The SoilPro - A Device to Increase Farming Yield Using Scientific Farming

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Abstract: *Research has shown that appropriate response to soil and atmospheric conditions can drastically increase both harvest quality and quantity. The rate of photosynthesis, plant growth etc. is determined by the interplay of soil hydration, soil temperature, atmospheric humidity and atmospheric temperature. This data, if accurately measured, can be used to find scientific solutions for increasing farm yield. Simplicity, affordability and accuracy are critical to the widespread use of such data gathering equipment. The SoilPro is a device that aims to fulfill these criteria and subsequently increase farming yield.*

Keywords: SoilPro, Farming

1. Introduction

The aim of the SoilPro is to make scientific farming accessible and affordable. Scientific farming holds the key to food security for many developing nations as it maximizes yield by efficiently using the given natural resources.

Commercially available solutions are often lacking in features and also exorbitantly priced, costing upwards of $500 - out of reach for most farmers in developing countries. The prototype of the SoilPro costs $80 for a suite of 3 sensor boards and 1 base station- a cost which would be further reduced by mass manufacturing.

The data from the SoilPro can be used to optimize growing conditions for the particular crop, thereby maximizing yield from a given piece of land. This paper outlines the design, implementation and testing of the SoilPro.

Outline First we start with existing research done in this field in Section 2 which provides the basis for scientific farming. Section 3 outlines the design procedure followed for the SoilPro and Section 4 details its implementation. Section 5 gives the testing methodology and results. Finally, Section 6 concludes the paper and provides future direction.

2. Research

On investigation of studies on measurable parameters that impact harvest yield, we found an abundance of prior research. The subject matter of these studies varied from the heavy metal intake of plants as a function of soil temperature to the variation of lettuce leaf size with humidity. Some of the research that significantly influenced the design of SoilPro was:

- Increasing agricultural water use efficiency to meet future food production [1]
- Effects of Atmospheric humidity on greenhouse crops [2]
- Effects of atmospheric humidity on photosynthesis [3]
- Effect of Plant Growth Temperature on Antioxidant Capacity in Strawberry [4]
- Plant Uptake of Cadmium as influenced by soil temperature and other factors [5]

These studies gave valuable input on the factors that should be measured by the SoilPro. Keeping these studies in mind along with the cost of measuring the particular parameter, the following were chosen to be measured:

- Soil Hydration
- Soil Temperature
- Atmospheric Humidity
- Atmospheric Temperature

3. Design

Since the cost was critical to the design of the SoilPro, integrated modules such as the LM35 by Texas Instruments and the DHT11 were used. The LM35 measured the Soil Temperature while the Atmospheric Humidity and Temperature were measured by the DHT11. Each sensor board relays its set of data to the base station which averages it to reduce error.

Measuring Soil Hydration There are two major ways of measuring soil hydration content- capacitive and resistive. Some commercial products use resistive sensing due to its relative simplicity but we found that this method has many drawbacks viz. Corrosion of metals from electrodes due to passage of current Large variation of resistance due to ion concentration resulting from fertilizer use and temperature dependence Due to these drawbacks, we decided to use capacitive sensing. Capacitive sensing uses two insulated plates buried in the ground with some soil in between. The capacitance of the arrangement varies with the soil water content. We encountered the challenge of measuring the capacitance with a digital microcontroller but solved it by using Schmitt trigger oscillator with the NE555 timer chip wired as a Schmitt trigger. Thus the frequency f_0 of the oscillator was determined by the capacitance C_0 of the soil and resistor R. The frequency varied as:

$$f_0 = \frac{0.8}{RC_0} \qquad (1)$$

pH Sensing The inclusion of pH sensing on the SoilPro would have been beneficial given the impact of pH on the health of the crop. Most plant species grow within a narrow pH range in which an optimum pH can be highly beneficial to the plant's growth. To be viable, the pH had to be sensed without human intervention and at a reasonable price point.

An ISFET (ion-sensitive field-effect transistor) was investigated as potential candidate for pH measurement but it proved inadequate for use in the SoilPro as it could not be used without making a solution of the soil and needed regular maintenance.
A standard AgCl based electrode needed constant maintenance of solution and also needed the soil sample to be made into solution for accurate pH readings and hence could not be used for the SoilPro. Its fragility and cost was an added disadvantage.

King Tong Lau et al. in Novel fused-LEDs devices as optical sensors for colorimetric analysis (2004) [6] devised a novel way of measuring pH with the help of LED coated with pH indicator's but this method too could not be used in the SoilPro as it also required a soil solution to be made.

