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WETTING FRONT OF SOIL INFILTRATION TEST BY REAL-TIME SENSING IN PROTOTYPE SYSTEM REAL-TIME WETTING FRONT IN SOIL INFILTRATION TESTS

Jorge Otta Júnior[1]*, Leandro Augusto de Carvalho[1], Pedro Luíz de Paula Filho[2] & Glauco Vieira Miranda[3]

1 - Federal Technology University of Parana, Toledo, Brazil

2 - Federal Technology University of Parana, Medianeira, Brazil

3 - Federal Technology University of Parana, Santa Helena, Brazil

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ABSTRACT

Agriculture is the most water-demanding economic activity. Nevertheless, the monitoring of agricultural production systems can improve the soil water condition and contribute to soil conservation, as well as increase irrigation efficiency through quick and assertive decision-making. Thus, the objective of this work was to carry out a real-time evaluation of the wetting front (WF), the water infiltration rate in the soil, and to verify whether the system performance can affect infiltration test data in a Red Latosol with clayey and very clayey textures. The public domain prototype system consisted of a permeameter, and 10 soil moisture sensors that were calibrated by the oven drying method and inserted into a PVC pipe from 10 cm to 100 cm depth. The equipment allowed the evaluation of the wetting front and calculation of the infiltration rate and water retention and variations along the soil profile. Data were analyzed using descriptive statistics using RStudio and Excel. The results showed that the prototype system is effective to simulate the water infiltration rate in the two soil textures analyzed at low cost.

Palavras-chave:
Umidade do solo
Monitoramento
Arduino

FRENTE DE MOLHAMENTO DE ENSAIO DE INFILTRAÇÃO NO SOLO POR SENSORIAMENTO EM TEMPO REAL EM SISTEMA PROTÓTIPO

RESUMO

A agricultura é a atividade com maior uso da água e o monitoramento eficiente da condição hídrica do solo pode contribuir para a sua conservação e ampliar a efetividade da irrigação por meio de decisões rápidas e assertivas. Assim, o objetivo deste trabalho foi avaliar em tempo real a frente de molhamento (FM) e a taxa de infiltração a partir de ensaios de infiltrações em Latossolo Vermelho com texturas muito argilosa e argilosa utilizando um sistema protótipo de baixo custo e domínio público composto por tubo PVC, permeâmetro e 10 sensores de umidade que foram calibrados pelo método de estufa e inseridos no cano a partir de 10 cm de profundidade até 100 cm. Foi possível avaliar a frente de molhamento e calcular a taxa de infiltração e a retenção hídrica e suas variações ao longo do perfil de solo. Conclui-se que os resultados mostraram a efetividade do sistema protótipo para simular a infiltração de água para duas texturas de solo com baixo custo.

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Email (corresponding author)*: tamahome14@gmail.com

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Gabriel Araújo e Silva Ferraz

INTRODUCTION

The excessive water use in agriculture irrigation and the current water crisis published in the annual reports on water resources of the National Water Agency (ANA, 2020) lead to a growing need to optimize the use of water resources. Thereby, in the planning of soil and water conservation systems, the water infiltration rate in the soil is one of the essential parameters for the management and optimization of irrigation systems. Irrigation must based on the water demand of the crops, and real-time information on the soil water conditions can help in the decision making process (SENAR, 2019).

These systems help maintain soil moisture at optimal level for crop growth, being an essential environmental and climatic variable, which strongly affects the soil water infiltration rate and impact the temperature and water loss by soil and plants through evaporation and transpiration, known as evapotranspiration (MITTELBACH *et al*., 2012). This interaction between climate and soil moisture has received increasing attention in the sowing planning of non-irrigated crops such as soybean, corn, and others (SISDAGRO, 2021).

Other factors that affect the plant growth are the water balance in the root zone, infiltration mechanics, the movement of water from the surface into the soil (Silva *et al*., 2017), wetting front, which is a small region characterized by a steep hydraulic gradient and important for the prediction of water propagation (LIBARDI, 2005) and water retention in the soil. By measuring changes in water volume, it is possible to determine the speed and efficiency of root systems in absorbing water and nutrients such as nitrogen for growth.

Direct methods of measuring water content of soil samples are laborious and destructive, do not allow reproducibility on the same sample, and take from 24 to 48 hours for determination (GUBIANI *et al*., 2015). Indirect methods are mostly automated and measure soil moisture in space and time (GUBIANI *et al*., 2015). The main advantages of indirect methods are the structural integrity of the sample analyzed and the high reliability of the measurement, besides the applicability to various materials (MANTOVANI, 2009). Industrial sensors using neutron thermalization methods include a radioactive source and are expensive due to their fragile parts and complex use (LIBARDI, 2012), while low-cost sensors, such as the one proposed in this study, may cost up to R$ 600.00 and be easy to handle.

