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Measurement of initial soil moisture conditions for purposes of rainfall simulation experiments

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Abstract: The research on rainfall-runoff processes has become even more important in recent decades with respect to both flood and drought events as well as to expected impacts of considered climate changes. It is researched in different ways and at different scales according to the purpose. The rainfall simulator developed at Department of Irrigation, Drainage and Landscape Engineering is being used for purposes of detail analysis of rainfall-runoff process in order to research infiltration process which is straight related to retention of water in soil profile. It is necessary to measure initial soil moisture content as well as soil moisture content after the simulation for this purpose. Standard way to do it consists in taking undisturbed samples and analyzing them using gravimetric method which is considered as a direct way to do it. However, this way is time consuming and do not provide instant data. It is therefore considered as a good option to use sensors measuring soil moisture content indirectly using different sensors. The application of Theta Probe ML2x has been tested for this purpose because it would be an easy to use device providing instant data. As reference, gravimetric method and TOMST TMS3 sensors were used because gravimetric method is assumed to be the most precise way to measure soil moisture content and TMS3 sensors were in detail tested in laboratory of Department of Irrigation, Drainage and Landscape Engineering. The results of testing were analyzed using statistic measures and are presented in this paper together with the evaluation of data obtained during the simulation experiment. The results indicate reasonable results obtained by both considered types of sensors which are slightly better for TMS3 sensor.

1. Introduction

Soil erosion remains a big problem in the Czech Republic. It is estimated that about 50 % of agricultural land is at risk of increased soil erosion (Krása 2010). The factors controlling soil erosion are the climate (rainfall erosivity), the erodibility of the soil (soil texture), morphology (the slope), canopy cover and agrotechnology (Morgan, 2005). Soil moisture content influences the soil infiltration capacity which further affects the volume of surface runoff and consequently soil erosion (Gyssels et al. 1995).

Field rainfall simulator MDS NZ2 (Kavka et al. 2012) has been developed at the Department of Irrigation, Drainage and Landscape Engineering in 2011 and now it is used for estimation of vegetation protective effect called *C* factor (Wischmeier and Smith 1978). It is important besides others to measure soil moisture in the experimental plot before the simulation to be able to describe initial conditions of each simulation.

Until now, standard procedure (ASTM D 6459 2007) has been applied for purposes of soil moisture content measurement which consists in taking undisturbed soil samples and their gravimetric evaluation in laboratory. However, this method is demanding a lot of manpower and time for the laboratory analyses. Moreover, sampling affects conditions in the plot by disturbing the surface at several points which can affect the results or measured data. Thus, it can be advantageous to use for this purpose soil moisture content sensors. Its advantage consists in the fact that soil moisture content can be recorded continuously during the

simulation as well as after its end which provides more data for the evaluation of infiltration process.
For mentioned purpose, two different sensors for measurement of soil moisture content measurement were tested in relation to the standard one based on soil sampling and gravimetric analysis. These were ThetaProbe ML2x (Miller and Gaskin, 1996) and TOMST TMS3 Measuring System (Šanda et al., 2014). ThetaProbe is based on measurement of the change of impedance which depends on dielectric constant of the matrix into which the device is inserted. This device is only the sensor which cannot operate without power supply and datalogger which can store measured analogue data. TOMST TMS3 Measuring System is an independent system unit for measurement of soil and air temperature and soil moisture content. The measurement is based on time domain transmission principle and there is rich database of parameters related to different soil textures available for the conversion of measured values to desired units of temperatures and soil moisture content.

