MINTS Soil Sensors

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1 Introduction

In this analysis, we present our findings on a multitude of soil sensors, all of which have the potential to be useful for the MINTS soil research program's goal of creating a low-cost, reliable, and efficient soil sensing package. Given the variations among these devices (in price, reliability, build quality, technical popularity, etc.), sensors belonging to a unique category will be collectively examined in accordance with several criteria which we determined to be pertinent to MINTS soil research:

1. Reliability and cost effectiveness
2. Outputs
3. Quality
4. Popularity within the scientific community (based on scholarly articles and papers)

2 Sensor Profile 1: Probes

The probes included within this section have the ability to measure both soil moisture and temperature

2.1 Probes

1. GroPoint Profile: Multi-Segment Soil Moisture and Temperature Profiling Probes
    - Utilizes Time Domain Transmissometry (TDT) to accurately measure soil's dielectric properties (which are governed by moisture content) over the entirety of the sensor
    - Provides cost effective soil moisture measurement (exact pricepoint couldn't be determined) over several depths using a single probe, eliminating the need for multiple cumbersome sensors while also reducing the manufacturing cost

- Entirety of the sensor's circuit board (including the antenna) is housed within a polycarbonate housing sealed with epoxy, resulting in maximum durability
- Sensors are deployed in scientific research within the fields of farming, agriculture, mining, and hydrology

2. Irrometer Tensiometers
    - First developed in 1951, remains the standard tensiometer (soil moisture measurement device) for scientific agricultural research to this day
    - Generally inexpensive and reliable - comes in three different models that are all suited to their own respective environments
    - Membrane-vented cover prohibits entry of dirt or other particulates into device, thus ensuring both accuracy and longevity of the product

2.2 Conclusion

Although the GroPoint Multi-Segment Probe proved to be useful in cutting costs, we claim that the Irrometer Tensiometer's superior reliability, popularity amongst researchers, and acceptable cost establish it as the better option for the MINTS soil research team.

3 Sensor Profile 2: Shallow/Single Depth Sensors

For the purposes of the MINTS soil research, shallow/single depth sensors are sensors that collect data on soil's moisture and temperature, similar to the probes above. None of the sensors in this section have been extensively used in soil research.

3.1 General Single-Depth

1. Milesight LoRaWAN Soil Moisture, Temperature, and Electrical Conductivity Sensor (EM500-SMTC)
    - Can output/measure soil moisture, temperature, and electrical soil conductivity (soil moisture and electrical soil are particularly useful in agricultural monitoring and examining the concentration of soil nutrients)
    - Medium-High cost (pricetag of $600)

2. SenseCAP S2105-LoRaWAN Soil Moisture, Temperature, and EC Sensor

- Measures soil moisture, temperature, and electrical conductivity, metrics which are useful measurements for assessing soil quality and subsequent plant health.
- Low-Medium cost (pricetag of $139)

3. SenseCAP Wireless Soil Moisture and Temperature Sensor - LoRaWAN EU868MHz
   - Capable of measuring temperature and soil volumetric water content, which provides useful indication of soil and plant health.
   - Medium cost (pricetag of $219)
4. LSE01 – LoRaWAN Soil Moisture EC Sensor
   - Capable of measuring soil moisture, temperature, and electrical conductivity
   - Low-Medium cost (pricetag of $130)

3.2 NPK

1. LoRaWAN Soil NPK Sensor (LSNPK01)
   - Capable of measuring soil fertility nutrients like nitogen, phosphorus, and potassium.
   - Medium cost (pricetag of $150)

3.3 pH

1. LSPH01 – LoRaWAN Soil pH Sensor
   - Capable of measuring pH and soil temperature, which are important metrics in order to assess potential soil nutrients based off acidity and akalinity.
   - Low-Medium cost (pricetag of $130)

3.4 Ambient

1. KIWI Agriculture Sensor
   - Capable of measuring soil moisture, ambient temperature, and humidity
   - Exact price not listed
2. Clover Agriculture Sensor
   - Capable of measuring ambient temperature, humidity, and soil moisture
   - Exact price not listed
   - Nearly same specs as the KIWI agriculture sensor

3.5 Conclusion

We conclude that in order to have wide-scale deployment of soil sensors while still maintaining cost efficiency, a combination of the LSPH01, LSNPK01, and the LSE01 would prove effective. Because these three sensors combined are capable of measuring pH, soil fertility nutrients, electrical conductivity, soil moisture, and soil temperature, a wide variety of data could be collected to assess soil health with the combination of these three sensors. Although not much research is done looking at the reliability and uncertainty of these sensors, due to the fact that these sensors largely come from the similar companies, the reliability is probably good enough to satisfy years worth of data collecting. The price discrepancy between some of the cheaper and more expensive sensors is most likely the uncertainty of the data outputted, which is most likely minor and not evidently detrimental to the soil project. If ambient temperature is also needed, either one of the ambient agricultural sensors would suffice since their specs are nearly identical.

4 Sensor Profile 3: Various Depth Sensors (Includes Multi-Depth)

The sensors included within this section all have the ability to record data at different soil depths either discretely or simultaneously.

4.1 Various Depth

1. Sensoterra Soil Moisture Sensors
    - Available in several depth sizes (15cm, 30cm, 60cm, 90cm); takes hourly measurements on soil moisture and uses the LoRaWAN network to transmit this data wirelessly
    - Medium-cost (pricetag of $300)
    - Internal housing for onboard electronics enables an effective system that is largely unhindered by surroundings particulates
    - Is popular among researches seeking low-cost, durable, and accurate moisture sensors

4.2 Multi-Depth

1. Sensoterra Multi-Depth Sensors
    - Comes with 6 soil moisture sensors and a temperature sensor attached (meaning it can simultaneously track soil metrics at several different depths), uses LoRaWAN to relay data (akin to the variable-depth sensor)
    - Mid-High Cost (pricetag of $500)

- Similar design to the aforementioned single-depth version, which itself seemed robust and durable
- As a result of its heftier price, the sensor doesn't find much use within the scientific community

4.3 Conclusion

We conclude here that to recommend one Sensoterra Variable-Depth sensor over the other is impractical, as both have their own situational strengths: the variable single-depth devices come at a low cost, offering less flexibility with measurement, while the multi-depth sensors come with additional moisture and temperature probes at a higher price.