Precision Irrigation Management Using Sensor Technology in Christmas Tree Fields

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During 2023, most of the Great Lakes region experienced significant drought conditions Young trees often have a small, poorly developed root system and are vulnerable to drought stress, which can result in reduced growth or tree mortality (Fig. 1). In experimental trials, irrigation improved the survivability and increased the rate of growth of young trees (Cregg et al., 2009). However, over-irrigation can waste water resources and leach nutrients from the soil profile. Excessive soil moisture can also promote phytophthora root rot, which is a significant pathogen in tree plantations. The Great Lakes region has experienced more erratic precipitation over the past decades. Extended periods of drought will increase tree mortality of Christmas tree transplants. Therefore, proper irrigation management is critical to improve survivability, increase the rate of tree establishment, prevent drought stress, and minimize the spread of phytophthora root rot.

***Figure 1 –** Dying tree seedling due to drought.* Photo credit Bill Lindberg

Figure 2 – Installed IoT-based Sensor Monitoring System in Christmas Tree Farms (left and middle). Installed Soil Moisture Sensors at 6-, 12-, and 24-inch Depth (right).

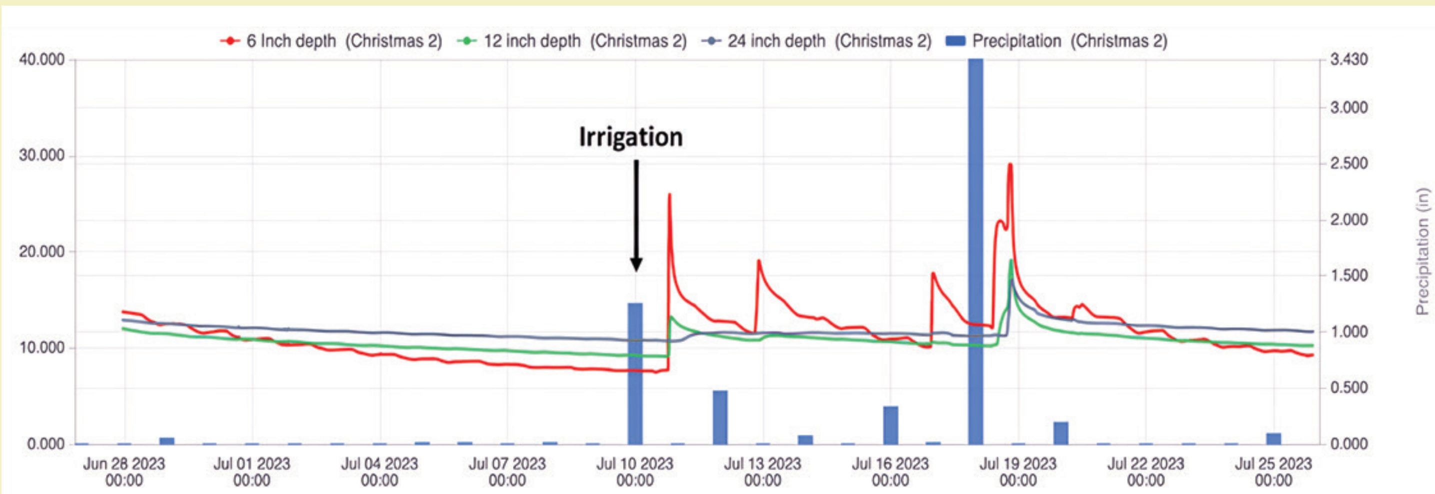

Figure 3 – *Soil moisture sensor data and precipitation collected under solid set/traveler irrigation systems.*

