Drought Adaptation Option: Soil moisture monitoring

José Payero, Ahmad Khalilian, and Rebecca Davis: Clemson University

What are the benefits of monitoring soil moisture?

Local climate, as reflected by daily weather conditions, is one of the major factors driving the daily and seasonal evapotranspiration demand of crops. The evapotranspiration rate of the crop, the rainfall pattern, and the soil type combined determine the timing and amount of irrigation that needs to be applied to avoid crop stress and produce high crop yields. Since weather conditions are unpredictable, especially under a changing and varying climate, it is difficult to develop consistent guidelines or "*rules of thumb*" about how to irrigate crops. Therefore, measuring soil moisture is one of the ways to properly determine irrigation timing and amount. Measuring soil moisture can help farmers save water, reduce energy costs, increase yields, and protect the environment. Excess irrigation will increase cost of production and can have negative environmental effects such as runoff, waterlogging, and leaching of soil nutrients and other chemicals that can eventualy contaminate water sources and reduce yield. Insufficient irrigation, on the other hand, can result in crop stress and reduced yields.

Although it is common for farmers to estimate soil moisture by the hand-feel method (Figure 1), soil moisture can be measured or monitored more effectively and accurately using a variety of commercially available soil moisture monitoring systems, some of which provide continuous data collection.

Figure 1: Hand feel method of estimating soil moisture.

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What is a soil moisture monitoring system?

A soil moisture monitoring system is a combination of devices that can perform one or more of the following functions: sense soil moisture, read/store data, and transmit data to a computer, which helps organize, visualize and interpret the soil moisture data (Figure 2).

A soil moisture monitoring system can, therefore, be divided into the following five components: (1) the soil moisture sensing probe, (2) the power supply, (3) the data collection device, (4) the data transmiter, and (5) the base station (Figure 3)

Figure 2: Functions of a soil moisture monitoring system

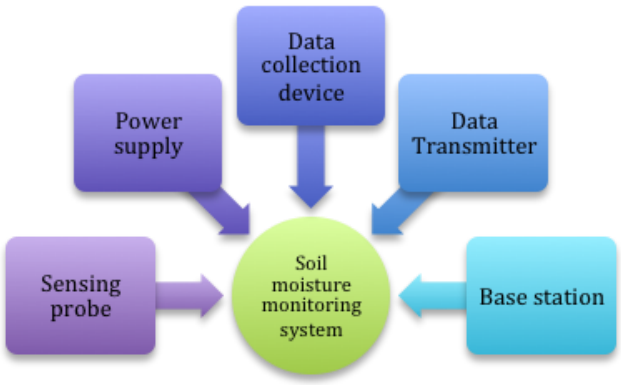

Figure 3: Components of a soil moisture monitoring system.

What is the soil moisture sensing probe?

The soil moisture sensing probe or soil moisture sensor is a device that measures or estimates how much water the soil contains at a given depth and time. The soil moisture probe/sensor does not measure soil moisture directly, but usually derives soil moisture indirectly by measuring other soil properties that depend on soil moisture, such as soil water tension or the ability of soil to conduct or store electricity. There is great variety of soil moisture probes/sensors on the market today. They range from single soil moisture sensors (Figure 4) that are buried in the ground at the required depth, to soil moisture probes with multiple sensors at different depths (Figure 5), which are installed via an access tube. Probe selection depends on the crop, cost, preference, availability, ease of installation, etc.

What is the power supply?

Since most current soil moisture monitoring systems rely on electronics, a reliable source of electricity is required. Most systems have been designed to operate in remote locations (like in the middle of a corn field) where AC electricity is not available. Therefore, they usually operate with DC power supplied by batteries. Some systems can operate for months using small AA batteries, but others need more power and rely on larger batteries that are recharged with solar panels (Figure 6).

Figure 4: Single soil moisture probe

Figure 5: Soil moisture probe with multiple sensors.

Figure 6: System showing solar panel.

What is the data collection device?

Although some sensors like tensiometers have a manual readout (Figure 7) to directly read the soil moisture (tension), nowadays most soil moisture probes produce an electronic signal (such as resistance or voltage) that changes with soil moisture, which cannot be seen directly. Therefore, some kind of data collection device is needed to obtain the electrical output from the sensor (s) and convert it to soil moisture or some other unit that is meaningful to the user. Data from the sensor can be collected manually or automatically. For manual data collection, portable readouts are usually employed (Figure 8) and the user has to go to the field and connect the portable readout to the soil moisture probe installed in the field.

