Internet of Things (IoT)-Based Precision Irrigation System for Specialty Crops

Long He

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PennState College of Agricultural Sciences

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Importance of Precision Irrigation

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Benefit of Irrigation:

- ❖ Improve crop yield and quality
- ❖ Conserve water and save energy
- ❖ Reduce nutrient leaching and environmental impact

Challenges for Conventional Method:

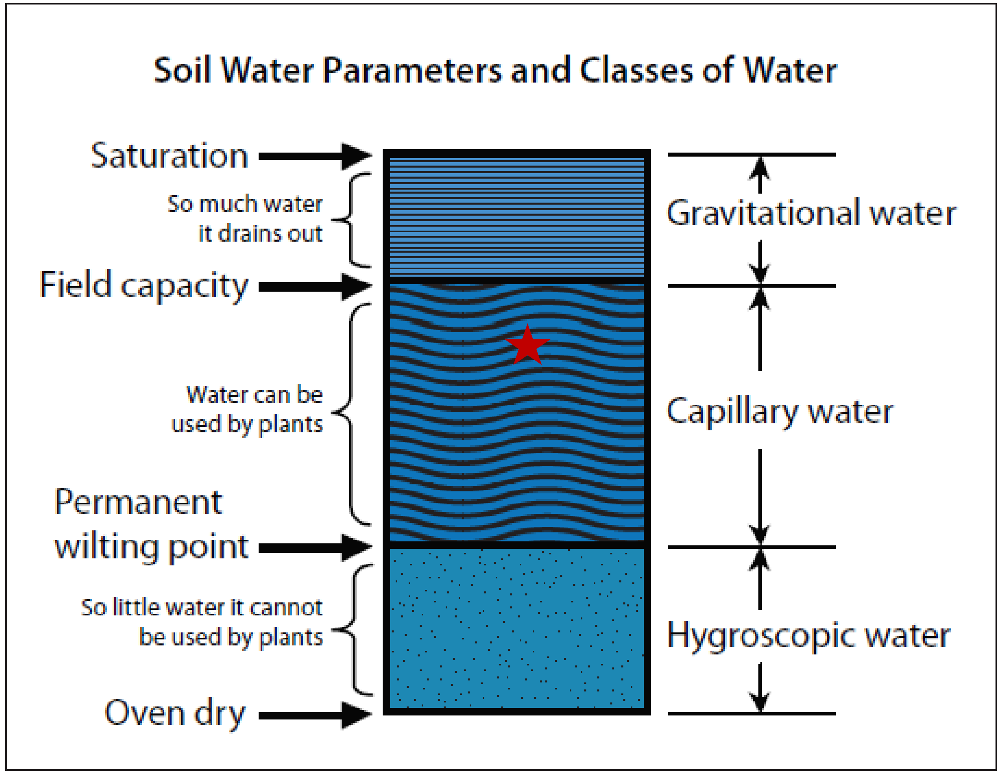
- ❖ Rely on human experiences
- ❖ Cause over- or under-irrigation

Precision Irrigation:

- ❖ Rely on data
- ❖ When and how much to irrigate

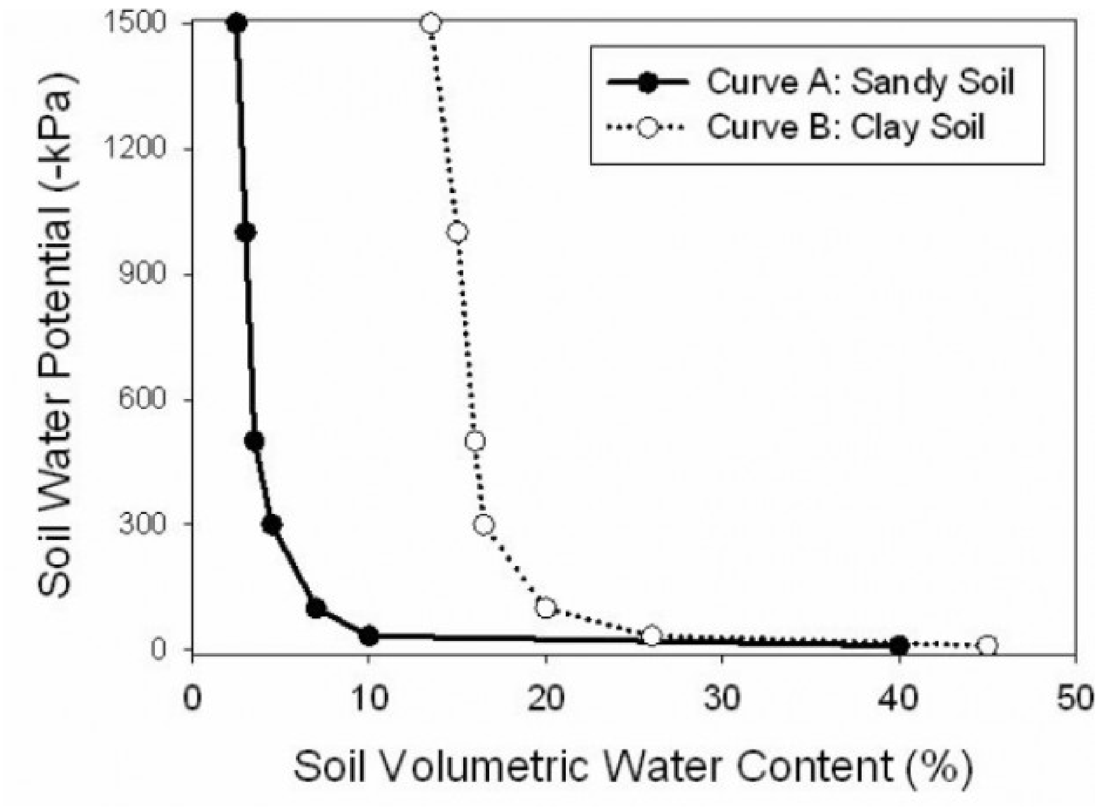
Soil Moisture Measurement

Fundamental Principles



Soil Water Parameters (From: Texas A&M AgriLife Extension, E-618)

Soil Water Content vs. Soil Water Potential



(From www.ictinternational.com)

Internet of Things (IoT) Basics

IoT Fundamental

Internet of things (IoT) is the interconnection through the internet of computing devices embedded in everyday objects.

Crop + Machines + Sensors + Data + Expert + User

IoT Systems

- Common wireless technologies
  Wi-Fi, Bluetooth, ZigBee, Sigfox, cellular network, LoRa
- Long range IoT systems
  Cellular network
  LoRaWAN: low power, Low cost, Long range, Low data rate

IoT for Irrigation System

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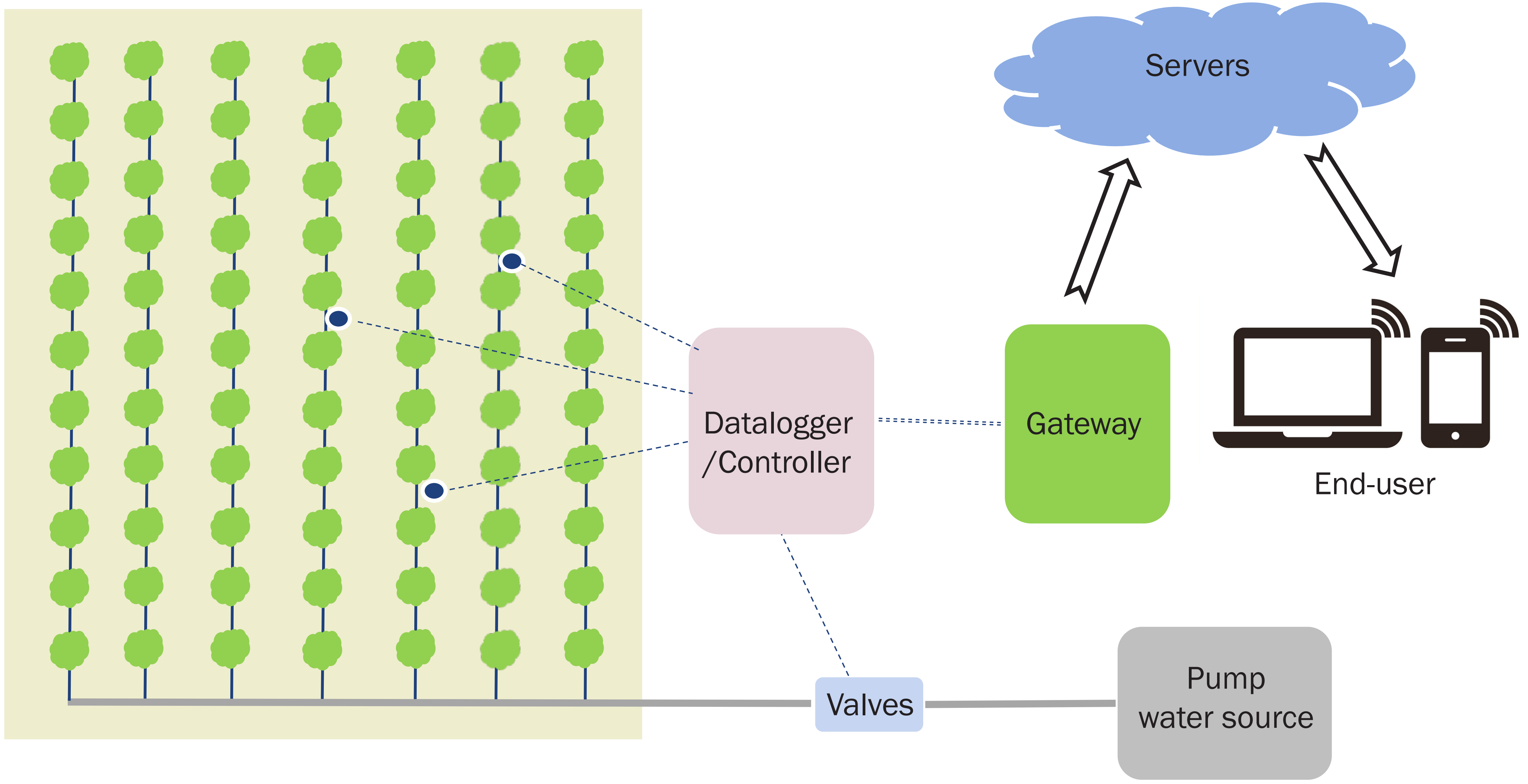

