Overland flow generation at flysch slopes

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1. Background

Overland flow is one of basic components in any concept of runoff formation. Numerous field studies using different approaches (water balance components at experimental runoff plots, rainfall simulators experiments, infiltration measurements, etc.) related to the overland flow generation were conducted over decades.

Despite of that, it is not easy to find the information on how much rainfall can be expected to flow on a hillslope as an overland flow at certain rainfall intensity and soil surface characteristics (e.g. hydraulic conductivity, slope, wetness, vegetation cover). Such information is important for flood forecasting and protection as well as for validation of the models. It is especially topical when considering hydrological response under expected climate change, namely due to higher rainfall intensities caused by intensified meteorological phenomena.

We would like to start filling the gap in Slovakia (Western Carpathians) by conducting rainfall simulator experiments for characteristic landuse units. This poster presents first results of the experiments from a small mountain catchment typical for higher elevated regions of the Western Carpathians.

The objectives of the research are to answer the following questions:

1. How quickly does the overland flow form?
2. How much of rainfall flows as an overland flow?

2. Study area and approach

The study was conducted in the foothill part of the Jalovecký creek, northern Slovakia, a typical small tributary of the main mountain river (the Váh river) flowing through the valley surrounded by mountain ranges (Fig. 1).

- We selected 5 research plots on slopes built by the flysch rock formations (hydrogeologically little permeable complex of repeating layers of claystone, shale and sandstone). Loams, clay loams and silt loams developed on the bedrock. Median unsaturated hydraulic conductivity of soil surface measured by Decagon Mini Disk Infiltrometer at tension -2 cm varies mostly around 5.10^{-5} $m.s^{-1}$ (Fig. 3).
- Research plots used to be argicultural land in the past. At present they are permanent grasslands.
- 100 rainfall simulator experiments were conducted using the portable Wageningen simulator. Mean slopes and soil moisture on the sites were 7 ° - 12 ° and 20- 41 vol. %, respectively.
- The most frequent 10-min. rainfall intensities in the area reach up to 0.5 mm per 10 minutes (Fig. 3).
- Replicated rainfall simulator experiments with three extreme intensities of simulated rain of 5.3 $mm.min^{-1}$, 4.2 $mm.min^{-1}$ (both with durations 5 minutes) and 2.4 mm.min-1 (duration 10 minutes) were conducted at each plot.
- Two main characteristics were evaluated, namely **time of overland flow appearance** and the amount of applied rainfall which left the irrigated plot as overland flow (further **overland flow percentage**). Increase of soil moisture caused by the irrigation was measured as well.
- Independent 1 to 3 profiles of electrical resistivity tomography (ERT) were made at each research plot using the original design allowing to obtain higher resolution data for shallow soil layer (Kostka and Holko, 2016). The ERT was first measured before the irrigation. Then, the center of the profile was irrigated with simulated rainfall of 60 mm and 9-18 repeated ERT measurements were carried out.

References:
Kostka, Z., Holko, L. (2016): Non-destructive vizualization of infiltration using electrical resistivity tomography. *Acta Hydrologica Slovaca*, 17, 1, 51-64.

Kostka, Z., Holko, L. (2017): Application of electrical resistivity tomography at the monitoring of infiltration into soil profile. *Acta Hydrologica Slovaca*, 18, 1, *in review*.

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Fig. 1. Typical landscape of northern Slovakia – the mountain valley surrounded by mountains. The Jalovecký creek catchment is located on the left side of the photograph (arrows).

