Fer$_2$O

Team Rundle

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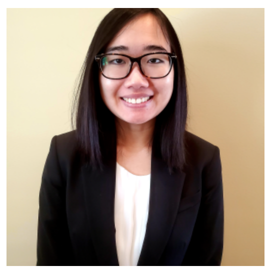

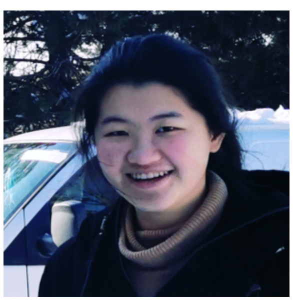



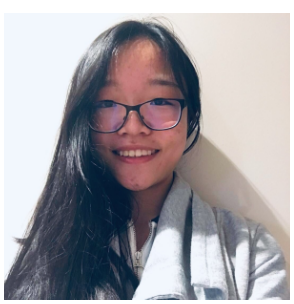

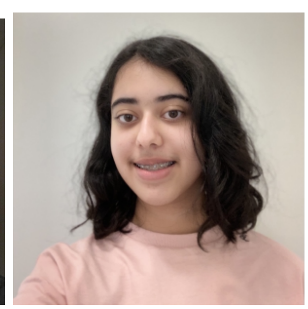

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1. Understanding of Shad 2021 design challenge

Theme: How might we help Canadians treat our fresh water with more respect?

This year's theme relates to helping Canadians understand the value and importance of water. Due to the rich supply of water in Canada, Canadians treat water disrespectfully and are ignorant to the world's limited supply of freshwater. Clean drinking water is depleting and respect is necessary for one of Canada's most abundant natural resources. Our challenge is to find an innovative solution that can help Canadians understand the importance of water and rightfully respect it.

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2. Problem definition

Problem statement: How might we change consumer behaviour to decrease the demand for water?

Often, Canadians overuse freshwater and fertilizer while irrigating their crops. This wastes time, money and natural resources like water. Using too much water or fertilizer creates runoffs. Fertilizer runoffs endanger natural water sources like lakes and rivers, and destroy ecosystems that rely on those freshwaters to survive. The environmental impact of overusing both fertilizer and water irrigation is astronomical. The problem demands a change in consumer behaviour to be resolved.

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3. Solution statement

Fer_2O aims to greatly reduce the amount of water used for irrigation while decreasing the risk of fertilizer runoffs. Fer_2O aims to change consumer behaviour and increase water literacy for all Canadians by helping them become more mindful of their water and fertilizer usage. By being able to monitor one's usages, one can adjust their consumption patterns and behaviours accordingly, thus demonstrating their respect for water. Fer_2O can detect when the user over irrigates their fields, and send a notification to the user to bring it to attention. Creating respect for water and lowering environmental impacts are our top priorities.

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4. Research

4.1 Research questions

1. What nutrients are necessary for healthy development of plants?
2. Sensors capable of identifying the nutrients mentioned above
3. Effects of overwatering
4. What are the top most common plants? (in both farmland and houseplants)
5. How can location affect soil needs/plant needs?
6. What materials would be safe to use in the long term in the soil?
7. Different plants have different water needs: how will we determine how much water is "enough" or will the app only determine "moisture" and the user needs to calculate themselves? Or maybe the app lets users set water needs for each field/area of soil so it can tell the user how much more to water?
8. How do the minerals and salts from groundwater affect plants and the soil?
9. How will the sensor(s) in the ground communicate with the app?
10. Could we possibly add a structure to our idea where the individual can see how much water they are using? (connect data from water bills to app?)
11. Different areas have different soils and weather, how can we make sure that the app will work with all the different types of soil and weather conditions?
12. How is our product different and/or better than the ones already existing on the market?
13. How will the sensor work?
14. Why do we need soil moisture and soil nutrients?

4.2 Research findings

1. What nutrients are necessary for healthy development of plants?

Three Main Ones: N-P-K

Nitrogen: When applied to soil, nitrogen is converted to mineral form, nitrate, so that plants can take it up. Nitrogen is a key element in plant growth. It is found in all plant cells, in plant proteins and hormones, and in chlorophyll ("Plant nutrients in the soil," 1970).

