# Task 2: Wireless Soil-Moisture Sensors

## Task Proposed by USDA and developed by NMSU Dept. of Agricultural Sciences

**Background**

Precision Farming refers to a method of managing farms and conserving resources through the Internet of Things (IoT) and Information and Communication Technologies (ICT)[1]. Precision Farming primarily focuses on technological innovation, including real-time data collection, to measure accurately environmental factors related to water management, with focus on minimizing operating costs and conserving natural resources.

A major challenge in farmland irrigation is water conservation. The primary issue in effective irrigation is that soil moisture can vary dramatically across a field, even within a few feet within the same seed row, due to variance in rainfall/irrigation and/or to variance in soil types: from sandy soil that does not hold water well, to heavy clay soil that retains water for long periods. The ability to monitor micro zones within a field for their watering needs could greatly improve water conservation efforts.

A number of issues currently discourage farmers from using existing soil-moisture sensor technologies:

1. The sensors are expensive ($250-$400 each)
2. The sensors must be connected by wires to an expensive data logger ($2500-4000) to record soil moisture and temperature from the sensors.
3. Placing the wires at the beginning of the planting season and pulling them at the end is costly and often results in damage to wires.
4. Cultivation may damage the wires.
5. Sensors often become damaged when they are removed from the soil, requiring that they be replaced the following year, making these expensive sensors, in essence, one-time-use devices.

Because of the issues listed above, farmers, if they choose to use moisture sensors at all, typically place no more than 1-2 sensors per field (typical field > 10 Hectares), and the watering needs of the entire field are typically determined by the needs of the few driest zones in the field. As a result, farmers usually choose to water the entire field more generously to allow for the sandy soil zones, leading to wasted water resources.

**Problem Statement**

Design and develop an inexpensive soil moisture sensor that accurately measures soil moisture and temperature and transmits these data wirelessly to a data logger over the course of a growing season. Sensors should be robust in design to last an entire growing season.

Teams will provide their own data logger for use during testing. Note that the data logger design is not part of the judging criteria. You may obtain a data logger at your institution, purchase a commercial data logger ($2500-4000) or build your own. If you would like to build a low-cost data logger (less than $300), specifications are listed on page 4.

## Task 2: Wireless Soil-Moisture Sensors

**Design Considerations**

Your wireless soil moisture sensors should achieve the following outcomes.

- Measure moisture and temperature of in-situ soil samples at a depth of 30 cm.
- Wirelessly communicate moisture within +/-2.5% and temperature data +/-1ºC to a data logger at varying distances, up to a horizontal distance of 100' in any direction.
- Transmit the raw data to a data logger, either passively or actively (team's choice).
  a. For passive transmission, the logger will 'ping' the sensor.
  b. For active transmission, the sensors require energy technologies that will last through a 9-month growing season.
- Transmit moisture and temperature data in 10-minute intervals.
- Record a time/date stamp for all data transmitted from the sensor to the data logger.
- Collect and log all data with a minimum time step of 10 minutes. Data logging should have sufficient storage that the data does not need to be downloaded more often than once per day.
- Sized such that it will not be disturbed by cultivation equipment if placed within a 6-inch-center seed row. If this size proves too limiting for practical farming use, teams may appeal through the FAQs for a larger seed-row distance.
- Be simple to install and be either: 1) easily removed and reused, 2) easily removed and safely discarded, or 3) safely degraded into the soil. This is the team's choice.
- Data should be able to be transferred to a portable device (e.g. smart phone, laptop). Either code this, or provide plans in the written report for this technology.
- Be easy to locate at the end of the planting season (unless degradable).

<u>Additional Design Considerations</u>

- Your sensors will remain in the soil for the duration of the contest (two days) and should be able to measure soil of varying moisture levels over the two-day period.
- The sensors will be tested in a soil composition of 10-20% clay, with the remaining consisting of sand and silt.
- Consider the needs of the farmer as you design the device: profile of the sensors, ability to locate a damaged sensor during the growing season, growth of crops over the season, etc.
- Sensors should be sufficiently inexpensive that farmers can afford to place a large array of sensors each year to monitor moisture and temperature levels at many points in a field. Note that the inexpensive moisture sensors found in most 'big-box' stores do not have the durability/reliability to serve a farmer's needs.
- Reports and presentations must indicate all parameters measured by the sensors, such as resistance, voltage, temperature dissipation, salinity, dielectrics, etc., and must indicate how these measurements are used to obtain a value for soil moisture.
- Data loggers should be coded so that the output data file includes team name, sensor number, and depth at which the sensor is installed.
- Safety issues should be addressed in the Experimental Safety Plan (ESP).

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**Bench-scale Demonstration**

You will bring to the contest:

- a minimum of three sensors: at least two sensors for testing and one for judges to examine. This number may change as the contest progresses. (Watch for FAQs)
- We recommend that you bring back-up sensors for testing, in case damage is incurred to the sensor.

Your team will demonstrate your design at bench-scale level using the following parameters.