Saleh *et al* (2016) assessed the accuracy of low-cost resistive sensors using an EC-5 Decagon soil moisture resistive sensor connected by an analog port to a data store based on the ATmega32u4 microcontroller, Arduino Micro, and reading converted to digital using an analog to digital converter. The sensor rods were inserted into the soil and the soil resistance varied according to the moisture variation. The readings were presented as values between 0 and 1023, or 4.9 mV per unit, as the result of mapping the input voltage into integer values by the 10-bit Arduino Analog-Digital Converter.

Studies on infiltration rate and water retention of soil with unaltered structure have been carried out using low-cost sensors. Silva *et al* (2020) used the US-015 ultrasonic sensor to perform automatic and manual measurements of the water infiltration rate using concentric metal ring infiltrometers in the field, however, the authors did not evaluate these water characteristics along the soil profile.

Therefore, the objective of this study was to evaluate the real-time wetting front and determine the infiltration rate and soil water retention at a depth of 100 cm in the soil profile by means of soil infiltration tests in a Red Latosol with clayey and very clayey textures, using a prototype system in this analysis.

MATERIALS AND METHODS

The prototype system was used in a closed environment in the soil laboratory of the Federal University of Paraná – Campus Toledo, at 21-26º C room temperature.

To built the prototype system proposed we followed the sequence steps: assembly of soil moisture sensors and sensor data collector, development of the prototype system of the soil profile, calibration of the moisture sensors, assembly of the prototype system, and data analysis.

Ten soil moisture sensors were built as described in the Gardenbot project (FRUEH, 2017) and connected to an Arduino Mega microcontroller board, which acted as a data collector. Two straight galvanized wire sections were fixed in rigid material, 3 cm apart, 1 mm in diameter and 15 cm in length, of which 10 cm were covered with non-conductive material and the other 5 cm remained exposed. A resistor was connected to each covered end: a 100 ohm resistor connected to an analog port (A0 to A9) and to an even digital port (from 22 to 40), and a 4.7 kiloohm resistor connected to an odd digital port (from 23 to 41) (Figure 1).

A DHT22 temperature and air humidity sensor was coupled with the soil moisture sensors to monitor environmental conditions, plus four DS18B20 temperature sensors to monitor soil temperature during the tests.

A Raspberry Pi 3 Model B+ data storage that powered the collector was connected to an external 10 Ah battery. We used the Raspbian data store operating system as it is a native application that provides a complete development environment based on free software.

The readings of the soil moisture sensors were used in a regression equation to estimate the substrate moisture. The more humid the soil, the higher the reading, up to the limit of 1023. The reading of the soil moisture sensors was performed sequentially from the most superficial sensor to the deepest sensor, following the steps: energizing one of the ends, waiting 150 milliseconds (ms), performing the humidity reading, waiting 150ms, energizing the other end, waiting 150ms, performing the reading, and waiting 150ms before moving on to the next sensor. The average of these two readings (with values between 0 and 1023, mapped from zero to operating voltage, 3V or 5V) was stored as the soil moisture reading (su – sensor unit) on an external hard drive. Initially, an SD shield was used as a storage method, but the writing constants required by the storage routine caused read errors on the SD cards.

The calibration followed the recommendations of NBR 6457:2016 (ABNT, 2016), according to Pizetta (2015), and the readings of the soil moisture sensors were mapped using the moisture obtained with the oven drying method.