Phosphorus: Phosphorus helps transfer energy from sunlight to plants, stimulates early root and plant growth, and hastens maturity. All manures contain phosphorus; manure from grain-fed animals is a particularly rich source ("Plant nutrients in the soil," 1970).

Potassium: Potassium increases vigour and disease resistance of plants, helps form and move starches, sugars and oils in plants, and can improve fruit quality. Muriate of potash and sulfate of potash are the most common sources of potassium ("Plant nutrients in the soil," 1970).

Calcium: Calcium is essential for root health, growth of new roots and root hairs, and the development of leaves. Superphosphate is useful where calcium and phosphorus are needed ("Plant nutrients in the soil," 1970).

Magnesium: Green colouring material of plants → conversion of sun’s energy to food. A deficiency of magnesium can be overcome with dolomite, magnesite, or epsom salts (“Plant nutrients in the soil,” 1970).

Sulfur: A constituent of amino acids in plant proteins and is involved in energy producing proteins and in energy-producing processes in plants. It is responsible for many flavour and odour compounds in plants such as the aroma of onions and cabbage. Superphosphate, gypsum, elemental sulfur and sulfate of ammonia are the main fertiliser sources (“Plant nutrients in the soil,” 1970).

Molybdenum: Helps bacteria and soil organisms convert nitrogen in the air to soluble nitrogen compounds in the soil (needed for legumes). Deficiency is prevalent in the North Coast’s acid soils, but can be remedied with molybdenum trioxide or sodium molybdate (“Plant nutrients in the soil,” 1970).

Boron: Helps the formation of cell walls in rapidly growing tissue. Deficiency reduces the uptake of calcium and restrains it’s use. Is remedied with borax applied to the soil (“Plant nutrients in the soil,” 1970).

Iron: Regulates and promotes growth of plants (“Plant nutrients in the soil,” 1970).

Manganese: Helps with photosynthesis. Toxicity is remedied with lime (“Plant nutrients in the soil,” 1970).

Copper: Constituent of enzymes in plants. Bordeaux mixture or copper oxychloride sprays to control diseases on horticultural crops (“Plant nutrients in the soil,” 1970).

Zinc: Helps in the production of a plant hormone for stem elongation and leaf expansion. This is easily cured with the addition of zinc sulfate or crushed zinc minerals. Fruit trees can be sprayed with zinc (“Plant nutrients in the soil,” 1970).

As far as we know plants need 18 elements in order to grow in a healthy way. Three of them - hydrogen, oxygen and carbon - are present and absorbed in the air and water. The others - nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, boron, copper, chlorine, iron, manganese, molybdenum, zinc, nickel, and cobalt - are derived mostly from the soil (“Soil Testing for Beginners and Soil Nerds,” n.d.)

Morgan, J. B. (n.d.). Plant-Soil Interactions: Nutrient Uptake. Retrieved July 20, 2021, from https://www.nature.com/scitable/knowledge/library/plant-soil-interactions-nutrient-uptake-105289112/

Macronutrients are the building blocks of crucial cellular components like proteins and nucleic acids; as the name suggests, they are required in large quantities. Nitrogen, phosphorus, magnesium, and potassium are some of the most important macronutrients. Carbon, hydrogen, and oxygen are also considered macronutrients as they are required in large quantities to build the larger organic molecules of the cell; however, they represent the non-mineral class of macronutrients. Micronutrients, including iron, zinc, manganese, and copper, are required in very small amounts. Micronutrients are often required as cofactors for enzyme activity (Morgan, n.d.).

