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Tracking Nutrient Movement with Soil Moisture Sensor EC Data[1]

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Introduction

How do you know if fertilizer reaches plant roots or leaches below the root zone? Electrical conductivity (EC) monitoring using soil moisture sensors provides real-time information, enabling irrigation adjustments that keep nutrients where crops can use them. Proper nutrient management is essential for plant growth, but excessive nutrient use leads to economic losses and environmental problems (Korsaeth 2005; Shi et al. 2009). Tracking nutrient movement at the field scale offers timely information that complements traditional soil sampling and laboratory analysis (Gholizadeh et al. 2011; Korsaeth 2005).

This publication provides guidance on using EC data from field-installed soil moisture sensors. When fertilizers are applied and followed by irrigation or rainfall, nutrients dissolve and move through the soil. EC sensors can help identify this movement, regardless of crop type. A case study from a citrus demonstration trial at the UF/IFAS Indian River Research and Education Center (UF/IFAS IRREC) presents how sensors track nutrient movement after irrigation and rainfall. This information helps irrigation managers, especially those using soil moisture sensors and irrigation dashboards, adjust fertilizer and irrigation practices to improve nutrient placement in the crop root zone. This publication is intended for irrigation managers, growers, consultants, and Extension professionals who use soil moisture sensors and irrigation dashboards to support nutrient and water management decisions.

Scope and Applicability

This publication focuses on interpreting EC data from soil moisture sensors using examples from Florida citrus on sandy soils with drip and microsprinkler irrigation. The principle that EC indicates dissolved ion, salt, or nutrient movement applies to other crops and soils. However, the timing ranges, irrigation amounts, and sensor depths presented here are based on citrus systems and should be adjusted as needed.

- **Vegetables and row crops**: May require shallower sensor placement (2–8 inches) and more frequent, lighter irrigation.
- **Ornamentals**: Often grown in modified soils or containers with different drainage behavior.
- **Heavy soils (clay, loam)**: Show slower water movement and delayed EC responses.
- **Other irrigation systems**: Overhead, flood, or furrow irrigation create different water and nutrient distribution patterns.

Growers using other systems should establish baseline conditions during the first 4–6 weeks of monitoring and consult local Extension professionals for site-specific guidance.

Why Monitor EC for Nutrient Movement?

Traditional soil testing provides information on nutrient availability but does not show how nutrients move through the soil. EC monitoring complements soil testing by providing real-time insight into nutrient movement. This allows growers to identify potential nutrient leaching below the root zone, confirm whether nutrients reach the target root depth, improve irrigation timing after fertilizer application, optimize water use, and reduce input costs.

For example, a citrus grower may observe high EC values at 4 inches but low values at 8 inches after irrigation. This indicates that nutrients remain shallow at 4 inches. EC data from sensors can be used to target irrigation frequency and volume so nutrients stay in the root zone. These adjustments can improve nutrient use efficiency, although outcomes vary by system.

Note: EC data from sensors do not replace soil testing or determine nutrient requirements. Soil testing defines

what to apply; EC data show how applied nutrients move through the soil.

What Is Electrical Conductivity (EC)?

Electrical conductivity (EC) measures dissolved salts in soil water. When fertilizer dissolves, EC increases. EC is commonly reported in milliSiemens per meter (mS/m) or deciSiemens per meter (dS/m). Higher EC indicates greater concentrations of dissolved salts, which may include nutrients. Lower EC suggests fewer nutrients or possible leaching (Sandoya et al. 2021; Vought et al. 2025; Cabrera Corral et al. 2016). Because EC reflects all dissolved ions, it serves as a rapid field indicator but cannot identify specific nutrients. An increase in EC after fertilization indicates that dissolved nutrients have moved past the sensor. If EC data from sensors are low, nutrients may not yet have reached the sensors' depth. EC data should be incorporated into a comprehensive management plan that includes fertilizer timing, irrigation, rainfall records, soil properties, water quality, and periodic soil testing (Zarai et al. 2023).

