STUDY OF SOIL TRANSPORT FUNCTION IN CONDITIONS OF HEAVY SOILS IN THE EASTERN SLOVAK LOWLAND

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Abstract

The quality of environment is directly influenced by transport of substances in the soil. This study was realized in the years 2012-2014 in the locality Eastern Slovak Lowland. The transport function of heavy soils was observed by selected soil parameters. Soil samples were taken from three depths from 0.0-0.6 m to 0.2m. The results of the study showed significant heterogeneity of soil conditions in the Eastern Slovak Lowland. We found changes of different soil types over very short distances. The analysis of variance confirmed statistically significant effect of experimental year and soil profile on bulk density, total porosity and maximum capillary capacity of soil.

Key words: *Eastern Slovak lowland, environmental functions, heterogeneity*

1. INTRODUCTION

Ecological functions of soil are used automatically no matter how people recognize it or not. The individual environmental functions occur at the same time, i.e. in a mutual complex. The transport function of soil is very closely related to other functions of soil, but also to water regime of the soil and the soil profile structure that modifies the transport process. Range of the transport of substances is related to the depth of the soil, grain composition and structure of soil. The size and direction of the transport of substances through the soil water is modified by structure of the soil profile (Igaz *et al*. 2011). Transport of substances in Fluvisol (Demo *et al*. 1998; Whitmore 2009) is significantly dependent on the grain composition. During dry and warm periods, it occurs in the soil the transport of substances contained in groundwater upward to the soil profile.

The aim was to analyse and quantify the transport function by the characteristic soil parameters in heavy soils of Eastern Slovak lowlands.

2. MATERIALS AND METHODS

Studied territory belongs to the Košice Region, Michalovce district and almost the whole territory belongs to the land of the village of Besa (Fig. 1). The study area is the dominant soil type Fluvisols with Gley subtypes. Smaller area covers Haplic Gleysols, Haplic Luvisols, Eutric Regosols. The soils in this area can be characterized as deep and heavy soils. Widespread types of soil are clayey soil and clay, less represented are clay-loam and sandy-loam soil types.