Due to these limitations, pH sensing was finally not added to the SoilPro

4. Implementation

The goals set for the SoilPro during the implementation phase were:

- Collection of important soil and atmospheric parameters to a reasonable degree of accuracy
- Long range RF link to allow for its usage in bigger farms
- Provision of multiple sensor boards connected to a single base station 4. A low cost system- costing under $100 in total
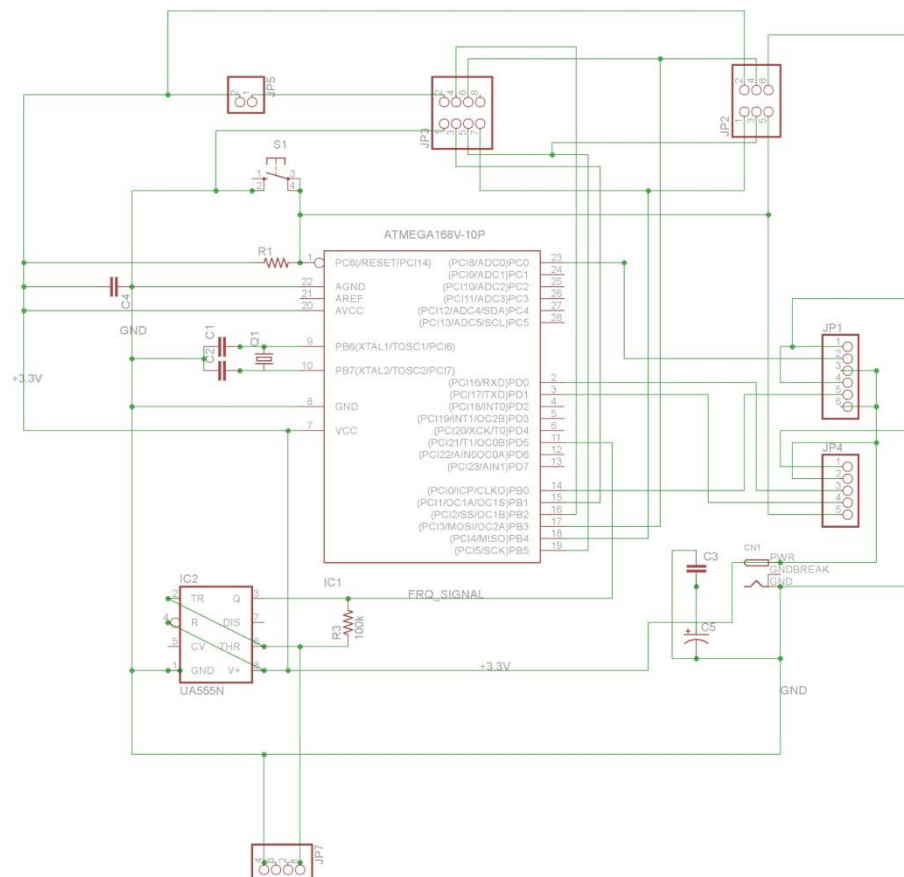

Figure 1: Schematic for the Sensor board

Suitable components were chosen for the device keeping into account the cost. Thereafter a schematic for sensor board (Figure 1) was created in CadSoft EAGLETM followed by PCB layout and routing. The PCB thus designed was suitable for production. The prototype sensor board however, was built using a perfboard (Figure 2).
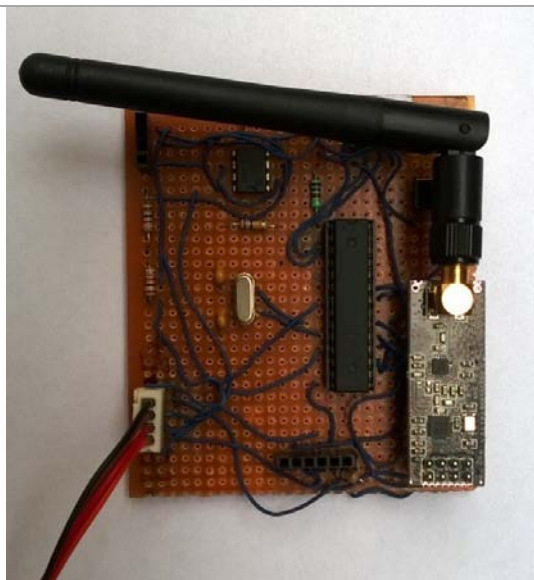
Figure 2: Sensor board Prototype