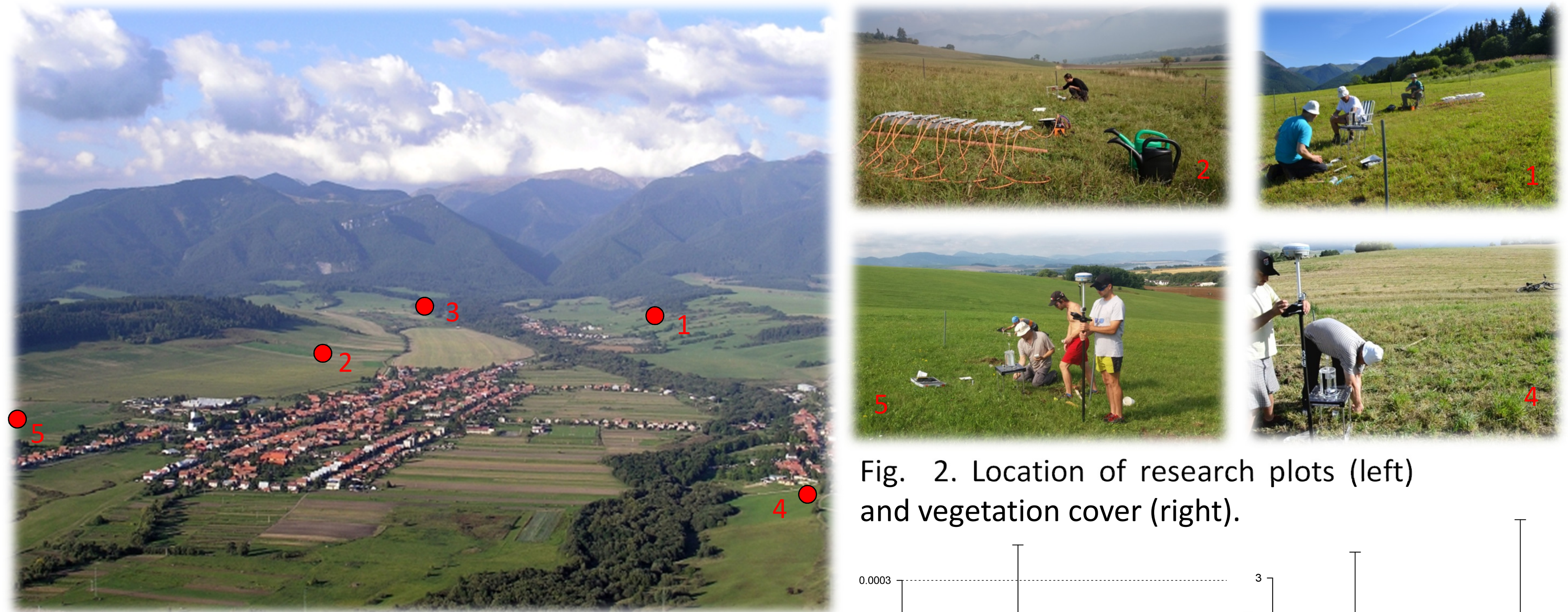

Fig. 2. Location of research plots (left) and vegetation cover (right).

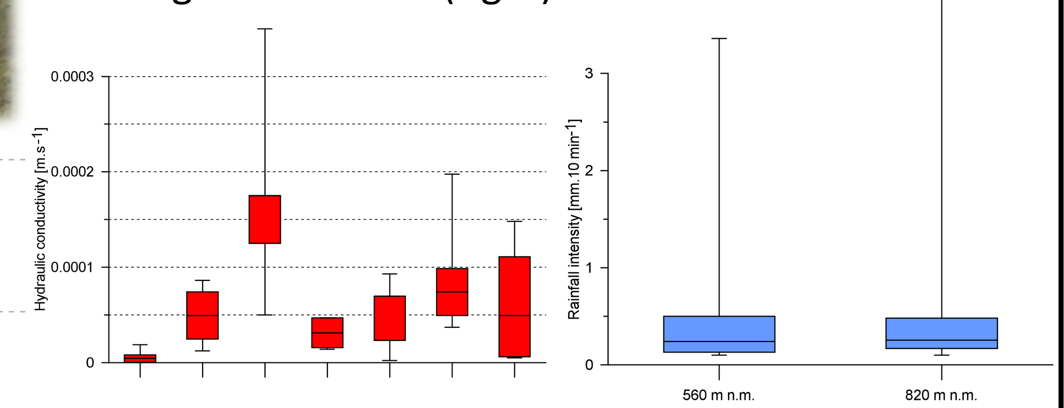

Fig. 3. Unsaturated hydraulic conductivity of the soil surface and intensities of 10-minutes rainfalls at the lowest and highest altitudes of the studied area in warm periods of years 2013-2016.

