Acta horticulturae et regiotecturae 2
Nitra, Slovaca Universitas Agriculturae Nitriae, 2013, s. 29–32

DETERMINANTS OF SLOPE STABILITY REDUCTION

DETERMINANTY ZNIŽOVANIA STABILITY SVAHU

Dagmar DOBIAŠOVÁ, Jozef STREĎANSKÝ, Lucia TÁTOŠOVÁ
Slovak University of Agriculture in Nitra, Slovak Republic

The formation or activation of landslide movements in Podtatranská kotlina is quite common, as it is flysh and volcanic area. There is a high incidence of sandstones in this area. The sandstones crumble and weather, and this is the reason why the subsoil becomes unstable. The rainfall is accumulated, and there is a danger of soil sliding down. There was located groundwater level in the central part of the slope (in the height of 30 cm), and in some parts, the water accumulation occurred in the depression places on the landslide body. There were created small landslide lakes, where the water was held during the year. The slope was soaked and the erosion started to increase. The slope with its instability has pushed the construction of road that leads underneath the heel of the slope. Neglected and improper construction in areas of slope landslides has become a relatively common phenomenon. Stabilization measures are often made up only when real problem occurs. An anthropogenic activity usually starts this problem. This refers to deforestation, grassing or deformation of slope stability in the heel by improper construction. The landslide was not the first one in the area. In 1898, there was the first landslide, but it was not as intensive as this one. Retaining wall was the only one stabilization measure which was built in that time. It also had a drainage outfall. However, during the summer months in 2010, the stabilization measure was disrupted and cracked. This occurrence started after the slope separation and by the foremost pressure on the given wing wall. During our measurements, we found out that in that area, there was a loss of plant cover, erosion accrued and soil physical properties changed. Our aim is to show the seriousness of the situation and propose appropriate stabilizing measures.

Keywords: landslide, plant cover, stabilization measures, erosion

In the present time, the soil degradation processes have reached alarming intensity and have become one of the most serious environmental problems. Therefore, the issue of soil protection is the most serious environmental problem (Fulajtár a Jansky, 2001). Intensity of soil erosion is very important in terms of the creation and preservation of soil. The point, at which soil loss is equal to or higher than quantitative formation of soil, is considered the critical threshold. The erosion, whose intensity does not exceed the critical threshold, is called benign erosion. If the critical point is exceeded, we can talk about the damaging erosion.

Erosion control measures for soil protection are based on the principles of landscape stability. In our conditions, approximately 1 cm of soil creates in time of 200 years (Antal, 2005). Current trends point on relatively frequent intervention in the country in form of road construction and also moving the borders of urban areas. This is often done by working out a forest. Forests do not have only the production function, but also the stabilizing function and function of accumulation of rainfall (intercept). We rate the effect of plant cover in the sense that plants affect the behavior of water erosion as an erosion determinant.

For several decades, global climate changes have been a real problem, related to several changes in the ecological conditions of the country. Increasingly, there are torrential rains, which induce erosion on areas without grass and forests. The pluvial erosion occurs the most frequently. It comes into being on the slopes which are highly divided by potholes. The occurrence of slope processes is also possible here. The geomorphology and geography are understood as processes whose common feature is the action of Earth's gravity, which affects unpaved material. Origin and evolution of slope movements are mainly conditioned by the effect of gravitational forces on particles of rock that make up a slope. Stability of soil and rock in a slope is infringed by the interaction of water (Rybáriková, 2004). In such case, the problem can lead to the landslide slope. The solution may be in technical or biological erosion protection.

The decision, if it is possible to use only agro-technical and biological erosion control in some areas or if it is necessary to draft the technical erosion control measures, depends not only on natural conditions, but also on the way of using the area. We have performed mapping of the landslide slope and we have modeled the appropriate surface stabilization of the slope in the observed area of Liptovský Mikuláš. We have monitored the slope surface subsidence, caused by water erosion and inappropriate vegetation cover. We focused on the impact of climate, ecological soil and hydrological relationships in the country. In the past, the slope was used for activities of pasture and as a place where power lines used to run. It is located in the recreation area on Liptovska Mara dam banks.

Material and methods

- Selection of the area, which is the subject of the research (Liptovský Mikuláš – village Gotovany).
- Summarizing methodologies, manuals for design of slope stability.

