Soil water availability monitoring for diversified vegetable farms

Rachel Schattman[1], Haley Jean[1], Joshua Faulkner[2], Rebecca Maden[2], and Bee Khim Chim[3]

[1]The Agroecology Lab, University of Maine School of Food and Agriculture
[2] University of Vermont Extension
[3] University of Maine Cooperative Extension

What is soil water availability?

Soil water availability is the amount of plant-available water that is stored in the soil profile at a specific point in time. Plant-available water is affected by many factors including soil physical properties, temperature, precipitation, irrigation, crop type, and more. Too little water for an extended period of time in the soil can reduce yield and impact plant quality because drought causes plant stress. Too much soil water can lead to root anoxia (a lack of oxygen within the soil) as well as nutrient depletion, causing negative effects on quality and yield of cash crops.

Figure 1: Ceramic-tipped tensiometer (left) and granular matrix sensor (right). Image credit: Irrometer

Banner image credit: Rachel Schattman, 2019

As our climate changes, managing soil water availability will become increasingly important and challenging. In particular, irrigation systems are becoming critical. Farmers and researchers are exploring new irrigation-management strategies, particularly in regions that have not historically relied upon irrigation to meet crop water needs. Soil water monitoring systems are a key component of efficient irrigation, enabling farmers to both maximize water-use efficiency and ensure that crops can thrive. This is especially important given the increased variability in rainfall experienced in recent decades across many parts of the world.

Where to place sensors

When deciding where to place soil water sensors, there are five things to consider. First, you should place sensors in high-value crops, or crops where it is important that you achieve high yield or quality. Supplying the right amount of water to a crop at the right time will increase the chances that the plants will be healthy and productive. Consider placing sensors in high tunnels, where soil water additions are driven by irrigation, and where crop values are often high.

Second, place soil water sensors in areas with different soil conditions. If your farm has heterogeneous soils, you may want to locate sensors in such a way as to capture the variation. This will

January 2023

allow you to assess how different soils react over time to rainfall and irrigation, and will help with prioritizing irrigation-equipment placement and labor during the season.

Third, place soil water sensors in locations that you are able to irrigate. Knowing that you should apply water to a crop doesn't help if you can't actually deliver water to that crop. Knowing what crops depend on irrigation may help with future planning, prioritizing crop locations, irrigation-equipment placement, and labor during the season.

Fourth, if you are using a cellular system for uploading soil water data to the internet, you'll need to place your sensors somewhere with good cellular coverage. If you are using a wifi mesh network, the manufacturer will give you guidance on how far apart the sensor relays can be installed. You will also need sensors to be within a certain distance of an internet-connected computer or tablet.

Lastly, the depth of your crop's roots should determine the depth at which you set the sensors. For example, sensors in shallow-rooted crops should be set ~6" below the soil surface, while sensors in deeply-rooted crops could be installed 12-24" deep. You may consider setting two sensors side-by-side at different depths and tracking measurements over time. This will tell you how quickly your soil dries out. Deeper soils will generally retain moisture for longer periods of time, though the soil drying rate depends on multiple factors (e.g., soil texture, ground cover, crop water demand, air temperature).

How to measure soil water availability

Traditionally, farmers have used skill and experience to assess crop-irrigation needs through the feel of soil, signs of drought, or wilt in a crop. However, affordable technology is now available for farmers to assess soil water in real time. The two most common ways to approach soil water monitoring for irrigation scheduling purposes are *tensiometers* and *granular matrix sensors*. Both of these methods measure matric potential, which is an estimate of the potential energy of water in the soil.

A tensiometers has a porous tip that allows water to move through it based on how dry or wet the surrounding soil is. As water interacts with the tensiometer, an attached vacuum gauge reads the vacuum suction needed to pull water out of the soil. When there is high vacuum pressure, it is more difficult for water to move through the soil profile. These measurements tell us how much water is available to plants. Tensiometers can last for many years without needing to be replaced, but should be removed during the winter months. If these sensors are left outside in freezing temperatures, the ceramic tips may crack, rendering the sensor useless. Though tensiometers require some maintenance in the field, they are long-lasting and highly accurate in coarse-textured soils (e.g., sand). Users should be aware that when