Cellular Based IoT Irrigation

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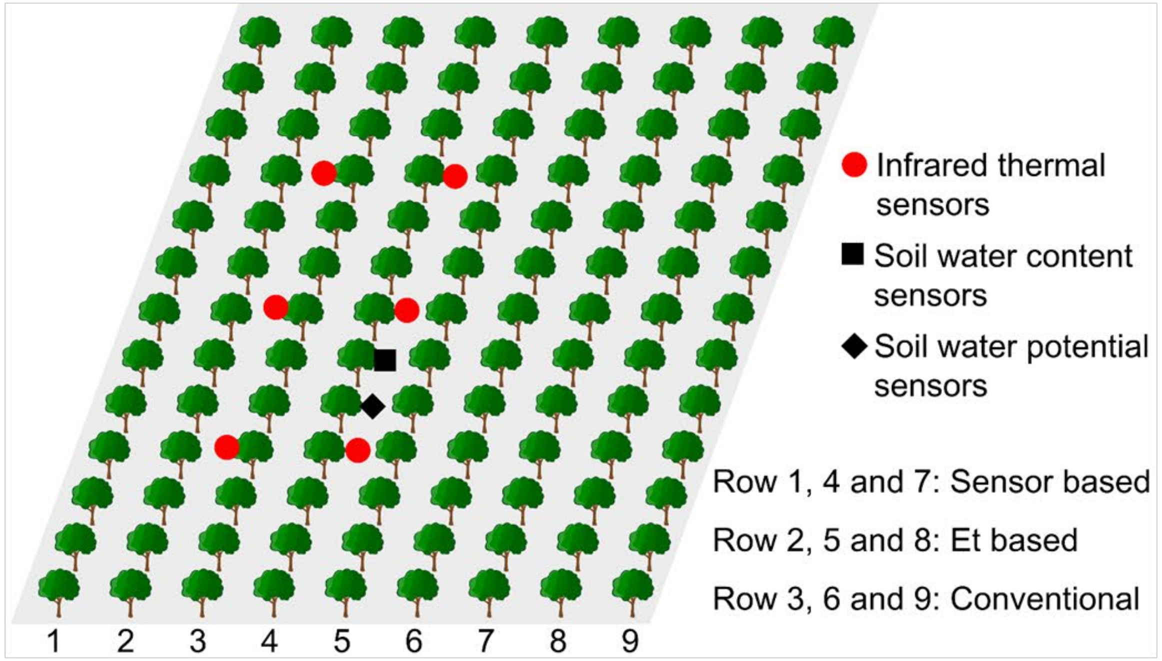
Primary Goal

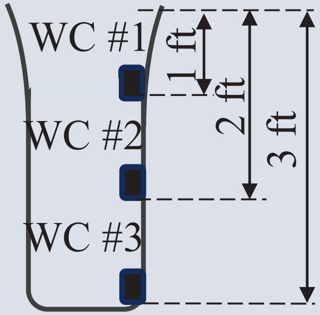
Investigate an efficient sensor-based irrigation scheduling strategy for apple orchards in Mid-Atlantic region.

Experimental Setup



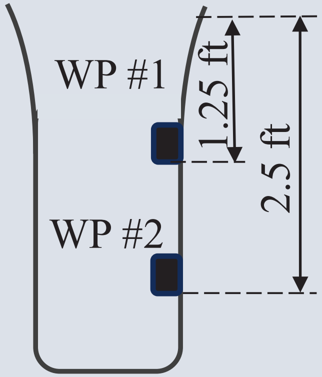
Soil Moisture Sensor

TEROS 12 @ QTY 3



Soil Water Content Sensor

TEROS 21 @ QTY 2



Soil Water potential Sensor

Irrigation Scheduling Methods

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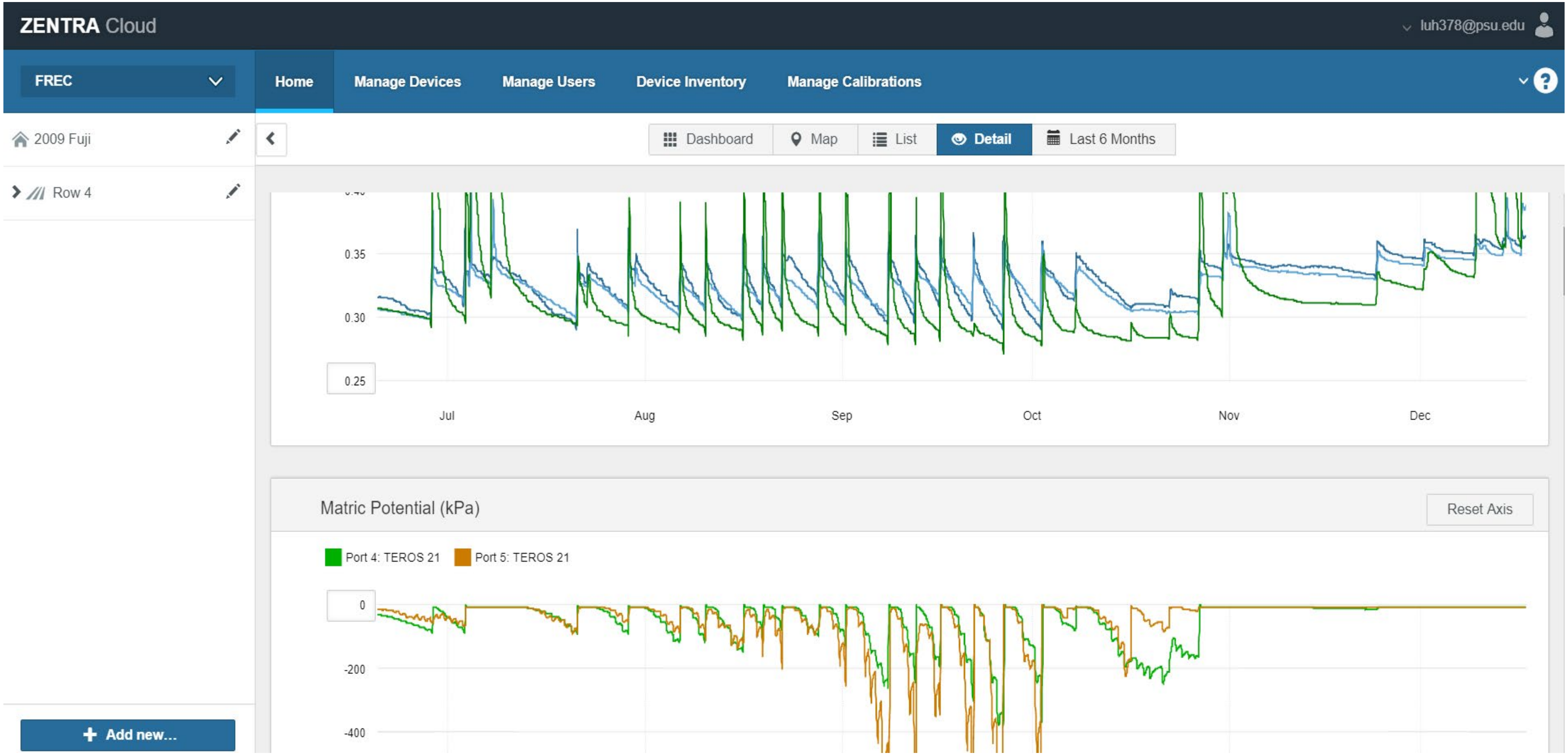
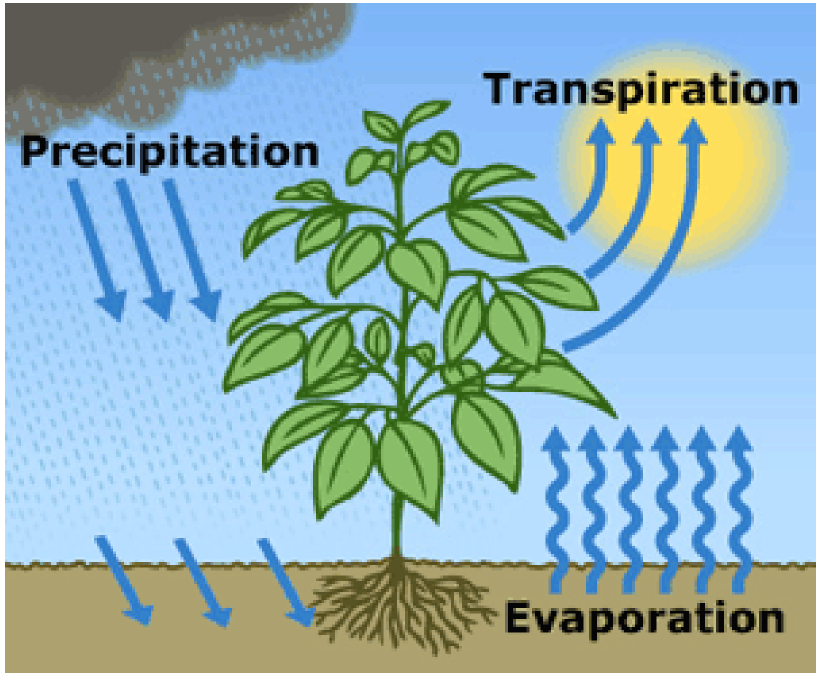
Soil Moisture Sensor Data Recording



Evapotranspiration (ET)



When **Transpiration + Evaporation** > **Precipitation**,
Irrigation is needed.