Figure 7: Tensiometer readout.

Figure 8: Portable electronic readout.

For applications requiring frequent data collection, or just for convenince, data collection can be automated using an electronic datalogger (Figure 9). A datalogger is just a type of computer that can be connected to the sensors and can be programmed to collect, store, and/or transmit data at regular time intervals ranging from seconds to days. Usually, the logger stores the date and time corresponding to the soil moisture reading from each sensor. Some dataloggers have a screen for viewing the data on-site and others do not.

Figure 9: System showing datalogger.

What is the data transmitter?

Once the datalogger collects and stores the soil moisture data, the next step is to send the data to a computer where it can be further processed. If the data is not needed to make decisions at the same time as it is being collected (in real time), an option is to store the data in the datalogger and periodically (such as weekly) the user can connect a computer to the datalogger and download the data to the computer. If the data is needed in real time, it can be transferred to a computer using either wired or wireless communication. Wired communication is just linking the logger and the computer with a wire connection, which could be adequate for short distances. In most cases, however, a wireless communication is more practical.

Wireless communicaiton can be done either via satellite, radio or cell phone. Each of these types of communication options would require special equipment, such as a radio transmitter (Figure 10), a satellite transmitter or a cell phone modem. One or several repeater antennas are also required to transmit the signal, depending on whether or not there is line of sight between the datalogger and the computer, and the distance involved. For satellite and cell phone data transmission, the user normally would need to suscribe to a monthly data plan, which represents an on-going cost in addition to the initial investment cost of purchasing the system.

Figure 10: System showing radio transmitter.

What is the base station?

The base station is usually a computer equiped with a data receiver of some type, such as a modum, radio, or satellite receiver. The computer is also equiped with some type of specialized software needed to communicate with the datalogger to download the data. Some systems also send the data via the internet to an external website, from which the base station can obtain them via the internet. Each company selling soil moisture monitoring systems usually has their own software. The sofware helps the user download, organize, view (Figure 11), interpret the data and create reports, among other functions.

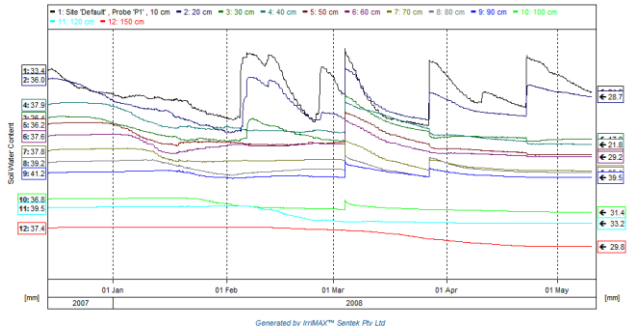

Figure 11: Soil moisture for different depths plotted by computer software.

What is the investment cost?

The cost of of a soil moisture monitoring system can vary significantly depending on the company, the number of sensor depths required, the data transmission option (manual, radio, satellite …), etc. For comparison, Table 1 shows the cost of setting up a system to monitor three soil depths and collect the data either manually, continously logged, or transmitted via radio or satellite; and the yearly cost of the data communication plan for two different soil moisture sensor types (Watermark and Decagon). These are just the cost to measure one site in the field. Some fields with different soil types may require more than one measurement site.

Table 1. Comparative cost of two soil moisture monitoring systems ($US in 2013, measuring 3 soil depths).

Options	Watermark	Decagon
Installation tool	$139	
Manual measurement	$303	$804
Data logged automatically	$570	$1,074
Data transmitted via radio	$1,790	$1,845
Data transmitted via satellite	$2,395	$1,682
Cost of transmitting data	$279/year	$200/year

What are the barriers to adoption?

Adoption of soil moisture monitoring systems by farmers has been limited by lack of information and training, difficulties in installing and calibrating the sensors in the field and difficulties involved in downloading and interpreting the data. Cost can also be an issue for some of the systems, although there are some very affordable systems available. Another problem has been that sensors installed in the field can interfere with farming operations.