COLLECTING AND EMPLOYMENT OF SOIL PARAMETER FOR NUMERICAL FLASH FLOOD MODELING IN ULTRA-SMALL WATERSHEDS

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ABSTRACT. Collecting and employment of soil parameter for numerical flash flood modeling in ultra-small watersheds. Thunderstorms and other catastrophic whether phenomena more frequently occur over the past decades in Hungary. Their consequences, such as flash flood have been causing economic losses with an increasing frequency lately. The most hazardous areas are the mountainous-, and low-hilly areas. Numeric runoff models are essential tools for the prediction of flash floods. However they require several initial boundary condition parameters, among which soil data are indispensable elements. In the present study, we present the employment soil physical and precipitation data collecting methods from a pilot catchment in SW Hungary for runoff simulation and interpret their efficiency.

Key words: flash flood, soil moisture, soil thickness, numeric modeling,

1. Introduction

The frequency of extreme rainfall events have been increasing in Hungary (Horváth, 2005). Cumulative rainfall totals may also exceed the annual mean values for a given area during heavy downpours and intense updrafts. Their consequences may also be disastrous: ephemeral streams flood the floodplains causing serious damage and in cases loss of human lives (Czigány et al. 2010).

The major character of flash flood events is best described by the following term: too much precipitation in too little time (Czigány et al. 2010). The severity of flash floods, as well as discharge is affected by several environmental boundary conditions, including topography, land use, soil texture, soil depth, soil moisture content and infiltration rate.

The present study focuses on the methods of soil moisture content and soil depth data collection in an experimental watershed in SW Hungary. The reason for

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selecting these environmental boundary condition parameters for regular measurements and monitoring is their importance as input data for numeric runoff modeling. For monitoring purposes and to supply data for numerical runoff model we selected a small low-mountain catchment in the Western Mecsek Hills, SW Hungary. Our pilot catchment is the Pósa Valley, that covers an area of 1.7 km^2, is located in the Western in the immediate eastern vicinity of the village of Hetvehely (Figure 1.). The Pósa Valley is a tributary valley of the Sás Stream which belongs to the drainage system of the Bükkösdi-víz and the River Drava. This pilot catchment located on the upper part of the drainage system where seven major, 3-5 hours long flash flood event has occurred since 1951 and caused significant damages to the villages of Bükkösd and Hetvehely (Vass 1997).

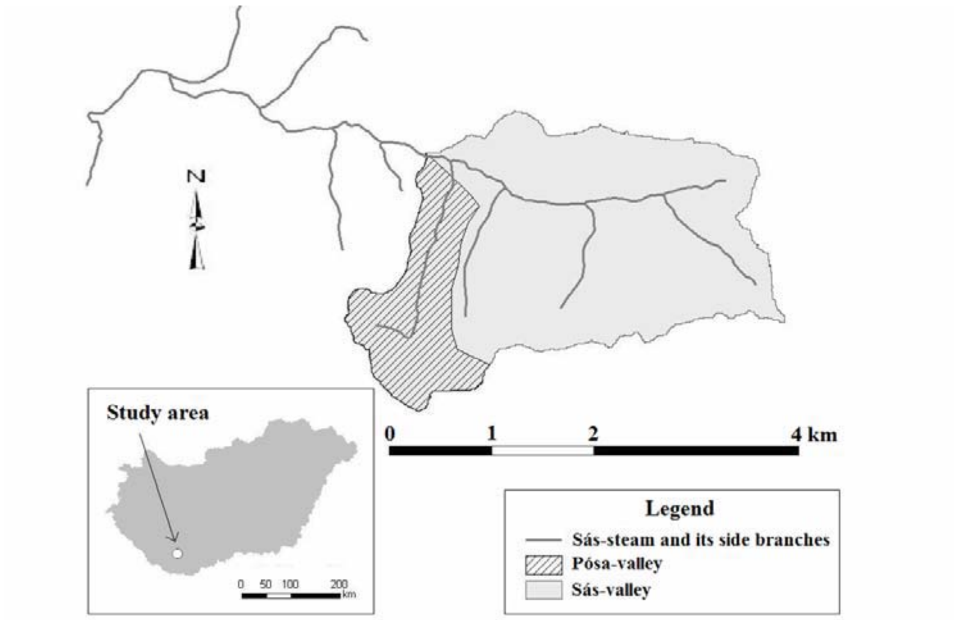

Figure 1. The location of our study area.

