Oregon State University Extension Service

# Soil moisture monitoring to support irrigation scheduling

Irrigation Technology and Management Program | Management Technical Guide 9

**María Isabel Zamora Re, Todd M. Peplin and Abigail Tomasek**

**CONTENTS**



## Summary

Soil moisture monitoring is an key component of irrigation scheduling and water management. It involves measuring the amount of water stored within the crop root zone to support timely and efficient irrigation decisions. Methods range from basic field observations using the feel and appearance method to advanced sensor-based technologies and remote sensing tools. Integrating soil moisture monitoring with effective irrigation scheduling improves water-use efficiency and helps maintain optimal crop growth conditions.

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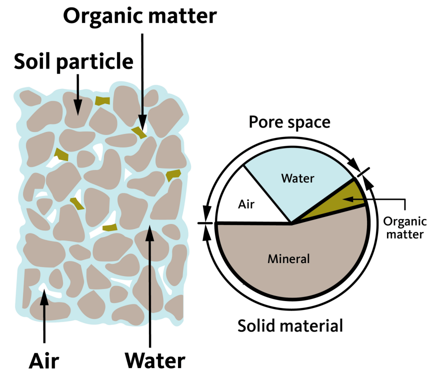


**Figure 1. Soil volume composition: distribution of solid materials (minerals and organic matter) and pore spaces (air and water).**

Credit: Kellen Grist, © Oregon State University

# What is soil moisture?

Soil moisture refers to the water stored within the pore spaces of unsaturated soil. It includes both liquid water and water vapor contained between soil particles. Unlike groundwater, which fills all pore spaces below the water table, soil moisture exists in the upper soil profile where air and water share the pore space.

The amount of soil moisture present depends on soil texture, structure, organic matter content, bulk density and soil depth. Weather conditions influence soil moisture through precipitation and evapotranspiration. Crop type and growth stage further affect soil water through varying rates of transpiration.

Soil moisture is typically monitored within the effective rooting depth of a crop to ensure sufficient water is available for optimal growth.

# Why measure soil moisture?

Water moves through soils differently depending on soil texture, structure, organic matter content and pore-size distribution. Soil texture refers to the relative proportion of sand, silt and clay particles, which strongly influences how water is stored and transported through the soil profile.

Water occupies the pore spaces between soil particles. When all pore spaces are filled with water, the soil is saturated. At saturation, air is displaced from the soil pores, reducing oxygen availability to roots.

After saturation, gravitational water drains from the large soil pores until the soil reaches **field capacity** — a relatively stable water content at which downward drainage becomes minimal and capillary forces retain water against gravity. As plants use water through evapotranspiration, soil moisture decreases, and the soil matrix holds the remaining water more tightly. Eventually, soil moisture reaches the **permanent wilting point**, the level at which plants cannot extract sufficient water to recover from wilting.

The difference between field capacity and permanent wilting point is known as **available water capacity** — the portion of soil water that is generally accessible for plant uptake. Available water capacity varies with soil texture and structure (Figure 2).

Measuring soil moisture allows growers to determine:

- How much plant-available water remains in the root zone
- How quickly water is being depleted through ET
- When irrigation is needed to prevent crop stress
- Whether irrigation is reaching the intended root depth

Maintaining soil moisture within the range of plant-available water supports adequate water and nutrient uptake, enabling optimal crop growth while minimizing water loss through deep percolation or runoff. Soil moisture monitoring therefore provides a direct, field-based method to improve irrigation timing and water use efficiency.

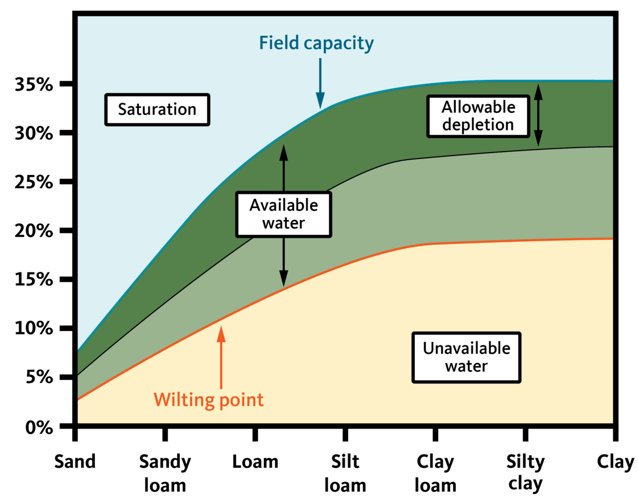


**Figure 2. Available water capacity is the difference between field capacity and the level at which plants wilt, known as the permanent wilting point.**

Credit: Kellen Grist, © Oregon State University

# Soil moisture content and soil moisture tension

Soil water can be described in two fundamentally different but complementary ways:

- **Soil moisture content** refers to *how much water is present.*
- **Soil moisture tension** (matric potential) refers to *how tightly water is held in soil*.

