IOWA

A smart-and-connected low-cost sensor system for measuring air and soil properties in the Central U.S.: first results

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Introduction

We present the design and development of a smart-and-connected low-cost sensor system that is enabled by the Internet of Things (IoT) devices capabilities, empowered by solar-based rechargeable batteries, and developed for citizen science applications. The sensor, the so-called canopy-air sensor, is designed for real-time monitoring of near-surface air properties (temperature, relative humidity, pressure) and soil properties (temperature and moisture) for a wide range of weather and canopy conditions. The sensor is well suited for rural areas where the real-time data of air and soil is lacking in part due to the lack of broadband internet connection, and in part due to the limited (if any) ground-based weather stations in the current federal and state observation network.

The canopy-air sensor has been tested in rural communities in western Nebraska to provide information for farmer's decision-making of irrigation and agricultural water use in the crop growing season. The sensor is capable to transmit data through both WiFi and LoRaWAN in real-time to a cloud data server and the local data server. Presented here are the first results of the sensor design and sensor data evaluation in various out-door environments, which illustrates the high-level readiness of the sensor for large-scale deployment for either routine or scientific applications for rural areas.

PCB Design

To fulfill the requirement of small and compact design, we have to design our own PCB board. The ESP32 works both as a microcontroller and wifi module. BEM280 is the air sensor, performance is pretty good as shown in the result section. RMF95 is the cheap LoRaWan transceiver for our project to get the long-range data transmission.

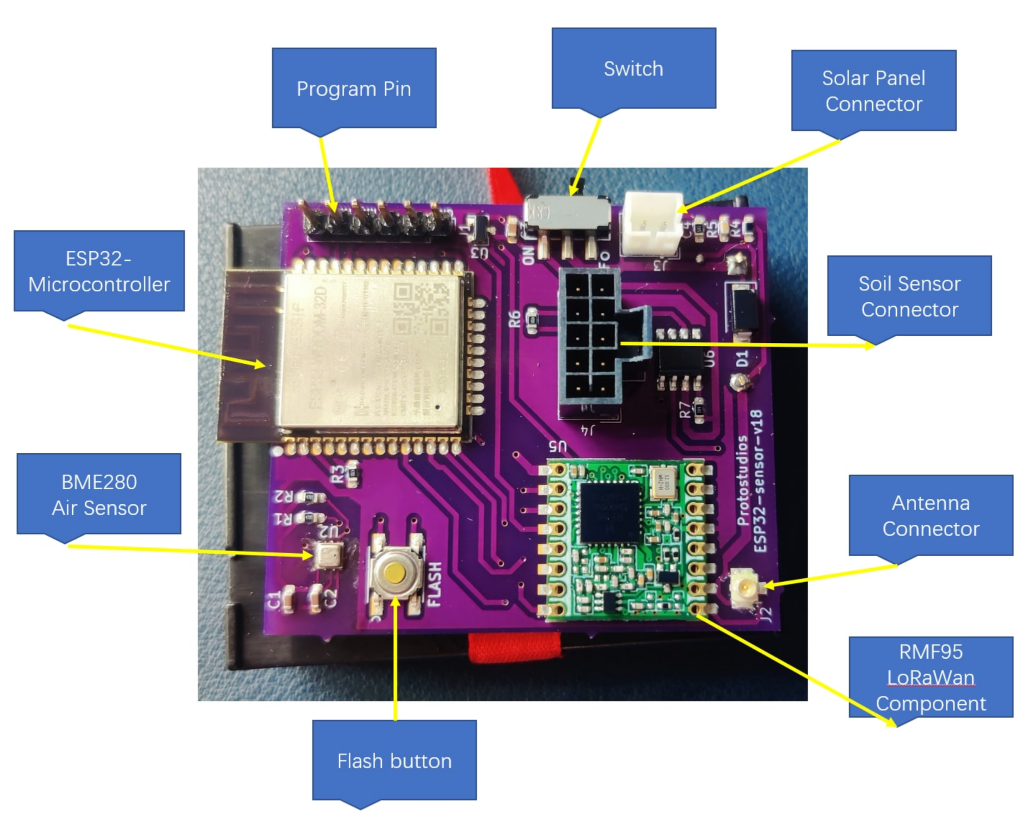

Figure 1. I-Canopy device

Ds18B20 is used as the soil temperature sensor. A good budget soil moisture sensor is hard to find, but the VH400 we used here is pretty good. To make the soil sensor easier to connect to our PCB board, we decided to use the Molex connector for our design. As for now, this design fulfills all of the requirements of our project.