3. Results – rainfall simulator experiments

- Despite extreme intensities of simulated rainfalls, overland flow was not observed in 7 out of 100 experiments.
- Time of overland flow appearance typically varied between 30 and 200 seconds. The overland flow mostly represented up to 40% of the applied rainfall (Fig. 4).
- ANOVA showed that the means of time of overland flow appearance are equal. All measurements of overland flow percentage represent the same population with exception of one research plot.
- Overland flow percentage was relatively similar for the two higher rainfall intensities and much smaller for the intensity 2.4 $mm.min^{-1}$ which is still extreme in the study area (Figs. 5 and 6).
- Overland flow percentage was increasing with rainfall duration (Fig. 7), but its value was smaller than expected taking into account extreme rainfall intensity.
- Initial soil moisture influenced the results only for the smallest rainfall intensity. Influence of slope was negligible in all experiments.
- Further experiments will be focused on the effects of rainfalls with smaller intensity and longer duration.

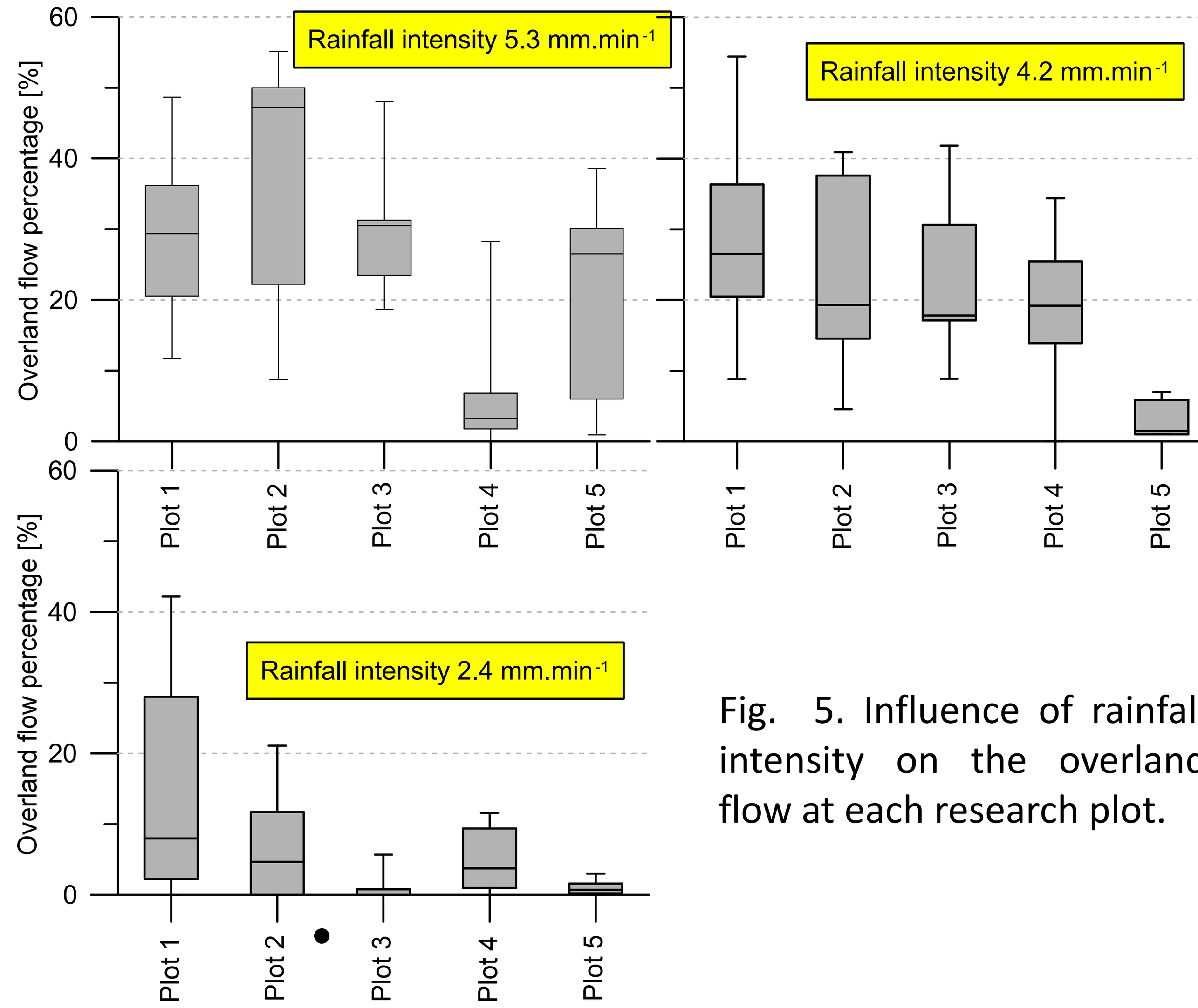

Fig. 5. Influence of rainfall intensity on the overland flow at each research plot.