Both are important for irrigation management.

## Soil moisture content

Soil moisture content describes the *quantity of water stored in the soil.* It can be expressed on either a mass or volume basis. You can determine soil moisture content by conducting gravimetric or volumetric testing, or through the use of sensors.

### Gravimetric soil moisture content ($\theta_g$)

Gravimetric water content is determined by measuring the *mass of water in a soil sample relative to its dry mass:*

$\theta_g$ = Mass of water/Mass of dry soil

Gravimetric water content ($\theta_g$) is typically expressed in g $g^{-1}$ or percent by weight.

- Determined by soil sampling: Use an auger or shovel to collect a soil sample. Weigh the sample to determine its fresh weight. Oven-dry the soil at 105°C, then weigh it again. This is the dry weight. The loss in weight represents gravimetric water content ($\theta_g$).

### Volumetric soil moisture content ($\theta_v$)

Volumetric water content is the *volume of water per volume of soil:*

$\theta_v$ = *Volume of water/Total soil volume*

Volumetric content ($\theta_v$) is expressed as $cm^3/cm^3$, $m^3/m^3$, or percent by volume.

Volumetric water content is often more useful for irrigation scheduling because it directly relates to water depth in the root zone. For example, a volumetric water content of 0.25 $cm^3/cm^3$ in a 12-inch root zone corresponds to 3 inches of stored water.

- Determined by soil sampling: Collect a soil core of known volume using a sampler (ring or core method). Weigh the sample, dry it in an oven at 105°C to constant mass, and reweigh it to determine the mass of water. The volume of water is calculated from its mass (using the density of water).

- Calculated from gravimetric water content: Volumetric content ($\theta_v$) may also be calculated from gravimetric content using soil bulk density: $\theta_v = \theta_g \times \rho_b$

Where:

- $\theta_v$ = Volumetric water content
- $\rho_b$ = soil bulk density
- $\theta_g$ = gravimetric content

### Practical considerations

Gravimetric and volumetric methods are:

- Highly accurate
- Considered reference methods
- Used to calibrate soil moisture sensors

However, they are labor-intensive and not real-time, making them impractical for routine irrigation decisions in most commercial fields.

To find out more about how soil moisture content is determined, see Gravimetric Water Content (https://www.youtube.com/watch?v=GSCE_7f5ZCM) from Virtual Soil Science Learning Resources.

### Sensors that measure soil water content

Examples include:

- Dielectric soil moisture sensors (capacitance and TDR probes)
- Neutron moisture meters

## Soil moisture tension (soil water potential)

Soil moisture tension, more accurately referred to as soil water matric potential, describes the *energy required by plant roots to extract water from the soil*. Unlike soil water content, which indicates how much water is present, matric potential describes how tightly that water is held.

Water is retained in the soil primarily due to:

- Adhesion (attraction between water and soil particles)
- Cohesion (attraction between water molecules)
- Capillary forces within soil pores

As soil dries, the largest pores drain first. Water remains in progressively smaller pores, water films surrounding particles become thinner, and the energy required to remove water increases. Therefore, *the drier the soil, the greater the force roots must exert to extract water.*

### Units of soil water tension

Soil water potential is expressed as a negative pressure relative to atmospheric pressure and is commonly expressed as:

- Kilopascals (kPa)
- Bars
- Centibars (cb)

(1 bar = 100 centibars ≈ 100 kPa)

### Typical soil water tension values

- Saturation ≈ 0 kPa
- Field capacity ≈ −10 to −33 kPa (texture-dependent)
- Permanent wilting point ≈ −1500 kPa

### Sensors that measure soil water tension

The following sensors measure matric potential (tension), not water content:

- Tensiometers
- Electrical resistance blocks

- Granular matrix sensors

# Measuring soil moisture

You can use several methods to measure and monitor soil moisture. These methods fall into two primary categories:

- **Soil water content methods,** which measure the amount of water in the soil.
- **Soil water tension (matric potential) methods,** which measure how tightly water is held in the soil and how much energy plants must use to extract it.

These methods quantify how much water is stored in the root zone and are useful for determining *how much water has been depleted* and *how much irrigation is needed to refill the soil profile.*

## Soil moisture sampling: Feel and appearance method

Estimating soil moisture by feel and appearance is a simple, low-cost field method for assessing soil water status within the crop root zone. This method involves collecting soil from different depths using a soil probe, auger or shovel and evaluating its texture, color, cohesiveness and ability to form a ball or ribbon.