2. Methods (and materials)

In the present study we analyzed some static (temporally constant or quasi-constant) environmental parameters. Thus studies parameters are soil moisture and soil depth. In addition, other parameters, such as soil moisture capacity, infiltration and canopy storage were also considered. To measure these factors, we set up a monitoring network in Pósa-valley so that the monitoring locations can represent the characteristic of the valley the best as it is possible, from the aspect of the relief, soil parameters, and land cover.

The system includes ten field-deployed Decagon EM50 (Decagon Devices Inc., Pullman, WA, USA) type rain gages, soil moisture sensors, and soil temperature sensors. In addition, we also carried out soil moisture measurements at the northern part of the valley with a TDR-300 portable soil moisture probe, to detect correlation between relief (elevation above valley floor), slope and soil moisture.To determine static boundary conditions, such as soil depth and stratification – on the whole area of the Pósa-valley – we carried our 1-dimensional geoelectric geophysical (vertical electrical sounding, VES) studies that were subsequently verified with direct augering. VES measurements were taken in a 50-meter grid network. To determine soil texture laboratory particle size analyses were taken using static light scattering methods.

3. Soil moisture analysis of the cross sections

TDR-moisture measurements were taken at six occasions along a 600 meter selected cross-section between 2010 September and November. The sample area is located at the northern edge, i.e. the outflow of the Pósa Valley, where valley floor broadens to 40 meter, however the characteristics of the relief is make the measuring reasonable (Figure 2.).

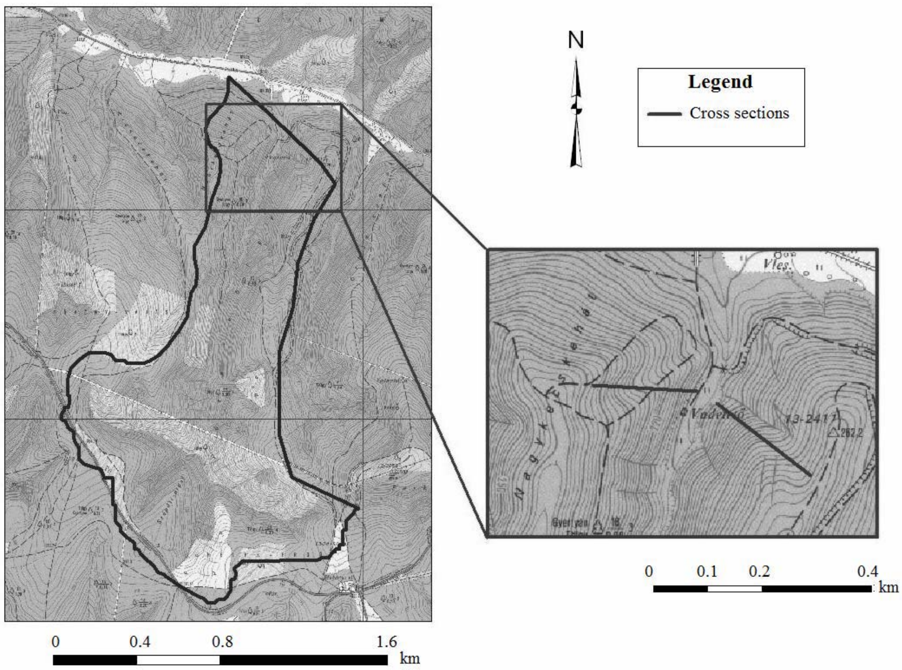

Figure 2. The location of cross sections

The western side of the cross-section is more diverse with a very steep slopes usually exceeding 40°. A forest service road crosses the slope about at halfway between the valley floor and the summit. Uphill form the road the slope gradually flattens out - even a little pit is noticeable – and on the upper part it is rising moderately to the top. The eastern side seems much more homogenous the elevation is constant with more or less 25° to the top. So we had expected different results about the two sides (Figure 3.).