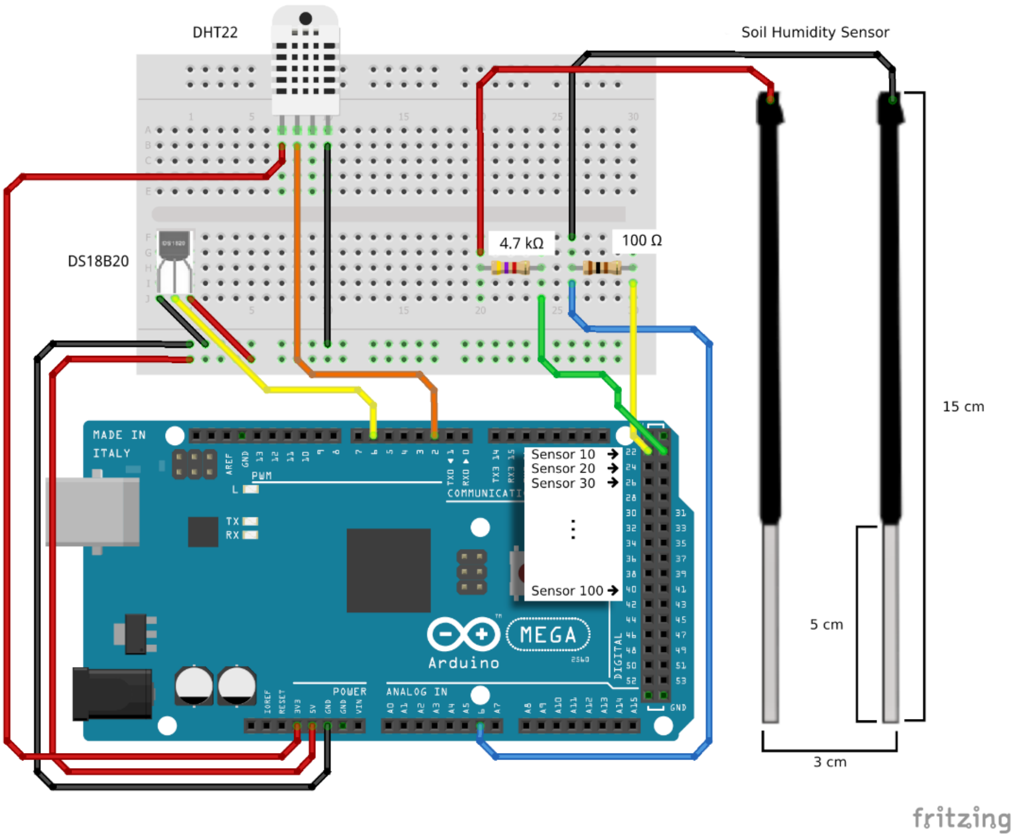

Figure 1. Soil moisture sensor interfaced with Arduino

Figure 2 shows the soil profile prototype. The system consists of soil moisture sensors spaced 10 cm apart, inserted into the wall of a 20 cm diameter PVC pipe. In the opposite side of the pipe, four DS18B20 temperature sensors were installed to confirm that eventual changes in the substrate temperature did not affect the readings of the moisture sensors.

Holes of 2 cm in diameter were drilled into the pipe at 90° of the sensors to extract the substrate samples and to measure moisture by the oven drying method. The bottom of the pipe was sealed and a 16 cm diameter plastic shower was placed on top and connected to a permeameter to ensure the water was applied at a constant speed over the soil. Of the total length of the pipe (140 cm), 120 cm were evenly filled with soil. The area of analysis was calculated using the average root size of crops of economic interest (Gonçalves *et al.*, 2018; Magalhães *et al.*, 2018; Inforzato, 1957; Pires *et al.*, 1991; Yoshida & Hasegawa, 1982).

The Red Latosol soil samples were collected in the municipalities of Toledo and Palotina, western Paraná, with humid subtropical climate (IDRParana, 2019) and fertile and flat soil with clayey and very clayey textures (Cunha, 2019). 2018). The soil with very clayey texture was collected at latitude 24°43'58.9"S and longitude 53°45'53.0"W while the soil with clayey texture was collected at latitude 24°11'33.4"S and longitude 53°48' 30.8"W. Table 1 shows the physicochemical properties of the soils.