**Figure 3. Determining soil moisture using the feel and appearance method.**

Credit: U.S. Department of Agriculture, Natural Resources Conservation Service, 2023.

Because soil behavior changes with texture and water content, interpretation varies for sandy, loamy and clay soils. For example:

- Sandy soils feel loose and crumbly when dry and will not hold together well even when moist.
- Loamy soils can form a weak ball when moist.
- Clay soils feel sticky when wet and form a strong ribbon.

With training and experience, the feel and appearance method can estimate volumetric soil moisture within approximately 5%–10%, depending on soil texture and operator skill.

Evaluate soil in 1-foot increments down to the effective rooting depth of the crop to determine where moisture is being depleted and where irrigation water is penetrating.

Although this method does not provide real-time quantitative data, it is an excellent tool for:

- Validating soil moisture sensor readings
- Verifying irrigation depth and uniformity
- Developing intuition about soil water behavior

For more information and soil texture comparison tables, see *Estimating Soil Moisture by Feel and Appearance,* (https://www.nrcs.usda.gov/sites/default/files/2022-09/Estimating%20Soil%20Moisture%20by%20Feel%20and%20Appearance.pdf) USDA Natural Resources Conservation Service.

## Tensiometers

Tensiometers are soil moisture sensors used to measure soil water tension (matric potential). Producers in horticultural, vegetable and specialty crop systems commonly use tensiometers where irrigation is frequent and soils are monitored closely.

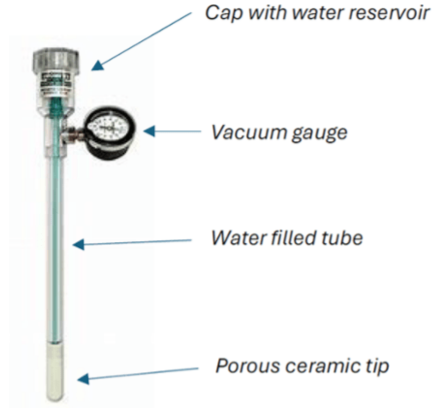


**Figure 4. Typical tensiometer with vacuum gauge.**

Credit: Adapted from University of Minnesota Extension

### How they work

A tensiometer (Figure 4) consists of:

- A water-filled tube approximately 1 inch in diameter
- A vacuum gauge, at the upper end
- A porous ceramic cup, at the lower end

The ceramic tip is installed at the desired depth within the root zone. Water moves through the porous tip in response to changes in soil water conditions. As the surrounding soil dries, water is drawn from the tensiometer through the ceramic cup, creating a measurable vacuum inside the tube. This vacuum reflects the soil water tension.

Tensiometers read in centibars (cbar) or kilopascals (kPa).

(1 cbar ≈ 1 kPa)

### Advantages, limitations and considerations

- The typical measurement range is 0 to approximately 70–85 cb. Beyond this range, air may enter the water column (a process known as cavitation), breaking hydraulic continuity and causing inaccurate readings.
- Because fine-textured soils often exceed this tension range before reaching irrigation thresholds, tensiometers may not fully capture the dry end of the available water range in clay soils.
- Tensiometers are relatively easy to install, read and maintain, but they must remain properly filled with water and free of air bubbles to function accurately.
- Interpreting tensiometer readings requires knowledge of soil texture and, ideally, a soil water characteristic curve to relate tension values to soil water content.

For additional guidance on installation and operation, see Tensiometers: Installation and Operation. (https://www.youtube.com/watch?v=kMnzxWOJHRU)

**Table 1. Approximate tensiometer readings at different soil moisture levels for various soil textures**

| Soil type | Saturated soils (cbars) | Field capacity (cbars) | Typical irrigation threshold (cbars) | cbars) |
|---|---|---|---|---|
| **Loamy sand/sandy loam** | 0–10 | 10–15 | 20–30 | 45–60 |
| **Loam/silt loam** | 0–10 | 20–30 | 30–50 | 50–70 |
| **Clay loam/clay** | 0–10 | 30–40 | 50–60 | 60–100 |

1 centibar (cbar) ≈ 1 kilopascal (kPa)

Credit: Adapted from Irrometer

Note: These values are approximate and may vary depending on crop type, rooting depth and management strategy. High-value or shallow-rooted crops are often irrigated at lower tension values, while deeper-rooted crops may tolerate higher tension before irrigation is required.

