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A low-cost microprocessor and infrared sensor system for automating water infiltration measurements

Katherine Milla[a,*], Stephen Kish[b]

[a] *College of Engineering Sciences, Technology and Agriculture, Florida A&M University, Tallahassee, FL 32307, USA*
[b] *Department of Geological Sciences, Florida State University, Tallahassee, FL 32306, USA*

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Abstract

Understanding the nature of soil infiltration properties is important for a number of applications, including planning efficient irrigation and erosion control practices, evaluating effectiveness of linings for sanitary landfills and waste lagoons, and landscape design and management. A common method for measuring infiltration is with the use of cylinder infiltrometers. This method can be very labor intensive and time-consuming, thus limiting its practicality. We describe the construction of an inexpensive system that can be readily adapted to single- and dual-ring infiltrometers to provide automated measurements on the scale of seconds to days. The system is comprised of an infrared distance-measuring sensor and microcontroller that can be programmed to collect water level measurements at various time intervals. Data are logged by the system in the field and can be downloaded for processing and analysis. This system is not only inexpensive, but also small, lightweight and versatile, and can be readily adapted to collect additional parameters.

Keywords: Infiltration; Infiltrometer; Instrumentation; Microprocessor; Infrared sensor

1. Introduction

Infiltration describes the process by which water, applied to a soil surface, moves into the soil. Infiltration properties of a soil have important implications for plant production, soil and water conservation, and irrigation management. Infiltration is a major factor in controlling crop yields and delivering water and agricultural chemicals to the soil profile (Ersahin and Karaman, 2000). Low infiltration rates can result in loss of irrigation water to runoff and loss of soil to erosion. Knowledge of soil infiltration characteristics of a soil can be used in farm management to predict and manage the performance of irrigation systems (Cahoon et al., 1993), and is important in evaluating the effectiveness of clay linings or other treatments to reduce seepage from sanitary landfills (Bouwer, 1986). Infiltration rates are of particular importance to turfgrass specialists for proper golf course design and maintenance (Ok and Anderson, 2003; Gregory et al., 2005).

* Corresponding author.
E-mail address: katherine.milla@famu.edu (K. Milla).

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Local soil infiltration properties may vary significantly (Ersahin and Karaman, 2000; Josiah et al., 2001; Ersahin, 2003; Cichota et al., 2003) due to a number of factors, including tillage practices, biological activity in the soil, crop or plant influences (Vervoort et al., 2001), natural variations in soil physical properties, and compaction. Depending on soil characteristics, it can take several hours to several days to make one reliable infiltration rate measurement (ASTM, 1994; Diamond and Shanley, 2003). Characterizing infiltration properties of a site can be very tedious and time consuming, especially when many measurements must be made.

Although several methods exist for measuring vertical soil infiltration rates, use of a cylinder infiltrometer is one of the most common. This method is simple and equipment costs are relatively inexpensive. The infiltrometer consists of either a single metal ring or two open concentric metal rings that are inserted into the ground and filled with water. Measurements are made on water volume over time as it moves into the soil.

In the double-ring infiltrometer, water infiltrating from the outer ring is considered to promote one-dimensional vertical flow beneath the inner ring (ASTM, 1994). Bouwer (1986) cites evidence that this notion is erroneous, and that increasing the size of the cylinder to at least 1 m diameter is the only way to obtain truly accurate measurements of infiltration rates. Even though smaller infiltrometers generally overestimate infiltration rates, the double-ring test using a 15–30 cm inner ring diameter is a common, well documented and relatively simple field test that can yield valuable information on general magnitude of infiltration rates and variability of soil infiltration properties. There are two techniques for determining infiltration rate with a double ring infiltrometer. For both methods water is maintained at a constant level in the outer ring. In the falling head test, the inner ring is filled with water and the decrease in water level is measured at regular intervals until the water disappears from the ring. In this method the head decreases as water level drops.

In the constant head technique, the water in the inner ring is maintained at a constant level and the volume of water used to maintain this level is measured over time. A common method for maintaining water level is with the use of a Mariotte siphon. This consists of a sealed container filled with water, into which are inserted two tubes. One tube supplies water to the infiltrometer. The second tube is an air intake tube that regulates the water level within the inner ring of the infiltrometer (Bouwer, 1986). Numerical modeling suggests that both falling and constant head methods yield similar results for fine-textured soils, but that the falling head technique overestimates infiltration rate in coarse textured soils (Wu et al., 1997).

We were only able to identify a few other methods in the literature for automating infiltration rate determinations using cylinder infiltrometers. Constantz and Murphy (1989) devised a method of determining infiltration rate by logging the gas pressure changes within a Mariotte reservoir during water outflow using a single pressure transducer. Gas pressure readings were converted by the data logger to produce a record of infiltration rate versus time. Prieksat et al. (1992) developed an automated, self-regulating system for use with a single-ring infiltrometer. The system employs two pressure transducers to measure water height changes in a Mariotte reservoir. Data are recorded by a datalogger. Maheshwari (1996) described a design for an automated double ring infiltrometer that employs two electrical contact water level sensors (for inner and outer rings), a capacitance type depth sensor and solenoid valves. A 12 V wet-cell car battery is used to power the solenoid valve and a laptop computer is required to control the valves and collect data from the sensor.

This paper discusses the construction of a simple, inexpensive infrared sensor system for making automated water level measurements. The system has a number of potential applications. In this paper we demonstrate the automation of soil infiltration measurements using a double-ring cylinder infiltrometer. Although various types of liquid level sensors are commercially available, we were unable to locate any commercial source for a completely automated system that can collect and store measurements unattended over a period of time. The system described can be constructed for less than US$ 200 at the time of publication.

2. IR sensor/microprocessor infiltrometer system

2.1. Description of system

The system described here has several advantages over those discussed above. The sensor is small, inexpensive, lightweight and versatile. It can be mounted on either single- or double-ring infiltrometers of any size or on the Mariotte reservoir. Additional sensors can be connected to the system, thus enabling collection of parameters such as water temperature and soil moisture. The sensor measures distance to water level, and can thus be used for other applications requiring water level measurements.