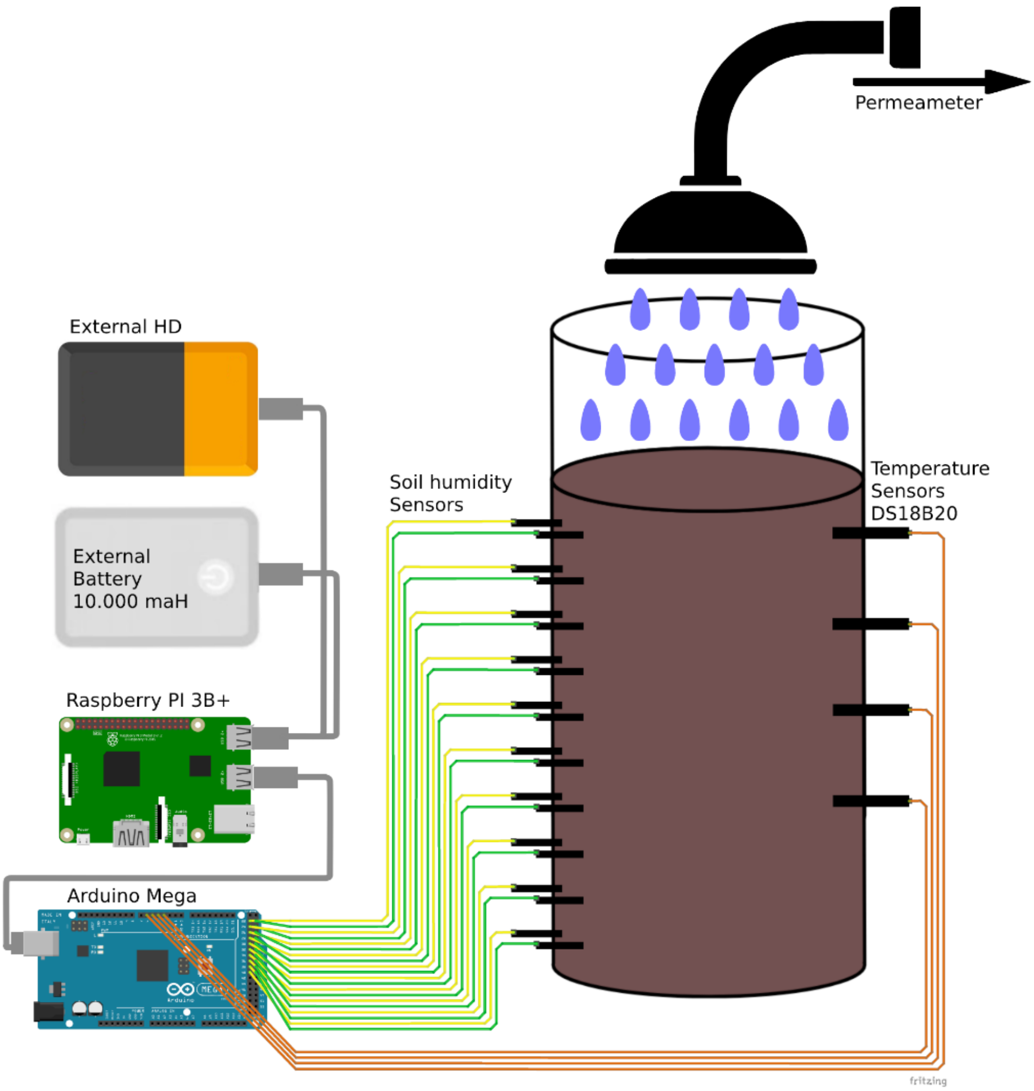

Figure 2. Prototype soil profile system for data collection

Table 1. Characteristics of the soil used in the study

Physicochemical property	Very clayey	Clayey
Sand (%)	16.25	43.75
Silt (%)	18.75	12.50
Clay (%)	65	43.75
Organic matter (g dm^{-3})	6.67	6.45
Carbon (g dm-3)	3.88	3.75
CTC pH ($Cmol_c$ dm^{-3})	9.37	7.31
CTC effective ($Cmol_c$ dm^{-3})	4.91	3.58
Base saturation – V ($Cmol_c$ dm^{-3})	50.80	45.69

Source: Solanalysis - Central de Análises LTDA (2021)

The assays were performed using air-dried and non-compacted samples. The apparent density of the very clayey substrate was 0.70 g cm^{-3} with dry substrate weight of 2.185 g and apparent density of the clayey substrate was 0.79 g cm^{-3} with dry substrate weight of 2.486 g. Soil moisture at different depths was estimated with the moisture dispersion equations obtained by the oven drying method and readings recorded by the moisture sensors, with coefficients of determination of 0.90 and 0.88, respectively. The linear model best fitted the data with the equation (1) for the very clayey texture and equation (2) for the clayey texture.

$$moisture = 22.151\ \text{reading} - 127.24 \quad (1)$$

$$moisture = 23.186\ \text{reading} + 19.442 \quad (2)$$

To simulate the rainfall amount in the soil collection areas, the websites of the Instituto Agronômico do Paraná (IAPAR, 2018) and the Instituto Nacional de Meteorologia (INMET, 2018) were searched to determine the maximum precipitation in 24 hours. The maximum amount of 183.8 mm day^{-1} was recorded in the municipality of Umuarama, in February 1998. Equation (3) was used to calculate the volume of water applied:

$$V = Rain * \pi * r^2 \quad (3)$$

Where: V is volume in liters equivalent to the cross-sectional area of the pipe; Rain, the volume in millimeters of rain (mm) and; r (radius) of 0.1 meter; resulting in 5.77 liters.

Thus, a flow of 5.77 L h^{-1} was applied to simulate the most intense rainfalls that would be most disturbing to soil management in the region. Simply for comparison, Souza Filho *et al*. (2013) applied to soil flow rates of 2.4 to 8 L h^{-1} and evaluated the zones of wetting and saturation to reach the soil water dynamic balance.

The standard deviations for the calibration of the moisture sensors were between 1.94 and 14.32 un for the very clayey texture and 0.91 and 6.89 un for the clayey texture.

The mean moisture content of the cylinder formed (5 cm above and 5 cm below the height of each of the 10 soil moisture sensors) was calculated for the two soil textures using Equation 4.

$$W = Weight/100 * \%Moisture \quad (4)$$

Where: W is the weight of the water content; Weight is the weight of the sample in the tube subsection; and %Moisture is the percentage estimated by the dispersion equations 1 (very clayey texture) and 2 (clayey texture), between percentage of soil moisture and mean of the moisture sensor readings.

Afterwards, the soil moisture was calculated 24 and 120 hours after water application on the two textures, aiming to compare the sensor readings with oven drying results and determine the stabilization of the wet bulb formed in the soil profile. In addition, the stabilization of the infiltration rate of each soil texture was determined in each sensor, in the two samples collected, as the first sensor reading when the difference in the two moving averages became constant. Each moving average consisted of seven sensor readings that corresponded to a 15 min interval between the first and last readings.

The graphical analysis and comparison of the water content observed between the texture samples was performed using RStudio and Excel spreadsheets and in relation to sensor readings and the oven drying method. Finally, a descriptive statistical analysis of the standard deviations helped to identify possible problems regarding the use of sensors in the data collection system.

RESULTS AND DISCUSSIONS

Figure 3 shows the real-time readings of the moisture sensors during the accumulated time in hours at the 10 depths in the soil infiltration test with very clayey texture.

