

# *Precision Irrigation Technologies for Specialty Crops*

## **Long He**

**2020 Mid-Atlantic Fruit and Vegetable Convention**

**Hershey, Pennsylvania, United State**

**January 29th, 2020**



**PennState**  
College of Agricultural Sciences



**PennState Extension**

# Importance of Precision Irrigation

## Challenges for Conventional Method:

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

## Precision Irrigation:

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

## Benefit of Precision Irrigation:

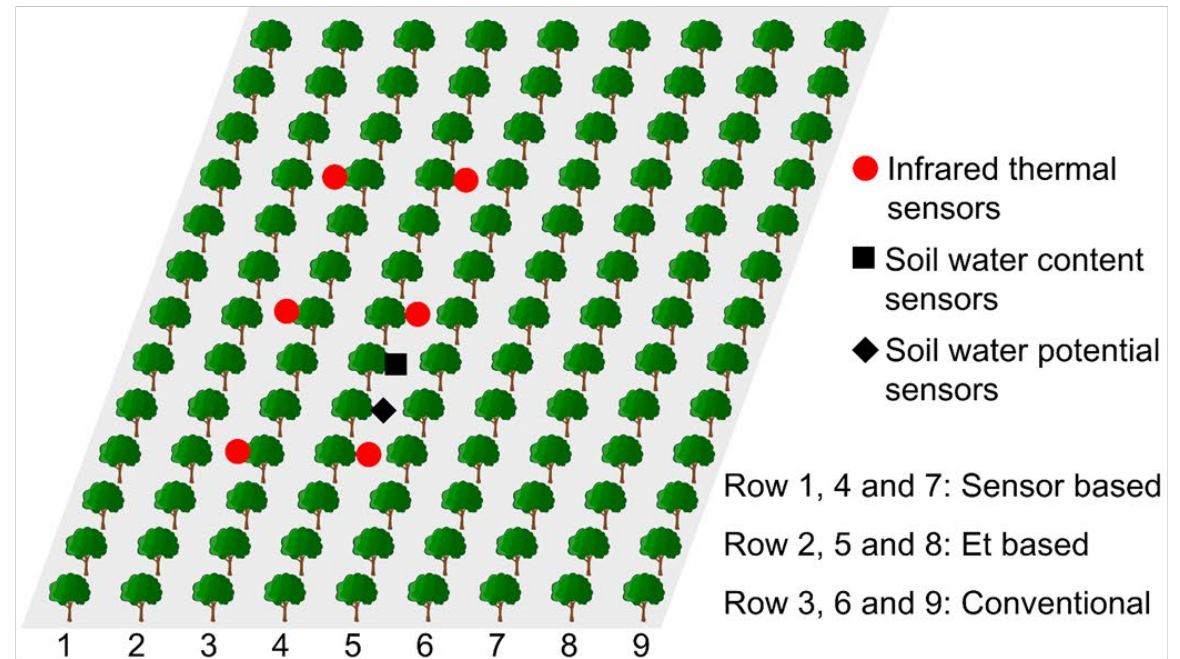
- ❖ Improve crop yield and quality
- ❖ Conserve water and save energy
- ❖ Reduce nutrient leaching and environmental impact



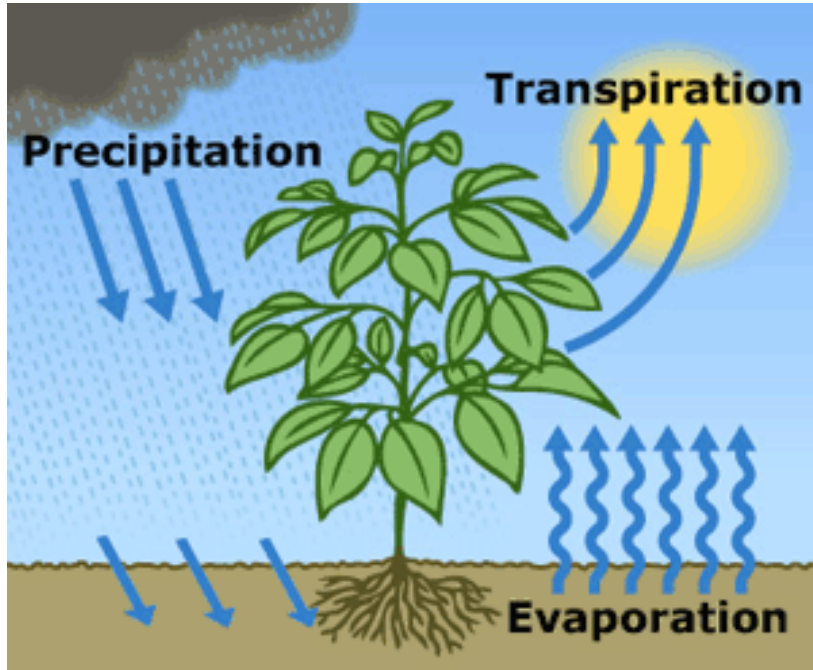
## Primary Goal

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

## Experimental Setup



## Evapotranspiration (ET)



### Penman-Monteith Model (P-M)

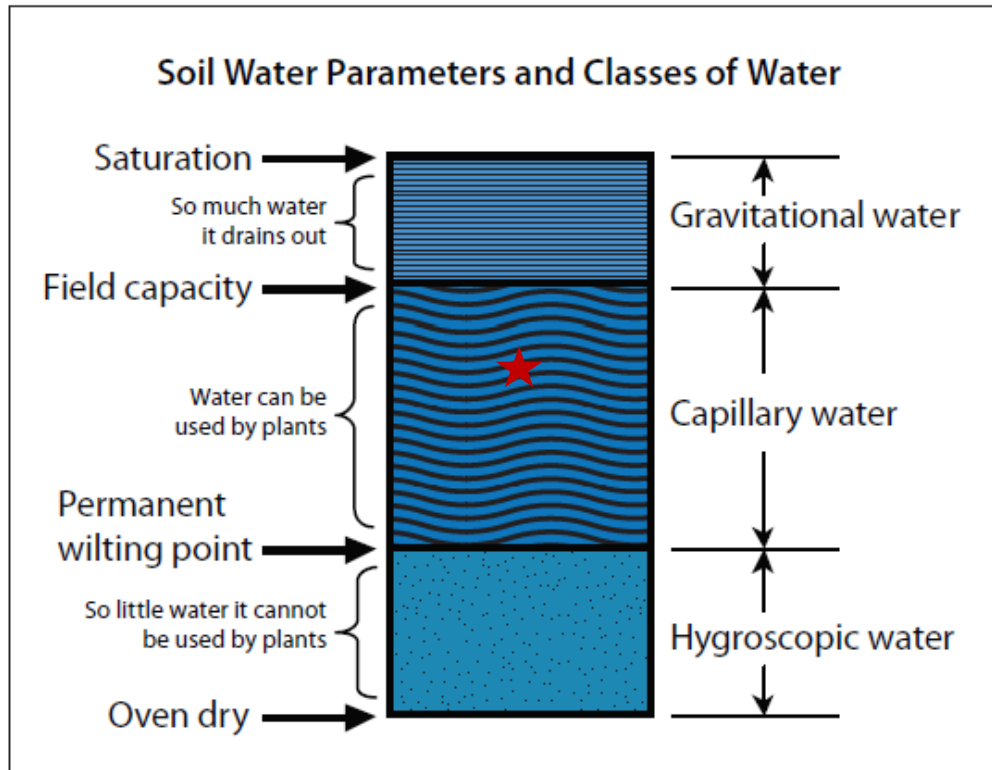
- Reference  $ET_0$
- Estimated  $ET = K_c \times ET_0$

#### Parameters:

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

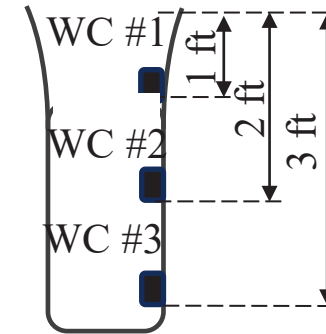
When  $\text{Transpiration} + \text{Evaporation} > \text{Precipitation}$ ,  
**Irrigation** is needed.

