82 | 1.17 |

B1 – conventional tillage, B2 – minimal tillage, 0 – control (without fertilization), CR – added crop residues
B1 – konvenčné obrábanie, B2 – minimalizačné obrábanie, 0 – nehnojená kontrola, CR – zaorané pozberové zvyšky

**Tabuľka 1** Štatistické zhodnotenie parametrov stability štruktúry hnedozeme (Dolná Malanta) – LSD testom
(1) parameter, (2) veľkostné frakcie agregátov, (3) spôsob obrábania, (4) hnojenie, (5) limita, (6) obsah štruktúrnych agregátov, (7) vodoodolné makroagregáty, (8) koeficient štruktúrnosti

**Table 2** Potential amount of soil (Haplic Luvisol in locality Dolná Malanta) vulnerable to wind erosion in $t.ha^{-1}$

| Factors (1) | Vulnerable size fractions of structural aggregates (2) | | |
|---|---|---|---|
| | <0.25 mm | 0.25 – 0.50 mm | ∑ |
| Tillage (3) | | | |
| B1 | 145 | 138 | 283 |
| B2 | 102 | 97 | 199 |
| Fertilization (4) | | | |
| 0 | 136 | 134 | 270 |
| CR | 110 | 101 | 211 |

B1 – conventional tillage, B2 – minimal tillage, 0 – control (without fertilization), CR – added crop residues
B1 – konvenčné obrábanie, B2 – minimalizačné obrábanie, 0 – nehnojená kontrola, CR – zaorané pozberové zvyšky

**Tabuľka 2** Potenciálne ohrozené množstvo pôdy veternou eróziou v $t.ha^{-1}$ (hnedozem v lokalite Dolná Malanta)
(1) faktory, (2) zraniteľné veľkostné frakcie štruktúrnych agregátov, (3) obrábanie, (4) hnojenie

0.5 – 1 mm size fraction (46%) and 1 – 3 mm fraction (19%) and also reduces the size fractions of 3 – 5 mm (7%) and 5 – 7 mm (16%) of the structural aggregates, which confirms the results of Šimanský et al. (2007). The portion of water-stable aggregates as well as the values of the structure coefficient also showed a positive effect of conventionally tilled treatments (Table 1). Under the conventional tillage system, favourable soil aggregation capacity depends on the optimum moisture content during the processing (Šimanský et al., 2007). Crop residues ploughed into the soil had a positive effect on the decrease of microaggregate content and the macroaggregate contents of size fraction 0.25 – 0.5 mm and > 3 mm. On the other hand, it was determined in treatments with added crop residues that the soil had a higher portion of structural aggregates of the size fraction 0.5 – 1 mm (about 33 %) and 1 – 3 mm (about 14%). It was therefore confirmed that the applications of crop residues have a favourable influence on soil aggregation (Lal and Shukla, 2004; Šimanský et al., 2008) (Table 1).

The size and stability of soil aggregates are primary factors that affect the soil susceptibility to wind erosion. Aggregates smaller than 0.84 mm in diameter are considered erodible by wind (Chepil, 1953). Soil samples were taken from the depth 0.2 m and the average bulk density of the investigated Haplic Luvisol (experimental site of SAU in Nitra, Dolná Malanta) is 1.59 $t.m^{-3}$ according to published results of Tobiašová and

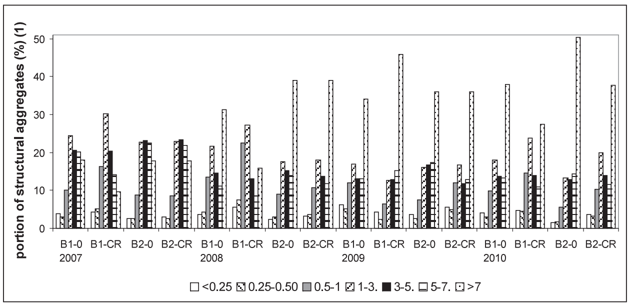


**Figure 1** Changes in portion of structural aggregates by soil tillage systems and crop residues ploughing during 2007 – 2010
B1 – conventional tillage, B2 – minimal tillage, 0 – control (without fertilization), CR – added crop residues

**Obrázok 1** Zmeny v zastúpení štruktúrnych agregátov v dôsledku obrábania a zaorávania pozberových zvyškov v priebehu rokov 2007 – 2010
B1 – konvenčné obrábanie, B2 – minimalizačné obrábanie, 0 – nehnojená kontrola, CR – zaorané pozberové zvyšky
(1) zastúpenie štruktúrnych agregátov