The measurement points on both sides were marked at a regular distance of 4 meters. In those cases, where there are major differences in the relief, or special circumstances were encountered, additional points were inserted. At every point, 2 consecutive measurements were taken, and after we registered their average value. If the deviation exceeded 20%, a third measurement was taken.

The parameters were collected from both sides of the cross section, in a weekly term. To collect data, we used the TDR-300 (Spectrum Inc. Planfield, IL, Unites States) sensor using 20-cm long stainless steel electrodes.

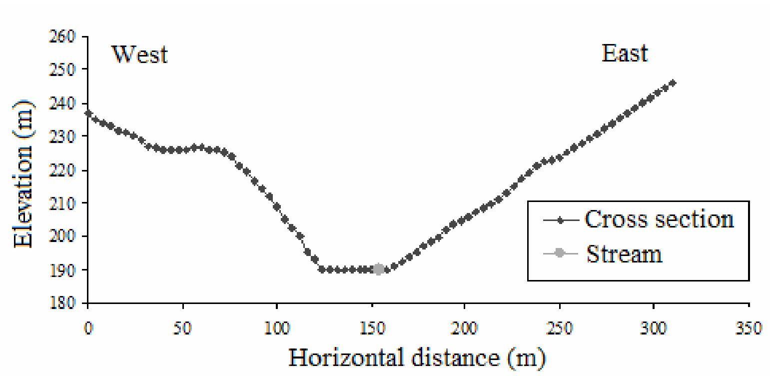

Figure 3. The cross section of the valley at the line of the TDR measured profiles

3.1 Soil moisture and relief analysis

On the eastern side of the studied cross-section between an elevation of 25 to 35 meters above the valley floor the soil was almost saturated for all six measurement occasions. This deviance and unusual behavior of soil at these locations is most likely caused by the forest service road that dissects the slope.

The more compacted soil of the forest road has a better water storage capacity compared to the intact soils. However the western slope has a noticeable trend of lower values, which can be explained with the changes in the relief. Usually the steepest area has lower soil moisture values. This is the consequence of the different soil thickness.

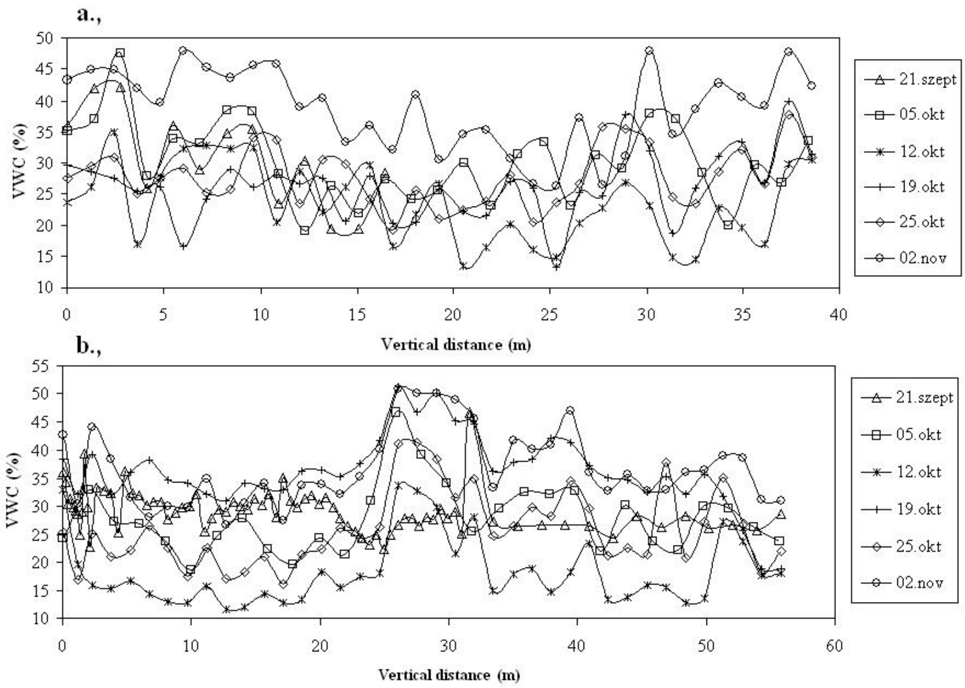

Figure 4. Comparison of the changes in the relief and soil moisture content.
a., western section, b., eastern section