Soil EC is widely used in precision agriculture to track field variability (Baldi et al. 2020; Eigenberg et al. 2002; Mylavarapu et al. 2020). Measurements are rapid and nondestructive, and they allow frequent monitoring (Corwin and Scudiero 2020). If salinity concerns arise, EC data should be supplemented with laboratory analysis. For more detailed information about EC and how it relates to soil chemistry, consult Ask IFAS publication CIR1081, "Soil pH and Electrical Conductivity: A County Extension Soil Laboratory Manual" (Mylavarapu et al. 2020).

How EC Monitoring Compares to Soil Testing

Conventional soil testing requires sample collection and laboratory analysis, with results typically available within 1 to 2 weeks (Dattatreya et al. 2024; Eigenberg et al. 2002). These results will provide soil nutrient concentrations. EC data from sensors provide continuous, near-real-time data that support irrigation scheduling and fertilizer management decisions (Hoang et al. 2019; Zhang and Wienhold 2002). Together, laboratory results and EC data can provide a comprehensive assessment of soil nutrient status and nutrient movement following irrigation. EC data can be checked daily or, if needed, hourly. This data will provide information on nutrient location and movement within the soil profile, but not nutrient concentration.

Case Study: Tracking Nutrient Movement in a Citrus Demonstration Trial at the UF/IFAS IRREC

Soil moisture sensors were installed in a citrus research demonstration trial at the UF/IFAS Indian River Research and Education Center (UF/IFAS IRREC) to study water and nutrient movement. The sensors were placed 4 inches deep in the soil, about 1 foot from the tree trunk. Figure 1 shows the sensor location marked with a red dot. Individual protective covers (IPCs) were placed over some young trees. For trees with covers, sensors were placed underneath the IPC. For trees without IPCs (control treatment), sensors were installed at the same distance, about 1 foot from the trunk.

Note: The data presented in this case study are preliminary demonstration results collected for educational purposes and have not been published as peer-reviewed research results. Results should be considered illustrative of the monitoring approach.

The sensors measure soil moisture (volumetric water content, VWC), EC, and soil temperature every 10 minutes using capacitance technology with metal probes inserted in the soil. Dry granular fertilizer (10-10-7 N-P-K) was applied on the soil surface around each tree under the canopy. The application rate followed the UF/IFAS citrus production guidelines. Irrigation was scheduled every 3 days based on calculated evapotranspiration (crop water use).



Figure 1. Left: Citrus tree with an individual protective cover (IPC) showing soil moisture sensor location. The red circle near the bottom of each image marks the sensor placement 1 foot from the trunk, at a depth of 4 inches. Right: For trees without IPCs, sensors were installed at the same depth and distance from the trunk.
Credit: Daniel Palacios-Linares, UF/IFAS IRREC.

Assessing Fertilizer Movement after Irrigation or Rain

Getting the Data

Soil moisture (VWC) and EC data were downloaded and plotted together over time (Figure 2). Most modern sensors support graphical data visualization via a website dashboard or a smartphone app, with displays similar to those shown in Figure 2.

Looking for Patterns

Plotting both soil moisture and EC on the same graph helps visualize how fertilizer and water events influence nutrient movement. In many cases, increases in soil moisture are followed by increases in EC because dissolved nutrients move with water. In Figure 2, fertilizer was applied on June 24 (shown by the vertical dotted brown line and circle 1). Two rain events followed the fertilizer application (shown by green lines and circle 2). EC increased after irrigation (event 1) and after rain (events 2 and 3). Note that before fertilizer application, a slight EC spike (event 1) occurred due to rain. This happens because water contains ions that can trigger this response. However, it is straightforward to identify which events are related to fertilizer application, as shown in events 2 and 3, where EC increases to around 0.2 dS/m and is visually more evident in the figure. The red arrow indicates the time lag between fertilizer application and the increase in EC. This lag is normal and reflects the time required for water (from either rain or irrigation) to move nutrients to the sensor depth. In this example, the type of groundcover influences EC responses, with soil moisture and EC slowing due to the IPCs (Figure 2, green and yellow time series).

