Soil Moisture Sensor Evaluation in Idaho Sugarbeets

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Abstract

Precision irrigation management can increase sugarbeet grower profits by improving crop quality, reducing water and pump costs, and building resilience in drought years. Soil moisture sensors provide a method for monitoring soil water status and ensuring crops do not experience drought stress while avoiding excess irrigation applications. The numerous options of commercially available soil moisture sensors can be overwhelming to growers, making it necessary to establish guidelines for navigating the various technology, installation procedures, prices, and performances. This study evaluated the performances of five different types of soil moisture sensors installed in two southern Idaho sugarbeet fields with loam and loamy sand soils. Based on metrics of accuracy and precision, sensors ranked from best to worst performance were as follows: Acclima True-TDR315, AquaCheck Sub-Surface Probe, PR2 Profile Probe, GroPoint Profile (installed using a pilot rod), Watermark 200SS, and GroPoint Profile (installed using auger and slurry procedure). Parameters of relative cost and ease of use are also discussed. With the results of this study, growers can make better informed decisions and have confidence in the technology they are investing in for improved irrigation management.

Introduction

Irrigation water availability from the Snake River and its aquifer is a significant driver of sugarbeet productivity in southern Idaho. Careful irrigation management can help to manage limited resources in dry years while improving sugarbeet quality and maximizing grower profits.

Irrigation is often scheduled on surface layer observations of soil moisture, which represents only a small fraction of water available throughout the sugarbeet rooting zone. Soil moisture sensors can be used to monitor water availability in deeper soils with higher water availability. Although many growers recognize the value of employing soil moisture sensors, the market for these sensors can be overwhelming due to the many different technologies, installation methods, and prices available.

Objectives

- To evaluate the performances of various soil moisture sensor installed among sugarbeets
- To provide impartial guidance to growers seeking to implement soil moisture sensing technology

Materials & Methods

Experimental Design

Figures 1-5. Soil moisture sensors evaluated in this trial, including Acclima TDR315H (1), Aquacheck Subsurface Probe (2), GroPoint Profile (3), PR2 Profile Probe (4), and Watermark 200SS (5).

- Sensors evaluated: Acclima True-TDR315 (Figure 1), AquaCheck Subsurface Probe (Figure 2), GroPoint Profile (Figure 3), PR2 Profile Probe (Figure 4), and Watermark 200SS (Figure 5)
- Sensors were installed within a 15-foot radius of one another to minimize the effects of spatial variability but provide enough distance to eliminate interference
- Replicates were installed in two sugarbeet fields with different soil types (described in Table 1)
- Figure 6 is a schematic diagram of reading depths for sensors installed at each site. Colored bars are sensor probes and numbers without bars are sensors that measure at a single depth.

Table 1. Site descriptions where sensors were installed.

Site Name	Location	Soil Type	Irrigation Type
Hatch	Declo, ID	Loam	Wheel Line
Suchan	Paul, ID	Loamy Sand	Solid Set Sprinklers

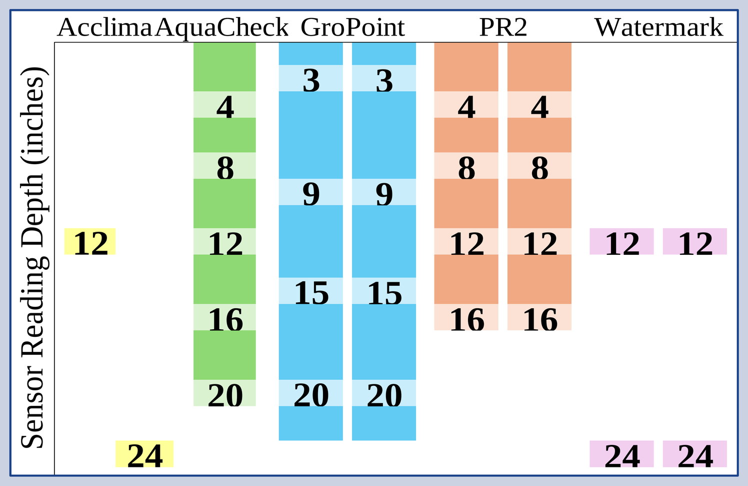

Figure 6. Schematic diagram of sensor reading depths in inches.