Methods

There are two ways to could put our sensor to the farmland. They are shown below.

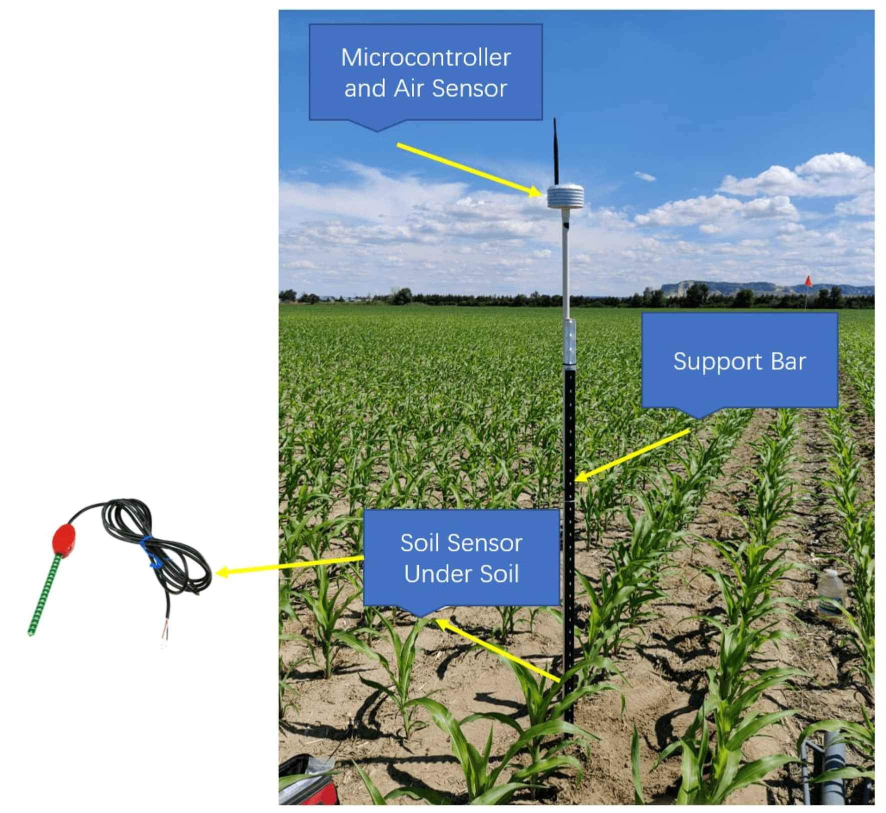

Figure 2. First way to place the I-Canopy device

Figure 2, shows the first method we would like to place our sensor. By using this method, our sensor could be working both as an air sensor and soil sensor. So, we could save the budget to place another air sensor for this farmland.