The wetting front (WF) movement is shown, from beginning of detection to maximum point, characterizing the soil-water interface of water migration in the soil profile (Table 2).

The wetting front interface was detected by the moisture sensors at the first four depths close to the water application from 7 min at 10 cm and 10 min intervals up to 40 cm. The water flow met greater resistance by the sensors at 50 and 60 cm depths, respectively at 70 and 570 minutes. The wetting front peaked at 0:15 am, 10 cm depth, and at increasing intervals with the depth of the soil profile.

Sensors at 70 cm to 100 cm depths did not detect the wetting front at 24 and 120 hours because of the water adsorption to the solid soil part. This shows that this volume of water would be insufficient to reach greater depths for deep root systems due to the distribution of soil pores. Flow stabilization was slower with increasing depth (Table 2).

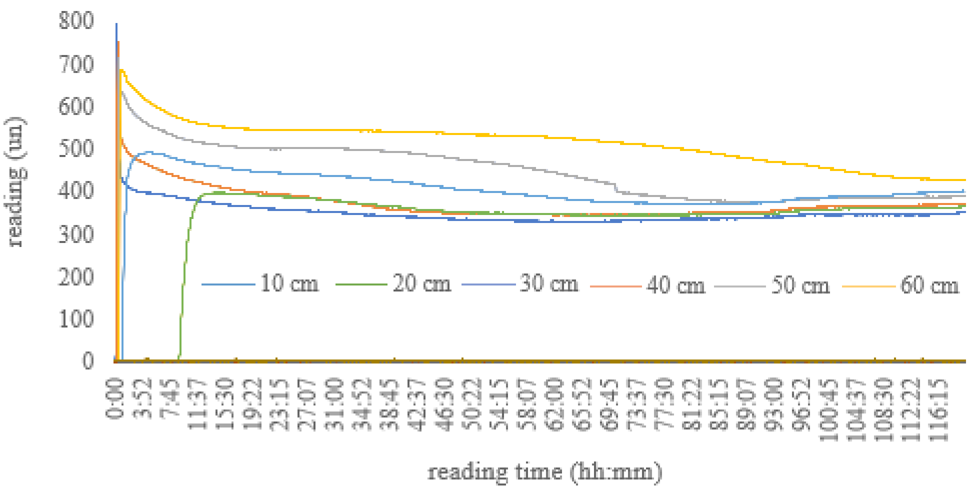

Figure 3. Wetting front (peak in the graph) and water infiltration in the prototype system measured by moisture readings (un) for the very clayey texture during the accumulated time in hours at different depths (10 cm to 100 cm) in the soil profile

Table 2. Accumulated time from beginning to peak of wetting front (WF), reading stabilization, and water infiltration rate in infiltration tests of very clayey soil

Depth (cm)	Beginning of WF (hh:mm)	Peak of WF (hours)	Stabilization (hours)	Infiltration rate (cm h^{-1})
10	0:07	0.20	2.33	4.3
20	0:17	0.37	2.95	6.8
30	0:27	0.58	4.37	6.9
40	0:37	0.87	5.25	7.6
50	1:10	4.33	3.42	14.6
60	9:02	14.53	12.50	4.8

Reichardt (1990), Tucci (2012), and Mantovani *et al*. (2009) also found that the speed at which water enters into the soil is initially high and gradually decreases to an almost constant value which can be called stable infiltration rate.

From Figure 3, the intermediate layers at 30 and 40 cm depths are influenced by the most upper layers that lose water to the atmosphere through evaporation and by the lower layers with differentiated distribution of smaller-diameter pores. At 30 and 40 cm depths, the highest moisture is due to gravity, absence of evaporation loss, and water retention by limiting percolation to lower layers.

The moisture content at 50 and 60 cm depths is lower than at 30 and 40 cm, indicating that the remaining water was retained in these layers and was insufficient to move the wetting front that reached 60 cm at 8 hours and 55 min after applying the water (Table 3 and Figure 3).

The evaporation rate between the beginning of data collection and the first sampling in 24 hours was 78.75 mL h^{-1}. The evaporation rate for 120 hours of data collection – total time – was 18 mL h^{-1}.

The readings of soil moisture sensors for the clayey texture are shown in Figure 4.