## Fundamental Principles

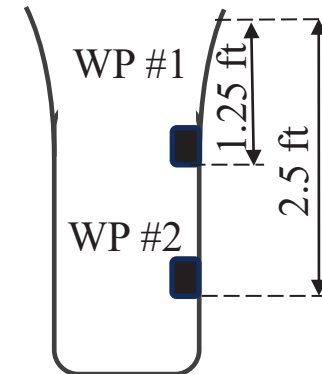


Soil Water Parameters (From: Texas A&M AgriLife Extension, E-618)

## Soil Moisture Sensors



Soil water content sensor: TEROS 12 @ QTY 3



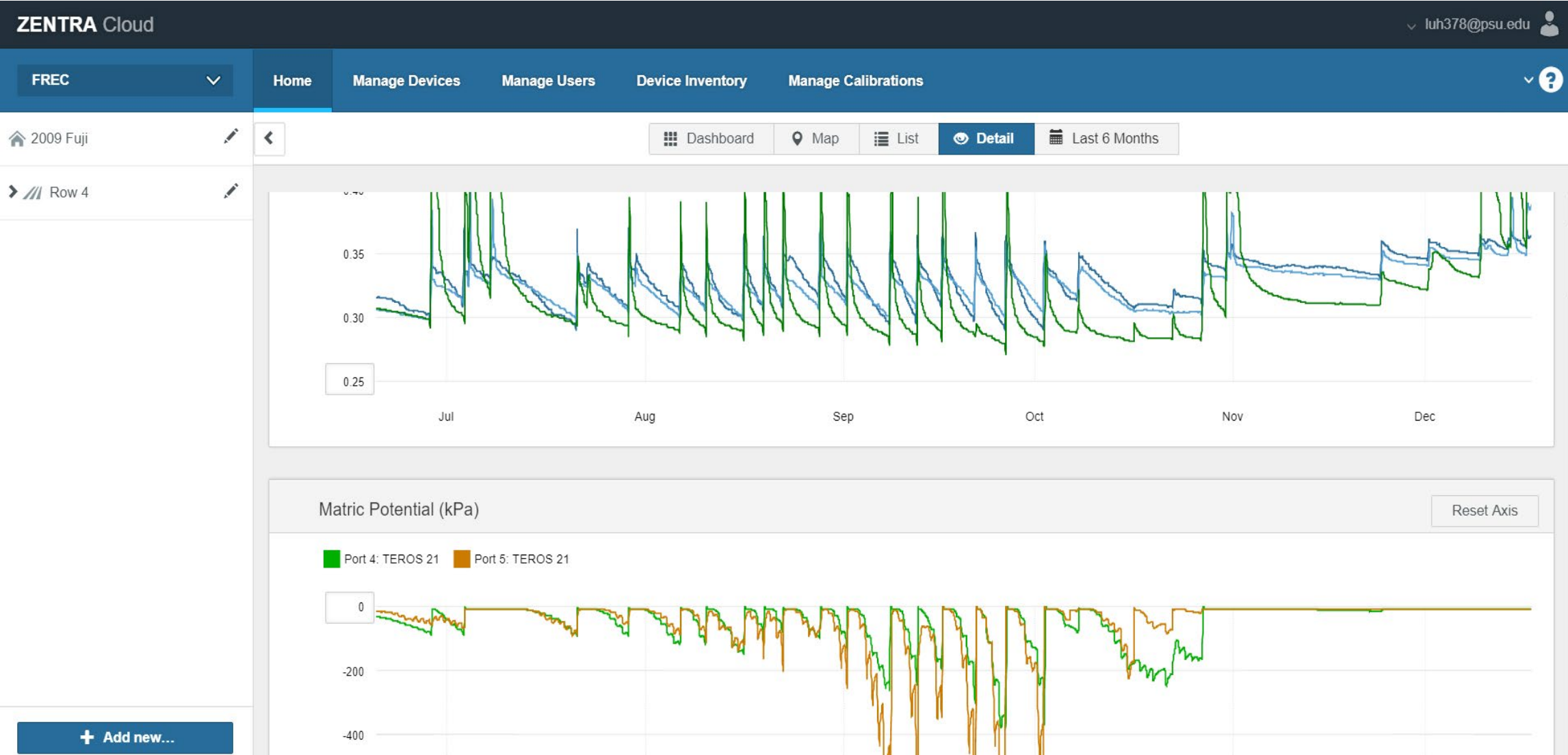
Soil water potential sensor: TEROS 21 @ QTY 2

## Sensor System Setup



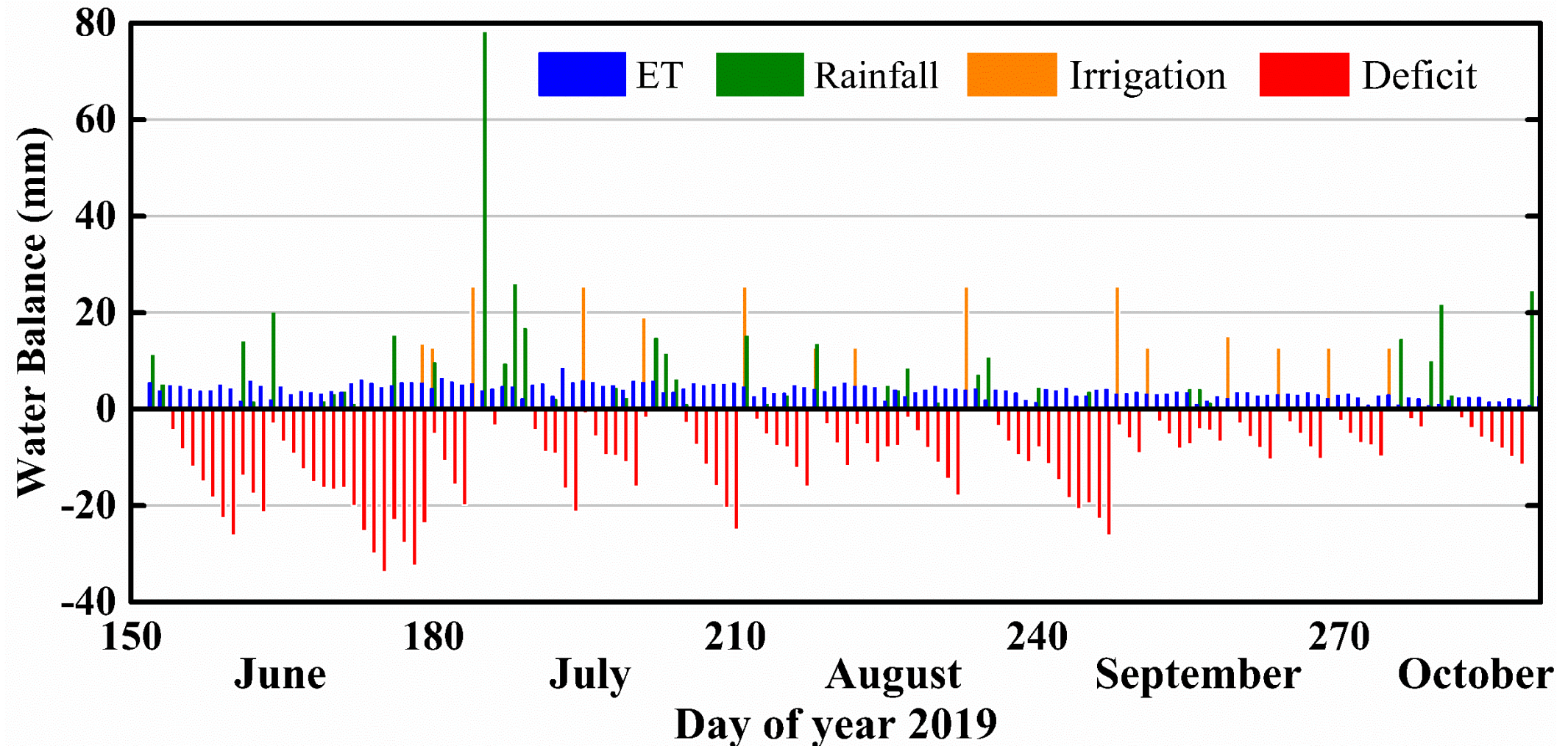
- Soil water content and Potential sensors
- Datalogger to record sensor data
- Cellular network for data communication (cloud server)