- You will be provided a sample of soil into which your sensor(s) will be placed. The sensor should monitor soil moisture and temperature at a depth of 30 cm. Your team will not know ahead of time the soil texture or the moisture content of any of the soil samples.
- Sensors will be tested over two days (Monday and Tuesday) at the contest, with soil moisture varying across the two days. When soil moisture is changed, time will be allowed for moisture equilibration in the soil.
- The current plan is to keep soil-moisture sensors in place during the course of the analytical testing, since removing sensors tends to damage them. (Watch the FAQs for any late-breaking news).
- Your sensors will be judged based on their ability to
  - Measure volumetric soil moisture of each soil sample to within +/- 2.5%.
  - Measure temperature of each soil sample to within +/-1°C.
  - Transmit the moisture and temperature data wirelessly to your data logger up to a distance of 100’ (either passively or actively).
- In addition:
  - The sensors should have a robust and durable design and consider needs of the farmer.
  - Data must be collected and logged with a minimum time step of 10 minutes. Data logging should have sufficient storage that the data does not need to be downloaded more often than once per day.

**Written Report Requirements**

The written report should demonstrate your team’s insight into the full scope of the issue and include all aspects of the task and your proposed solution. The report will be evaluated for quality of writing, organization, clarity, logic, and coherence. Standards for publications in technical journals (e.g., APA, CBE) apply. In addition to the listed requirements, your report must address in detail the items highlighted in the Problem Statement, Design Considerations, and Evaluation Criteria sections.

Particular to this task, your report should:

- Present a detailed cost/efficiency study that addresses economic feasibility of a scaled-up design. Consider initial costs, annual costs, time required to place and retrieve (unless degradable) sensors during regular farming operations, maintenance (including methods for locating and time required to locate and replace a malfunctioning sensor), seasonal replacement, etc.
- Indicate all parameters measured by the sensors, such as resistance, voltage, temperature dissipation, salinity, dielectrics, etc., and indicate how these measurements are used to obtain a value for soil moisture.
- Address the system’s (sensor + data logger) ability to transmit data wirelessly to a portable device (e.g. smart phone, laptop).

**Evaluation Criteria**

Each team is advised to read the Participation Guide for a comprehensive understanding of the contest evaluation criteria. Please visit the WERC website: [https://iee.nmsu.edu/outreach/events/international-environmental-design-contest/guidelines/](https://iee.nmsu.edu/outreach/events/international-environmental-design-contest/guidelines/) for a copy of the Public Involvement Plan and Participation Guide and other important resources. Additionally, your team will be evaluated based on:

- Originality, innovativeness, functionality, ease of use, maintainability, reliability, and affordability of the proposed technology.
- Thoroughness and quality of the economic analysis.
- Potential for real-life implementation.
- How well the bench-scale represents your full-scale design concept.
- Other specific evaluation criteria may be provided at a later date (watch the FAQs).

**FAQs/Deadlines**

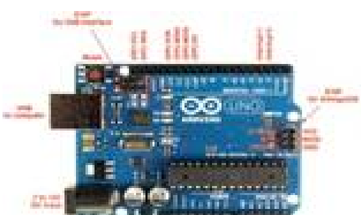
- Teams are expected to watch the online FAQs related to this task for any updates in the task requirements.
- The Experimental Safety Plan (ESP) is due 24 February, 2020.

**Data logger Design**

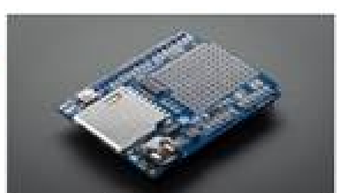
Teams must provide their own data logger for use during testing at the contest.
Your data logger design is not part of the judging criteria.

Commercial data loggers are available on most campuses, or for purchase ($2500-4000), or your team may opt to build your own Low-Cost Data Logger (under $300) using off-the-shelf components (see below).

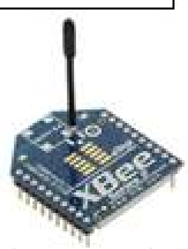
*<u>Specifications for a Low-Cost Data Logger</u>*
*Specifications designed and provided by Dr. Manoj Shukla, NMSU Soil Physicist.*
*Contact the FAQs for more information.*



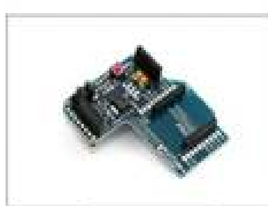
Arduino Uno



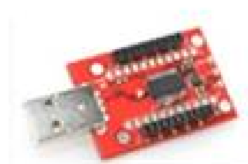
Data Logging Shield



XBee S2



XBee Shield



XBee Explorer

**Awards**

Each year, the WERC Environmental Design Contest and its sponsors award more than $30,000 in cash prizes. Successful completion of every stage of the design project qualifies each team for the following awards.

1. Task awards (First, Second, Third Place; minimum amounts: $2500-$1000-$500, respectively).
2. Freeport-McMoRan Innovation in Sustainability Award ($2500)
3. WERC Resources Center Pollution Prevention/Energy Efficiency Award ($500)
4. Judges’ Choice Award ($500)
5. Peer Award ($250)
6. Terry McManus Outstanding Student Award. (Minimum: $500, according to funding).

*Award amounts listed are minimum amounts and may increase with available funding. Detailed award criteria:*
https://iee.nmsu.edu/outreach/events/international-environmental-design-contest/guidelines/