4. Results – electrical resistivity tomography

- ERT proved useful to visualize inhomogeneities existing in the studied sections of the slope (length about 1.5 m, depth about 30 cm) **before** the application of irrigation.
- Downslope movement in the **upper 5-15 cm** of the soil was most frequently detected after the irrigation (Fig. 8). Preferential flow and slower percolation of the water to deeper soil horizons were less frequently visualized and their detection was burdened with **large uncertainty**.
- **Very large differences** in soil profile inhomogeneities and flow patterns were found at small distances (the distance of individual profiles was about 5 m).
- We are processing measurements of induced polarization carried out simultaneously with apparent specific resistivity.

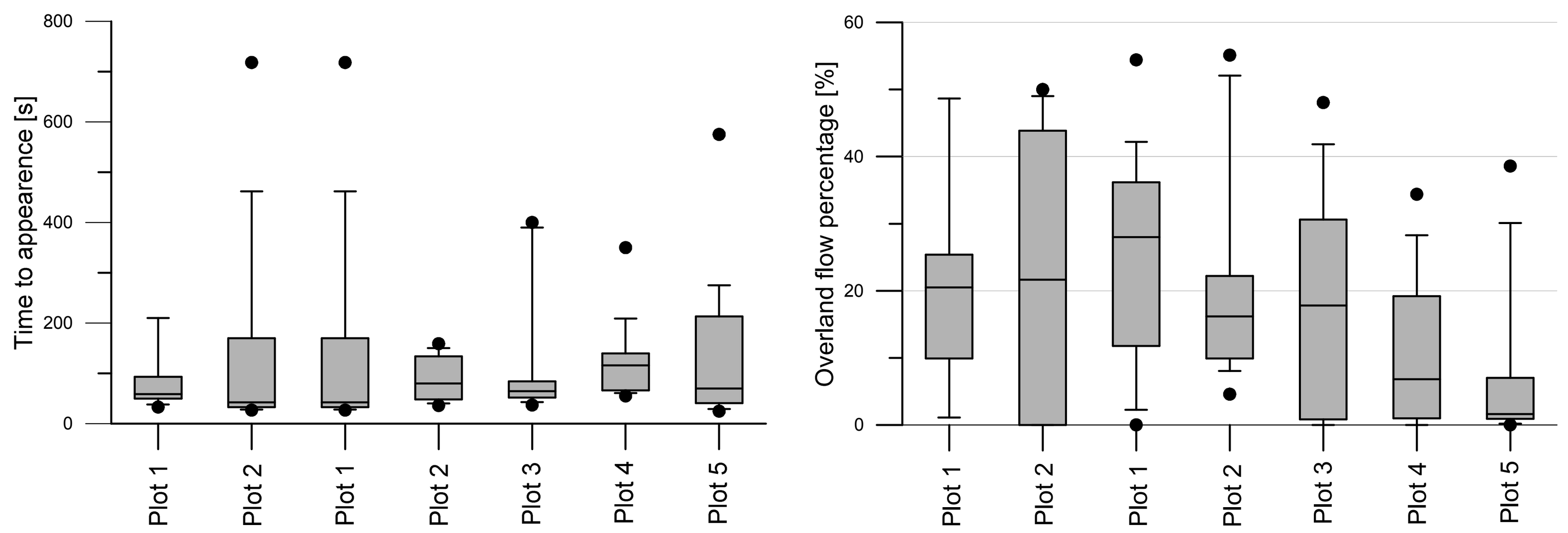

Fig. 4. Boxplots of all rainfall experiments.