## Soil Moisture Sensor Data Recording



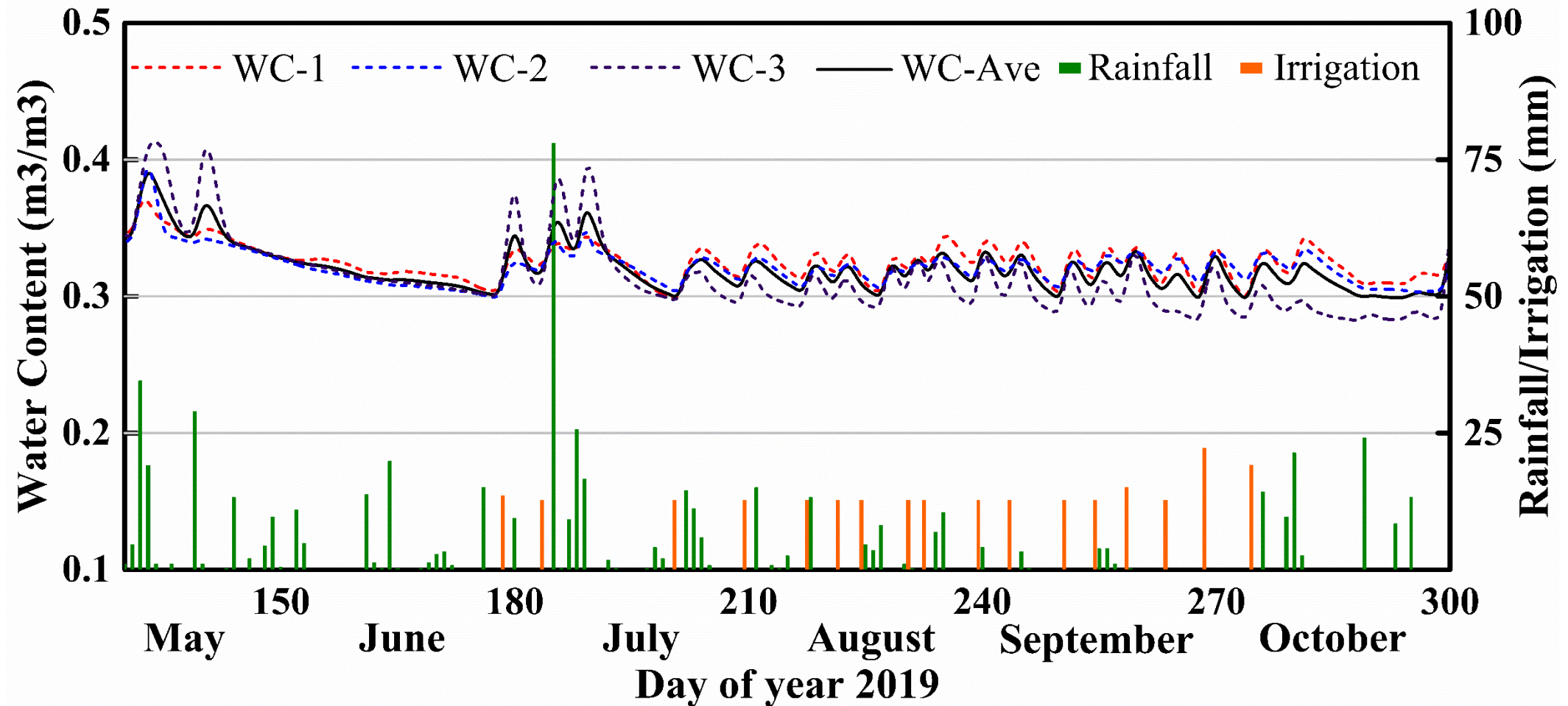
# Results – Irrigation Strategies

## Evapotranspiration (ET)



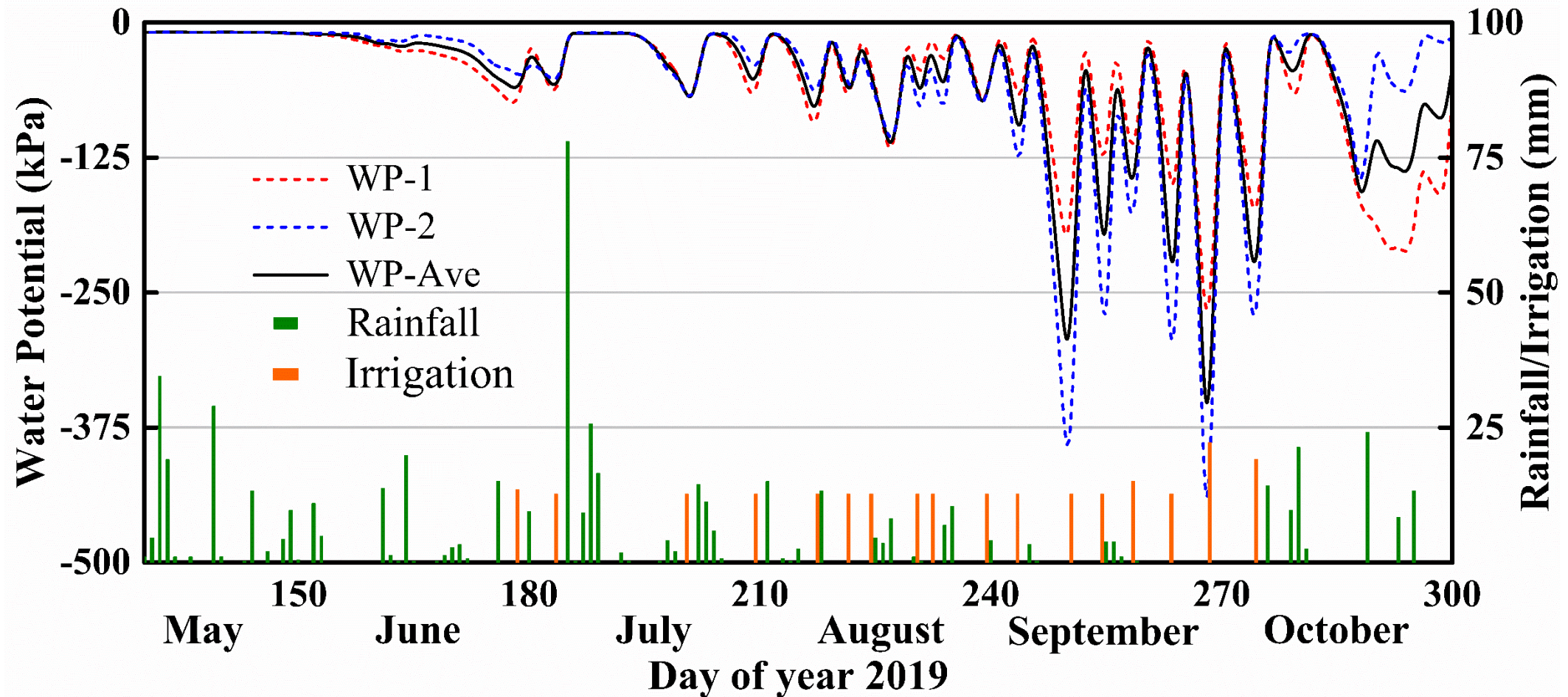


## Soil Water Content

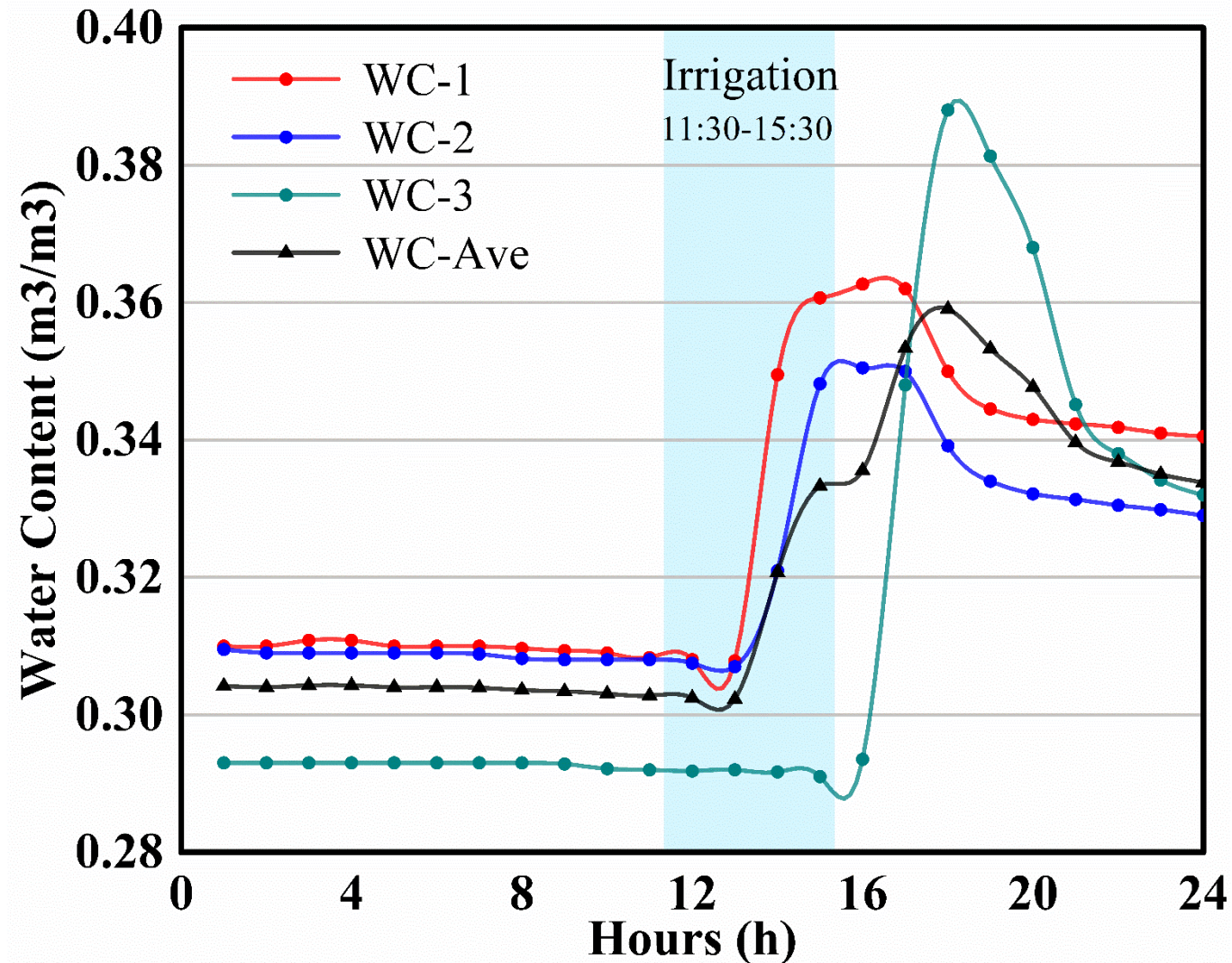


# Results – Irrigation Strategies

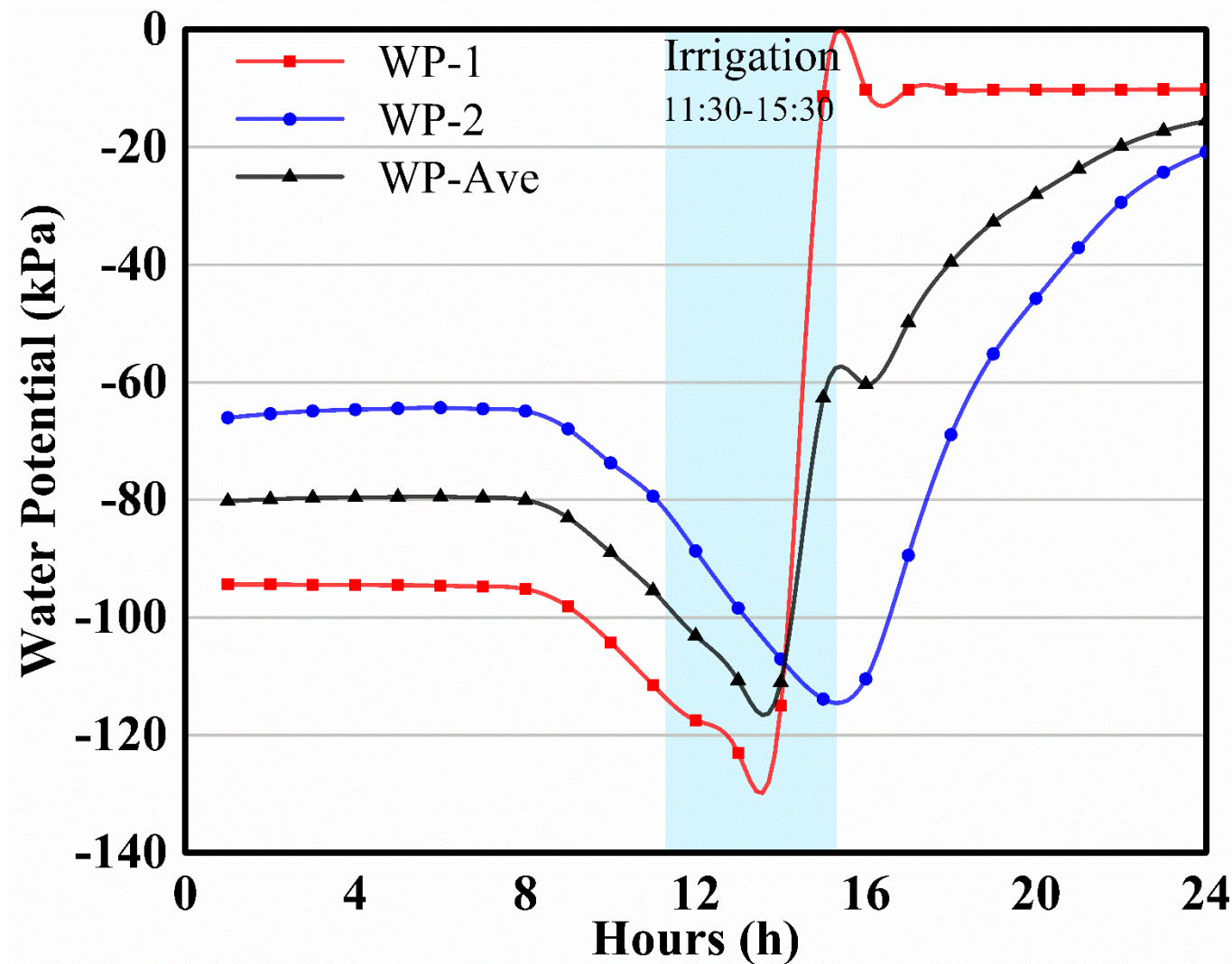
## Soil Water Potential



## Soil Water Content (Irrigation Event)



## Soil Water Potential (Irrigation Event)



## Water Use, Crop Yield and Quality

<b>Irrigation strategies</b>	<b>Overall water use (inch)</b>	<b>Crop yield/tree (kg)</b>	<b>Crop size (g)</b>	<b>Hardness (Kg)</b>	<b>Soluble solids (Brix)</b>
Sensor-based	8.7	28.2	247	8.0	16.1
ET	11	23.1	260	7.9	16.0
Conventional	9.2	18.8	265	8.2	16.0

