Comparison of the soil matrix potential using tensiometers and Watermark sensors

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ABSTRACT: The monitoring of the dynamic of water flow is more and more important in studies geared towards soil erosion. The main aim of this paper is to evaluate monitoring techniques of the matrix potential and the handling and use in relation to the hydrologic dynamic of the soil. The study was developed in erosion plots at Avelar Experimental Campus, located in the mountain range region of the State of Rio de Janeiro – Brazil. Mercury manometer tensiometers and granular matrix sensors have been used for the hydrologic monitoring. The hydrologic behavior in relation to the matrix potential in the erosion plots has demonstrated that the most superficial depth showed the smallest potentials as well as a quick response in relation to the drainage. In relation to the temporal variation of the matrix potential in the upper plot of the erosion plots, one can observe that the plots with different handling presented different hydrologic behavior.

INTRODUCTION

Soil water availability is a major topic in order to attain an effective planning of the many activities related to agriculture, hydrology, engineering and environmental sciences in general. The optimization of agriculture requires the knowledge of the temporal and spatial soil water content variations, over extensive areas. Another important issue related to soil water dynamics is the contamination of the water table. Much of the environment degradation caused by man is a consequence of improper handling not only of fertilizers and pesticides in the agriculture but also of hospital, radioactive urban and domestic wastes, among others. Finally, the understanding of the water dynamics also plays a major role on soil erosion studies.

The remediation and prevention of such problems should be based on the understanding of the erosive-hydrologic behavior of the hillslopes. In order to achieve this, the processes of infiltration, storage and drainage should be taken into consideration, what turns necessary the monitoring of soil water, both by measurements of the water content and the matrix potential. Therefore, the continuous improvement of methods and instruments that help to understand the spatial and temporal variability of the soil water distribution in the soil, constitute a major research line of investigation.

During the last decade, the granular matrix sensor - GMS - has proved to be useful in measuring the soil matrix potential (Eldredge et al., 1993; Shock, 1998). This instrument, which recently received the commercial name of Watermark (Irrometer Co.), reduces the problems associated with the gypsum blocks since it uses a silt granular matrix that minimizes both the problems of the dissolution of the blocks and that one of the poor pore-size distribution. It also operates based on the principle of electric resistance, and has a gypsum block inserted in the granular matrix and connected to an electric current gauge (30KTC, Irrometer, Co.).

Because the matrix potential varies with temperature (Reichardt, 1996), it becomes necessary the correction of the GMS measurements, which are made using the relationship proposed by Thomson & Armstrong (1987), relating resistance - R (kΩ), temperature - T (°C), and soil water matrix potential - ψ (Jkg^{-1}), as described by Equation 1. The data obtained by the Watermark 30KTC model is automatically corrected when the user sets the soil temperature.

$$-\psi = \frac{R - 0.5}{0.1759(1 - 0.013T)} \qquad (1)$$

After the sensor is inserted into the soil, it will gain or lose moisture to the soil until the hygroscopic balance is achieved. On connecting the sensor to the gauge, an electric current flows between the electrodes, which will provide the corresponding soil matrix potential value (Figure 1).

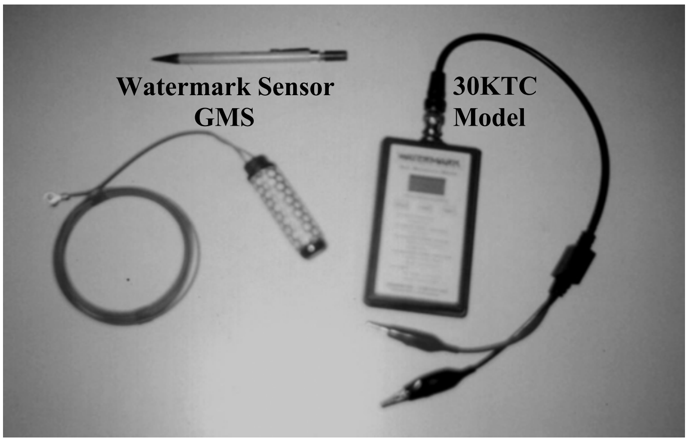

Figure 1. Watermark sensor (GMS) developed by Irrometer Co. On the left is shown the sensor with the cables, while on the right is shown the gauge used in this study (30KTC model).

This sensor is quite simple and extremely useful for the monitoring of soil water dynamics since it measures soil water potentials from 0 to –200 kPa. However, up to the moment, the GMS calibration curve was obtained only for matrix potentials from –10 to –100 kPa. According to Shock (1998), the granular matrix sensors are extremely convenient for water potential measurements because, unlike the tensiometers, they do not require fluxing the air outside the system after a long dry period, and the sensors start once again to record the data with the arrival of the new wetting front. Moreover, these sensors have a low cost and, using long electric wires, one can minimize the disturbing effects to plants and soils caused by the monitoring process.

Therefore, the main objective of this study is to compare the soil matrix potential measured by the Watermark sensor (GMS) and the tensiometer (mercury manometer), installed along different depths in erosion plots, in order to characterize their response to recharge and drainage periods.