From Figure 4, the wetting fronts (peaks in the graph) from 10 to 70 cm depths were very similar, while WF from 80, 90 and 100 cm were more distinct. It was also possible to detect that the soil-water interface moved in the soil profile from 0:05 hours at the 10 cm depth to 220 min at the 100

Table 3. Water retention according to volume and moisture measured at 24 and 120 hours after water application to the prototype system with very clayey texture soil

	24 hours		120 hours		
Depth (cm)	Moisture (%)	Volume (mL)	Moisture (%)	Volume (mL)	Difference (mL)
10	21.66	473	21.54	471	2.0
20	23.17	506	22.32	488	18
30	27.54	602	22.97	502	100
40	29.13	637	24.68	539	98
50	25.13	549	23.54	514	35
60	22.85	499	22.03	481	18
Total	24.15*	3.266	22.64*	2.995	271

* mean of the first six depths

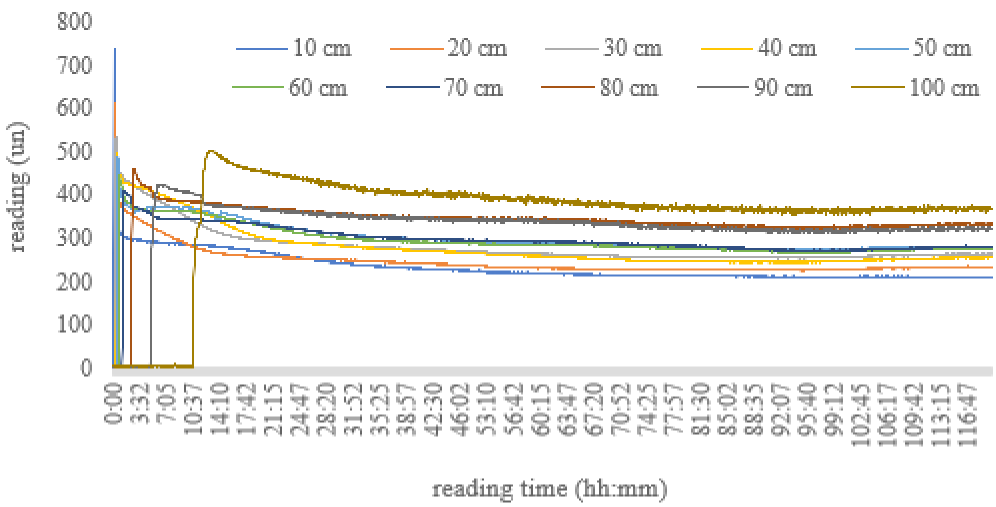

Figure 4. Wetting front (peak in the graph) and water infiltration in the prototype system measured by moisture readings (un) for the clayey texture during the accumulated time in hours at different depths (10 cm to 100 cm) in the soil profile

cm depth (Table 3). The wetting front peaked from approximately 0:07 h at the10 cm depth to 03:40 h at the 100 cm depth.

The water flow stabilization was faster from the first to the last depths (Table 4).

At the same depth used in concentric rings, the basic infiltration rate at 30 cm was 23.43 cm h^{-1}, at 100 cm was 23.0 cm h^{-1}, and was highest from 50 to 70 cm. This clayey soil has 43.75% of sand and is very close to clay-loam soils, agreeing with the reports by Almeida *et al*. (2020) for lower infiltration rates of sandy soils.

Water retention or moisture was always greater at 24 hours than at 120 hours in the system (Table 4). Water retention at depths of 30 cm and 40 cm stands out with the highest absolute values and differences in moisture between the evaluation times, which characterizes the zone as having the greatest water retention for the root system. However, the moisture up to 60 cm of depth is recorded between 21 and 29% but with a percentage variation of approximately 38% between the layers 10 and 40 cm.

Almeida *et al*. (2020) compared the basic infiltration rate (BIR) in an area with and without application of swine manure and in Permanent Preservation Areas on hill top (APPt) and close to riverbed (APPs) using the Kostiakov model to estimate BIR. In irrigated areas where the soil is clayey and BIR is very high, infiltration rates ranged from 1.14 cm h^{-1} to 6.9 cm h^{-1}, for areas with and without manure, respectively. In APPs with sandy soils, BIR ranged from 21.0 cm h^{-1} for APPt and 38.4 cm h^{-1} for APPs. In the studied soils, homogenized and the coarse organic matter removed, the BIR for the clayey texture was between 12 cm h^{-1} and 35.3 cm h^{-1} and for the very clayey texture between 4.3 cm h^{-1} and 14.6 cm h^{-1}.

Aragão *et al*. (2017) determined the equation of soil infiltration rate using a ring infiltrometer. They performed 17 consecutive readings interspersed at different times with a total duration of 65 minutes using the infiltration equation proposed by Kostiakov and obtained the basic infiltration rate (BIR) of 11.85 cm h^{-1}, which was classified as very high and was explained by the soil sandy texture in the study area.

There was a decrease of 2.586 mL in moisture in the time from the end of the water application until the evaluation after 24 hours, with the highest moisture between the two soil textures and the highest evaporation rate of 107.75 mL h^{-1}. The evaporation rate for the evaluation at 120 hours was 23.63 mL h^{-1}.

The soil moisture in the clayey texture increased with the greatest depths, varying from 9.88 % to 15.66%, and always being higher at 24 hours than at 120 hours (Table 5).