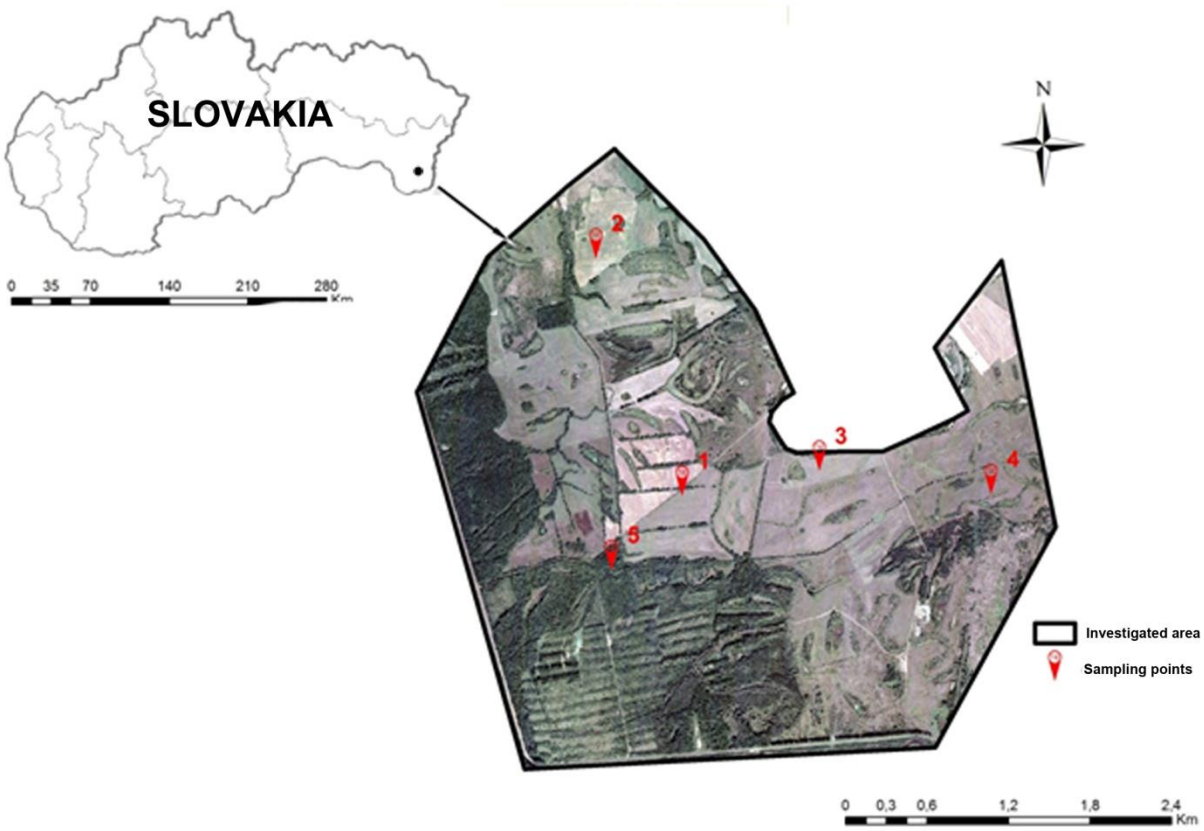


Fig. 1. Position of the investigated area in the Eastern Slovak lowland.

In connection with the transport function of soil, we investigated changes in physical and hydrophysical properties of heavy soil in the spring-summer period (May - June) in years 2012- 2014 from five research profiles that are listed in Table 1. The soil sampling was made according to the Ministry of Agriculture Slovak Republic No. 338/2005 and STN 10381-6. For the determination of grain composition, we collected samples from each soil profile and three depths. By pipette method, we determined following grain size fractions: 1 fraction - clay, <0.001 mm; 2 fraction - medium and fine dust, 0.001 to 0.01 mm; 3 fraction - coarse dust, 0.01 to 0.05 mm; 4 fraction - fine sand, 0.05 to 0.25 mm; 5 fraction - medium sand, 0.25 to 2.00 mm; Category I - clayey particles <0.01 mm. Content of clay particles was evaluated by Novak Rating Scale (Zaujec *et al*. 2009).

From other soil parameters we evaluated bulk density (ρ_d, kg m^{-3}), total porosity (Pc%), capillary maximum capacity (θ_{MKK}%), soil moisture percentage weight / weight ratio of water to dry soil (Hrivňáková *et al.* 2010, Fiala *et al*. 1999).

Parameters of work were oriented to quantification of selected environmental functions of the soil. The results were evaluated by mathematical - statistical methods by using the statistical program STATISTICA 10.

Table 1. Characteristics of sampling fields of the investigated area in the Eastern Slovak Lowland

	Description profile	**Position**	
		latitude N	**longitude E**
1.	arable land	48°31′43″	21°56′08″
2.	grassland, northern part	48°32′39″	21°55′34″
3.	permanent grassland, eastern part	48°31′50″	21°56′57″
4.	permanent grassland, western part	48°31′46″	21°57′59″
5.	forest soils	48°31′25″	21°55′44″

3. RESULTS AND DISCUSSION

The average grain compositions of soil sampling profiles in the studied area are shown in Table 2. Transport individual grain-size fractions and category I soil sampling profiles is characterized by the values of these parameters in different soil depth of the soil profile. The results show high differences in minimum and maximum content of each fraction, what is lost in the average values for all monitored profiles. According to the content of grains of Category I on a minimum of 19.27% it is a sandy-loam soil, but when the content is 81.31% it is clay.

Table 2. The average grain size composition of the investigated area in the Eastern Slovak Lowland

Depth [m]	**1. fraction**	**2. fraction**	**3. fraction**	**4. fraction**	**5. fraction**	**I. category**	**Soil texture**
0-0.2	25.69	29.73	21.10	17.03	6.43	55.42	clayey-loam
0.2-0.4	29.96	22.85	20.79	16.55	4.93	57.71	clayey-loam
0.4-0.6	36.44	24.60	19.71	14.35	4.87	61.05	clayey
Min.	**10.67**	**8.60**	**6.46**	**2.59**	**0.28**	**19.27**	sandy-loam
Max.	56.71	42.61	31.52	48.14	22.74	81.31	clay

Table 3. The average indicators of transport functions in the soil profile of the investigated area in the Eastern Slovak Lowland

Profile	**Depth**	**Year**	**ρ_d [kg.m^{-3}]**	**Pc [%]**	**θ_{MKK} [%]**	**Soil moisture [%]**
1	0.0-0.2	2012	1751	34.27	28.22	12.82
1	0.2-0.4	2013	1619	39.21	32.48	11.19
1	0.4-0.6	2014	1593	40.19	32.34	10.94
2	0.0-0.2	2012	1279	51.88	45.00	25.37
2	0.2-0.4	2013	1286	51.59	44.05	22.30
2	0.4-0.6	2014	1269	52.25	49.39	28.22
3	0.0-0.2	2012	1354	48.96	43.09	27.75
3	0.2-0.4	2013	1213	54.29	46.26	26.24
3	0.4-0.6	2014	1325	50.05	41.95	23.42
4	0.0-0.2	2012	1205	54.77	51.10	32.23