METHODS

The experiments were carried out in 4 erosion plots located at the Avelar Experimental Campus (PESAGRO/RIO), in Paty do Alferes (RJ). These plots were constructed by a previous project, coordinated by EMBRAPA Solos (Desusmo, 1998; Palmieri, 1998), which involved many universities and institutions. This area is characterized by a mountainous environment with steep slopes. Although agriculture (mainly vegetables) is still the main economic activity, the techniques used today for soil preparation did not change from the past, prevailing downhill plowing and land burning, which contribute to intensive soil erosion in the area.

The 04 erosion plots, with an area of 22x4m each (Wischmeier type), were installed in the middle portion of a typical hillslope of the region (steepness of 30%), where the soil is characterized by a Red-Yellow Oxisol (Kunzmann et al., 1997). The plots used present the following characteristics:

Plot A – bare soil, with the use of disc plow with tractor.

Plot B – conventional preparation system with the use of land burning and downhill plow with tractor.

Plot C – system without the use of land burning, plow with yoke of oxen and plantation on contour line. A strip of grass (“Colonião” grass) is present every 6 or 7 meters.

Plot D – system of minimum tillage.

Watermarks and tensiometers were installed at the top and at the bottom of each plot, at 15 and 30 cm depths, resulting in a total of 32 instruments. Measurements were taken twice a day (7:00 am and 5:00 pm) during a wet and a dry period, without any cultivation. The results discussed here are related to plots B and D, which represent the local and a conservative preparation system, respectively. Data concerning rainfall intensity and soil temperature were provided by the Meteorological Station of Avelar Experimental campus). Future studies will compare the data obtained with the Watermarks and with the tensiometers for periods with cultivation and also with irrigation, using automatic readings with a datalogger.

Laboratory analyses are being carried out for texture, micro and macroporosity, bulk density, particle density, as well as for the retention curve of the soils in the four plots, in order to get a better understanding of the relationship between the hydrologic and erosive responses. However, in this study only the results associated with soil texture will be discussed.

RESULTS AND DISCUSSION

During the period of monitoring it was observed a decrease of the total precipitation over the area, causing wet and dry periods, which made it possible an analysis of the instrument responses in both recharge and drainage periods.

Concerning the soil matrix potential, it was observed that the shallowest depth (15 cm), presented the smallest potentials due to the greater losses at the top of the soil (Figure 2). Despite these losses, it was verified that plot D retained more moisture. Regarding the grain size distribution, it was verified in plot D higher values for fine materials (clay and silt), both at 15 and 30 cm depths (Table 1). This fact seems to be controlling the greater moisture retention observed at this plot, which may also result from the more conservative soil preparation system (minimum tillage).

Table 1. Values of the texture (%) for the several depths of 15 and 30 cm in plots B and D, in the upper plot.

	Plot B (%)			Plot D (%)		
Depth (cm)	Clay	Silt	Sand	Clay	Silt	Sand
15	39.78	10.56	49.66	37.74	17.44	44.82
30	36.05	15.04	48.91	38.11	17.92	43.97

In a general sense, the data (Figure 2) attested a strong correlation between precipitation inputs and the response for the soil matrix potential, which is usually very rapid for the larger rains. However, depending on the antecedent moisture conditions, it can be observed a fast response even for small rainfalls. For example, plot B presented a quick response to a 2.6 mm precipitation, on March 20th, a fact that was not observed in plot D. It is believed here that this behavior may be connected with the compaction process at plot B, caused by the intensive use of tractors, producing a compaction layer (plough-pan), that acts as an impeding layer to soil water infiltration, between 17 and 22 cm depths.

On the other hand, for 30 cm depth (Figure 3), it was observed greater values of soil matrix potential both in plots B and D, when compared to those values obtained for 15 cm depth. However, plot D shows a saturation process for longer periods than those observed in plot B. Therefore, it can be concluded that there is a greater moisture retention in plot D, not only at 15 cm but also at 30 cm depth.

Comparing the data obtained by the Watermark with that one from the tensiometer, it is attested that they present similar readings up to the –70 kPa. Towards smaller values, the tensiometer readings are not reliable. On the other hand, the Watermark presented during the studied period, continuous readings up to –100 kPa, still inside the calibrated range.

The results also showed that the tensiometer presented a faster response, due to its smaller response time, both for recharge and drainage periods.

Under conditions close to saturation, the soil matrix potential curves obtained by both the tensiometer and the Watermark present basically no difference, attesting that their responses are closer for wet periods than for dry periods, as shown by the results presented at plot D (Figures 2 and 3).