Data Analysis

- Sensor readings were validated against soil moisture samples taken eight times at each location and processed for volumetric water content
- Sensor performance indicators included accuracy and precision
- Accuracy: how close the sensor readings are to actual soil moisture (Figure 7)
  - Helps irrigators decide the quantity of water to apply
  - Calculated using Root Mean Squared Error (RMSE, Equation 1), with lower RMSE values indicating higher accuracy
- Precision: repeatability of sensor measurements (Figure 8)
  - Helps irrigators decide timing of water applications
  - Calculated using the Coefficient of Determination (R^2) of sensor readings and true soil moisture content, with higher R^2 values describing greater precision

Figure 7. High accuracy, low precision.

Figure 8. High precision, low accuracy

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(VWC_{sensor} - VWC_{sample})^2}{n}}$$

RMSE = Root Mean Square Error
VWC = Volumetric Water Content
n = number of samples

Equation 1

Results & Discussion

Accuracy

Accuracy is represented by RMSE as shown in Figure 9, with lower RMSE indicating greater accuracy.

Accuracy Ranking (best to worst):

1. Acclima True TDR-315H
2. AquaCheck Sub-surface Probe
3. PR2 Profile Probe
4. Watermark 200SS
5. GroPoint (installed using a pilot rod)
6. GroPoint Profile (installed using a slurry)

Precision

Precision is represented by R^2 as shown in Figure 10, with higher R^2 indicating greater precision.

Precision Ranking (best to worst):

1. Acclima True TDR-315H
2. GroPoint (installed using a pilot rod)
3. PR2 Profile Probe
4. AquaCheck Subsurface Probe
5. Watermark 200SS
6. GroPoint (installed using a slurry)

