A Simple Alternative Instrument for Measuring Temporal Soil Water Content in Repacked Soils

Bandi HERMAWAN, Ph.D[1]; Indra AGUSTIAN[2], Hery SUHARTOYO[3], and SUKISNO[1]
[1]Soil Science, [2]Electrical Engineering, and [3]Forestry Department, University of Bengkulu, Indonesia

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Abstract

The objective of the study was to develop a dielectrically-based instrument to measure temporal soil water content. Electrical impedance, Z, was measured from March to August 2016 using a sinusoidal voltage generator at a frequency of 3 kHz. When inserted into the soil, resulting voltage was analyzed in a microcontroller to determine Z of the measured soil. Fifty repacked soils were saturated for about 24 hours, Z values (in kΩ) were measured using the instrument. At the same time, soil water content values (θ_g in $g.g^{-1}$) were determined using a standard gravimetric method. Soil samples were allowed to evaporate, both Z and θ_g measurements were repeated every second days. Pairs of Z and θ_g values were regressed to find the best equation in calculating water content from the measured impedance. Results showed that temporal soil water content were best calculated from Z values using a non-linear regression of $\theta_g = a.Z^b$ where a and b were constants. About 80 percent of study soils had R^2 values of above 0.90, suggesting the accuracy of the proposed simple instrument. These findings would contribute to the improvement of water use efficiency in crop production.

Background

Information on temporal soil water content is needed under soil and water management practices such as irrigation scheduling, but the available instruments are either difficult to use or expensive. Therefore, some alternative and cheaper methods of measuring temporal soil water content are urgently required. Many researchers worldwide use water-related characteristics such as electrical capacitance [1] and resistivity [2] as well as neutron properties [3] to determine temporal soil water content.

Repacked soils have been usually used for detail studies on soil water properties such as water movement related to nutrient leaching [4] and water-pore effects on element mobility in contaminated sediments [5]. However, repacked soils drain very quickly therefore require more frequent determination of temporal water content than the field soils. This study aims to evaluate the accuracy of a simple alternative instrument for the temporal water content measurements when compared to the standard gravimetric method.

Materials and Methods

A simple instrument was set to measure electrical impedance Z of soil. It transmitted the alternate current at a frequency of 3 kHz through a couple of probes. When inserted into the soil, Z values were measured and displayed on the LCD screen.

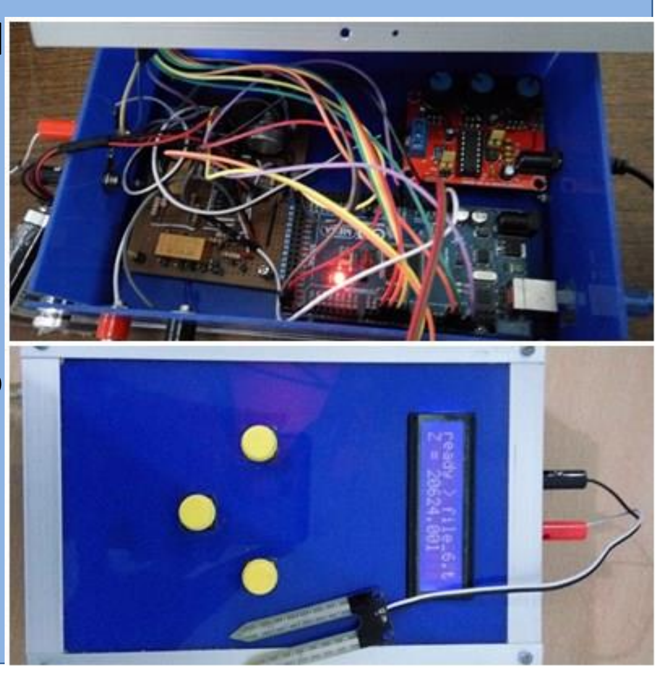

Figure 1. A portable impedance meter using auto-balancing bridge.

Figure 2. Instrument used to measure Z and balance to measure water content

A repacked soil was saturated, a couple of probes was inserted into the soil. Instrument was switched "on", Z value was read from the LCD screen. Repacked soil was weighted to measure gravimetric water content (θ_g).

Soil was evaporated, measurements were repeated over 50 samples taken from post-mined land sites. Values of Z and θ_g were regressed, and R^2 values were calculated.

Results

Results showed that temporal water content of repacked soils could be determined by measuring the electrical impedance. Soil water content decreased significantly with increasing the electrical impedance, but the decrease became smaller at the higher impedance values (Figure 3).

Typical relations between Z and θ_g values followed a non-linear regression of $\theta_g = a.Z^b$ where *a* and *b* ranged from 0.19 to 0.37 and -0.71 to -0,33 respectively (Table 1). When the equation was established for such a soil, the temporal water content determination could follow the model.