## Electrical resistance block and granular matrix and sensors

Electrical resistance blocks, commonly known as gypsum blocks or soil moisture blocks, measure soil water tension (matric potential) indirectly by monitoring changes in electrical resistance within a porous medium.

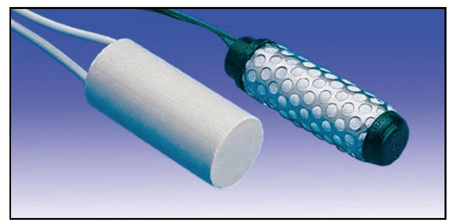

**Figure 5. Traditional matrix gypsum block (left) and a Watermark granular matrix sensor (right). Both sensors estimate soil water tension by measuring changes in electrical resistance within a porous matrix that equilibrates with surrounding soil moisture.**

Credit: Dominic Skinner, Agriculture Victoria

### How they work

These sensors contain two embedded electrodes surrounded by a porous material (typically gypsum or a granular matrix) (Figure 5). The block is installed in the soil at the desired monitoring depth.

As soil moisture changes, water moves into or out of the porous material until it equilibrates with the surrounding soil. Because electrical conductivity increases with moisture content:

- When the block is wet, electrical resistance is low.
- As the soil dries, resistance increases.

The resistance measurement is converted — using manufacturer calibration tables or electronic meters — into soil water tension values (usually reported in centibars or kilopascals).

## Gypsum blocks

Traditional gypsum electrical resistance blocks are relatively inexpensive and easy to install and read. However, they have limitations:

- They gradually dissolve in wet soils.
- They are influenced by soil salinity.
- Long-term stability may decline over time.

Because salts increase electrical conductivity, highly saline soils can cause inaccurate readings.

## Granular matrix sensors

Granular matrix sensors were developed to improve durability and reduce sensitivity to salinity. These devices typically consist of:

- A porous ceramic outer shell
- A granular internal matrix surrounding the electrodes

The matrix buffers salinity effects and improves long-term structural stability compared to gypsum blocks.

Granular matrix sensors measure soil water tension over a wider operating range than tensiometers and can function at drier conditions where tensiometers cavitate.

Readings can be collected with:

- Handheld meters
- Data loggers
- Automated irrigation controllers


**Figure 6. Watermark granular matrix sensors connected to a handheld data analyzer used to measure soil water tension in the field. Sensor readings can be used to monitor root-zone moisture conditions and assist with irrigation scheduling.**

Credit: Iowa State University Extension

### Advantages

- Relatively inexpensive
- Moderate measurement range (approx. 0–200 kPa, depending on model)
- Compatible with automation

### Limitations

- Require soil contact for accuracy.
- May require periodic recalibration.
- Less precise than laboratory methods.
- Temperature effects can influence resistance readings.

For more information on how to prepare and read granular matrix sensors, see Watermark Soil Moisture Sensor — How to Install (https://youtu.be/5StD2M4WgpE?si=7U-k3EHHXm8m-uq5)and Soil Sensors and ET Gauges. (https://www.youtube.com/watch?v=ayJfOs-BO90&t=20s)

## Dielectric soil sensors

Dielectric soil sensors, also called electromagnetic soil moisture sensors, measure volumetric soil water content by estimating the soil's dielectric permittivity (dielectric constant).

Water has a much higher dielectric constant (~80) than soil minerals (3–5) or air (~1). As soil water content increases, the bulk dielectric constant of the soil increases. Electromagnetic sensors measure this property and convert it to volumetric water content using calibration equations.

Unlike tension-based sensors, dielectric sensors directly estimate the quantity of water present, rather than how tightly it is held.

These sensors are widely adopted because they:

- Provide near-instantaneous readings
- Can be integrated into automated data logging systems
- Require less maintenance than water-filled sensors such as tensiometers

However, dielectric soil sensors require proper installation and calibration to ensure accurate readings.