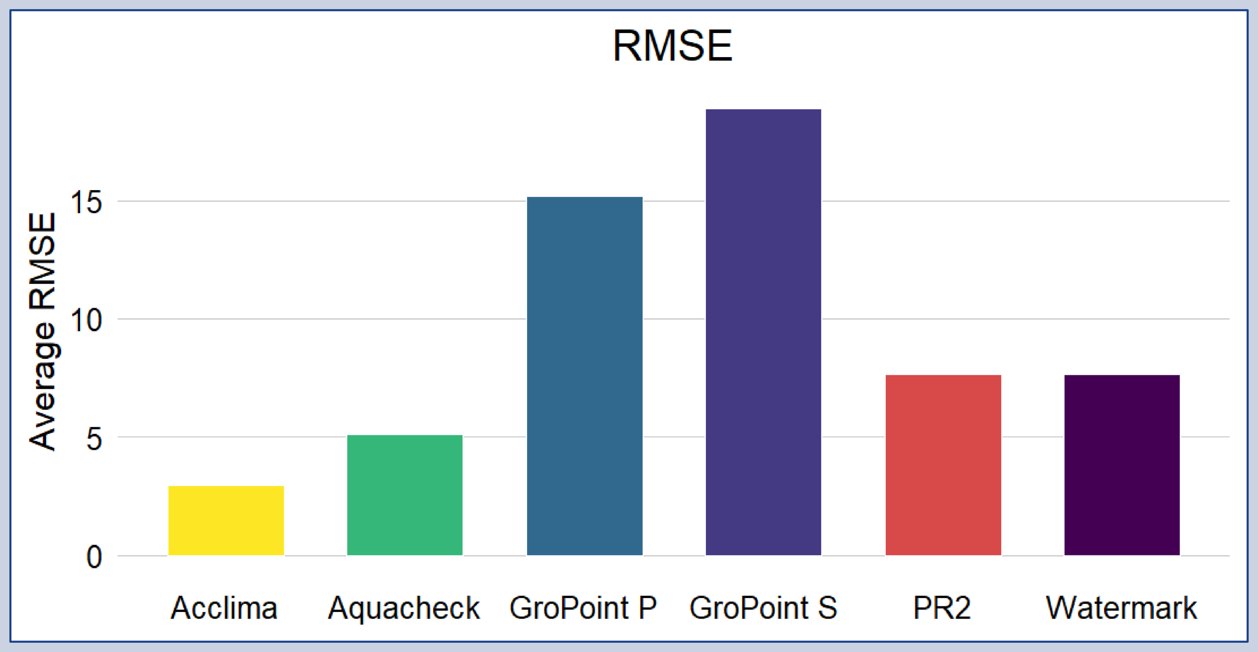

Figure 9. Average RMSE of sensors across both locations. Lower RMSE indicates better accuracy and higher RMSE indicates poorer accuracy.

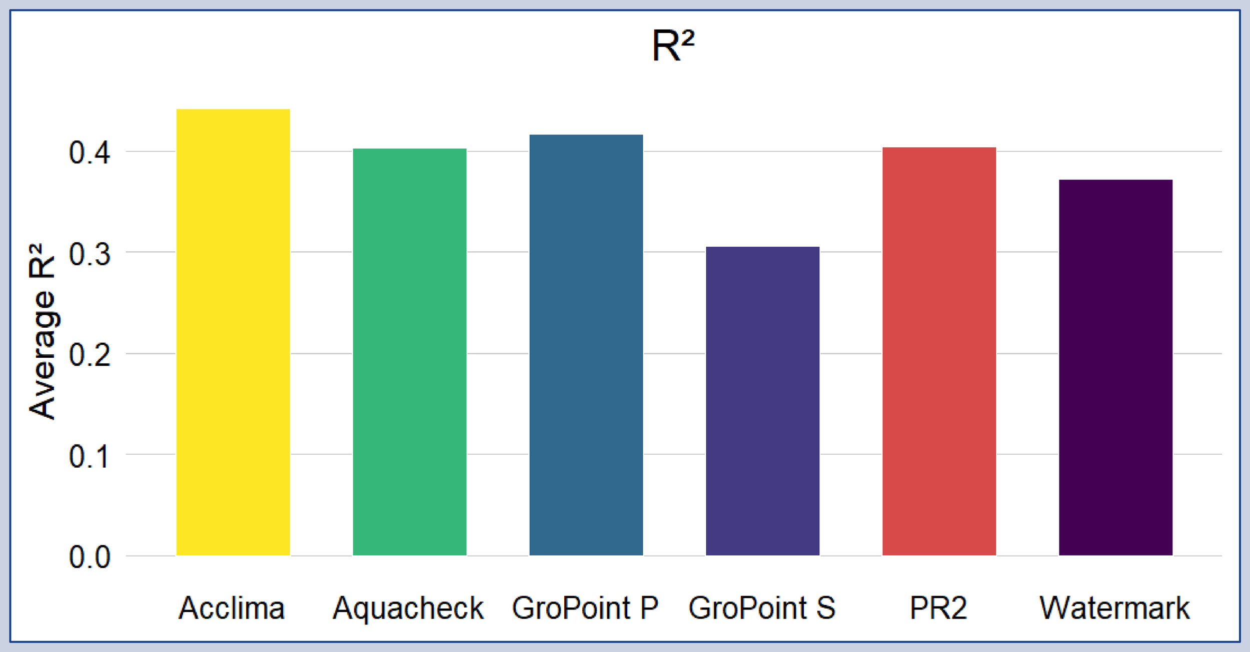

Figure 10. Average R2 of sensors across both locations. Higher R2 indicates better precision and lower R2 indicates poorer precision.

Site Comparison

- As shown in Figure 11, both accuracy and precision were better at Hatch than at Suchan, likely due to the soil texture differences.
- Sensor factory calibrations often account for only the most common soil types, like loam at Hatch. The high sand content found at Suchan likely lowered sensor performance.
- High infiltration rates and rapid moisture fluctuations in Suchan's sandy soils also probably caused greater error in sensor readings.