We experienced significant differences of the two slopes. In case 5 measurement of 6 the western side has higher soil moisture content values. This effected by the heterogeneous soil thickness and different rate of infiltration. Steep slopes spatially correspond with shallow soil, so the precipitation remains in the upper layer, cannot infiltrate deeper, than 20-30 cm. The relative proximity of soil surface will enhance evaporation and soil moisture loss from the soil (Figure 4.).

3.2 Soil moisture and precipitation analysis

For comparison we used the recorded precipitation data by the Decagon monitoring stations which are placed on slope of the cross sections for the period of 9. September to 11. November (Figure 5.). We used the average values of soil moisture content for the both cross sections.

The collected data was downloaded once a week. The time between the two measuring is a “blank” so we can not represent the changes affected by the rainfall.

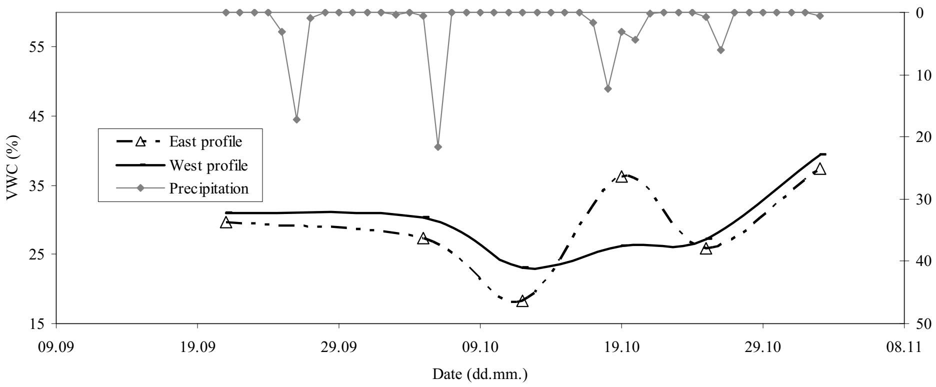

Figure 5. Comparison of the cross sections weekly average soil moisture content and the daily precipitationat since 9th September till 11th November.

However the precipitation values are presented in daily distribution (mm). To compare these two figures, it is assumed that although the precipitation is the most important factor affecting soil moisture, however, its role is not exclusive in determining the duration of runoff to infiltration into soil. explanation to the change of values. In October 12 the data value is correct, because there were no rainfall events on the previous days. In October 19 the rising level is belongs to an intense precipitation event However between October 18 and 22 there was 22 mm precipitation. The most unusual exception is November 2, when we have detected extremely high soil moisture, but the last rainfall event totaled a mere 7 mm, occurred 5 days before the selected rainfall event.

4. Real-time soil moisture and precipitation monitoring

Ten Decagon Em50 (Decagon Devices Inc., Pullman, WA, USA) type of real time precipitation, soil moisture, and soil temperature sensors wer deployed in our study area during August, 2010 (Figure 6.). The monitoring points were placed to represent the catchments geomorphology and vegetation coverage features accordingly (**Error! Reference source not found.**.). One monitoring station (1) was placed at the northern border (outflow point) of the catchment, 2.5 km east of a meteorological station of the National Meteorological Service as a reference point. Two monitoring stations (2 and 3) were placed in the line of our TDR-300 instrument measured cross sections. Four stations (2, 3, 4 and 5) are located under high dense canopy, two (6 and 7) in sparsely wooded sites and three (8, 9 and 10) are in clear cuts.

The precipitation data were recorded with automated tipping-bucket Decagon ECRN-100 High-Res Rain Gauges (Decagon Devices Inc., Pullman, WA, Unites States), The rain gage has a resolution of 0.2 mm rain.

