Automatic Irrigation to Reduce Freshwater Waste on Farms

Grant Proposal

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Abstract (RQ) or Executive Summary (Eng)

Over time, various automatic irrigation systems have been developed to reduce freshwater usage in agriculture. While many systems incorporate key components, such as weather or soil data, they often fail to integrate both types of data. Additionally, most systems are unable to handle variations in soil moisture caused by uneven terrains, such as slopes where water accumulates at one end. This project introduces a new irrigation system that integrates weather and soil data while accounting for topographical differences, offering a more efficient and sustainable water management solution.

Keywords: Arduino, Agriculture, Fuzzy Logic, irrigation, automatic

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Many anticultural operations worldwide rely on artificial crop watering, where environmental factors do not supply the water. This water is often pumped in from wells or provided via town tap water. Both consume a lot of water and other resources, such as electricity, to pump it to the correct location. When agricultural employees deem it necessary to provide the crops with irrigation, it is tough to know how much water they need to deliver their crops; therefore, they often overwater, which consumes excessive water. This excessive water, especially on the leaves, can evaporate, increasing humidity (Denning, 2024). There is only a limited amount of freshwater on this planet, making it highly viable and unimportant to waste, and currently, 85% of the freshwater used worldwide is consumed by agricultural operations (Taneja & Bhatia, 2017). Currently, there are systems aimed at reducing the amount of water used. However, there are some limitations to these systems. Most of them are not targeted to be used in the agricultural sector; instead, they are targeted for residential use. Additionally, many systems do not implement weather and soil data. Instead, they implement one or the other. The United States Environmental Protection Agency (EPA) has developed a program called WaterSense, with the goal being to reduce the amount of water used across the U.S. (USEPA, 2024). Over recent times, they have given their stamp of approval on a few lines of products targeted at home automatic irrigation systems and reduced freshwater usage. For these products to be given the "WaterSense" stamp, the product has to integrate either soil or weather-based data into the irrigation plan. The thought behind this is that it will reduce overwatering and erosion because it can ensure that the soil truly needs to be watered. Currently, some irrigation systems have WaterSense approval but have many limitations.
A prime example is the R3 Smart Sprinkler Irrigation Controller, 8 Zone, sold by RACHIO. This product contains many limitations, including the fact that it only gathers weather data and does not gather or interpret soil data (RACHIO, 2024). The lack of soil metrics can still cause overwatering as the system is unaware of other potential sources of soil moisture increase, such as floods.

Other products include the Melnor 65099-AMZ HydroLogic 1-Zone Digital Water Timer with Moisture Sensor Amazon Bundle, Timer & Moisture Set. However, this system is extremely limited as it only allows for one sensor control. Therefore, you could not achieve individual control over different rows of crops.

Additionally, this product does not have the WaterSense stamp of approval (Melonr, 2024). The lack of WaterSense approval can cause users to wonder if they are really reducing their water usage.

Additionally, the product only has access to analyze one row. In short, this means that the user is limited to watering the entire area at once instead of analyzing different rows of crops individually, which would save even more water. Also, this product still needs to receive the stamp of approval from the EPA, meaning that it might not significantly reduce the water used.

According to the EPA, if homes implement WaterSense products, they could save up to 15,000 gallons of water a year per house (Environmental Protection Agency, 2024). Other additional studies have proven similar responses. One example found that if control theory was integrated into irrigation, freshwater use could be significantly reduced (Romero et al., 2012). Considering that many industrial and agricultural operations consume much more water than residential areas, there is a lot of potential for additional water savings since American farms use approximately 85% of the freshwater (Taneja & Bhatia, 2017).

The goal of this project is to reduce this gap and create a system targeted at large industrial and agricultural operations that implements both soil and weather data to reduce the amount of freshwater used. With these systems implemented, the amount of freshwater used on farms could be drastically reduced, reducing the waste of freshwater worldwide.