The water retention at 40 cm depth stands out with the highest absolute values and differences in moisture between the evaluation times, characterizing the zone as the greatest water retention for the root system and corresponding with the very clayey soil. However, the greatest

Table 4. Wetting front (WF) beginning and peak, stabilization of reading and infiltration rate in infiltration tests with clayey soil

Depth (cm)	Beginning of WF (hh:mm)	Peak of WF (hours)	Stabilization (hours)	Infiltration rate (cm h^{-1})
10	0:05	0.12	0.83	12.0
20	0:07	0.17	0.83	24.1
30	0:10	0.20	1.28	23.4
40	0:15	0.28	1.58	25.3
50	0:20	0.33	1.62	30.9
60	0:25	0.45	1.70	35.3
70	0:35	0.7	2.12	33.0
80	1:05	1.28	2.72	29.4
90	1:52	3.08	4.12	21.8
100	3:40	4.35	4.35	23.0

water retentions are recorded from 30 cm of depth with moisture between 11 and 15%. These moisture values are around 40% and 50% lower than those observed in very clayey soils.

The comparison of the wetting front of the two soils shows that the very clayey soil has water retention of 24.9% and 40-50% superior at all depths in relation to the clayey soil. For the clayey soil, the wetting front was slower and the water retention was 12.8%. The average soil moisture was lower than in the very clayey soil. The highest water retention was recorded at the intermediate depths of 30 and 40 cm.

Figure 5 shows the tendency of the permeability rate to decrease with time for the two soils because the water retention initiates from the micropores of the most superficial layers.

Figure 6 shows the differences in water retention at the 24 and 120 hour evaluations of the two soils by moisture sensors. The behavior is likely caused by the transport of moisture from the wetter layers to the drier layers, so that the moisture remains constant between the adjacent layers.

Table 5. Water retention based on the volume and moisture measured at 24 and 120 hours after water application in the prototype system with clay texture

	24 hours		120 hours		
Depth (cm)	Moisture (%)	Volume (mL)	Moisture (%)	Volume (mL)	Difference (mL)
10	9.88	246	9.31	232	14
20	10.61	264	10.11	251	13
30	11.94	297	11.06	275	22
40	11.90	296	10.45	260	36
50	13.11	326	11.97	298	28
60	12.77	318	11.52	286	32
70	13.11	326	11.71	291	35
80	14.75	367	13.72	341	26
90	14.60	363	13.38	333	30
100	15.66	389	15.05	374	15
Total	12.80*	3.191	11.61*	2.941	250

* average

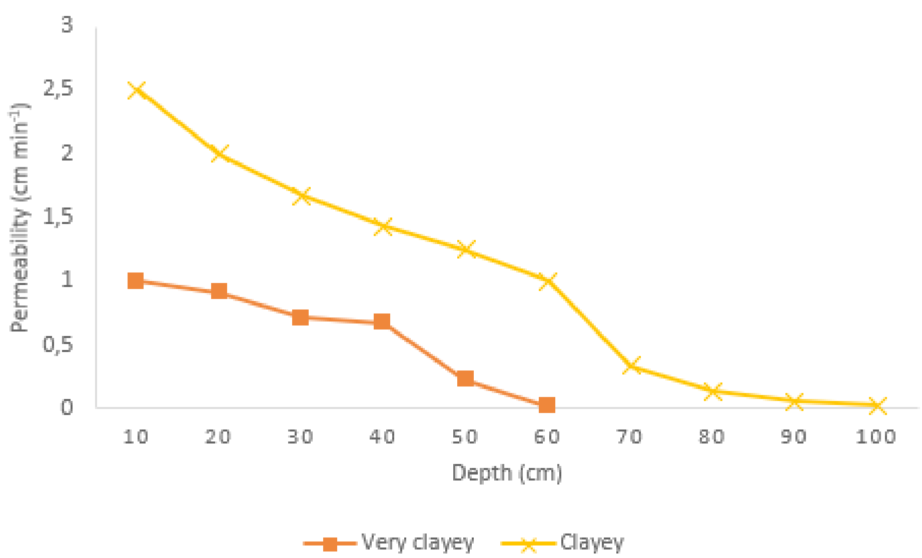

Figure 5. Permeability rate of the very clayey and clayey soil textures as a function of the depth of the sensors