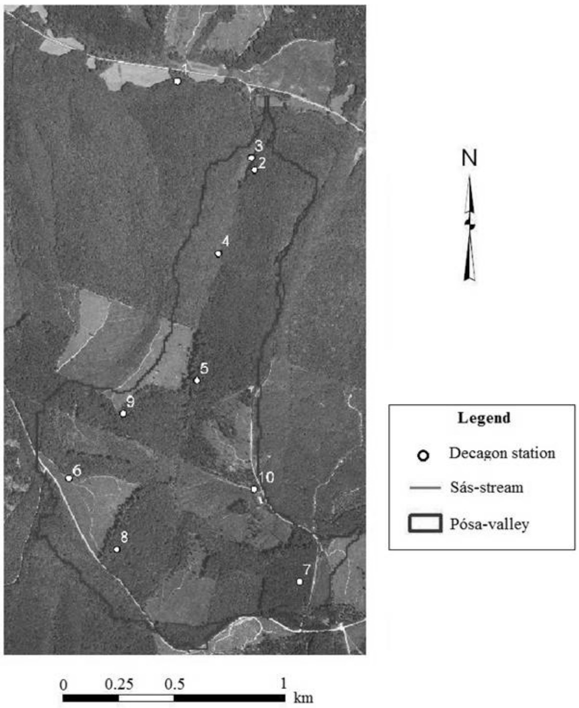

Figure 6. Location of the monitoring points

The soil moisture measurement is taken with Decagon 5TM sensors connected an EM52 logger. The 5TM determines VWC % by measuring the dielectric constant of the soil (or other media) using capacitance/ frequency domain technology. Signal filtering minimizes salinity and textural effects, making the 5TM accurate in almost any soil or soil-less media. Every soil moisture sensors were deployed at a soil depth of 20 cm. Data was logged and stored by Decagon Em50 dataloggers in 10-minute time intervals.

We were examined the correlation between the precipitation and soil moisture content of our cross sections. The data recorded in the same time interval as the case of the TDR-300 measured profiles thus the precipitation dataset is the same but the observed soil moisture content datasets resolution is higher (Figure 7.)

The recorded data show higher correlation. The curve of soil moisture content follows better the precipitation event than the smoothed curve by the data from TDR-300 instrument.

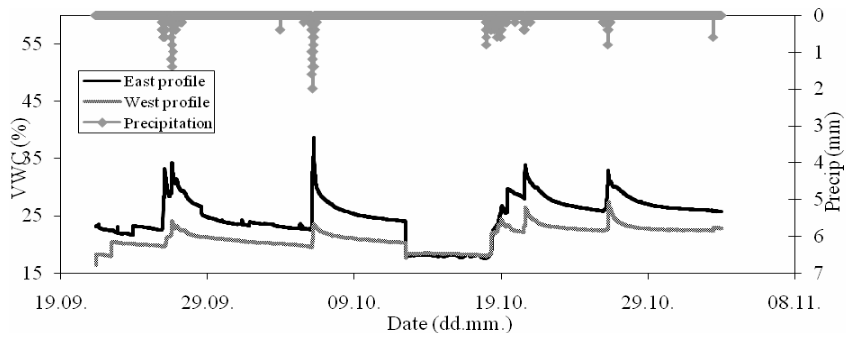

Figure 7. 10 minutes term recorded precipitation and soil moisture content data by the monitoring station 2 (East profile) and 3 (West profile).

5. Topsoil thickness examination

In Hungary the generally used database for topsoil thickness examinations is the AGROTOPO which edited by the Hungarian Pedologycal Research Institute. This database mainly set for agricultural researches.

According this database the topsoil thickness in our study area, and its surrounding is between the range of 0 and 40 cm, even so our primarily observation indicated much thicker soil layers in some places of the catchment.

For an accurate numerical model, we need higher resolution and accurate soil depth values are required therefore we obtained soil depth with various methods. We have used a geoelectrical geophysical method supplemented with direct soil mechanical soundings, and drillings to gather data of this type.