Section II: Specific Aims

This proposal's objective is to reduce the amount of freshwater used by farmers. Our long-term goal is to implement soil and weather-based metrics into all irrigation, where the central hypothesis of this is that water usage by farmers will drop worldwide. The rationale is that over time, to feed our increasing population, more and more farms have been populating our world, and along with global warming and irregular rain patterns, artificial irrigation is often required (Molotoks, 2021). The work we propose here will propose a system that can reduce the amount of freshwater use on farms.

Specific Aim 1: (Automatic)

The need for irrigation to be automatic is strong because it can alleviate the pressure off farms' backs and ensure that the plants always receive sufficient water. It also means that if the farmer falls ill and is unable to tend to his crops that day, he does not have to worry about watering.

Specific Aim 2: (Use Soil Data)

The implementation of soil data can drastically reduce water usage on farms and reduce natural disasters such as flooding. There have been prior studies that have analyzed the water savings if there were to be a soil moisture sensor (Taneja, & Bhatia, 2017). Additionally, if there were to be one on every row of crops with a corresponding solenoid, this could help reduce the water waste because only specific rows would turn on when the algorithm deems it necessary.

Specific Aim 3(Use Weather Data)

By adding weather data, it can add another layer of robustness and analysis ensureing that the system does not automatically water when a rainstorm is forcasted in the near future. Weather Data is essential for truly reading water by taking advantage of natural sources that require no man-made resources.

The expected outcome of this work is a system that could be implemented on a farm with relatively little effort that could significantly reduce the freshwater waste in their irrigation operations.

Section III: Project Goals and Methodology

Relevance

Many farms across America consume a lot of water, and many of them accidentally overwater plants.

Innovation

While there are currently many automatic watering systems on the market, none of them have the ability to analyze multiple rows of crops using the same system, and many also do not take into account pending weather conditions.

Methodology

This project uses an Arduino Giga as the central control hub for all operations. Connected to this is a soil moisture sensor that determines is water is needed. The sensor was initially calibrated by determining the value when it was dry and then when it was in a cup of water. Then, I set up a sample growing environment of the Wisconsin Fast Plant Deli Cup Method to determine the optimal soil moisture of this and determined it to be around 45-60% or, as my sensor read, 580-630.

After a reduction of water is detected in the soil, a signal is sent to a servo valve that can trigger the manual button on a smart plug, allowing the pump to be turned on. This step could be removed if there was access to proper water pressure; however, gravity did not provide enough pressure for the valve to open. When connected to a traditional hose picket outside of a residential house, the water pressure is sufficient. At first, a gravity field system was tried, with the buckling being 6 feet above the valve was still not enough pressure to open the valve.

After the pump has been on for 3 seconds and allowed time to purge air out and then a signal is sent to a motor controller that is connected to the solenoid allowing the solebnoid to open. A 9-volt bench power supply unit is connected to the motor controller to supply power for the solenoid to open. At this point, the current EPOCH time is gathered by the RTC and stored temporarily on the board.

Once the sensor reads higher values, the pump is then shut off, and the valve is then closed, and the end current EPOCH time is also recorded. Then, the system takes the difference of these values and logs it into a USB stick along with the date. Additionally, logged to the USB stick in a separate file is a file containing all of the oil readings from every two seconds.

The goal of this project is to hopefully be able to integrate this into farms across America and other countries to reduce the amount of freshwater waste. My goal would be for it to be “plug and play” for farmers, so all they would have to do is hook up the piping how it best fits their operation and for it to start working.

Specific Aim #1

The number one aim of this project was to develop an automatic irrigation system. Our approach was using a pump and a solenoid valve that opened automatically when Arduino told it to do so. Additionally, the water was provided right at the soil level to ensure that irrigation locations stay optimal by being close to the plants.