- Soil moisture based irrigation consumed the least water
- Soil moisture based irrigation had a slight higher yield
- Fruit quality in terms of size, hardness and brix is similar

# Discussion and Recommendation

	ET-Based	Soil Moisture-Based	Conventional
Advantages	<ul style="list-style-type: none"><li>▪ Easy to apply</li><li>▪ No in-field sensors</li><li>▪ Low cost</li></ul>	<ul style="list-style-type: none"><li>▪ Direct reading of soil moisture</li><li>▪ Low-mid cost</li></ul>	<ul style="list-style-type: none"><li>▪ No equipment needed</li></ul>
Challenges	<ul style="list-style-type: none"><li>▪ Estimated value</li><li>▪ Accumulating error</li><li>▪ Your own weather station</li></ul>	<ul style="list-style-type: none"><li>▪ Root region</li><li>▪ Sensor location</li><li>▪ Soil type</li></ul>	<ul style="list-style-type: none"><li>▪ Risk of over or under irrigation</li><li>▪ Varies among operators</li></ul>

# Test in Commercial Orchards



Hollabaugh Bro. Inc  
(Honey Crisp)



Mt. Ridge Farms  
(Fuji)

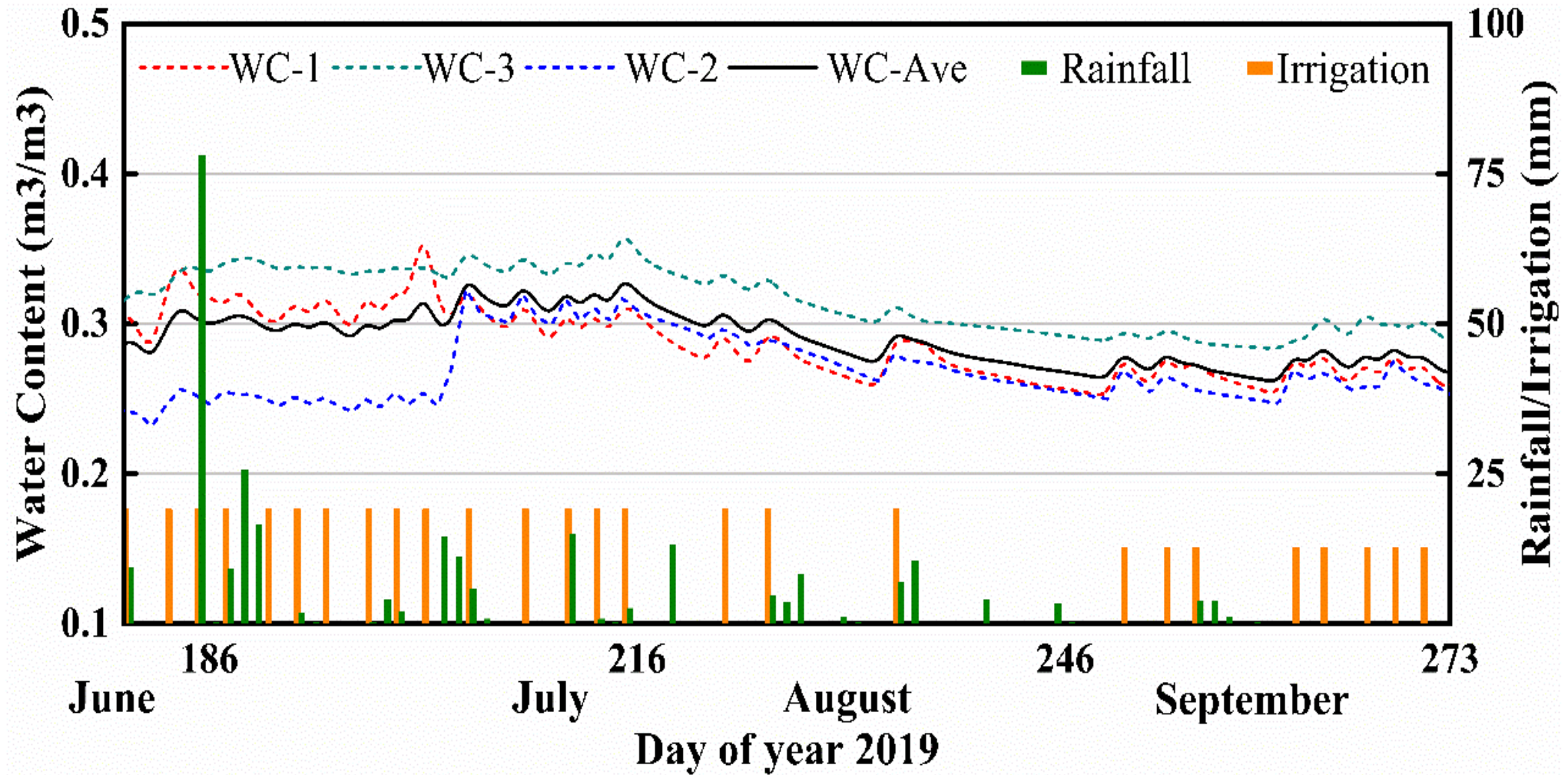


Twin Springs Fruit Farm  
(Crimson Crisp)



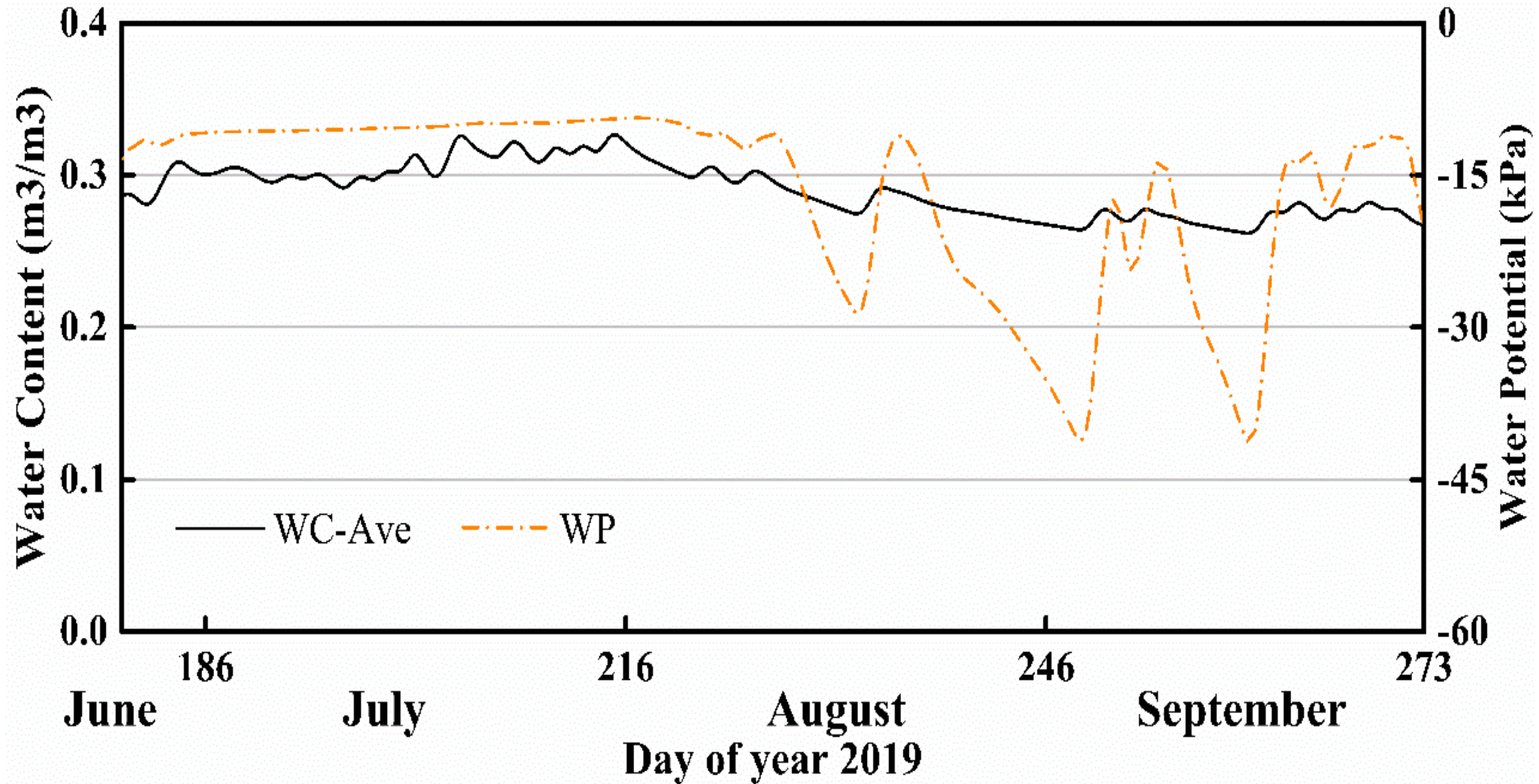
El Vista Orchards  
(Gala)

