ECE198 Project Proposal

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1. Needs Assessment

1.1 Customer Definition

With global warming and rising global temperatures, the dry season for many parts of the world is exacerbating [4]. Dry seasons are depicted by long periods of decreased and uneven precipitation [3]. This leads to the soil becoming unable to facilitate the rotation of nutrients as soil movement is decreased as it hardens [3]. Many microorganisms may cease to function during these dry periods, and plants absorb less water, directly impacting their ability to take in nutrients, leaving them dried and withered [3]. Farmers, or our targeted customers, often face such conditions with little ability to properly assess the exact amount of water needed to compensate for the drought [3]. Specifically, a lack of necessary tools to properly determine the amount of water needed is especially detrimental as the farmers are left to the device of their own assumptions. Should the dryness of soil be properly assessed, the farmers would have significantly more reliable agricultural yields, thus allowing them to not only increase earning, but also increase the reliability of their financial planning based therein.

In Ontario, there were around 49,600 farms in 2016 [7][8]. Between 2006 and 2016, there was an increase in drought and dry spells, as precipitation decreased over 50% in areas such as Ontario [1][7][8].

This also coincides close to the growing season in Waterloo specifically, where 1,300 farms reside [2]. Of those 1,300 farms, 31% are crop-based farms and therefore account for around 400 farms within the Waterloo region [2]. Hence, the customers for this project primarily will be the 400 farms in the Waterloo region affected by the droughts in the status quo, which comprises around 3,900 farmers [2][9].

1.2 Existing Approaches & Ineffectiveness

There have been many ways farmers dealt with drought in the status quo. Current technologies include diversifying plant distributions. This means planting several different species of plants within a single area, which makes the overall system more resistant to changes in weather, such as dry spells [5][12][11]. This is an excellent solution, but it has a high initial cost since farmers would have to grow new plants whilst also learning how to maintain them [12][11]. There is also the added complication of knowing what to plant since there is the inherent risk of certain plants outperforming others [12]. Further, cases of farmers planting early maturing crops also provide a solution, as they can decrease the possibility of reaching drought season [6]. This method has been developed and used in areas around Africa [6]. However, with the Waterloo region, since the drought season is becoming increasingly inconsistent with time, it is difficult to determine precisely both the arrival time and the length of drought seasons. Many farmers and scientists have begun to attempt to genetically breed crops that are adaptive to severe weather, but the long-term effects of such crops are disputed and concerns over plant diversity and the sustainability of such methods in the long run are raised [5][6][10]. However, a more common method is to abandon that crop cycle and plant less seeds at once to directly minimize the loss of a dry season [12][11]. This method directly decreases the yield of plants [12][11]. In short, as it stands right now, there are no notably effective solutions to the increase in drought with no significant drawbacks [12][11].

1.3 Solution

A better solution would be to directly address the problem. Since the issue is a lack of real-time knowledge regarding the state of the moisturization of the soil, a straight-forward solution is a device that measures the level of moisturization of the soil and alarms the client when needed. Since varying plants have varying specifications as to the amount of water needed, the threshold for the alarm should be able to be adjusted freely by the user. The device should also intermediately measure the humidity of the soil weekly, as well as whenever the user prompts it. The entire system should include, also, the function of notifying the user if the moisture has decreased below the aforementioned threshold with an audible noise. Therefore, for this project, two devices will be needed, one device to measure the dryness of the soil and to send out a message that the soil is dry, and a second device will receive that message and notify the customer of the soil becoming dry. The issue of the unpredictability of the humidity of the soil is thus solved, and the clients can now produce goods more effectively thanks to the additional knowledge provided by this product.

1.4 Stakeholders

Table 1. Stakeholders

Name	Description	Interest
TA	The instructor and assessor of this project	Help foster success within this project and quantify such success with a grade.
Amazon & W-store	The various providers of materials needed to construct the product	Increase sales of raw materials needed for the product through the success of the product.
Waterloo Farmers and Landowners	The customers and clients of the product	Maintain the current crop stock and mitigate drought impacts by purchasing the product.
Waterloo Federation of Agriculture	The governmental and regulatory body relevant to this project	Ensure the product does not violate current agricultural laws and policies, while strengthening the food system.
Environmental Activists	The special interest group concerned about the progression of this project and its side effects	Ensure that the product does not harm the welfare of the environment surrounding and including farms
Agricultural Credit Institutions	Supplier of fund to the farmers in the form of credits and loans	Loans to farmers are dependent on the survivability of the crops to meet quotas, and as the product increases such survivability, the interest of the credit institutions is tied to the product and its effectiveness.
Agricultural Input Companies	Supplier of raw material to the client (i.e. farmers).	Invests to overcome barriers to proper crop growth for farmers, hence potentially producing similar products as this project, creating potential competition. On the other hand, agricultural success helps agricultural input companies increase revenues, as more capital flows into agriculture should it be deemed profitable.
Secondary manufacturers	Direct customer of the client (i.e. farmers), companies that	Depending on agricultural performance as a primary supplier to produce secondary food products and operate

of various food products	produce and process raw agricultural products before selling them to the open market.	henceforth, thus the mitigation of the impact of drought is critical to their success. A greater yield of agricultural goods would also mean cheaper costs, thus lowering the operation cost of these manufacturers.
Consumer of Food	The Public	Needs to consume food daily, thus the price of food, which is partially dependent on the impact of drought, and thus the success of this product, is of interest to them.