Justification and Feasibility: The methods discussed help reduce the amount of freshwater because it can reduce the amount of irrigation by producing it at a particular spot instead of just throwing the water to the surface. When the water is only provided to the surface, it can increase the humidity of the surrounding area. (Denning, 2024). Additionally, this creates excess water waste because freshwater is being used; however, it is not impacting the plants. It has been found in the past that any form of automatic irrigation can reduce the amount of water used and its waste, and we would like to expand on that (Romero et al, 2012). Another study found

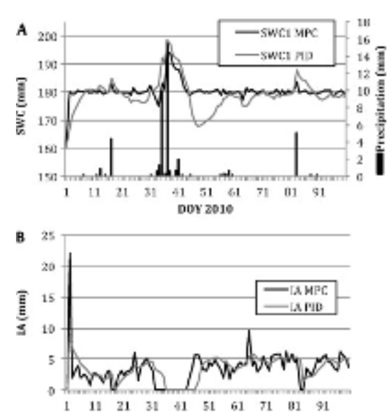


Figure 1: graph shows the reduction of water used in a system and the benefits that it could have. This system used a soil moisture sensor to limit watering (Romero et al. 2012)

similar results on the benefits of using automatic irrigation and found that it had significant impacts on the water consumption on farms (Anoop & Bala, 2023).

Summary of Preliminary Data. The preliminary data (Figure 2) gathered showed a strong reduction in the amount of water consumed by the automatic watering system compared to a traditional system. Across 5 days, it used a total of 91ml of water compared to the other systems 235ml. Additionally, the automatic watering system was not operational on the first day due to technical difficulties, so an amount of 50ml was provided to begin the growing process.

	Carolina Wick	Our System
Day 1	87	50
Day 2	37	8
Day 3	37	9.14
Day 4	37	11.71
Day 5	37	12.57
SUM	235	91.42

Figure 2: Shows the amount of water used by our system compared to the Carolina Wick. Amounts are in milliliters.

Expected Outcomes. The overall outcome of this aim is positive. The system showed a reduction in water usage. This knowledge will be used to advocate and push for more automatic irrigation systems to be used in farms across the world.

Potential Pitfalls and Alternative Strategies. We expect it to be difficult to transform this system into working outside due to weatherproofing. However, with enough testing and design, we will be able to build a robust system that can withstand the elements.

Specific Aim #2: Use Soil Data

Another aim of this project was to use soil moisture data. A capacitive soil moisture sensor was used to achieve this. Our rationale was that if this were to be used, it would also help to reduce the irrigation amounts.

Justification and Feasibility: Using a soil moisture sensor, we could determine the soil moisture at any given time, allowing us to incorporate these values into our algorithm. Over time, there have been studies that have tested the impacts that a sensor could have on the amount of water used. In a study conducted by Taneja & Bhatia in 2017, they found the impacts of using a sensor were large. Additionally, another study that conducted other types of automatic irrigation styles found similar results that soil-based watering was very efficient (Ali & Joshi, 2017).

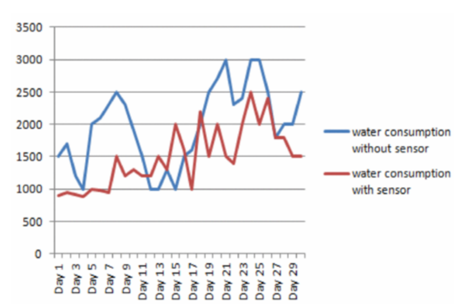
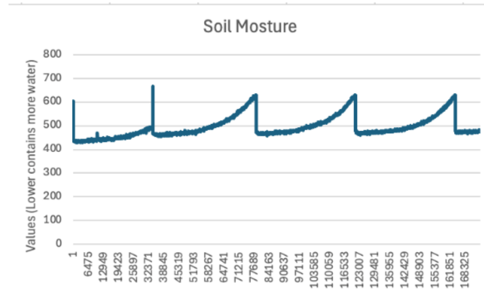


Figure 3: Graph shows us the red line, which is the water consumption with a sensor being under the blue line, which did not have a sensor (Taneja, & Bhati, 2017)

Summary of Preliminary Data:

If we examine the data, we can see the values slowly increasing over time, representing the soil's drying over time and the plants using the water. we see a sudden increase in the water, representing that the pump turned on and water was provided to the plant.



Shows readings from our system. Clearly, it shows the drying of the soil followed by immediate watering. Technical difficulties caused note irregularities at fault.