# Test in Commercial Orchards





# Test in Commercial Orchards



## IoT Fundamental

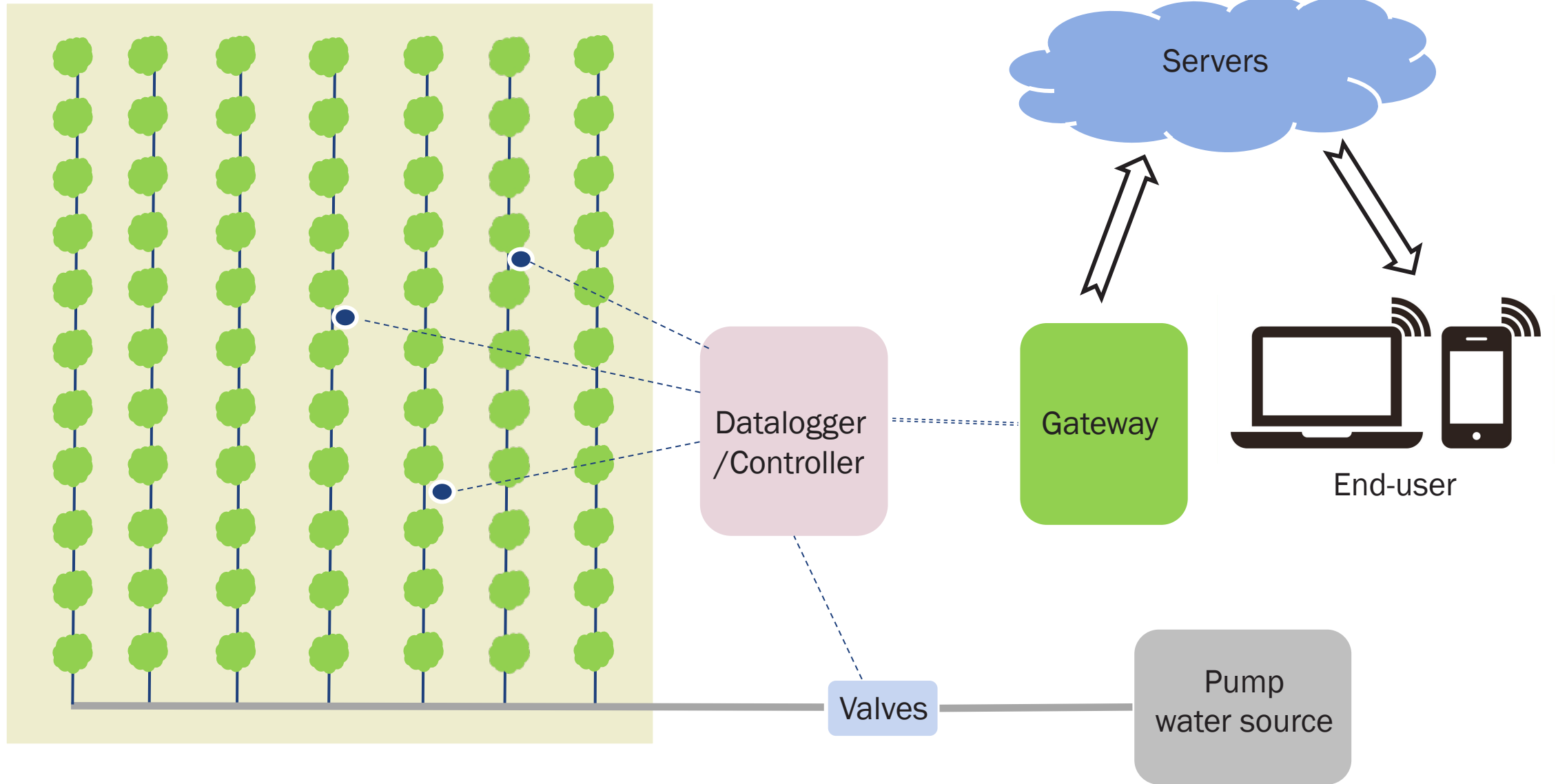
Internet of things (IoT) is the interconnection through the internet of computing devices embedded in everyday objects.