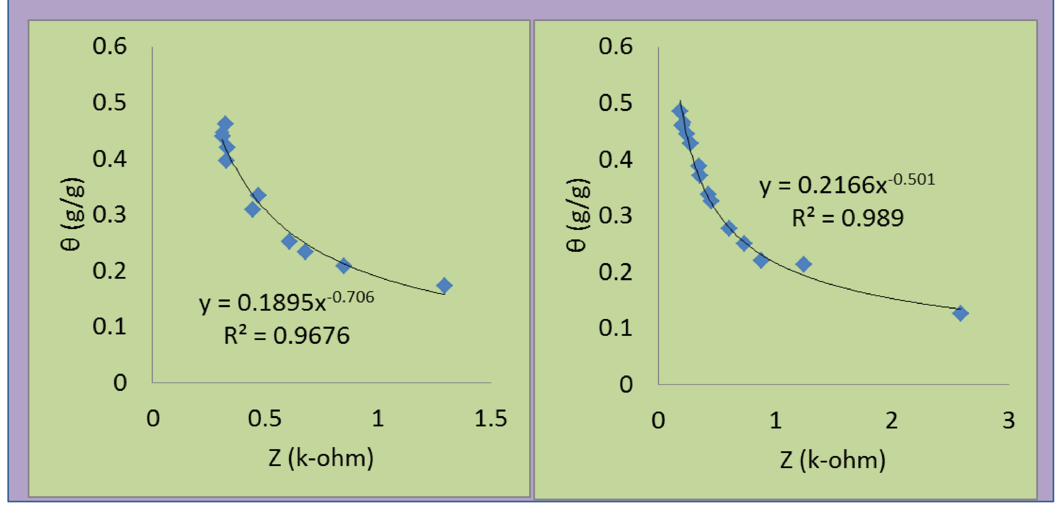

Figure 3. Typical non-linear models to predict temporal water content (θ) from electrical impedance (Z) at repacked soils.

Table 1. Values of constants *a* and *b* for selected repacked soils.

Samples	a	b	R^2
1	0.19	-0.54	0.99
2	0.21	-0.34	0.83
3	0.19	-0.71	0.97
4	0.22	-0.50	0.99
5	0.20	-0.64	0.91
6	0.32	-0.40	0.97
7	0.30	-0.41	0.89
8	0.37	-0.42	0.98
9	0.35	-0.35	0.99
10	0.21	-0.33	0.93

The instrument has been successfully used to calculate the water use efficiency at palm oil nursery and upland rice under two contrasting repacked soil types as reported elsewhere [6]. Significant differences in water uses were recorded by the instrument between the soil types. This finding may become an alternative technique to measure soil water properties using a simple and cheap instrument for agricultural and non-agricultural purposes.

Our future studies will install a component called ESP8266 functioned as the face-to-face system for the internet connection purposes. Electrical impedance and water content data measured by the instrument will be sent to the component of ESP8266, then every 20 seconds, the ESP8266 will send the data to the internet router and received by Thingspeak.com server, a free server of IoT (Internet of Thing).

The measured data can be performed in both graphics and numbers that can be downloaded from a smartphone by accessing ThingSpeak.com. The future studies will result in a remotely accessed instrument for measuring temporal soil water content under various land management systems. Solar power can be used as the source of alternate current to measure the electrical impedance.

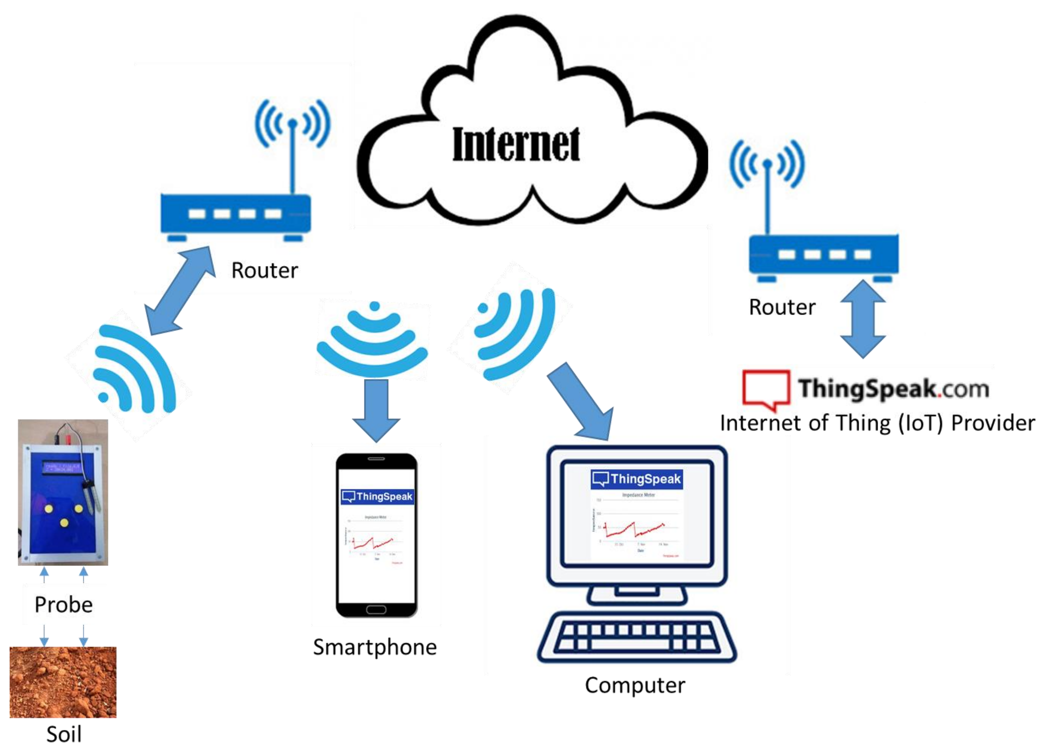

Figure 4. Future development of the remote instrument for temporal soil water measurements.

Conclusions

A simple alternative instrument developed in this study was successfully cable of measuring temporal water content at some repacked soils taken from the post-mined land. The instrument should first be calibrated to calculate constants *a* and *b* at the equation to convert electrical values to water content, then the soil water could be monitored periodically.

In the future, the proposed instrument can be developed for the remote determinations of soil water. The electrical impedance can be read, for example, from smartphones since the instrument is designed to transmit the measured impedance and soil water values directly to satellites.

Contact

Bandi Hermawan, Ph.D.
Department of Soil Science, University of Bengkulu, Indonesia
Email: bhermawan@unib.ac.id
Scopus Index: 6507174534
Website: https://psit.faperta.unib.ac.id
Phone: +62811737610

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