4	0.2-0.4	2013	1218	54.28	49.42	28.89
4	0.4-0.6	2014	1094	58.92	51.99	38.96
5	0.0-0.2	2012	1256	52.12	43.81	25.68
5	0.2-0.4	2013	1263	51.91	45.00	22.03
5	0.4-0.6	2014	1323	49.61	43.88	22.84

ρ_d – bulk density, Pc – total porosity, θ_{MKK} – maximum capillary capacity

The area of the Eastern Slovak lowland is characterized by complex geology, which causes large soil heterogeneity. These data confirm finding of Vilček (1998), Kotorová *et al*. (2005), Fulajtár (2006), Kondrlová *et al*. (2013) that a territory is characterized by alternation of various soil textures on short distances. Content of clay (1. fraction) is increased with the depth of the soil profile, and the average was from 25.69% at a depth 0.0 - 0.2 m to 36.44% at a depth 0.4 - 0.6 meters. For other grain size fractions the trend was opposite, i.e. there was a decrease in dusty and sandy grains with an increase in the depth of the soil profile.

Grain content I. Category, i.e. the sum of the contents of clay and fine and medium dust was increasing together with depth of profile, reflecting both fluctuation of the ground water level, but also irregular flooding in the Eastern Slovak lowland and changes in transfer of particles from the upper layers to the lower layers of profile. The content of individual grain-size fractions indicates the transport function of the soil, which is also associated with the water regime of the area.

Range of transport in the soil profile characterizes the fact whether the soil is compacted, or has a sufficient pore volume for its completion (Papatheodorou *et al*. 2004). Líška *et al.* (2008) considers the critical values indicating soil compaction a bulk density higher than 1400 kg m^{-3}, the total porosity lower than 47%, content of clay higher than 30%. Transport media in soil is most commonly water, which provides transfer of substances and chemicals through the porous system (Fazekašová *et al.* 2014). On the condition of soil environment and the possibilities of transport of substances affect physical parameters of soil which characterize the condition of soil. The Table 3 shows the average values of the physical indicators of land that indicate the possibility of soil compaction and thus reduction of the transport function in profile 1. In connection with a bulk density we confirmed its increase with depth of the soil profile, where were found the highest average and maximum values of bulk density.

For soils of the Eastern Slovak lowland similar findings were published by Kotorová (2007), Kotorová & Mati (2008). From the presented results (Table 3.) we noticed the critical values of bulk density in profile 1. According to Speir *et al.* (2003) bulk density in this type of soil shouldn't exceed the value higher than 1550 kg m^{-3}.

During the observed period, the values of bulk density that we investigated showed critical values, which can cause compaction of the soil. It is similar to the total porosity. We can conclude that the higher are values of total porosity; the lower are values of bulk density (Líška *et al.* 2010). The total porosity is considered to be critical property of heavy soils, especially total content of pores and their size.

A lower total porosity indicates the very probable possibility of compacting of a soil profile. Soil water and the heterogeneity of the soil profile are closely related with maximum capillary capacity, which is one of the relatively unstable hydrophysical parameters. As we can see from the results, a wide range of maximum capillary capacity is not unusual for the soil with a high content of clay particles. All observed parameters were significantly affected by the type of ecosystem, year of observation and depth of the soil profile (Table 4). For collecting of a large amount of water it is important permeability of soil for water and therefore its transport function to be significantly reduced.

Table 4. Analysis of various physical soil parameters of the investigated area in the Eastern Slovak lowland.

Parameter	**Sources of variability**	**Degree of discretion**	**Calculated F-values**	**P significance**
ρ_d	ecosystem	2	633.31	++
	year	3	6.35	++
	depth	2	93.63	++
	repeat	3	0.64	-
	rest	133		
	in sum	143		
Pc	ecosystem	2	562.78	++
	year	3	4.88	++
	depth	2	84.03	++
	repeat	3	0.49	-
	rest	133		
	in sum	143		
θ_{MKK}	ecosystem	2	1288.54	++
	year	3	13.84	++
	depth	2	50.46	++
	repeat	3	1.03	-
	rest	133		
	in sum	143		
I. category	ecosystem	2	3912.44	++
	year	3	10.73	++
	depth	2	46.92	++
	repeat	3	0.57	-
	rest	133		
	in sum	143		
Soil moisture	ecosystem	2	1776.14	++
	year	3	105.05	++
	depth	2	8.45	++
	repeat	3	0.40	-
	rest	133		
	in sum	143		

ρ_d – bulk density, Pc – total porosity, θ_{MKK} – maximum capillary capacity, significance level P = 0.05; ++ Significant; - Statistically insignificant.