Understanding this lag, marked by the red arrow, allows for the refinement of irrigation schedules. For example, if EC increases in a shallow sensor (2–4 inches deep) hours after irrigation, the irrigation volume is moving nutrients to that depth at a reasonable pace. The expected response time will vary depending on soil texture, sensor depth, irrigation volume, and environmental conditions. A markedly faster EC response for a deep sensor (6–8 inches deep) may indicate excessive water application and an increased risk of nutrient movement below the target root zone.

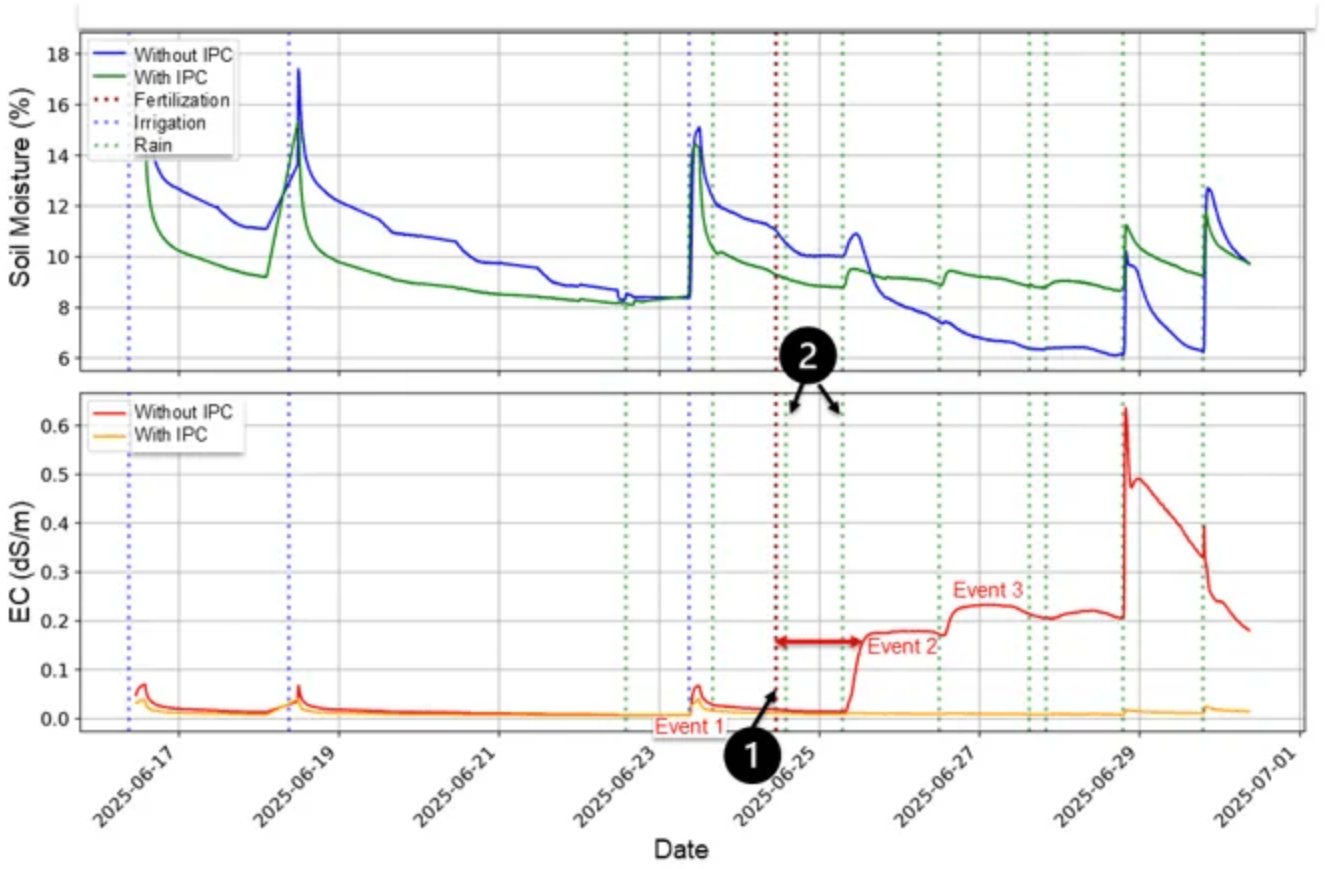

Figure 2. Soil moisture (solid blue line: without IPC; solid green line: with IPC) and electrical conductivity (EC: dS/m, red line: without IPC; orange line: with IPC, lower axis) measured by two sensors installed at a depth of 4 inches, one beneath an individual protective cover (IPC) and one in an uncovered control treatment, in a citrus demonstration trial at the UF/IFAS IRREC from June 15, 2025, to July 5, 2025. Each sensor measured both soil moisture

Credit: Daniel Palacios-Linares, UF/IFAS IRREC.

Understanding Time Delays: How Long Nutrients Take to Move

Figure 3 presents a detailed view of the data in Figure 2, focusing on the periods immediately before and after fertilizer application. This zoomed view highlights three important patterns. First, the irrigation event on June 23 increased soil moisture noticeably for both monitored systems, but EC showed only a minimal response (circle 1). Second, fertilizer was applied on June 24, and two rainfall events occurred during the following 24 hours (circle 2). These events were followed by a sharp increase in EC, suggesting that water mobilized recently applied fertilizer and moved nutrients to the sensor depth of approximately 4 inches. Third, EC remained around 0.2 dS/m (circle 3) even as soil moisture declined. This suggests that dissolved nutrients remained near the sensor depth between June 25 and June 27.

Troubleshooting

If EC stays high while soil moisture drops, nutrients or salts may be concentrating as the soil dries. In Florida's sandy soils, this pattern may indicate a need for supplemental irrigation to prevent salt stress or to move accumulated nutrients back into the active root zone. Avoid applying additional fertilizer when EC is already elevated, as this may increase the risk of salt accumulation or nutrient toxicity.