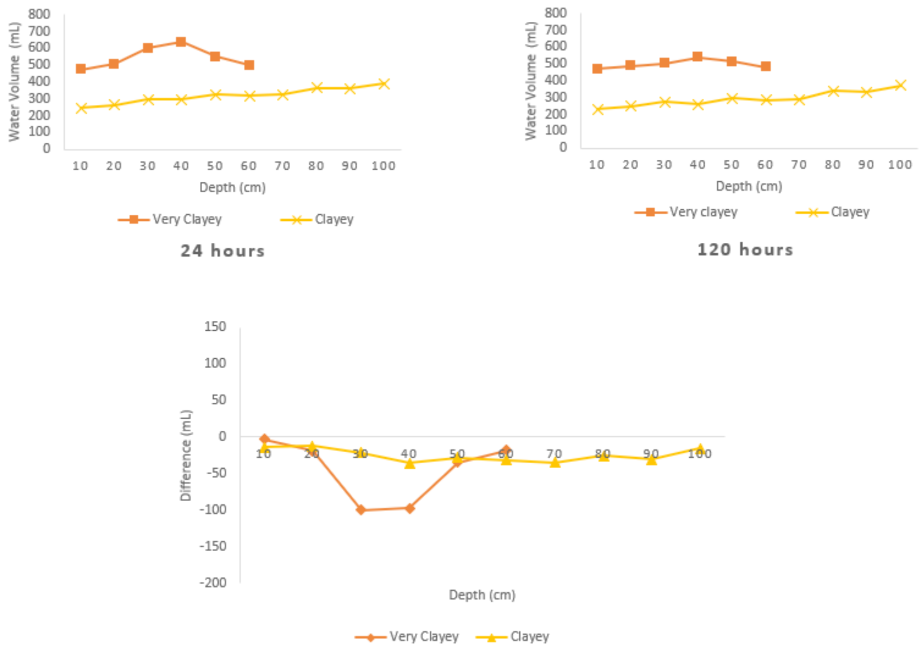

Figure 6. Water retention and differences detected by moisture sensors of the very clayey and clayey soil textures at 24 and 120 hours

The water retention in the very clayey soil was higher and permeability was lower due to the greater amount of micropores, with water being more retained at depths 30 and 40 cm at 24 hours (Figure 6). The wetting front was not detected from the 60 cm depth, demonstrating the high water retention of this soil. With advancing time, at the 120 hour evaluation, gravity acts and there is nearly a stabilization of the water retained at all depths. This soil also stands out for its greater water retention in relation to clayey at all depths.

On the other hand, the clayey soil presented the lowest water retention and the highest infiltration, characterizing a greater presence of macropores, which are functional only when close to saturation and capable of quick and preferential transport of water and chemical substances during the infiltration process (EDVANE *et al.*. 1999). In addition, it presented the difference in accumulative water retention at depths as it occurred for very clayey soil at depths of 30 and 40 cm (Figure 6).

Figure 7 shows the differences in water retention for evaluations at 24 and 120 hours of the two soils tested in the laboratory by the oven drying method.

The results in the laboratory are very similar to those obtained by the sensors, showing the agreement between the two measuring methods. However, the variation of values obtained by the oven drying method is greater and, in some observations, data are not explained by the methodology such as the very clayey soil at 30 cm depth.

The standard deviations calculated based on 2600 to 2900 sensor readings during data collection range from 28.63% for the most superficial layer to 118% for the deepest layers as it is shown in Table 6.

The results, considering those calculated in the calibration, suggest that the sensor used can be negatively influenced by the pressure caused by the substrate along the soil profile when the wetting front reaches the deeper sensors, notably the sensor placed at 70 cm from the surface. The increasing standard deviations, which apparently are caused by the increasing pressure of the soil profile, may augment due to the less homogeneous distribution of macropores of an *in situ* substrate.

According to Carvalho (2016), possible causes of error for this type of sensor are the dependence on both the homogeneity of the zone near the probe and the speed of water infiltration.

The prototype system proved to be suitable for use in a controlled environment and can be adapted for field evaluation, since the water retention curve obtained allows greater efficiency in estimating the irrigation depth while establishing critical tensions for replenishing water in the soil.

Figure 7. Water retention and differences detected in the laboratory by the oven drying method, for the two soil textures evaluated at 24 and 120 hours

Table 6. General standard deviations (%) of moisture sensors for the very clayey and clayey texture soils

	Texture	
Depth (cm)	Very Clayey	Clayey
10	28.63	33.74
20	41.80	34.15
30	67.66	43.49
40	62.36	50.17
50	52.91	37.80
60	54.72	38.97
70		41.41
80		54.0
90		73.42
100		118.39

* The volume of water was insufficient to reach the layers below 70 cm in the soil with a very clayey texture

CONCLUSIONS

- The results showed the effectiveness of the system to assess water infiltration in both soil textures. Soil moisture sensors proved to be promising for use in this type of study. It is possible to reduce the cost of the system by replacing the collector with an SD shield for data storage, but the storage routine must be optimized to avoid data loss.
- To improve results, the evaluation of the wetting front should be performed at shorter intervals and validated in less than 24 hours according to the highest soil infiltration.
- In future versions, less conceptual water volumes, application rates and frequencies could be obtained using intense rainfall equations, including the application of PLUVIO, a free-licensed software developed by the Water Resources Research Group of the

Federal University of Viçosa. For this study, however, we select a methodology that farmers can actually use in their farms.

AUTHORSHIP CONTRIBUTION STATEMENT

OTTA JÚNIOR, J.: Conceptualization, Formal Analysis, Methodology, Resources, Writing – original draft; **CARVALHO, L.A.:** Conceptualization, Writing – original draft, Writing – review & editing; **PAULA FILHO, P.L.:** Data curation, Formal Analysis, Supervision, Writing – review & editing; **MIRANDA, G.V.:** Data curation, Formal Analysis, Supervision, Writing – review & editing.

DECLARATION OF INTERESTS

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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