5.1. Geoelectrical geophysical examinations and drillings

To determine the soil depth we used a 1-dimensional VES surface geoelectrical method applied the RESP-12 geoelectrical system with Schlumberger electrode arrangement. The method is that from the surface direct current is conveyed into the ground through two mobile current probes (A, B) and two steady potential probes (M, N) are detecting the vertical changing of resistivity, what is determined primarily by the moisture content and porosity, secondly by the mineral composition of the layers.

Those layers which have higher porosity, and the pores that are filled with moisture, convey the current more efficiently, than the more compact bedrock thus the resistivity is lower in these layers and when the current reach vertically the bedrock, a high drop expected in the resistivity curves.

The first VES results what we get in the field, are need further evaluation, because these data are giving only apparently resistivity information. These evaluations are done with the Res1D, 1-D resistivity, IP and SIP modelling software, by M.H. Loke (Figure 8.).

Very important to the geological surround of the probing is taken into account the interpretation of the resistivity curves, because each type of rock has different resistivity according their fragmentation, porosity and mineral composition. The geology of our study area is reasonably heterogeneous. Nine types of rock formations are found, for instance. Some of them show lower drop of in the resistivity curve compared the topsoil therefore we need direct information through boreholes of the depth of bedrock to validate the VES (Table 1**Error! Reference source not found.**.).

For these drilling according the accessibility we use a mobile tracked KUBOTA KCR121R type hydraulic drilling machine, with 125 mm diameter spiral auger or a manual Stihl BT 360 auger with 60 mm diameter spiral drill. In both case dry drill methods are used.

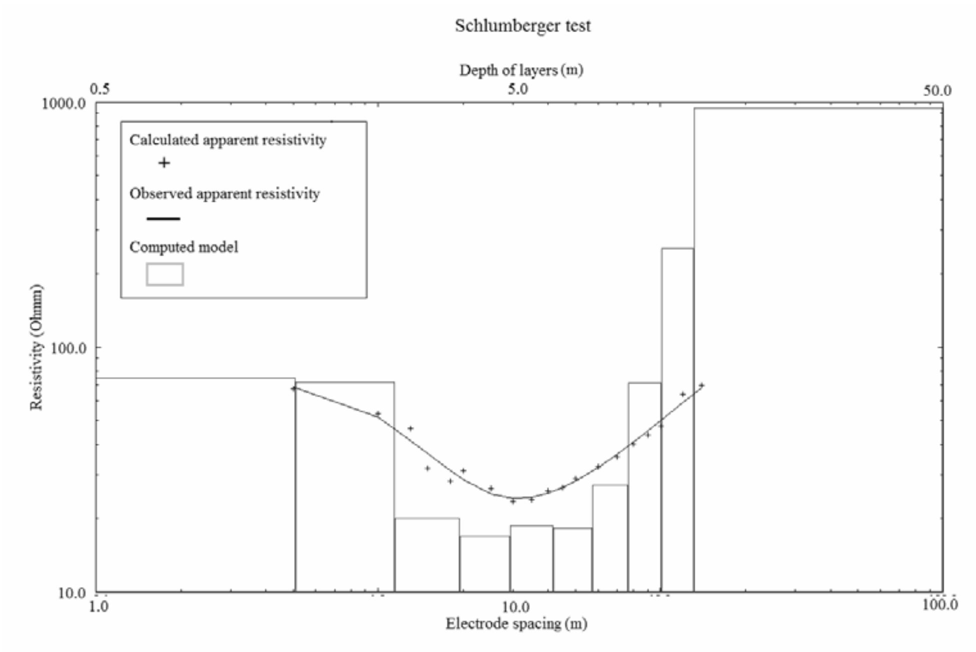

Figure 8. The V11/4 marked VES points evaluated resistivity curve by Res1D software

Table 1. Comparison of VES indicated bedrock depth and borehole depth.

ID of Drilling and VES points	Drilling diameter (mm)	Dept of drillings (meter)	VES indicated bedrock depth (meter)
V41/6	125	5.0	4.9
V42/6	125	2.8	3.1
V43/6	125	4.9	5.7
S1/1	60	2.0	2.1
S1/2	60	1.4	1.6
S1/3	60	2.2	2.1
S1/5	60	1.2	1.5
S1/6	125	1.2	1.0
S1/7	125	3.3	2.9

Since July, 2010 we have taken 190 VES point measurements, 9 borehole drillings and 8 soil mechanical soundings to verify VES measurements. VES measurements were taken in 50 x 50 m grid in order to get sufficiently high resolution data on soil depth in the Pósa-valley. Until today, about half of the total area of the Pósa-valley mapped with VES at 50-meter spatial resolution (Figure 10).