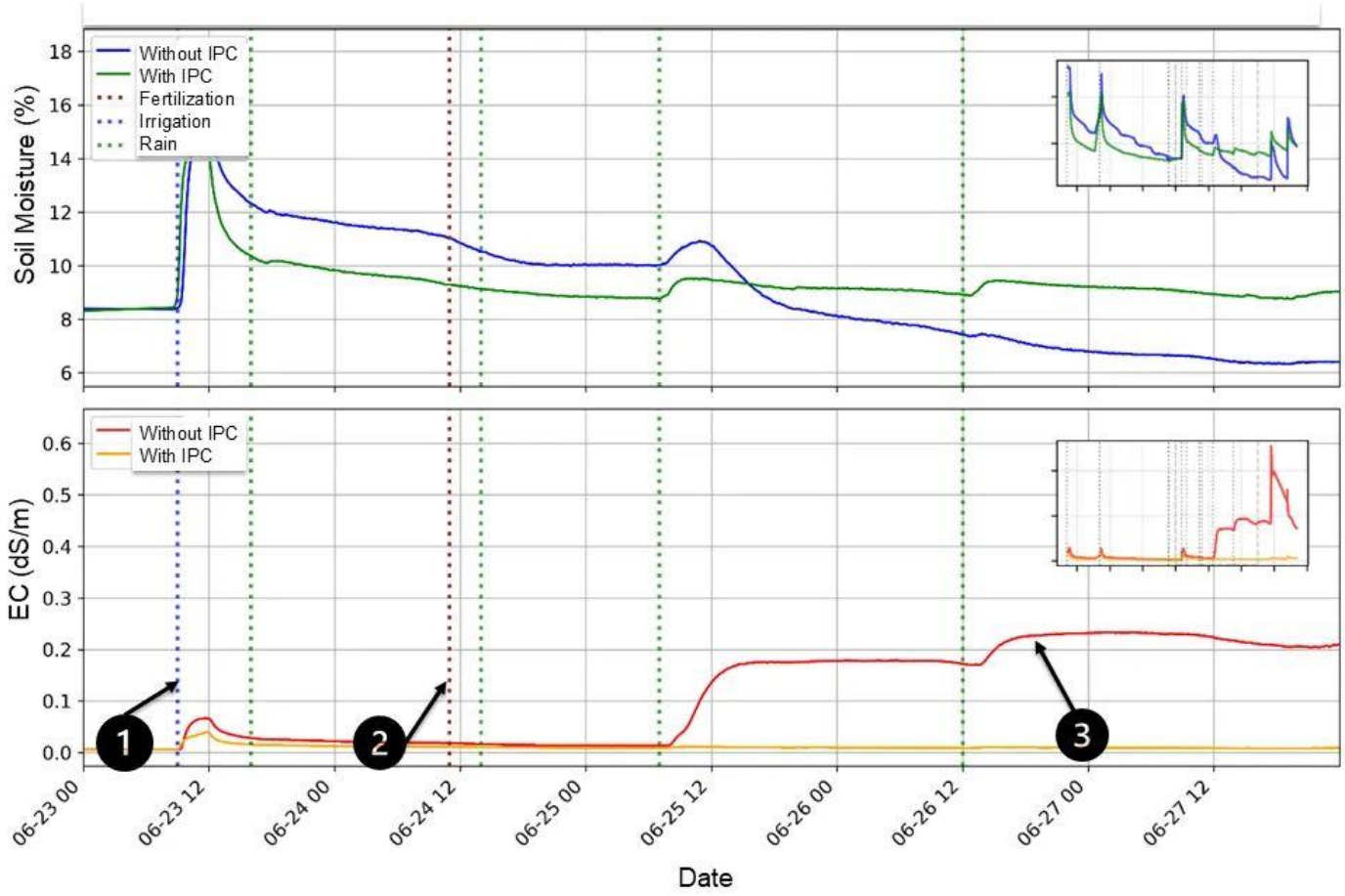

Figure 3. Detailed view of soil moisture (VWC; upper panel) and electrical conductivity (EC; lower panel) before and after fertilizer application on June 24 in the citrus demonstration trial at UF/IFAS IRREC. The irrigation event on June 23 increased soil moisture but produced little change in EC (circle 1). Following fertilizer application on June 24, rainfall events increased EC values, suggesting nutrient movement toward the sensor depth of 4 inches (circle 2). Elevated EC persisted after soil moisture declined, suggesting dissolved nutrients remained present in the soil profile near the sensor location (circle 3).
Credit: Daniel Palacios-Linares, UF/IFAS IRREC.

Using Multiple Sensor Depths to Track Nutrient Movement

Sensors installed at different depths can help visualize how water and nutrients move through the soil profile. Figure 4 shows data collected from a multi-depth soil moisture and EC probe installed in the citrus demonstration trial at UF/IFAS IRREC. Measurements at depths of 2 inches, 4 inches, and 8 inches allow comparison of water and nutrient movement following irrigation and rainfall events.

The day after fertilization on March 25 (circle 1), soil moisture increased at all depths following an irrigation event, with the largest increase observed at the 2-inch depth. At the same time, EC increased slightly, with the greatest response also occurring at the 2-inch depth. This suggests that water began to dissolve and mobilize surface-applied fertilizer. Following a rainfall event later on March 25, increases in both soil moisture and EC became more pronounced. The 2-inch depth and 4-inch depth sensors showed strong EC responses and maintained higher readings than the 8-inch depth sensor (circle 2). This suggests that nutrient movement was greatest in the upper portion of the soil profile, while EC remained relatively low at the 8-inch depth. For young citrus trees, nutrient movement within the upper portion of the soil profile is generally desirable because most active feeder roots are concentrated in this zone. This pattern reflects an irrigation and fertilization strategy that moved nutrients into the active root zone while

minimizing nutrient movement below the monitored root zone.