Expected Outcomes: The overall outcome of this aim is to be able to build an algorithm around soil moisture. This knowledge will be used to advocate for it to be incorporated no more automatic watering systems.

Potential Pitfalls and Alternative Strategies:

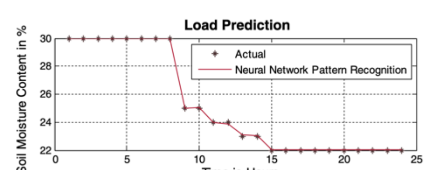
There is a potential that when irrigation begins, if this water does not seep into the soil and instead ponds, it could cause an issue with the sensor touching the water. Deeper soil could be used so that the sensor could be placed under more soil. On top of the sensor, there would need to be a piece of heat shrink over to protect the components.

Specific Aim #3

Integrating weather data is crucial for reducing the amount of water used. Our rationale for this was that if it were going to rain soon, it would be counterintuitive to irrigate the crops. To conduct this, the Arduino will communicate with the Natioanl Weather Service (NWS) to predict an area's weather.

Justification and Feasibility:

If there were to be a weather analysis, it could strongly reduce the water used as it would not irrigate before predicted rainfall. In a prior study conducted by Keswani et al. in 2018, they found that they could predict the soil moisture content over time through a weather algorithm and a neural network. In another study, they were able to monitor both the weather data to limit the strain for freshwater. They were able to make predictions about the soil moisture, therefore delaying irrigation (Ziaei et al., 2024).



Their prediction was always consistent with what the actual SMC was (Keswani et al., 2018).

Summary of Preliminary Data:

We have JSON files from the NWS that contain the current precipitation chances and can obtain this data as needed. From this, we will be able to delay the irrigation and recheck the soil moisture later to confirm the irrigation status.

Expected Outcomes: We expect an even more efficient algorithm as it will not provide water to crops when rain is predicted.

Potential Pitfalls: It might be difficult to obtain the weather using the Web APIs on the Arduino; if this is true, we could switch to an onboard analysis of the current data and use the Zambretti Algorithm to predict future rain.

Section III: Resources/Equipment

Water Solenoid
Male to Female Jumpers
Male to Male Jumpers
Arduino Giga
Arduino Uno R1
Motor Controller
Real Time Clock Module
Bread Board
Servo
Water Pump (Rigid ¼ HP 120 Volt Pump)
5 Gallon Bucket
Smart plug (iHome Smart Plug)
Soil Moisture Sensor
Wire (for soldering)
9 Volt Bench Power Supply (or 9v battery)
1 Foot Section of a 2x4
4 Foot Female to Female Garden Hose
3/4 in. MHT x 1/2 in. MIP Brass Adapter Fitting
PTFE Tape
3/4 in. FHT x 1/2 in. FIP Brass Adapter Fitting
¾ Inch Male to ½ inch barbed (2)
1/2 in. I.D. x 5/8 in. O.D. x 10 ft. Clear Vinyl Tubing
0.5 GPH Pressure Compensating Spot Watering Drippers/Emitters (10-Pack)
3/4 in. FHT Brass Cap Fitting
1/6 in. I.D. x 1/4 in. O.D. x 10 ft. Clear Vinyl Tubing
GoPro
16 GB USB Drive
1/2 - 1-1/4 in. Stainless Steel Hose Clamp
.25-inch wooden dowel x2
Cable Ties
2Pcs DC 3-5V Micro Submersible Mini Water Pump for Aquariums Fish Tank Pond Fountain Hydroponics Garden (2Pcs White)
Soldering Iron

Heat Shrink
Diode

Section V: Ethical Considerations

We are considering our water usage and trying to keep it to a minimum by reusing water when possible, between tests.

Section VI: Timeline

We would like to have initial testing with soil moisture completed by December and begin to be able to transition into weather integration for February.

Section VII: Appendix

For the most up to date code and data please visit the link below
https://github.com/proctornt/MAMS-STEM-1/tree/experimental

Section VIII: References

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