Computational Analysis of Specific Indicators to Manage Crop Yield and Profits Under Extreme Heat and Climate Change Conditions

Inspiration For My Project

Last summer, Washington experienced a record-breaking heatwave. The three-day stretch of scorching heat not only had a catastrophic effect on the state's residents, but also its crops, thus impacting the food supply. I recorded 116 degrees at my house on June 28th, 2021. I saw news reports of entire fields of potatoes and cherries being destroyed, and fruits that stopped growing from the unusually high temperatures. With so much devastation to farmers, I began wondering how farmers are going to cope with the inevitability of future heat waves. To study this issue in more detail, I sought out datasets that would help me analyze the impact of extreme heat on crops.

After visiting an apple orchard in Grandview located in Eastern Washington, I learned about different sensor measurements, such as sap flow, soil moisture, and leaf temperature. I talked to several farmers who told me their struggles in managing irrigation during the unbearable heat in the summer months. One farmer told me he had no scientific way of knowing when to irrigate. I realized farmers needed an effective way of collecting and synthesizing data from various sensors. I began working with researchers at Washington State University (WSU) and an innovative startup called innov8.ag to collect data from IoT (Internet of Things) sensors as well as drone and LiDAR (Light Detection and Ranging) imagery from the Honeycrisp apple orchard.

Though the capabilities of LiDAR and drone imaging technologies excited me, I was more amazed by the results from applying modern edge computing, data mining and software techniques to an old profession like farming. As I delved deeper into the project, I learned how new technologies such as 5G wireless networks, imaging tools, and edge computing can help unravel profound insights for farmers in real-time.

This pursuit of interdisciplinary research has enriched my scientific foundations and stretched my curiosity in ways I couldn't have imagined. Working with the researchers from WSU and innov8.ag taught me the importance of collaboration, analyzing an inordinate amount of data to find meaningful insights, and patience as I sought out answers to my questions.

While I had initially taken up this project to explore my curiosity and connect the dots between climate change and our food supply, I used this opportunity to find solutions for farmers in my community. My research provides a window into the future of how farms can and should be managed using sensors that provide deeper and actionable analysis to farmers, researchers, and policy makers to keep our food supply secure and farm communities sustainable.

My Advice to High School Students

My advice to other high school students who want to tackle a project dealing with math and science is to pursue your curiosity. It doesn't matter if your interest is in Euclidean geometry or microbiology, if you seek out research on a topic you are interested in, it will make the whole process easier and more enjoyable. It's also important to remember that research is a long process and if you are working on a project that you aren't even interested in, it's going to make the learning process a lot harder if you aren't enthusiastic about what you are doing.

My other piece of advice is to be okay with failure and never give up. I ran into a lot of dead ends in my project and the reason that didn't bother me was because each time I failed I learned something new. There is more learning that happens in research failures than successes, so remember that your end goal doesn't always have to be a new cure or a revolutionary invention. Think of failure as bringing you a step closer to success rather than taking a step backwards.

Key components of the project

My goal was to develop a decision framework for farmers to determine when they needed to irrigate or fertilize their crops. This was used to perform computational analysis of specific sensor variable indicators to help manage crop yield under extreme heat. I had never analyzed data from IoT sensors or LiDAR imagery, so learning how to use Quantum Geographic Information System (QGIS) to analyze geospatial information was a bit of a challenge for me. I not only had to understand how to analyze the data coming from the sensors and drone imagery, but also figure out how to interpret the results from QGIS. Using QGIS I was able to split the orchard into 30 feet segments (a 16.9 acre field was divided into 1,507 sections for analysis). This made it easier to click into any section of the orchard and understand, on a specific level, what was going on. I was able to look at the Normalized Difference Vegetation Index (NDVI) value for each segment, which told me how green (in terms of color) that section of the orchard was. Using the NDVI values I was able to identify which segments had crops suffering from extreme heat – this was an incredibly useful insight for the algorithm I made.

I designed my algorithms based on variables reaching certain thresholds. The algorithm starts by looking at the drone imagery of the orchard to seek out any "problem areas", meaning based on the color intensity, if certain areas of the orchard are orange or deep red, they would require further investigation. The farmer would then place sensors in these problem areas to figure out why the crops in specific regions are under heat stress. Based on what these sensors tell the farmer, they can decide which type of irrigation to use. There are two main types of irrigation: drip and overhead irrigation. Drip irrigation supplies crops with water to “drink” while overhead irrigation is a sprinkler system above the plants that drizzles water on the crop to cool down. Drip irrigation uses more water than overhead irrigation. For example, if the soil water potential sensor is showing that the lower end of the threshold has been breached, it is clear that the plant needs water to drink so the farmer would use drip irrigation. But, if the leaf temperature sensor shows the upper end of the threshold has been breached, the farmer will know the plant is overheated and needs water to cool down, not to drink, and will use overhead irrigation. It is important for farmers to know what type of irrigation is required (drip vs overhead) and in what section of the farm. Using the information from these sensors, farmers will be able to manage their irrigation systems much more efficiently and save water. After running simulations based on my decision framework, I concluded that farmers would save an estimated 55% in irrigation costs over the course of the season (see graph below). My algorithms are independent of the crop type or region and thus have wide applicability. Using these insights, farmers can better manage irrigation resources and labor, thus maximizing their yield and profits.

