Infiltration and runoff measurements on arable land with different slopes and rainfall intensities

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Abstract: Nowadays the fertile soil and the water retention have a great importance, therefore more and more studies deal with the subbject of surface runoff decrease and infiltration capacity increase. In the present study *in situ* rainfall simulation experiments were carried out on different plots in order to characterize the soils' infiltration rate under different circumstances. On the field three intensities (30–60 and 90 mm/h) and two slope steepness (5-12%) were investigated. The main objective was that analyses of the effect of different conditions on soil permeability, conductivity and infiltration capacity. During the measurements, the wetting, the ponding and runoff periods and rates were registered, so the soil saturation process was permanently followed. The results show that the infiltration rate decreased, while runoff rate increased with time and higher intensities. Proportionally with slope increasing the infiltration rates were decreasing. At 30 mm/h rainfall intensity the infiltration rate mostly exceeds the runoff rate, while at higher intensities the runoff starts earlier. On average the infiltration intensity not increased with increasing rain intensities.

Keywords: Rainfall simulation, runoff, infiltration rate,

Introduction

Soil protection plays a crutial role in our future, especially with the threats of climate change, increasing brownfield investments (Martinát et al. 2016), and furthermore, urbanization processes. Soil infiltration capacity is one of the most important factors with respect to soil water erosion. The surface runoff occurs when the rainfall intensity exceeds this infiltration capacity (Dunne and Leopold, 1978), therefore the challenge of recent days is the water retention within landscape by increasing the infiltration capacity. Infiltration capacity depends on several soil properties as soil texture, soil organic matter, soil pore system configuration etc. In case of soil erodibility, the soil hydraulic conductivity has a determining importance (Várallyay, 2011). Infiltration process is affected by rainfall intensity, soil surface state (crusted, freshly tilled), antecedent soil moisture content, surface roughness, slope steepness, as reported from studies under simulated rainfall conditions (Janeau et al., 2003; Rodrigo Comino et al., 2016; Van den Putte et al., 2013; Ribolzi et al., 2011; Truman et al., 2011; Rimal and Lal, 2009; Kato et al. 2008).

During the rainfall, the most important events are the start of ponding and runoff. The surface ponding indicates the surface saturation or sealing and crusting formation. At this stage the infiltration rate is less, than the rainfall rate, resulting in surface runoff. In some cases the hydraulic conductivity increasing, as it was noticed in case of higher rainfall intensities (Nassif & Wilson 1975). This phenomenon can be explained with the higher kinetic energy which can destroy and disrupt the surface seals and crusts, which could obstruct the infiltration (Bowyer-Bower, 1993). Similar observations were found by Jakab and Szalai (2005) who determined that the soil permeability increase proportionally with higher rainfall intensity load which is partly due to the increasing pressure of the water and partly due to influential effect of slope gradient.

Within this study our main objective was to examine the runoff and the soil infiltration rate under different rainfall intensities and slope gradients. The main research questions were as follows: 1. which parameter has greater impact on the infiltration rate; and 2. how the rainfall intensity affects the infiltration rate?

Materials and methods

The experiment was carried out in July 2015, in Gerézdpuszta (Somogy County, Hungary) with Shower Power-02 rainfall simulator, which was constructed by the Geographical Institute, Research Centre for Astronomy and Earth Sciences, Hungarian Academy of Sciences. In field 30–60 and 90 mm/h rainfall intensities and two slope sections with 5 and 12% inclinations were applied on fenced ground with 6 m^2 plot size (3x2 m). The device is equipped with two 80100 Veejet alternating nozzles. The rainfall intensity can be adjusted with the number of nozzle-swing during a given time. The drainage water is collected by two metal triangles with drain-pipe at the bottom of the plot. The runoff volume was registered through these triangles, and the time with the amount of runoff was read when one of the two measuring barrels reached the 2 liter limit.

The experimental area can be characterized with eroded Raman's brown forest soil and Regosol. At the infiltration intensity determination, the applied model was the Horton (1933) type, where the illustration of intensity in the mirror of time can give a curve which can characterize the whole process. The relationship has the following format:

$$Y = P0 * (x – P1) – (P0 / P2) * (1 – \exp (-P2 * (x-P1)))$$

where Y: Cumulative runoff (l); x time of the process (min); P0 maximal, constant runoff intensity (l/min); P1 the starting time of runoff (min); P2 Runoff changing indicator (1/min). In knowledge of P0 parameter we can represent the soil permeability in mm/h.