Penman–Monteith Model (P-M)

- Reference ET_0
- Estimated $ET = K_c \times ET_0$

Parameters:

- Maximum air temperature
- Minimum air temperature
- Relative humidity
- Wind speed
- Solar radiation

Crop Water Stress Index (2018)

IR/t 3x (Thermal sensor) @ QTY 6

Crop Water Stress Index:

$$\text{CWSI} = \frac{\Delta T_m - \Delta T_l}{\Delta T_u - \Delta T_l}$$

- ΔT_m: Measured difference of canopy and air temperature
- ΔT_u: Difference of canopy and air temperature for non-transpiring canopy
- ΔT_l: Difference of canopy and air temperature for well-watered canopy

- Canopy Temperature
- Air temperature
- Relative humidity
- Wind speed
- Solar radiation

Results

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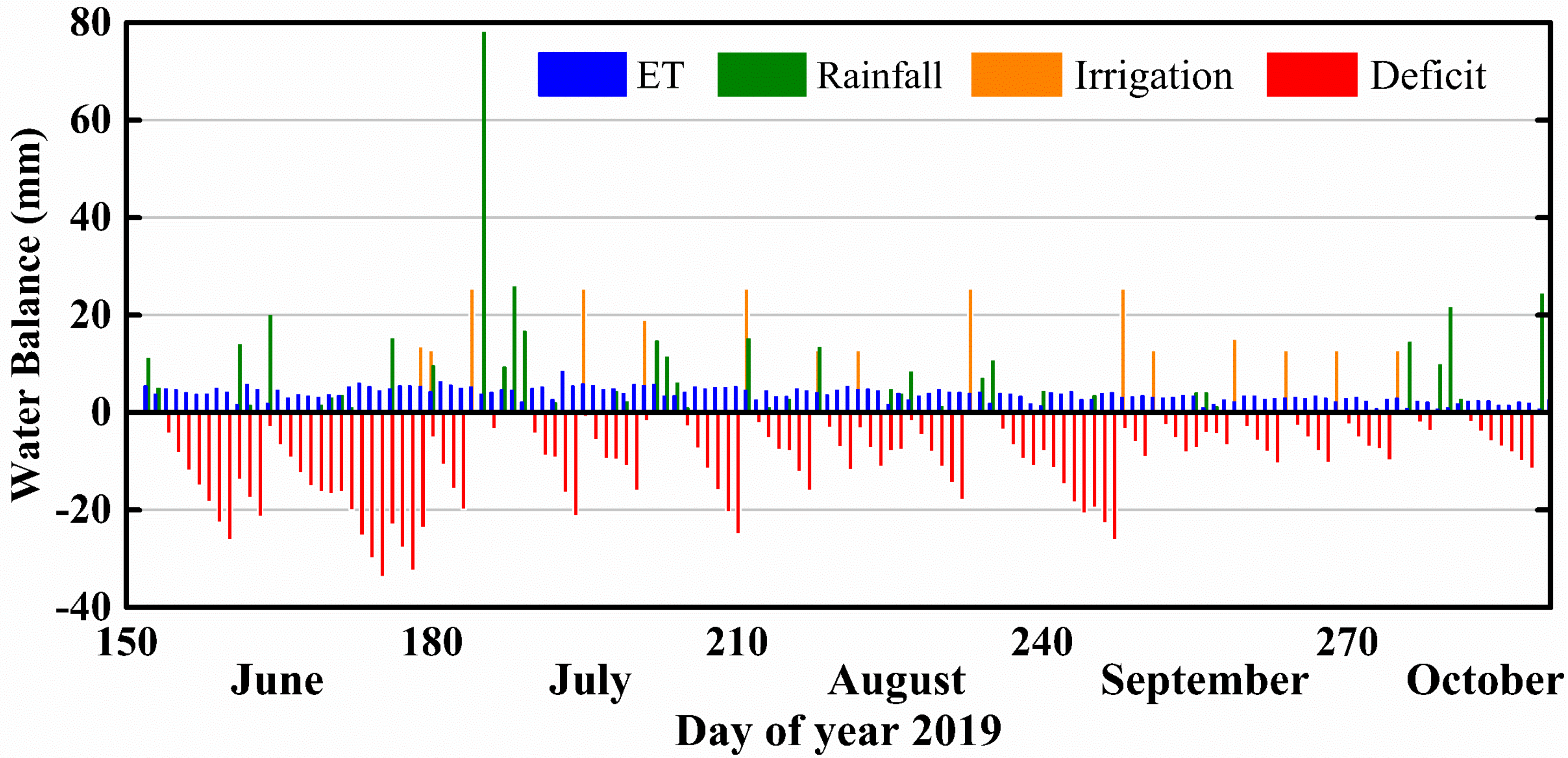
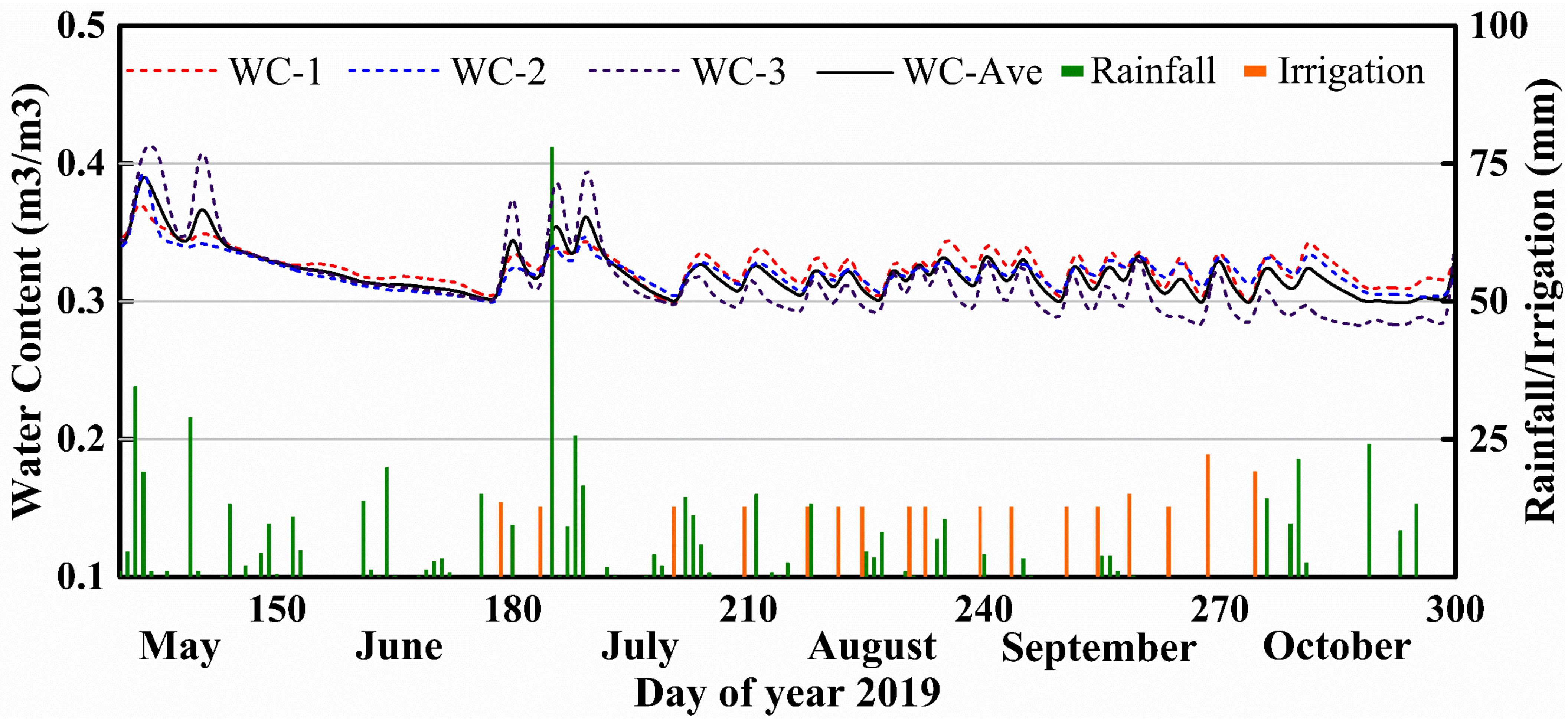
Evapotranspiration (ET)