- Drawing up a review of computational equations for determining the possibility of erosion.
- Implementation of laboratory measurements determining hydraulic conductivity of soil, physical properties of soil and determination of soil.
- Modeling of erosion loss using GIS and universal Wischmeier-Smith.
- Performance and design of appropriate anti-erosion measures.

Methods for determination of hydraulic and physical characteristics are drawn from the following publication: Applied Agrohydrology (Antal a Igaz, 2010). Measurements are taken from 2010.

Results and discussion

The observed area is located in the flysh territory with representation of cambisol. There is medium-deep soil with an area of 4.2 hectares, with BPEJ code 0869412. From a botanical point of view, we talk about the area planted mostly with grasses: *Poa pratensis, Agropyron caninum, Calamagrostis arundlinacea, Calamagrostis epigejos*. In the bottom of the area in danger, there grow mostly grasses, which need waterlogged soil: *Carex acutiformis, Carex nigra*. The most common tree in that area is *Altus Glutinosa*. The occurrence of the above-mentioned plant communities is an indicator of increased concentration of water in the soil.

The results of the basic physical soil physical characteristics assessment

The characteristic feature of the soil porosity is rhythmic oscillation of the average of soil pores in the area which occurs on very small distances. There are all physical, physicochemical, chemical and biological processes in soil pores, which are very important for existence of organisms in soil, and for the formation of soil as well. The shape and size of pores is crucial for the dynamics of soil water, soil air circulation and evaporation. In heavy clay soils, there is a very low value of the porosity, due to soil creep and low values of inter-aggregate porosity. The values were measured in the range from 42.2% to 62.5%. Thus, the soil can be classified in the scope from moderately compacted to compacted. We assessed the soil compactness based on

Table 1 Determination of physical and hydrophysical characteristics of soil

Number of sample (1)	Weight of soil (2) / Weight of the solid part of soil (3)	Bulk density (4)	Total weight of the solid part of soil (5)	Bulk density unreduced (6)	Bulk density of the solid part (7)	Porosity (8)	Maximal capillary capacity (9)	Water holding capacity (10)	Capillary absorption (11)
	m_s	ρ_d	m_t	ρ_t	ρ_s	P	θ_{MKK}	θ_{RVK}	θ_{KN}
	g	g.cm^{-3}	g	g.cm^{-3}	g.cm^{-3}	% vol.	% vol.	% vol.	% vol.
1	120.78	1.21	162.02	1.62	2.54	52.5	50.83	0.18	52.03
2	113.48	1.13	160.76	1.61	2.55	55.5	55.72	55.03	55.82
3	107.06	1.07	157.15	1.57	2.52	57.5	60.13	59.86	60.97
4	96.73	0.97	147.64	1.48	2.45	60.5	63.31	62.8	63.5
5	106.8	1.07	148.28	1.48	2.51	57.5	55.71	55.3	56.9
6	106.87	1.07	158.39	1.58	2.51	57.5	58.7	58.54	59.03
7	95.21	0.95	133.99	1.34	2.47	61.5	54.52	53.81	55.37
8	147.16	1.47	183.98	1.84	2.56	42.5	43.11	42.7	44.39
9	119.71	1.20	164.39	1.64	2.57	53.5	51.74	50.9	52.9
10	116.09	1.16	159.66	1.60	2.55	54.5	55.44	54.95	55.76
11	113.48	1.13	161.58	1.62	2.44	53.5	56.07	55.79	57.41
12	119.37	1.19	160.97	1.61	2.54	53	54.36	53.91	55.23
13	101	1.01	142.51	1.43	2.69	52.5	56.82	56.78	57.79
14	96.98	0.97	131.17	1.31	2.66	63.5	51.33	50.92	67.2
15	138.72	1.39	171.86	1.72	2.98	53.5	46.48	45.75	44.09
16	138.64	1.39	165.23	1.65	2.80	50.5	42.58	42	44.89
17	94.97	0.95	134.78	1.35	2.53	62.5	53.58	53.28	56.19
18	140.68	1.41	175.87	1.76	2.96	52.5	43.11	42.59	43.71