Results and discussion

Generally, the infiltration rate decrease is typical with time and when the runoff starts it shows near constant values. The runoff intensity proportionally increased with ascending rainfall intensity and slope gradient. Based on the charts (Figure 1-2.) we can reveal that under 20 mm/h rainfall intensity runoff doesn't occur, while at about 50 mm/h, the rate of infiltration and runoff is almost equal and above that the runoff rate exceeds the infiltration rate.

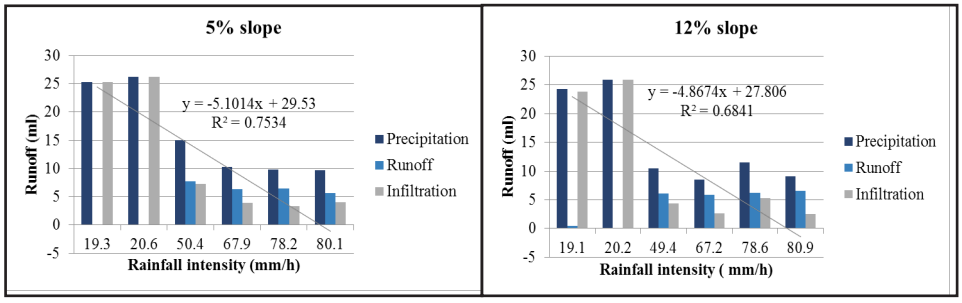

Figure 1.: Relationship between rainfall intensity and infiltration rate in case of 5% and 12% slope

Infiltration intensities were further investigated with respect to rainfall intensities and

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two different slope inclinations (Figure 2.), where at 5% slope the infiltration intensity increased slightly with the rainfall intensity, what has not proved in case of 12% slope.

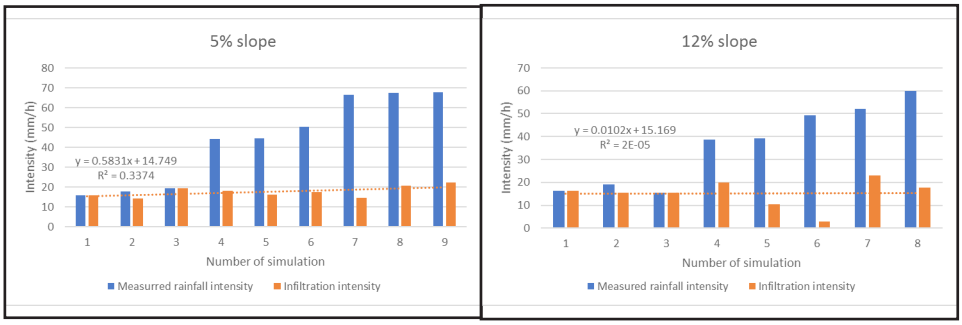

Figure 2.: Relationship between rainfall infiltration intensity in case of 5% and 12% slope

Based on the measurements, the relationship between the rainfall intensity and runoff is high (Figure 3.), therefore in this case we can tell that while the infiltration rate doesn't the amount of runoff more depend on the rainfall intensity.

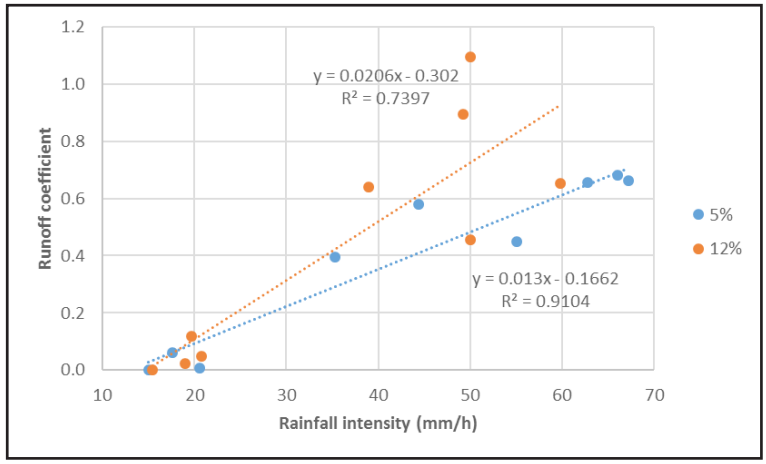

Figure 3.: Relationship between rainfall intensity and runoff coefficient in case of 5% and 12% slope

Conclusions

Based on the results the slope category and the rainfall intensity do not determine the infiltration rate, although on lower slope section slight (statistically insignificant) increasing was observed with higher rainfall intensities. Stronger relationship was observed between the rainfall intensity and the runoff coefficient.

