Decreasing Water Usage and Increasing Income for Vietnam Small Farmers: Modeling Plant Stress with Handheld Infrared Thermometers

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Research Question:

"How can canopy temperature be used to determine plant stress and calculate watering amounts to optimize water usage in Vietnamese small farms?"

Introduction:

The EPICS (Engineering Projects in Community Service) Vietnam Smart Agriculture team is designing a smart agriculture apparatus that would allow Vietnamese small farmers to reduce water usage and increase their overall profit. It has been shown that more controlled irrigation techniques in Vietnam could lead to using 30% less water and a median increase in annual income of up to $350 [Karol 2017]. With an average Vietnamese annual rural household income of $857/year, this sustainable technology could provide a 40.8% increase in annual income for many farmers [Anh 2018].

The inexpensive system would function by having a farmer take surface temperature measurements of randomly selected plants around the farm using a handheld infrared sensor. The data would be used to suggest watering amounts displayed through a mobile app. The goal of this research project was to provide necessary background for the EPICS team to continue in creating a functional and accurate system during the fall.

Fig. 1: An EPICS student manually watering crops at the Tra Que vegetable village during the 2019 Fulton Vietnam Global Intensive Experience.

Crop Water Stress Index:

The crop water stress index (CWSI) produces a value from 0 (a plant not stressed for water) to 1 (fully water-stressed), used as an indicator of a crop's health and water needs. As shown in Fig. 2, (T_c-T_a) represent the difference between canopy temperature and ambient temperature [Nanda 2018]. D_2 and D_1 are baselines for a crop's temperature difference when non-stressed and fully stressed, respectively. Both baselines are calculated based on data taken from the specific climate and plant being indexed. This project investigated using both the Idso and Jackson method of determining CWSI.

$$\mathrm{CWSI} = \frac{\overbrace{(\mathrm{T_c} - \mathrm{T_a}) - \mathrm{D_2}}^{\text{The difference between a crop's instantaneous canopy-air temp. difference and its temp. difference when fully stressed}}}{\underbrace{\mathrm{D_1} - \mathrm{D_2}}_{\text{The maximum difference in canopy-air temp. difference between fully stressed and non-stressed plants}}}$$

Fig. 2: A labelled depiction of the formula for CWSI.

Design Additions:

This project has revealed important additions that could be made to the design to increase functionality. First, adding a level system to the handheld device could aid accuracy of the human-performed measurements. Second, using human input and both the Idso and Jackson methods (which use different variables to calculate CWSI) would provide better understanding of the accuracy of results. Finally, connecting the app to weather station data would be required in order to gain access to the necessary variables for computing CWSI without overcomplicating the system.

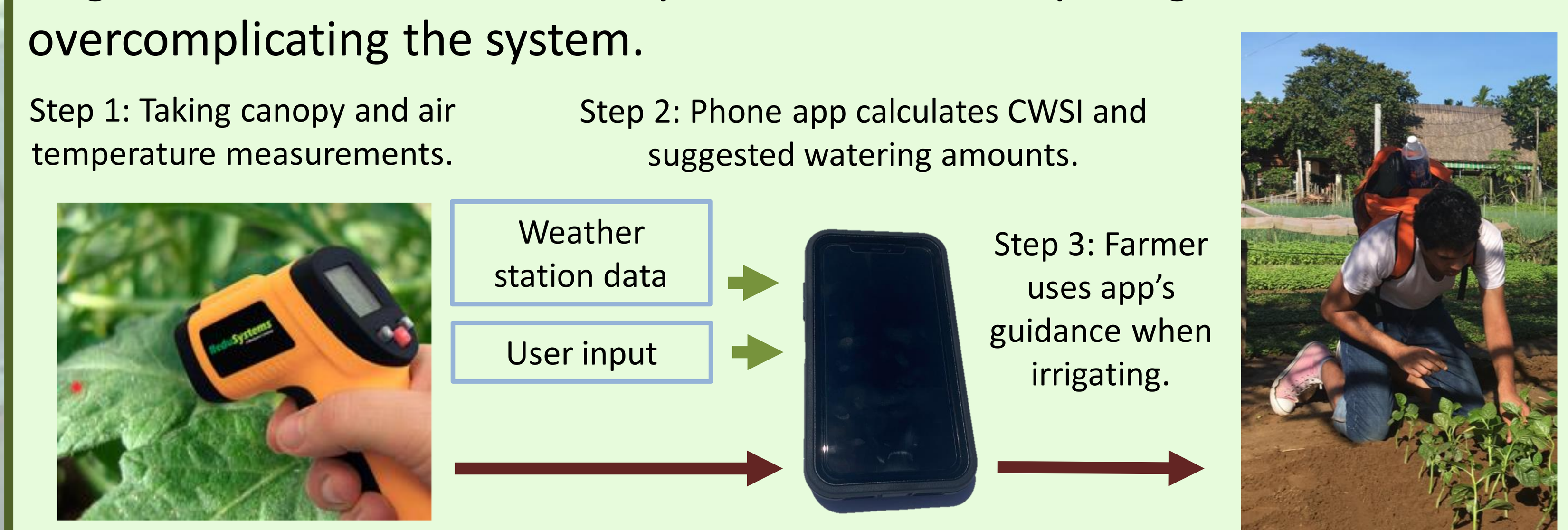

Fig. 3: A diagram displaying the process of using the team's updated device.

Key Insights and Future Research:

As baselines are dependent on crop and climate, a large number of baselines would be required for the average Vietnamese small farm as they typically feature a variety of plants. Furthermore, Vietnam has a tropical, fluctuating climate. Since this technology is more often used for certain crops on large farms in locations such as the south west USA, more data is necessary to determine baselines for calculating crop water stress indices for the small plots found on the farms and gardens in Vietnam.

Future research will focus on finding suitable baselines to be used in the EPICS team's product algorithm, along with creating a procedure for the farmers to use when taking plant canopy temperatures in order to minimize human error.

Fig. 4: The size of a small plot of crops in the Tra Que vegetable garden in Hoi An, Vietnam.

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