2. Sensors capable of identifying the nutrients mentioned above (Sensor)

pH test. NPK sensor

3. Effects of overwatering (Water Moisture)

- Plants growing in soil that is too wet can suffer from a lack of oxygen (Overwatering, n.d)
- death of roots (Overwatering, n.d)
- loss of physical strength and health (Overwatering, n.d)
- stunted slow growth (Overwatering, n.d)
- yellowing leaves or leaf scorch/burn (Overwatering, n.d)
- Edema may appear on stems and leaves. (Overwatering, n.d)
- Crown of the plant may rot (Overwatering, n.d)
- Death of plants → wasted water (PSYCH 424 blog. n.d.)
- Overwatering is also an unnecessary waste of water that could have been used for something else (Overwatering, n.d)
- Overwatering can cause runoffs of fertilizers that was applied on top of the soil into nearby water source (also a waste of fertilizer) (Overwatering, n.d)

4. What are the top most common plants?

Farmland plants: The most popular plants in farmlands are grains such as corn, wheat and rice.

House plants: Household gardens generally have a lot of Perennials such as Daylilies and Hostas. Fruits and vegetables like tomatoes, blueberries, cucumbers and peppers are also very popular plants that are grown at home.

5. How can location affect soil needs/plant needs? (Water Moisture and Nutrients)

The shape, slope and position of the plant on its landscape influence soil to a great extent. They lead to various drainage conditions and surface runoff.

Soils that develop on higher elevations and sloping areas are usually over drained or well-drained. Soil profiles within these areas commonly have a bright coloured strong brown to yellowish-brown upper solum grading to a lighter, grayer, unweathered substratum.

Soils that occur at lower elevations, adjacent to drainage ways and water bodies, and within depressions usually receive surface runoff from higher elevations and often have a seasonal high water table at a shallow depth. Soil profiles within moderately well-drained and poorly drained areas have irregular spots of brown, yellow and grey colours. In poorly drained areas, the water table is at or near the surface for prolonged periods, soil profiles characteristically have a dark-coloured organic or organic-rich surface layer underlain by a strongly mottled or gleyed (gray colour indicating a reduced condition) subsoil and substratum.

The nutrients may not be available in certain soils, or may be present in forms that the plants cannot use. Soil properties like water content, pH, and compaction may exacerbate these problems.

Potassium deficiency occurs frequently in plants grown on sandy soils resulting in a number of symptoms including browning of leaves, curling of leaf tips and yellowing (chlorosis) of leaves, as well as reduced growth and fertility. Despite the fact that iron is the fourth most abundant element in the earth's crust, it is often limiting for plants due to the fact that it tends to form insoluble complexes in aerobic soils of neutral to basic pH (Guerinot & Yi, 1994). Plants are unable to utilize the element in this form (N_2) and may experience nitrogen deficiency in some soils that have low nitrogen content (Morgan, n.d.).

6. What materials would be safe to use in the long term in the soil?

- **Steel with coating that prevents rusting**
- Rebar
- Not stainless steel

7. Different plants have different water needs: how will we determine how much water is "enough" or will the app only determine "moisture" and the user needs to calculate themselves? Maybe the app can let users set water needs for each field/area of soil so it can tell the user how much more to water? (Water Moisture)

100 mm (4 inches) and often closer to 125 mm (5 inches) of water are needed to get a crop from germination to the reproductive growth stage where it can produce grain. (Wheat, Barley, Canola) (McKenzie & Woods, 2011).

Wheat: Cereal crops at the tillering stage use approximately 2 to 3 mm/day of water, and at the stem elongation stage, they need about 3 to 5 mm/day of water (McKenzie & Woods, 2011).

Canola: Cereal crops at the tillering stage use approximately 2 to 3 mm/day of water, and at the stem elongation stage, they need about 3 to 5 mm/day of water (McKenzie & Woods, 2011).

Barley: Cereal crops at the tillering stage use approximately 2 to 3 mm/day of water, and at the stem elongation stage, they need about 3 to 5 mm/day of water (McKenzie & Woods, 2011).

Corn: Cereal crops at the tillering stage use approximately 2 to 3 mm/day of water, and at the stem elongation stage, they need about 3 to 5 mm/day of water (McKenzie & Woods, 2011).

Potato: Approximately 7mm each day in the summer months, otherwise 50mm weekly (McKenzie & Woods, 2011).