Results

Soil Water Content



Results

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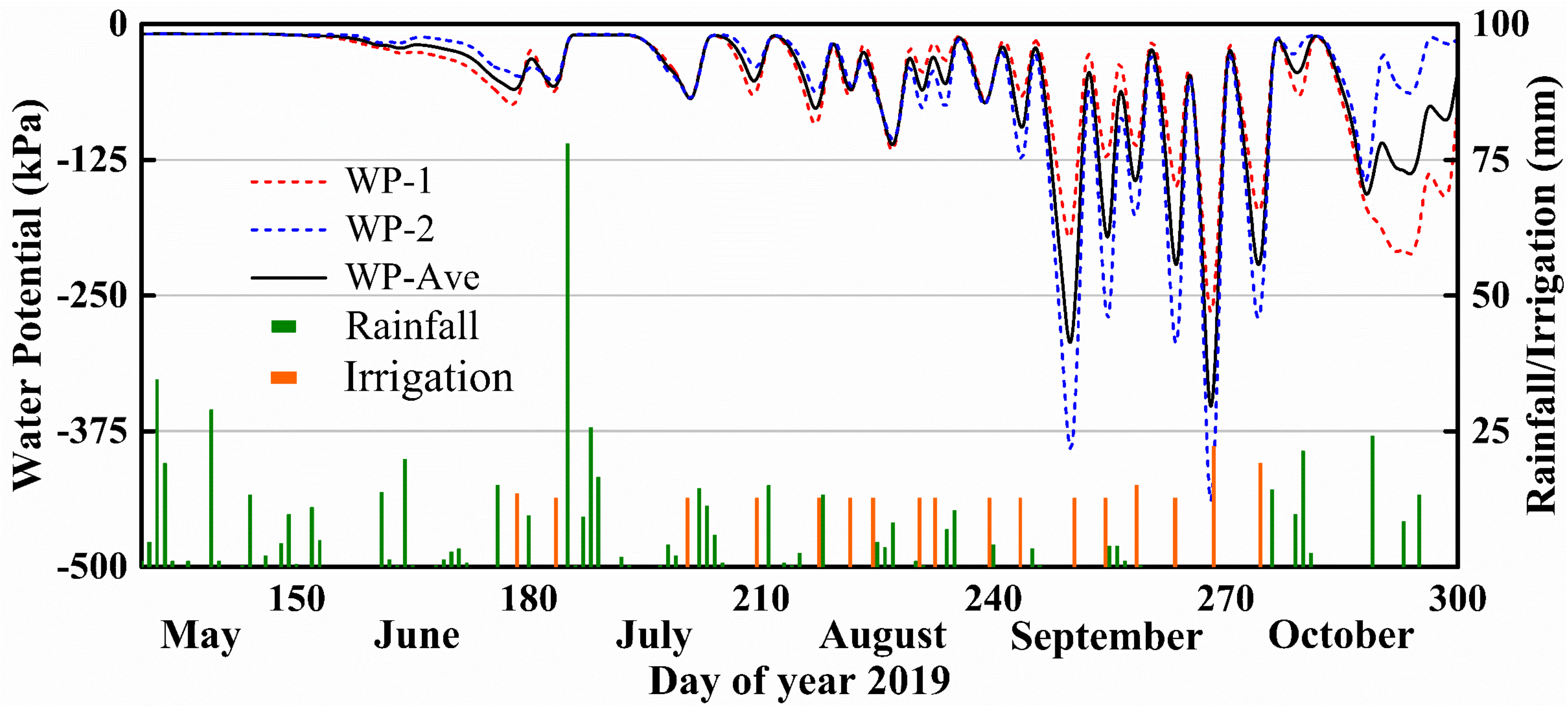
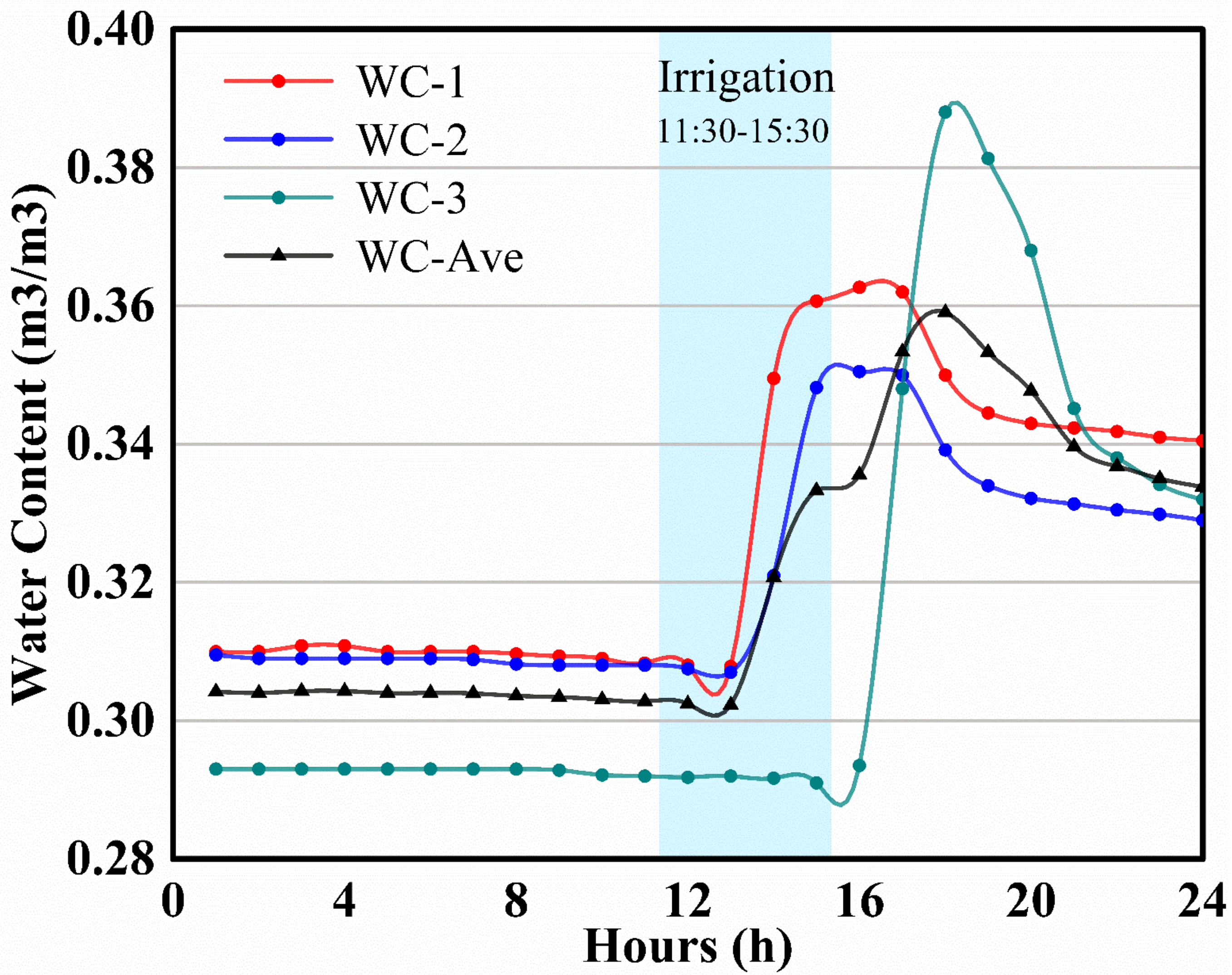
Soil Water Potential



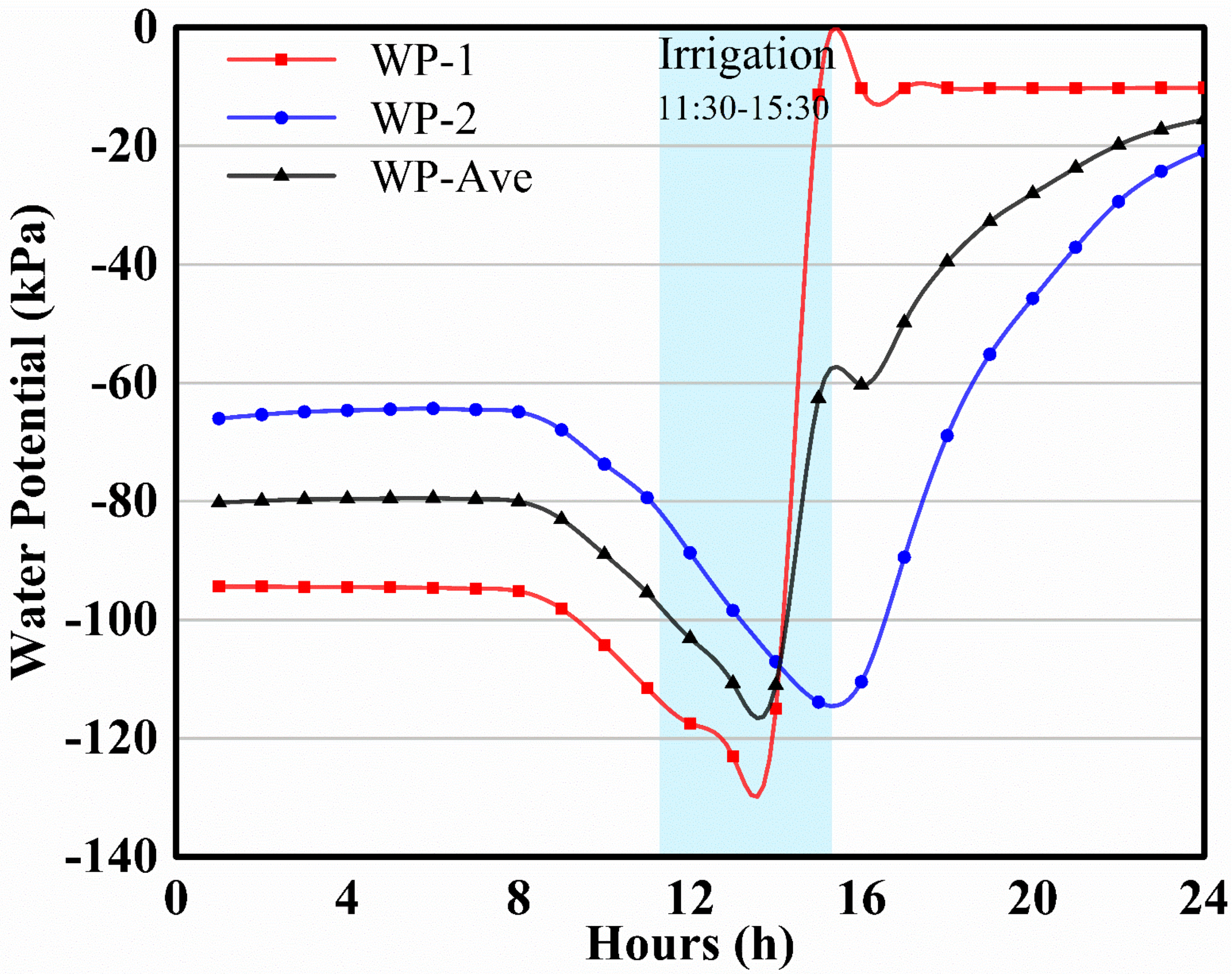
Results

Soil Water Content (Irrigation Event)



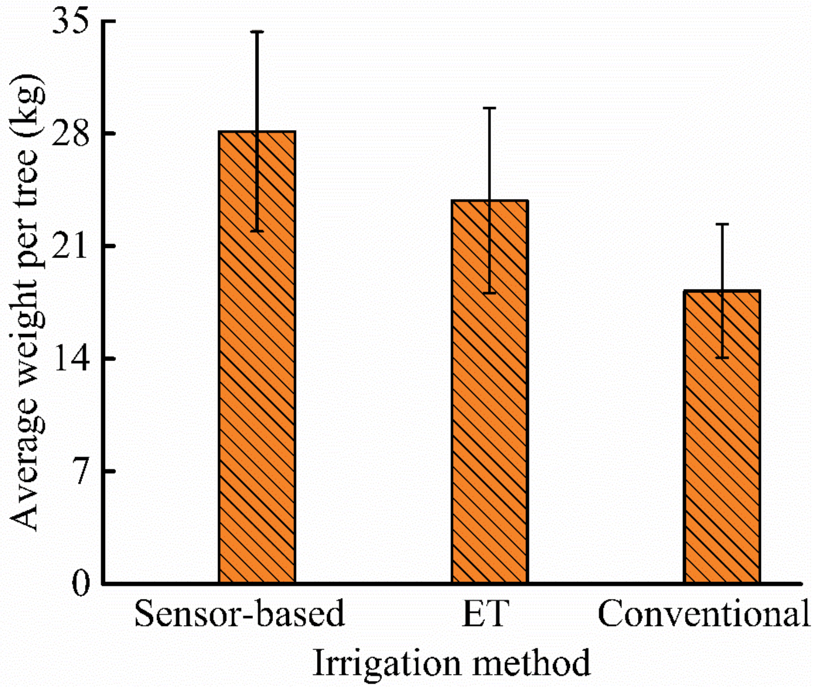
Results

Soil Water Potential (Irrigation Event)