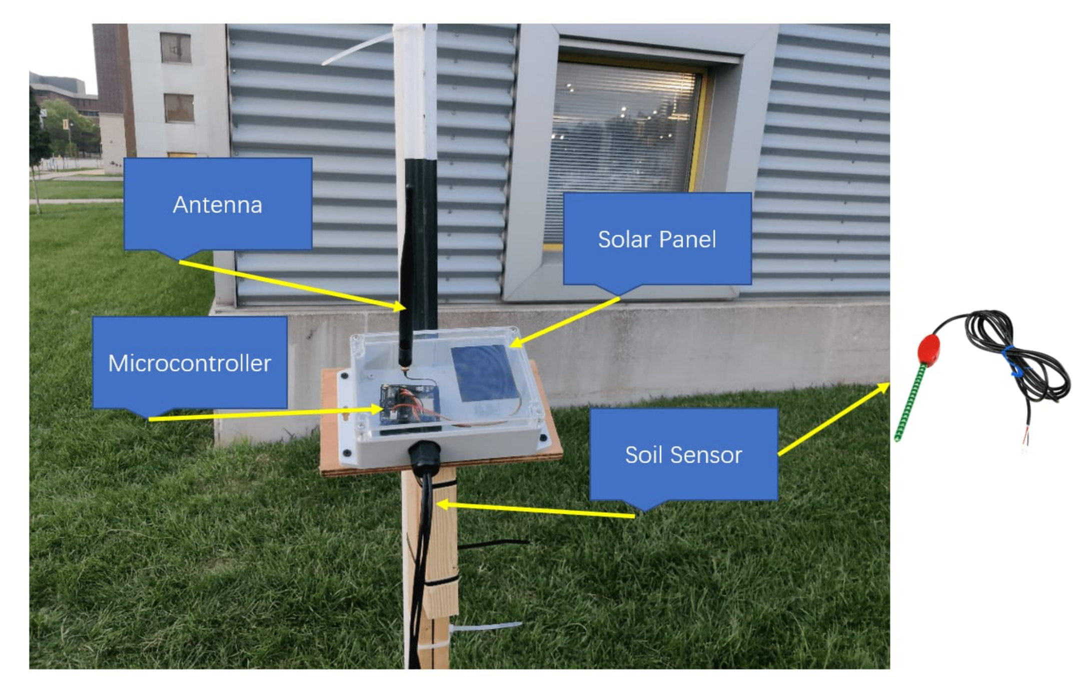

Figure 3. Second way to place the I-Canopy device

Figure 3, shows another way we could place our sensor. It depends on the irrigation mothed and other factors. We might need strict waterproof for our sensor. By using this method, we could give our sensor the best performance of waterproof. But by using this method, we need another air sensor to read the temperature, air pressure, and relative humidity for the same farmland.

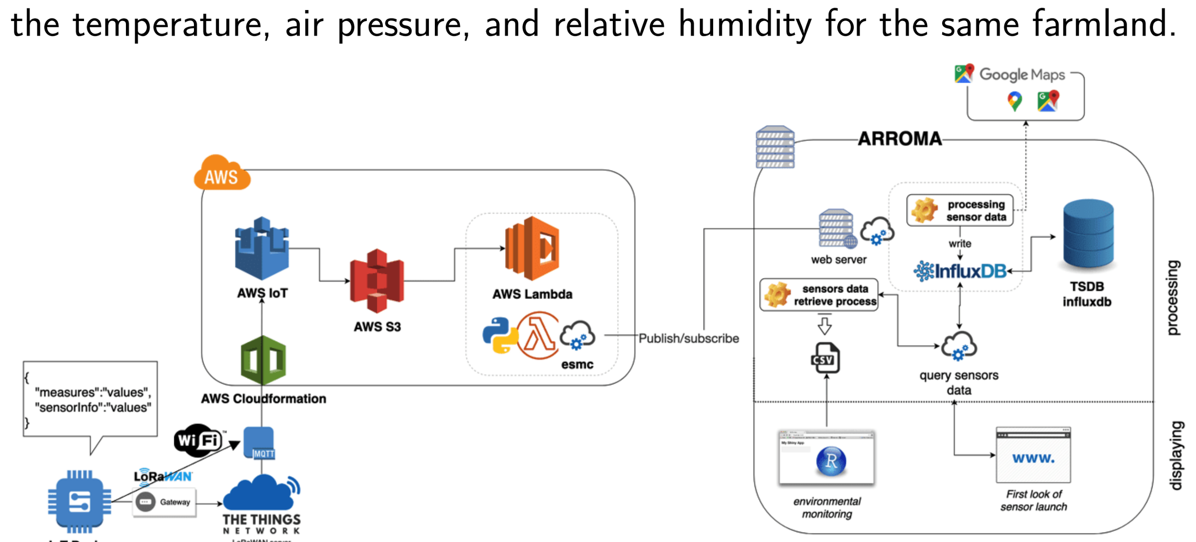

Figure 4. I-Canopy data flow

Figure 4, shows how we send our data from the smart sensor to our server by using both the LoRaWAN method and WiFi method.