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References

Bowyer-Bower, T.A.S. (1993): Effects of rainfall intensity and antecedent moisture on the steady-state infiltration rate in a semi-arid region. Soil Use and Management 9: 69–76. DOI: http://dx.doi.org/10.1111/j.1475-2743.1993.tb00932.x

Dunne, T., L. B. Leopold, (1978): Water in Environmental Planning. W H Freeman and Co, San Francisco, 818 p. DOI: http://dx.doi.org/10.1177/030913338000400216

Jakab G., Szalai Z. (2005): Barnaföld erózióérzékenységének vizsgálata esőztetéssel a Tetves-patak vízgyűjtőjén. Tájökológiai Lapok 3(1): 177–189. DOI: http://dx.doi.org/10.14232/phd.1729

Jakab G., Szabó J., Szalai Z. (2015): Lepeleróziós vizsgálatok eredményei Magyarországon. Tájökológiai Lapok, 13(1): 89–103. DOI: http://dx.doi.org/10.17836/ec.2014.2.018

Janeau, J.L., Bricquet, J.P., Planchon, O., Valentin, C. (2003): Soil crusting and infiltration on steep slopes in northern Thailand. European Journal of Soil Science 54, 543–554. DOI: http://dx.doi.org/10.17836/ec.2014.2.018

Kato H., Onda Y., Tanaka Y., Asano M. (2008): Field measurement of infiltration rate using an oscillating nozzle rainfall simulator in the cold, semiarid grassland of Mongolia. Catena 76: 173–181. DOI: http://dx.doi.org/10.1016/j.catena.2008.11.003

Martinát S., Dvořák P., Frantál B., Klusáček P., Kunc J., Navrátil J., Osman R., Tureckova K., Reed M. (2016): Sustainable urban development in a city affected by heavy industry and mining? Case study of brownfields in Karvina, Czech Republic. Journal of Cleaner Production, 118: 78–87. DOI: http://dx.doi.org/10.1016/j.jclepro.2016.01.029

Nassif, S.H. and Wilson, E.M. (1975): The influence of slope and rain intensity on runoff and infiltration. Hydrological Sciences Bulletin 20: 539–53. DOI: http://dx.doi.org/10.1080/02626667509491586

Ribolzi O., Patin J., Bresson L.M., Latsachack K.O., Mouche E., Sengtaheuanghoung O., Silvera N., Thiébaux J.P., Valentin C. (2011): Impact of slope gradient on soil surface features and infiltration on steep slopes in northern Laos. Geomorphology 127: 53–63. DOI: http://dx.doi.org/10.1016/j.geomorph.2010.12.004

Rimal B. K., Lal R. (2009): Soil and carbon losses from five different land management areas under simulated rainfall. Soil & Tillage Research 106: 62–70. DOI: http://dx.doi.org/10.1016/j.still.2009.09.014

Rodrigo Comino J., Iserloh T., Lassu T., Cerdà A., Keestra S., Prosdocimi M., Brings C., Marzen M., Ramos M. C., Senciales J. M., Ruiz Sinoga J. D., Seeger M., Ries J.B. (2016): Quantitative comparison of initial soil erosion processes and runoff generation in Spanish and German vineyards. Sci Total Environ. 565: 1165–1174. DOI: http://dx.doi.org/10.1016/j.scitotenv.2016.05.163

Truman C.C., Potter T.L., Nuti R.C., Franklin D.H., Bosch D.D. (2011): Antecedent water content effects on runoff and sediment yields from two Coastal Plain Ultisols. Agricultural Water Management 98: 1189–1196. DOI: http://dx.doi.org/10.1016/j.agwat.2011.03.001

Van den Putte A., Govers G., Leys A., Langhans C., Clymans W., Diels J. (2013): Estimating the parameters of the Green–Ampt infiltration equation from rainfall simulation data: Why simpler is better. Journal of Hydrology 476: 332–344. DOI: http://dx.doi.org/10.1016/j.jhydrol.2012.10.051

Várallyay Gy., (2011): Water storage capacity of Hungarian soils. In: Agrokémia és talajtan. 60. Suppl. (online-ATON) 7-26. DOI: http://dx.doi.org/10.1556/agrokem.59.2010.1.2

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