Pea: 25mm weekly (McKenzie & Woods, 2011).

Grass: 25mm weekly, more in hotter months (McKenzie & Woods, 2011).

8. How do the minerals and salts from groundwater affect plants and the soil?

Minerals and salts from groundwater can affect the plant growth, taste, and appearance. If your soil has a high salinity content, the plants in that soil would not be able to grow as fast as they would in normal soil. This is because seeds would germinate (if they even do) poorly leading to a stunted growth, altered plant, or death. As soils become more saline, plants become unable to draw as much water from the soil. This is because the plant roots contain varying concentrations of ions (salts) that create a natural flow of water from the soil into the plant roots. (Provin & Pitt, 2019).

9. How will the sensor(s) in the ground communicate with the app?

- Bluetooth
- Like google chrome (upon setting up, before the sensor is put into the ground, the set up would include activating the sensor via the app and renaming it to fit a person's needs. Further on after using, the sensor would be connected to the app. If it ever gets disconnected, there would preferably be bluetooth on the sensor for easier connection)

10. Could we possibly add a structure to our idea where the individual can see how much water they are using? (connect data from water bills to app?) (Sensor)

For this, I don't think we need to attach the water bills to the app. It could pose a security issue for the consumers, but with proper security within the app, we could do it.

11. Different areas have different soils and weather, how can we make sure that the app will work with all the different types of soil and weather conditions?

The sensor would still sense nutrients and moisture, so all we'd have to do for different types of soil is know the usual/regular moisture levels for that type of soil. In different weather conditions, we would only need to ensure that the sensor is weatherproof.

12. How is our product different and/or better than the ones already existing on the market?

- More affordable
- Can be used in a variety of different areas (not only house plants, but also grass, farms)
- Stays in the ground for a long period of time rather than testing
- NPK Sensor, Moisture

13. How will the sensor work?

- Different prongs that would stick into the soil for each thing that we are measuring→ NPK and moisture

14. Why do we need soil moisture and soil nutrients? Why is measuring soil moisture important?

i) Despite the fact that it helps Canadians adjust their amount of water and recognize the right time for irrigation, it is critically important to "hydrological, biological, and biogeochemical processes" ("Soil Moisture Study," 1999). That concerns with:

1) Weather and climate
2) Runoff potential and flood control
3) Soil erosion and slope failure
4) Reservoir management
5) Geotechnical engineering

6) Water quality

ii) It is the key for evaporation and plant transpiration → important role in

1) Weather patterns
2) Production of precipitation (that runs off into streams and rivers)
3) Forecast improvements
4) Disasters prevention

iii) On top of all its info can be used for Irrigation scheduling and crop yield forecasting - particularly for farmers

1) **I.e.** soil moisture sensors can prevent more water coming out from the irrigation system by the time it passes the threshold limit (Blackstone, 2020)

15. Why are we focusing on this?

Canadian agricultural producers used approximately 2.95 billion cubic metres of water to irrigate their crops in 2018. This is equivalent to the volume of water that flows over Niagara Falls over a two-week period (Government of Canada, 2019).

Agriculture is the #1 consumer of water, with only 25% of the water it withdraws being returned to its source. 85% of agricultural withdrawals of water are for irrigation, and 15% are for watering livestock. Alberta has approximately 60% of the irrigated cropland in Canada. Much of Alberta's irrigated land lies in the Saskatchewan River Basin. Agriculture in this region consumes roughly 2,200 MCM a year from the river, removing about 28% of the total annual flow of the river (Shrubsole & Draper, n.d.).

