# Runoff and infiltration – Case study of a Cambisol

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Abstract:The soil erosion is a complex phenomenon, which depends on influencing factors. It is also a potential hazard of agricultural fields of Hungary. The runoff is one of the driving forces in soil loss, hence it is important to have knowledge of hydraulic characteristics of a soil. The runoff/infiltration ratio depends on several factors. The soil crust, the soil moisture content, the slope and the intensity creates a complex dependency matrix where the determination of the most influencing factor on the runoff is complicated. The main goal was to compare the runoff ratios of the same soil under constant high intensity but different surface conditions (moisture content; crust) and slope steepness. An intensively tilled Cambisol was studied with laboratory rainfall simulator, and the results were validated with field simulations. According to the runoff results, the runoff/infiltration ratio shows similar values in the laboratory and in the field, although it is higher in the field. Generally, the 12% slope triggers the highest values in the runoff and sediment concentration but the moisture content or a developed crust can influence the results, which means in erosion estimation ”the soil surface status” factor has to get more attention.

Keywords: infiltration; runoff; rainfall simulation

## Introduction

The accelerated soil erosion is a serious problem in Hungarian agricultural areas, the rainfall simulator experiments, concentrates on soil erodibility in Hungary was summarised by Centeri et al. (2011). With the climate change, high intensity rainfalls occur more and more often and causes accelerated soil loss. Measuring the effect of combined factors on soil erosion regards to their interrelated influences are having increasing importance. A laboratory-scale rainfall simulator is a useful tool for examining the influencing factors of soil erosion one by one or as a system. The literature of simulated soil erosion experiments suggests several approaches due to the complex process of erosion. Kerényi (1986) studied the splash erosion, Defersha – Melesse (2012) examined the effect of the rainfall intensity, the initial moisture content and slope steepness on erosion, while Gómez – Nearing (2005) concentrate on the effect of the surface roughness on soil loss and runoff. Kinnell (2016) reviewed the main use and limitations of the rainfall simulators but a general standard of simulator design or simulation method still does not exist. In this study, we examined the response of a Cambisol on erosion under different slope angles and initial soil moisture contents with a lab rainfall simulator and field validation. The main questions were: 1) How does the runoff and infiltration ratio change with the slope steepness and soil moisture content? 2) In a pairwise comparison of the simulations, which parameter is the most influencing related to the runoff ratio and sediment concentration values?

## Materials and methods

The rainfall simulations were conducted at the Eötvös Loránd University with a redesigned Zámbó-Weidinger type simulator (Zámbó – Weidinger, 2006). During the field validation a redesigned Pannon-R2 simulator (Jakab – Szalai 2005) was used. The main differences between the simulators were the experimental area: in the laboratory $0.5m^2$ while in the field $6m^2$ were used, respectively.

The sample was taken from an intensively tilled field near Ceglédbercel, Hungary (N 47.249765°, E 19.678761°, 150 m asl.). Previously, field scale erosional studies were done by Szalai et al. (2016) and detailed aggregate related laboratory scale soil loss was also studied by Szabó et al. (2015). The current study concentrates on erosional response of the soil in case of the slopes (2; 5; 12% steepness) and surface status (Table 1.) changes. The surface status combines the initial moisture content and the roughness together because of the effort to model frequent surface statuses.

During the high intensity experiments, all the runoff was collected. The time was recorded after every 1-litre runoff in the laboratory and 1.5-2l in the field due to the experimental design. Weights of dried soil losses per litre of runoff were recorded at the nearest 0.01 g and summed per simulations.

*Table 1: Applied surface characteristics during the experiments (moisture content and roughness variations)*

| Code | Description |
|---|---|
| 1 | tilled surface and field capacity moisture content |
| 2 | crusted surface and saturated soil |
| 3 | inland inundation and saturated soil |
| 4 | drought simulation with big rifts, dry, crusted surface |

The simulations were planned to collect predetermined amount of runoff hence the time period and the amount of precipitations vary in relatively wide range (525–2531 s and 13.58–52.03 mm) (Table 2.). The effect of length and amount of the precipitation on runoff was disregarded because we assumed, this effect is not significant in this case.