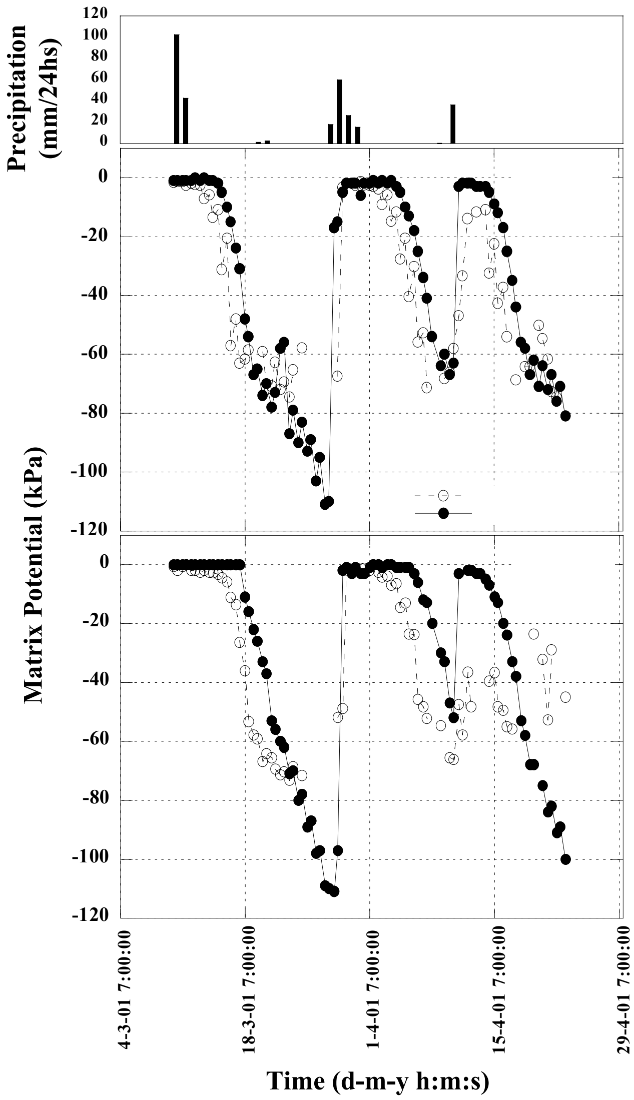

Figure 2. Soil matrix potential response to the pluviometric events (mm/24hs), obtained the tensiometer and by the Watermark (GMS) (kPa), for 15 cm depth, for plots B and D.

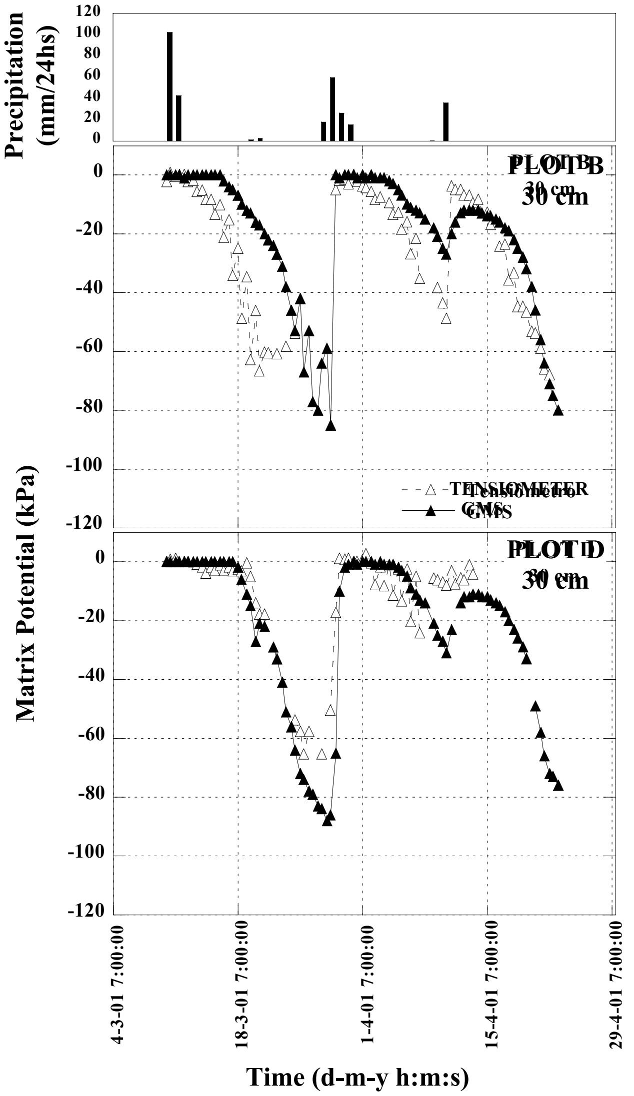

Figure 3. Soil matrix potential response to the pluviometric events (mm/24hs), obtained the tensiometer and by the Watermark (GMS) (kPa), for 30 cm depth, for plots B and D.

FINAL CONSIDERATIONS

In a general way one can observe that:

In plot D, at both 15 and 30 cm depths, shortly after any rain, soil matrix potential gets closer to saturation, keeping this condition for longer periods than plot B. Concerning the instruments, it is possible to say that both presented a reliable response throughout the studied period. Such ehavior is more evident under wet periods than dry periods. However, below –70 kPa, soil matrix potential curves start to differ due to tensiometer limitations. In order to characterize the arrival of the wetting front it becomes necessary the use of a automated acquisition and storage system. Therefore, the Watermark may be used in soil water monitoring systems, under drier conditions than the ones measured by the tensiometer, contributing to a better understanding of the different hydrological and erosional processes acting on the hillslopes.

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