Troubleshooting

Continued EC increases at deeper depths may indicate nutrient leaching below the root zone. In sandy soils, this can occur when irrigation amounts exceed crop needs. Reducing irrigation volume per event or applying fertilizer in smaller, more frequent applications may improve nutrient retention.

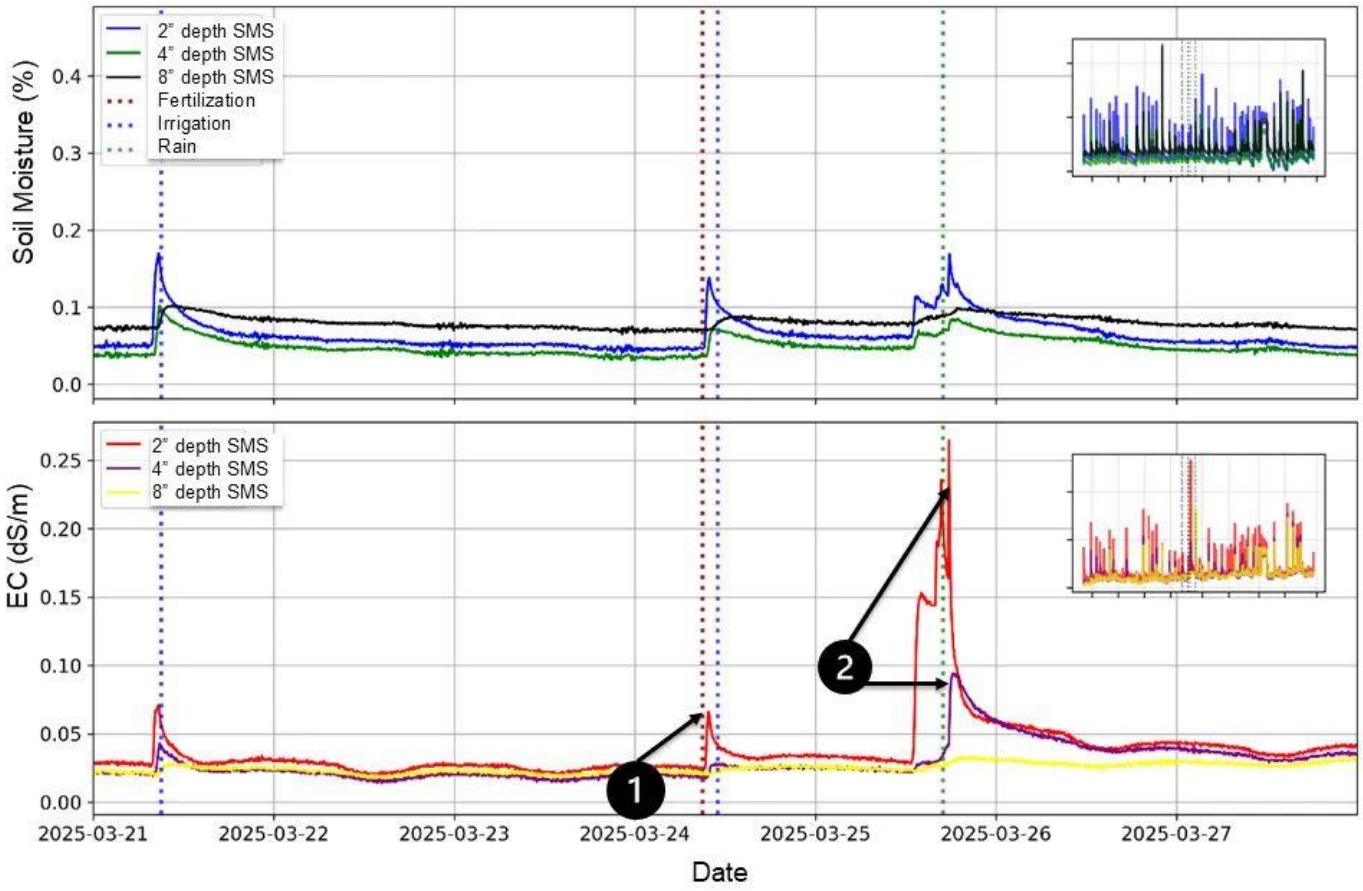

Figure 4. Soil moisture (upper panel) and electrical conductivity (EC; lower panel) measured at depths of 2 inches, 4 inches, and 8 inches during a citrus demonstration trial at UF/IFAS IRREC. Following fertilizer application and irrigation (circle 1), increases in soil moisture and EC were first observed at shallower depths. After a subsequent rainfall event (circle 2), EC responses increased at the 2-inch and 4-inch depths, suggesting nutrient movement through the upper soil profile. EC remained low at the 8-inch depth, indicating limited nutrient movement beyond the active root zone during the monitoring period.
Credit: Daniel Palacios-Linares, UF/IFAS IRREC.

Guidelines for Analyzing Your Own Sensor Data

Based on the case study from the UF/IFAS IRREC trial above, a step-by-step guide has been created to help users interpret EC data from soil moisture sensors in their own fields. Following these steps will help identify when and where fertilizer moves, allowing for adjustments to irrigation and nutrient management to achieve better results.

Note before you start: The specific timing ranges (such as hours until EC responds) and irrigation amounts (such as inches applied) mentioned in this publication are examples based on Florida sandy soils with drip and microsprinkler systems. Specific field conditions, including soil texture, crop type, rooting depth, and irrigation method, will affect these numbers. It is recommended to use the first few weeks of sensor data to monitor and learn what is "normal" for a specific operation. Keep records of how long it typically takes for

EC to respond after irrigation in your own field, and adjust these example ranges accordingly.

Step 1: Download data. Retrieve EC and soil moisture datasets from sensors, noting the depth and field location of each sensor. Most systems allow manual download from field dataloggers or remote access via a web dashboard or smartphone app. Data covering at least 2 to 3 weeks after fertilizer application should be available to see the full pattern of nutrient movement.