*Table 2: Main characteristics of the simulations (L-laboratory; F-Field; slope angle (2, 5 or 12%); surface characteristic (see Table 1.) code)*

| Experiment code | Precipitation (s) | Precipitation (mm) | Intensity (mm/h) |
|---|---|---|---|
| L/5/1 | 2531 | 54.84 | 78 |
| L/5/2 | 1963 | 47.98 | 88 |
| L/12/1 | 2014 | 52.03 | 93 |
| L/12/2 | 525 | 13.85 | 95 |
| L/2/3 | 1309 | 36.36 | 100 |
| L/2/4 | 1762 | 50.41 | 103 |
| F/5/2 | 626 | 16.87 | 97 |
| F/12/2 | 635 | 18.17 | 103 |

## Results and discussion

Figure 1. illustrates the runoff and infiltration ratio and sediment concentration of the experiments arrayed by precipitation intensity to show, the differences of the intensity has not caused significant impact neither on runoff ratio neither on sediment concentration. The runoff rate varies between 35–55 % in the laboratory and is around 25% on the field (Figure 1.). This difference corresponds to the scale effect (Iserloh et al. 2012) hence during the comparison, the field experiments count as a control, and underline, the scale is matter. The sediment concentration increased with the slope steepness on both locations and it was higher on the tilled surface compared to the crusty one which indicates detachment limited erosion on crusty surface. The runoff rate was the lowest in case of the drought simulation (2%) where the big rifts were draining the water, and as it was expected, the

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highest on 12% slope. The infiltration rate is not related to the crusts clearly although Assouline – Ben-Hur (2006) found strong relationship between surface sealing and runoff production.

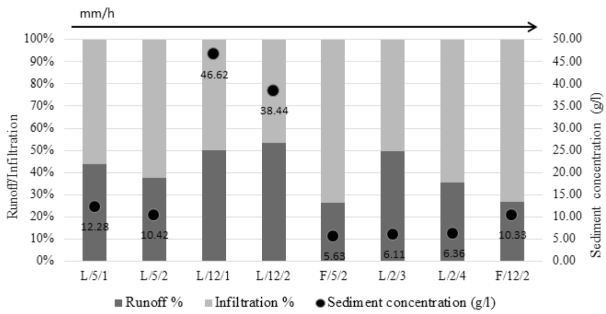


*Figure 1. Runoff, infiltration rate and sediment concentration arrayed by precipitation intensity (Table 2.)*

Figure 2. shows a pairwise comparison of the runoff rate ([%]; upper part of the matrix) and sediment concentration ([g/l]; lower part of the matrix) among the experiments to examine the effect of the slope and surface. Simulation code in the matrix cells reveals the higher value from the comparison. Beside the 12% slope dominancy on both runoff rate and soil loss concentration, the marked (asterisk) cells –primarily extreme moisture content simulation – show the pairs, where the surface status was dominant against the slope. During the inland inundation, simulation (L/2/3) the runoff rate was higher than in laboratory 5% slope steepness, and field experiments (Figure 1, 2.). Defersha, – Melesse (2012) studied the erosion of three different soil types (one of them was a Cambisol) also in laboratory, but in smaller plot. They also found that slope was a dominant factor during the erosion but the runoff rate and sediment concentration varied with initial moisture contents.

| | **L/5/1** | **L/5/2** | **L/12/1** | **L/12/2** | **L/2/3** | **L/2/4** | **F/5/2** | **F/12/2** |
|---|---|---|---|---|---|---|---|---|
| **L/5/1** | | L/5/1 | L/12/1 | L/12/2 | L/2/3* | L/5/1 | L/5/1 | L/5/1* |
| **L/5/2** | L/5/1 | | L/12/1 | L/12/2 | L/2/3* | L/5/2 | L/5/2 | L/5/2* |
| **L/12/1** | L/12/1 | L/12/1 | | L/12/2 | L/12/1 | L/12/1 | L/12/1 | L/12/1 |
| **L/12/2** | L/12/1 | L/12/1 | L/12/1 | | L/12/1 | L/12/1 | L/12/1 | L/12/1 |
| **L/2/3** | L/5/1 | L/5/2 | L/12/1 | L/12/2 | | L/2/3 | L/2/3* | L/2/3* |
| **L/2/4** | L/5/1 | L/5/2 | L/12/1 | L/12/2 | L/2/4 | | L/2/4* | L/2/4* |
| **F/5/2** | L/5/1 | L/5/2 | L/12/1 | L/12/2 | L/2/3* | L/2/4* | | F/12/2 |
| **F/12/2** | L/5/1* | L/5/2* | L/12/1 | L/12/2 | F/12/2 | F/12/2 | F/12/2 | |