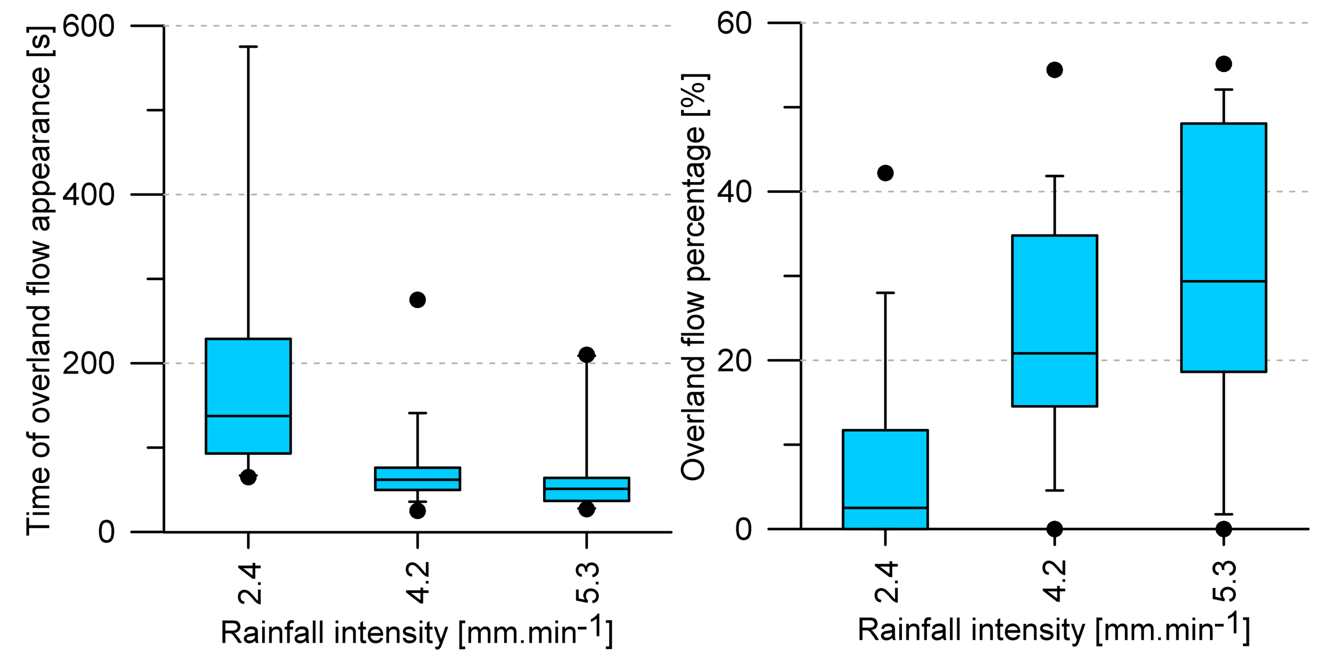

Fig. 6. Influence of rainfall intensity in the entire study area (all plots combined) .

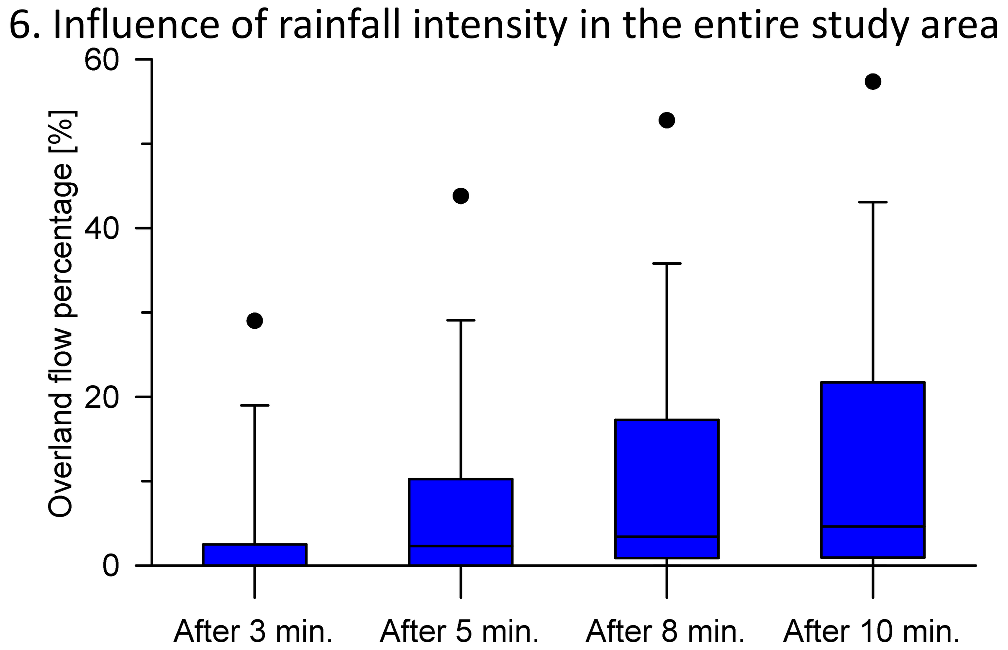

Fig. 7. Increase of overland flow percentage with rainfall duration.