**Figure 7A. A time-domain reflectometry (TDR) soil moisture probe measuring real-time soil moisture in the field.**

Credit: Adobe Stock

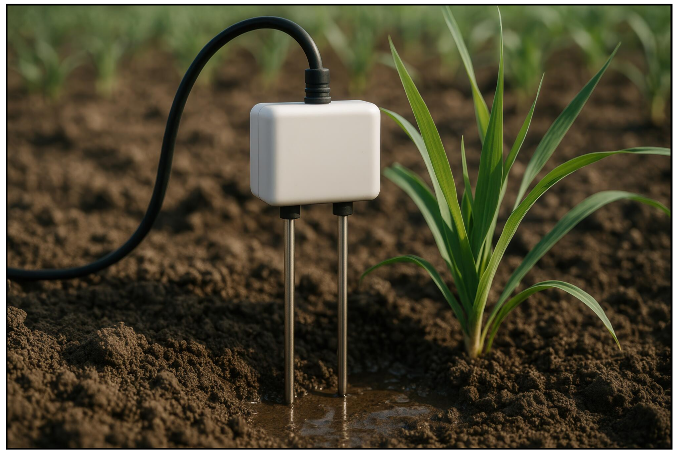

**Figure 7B. A TDR soil moisture probe measures volumetric water content in the soil.**

Credit: Adobe Stock

## Time-domain reflectometry

Time-domain reflectometry determines soil water content by measuring the **travel time of an electromagnetic pulse** through the soil.

A TDR sensor consists of two or three parallel stainless steel rods (waveguides) inserted into the soil (Figure 7A-B). The instrument sends a high-frequency electromagnetic pulse along the rods. TDRs measure the time required for the pulse to travel through the soil and reflect back to the sensor.

Because electromagnetic waves travel more slowly in wetter soils (due to higher dielectric permittivity), travel time increases as soil water content increases.

TDR sensors are:

- Generally very accurate (±2%–3% volumetric water content under proper calibration)
- Less sensitive to salinity compared to capacitance sensors
- Available in probe lengths ranging from several inches to several feet

Calibration may be soil-specific, especially for soils high in clay or organic matter.

To find out more about how these sensors are installed, see Soil Moisture Sensor Installation (https://www.youtube.com/watch?v=Zh7SSzc10O4&t=38s) and Soil Water Content. (https://youtu.be/J24Fvi0F76s)

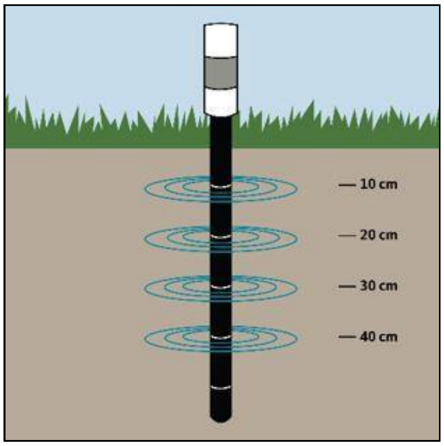


**Figure 8A. Capacitance (frequency-domain reflectometry) soil moisture sensor probe showing oscillating waves emanating from the probe.**

Credit: Carol Rang, © Oregon State University. Adapted from Minnesota State University

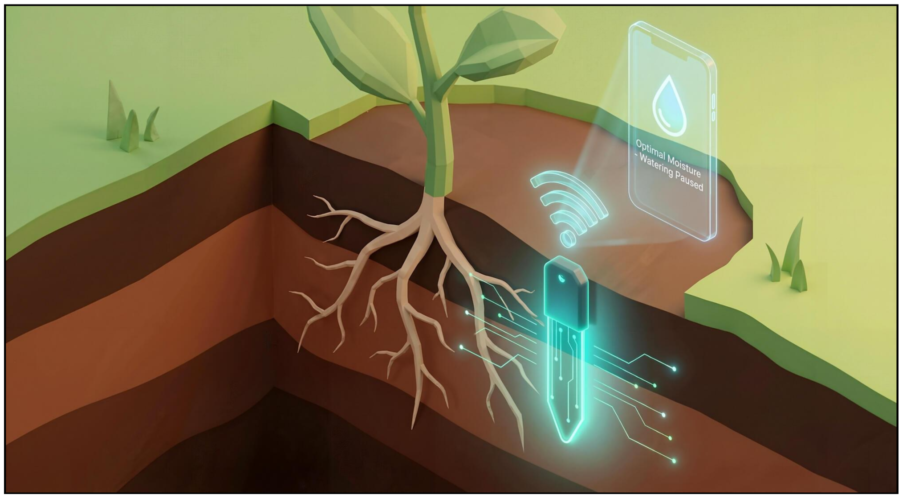


**Figure 8B. Conceptual illustration of electromagnetic signal interaction with soil and roots of a capacitance soil moisture sensor. These sensors estimate volumetric water content based on changes in soil dielectric properties.**

Credit: Adobe Stock

## Frequency-domain reflectometry/capacitance sensors

Frequency-domain reflectometry, often referred to as capacitance sensors, estimate volumetric water content by measuring changes in the resonant frequency of an oscillating electrical circuit (Figures 8A, 8B).