*Figure 2. Matrix summarizes the pairwise comparison of the runoff ratio and sediment concentration among the experiments. Different colours indicate different slope angles.* indicates the results which are not follow the slope trend*

## Conclusions

Based on the gained data runoff and sediment concentration were correlated better with slope but its actual effect on the runoff and sediment concentration could vary with the moisture content and surface roughness. Inland inundation occurs mostly in flat terrain, where local topology has a small relief. Our results imply, in saturated soil condition the sediment transport is significant in local scale, which could encourage the crust development and change hydraulic conditions as well. Hence, more experiments that are complex are needed to reveal the dependences of the factors. It was also found that the field validation is essential for checking the goodness of the laboratory experiments to avoid extrapolation errors.

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**References**

Assouline, S., Ben-Hur M. (2006): Effects of rainfall intensity and slope gradient on the dynamics of interrill erosion during soil surface sealing. Catena **66**: 211 – 220. DOI: 10.1016/j.catena.2006.02.005

Centeri Cs, Jakab G, Szalai Z, Madarász B, Sisák I, Csepinszky B, Bíró Zs (2011): Rainfall simulation studies in Hungary In: Fournier A J (szerk.) Soil erosion: causes, processes and effects. 276 p. New York; Basel: Nova Science Publishers, pp. 177-218. (ISBN:978-1-61761-186-5)

Defersha, M. B. and Melesse, A. M. (2012): Effect of rainfall intensity, slope and antecedent moisture content on sediment concentration and sediment enrichment ratio. Catena **90,** 47–52. DOI:http://dx.doi.org/10.1016/j.catena.2011.11.002

Gómez, J.A. and Nearing, M.A. (2005): Runoff and sediment losses from rough and smooth soil surfaces in a laboratory experiment. Catena **59**, 253–266. DOI: http://dx.doi.org/10.1016/j.catena.2004.09.008

Jakab, G., Szalai, Z. (2005): Barnaföld erózióérzékenységének vizsgálata esőztetéssel a Tetves-patak vízgyűjtőjén (Erodibility measurements in the Tetves catchment using rainfall simulator) . Tájökológiai Lapok **3** (1): 177–189.

Iserloh, T., Ries, J.B., V., Cerdà, A., Echeverría, M.T., Fister, W., Geißler, Kuhn, N.J., León, F.J., Peters, P., Schindewolf, M., Schmidt, J., Scholten, T., Seeger, M., (2012):. Comparative measurements with seven rainfall simulators on uniform bare fallow land. Zeitschrift für Geomorphologie, **57**, 11–26.

Kerényi A. (1986): Az iniciális erózió laboratóriumi vizsgálata homokon és szerkezetes talajokon (Laboratory Simulation Study on the Initial Erosion of Sand and Soils with Well Developed Structure) Agrokémia és Talajtan **35**: pp. 18-38.

Kinnell, P.I.A. (2016): A review of the design and operation of runoff and soil loss plots. Catena **145**: 257–265. DOI:http://dx.doi.org/10.1016/j.catena.2016.06.013

Szabó J., Jakab G., Szabó B. (2015): Spatial and temporal heterogeneity of runoff and soil loss dynamics under simulated rainfall. Hungarian Geographical Bulletin **64:**(1) 25-34.

Szalai Z, Szabó J, Kovács J, Mészáros E, Albert G, Centeri Cs, Szabó B, Madarász B, Zacháry D, Jakab G (2016): Redistribution of soil organic carbon triggered by erosion at field scale under subhumid climate, Hungary. Pedosphere 26:(5) 652-665. DOI: http://dx.doi.org/10.1016/S1002-0160(15)60074-1

Zámbó, L., Weidinger, T. (2006):Karsztkorróziós talaj-hatás néhány tényezőjének vizsgálata esőszimulációs kísérletek alapján. Táj, környezet és társadalom. Ünnepi tanulmányok Keveiné Bárány Ilona professzor asszony tiszteletére. Szeged. 757–765.

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