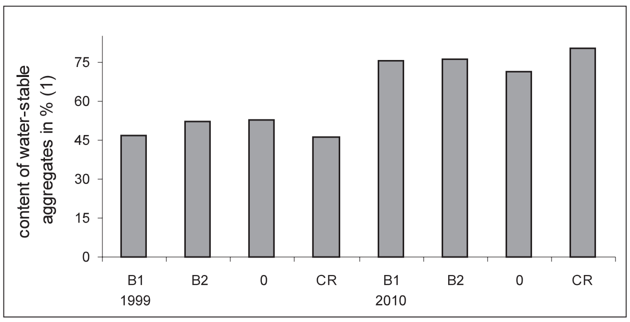


**Figure 2** Water-stable content of macro-aggregates at the begining (1999) and end of the experiment
B1 – conventional tillage, B2 – minimal tillage, 0 – control (without fertilization), CR – added crop residues

**Obrázok 2** Obsah vodoodolných makroagregátov na začiatku a na konci experimentu
B1 – konvenčné obrábanie, B2 – minimalizačné obrábanie, 0 – nehnojená kontrola, CR – zaorané pozberové zvyšky
(1) obsah vodoodolných makroagregátov

Šimanský (2009). Thus, the potential amount of soil which is vulnerable to wind erosion was calculated (Table 2). More than a third (42%) of the soil studied at Haplic Luvisol showed the vulnerable impacts of the conventional tillage system as compared to the minimal tillage. The ploughing of crop residues into soil has an anti-erosion effect as confirmed by the results (Table 2). Conservation tillage and the use of crop residue mulch is an important strategy to maintain a favourable structure of some soil (Lal and Shukla, 2004) and a method of decreasing soil loss (Barthès and Roose, 2002).

The most important indicator of the soil structure stability is the water-stable macroaggregates content. In order to assess the longer-term impact of different tillage systems and the ploughing of crop residues on water-stable content in the studied Haplic Luvisol, there was a comparison made between the content at the beginning and the end of the experiment (Fig. 2). At the end of the field experiment, treatments that were conventionally tilled marked approximately 62% more water-stable macroaggregates than before its establishment and in treatments where there had been minimal tillage the results were 45%.

### Conclusion

During the period 2007 – 2010 the conventional tillage and ploughing of crop residues in the studied Haplic Luvisol had a positive effect on the increase of favourable structural macroaggregates and the values of structure coefficient compared with the minimal tillage and treatments without fertilization. Also after the long period (11 years), positive effects of conventional tillage and added crop residues on the content of water-stable aggregates were found. On the other hand in the Haplic Luvisol study, conventional tillage in comparison to minimal tillage was about 42% more potentially vulnerable to wind erosion.

The obtained results of the structural state of the studied Haplic Luvisol showed the validity of using conventional tillage systems and the addition of crop residues to soil. At the present time, we must not forget that the correct tillage systems or fertilization should always be specific for concrete soil and climatic conditions.

## Súhrn

V rámci poľného experimentu založeného Katedrou rastlinnej výroby SPU v Nitre v roku 1999 bol zhodnotený štruktúrny stav pôdy a jej náchylnosť na veternú eróziu (hnedozem kultizemná). Vyhodnotili sa varianty, ktoré boli obrábané konvenčným a minimalizačným spôsobom, rovnako vyhodnotené boli aj varianty bez hnojenia a so zaoranými pozberovými zvyškami. Za sledované obdobie (2007 – 2010) malo konvenčné obrábanie a zapracovávanie pozberových zvyškov v skúmanej hnedozemi pozitívny vplyv na zvýšenie priaznivých frakcií štruktúrnych makroagregátov, hodnoty koeficientu štruktúrnosti v porovnaní s minimalizačným spracovaním pôdy a variantov bez hnojenia. Rovnako aj z dlhodobého hľadiska (11 rokov) bol zaznamenaný pozitívny efekt konvenčného obrábania pôdy a zapracovávania pozberových zvyškov na obsah vodoodolných makroagregátov. Na druhej strane bola skúmaná hnedozem o 42% potenciálne ohrozenejšia veternou eróziou práve vo variantoch, ktoré boli konvenčne obrábané v porovnaní s minimalizačne obrábanými. Získané výsledky poukázali na opodstatnenosť používania konvenčného obrábania a zaorávania pozberových zvyškov do pôdy. V súčasnej dobe preto nesmieme zabúdať, že správne zvolený systém obrábania a hnojenia musí vždy zohľadňovať konkrétne pôdno-klimatické podmienky stanovišťa.