CONCLUSION

Based on the research results for observed period 2012 - 2014, we came to the following conclusions:

- range of transport in the soil profile characterizes whether the soil is compacted or has a sufficient pore space for its completion;
- reduction of transport function in the Eastern Slovak lowland occurs from the depth of 0.2 meters, when the bulk density increases above a critical value, the total porosity decreases under a critical value and the content of clay increases above 30%;
- higher values of bulk density and a lower total porosity indicate the possibility of secondary compaction of heavy fluvial gley, which may negatively affect the range of transport of nutrients and water in the soil profile;
- the analysis of variance confirmed statistically significant effect of experimental year and soil profile on bulk density, total porosity and maximum capillary capacity of soil in the Eastern Slovak lowland.

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REFERENCES

Čimo, J., F. Špánik, L. Maderková, D. Igaz, J. Horák and A. Báreková 2010. Agroclimatic diagram of grape phytomass production in Slovak Tokaj region. *Journal of International Scientific Publications: Ecology&Safety* **4** (1): 186-191.

Demo, M., P. Bielek, M. Džatko, M. Lacko-Bartošová, B. Juráni and J. Vilček 1998. Arrangement and use of soil in the agricultural landscape (in Slovak). Nitra, Slovak University of Agriculture in Nitra.

Fazekašová, D., G. Barančíková, S. Torma, M. Ivanová and P. Manko 2014. Chemical and environmental aspect of the component of the environment and landscape (in Slovak). Prešov, University of Prešov in Prešov, Faculty of Management.

Fiala, K., G. Barančikova, V. Brečkova, V. Burik, B. Houškova, A. Chomaničova, J. Kobza, T. Litavec, L. Makovnikova, B. Pechova and D. Varadiova 1999. Partial monitoring system – soil, binding methods (in Slovak). Bratislava, Research Institute of Soil Science and Conservation.

Fulajtár, E. 2006. Physical parameters of soil (in Slovak). Bratislava, Research Institute of Soil Science and Conservation.

Igaz, D., J. Horák, J. Čimo, R. Pospíšil and A. Báreková 2011. Influence of digestate and farmyardmanure on soil moisture regime. *Növénytermelés* **60** (suppl. 1): 291-294.

Kondrlová, E., D. Igaz, J. Horák and K. Halászová 2013. Soil texture analysis by optical method laboratory experiment on sample preparation prior to analysis. In Water resources. Forest, marine and ocean ecosystems. International multidisciplinary scientific geoconference SGEM. Sofia: STEP92 Technology, pp. 677-683.

Kotorová, D. 2007. Changes the properties clay-loam soil during it's a different cultivation (in Slovak). *Agriculture (Poľnohospodárstvo*) **53** (4): 183-190.

Kotorová, D. and R. Mati 2008. Properties and moisture regime of heavy soils in relation to their cultivation. *Cereal Research Communications* **36** (suppl.1): 1751-1754.

Líška, E., J. Bajla, E. Candráková, J. Frančák, D. Hrubý, L. Illeš, M. Korenko, L. Nozdrovický, R. Pospišil, F. Špánik and J. Žembery 2008. General Crop Production (in Slovak). Nitra, Slovak University of Agriculture in Nitra.

Papatheodorou, E.M., M.D. Argyropoulou and G.P. Stamou 2004. The effects of large- and small-scale differences in soil temperature and moisture on bacterial functional diversity and the community of bacterial nematodes. *Applied Soil Ecology*, **25:** 37-49.

Speir, T.W., A.P. Van Schaik and A.R. Lloyd-Jones 2003. Temporal response of soil biochemical properties in a pastoral soil after cultivation following high application rate of undigested sewage sludge. *Biology and Fertility of Soils* **38:** 377-385.

Vilček, J. 2006. Potential of energy of agricultural soils - the criterion of assessment and land use (in Slovak). Bratislava, Research Institute of Soil Science and Conservation.

Whitmore, A. P. 2009. The effect of long-term soil management on the physical and biological resilience of a range of arable and grassland soils in England. *Geoderm.* **153** (suppl. 1-2): 172-185.

Zaujec, A., J. Chlpík, J. Nádašský, N. Szombathová and E. Tobiašová 2009. Pedology and base of geology (in Slovak). Nitra, Slovak University of Agriculture in Nitra.