These sensors contain:

- Two or more electrodes
- An oscillating circuit

The electrodes use the soil as part of the capacitor's dielectric medium. When inserted into the soil, the sensor applies an oscillating electromagnetic signal (typically 50–150 MHz). As soil moisture increases, dielectric permittivity increases, altering the resonant frequency of the circuit.

In general:

- Soil moisture affects the dielectric permittivity of the soil, which changes the resonant frequency measured by the sensor.
- In most capacitance sensors, higher soil moisture results in lower resonant frequency, while drier soil results in higher resonant frequency.

The exact frequency response depends on sensor design and calibration.

### Advantages

- Typically, lower cost than TDR sensors

- Compatible with telemetry and automated irrigation systems
- Available in multi-depth or profile probe configurations
- Provide near real-time measurements

### Limitations

- More sensitive to salinity and temperature effects
- Sensitive to air gaps around the probe
- Accuracy depends on proper soil contact and installation

Calibration is recommended for improved accuracy in different soil textures, especially in high-clay, saline or high-organic-matter soils.

## Neutron moisture meters

Neutron moisture meters, also known as neutron probes or neutron scattering devices, estimate volumetric soil water content using radioactive neutron sources (Figure 9).

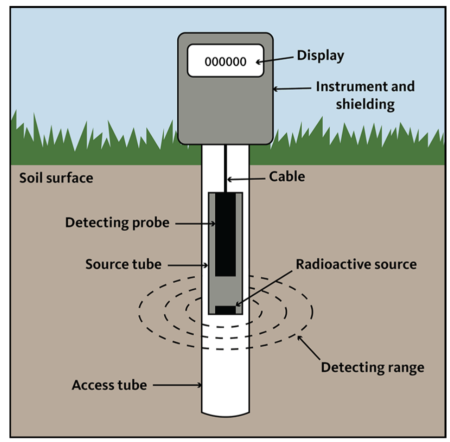


**Figure 9. Neutron moisture meter components showing source, detector and access tube system used to estimate volumetric soil water content.**

Credit: Carol Rang, © Oregon State University. Adapted from the University of California at Davis.

A neutron probe consists of:

- A sealed radioactive neutron source
- A detector
- An electronic gauge
- A surface readout connected by cable

An aluminum or PVC access tube is installed vertically in the soil profile. During measurement, the neutron source is lowered to a specific depth inside the access tube.

The radioactive source emits high-energy (fast) neutrons into the surrounding soil. These neutrons collide with hydrogen atoms, primarily found in soil water. When fast neutrons collide with hydrogen nuclei, they lose energy and become slow (thermalized) neutrons.

The detector counts the number of slowed neutrons returning to the probe. Because hydrogen concentration is directly related to soil water content, neutron counts are proportional to volumetric water content.

Readings are converted to volumetric soil moisture using soil-specific calibration equations.

Neutron moisture meters are commonly used for research and to calibrate other soil moisture sensors.

### Advantages

- High accuracy
- Excellent depth control
- Reliable for research applications
- Effective in deep soil profiles

### Limitations

- Requires special licensing and regulatory compliance due to radioactive material
- Requires operator training and radiation safety protocols
- Relatively expensive
- Not practical for routine on-farm irrigation monitoring

For these reasons, neutron probes are primarily used in research settings and for calibrating other soil moisture sensors.

For more on installation protocols when using the neutron probe, see How to Measure Soil Moisture by Using a Neutron Probe. (https://www.youtube.com/watch?v=Rrv0CSNFKgo)

## Advantages and disadvantages of soil monitoring methods

**Table 2. Differences between soil moisture monitoring techniques, advantages, disadvantages and approximate costs**

| Soil moisture monitoring technique | Advantages | Disadvantages | Cost |
|---|---|---|---|
| **Feel and appearance** | • Easy to conduct<br>• Inexpensive | • Subjective and qualitative<br>• Time-consuming and labor-intensive | Labor |
| **Gravimetric** | • Accurate results<br>• Inexpensive<br>• Ability to sample multiple locations | • Time-consuming and labor-intensive<br>• Time to get results | Labor, oven, scale |