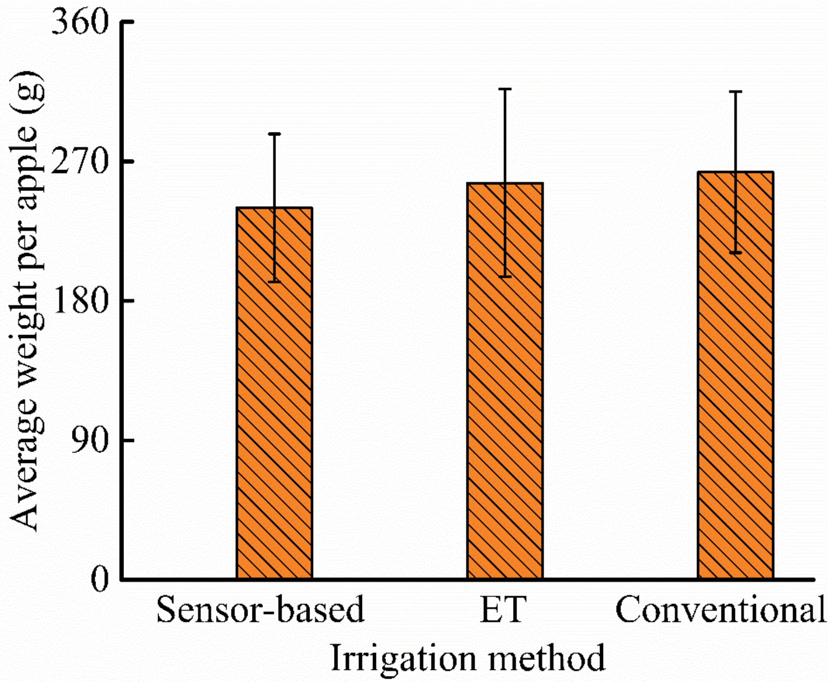


Results

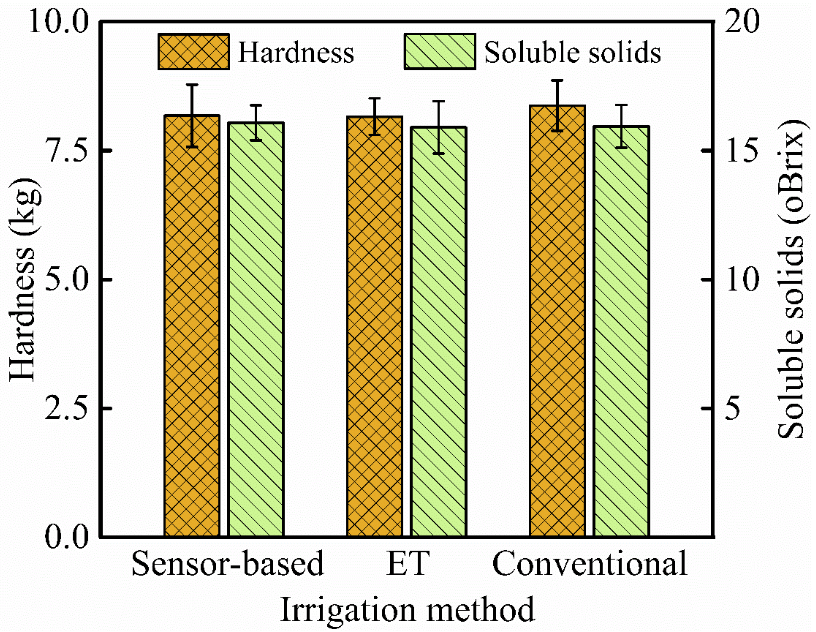
Crop Yield and Fruit Quality Assessment



Average weight per tree



Average weight per apple



Fruit quality assessment

Results

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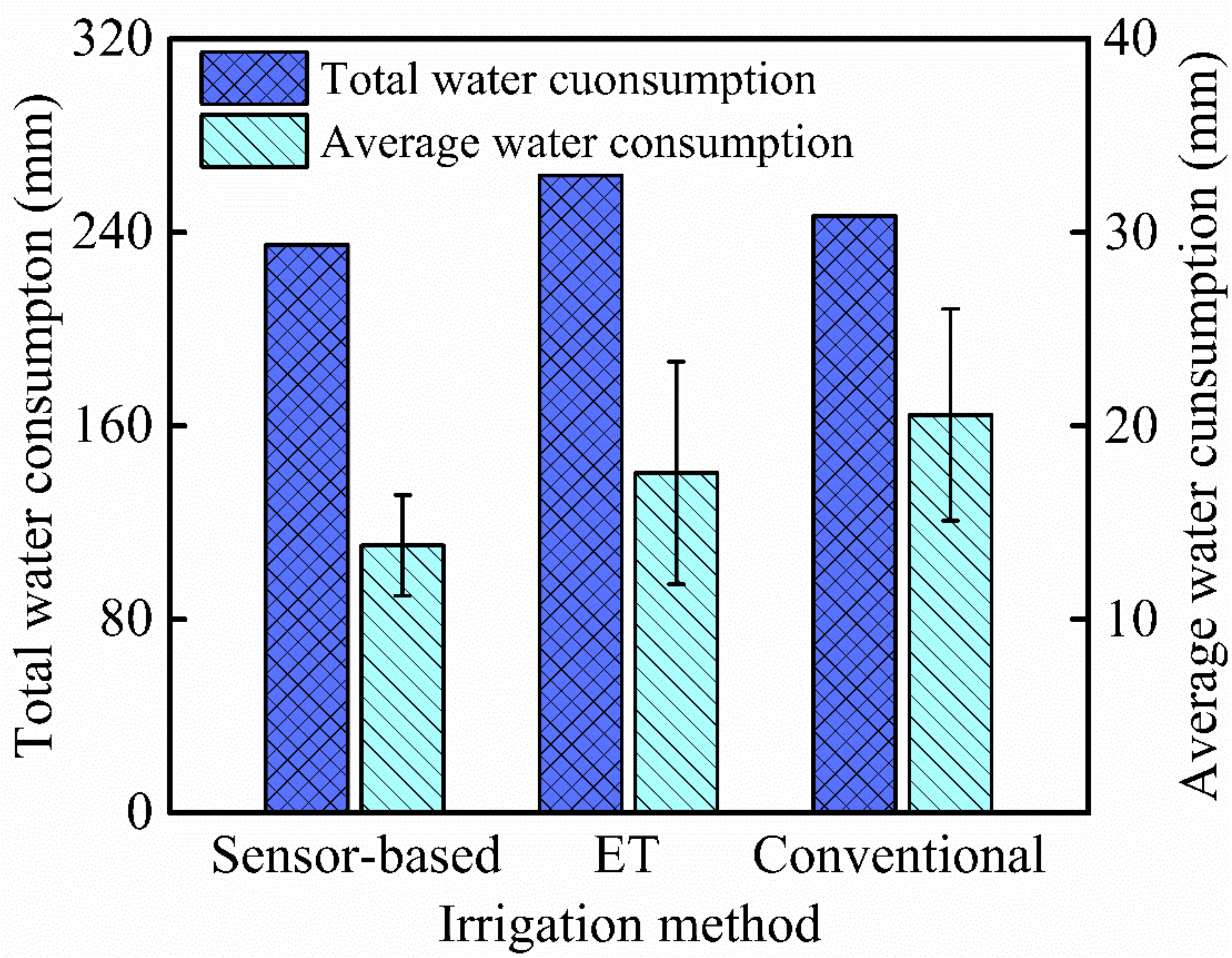
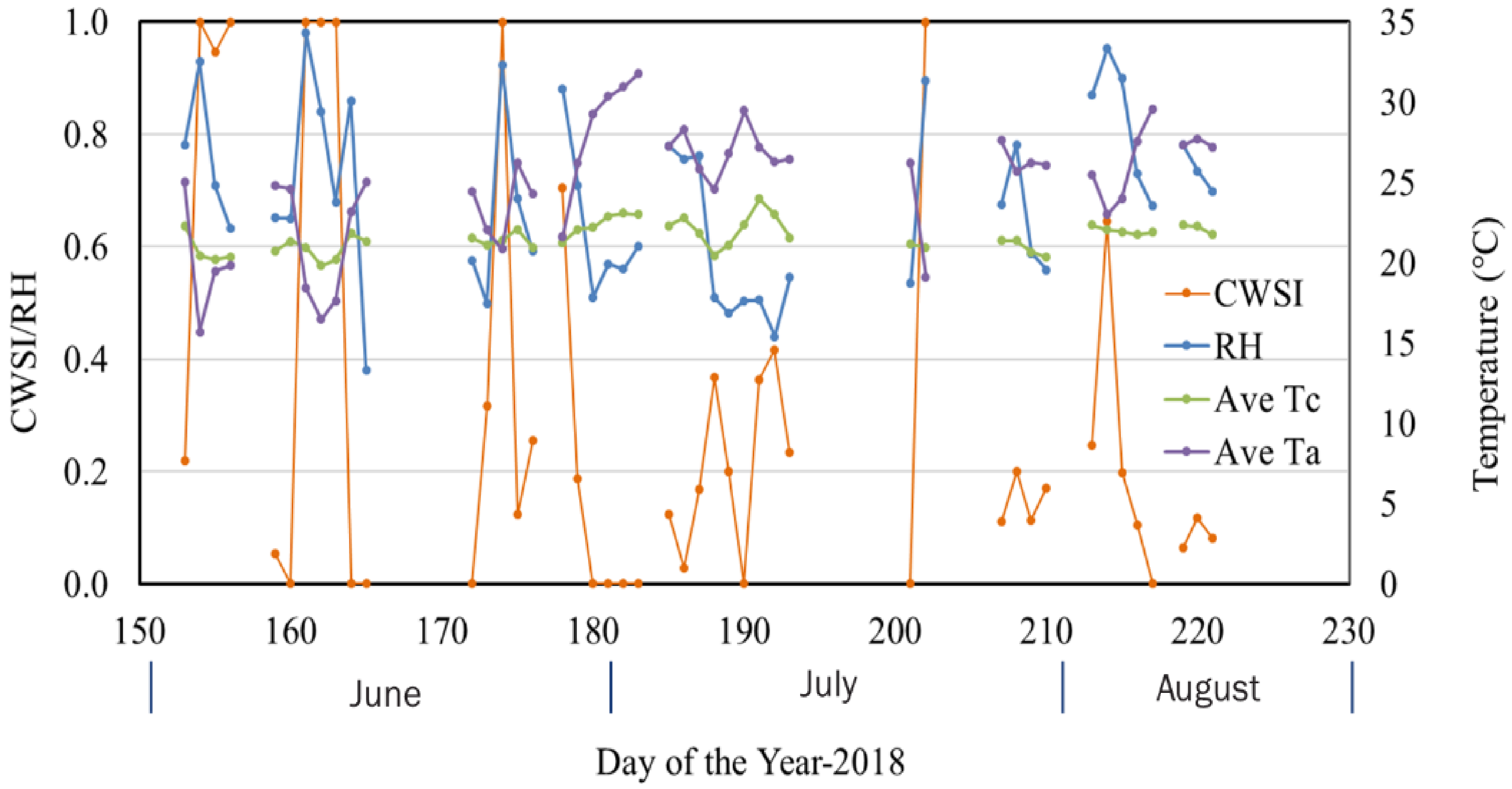
Water Use



Results

Crop Water Stress Index (2018)