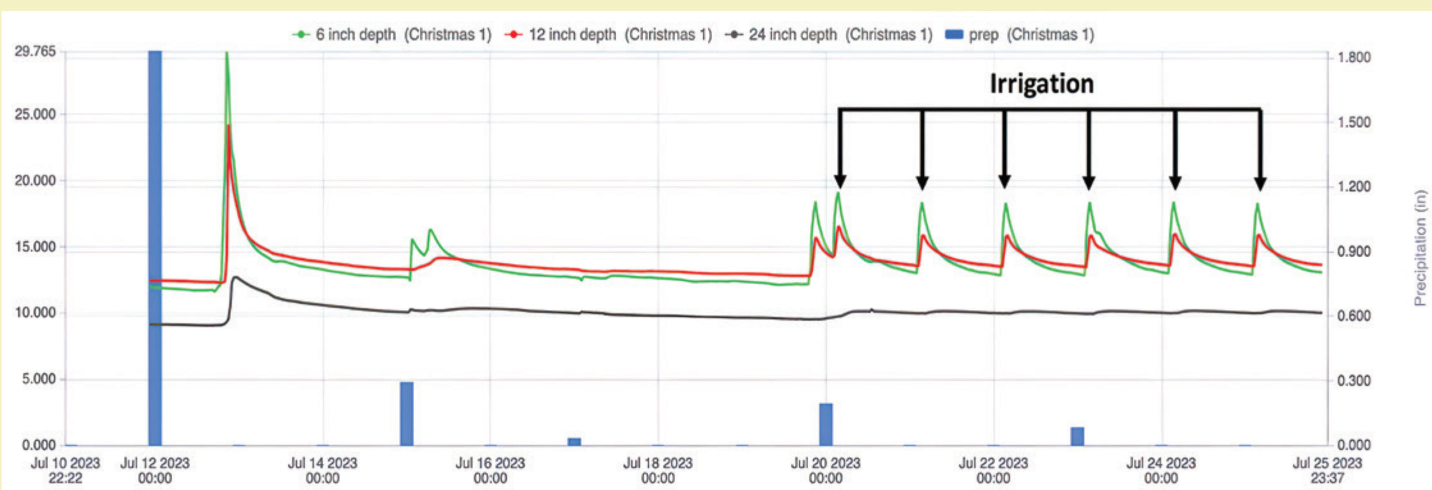

Figure 4 – *Soil moisture sensor data and precipitation from a Christmas Tree Field that uses a drip irrigation system.*

Currently, most growers use personal observations and experience to schedule irrigation events. A commonly accepted viewpoint is irrigation events of 1 inch per week are sufficient in the absence of rainfall. However, there is limited evidence to support this value and determining the actual amounts of irrigation applied can be difficult. In addition, many Christmas tree farms are on light texture soils. These soils have limited water holding capacity and may require more precise irrigation management to prevent drought stress. Thus, Michigan State University (MSU) Irrigation team and MSU Christmas Tree team collaborated to improve the irrigation practice in Michigan Christmas tree farms by demonstrating a sensor-based technology.

The MSU Irrigation Team has developed a new irrigation monitoring system called LOCOMOS (Low-Cost Sensor Monitoring System). LOCOMOS uses Frequency Domain Reflectometry (FDR) sensors to sense soil moisture. The system is affordable and allows growers to access soil moisture data in real-time from a cloud-based data storage system. This system also has the ability to send notifications at critical irrigation thresholds via text message or email.

In 2023, the team installed LOCOMOS at three farms and evaluated the cooperative farmer's current irrigation practices. The evaluation was conducted in fields planted during the spring of 2023, each implementing different irrigation systems [center pivot (Badger Evergreen, Allegan, MI), a drip (RA Farm, Nunica, MI), and a solid set/traveler irrigation system (Needlefast Evergreen, Ludington, MI)]. Figure 2 shows the installed IoT-based sensor monitoring system in Christmas tree farms in Michigan. Soil moisture sensors were installed at 6-, 12-, and 24-inch depths, as shown in Figure 2. A rain gauge is also installed at each farm to record rainfall and irrigation (only for overhead irrigation system). Sensor data were recorded every 30 minutes and displayed on a website.