Results

Here are the results we have for now. The results show that our sensor is stable and the data read from our sensor is very good. The device in the figure is the sensor we are having in our school which already running for 2 years without any problem.

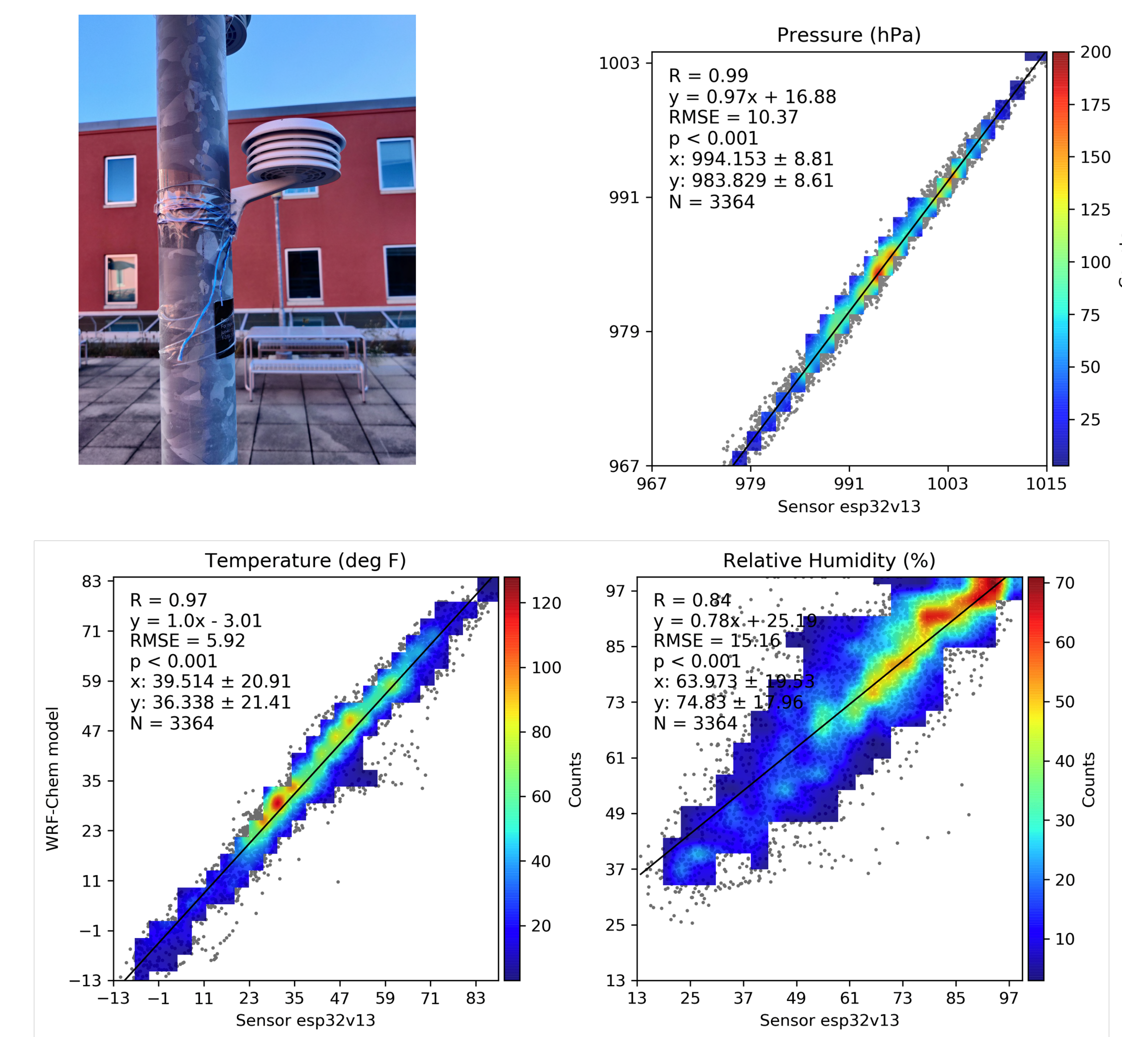

Figure 5. I-Canopy data compared with forecast

We are not just testing our sensor at the University of Iowa, we also test our sensor at Nebraska.