2. Materials and Methods

The study area is located in the Central Bohemia Region (49°46'55.0"N, 14°49'48.4"E). The climate is moderately warm with mean temperature 7.7 C and mean annual rainfall 596 mm. Cambisol is the most common soil at the site. From the point of view of texture, loamy sands dominate in the area according to classification after Novák.
The methodology consisted in measurement of several small plots by different methods and further evaluation of measured data. For this purpose, small plot was chosen at each locality of measurement with emphasis on its homogeneity with respect mainly to soil surface and slope. The dimensions of such plots were approximately 1.5×1.5 m. This plot was first equipped by six TMS3 sensors in a regular grid as the sensors need some time to get stabilized in the profile which is disturbed by their installation. Then, the soil moisture was measured between TMS3 sensors and around them at nine points in total by ThetaProbe. Finally, undisturbed soil samples were taken at also nine points in the plot. For sampling, sampling rings were used with inner diameter 7.2 cm and height 7.8 cm. The total volume of these rings is 0.318 liter. Samples were weighed immediately to avoid losses of water by evaporation which could affect measured values of soil moisture content.
Measurements were taken at two sites in the catchment of Býkovický stream which is one of experimental catchments operated by the Department of Irrigation, Drainage and Landscape Engineering and where rainfall simulator experiments are carried out. Plots were chosen on fields at different locations to represent different conditions from the point of view of soil moisture content. First one (Site 1) was located in the floodplain close to the stream to represent wet conditions while the second one (Site 2) uphill from the first one to represent drier conditions.

3. Results

The results obtained by the measurements were compared with respect to their average values as well as to their variance and range. First, the data obtained by gravimetric method were assessed as they were considered as a basis for further evaluation. There is high difference in variations for two sites. The variation was very high at the Site 1 (19.8) while it was low at Site 2 (2.0). The reason consists most likely by the water stored in macropores at Site 1.
As a second step, two-tailed test was performed on the difference of means of measurements carried out using tested sensors. The results show that at both sites the values can have mean equal to those obtained by gravimetric method ($t_{\alpha/2}$=2.16, t=1.21, α=0.05 for ThetaProbe; $t_{\alpha/2}$=2.17, t=2.16, α=0.05 for TMS3). However, the t-value is close to rejection region for TMS3. At Site 2, only TMS3 show possible equality of mean to the mean of results obtained by gravimetric method ($t_{\alpha/2}$=2.31, t=1.39, α=0.05) while ThetaProbe provided values which have different mean ($t_{\alpha/2}$=2.18, t=3.61, α=0.05). At Site 1, the mean of values measured lower in case of ThetaProbe (-5.8 %) and higher in case of TMS3 (10.2 %) when comparing to mean of values obtained gravimetrically. At Site 2, the mean values are lower for both tested methods (-15.7 % for ThetaProbe and -5.8 % for TMS3). All values are shown in Figure 1.

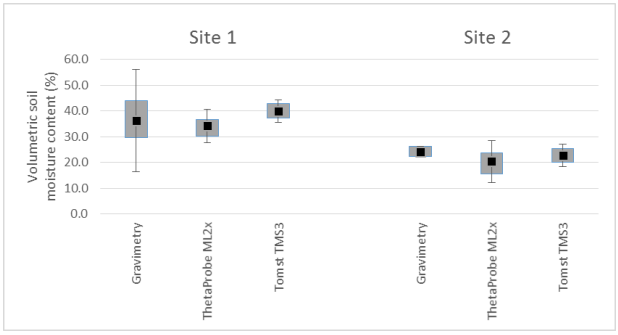

Figure 1.*Comparison of measured values of soil moisture content obtained by considered methods.*

4. Conclusions

The results of performed measurements show slightly better values for TOMST TMS3 sensors than for ThetaProbe. However, the difference between mean values are not high enough to exclude any of two tested sensors for further consideration for given purpose. Recent results are based only on measurement performed at two sites with different soil moisture content. It will be necessary to perform further measurements to have enough data for the final decision. When comparing the technical parameters of both tested sensors, more advantages can be found for ThetaProbe. This consists mainly in possibility to display measured data instantly using datalogger and in easier installation in soil profile because TMS3 sensors can be only hardly installed in compacted soil profile without damaging it which results in distortion of measured data.

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