Figure 3 is the collected soil moisture sensors and rainfall/irrigation data from Needlefast Evergreen (Ludington, MI), which uses a solid set/traveler irrigation system. The trees were planted in the spring of 2023 and rye was also planted as a pre-plant cover crop. The soil type in this field is Spink soil (loamy sand), according to USDA Natural Resource Conservation Service (NRCS) Web Soil Survey. Spink soil has approximately 2.16 inches of available water in the top 24-inch soil depth. The available water holding capacity for different types of soils and their soil depths can also be found on the USDA NRCS Web Soil Survey website. As shown in Figure 3, the 6-inch depth soil moisture (red in Figure 3) was continuously depleted over time. This indicates that the tree roots actively uptake the soil moisture from the 6-inch depth. On July 10, 1.25 inches of irrigation application increased soil moisture levels at 6-, 12-, and 24-inch depths. The root depths of these tree seedlings are estimated between 6- and 12-inches. For new stands of trees the irrigation goal is to wet the soil at least up to 12-inch soil depths while not increasing soil moisture at the 24-inch soil depth, given that irrigation water that reaches 24" is below the root zone and unavailable to young trees. In this case, since a 1.25-inch application increases the soil moisture level at 24-inch depths, a reduced irrigation amount is recommended. As tree seedlings actively uptake soil moisture at shallow depths, more frequent application with reduced amounts is suggested in this field.

Figure 4 is the collected soil moisture sensors and rainfall/irrigation data from RA Farm (Nunica, MI), which uses a drip irrigation system. The trees were planted in the spring of 2023. The soil type in this field is also Spink soil (loamy sand), according to the USDA NRCS Web Soil Survey. The grower typically irrigates once a day, except when the field receives heavy rainfall. On July 12, the 1.8 inches of rainfall increased the soil moisture levels at all 6-, 12-, and 24-inch depths. This rain allows the soils at the top 24-inch depths to reach their field capacity. The grower started the irrigation on July 20 and used a timer to turn the irrigation system on and off. The grower's irrigation increased soil moisture levels at 6- and 12-inch soil depths, but not 24-inch depth. This indicates that their irrigation amount is the optimal amount, and there is no need to adjust his irrigation practice. Drip irrigation system provides the benefit of wetting the shallow soil depth frequently, which can help to maintain adequate soil moisture conditions for tree transplants. In addition, an advantage of the soil moisture sensor data is to assist the grower when deciding when to resume irrigating after a heavy rainfall. Finally, the soil moisture data is helpful when checking whether irrigation is functioning as intended. If the soil moisture levels at shallow soil depths do not increase after scheduled irrigation, the irrigation system may have some issues.

Another way to visualize the benefit of the LOCOMOS in irrigation management is by visualizing irrigation water flow through soil profile. Blue dye was injected into the drip irrigation system, and this indicates the overall wetting pattern (Figure 5), and depth water traveled through the soil profile at different irrigation applications. With an irrigation event of approximately ¼ inch application, water had moved into the soil profile approximately 6". With irrigation application of about ½ inch application, the dye indicates water had moved in the soil profile approximately 12". Irrigation at greater than ½ inch would push water past the

***Figure 5 –** Blue dye demonstration to show the water flow in soil caused by different irrigation amount.*

point in soil profile where tree roots are located. At this point water is not being captured by the tree and is lost to the environment.

These initial observations have demonstrated that the LOCOMOS system can improve irrigation efficiency by tracking the movement of irrigation water through the soil profile, enabling growers to avoid over-irrigation below the active root zone.

Ultimately these data can aid growers in developing more efficient long-term irrigation plans. In addition, low-cost sensors and data-logging systems can also be combined with automated solenoids for growers that wish to develop sensor-controlled irrigation systems to further improve irrigation efficiency.

The authors would like to thank the Michigan Christmas Tree Association for funding to support this irrigation demonstration project.