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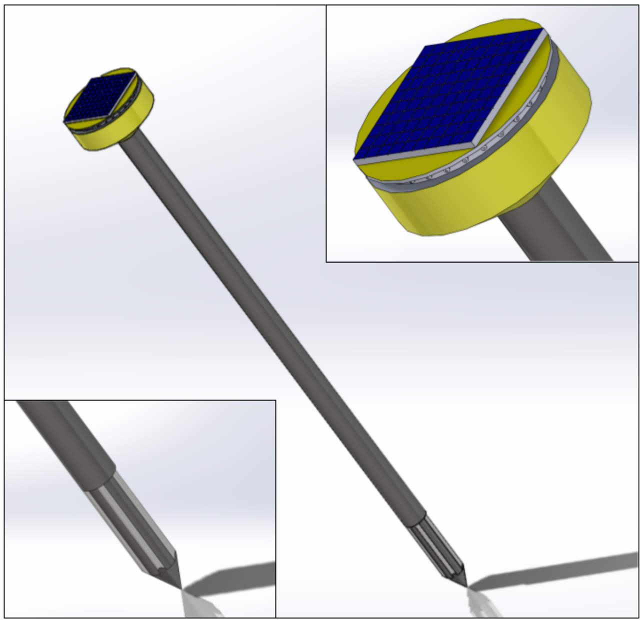
5. Product idea

A smart Sensor that uses NPK sensors and moisture sensors to evaluate the quality of soil. This information is automatically sent to an app connected to the sensor. The app has the capacity to hold any number of sensors, allowing larger farms to create a web showing what areas of the farm needs watering and fertilizing when, saving time and money. The sensor itself is a stake that digs into the ground and is powered by a solar panel on its head. The appeal of Fer_2O is that farmers are able to virtually check the qualities of each of their fields, saving time and money.

5.1 Targeted beneficiaries

According to Statistics Canada, there are 271,935 farm operators in Canada as of 2016. Thereby, Fer_2O can help thousands of farms across the country. In addition, Fer_2O can not only help farmers, but also the general Canadian public, therefore possibly 37.59 million people.

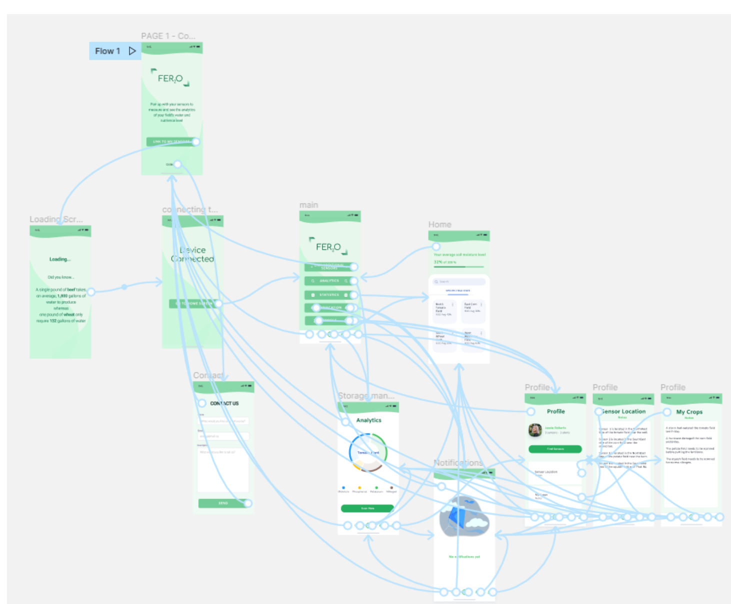
5.2 High-level design



The prototype is in the picture on the left. Feel free to access the sensor prototype of our design by clicking the blue underlined text. It has a few different components. The main part is the different sensors mounted at the bottom. Three of these leads are part of the NPK sensor that tests for nitrogen, phosphorus and potassium in the soil. The other two are part of the water moisture sensor that detects the amount of water moisture in the soil. This information gets sent up to a microcontroller that does a couple of things. The first thing it does is determine if the values are correct for the certain plant specifications. If so, it presents a blue light to show that the water value is correct and green to show that the nutrient values are correct. Otherwise the colours would present a red for nutrients and a yellow for water. By having these bright leds, we have reduced the need for farmers and users to walk into their fields and have to search for the Fer_2O. The data collected from the sensors would be sent to an emitter. This data then would be received by the user's phones and recorded in the app. Our prototype is powered by a solar panel which is attached to the top of the head, and includes a battery for when there is no sunlight.