## 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



# LoRa Based IoT Irrigation

## Primary Goal

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

### Soil Moisture Sensor



### Datalogger & Gateway



### Valve Control



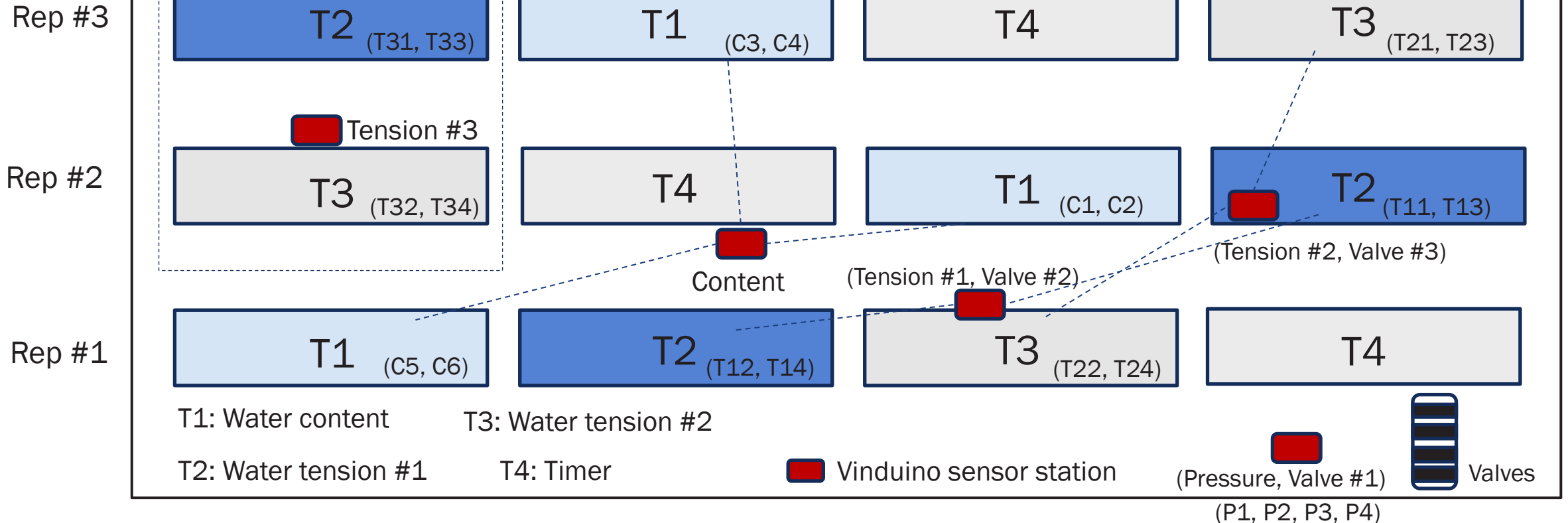
### IoT Platform



AllThingsTalk

# LoRa Based IoT Irrigation

## 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.

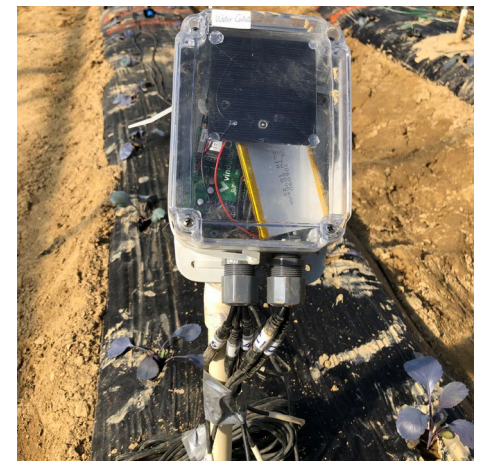
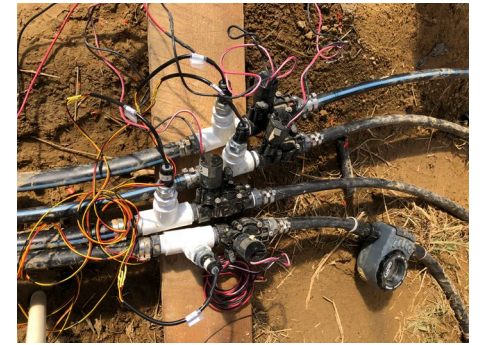
**Pressure:** P1, P2, P3, P4 are pressure sensors (psi) for treatment T1, T2, T3, T4 respectively. Valve #1 is in this box.

**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.

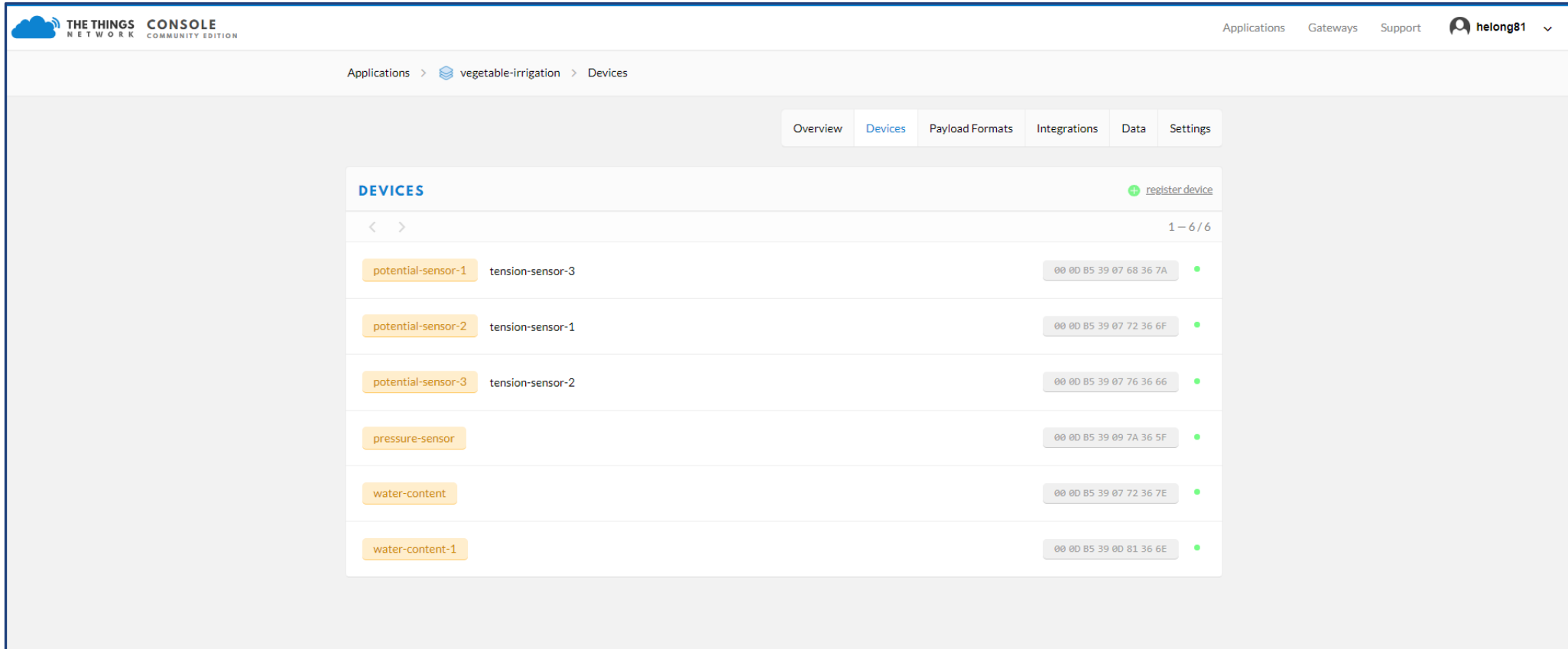
**Tension #2:** T21, T22, T23, T24 are tension sensors, T21 and T22 are at 15 cm, and T23 and T24 are at 30 cm. Valve #3 is in this box.

**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



## Wireless Communication Configuration



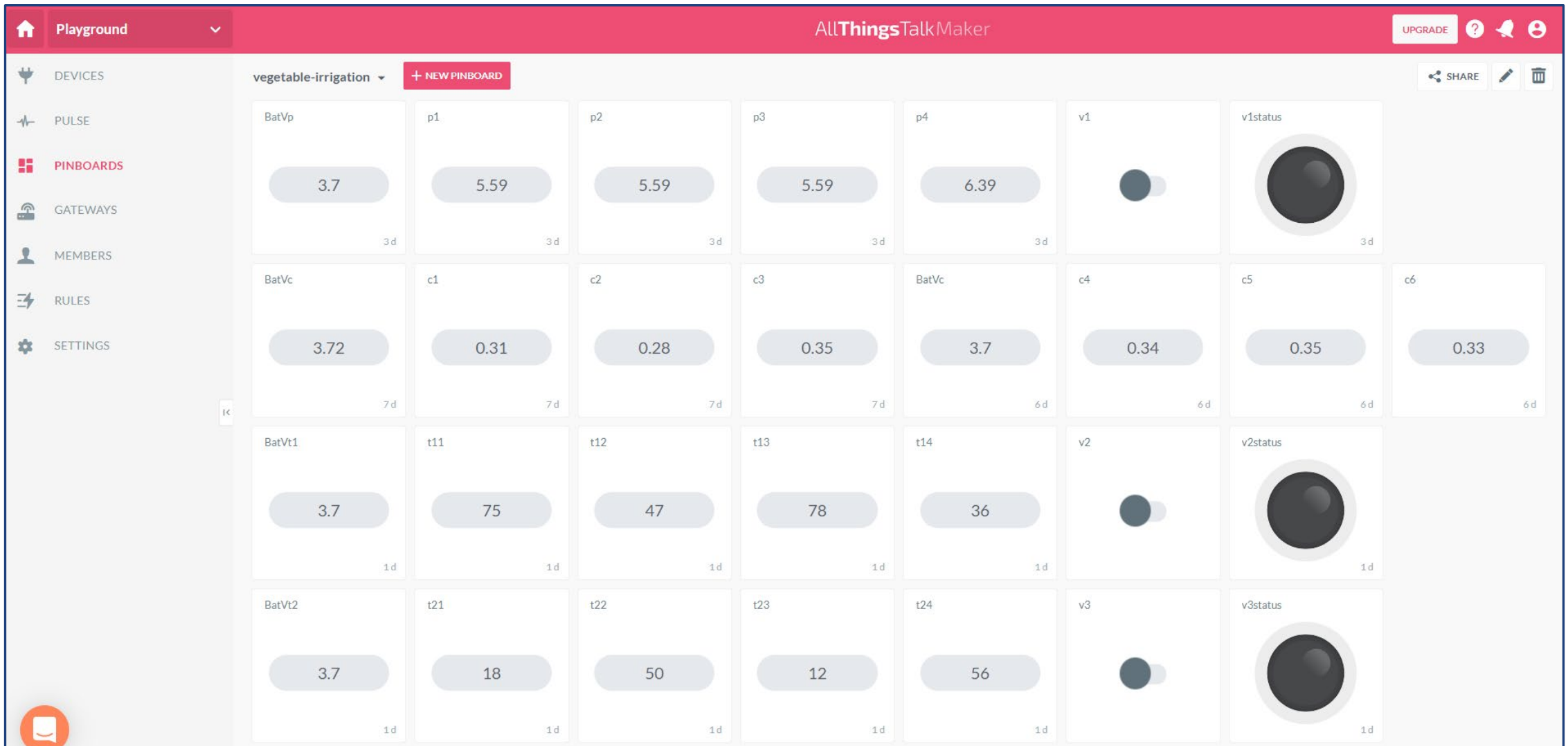
The screenshot displays the 'THE THINGS NETWORK CONSOLE' interface. The breadcrumb navigation shows 'Applications > vegetable-irrigation > Devices'. The 'Devices' tab is active, showing a list of six registered devices. Each device entry includes a name, a description, a MAC address, and a status indicator (a green dot).