Important Figures

Figure 1. Drone imagery of the Grandview orchard in April and June 2021 *(The darker the color, the greener is the orchard segment)*

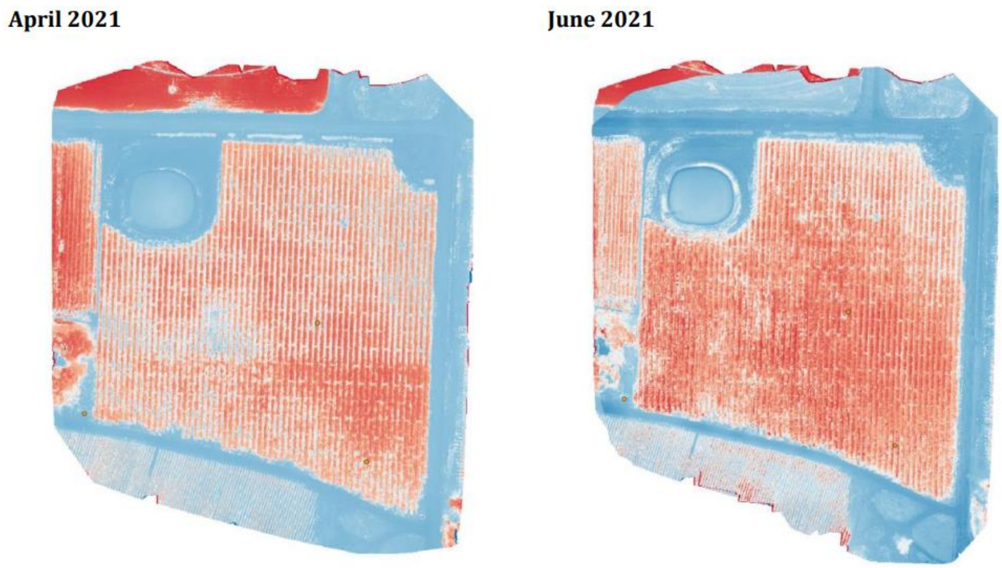

Figure 2. a) The Grandview orchard split into 30 feet segments. The circles indicate the location of the sensors in the orchard. b) This image is a zoomed version showing the location of the sensor set. *Each location ID (represented by numbers 150-159) refers to a specific set of sensors that measure weather and soil parameters like air temperature, atmospheric and vapor pressure, leaf wetness, precipitation, soil water potential, wind, etc.*

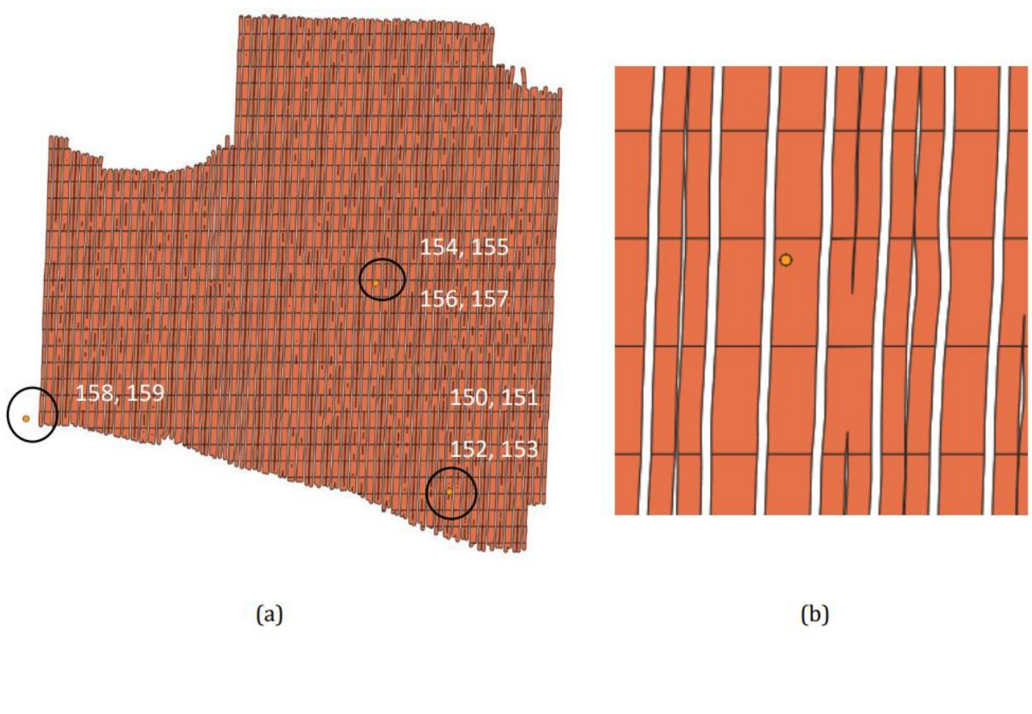

Figure 3. Estimated water cost savings using IoT-sensor-based decision system