Results

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	ET-Based	Soil Moisture-Based	Canopy Temperature-Based	Combination
Advantages	▪ Easy to apply ▪ No in-field sensors ▪ Low cost	▪ Direct reading of soil moisture ▪ Low cost	▪ Direct measuring plant stress ▪ Can be little bit costly	▪ ET + Soil Moisture ▪ Soil moisture + Canopy Temperature
Challenges	▪ Estimated value ▪ Accumulating error ▪ Your own weather station	▪ Root region ▪ Sensor location ▪ Soil type ▪ Real canopy stress	▪ Targeted area of sensor ▪ Climate (too humidity)	

Test in Commercial Orchards

Hollabaugh Bro. Farm
(Honey Crisp)

Mt. Ridge Farm
(Fuji)

Twin Spring Farms
(Crimson Crisp)

El Vista Orchards
(Gala)

Test in Commercial Orchards

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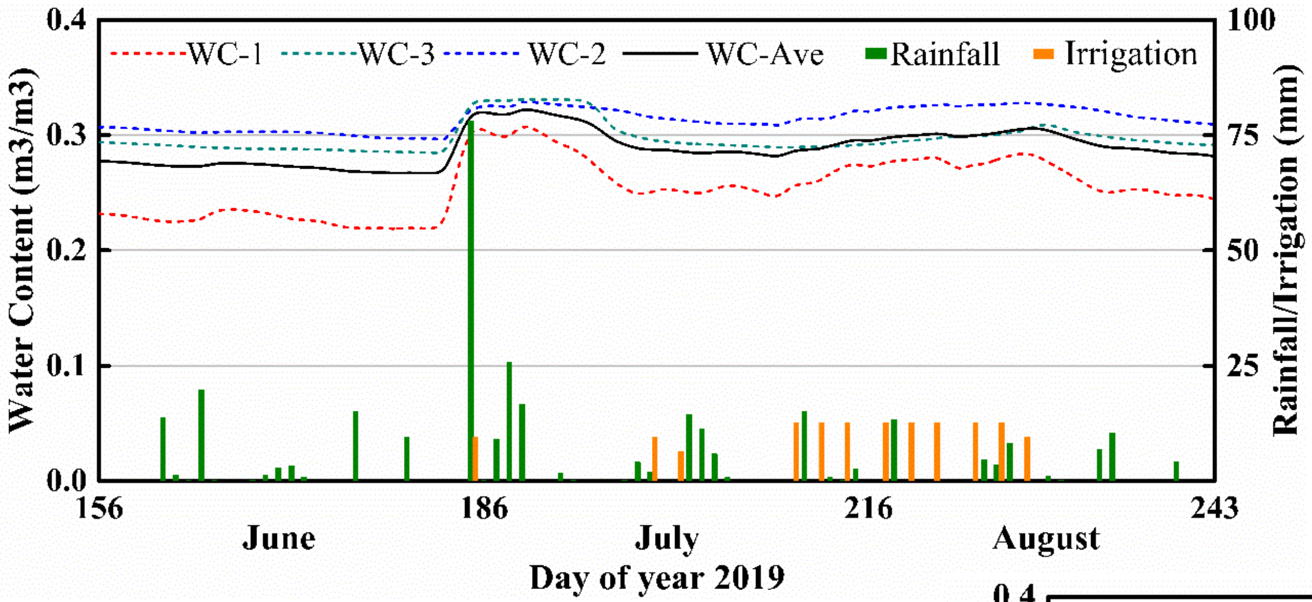
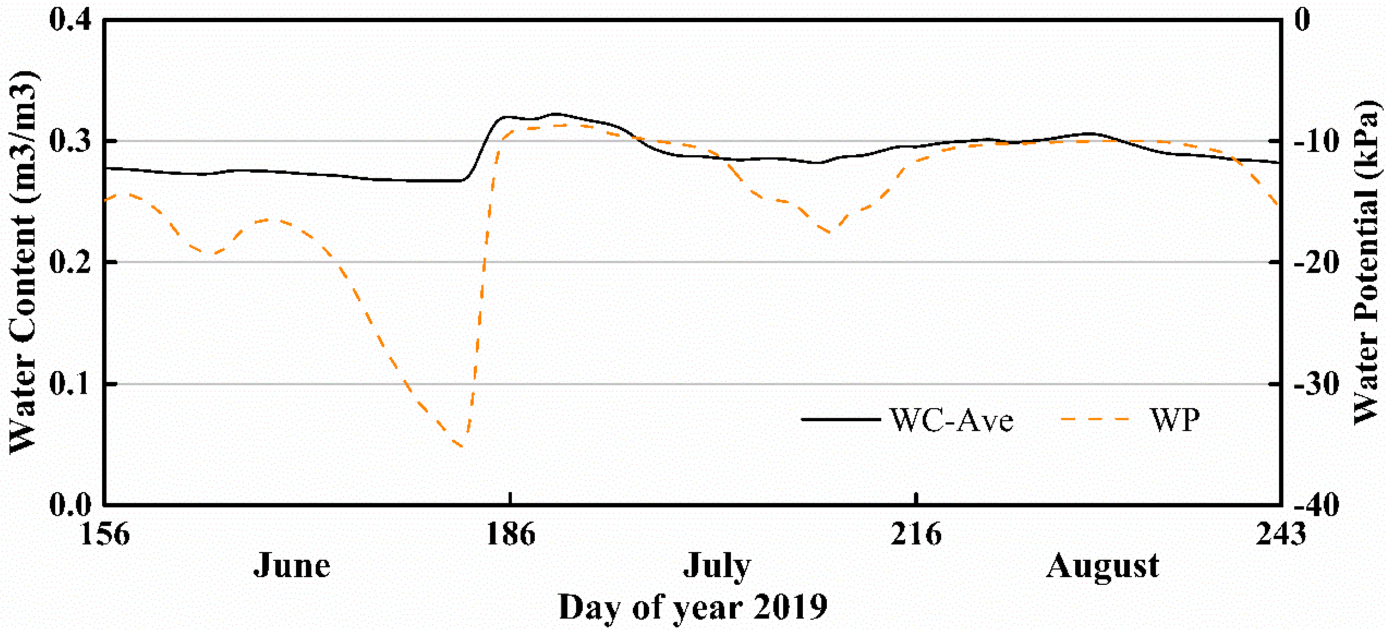


Hollabaugh Bros. Farm



Test in Commercial Orchards

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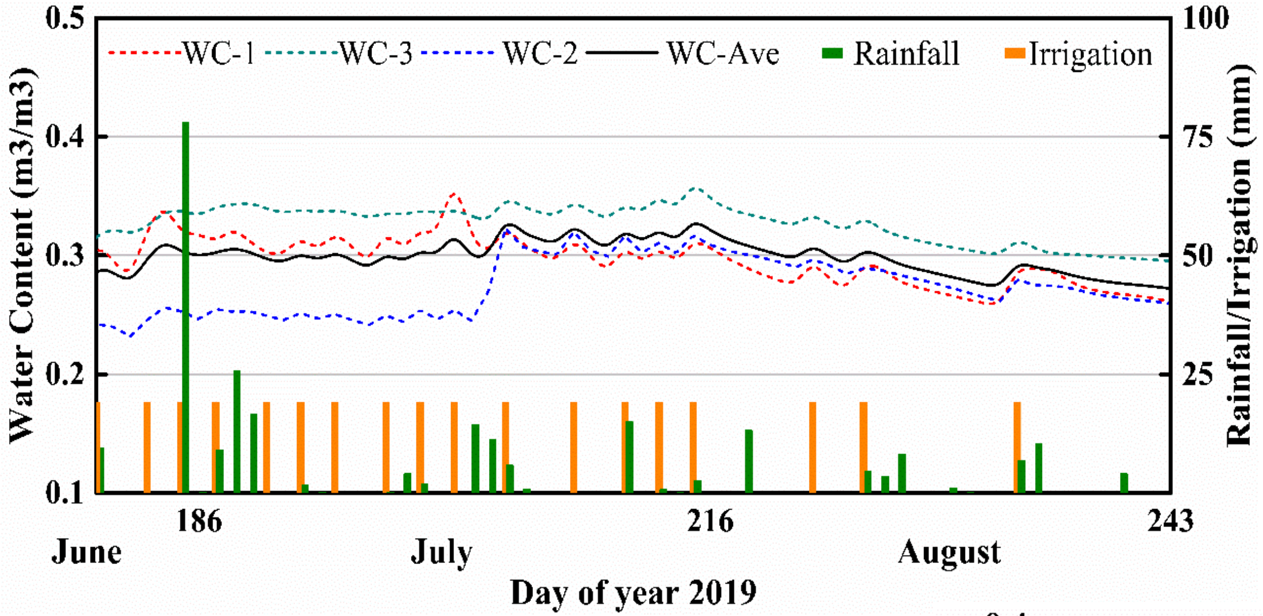
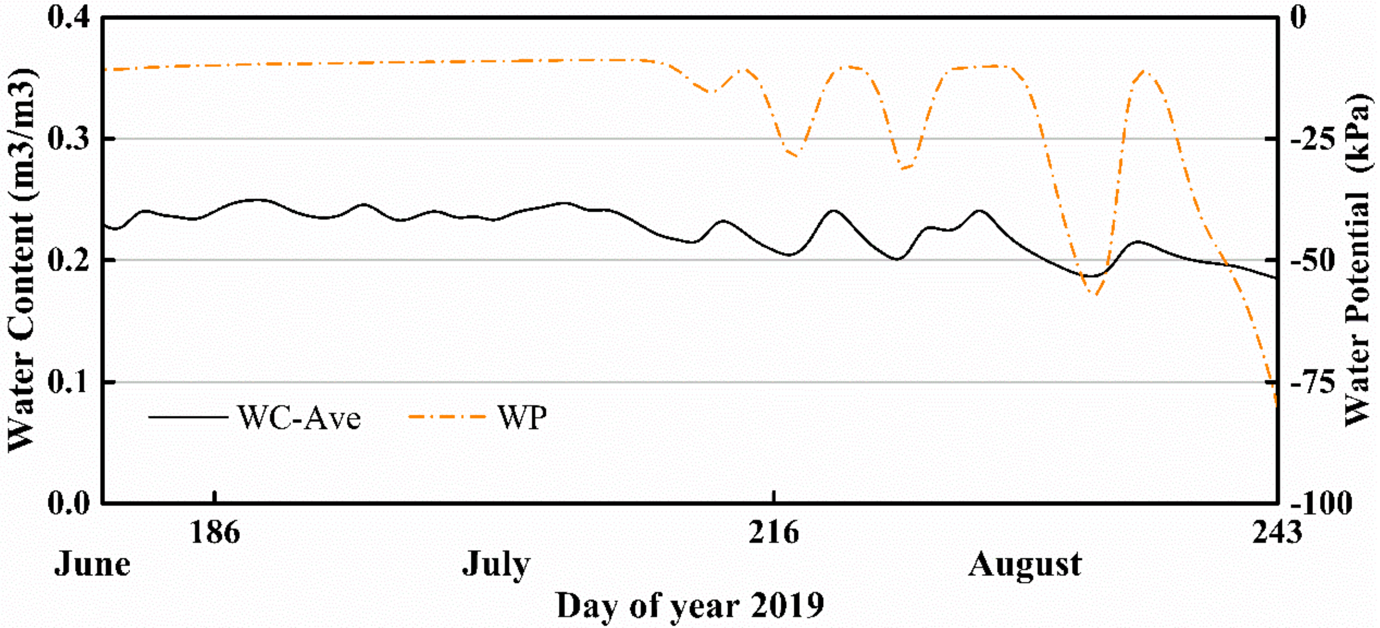