Tabuľka 1 Stanovenie fyzikálnych a hydrofyzikálnych vlastností pôdy
(1) číslo vzorky, (2) hmotnosť pôdy, (3) hmotnosť pevnej zložky pôdy, (4) objemová hmotnosť, (5) celková hmotnosť pevnej zložky pôdy, (6) neredukovaná objemová hmotnosť, (7) objemová hmotnosť pevnej zložky, (8) pórovitosť, (9) maximálna kapilárna kapacita, (10) vodná kapacita, (11) kapilárna absorpcia

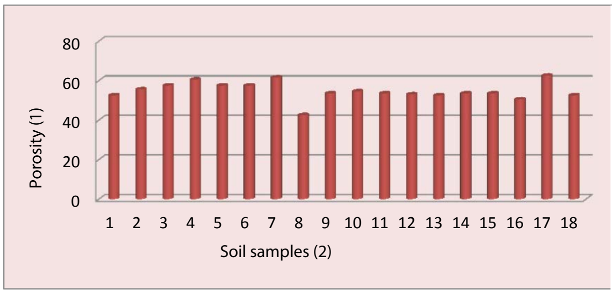

Figure 1 Determination of soil porosity
Obrázok 1 Stanovenie pórovitosti pôdy
(1) pórovitosť, (2) číslo vzorky

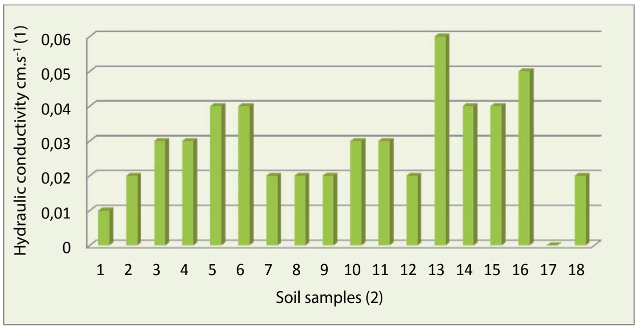

Figure 2 Determination of hydraulic conductivity
Obrázok 2 Stanovenie hydraulickej vodivosti
(1) hydraulická vodivosť, (2) číslo vzorky

its porosity (Kutílek, 1978). The maximum capillary capacity, water holding capacity, and capillary absorption has on average lower value in the bottom part of the area affected by landslides than on the top of the area.

The results of the laboratory assessment of the hydraulic conductivity coefficient on the device with an average hydraulic gradient

The hydraulic conductivity was higher, on average, in the bottom of the deformed area than in the top part. The deformation is usually a bigger problem in moist soil than in dry one. The deformation decreases on dry soil when there are pressures, causing disruption of soil aggregates, due to the size of aggregates. On the moist soil, it increases again. The soil is compressed when there is a long-time load; it does not have enough time to be compressed during a short-time load, and its deformation is smaller.

The results of soil type determination

The samples taken from the bottom of the slope and directly from the landslide pointed out that it is a clayey loamy soil. The samples taken from the upper part of the slope, which is unaffected by landslide, pointed out a representation of a loamy soil. Laser diffraction of particles in percentage <0.01mm pointed out that on the bottom part there are values on average 63.8% of particles <0.01 mm. It was the kind of loamy soil, but after conversion to the pipetting method, it decreased to 47.07%, therefore, it was a clayey-loamy soil. In the upper part, laser diffraction of particles in percentage <0.01mm determined the value 56% of particles on average, <0.01mm. MMCO classifies the soil as a clayey loamy soil, and after conversion to the pipetting method, 43%, it classifies as a loamy soil. The conversion to the pipetting method was performed in terms of more frequent publications. Laser method is still an innovation in the determining of soil types. Based on the article, which was published by Kondrlová (2012), we used the calculation of the percentage representation of laser diffraction for pipetting method. Coefficient used for calculation is $y = 15.613e\ 0.0173x$.

Loamy soil contains 25–45% of particles of the first category. With convenient conditions, especially in good structural status, they have optimal physical, chemical, and biological characteristics. Water permeability and infiltration of rainwater are average; they also depend on the soil structure. Sorption capacity is sufficient. The particles are consistent and they can be cultivated without difficulties, if the moisture is suitable. Dust particles are dominant within the fraction of medium-heavy soils. Thus, we do not observe extreme problems, determined by the high contents of clay (moisture) or sand (aridity/dryness). Dust particles affect the movement of water and air positively, and affect the physical and mechanical characteristics of soil (soil cohesion and consistency), too.