Testing temp and RH sensors

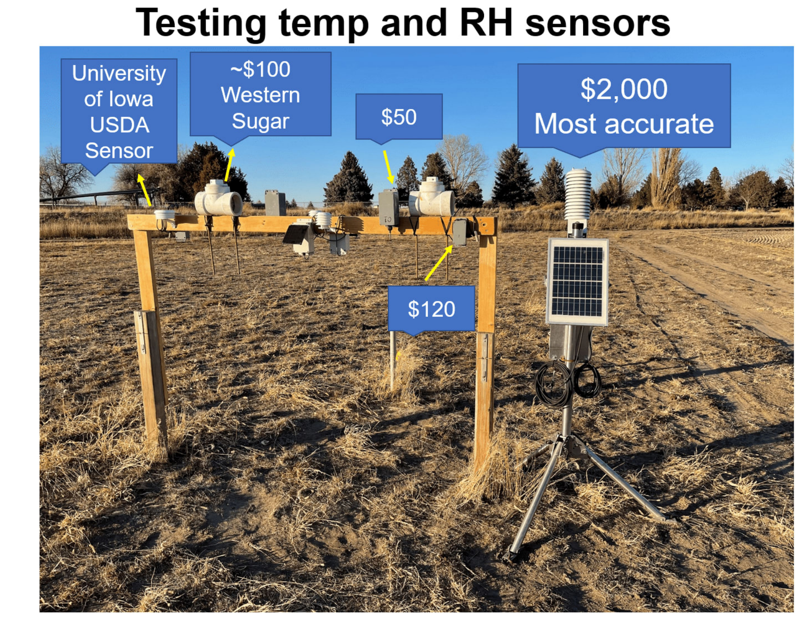

Figure 6. Setting used to test the air sensor with others in Nebraska

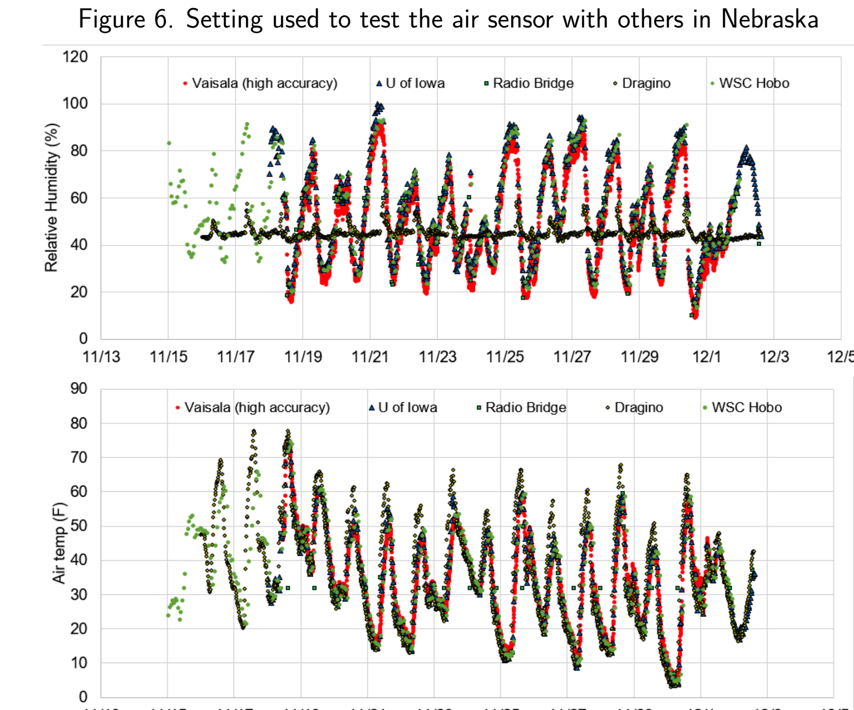

Figure 7. I-Canopy data compared with other devices

Figure 7. shows the result of temperature and relative humidity from our sensor compared with other devices. It shows that our sensor's air reading is pretty accurate.