6. Soil sample analyses

To analyze the soil samples for soil moisture content and soil texture, soil samples were collected in 20-centiemeter vertical intervals from the borehole soil cores. Samples were taken into ziplock bags immediately after removal form the auger and then were taken to the Soil Physical Laboratory of University of Pécs, Soil samples were then weighed and then were subsequently oven-dried at a temperature of 60 ^{o}C until constant weight was achieved. The oven-dried samples were then weighed again order to calculate and obtain their gravimetric moisture content.

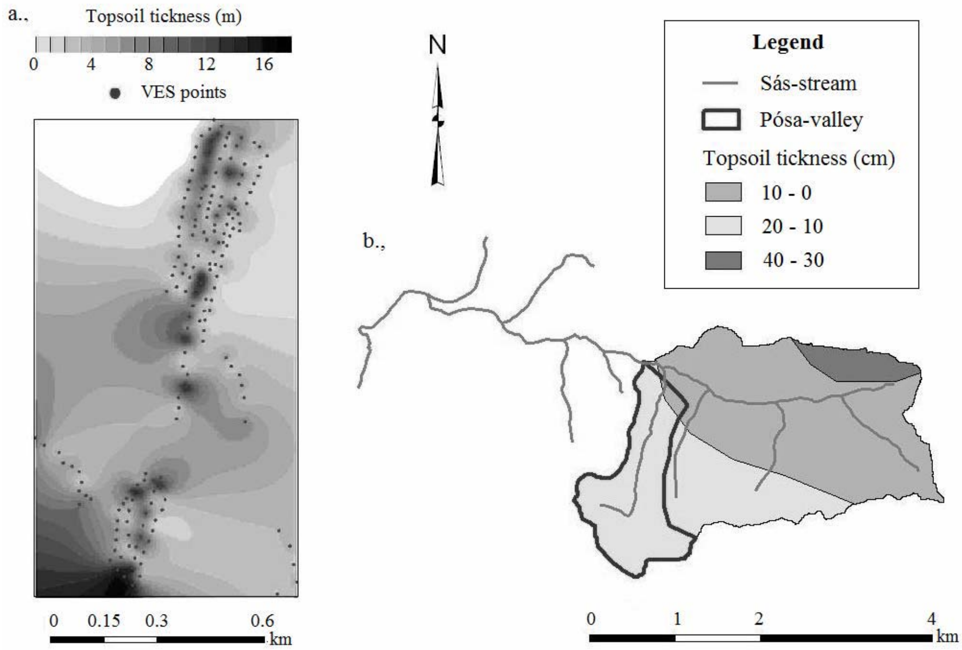

Figure 9. Comparison of our measured soil and sediment depth (a) data and AGROTOPO (b)

Particle size analyses were carried out by static light scattering method using a Fritsch ANALYSETTE 22 (FRITSCH GmbH, Idar-Oberstein, Germany) particle size analyzer.

As the measurement range of the instrument spans from 0.3 μm to 300 μm particles larger than 300 μm were removed from the sample. 1.4 mm, 1.0 mm, 0.5 mm and 0.25 mm mesh diameter sieves were used, with wet sieving method. The weight of each classified samples was determined after drying. The rest of the sample was collected in the throughflow suspension. Suspension particle size distribution was the determined by static light scattering methods.