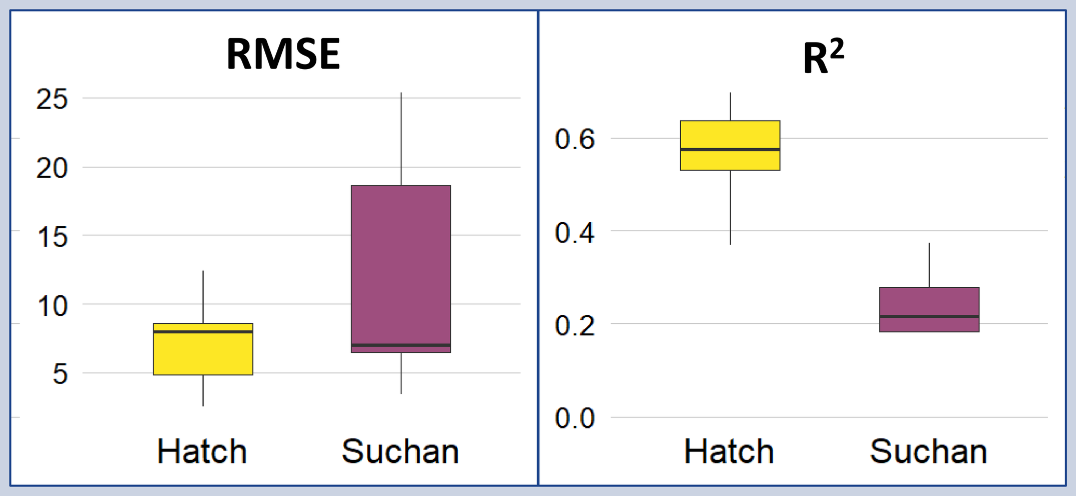

Figure 11. Boxplots of sensor performance by site.

Sensor Summaries

- Table 2 shows cost comparison, installation method, and single vs. multidepth reading availability for the sensors in this trial.
- Acclima TDR-315H had the highest performance, but a relatively more difficult installation procedure than other sensors. It also only measures at a single depth, whereas the AquaCheck and PR2 probes provide multi-depth measurements at a higher initial cost.
- The Watermark 200SS is the least expensive but requires more frequent replacement due to natural degradation of its granular matrix.

Table 2. Summary of sensor characteristics, including the manufacturer/company, measurement type, reading depth, installation method, relative cost, and overall performance rank. Ranges in sensor cost are due to the various lengths available.

Sensor:	**Acclima**	**AquaCheck**	**GroPoint P**	**GroPoint S**	**PR2**	**Watermark**
Company:	Acclima	AquaCheck	RioT Technology Corp.	RioT Technology Corp.	Delta-T Devices	Irrometer
Measurement:	VWC	SFU (converts to VWC)	VWC	VWC	VWC	MP
Readings:	single-depth	multi-depth	multi-depth	multi-depth	multi-depth	single-depth
Installation Method:	rods inserted into sidewall of dug trench	auger and slurry	pilot rod	auger and slurry	augering sequence using specialized tools	auger and slurry
Cost:	$$	$$$-$$$$	$$-$$$	$$-$$$	access tube: $ probe: $$$$$ reader: $$$	$
Overall Performance Rank	1	2	4	6	3	5

Conclusions

- Moisture sensors behave differently depending on soil type and installation method used. Good soil contact is critical for optimal sensor performance, so careful installation according to manufacturer's instructions is necessary for dependable readings.
- Variation in sensor performance, soil type, and irrigation can be significant within a field , so more than one sensor should be used to track moisture conditions. Ideally, at least three sensors should be installed per field.
- While accuracy helps determine available soil water, precision builds confidence in using moisture sensors for irrigation scheduling. A few shovel checks at different sensor-reported moisture levels can help establish a practical dryness threshold for triggering irrigation events.
- Over time, soil moisture sensors provide valuable insight into soil moisture dynamics and improve irrigation decision-making, leading to more efficient water use and successful crop production.

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