Step 2: Create a graph showing both EC and soil moisture over time. Both measurements should be placed on the same plot to facilitate comparison. Mark all fertilizer applications, scheduled irrigations, and rainfall events on the graph. The graph can be printed and used as a field reference to quickly see how nutrients, water, and management practices interact. Many sensor platforms generate these plots automatically, but spreadsheet software can also be used if needed.

Step 3: Look for increases in EC. When soil moisture and EC rise together after irrigation or rain, this indicates nutrient movement past the sensor at that depth. A rapid EC jump shortly after watering suggests nutrients are reaching that zone quickly. Several patterns should be noted.

- If soil moisture increases but EC does not, water is moving, but nutrients are not reaching the sensor depth yet.
- If a delayed EC increase occurs hours or a day after watering, this lag indicates how long nutrients take to move down. This information can be used to fine-tune irrigation timing.
- If sensors are installed at multiple depths, look for sequential EC increases at deeper sensors.
- Persistently elevated EC at a specific depth may indicate nutrient accumulation in that layer.

Step 4: Use the EC and soil moisture patterns observed in your field to guide irrigation and nutrient management decisions. Compare your observations with the interpretation guide in Table 1. Responses will vary depending on soil texture, crop rooting depth, irrigation method, and environmental conditions. Use the first few weeks of monitoring to establish a baseline and compare future responses against typical field conditions. Questions to consider include the following.

- Are nutrients reaching the target root-zone depth?
- Is nutrient movement slower or faster than expected?
- Are nutrients accumulating at a particular depth?
- Is there evidence of nutrient movement below the active root zone?

Step 5: Watch for troubleshooting situations. Certain patterns require special attention.