In practice, simplified classification of soils is used, related to the technological characteristics of soil – cohesion, adhesion, plowing resistance, and it is indirectly derived from grain. According to the difficulty of processing, we differ light soil, medium-heavy and heavy soils (Zaujec, 2002). Novak´s classification is the most frequently used classification in our country. Abroad, the most frequently used classification is USDA or FAO (Fulajtár, 2006). To determine the type of soil it is necessary to know the percentage of particles of first category, according to Kopecký. According to soil segmentation by Kopecký, we can define soil in this area as heavy soils.

Calculation of erosion sediment according to Wischmeier-Smith´s equations and modelling in GIS

Using the Wischmeier-Smith ´s equations, we calculated the data that we had expected. The highest degree of erosion is reflected in the bottom part of the slope. In this area, the erosion ranged from 13 t/ha/year to 91 t/ha/year. The average is 52 t /ha/year. The Act nr. 220/2004 Coll. provides erosion sediment by water erosion on deep soil for 30 tons of 1 ha per year. On the area with meadow vegetation, the values ranged from 0.14 t/ha/year to 1.82 t/ha/year. The Wischmeier and Smith ´s equation modeling was processed in GIS Program (Sink, 2008).

- *R*-factor of rain erosion efficiency was determined from the OMBRE graphic record in station Liptovský Hrádok and its value is 20.05 $MJ.ha^{-1}yr^{-1}$. It was necessary to process the complete data of SHMU observations for a period of 50 years, to obtain representative data about average annual value of the *R*-factor.
- *K*-factor of the soil ´s susceptibility to erosion, the soil pedo-ecological units, more exactly as a function of the main soil unit with the 0.25 $t.MJ^{-1}$, (the soil pedo-ecological unit 0869412).
- *L* and *S* factors of a length and incline of a slope was determined by topographic factor (*L*, *S*) which was expressed by the relation:

$$LS = \text{ld}\ 0.5\ (0.0138 + 0.0097 \times s + 0.00138 \times s2)$$

where:
ld – unbroken length of slope (m)
s – incline of slope (%)

Both components of the equation – incline of slope and length – were obtained according to GIS (Spatial Analyst Hydrologic Model)

- *C*-factor for the protective effect of vegetation was replaced by the value 0.05 (value for multi-annual grassed, meadows). The part of slope in danger was expressed as 1 (without erosion effect of vegetation).

Súhrn

Výsledky poukázali na nutnosť riešenia vzniknutej situácie, aby nedochádzalo k ďalším odnosom pôdy a čoraz výraznejšiemu narušovaniu svahu. Svah svojou nestabilitou tlačí na cestnú komunikáciu a tá sa v dôsledku tohto pôsobenia stáva nefunkčnou. Faktorom zosuvu sa stala zmena obsahu vody, činnosť mrazu, zvetrávanie hornín a zmeny vo vegetačnom poraste. Podľa rýchlosti a mechanizmu pohybu môžeme hovoriť o zosúvaní, keďže sa jedná o rýchli pohyb svahových hmôt pozdĺž šmykovej plochy. Dĺžka a šírka zosuvu je proporcionálna, takže môžme hovoriť o plošnom zosuve, a stupeň stabilizácie je aktívny. Povrch zosuvu je intenzívne rozčlenený a nesie stopy čerstvých pohybov. Pohyby sa periodicky opakujú vplyvom prírodných faktorov. Znovuobnovenie ochranného lesného porastu nad hranicou nami pozorovaného územia by malo tiež pozitívny vplyv, keďže na miestach kde sa lesný porast nachádza nedochádza ku žiadnym svahovým procesom. Ďalším opatrením by bolo v spodnej časti pozemku navrátiť a znovu obnoviť pôdny kryt. Na spodnú časť časti pozemku by sme zvolili výsadbu drevín z rodu *Salix*, aby dokázali správne hospodáriť s nadmernými hromadením povrchového odtoku. Keby sa pozemok zalesnil a zatrávnil, tak by došlo k jeho stabilizácii. Tiež by sa znížila hladina podzemnej vody, ktorú by odčerpávali dreviny.

Kľúčové slová: zosuv pôdy, rastlinný porast, stabilizačné opatrenia, erózia

Poďakovanie:
Práca vznikla za podpory VEGA 1/0711/11.