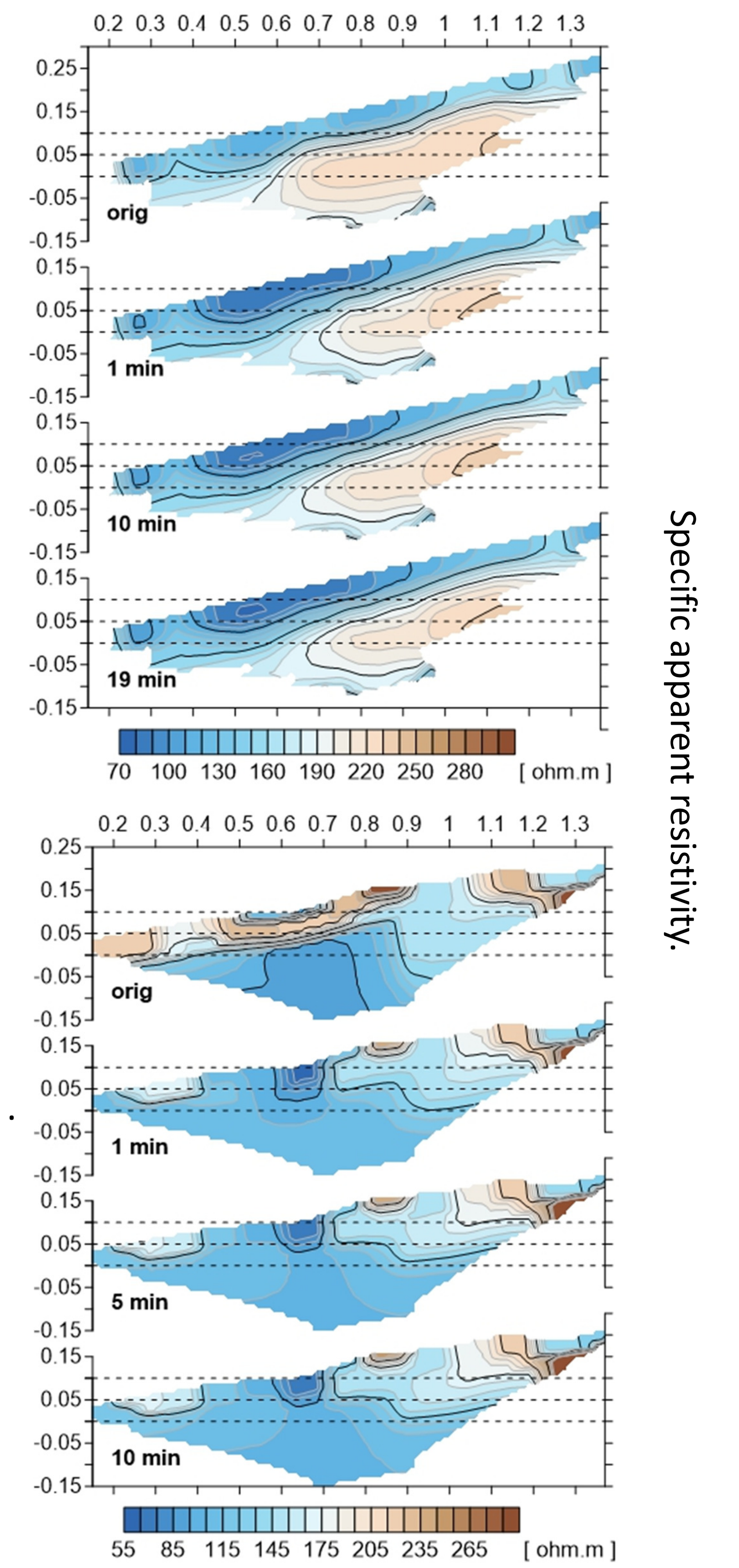

Fig. 8. Examples of downslope movement (above) and percolation (below) of irrigation water visualized by ERT.