The outside colour choice was strategically planned as a bright fluorescent yellow. The idea behind this was that when light sources shone onto a theoretical field, the Fer_2O would be visible and easily located. With a height of around 2.5 meters and aluminum that would not leech into the soil over time, our prototype proves to be a help to farmers and plant enthusiasts alike.

Part of Fer_2O also includes an app that allows users to connect to multiple sensors and display different statistics regarding soil moisture and nutrient levels. The five options on the home page include linking to additional sensors, analytics, statics, notifications, and profile. Users may see the distribution of nutrients from a pie chart in the analytics page, and can view other specific field statistics under the "statistics" section. The profile page



allows users to find sensors and record additional notes like approximate sensor location and what has been happening to the crops. The app also includes a notification system where it will send notifications if more nutrients or water is required for a specific crop.

5.3 Impact analysis

- 70% of water used annually is on farmland, and 40% is wasted due to environmental factors like evaporation and ineffective irrigation systems. Fer_2O could drastically decrease this number by informing farmers and saving millions of litres of water and dollars in fertilizer. (“water usage in the agricultural industry”,2020)
- “Agriculture is an important sector of Canada's economy. As of 2018, there were 269,000 jobs in farming” (“Agriculture in Canada.”, 2020). This implies the importance of agriculture in Canada and suggests the potential impact that a change in agriculture practices can have on Canada as a whole.
- Measuring soil moisture is fundamentally important “to many hydrological, biological, and biogeochemical processes” (NASA, 1999). That involves the concerns with “weather and climate, ruoff potential and flood control, soil erosion, slope failure, and the atmosphere through evaporation and plant transpiration.”

5.4 Limitations

- The System is not automatic, it relies on a human to connect the irrigation system with the sensors.
- The user cannot find the exact location of the sensors through the app
- It may be a bit difficult to put the device in the ground
- The app does not have a section where the user can invite friends or share the app with their friends.

5.5 Further improvements

We would like to build a physical prototype on top of our CAD design and app layout. We would also like to build an actual app instead of a mock up that is accessible to anyone using a mobile device. In addition, we would like to make it accessible to not only farmers but also the general public.

6. Self-assessment

6.1 Relevance to Shad 2021 theme

Fer_2O is relevant to the Shad 2021 theme: it helps Canadians treat water with more respect. Our design increases water literacy of its users by providing a platform for users to monitor and limit their usage of water and fertilizer on a farm or garden. When Canadians realize and understand where and how much water they use when it is not needed, they are able to provide water with more respect and demonstrate this by avoiding unnecessary usage.

6.2 Application of scientific principles

- Most Canadians over water or fertilize their crops or lawns, leading towards water wastage, contamination, and soil contamination.
- If Canadians are able to understand how much water and fertilizer their crops/lawns need, water can be saved, and the amount of contaminated water and soil can be decreased.
    - At times over-watering can lead to run off, especially if the lawn/field is steeped. Additionally, due to the fertilizers in the soil, this water can become contaminated, leading towards the contamination of water bodies.
    - An unbalance of soil nutrients can lead to soil contamination and pollution leading towards salinity.

6.3 Innovation

Fer_2O differentiates from other smart-agricultural products, including nutrient and moisture sensors. Fer_2O detects NPK levels and soil moisture and sends this information to the app that presents the data in a simple, but effective, format. Moreover, Fer_2O can withstand poor weather and has lights to locate the sensor if needed.

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7. Conclusion

The overuse and disrespect of water is a significant problem in Canada. Canadians do not understand or acknowledge their consumption behaviours or patterns, displaying carelessness and a lack of water literacy. However, Fer_2O has the potential to help promote water literacy, conservation, and advocacy amongst Canadians. This product helps Canadians understand their water consumption behaviours and patterns, resulting in water efficiency and conservation. In detail, if Canadians are able to understand their consumption behaviours, they will decrease their usage of water and understand the fundamental importance of it.

8. Acknowledgement

We wish to thank our mentors Lee Jackson and Denis Onen for providing valuable insight.

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