Before applying fertilizer: Check the weather forecast. If heavy rain is expected within 1 to 2 days, delay fertilizer application to prevent leaching. What counts as "heavy" depends on your soil. Sandy soils may experience nutrient leaching after approximately 1 inch or more of rainfall, while heavier soils may tolerate more.

- If EC stays elevated after the soil dries: Salts or unused fertilizer may be accumulating. Apply light irrigation to flush the root zone, or collect a soil sample and submit it to a laboratory to check for salt buildup or specific nutrient imbalances. Start with a small flush amount (e.g., 0.25–0.5 inches) and adjust based on results.
- If EC increases suddenly without irrigation or rain: Check sensors and dataloggers for malfunctions. Temperature changes can sometimes cause small EC fluctuations, but large spikes without water input are unusual and may indicate equipment problems.

Important Limitations of EC Monitoring

EC monitoring provides valuable real-time insights, but it has limitations. As noted earlier, EC reflects total dissolved ions rather than specific nutrients. Therefore, it should be used alongside periodic soil testing to determine nutrient composition. EC readings may also reflect salts from irrigation water, natural minerals, and organic matter. Environmental factors such as temperature, soil texture, and organic matter content influence EC behavior. Interpret EC trends within the context of site-specific conditions. Establishing a baseline during the first few weeks of monitoring is essential for accurate interpretation.

For information on soil sampling and testing in Florida, find your local UF/IFAS Extension office. Other helpful Ask IFAS publications are SL 281, "Soil Sampling and Testing for the Home Landscape or Vegetable Garden," and AE551, " Common Questions When Using Soil Moisture Sensors for Citrus and Other Fruit Trees."

Conclusions

EC monitoring with soil moisture sensors provides real-time insight into nutrient movement, complementing

traditional soil testing. By tracking EC patterns, growers can:

- Determine whether nutrients reach the root zone.
- Adjust irrigation to improve nutrient placement.
- Reduce nutrient losses through leaching.
- Improve water and fertilizer use efficiency.

Install sensors at appropriate depths based on crop type. Use multiple sensor depths when possible to better understand nutrient movement throughout the root zone. For most row crops and vegetables, this is typically 5–12 inches (13–30 cm), while deeper depths (12–24 inches, or 30–60 cm) may be needed for tree crops. Use EC monitoring together with routine soil testing to fully understand nutrient dynamics. Soil testing determines fertilizer needs, and EC monitoring shows how those nutrients move. Start with a small area, establish baseline patterns, and expand monitoring as experience increases.

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Table 1. Quick reference for interpreting EC and soil moisture patterns.

EC Pattern	Soil Moisture Pattern	Likely Interpretation	Suggested Action
EC increases after irrigation.	Soil moisture increases.	Nutrients reached the sensor depth.	Continue current irrigation schedule.
No EC increase after irrigation.	Soil moisture increases.	Water moved, but nutrients have not reached the sensor depth.	Continue monitoring EC or adjust irrigation depth.
EC increases after a delay.	Soil moisture increases immediately.	Nutrients are moving through the profile with a normal delay.	Record the response time and compare it with the baseline. This delay comparison indicates how long it takes nutrients to reach the soil (root) depth. Good water and nutrient availability.
EC increases only at shallow sensors.	Soil moisture increases at multiple depths.	Nutrients remain in the upper root zone.	No action needed. Good water and nutrient availability.
EC increases at deeper sensors.	Soil moisture increases.	Nutrients may be moving below the target root zone.	Reduce irrigation volume or split applications.
EC remains elevated after the soil dries.	Soil moisture declines.	Nutrient or salt accumulation may be occurring.	Evaluate irrigation management and consider soil testing.
EC increases after rainfall but not irrigation.	Soil moisture increases.	Irrigation may not be moving water deeply enough.	Evaluate irrigation volume and duration.
Sudden EC increase without water input.	No increase in soil moisture.	Sensor issue or unusual field condition.	Inspect sensors and verify readings.

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