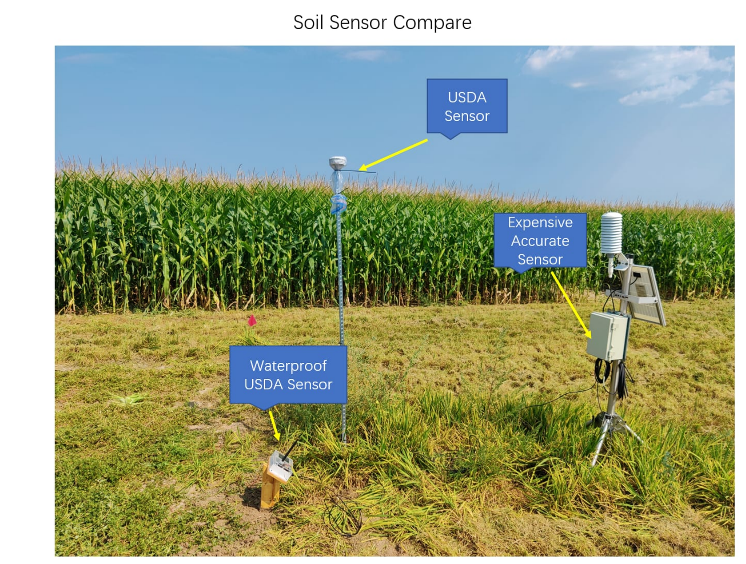

Figure 8. Setting used to test the accuracy of our soil sensor in Nebraska

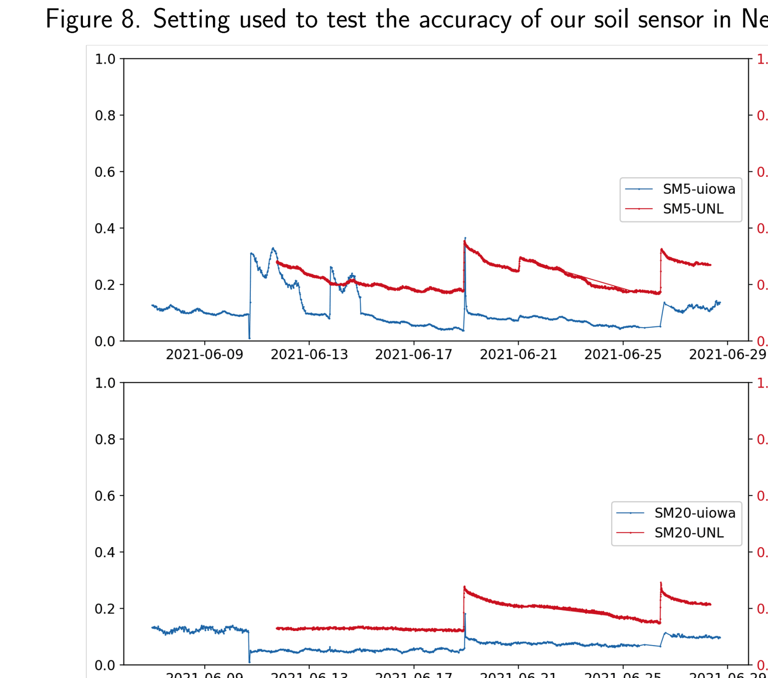

Figure 9. I-Canopy measurements along with the measurements from an expensive device

Figure 9, is the result we get from Figure 8 setting. As shown in the figure, our budget soil moisture reading at 5cm and 20cm are pretty good, it catches all the irrigation they had in the farmland.

Problems and solving

Two problems were very interesting when we design this sensor.

- The sensor stops when the temperature is too low. It is the first winter we test this version of the sensor. We find that all of the sensors stop for no reason. It took us a long time to find out that the battery could not handle the cold weather. After we change to a special NiMH battery, the problem was solved. Now, the sensor will work as long as the temperature is above -4 Fahrenheit.
- The second problem we had was the sensor always stopped when they running on the farmland of Nebraska. We have to travel there to figure out that our design of waterproof is not good for their irrigation system. As a result, we have the Figure 2 design to avoid their irrigation system damaging our sensor.

Figure 10. Field's irrigation systems

Figure 10, shows why the irrigation system causes water damage to our sensor

Acknowledgments

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