**Kľúčové slová**: vodoodolné makroagregáty, koeficient štruktúrnosti, hnedozem, obrábanie pôdy, pozberové zvyšky

**Acknowledgement**

Project supported by the Scientific Grant Agency of the Ministry of Education, Science Research and Sport of the Slovak Republic and Slovak Academy of Sciences (No. 1/0597/10 and No. 1/0300/11).

## References

BARTHÈS, B. – ROOSE, E. 2002. Aggregate stability as an indicator of soil susceptibility to runoff and erosion; validation at several levels. In: Catena, 2002, no. 47, p. 133 – 149.

FAO. 2006. World Reference Base for Soil Resources. Rome : FAO, 2006, 128 p. ISBN 92-5-105511-4.

HRAŠKO, J. – ČERVENKA, L. – FACEK, Z. – KOMÁR, J. – NĚMĚČEK, J. – POSPÍŠIL, J. – SIROVÝ, V. 1962. Rozbory pôd. Bratislava : Slovenské vydavateľstvo pôdohospodárskej literatúry, 1962, 334 s.

CHEPIL, W. S. 1953. Field structure of cultivated soils with special reference to erodibility by wind. In: Soil Sci. Soc. Am. Proc., 1953, no. 17, p. 185 – 190.

LAL, R.– SHUKLA, M. K. 2004. Principles of soil physics. New York : Marcel Dekker, 2004. 716 p. ISBN 0-8247-5324-0.

LUPWAYI, N. Z. – ARSHAD, M. A. – RICE, W. A. – CLAYTON, G. W. 2001. Bacterial diversity in water-stable aggregates of soils under conventional and zero tillage management. In: Appl. Soil Ecol., 2001, no. 16, p. 251 – 261.

PIMENTEL, D. – HARVEY, C. – RESOSUDARMO, P. – SINCLAIR, K. – KURZ, D. – MCNAIR, M. – CRIST, S. – SHPRITZ, L. – FITTON, L. – SAFFOURI, R. – BLAIR, R. 1995. Environmental and economic cost of soil erosion and conservation benefits. In: Science, 1995, no. 267, p. 1117 – 1123.

SIX, J. – ELLIOTT, E.T. – PAUSTIAN, K. 2000. Soil structure and soil organic matter: II. A normalized stability index and the efect of mineralogy. In: Soil Sci. Soc. Amer. J., 2000, no. 64, p. 1042 – 1049.

ŠIMANSKÝ, V. – TOBIAŠOVÁ, E. – CHLPÍK, J. 2006. Influence of tillage system and fertilization on soil structure stability and chemical properties of Haplic Luvisol. In: Acta Fytotechnica et zootechnica, vol. 9, 2006. no. 3, p. 75 – 80.

ŠIMANSKÝ, V. – TOBIAŠOVÁ, E. – CHLPÍK, J. 2008. Soil tillage and fertilization of Orthic Luvisol and their influence on chemical properties, soil structure stability and carbon distribution in water-stable macro-aggregates. In: Soil & Tillage Research, vol. 100, 2008, no. 1 – 2, p. 125 – 132.

ŠIMANSKÝ, V. – TOBIAŠOVÁ, E. – ZAUJEC, A. 2007. Vplyv obrábania na stabilitu pôdnej štruktúry vo vzťahu ku kvantite a kvalite pôdnej organickej hmoty. In: Agrochémia, roč. XI. (47), 2007, č. 1, s. 27 – 30.

TOBIAŠOVÁ, E. – ŠIMANSKÝ, V. 2009. Kvantifikácia pôdnych vlastností a ich vzájomných vzťahov ovplyvnených antropickou činnosťou. Vedecká monografia. Nitra : SPU, 2009. 113 s. ISBN 978-80-552-0196-2.

ZAUJEC, A. – ŠIMANSKÝ, V. 2006. Vplyv biostimulátorov rozkladu rastlinných zvyškov na pôdnu štruktúru a organickú hmotu pôdy. Vedecká monografia. Nitra : SPU, 2006. 112 s. ISBN 80-8069-779-5.

Kontaktná adresa:
Ing. Vladimír Šimanský, PhD., Katedra pedológie a geológie, FAPZ, SPU, Tr. A. Hlinku 2, 949 76 Nitra
e-mail: Vladimir.Simansky@uniag.sk