| Soil moisture monitoring technique | Advantages | Disadvantages | Cost |
|---|---|---|---|
| **Tensiometer** | • Relatively accurate<br>• Affordable<br>• Ability to install in different locations<br>• Easy to install<br>• Continuous reading possible using transducer<br>• Not affected by salinity<br>• Minimal skill level to install<br>• Data easy to read and interpret | • Limited operating range (up to 85 cbars)<br>• Relatively accurate<br>• Affordable<br>• Ability to install in different locations<br>• Easy to install<br>• Continuous reading possible using transducer<br>• Not affected by salinity<br>• Minimal skill level to install<br>• Data easy to read and interpret<br>• Need good contact between sensor and soil (no gaps)<br>• Relatively accurate<br>• Affordable<br>• Ability to install in different locations<br>• Easy to install<br>• Continuous reading possible using transducer<br>• Not affected by salinity<br>• Minimal skill level to install<br>• Data easy to read and interpret<br>• Requires frequent maintenance (constant refilling tube with water)<br>• Relatively accurate<br>• Affordable<br>• Ability to install in different locations<br>• Easy to install<br>• Continuous reading possible using transducer<br>• Not affected by salinity<br>• Minimal skill level to install<br>• Data easy to read and interpret<br>Sensor is not effective on fine-textured soils | $60–$80 (requires 3–4 sensors) plus $140-$160 if installed with transducer |
| | | | |

| Soil moisture monitoring technique | Advantages | Disadvantages | Cost |
|---|---|---|---|
| **Electrical resistance block/granular matrix** | • Inexpensive<br>• Relatively accurate<br>• Affordable<br>• Ability to install in different locations<br>• Easy to install<br>• Continuous reading possible using transducer<br>• Not affected by salinity<br>• Minimal skill level to install<br>• Data easy to read and interpret<br>• Relatively accurate<br>• Affordable<br>• Ability to install in different locations<br>• Easy to install<br>• Continuous reading possible using transducer<br>• Not affected by salinity<br>• Minimal skill level to install<br>• Data easy to read and interpret<br>• Can be used in a large sample area<br>• Easy to install<br>• Can be used in moderately saline soils<br>• Continuous measurements can be collected with data logger<br>• Well-suited for irrigation water management | • Less accurate<br>• Not recommended in some soil types (sand and clay) and soils with high salt content<br>• Affected by soil temperature fluctuations<br>• Sensors degrade over time | \$20–\$40 per sensor (requires 3–4 sensors per location) plus \$200 for hand manual reader and \$500 for data logger |

| Soil moisture monitoring technique | Advantages | Disadvantages | Cost |
| --- | --- | --- | --- |
| **Time domain reflectometry** | • Accurate (2%-3%)<br>• Soil/site calibration usually not required<br>• Remote access of data available<br>• Continuous measurement can be collected with data logger<br>• Insensitive to salinity | • More complicated than capacitance probes<br>• Takes time to install<br>• Does not work well in high salinity soils<br>• Small area of influence<br>• Expensive | $250–$350 per sensor plus $1,000–$3,500 for data logger |
| **Capacitance** | • Continuous measurement can be collected with data logger<br>• Response time is very fast<br>• Remote access available<br>• Accurate if site calibrated (2%–3%)<br>• Less expensive than time domain reflectometry<br>• Can be used in high-saline soils compared to time domain reflectometry | • Small sensing area<br>• Affected by soil conditions (high salinity, clay content, temperature, bulk density)<br>• Site/soil-specific calibration preferred | $250-$350 per sensor plus $500–$2,500 for data logger |
| **Neutron probe** | • Accurate measurements<br>• Large measurements of volume of soil<br>• Samples a relatively large area<br>• One sensor for all sites and depths<br>• Unaffected by salinity and air gaps around access tube | • Soil/site-specific calibration usually required<br>• Expensive (~$10,000)<br>• Heavy<br>• Contains radioactive material (safety hazard)<br>• Licensing is required<br>• Manual reading and recording (~3 min/access tube)<br>• Not good at shallow depths ( | Approximately $10,000 and $25–$30 for access tubes |

# Considerations when using soil moisture sensors

Proper installation, placement and interpretation of soil moisture sensors are critical to obtaining reliable and actionable data.

## Define management zones first

Before installing sensors, divide the field into **management zones** based on relatively uniform characteristics such as:

- Soil texture and depth
- Topography and slope position
- Irrigation system type and uniformity
- Historical yield maps or crop vigor patterns

Each management zone should represent an area where soil water behavior is expected to be similar.

The USDA Web Soil Survey (//websoilsurvey.nrcs.usda.gov/app/) and the University of California, Davis, California Soil Labs (https://casoilresource.lawr.ucdavis.edu/soilweb-apps) can help you identify soil variability within fields. Install sensors in representative areas of the field with average soil and surface conditions. Avoid field edges, wheel tracks, ponded areas, or unusually wet or dry spots.

## Number of monitoring locations

- Install a minimum of two monitoring locations per management zone to capture variability.
- In relatively uniform fields (up to about 40 acres), two monitoring sites are often sufficient.
- Fields with higher spatial variability in soil texture, elevation or irrigation uniformity may require additional monitoring locations.