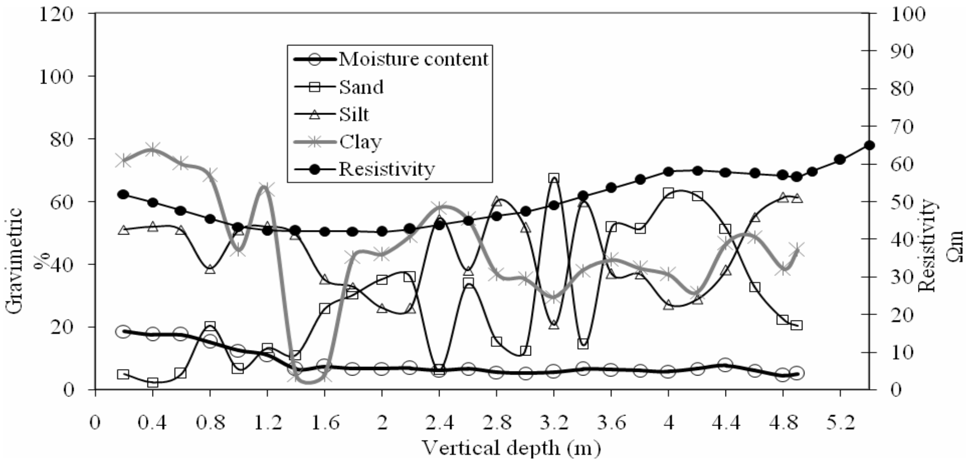

Figure 10. The V43/6 marked borehole and VES points vertical changes of interpolated resistivity dataset (Ωm), particle size and moisture content (%).

In general, the ratio of clay size particles increased with increasing depth . The resistivity remained 60 Ωm below the depth of 5.4 m indicating bedrock below this depth. Here, the bedrock is consist of shale and clay stone according to literature data –maps compiled for the studied area (Konrád 2002). The resistivity of clay stone represents lower resistivity value, meaning a resistivity less than 50 Ωm (Erkel 1970.) This boundary between the unconsolidated sediments and the hard bedrock is indicated by a drop in the resistivity curve. Particles size distribution of borehole samples indicate alternating layers of clayey, sandy and silty sediments. Resistivity curves however do not correlate with the alternating pattern of soil texture.

7. Results

We have used various methods to collect soil physical data. Each method, to a certain degree, owes many advantages and disadvantages (Table 2.) but if these methods are combined, the fault and measurement errors are minimized.

The TDR-300 instrument is mobile a presents instant data what is not accurate any cases of our tested profiles hard to done the measurement correctly time to time in the same measuring points despite they are marked. The smaller pores and roots can be influence the results. The decagon monitoring points are more reliable from this aspect because those fix placed thus. But this network is not able to represent the soil moisture changing of the function of elevation as the TDR-300 instrument.

Table 2. Advantages and disadvantages of the employed methods.

Methods	Advantages	Disadvantages
TDR-300 measured cross sections	• Mobile • Gives instant result • Rapid	• Manual measurement (measurement faults can occur) • Longer term measured dataset • Measure only one parameter
Monitoring system of Decagon Em50 stations	• Accurate (not changing place) • Shorter term measured dataset • Real-time measurement	• Low horizontal resolution • Needs battery • Few data storage
VES	• Mobile • Not destructive • Rapid	• Small resolution • Presents mediate data • Validation needed
Drilling	• Presents direct information • Soil sampling	• Depends on accessibility • Not accurate in soil sampling (mixing samples) • Destructive
Soil sample analyses	• Accurate • Presents direct information	• Depend on the accuracy of drillings • Time-consuming

The VES measurements are suitable only to determine the depth of unconsolidated sediments and insufficient to track subsurface horizonation. Due to the longer electrode spacing the current entry is mixing the smaller resistivity variances layers. This inaccuracy can be amended by decreasing the electrode spacing but it is still insufficient to obtain highly reliable and accurate data. With 2-dimensional multi-electrode geoelectrical resistivity methods, planned to be employed in the near future, higher resolution resistivity and soil depth data will be obtained. In spite of the disadvantages of the VES method, it is fast and the measuring points easily accessible. However the measurement needs horizontal space, and profoundly depends on geomorphology

Thus, for verification and validation purposes, on-site augering and soil sampling are indispensable and essential tools, if data of high accuracy is needed. Through laboratory analysis of soil samples obtained important information about the individual layers of soil particle size distribution. The analyses are consuming more time and the accuracy of the result is depend on the drilling methods

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