2. Requirements

2.1 Functional Requirements

Table 2: Functional Requirements

Name	Description	Justification
Soil Humidity Measurement Range	The product must be able to measure the humidity of the soil within the range of 0 to 0.55 wfv (water fraction by volume, or m^3m^{-3}).	Full saturation of soil (i.e. all soil pore spaces filled with water) usually occurs between 0.35 to 0.55 wfv [13].
Alarm Sound Level	The product must be able to produce an audible noise akin to alarms, or around 80 dB, to inform the client of dry soil.	A typical alarm clock designed to raise awareness has a noise level of around 80 dB [14].
STM32 Communication	The product must be able to communicate between the two microcontrollers within a delay of less than 30 ms.	The lowest noticeable delay in electronic devices is 30 ms [15].

Measurement Accuracy	The product must be able to measure the moisture of the soil with a correlation of above 0.95 and a root mean square error of ±0.051 wfv.	The dataset collected from a lab-used soil moisture sensor generated a correlation of 0.95 and a RMS error of ±0.051 wfv [16].

2.2 Technical Requirements

Table 3: Technical Requirements

Name	Description	Justification
Operating Voltage	The operating voltage should be between 3.5 volts and 20 volts.	The moisture sensor probe can be powered with a DC supply or batteries in the range of 3.5 volts to 20 volts [17].
Microcontroller Capacity	Operating frequency of 180 MHz, at least 512 KB of flash memory and 128 KB of RAM.	A standard STM32F4 series microcontroller has at least 180 MHz operating frequency, 512 KB flash memory, and 128 KB of RAM [18].
Enclosure (Waterproofing & protection against solid foreign objects)	The device must be at least IP 55 rated.	As the device is located near frequently watered soil and fields, it must be dust-protected and protected against water jets, which warrants a rating of IP 55 [19].
Signal Processing Unit Accuracy	The analog-to-digital converter must have a resolution of at least 18 bits.	18 bits is considered the standard resolution by sensor manufacturers such as Bosch Sensortec [21].

2.3 Safety Requirements

- The product must not expend more than 30W of power at any point in time, and it must not contain more than 500mJ of energy at any point in time.
- Any design component that connects directly to a building electrical supply outlet (110V AC outlet) must be CSA approved.

3. Principle

Mathematical Principle
The device collects a varied amount of data over time [26]. This also means that there is going to be some degree of difference between values that have limited effect on the overall result [26]. For this reason, the mathematical principle of average will help as it will show outliers as well as find the center-point value. Below is how to compute the average of a dataset: $$\bar{x} = \frac{(x_1 + x_2 + x_3 + \cdots + x_n)}{n}$$ This will help the device as it will serve as a method to analyze large sets of data without having to deal with high variance in data. This formula is also imperative when determining the percent errors as there needs to be a standard to measure the errors off from. For this reason, the standard to measure how much of an error is an error based on the data set itself will use the average.

Scientific Principle – Propagation of Electric Waves
Soil moisture sensors work by sending out electromagnetic waves out towards the soil [24]. By measuring the time, it takes for the wave to propagate, it is possible to measure the moisture content in the soil [24]. When there is a high moisture content surrounding the probes, the signal will travel at a lower speed. The opposite is true for low moisture content. The following formula is used to determine the propagation of an electromagnetic wave [24]. $$\left(v_{ph}^2 \nabla^2 - \frac{\delta^2}{\delta t^2}\right) E = 0$$ $$\left(v_{ph}^2 \nabla^2 - \frac{\delta^2}{\delta t^2}\right) B = 0$$ E is the electric field, B is the magnetic field, v_{ph} is the phase velocity in a medium of permeability μ and permittivity ε . The ∇^2 is LaPlace's operator [25]. This principle allows us to detect the amount of water within the soil, thus satisfying the main goal of this product.

Scientific Principle – Galvanic Corrosion
Galvanic corrosion refers to the degradation of metal caused by an electrochemical reaction when two dissimilar metals are in contact in the presence of an electrolyte (such as soil with moisture) [20]. Faraday's Law of Electrolysis [25].

$$M = \frac{Q}{v \cdot F}$$

In the simple case of constant-current electrolysis, $Q = I \cdot t$.

$$m = \frac{I \cdot t \cdot M}{v \cdot F}$$

- **m** - the mass of metal corroded
- **I** - the current
- **t** - the time the current flows
- **M** - the molar mass of the metal
- **v** - the valency of the ions
- **F** - Faraday's constant

Based on this principle, to reduce the corrosion of soil moisture sensor (consists of two electrodes) and thus increase the lifetime of this product, the sensor should be designed to only be powered when reading values

Engineering Standards

IEEE Standard for Safety Levels with Respect to Human Exposure to Electrics, Magnetic, and Electromagnetic Fields Section 4.4: This section specifies the risks and standards for those risk when people meet low voltages. The recommended limit is 0.167f [22]. This standard will help contribute to our device because it lays out specific safety requirements and what needs to be considered when designing it.

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