El Vista Orchards



Test in Commercial Orchards

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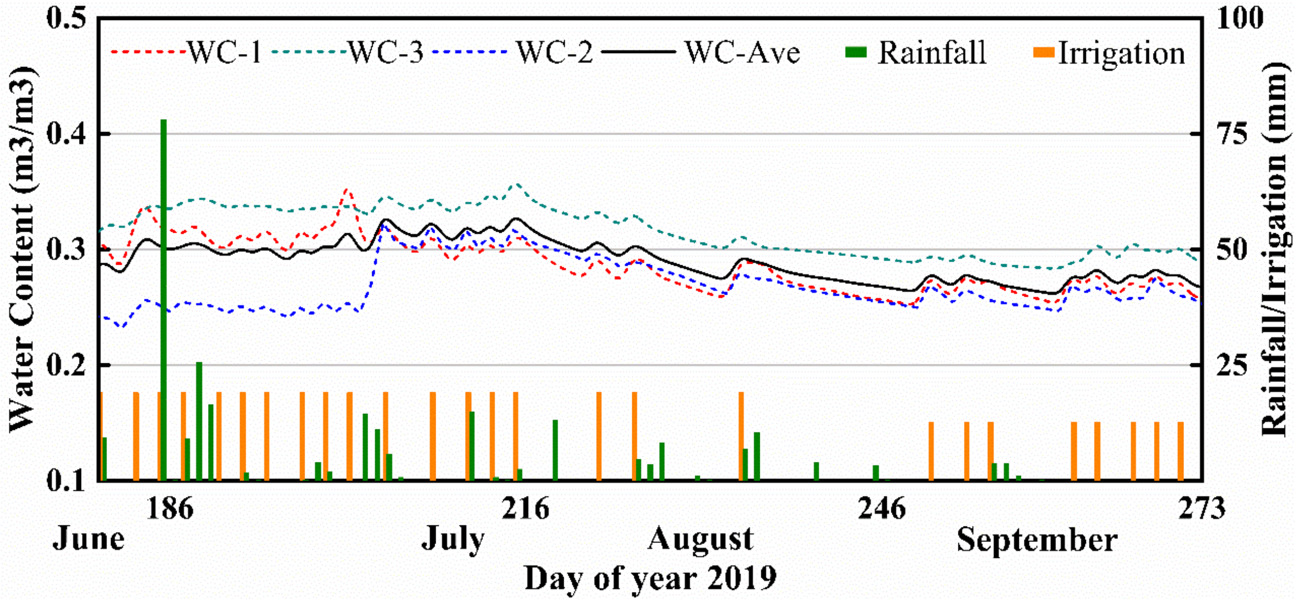
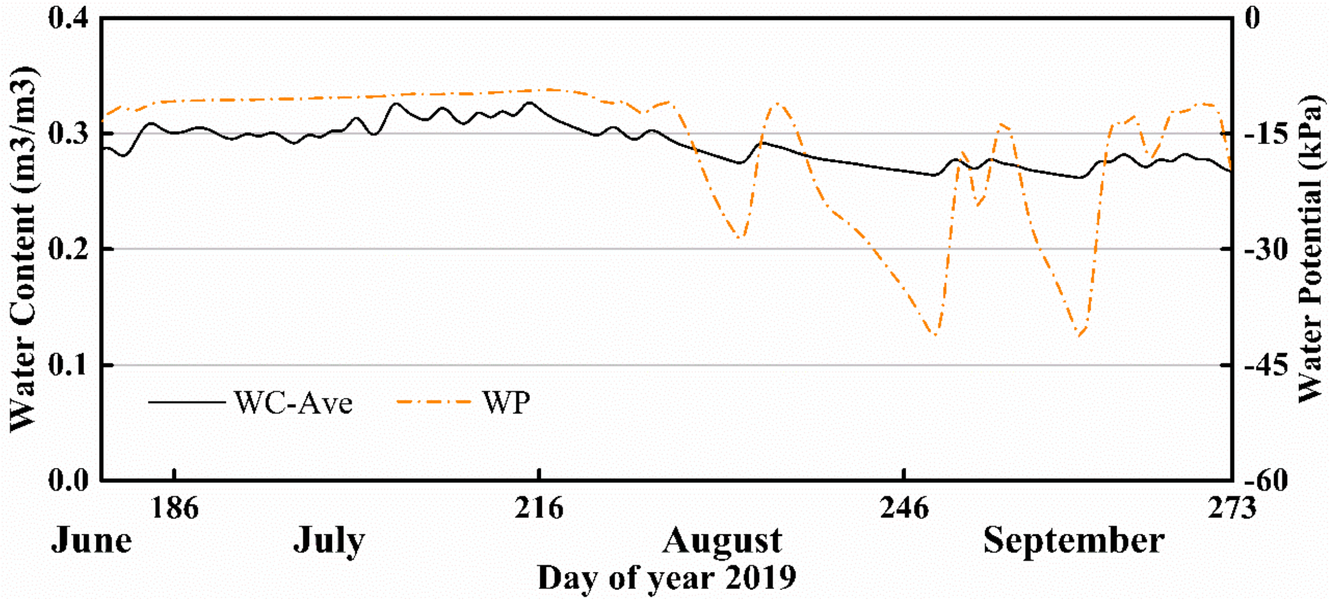


Twin Spring Farms



Test in Commercial Orchards

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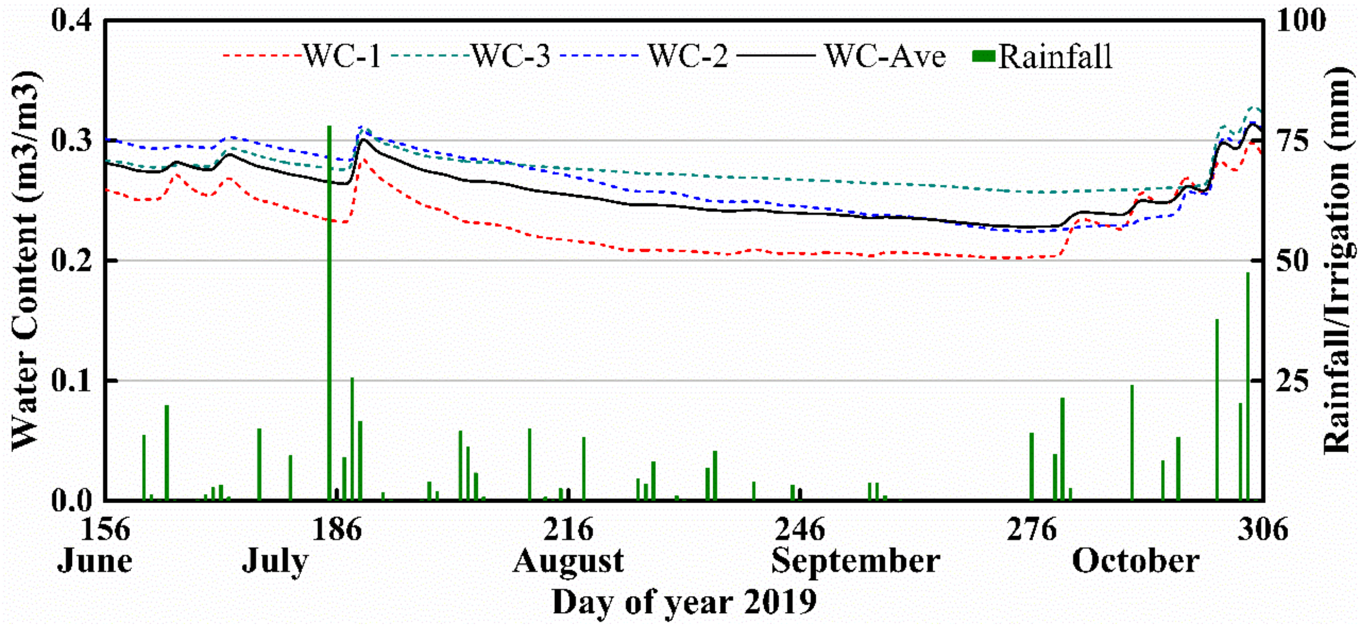
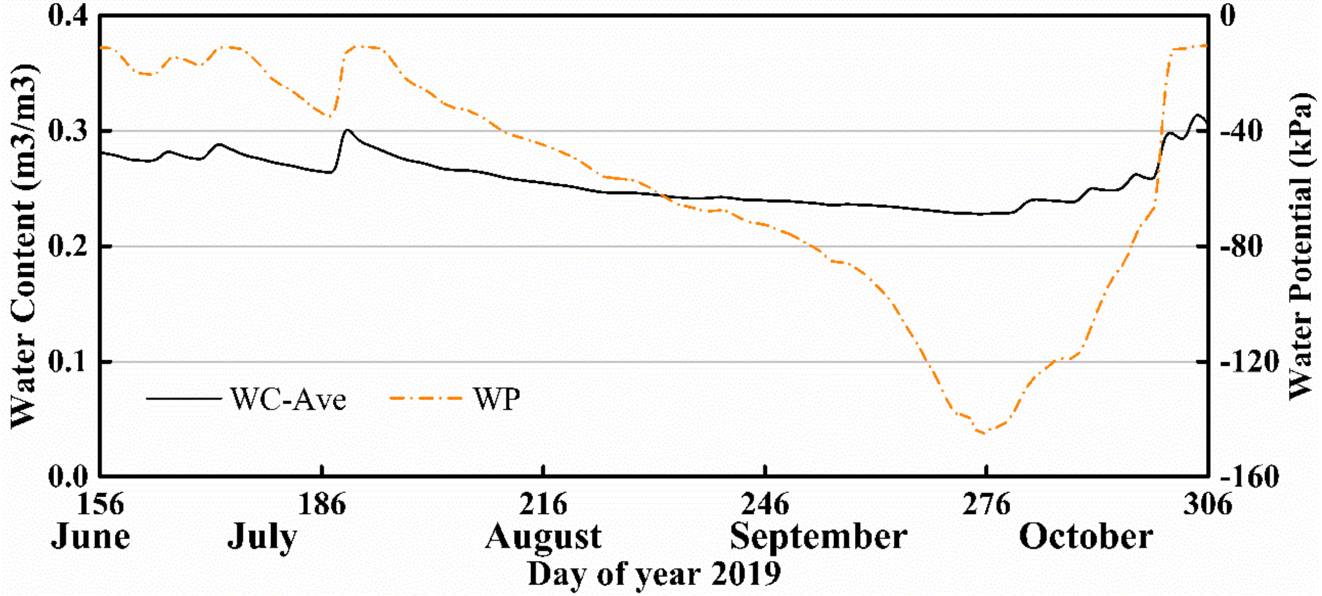


Mt. Ridge Farm



LoRa Based IoT Irrigation

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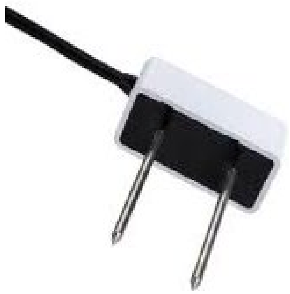
Primary Goal

Investigate an effective Lora-based IoT system for the precision Irrigation management for Specialty Crops.