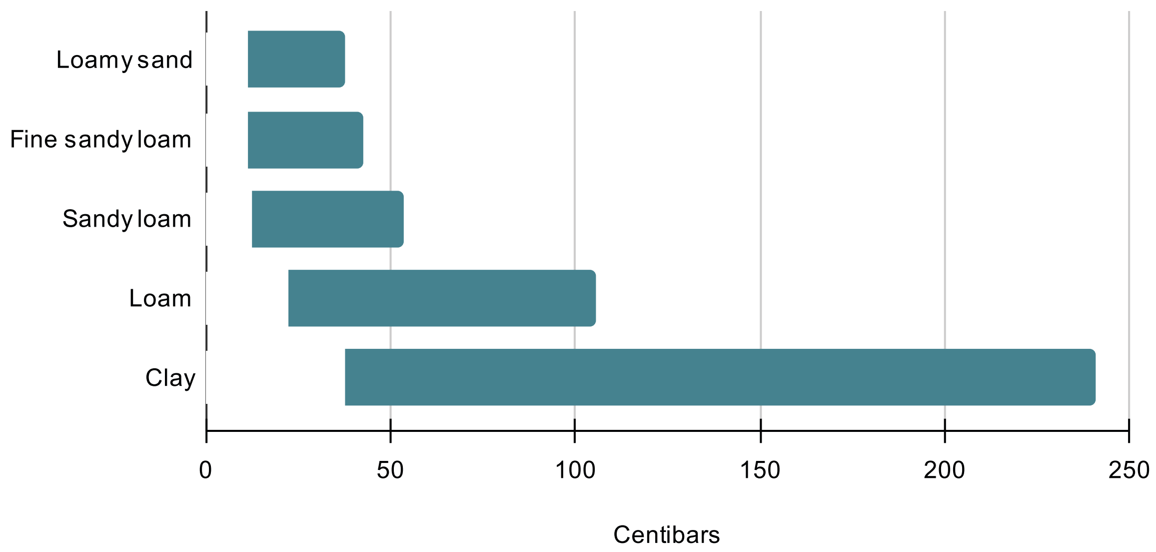

Figure 2: Optimal irrigation range by soil texture

soil suction exceeds 100 centibars (cb), tensiometers will no longer give accurate readings. Also, if the porous ceramic tip loses contact with the soil, the tensiometer will not give accurate readings. When the soil is re-wetted, either by irrigation or rainfall, the tensiometer should be refilled with water before it is used again.

Granular matrix sensors also measure soil matric potential. These sensors consist of a probe with a porous tip, with two electrodes that are buffered with gypsum. As water interacts with the two electrodes, the electrical resistance between the two electrodes changes. With a higher soil water content, the resistance between the two electrodes decreases because water conducts electricity better than soil. Perhaps the biggest advantages of using a granular matrix system is the low cost and limited maintenance. These sensors are also unaffected by freezing temperatures.

Information from tensiometers and granular matrix sensors can be read manually or digitally. Measurements from these systems can be read through handheld readers, downloadable data loggers, or continuously read cellular or wifi systems linked to a smartphone or computer.

Handheld readers are portable and are used to capture soil water measurements at a single point in time. Because soil water changes frequently, these readers are most useful when measurements are taken frequently. This can be time consuming. However, having the handheld system allows for fairly simple, low-tech gathering of soil water data. Some handheld readers allow multiple readings to be stored, so it's easy to average the soil water availability of the whole field before assessing irrigation needs. Data loggers are typically placed in a field for the duration of a growing season. Data must be downloaded onto a computer, and should be checked on a regular basis to establish irrigation needs. Continuously read cellular or wifi systems are connected to in-home networks, and going in the field is not required to check soil water levels.

How to use soil water data

Soil water for irrigation scheduling is most commonly measured as soil matric potential, measured in centibars (cb) or kilopascals (kPa), which are equivalent and indicate the amount of water available to plants. Based on this information, you can establish if irrigation is needed and how much water to supply. Soils are critically dry when 50% of the plant-available water has been depleted. *Plant-available water* is the maximum amount of water in the soil that can be used by plants, which varies by soil texture. The soil tension that corresponds with this critically dry level varies from field to field, depending on soil texture. For example, sandy soils are thought to need irrigation between 20cb and 30cb, and silty soils between 30cb and 50cb (see figure 2). Typically, clay soils need to be irrigated between 50cb and 60cb. A good rule of thumb is that for most soils irrigation is needed between 30cb-60cb. It should be noted that this is a general rule of thumb, and different crops require different amounts of water at different stages of development.

Additional resources

Does irrigation pay? Case study: https://www.climatehubs.usda.gov/irrigation-pays-protecting-crop-revenues-northeast

Soil water basics from Irrometer: https://www.irrometer.com/basics.html

Water needs based on crop development stages: https://www.irrometer.com/pdf/ext/ANR-1169.pdf

Climate adaptation resources website: https://www.uvm.edu/climatefarming/home

Acknowledgements

This factsheet was created with support from The National Institute of Food and Agriculture, U.S. Department of Agriculture, through the Northeast Sustainable Agriculture Research and Education program under subaward number LNE19-391R, and the Maine Agricultural and Forest Experiment Station Hatch Project number ME0-1022424. This project was also supported by the USDA Northeast Climate Hub, through 20-JV-11242306-087. Special thanks to Dr. Stephanie Burnett and Erin Lane for their content review, and Karrah Kwasnik for design consultation.

NORTHEAST SARE Sustainable Agriculture Research & Education

USDA United States Department of Agriculture Northeast Climate Hub

The Agroecology Lab

1865 THE UNIVERSITY OF MAINE

THE UNIVERSITY OF VERMONT EXTENSION