Device Name	Description	MAC Address	Status
potential-sensor-1	tension-sensor-3	00 0D B5 39 07 68 36 7A	Online
potential-sensor-2	tension-sensor-1	00 0D B5 39 07 72 36 6F	Online
potential-sensor-3	tension-sensor-2	00 0D B5 39 07 76 36 66	Online
pressure-sensor		00 0D B5 39 09 7A 36 5F	Online
water-content		00 0D B5 39 07 72 36 7E	Online
water-content-1		00 0D B5 39 0D 81 36 6E	Online

- ❖ Internet gateway + Application (*thethingsnetwork*)
- ❖ Configurating the wireless module (Lora) in *thethingsnetwork*
- ❖ Connecting sensors/valves to the wireless module

# LoRa Based IoT Irrigation System

## Interface of IoT irrigation System



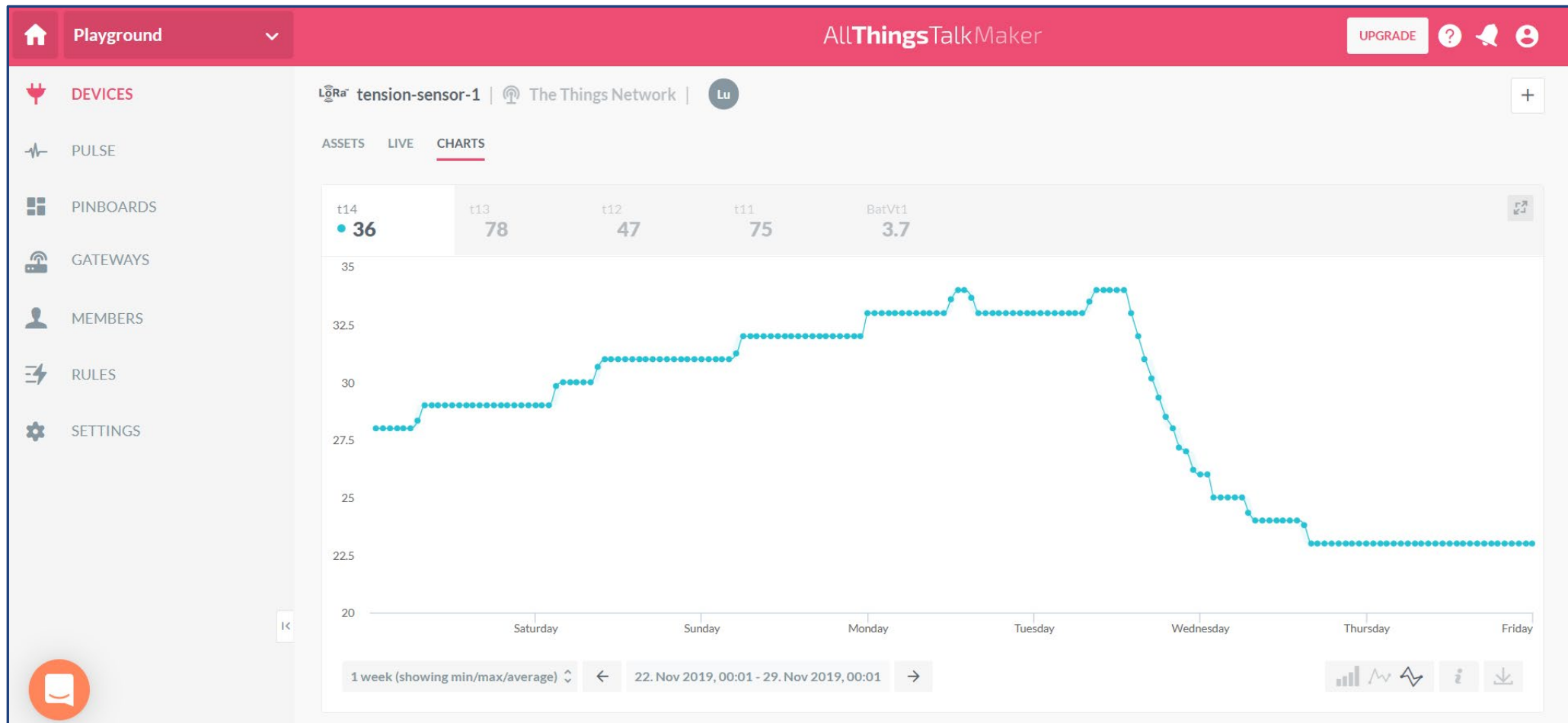
The interface displays a dashboard for an IoT irrigation system. The top navigation bar includes a home icon, 'Playground', the 'AllThingsTalkMaker' logo, and an 'UPGRADE' button. A left sidebar contains navigation options: DEVICES, PULSE, PINBOARDS (highlighted), GATEWAYS, MEMBERS, RULES, and SETTINGS. The main content area shows a 'vegetable-irrigation' pinboard with a '+ NEW PINBOARD' button and a 'SHARE' icon. The dashboard is organized into a grid of data cards:

- Row 1:** BatVp (3.7, 3d), p1 (5.59, 3d), p2 (5.59, 3d), p3 (5.59, 3d), p4 (6.39, 3d), v1 (toggle switch), v1status (circular gauge, 3d).
- Row 2:** BatVc (3.72, 7d), c1 (0.31, 7d), c2 (0.28, 7d), c3 (0.35, 7d), BatVc (3.7, 6d), c4 (0.34, 6d), c5 (0.35, 6d), c6 (0.33, 6d).
- Row 3:** BatVt1 (3.7, 1d), t11 (75, 1d), t12 (47, 1d), t13 (78, 1d), t14 (36, 1d), v2 (toggle switch), v2status (circular gauge, 1d).
- Row 4:** BatVt2 (3.7, 1d), t21 (18, 1d), t22 (50, 1d), t23 (12, 1d), t24 (56, 1d), v3 (toggle switch), v3status (circular gauge, 1d).

Each data card displays a numerical value and a refresh interval (e.g., '3d', '7d', '1d'). The interface also features a bottom-left notification icon.



## Interface of IoT irrigation System – Sensor Data



## 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

## ***Funding Sources:***

State Horticultural Association of Pennsylvania (SHAP)  
Northeast SARE, Project No. 19-378-33243

## ***Project Personnel:***

PIs: Long He, James Schupp, Daeun Choi, Francesco Di Gioia,  
Daniel Weber, Tara Baugher  
Students: Xiaohu Jiang, Haozhe Zhang

**Thank you!**