The base station, which currently connects to a computer and relays the data from multiple sensor boards, was also created using a perfboard (Figure 3).
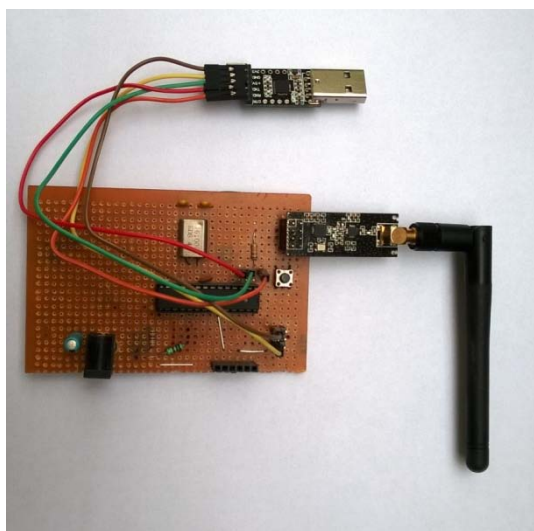

Figure 3: Base station Prototype

5.   Testing Methodology and Results

Hydration Sensor An open field (soil type: loam) usually used for wheat plantation was used to measure the variation of capacitance of the soil with quantity of water added. The test was conducted before the field had been irrigated and the ambient temperature during the test was 31∘C on average. Two 10.5 cm wide aluminum sheets coated with a layer of insulating paint were embedded 6 centimeters into the ground at a distance of 10 cm from each other. The readings were taken 15 minutes after the water was added to ensure that the water had fully percolated. The observations of the experiment are shown in the table and plot below:

Table 1: Variation of capacitance with volume of water added

Serial Number	Water added	Soil Capacitance
1	0 mL	2.86 nF
2	50 mL	7.79 nF
3	100 mL	8.89 nF
4	150 mL	9.54 nF
5	200 mL	9.91 nF
6	250 mL	10.71 nF

Volume of water added
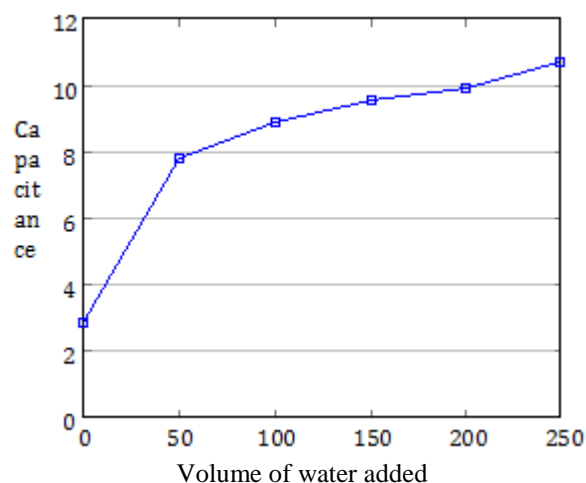
RF link Range the NRF24L01+ module with an amplifier and an antenna was used as the RF link between the sensor board and the base station. The range of the modules was tested in a large open field without any obstructions. The maximum distance between the sensor board and the base station where a reliable connection (defined as point where at least one update was received per minute) could be achieved was 600 meters.

6.   Conclusion and Future Direction

The SoilPro was found to successfully work in reporting the following parameters:

Soil hydration
Soil temperature ($\pm 1\circ$C)
Atmospheric humidity (± 5 RH)
Atmospheric temperature ($\pm 2\circ$C)

We firmly believe the SoilPro has the potential to change millions of lives world over. The increased crop production due to scientific farming will go a long way towards ensuring universal food security.

Future Direction While currently SoilPro achieves most of the objectives that we had in mind, we believe that it has scope for improvement. The following features could potentially be added to the SoilPro to enhance its functionality:

- An ISFET based pH sensor at a less than $20 price point

- AI based analytical software that can provide solutions to the farmer by using data from the base station
- Integration of irrigation system with base station for autonomous irrigation
- Transmission of data via SMS/Internet to the farmer as well as for research including academia, meteorological departments and laboratories, also enabling remote farm management by managers and consultants

References

[1] J. S. Wallace Increasing agricultural water use efficiency to meet future food production AgricEcosyst Environ, Volume 82, Issues 1–3, December 2000, Pages 105–119

[2] D.W. Hand; Effects of Atmospheric humidity on greenhouse crops Acta Hort. (ISHS) 229:143-158 1988

[3] H. M. Rawson The effect of atmospheric humidity on photosynthesis, transpiration and water use efficiency of leaves of several plant species; Planta; 15. II. 1977.

[4] Shiow Y. Wang Effect of Plant Growth Temperature on Antioxidant Capacity in Strawberry J. Agric. Food Chem., 2001, 49 (10), pp 4977–4982

[5] F. Haghiri; Plant Uptake of Cadmium as Influenced by Cation Exchange Capacity, Organic Matter, Zinc, and Soil Temperature JEQ Vol. 3 No. 2, p. 180-183 1974

[6] Lau KT et al. Novel fused-LEDs devices as optical sensors for colorimetric analysis MERL TR2003-150 May 2004