Sensor placement density should reflect field variability, not acreage alone.

## Sensor depth placement

- Install sensors within the effective rooting depth of your crop.
- Monitor at least two to three soil depths to capture soil water distribution.
  - For deep-rooted crops such as alfalfa, consider installing the sensors at 1-foot increments up to 3 feet.
  - For shallow-rooted crops, two depths are typically sufficient.

- Multidepth monitoring allows detection of:
  - Overirrigation (deep percolation)
  - Shallow drying
  - Root-zone depletion patterns

**Figure 10. Proper installation of a soil moisture sensor within the crop root zone. Sensors should be installed in representative management zones with firm soil contact and minimal disturbance to ensure accurate, reliable readings for irrigation decision-making.**

Credit: Adobe Stock

### Installation best practices

- Sensors should be carefully installed within the root zone, ensuring good soil contact.
- Avoid air pockets during installation; these can cause false sensor readings.
- Install sensors in undisturbed soil where possible.
- Protect and clearly mark sensor locations for easy identification in the field.
- Allow time for soil to settle around newly installed probes before relying on readings.

### Interpretation and data

- Recognize that spatial variability in soil texture, structure, organic matter and salinity can influence readings.
- Keep detailed records of irrigation events, rainfall and crop condition.
- Correlate sensor readings with field observations (soil feel, plant stress indicators).
- Integrate soil moisture measurements with evapotranspiration estimates and other irrigation scheduling tools (for example, the irrigation checkbook method or computerized scheduling applications).

Developing confidence in sensor interpretation requires consistency and experience. Long-term monitoring improves decision accuracy.

## Remote sensing and other soil moisture monitoring techniques

Remote sensing techniques estimate soil water content using satellite, aircraft (manned or unmanned) or proximal sensing platforms. A key advantage of remote sensing is its ability to provide spatial information over large geographic areas.

Satellite-based soil moisture products such as Soil Moisture Active Passive (https://smap.jpl.nasa.gov/) and Soil Moisture Ocean Salinity (https://extension.oregonstate.edu/earth.esa.int/eogateway/missions/smos) use microwave sensors to estimate surface soil moisture. These systems typically represent moisture conditions in the upper approximately 5–10 cm of soil. Because of this shallow measurement depth, they may not reflect moisture conditions throughout the full crop root zone.

Additionally, satellite soil moisture products often have coarse spatial resolution (several kilometers per pixel), which limits their usefulness for field-level irrigation scheduling but makes them well-suited for regional drought monitoring and large-scale water resource assessment.


**Figure 11. Conceptual illustration of satellite-based remote sensing. Microwave sensors mounted on satellites detect reflected electromagnetic signals from the Earth's surface to estimate near-surface soil moisture across large geographic areas.**

Credit: Adobe Stock

Other emerging technologies include:

- **Cosmic-ray neutron probes**, which estimate area-integrated soil moisture across several hectares using neutron moderation by hydrogen in soil water.
- **Center pivot–mounted microwave sensors**, which estimate near-surface soil moisture during irrigation passes.
- **Thermal and multispectral imagery**, which can infer crop water stress through vegetation indices or canopy temperature.

Some systems integrate surface soil moisture measurements with weather data and soil water balance models to estimate root zone moisture through modeling approaches.

While remote sensing provides valuable spatial information, it is best used in combination with field-level soil moisture measurements when making irrigation management decisions.

### Assess your soil moisture monitoring

Evaluate your property and knowledge about irrigation and monitoring soil moisture.

**Download the worksheet (https://oregonstate.box.com/s/hz8lc1doosfihqts5va4c1mhehk81432)**

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## About the authors

**María Isabel Zamora Re (https://bee.oregonstate.edu/users/maria-zamora-re?gid=25345)**

Assistant Professor, Water Management/Statewide Irrigation Specialist

**Todd M. Peplin**

Lead Planner

*Deschutes Soil and Water Conservation District*

**Abigail Tomasek (https://extension.oregonstate.edu/people/abigail-tomasek)**

Assistant Professor and Statewide Soil Water Quality Extension Specialist (Former), Crop and Soil Science (Former)

## Related publications

Irrigation Technology and Management Program Management Technical Guides (https://extension.oregonstate.edu/collection/irrigation-technology-management-program-management-technical-guides)

Irrigation water scheduling (https://extension.oregonstate.edu/catalog/em-9717-irrigation-water-scheduling)

Inspecting and maintaining irrigation systems (https://extension.oregonstate.edu/catalog/em-9869-inspecting-maintaining-irrigation-systems)