References

ALENA, F. 1986. Stanovenie straty pôdy eróznym splachom pre navrhovanie protieróznych opatrení: Metodická pomôcka. Bratislava : ŠmS, 1986. 58 s.

ANTAL, J. 1990. Ochrana a zúrodňovanie pôdy. Nitra : VŠP, 1990. ISBN 80-85175-57-6.

ANTAL, J. 2005. Protierózna ochrana pôdy. Nitra : SPU, 2005. 79 s. ISBN 80-8069-572-2

ANTAL, J. – IGAZ, D. 2010. Aplikovaná agrohydrológia. Nitra : SPU. 210 s. ISBN 978-80-552-0455-0

FULAJTÁR, E. – JASENSKÝ, L. 2001. Vodná erózia pôdy a protierózna ochrana. Bratislava : VUPOP, 2001. 310 s. ISBN 80-85361-85-X.

FULAJTÁR, E. – STYK, J. 2007. Pôdna erózia a protierózne opatrenia. In: Zborník referátov zo seminára „Pozemkové úpravy na Slovensku II". Bratislava : Ministerstvo pôdohospodárstva SR, Komora geodetov a kartografov, Slovenský zväz geodetov, 2007, s. 38–45

GEISSÉ, E. 1995. Pozemkové úpravy, projektovanie. Bratislava : STU, 1995

JANEČEK, M. 1992. Ochrana zemědělské půdy před erozí. Metodika 5/92. Praha : ÚVTIY, 1992. 77 s.

JESENÁK, J. 1994. Mechanika zemín. Bratislava : STU, 1994. 406 s. ISBN 80-227-0642-6

HALAJ, P. 1998. Vplyv poľnohospodárskej činnosti na kvalitu podzemných a povrchových vôd. Nitra : SPU, 1998, 35–38 s.

KONDRLOVÁ, E. – IGAZ, D. – HORÁK, J. – ČIMO, J. 2012. Comparison of sample preparation methods for laser diffraction to determine the particle size distribution of medium fine soils. In Land Degradation and Challenges in Sustainable Soil Management. Istanbul : Ege University, 2012. pp. 432–437. ISBN 978-975-96629-9-8.

KORTE, B. G. 2001. The GIS book – How to implement, manager, and assess the value of geographic information systems. 5. ed. New York : On word press-Thomson Learning, 2001. 377 p.

KUTÍLEK, M. 1978. Vodohospodářská pedologie. Praha : SNTL/ALFA, 1978. 295 s.

RYBÁRIKOVÁ, R. 2004. Geológia nielen pre stavbárov. Žilina, 2004. s. 137. ISBN 80-969059-3

STREĎANSKÁ, A. – BUDAY, Š. 2006. Bonitácia a cena pôdy. Nitra : SPU, 2006. 160 s. ISBN 80-8069-656-X

ŠINKA, K. 2008. Tvorba hydrologických podkladov pre návrh protieróznych opatrení v krajine v prostredí GIS. In Fórum mladých geoinformatikov : zborník príspevkov a prezentácií, 16. máj 2008. s. 1–12. ISBN 978-80-228-1876-6

TÁRNÍK, A. – VARGA, V. 2013. Výpočet intenzity vodnej erózie pôdy na základe USLE s použitím variantných topografických faktorov v GIS – grafy, ilustr. – 6 s. In: Symposium GIS Ostrava 2013. 1 DVD--ROM (nestr.). ISSN 1213-239X. 978-80-248-2951-7 Symposium GIS Ostrava. Ostrava : Vysoká škola báňská, 2013.

ZÁRUBA, Q. – MENCL, V. 1974. Inženýrská geologie. Praha : Academia. 512 s.

ZAUJEC, A. a i. 2002. Pedológia. 1. vyd. Nitra : SPU. 2002. 98 s. ISBN 80-8069-090-1

WISCHMEIER, W. H. – SMITH, D. D. 1978. Predicting rainfall erosion losses. Maryland : SEA USDA Hystaville, 58 p.

Contact address:
Ing. Dagmar Dobiašová, Slovak University of Agriculture in Nitra, Horticulture and Landscape Engineering Faculty, Department of Landscape Planning and Ground Design, Hospodárska 7, 949 76, Nitra, Slovakia, e-mail: obertova.d141@gmail.com