Soil Moisture Sensor



Datalogger &Gateway

Valve Control

IoT Platform

THE THINGS NETWORK

AllThingsTalk

LoRa Based IoT Irrigation

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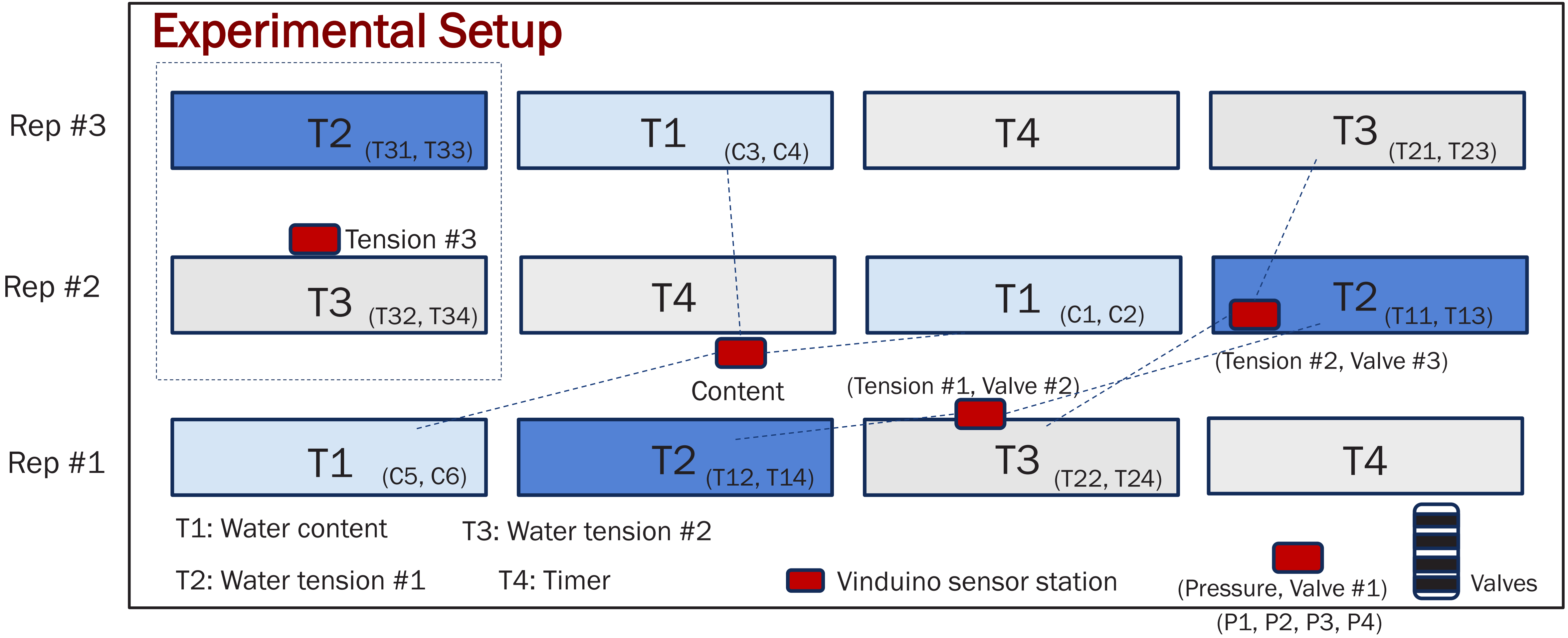
Experimental Setup



Content: C1, C2, C3, C4, C5, C6 are water content sensors, odd numbers are at 15 cm, and even numbers are at 30 cm.
Pressure: P1, P2, P3, P4 are pressure sensors (psi) for treatment T1, T2, T3, T4 respectively. Valve #1 is in this box.
Tension #1: T11, T12, T13, T14 are tension sensors, T11, and T12 are at 15 cm, and T13 and T14 are at 30 cm. Valve #2 is in this box.
Tension #2: T21, T22, TS23, T24 are tension sensors, T21 and T22 are at 15 cm, and T23 and T24 are at 30 cm. Valve #3 is in this box.
Tension #3: T31, T32, T33, T34 are tension sensors, T31 and T32 are at 15 cm, and T33 and T34 are at 30 cm.

LoRa Based IoT Irrigation

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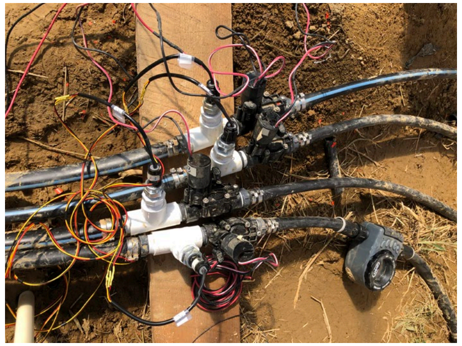

LoRa Based IoT Irrigation

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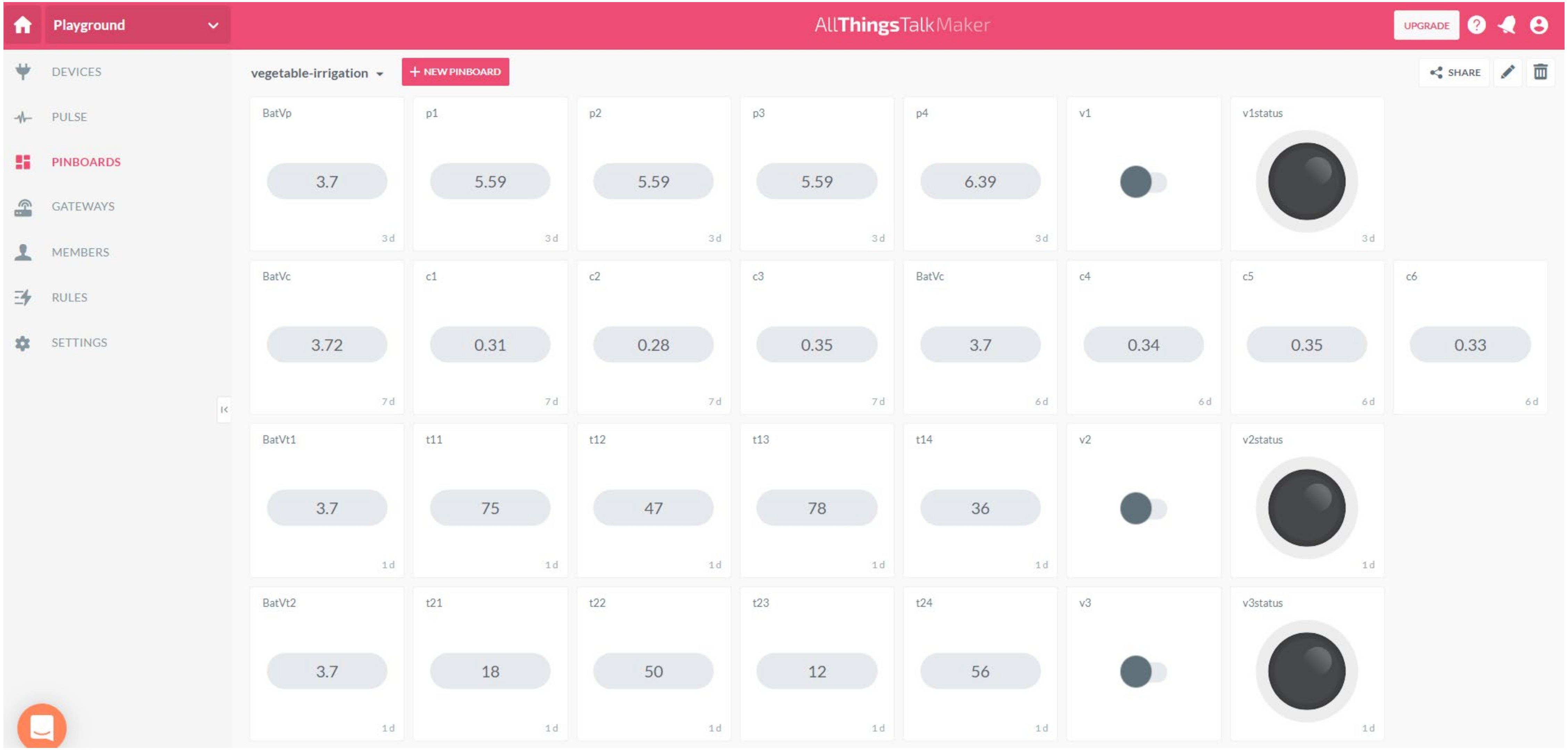
Interface of IoT irrigation System



Future Work

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Basic Studies

- Sensor testing
- Different irrigation strategies
- Soil moisture sensor installation location

IoT-Based Irrigation

- Communication robustness
- Different IoT systems
- Automated Irrigation system

Extension Activities

- Demonstrations & workshops
- Commercial orchard trials
- Orchard/vegetable fields/greenhouse

Acknowledgement

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State Horticultural Association of Pennsylvania (SHAP)

Project Personnel:

PIs: Long He, Francesco Di Gioia, Daniel Weber
Students: Xiaohu Jiang, Haozhe Zhang

Thank you!