

Updates on Precision Agriculture Program

Intelligent Spraying and Sensor-Based Irrigation

Long He

2020 Winter Fruit School

Biglerville, Adams County, PA

February 17th, 2020



PennState
College of Agricultural Sciences



PennState Extension

Intelligent Spraying for Tree Fruit Orchards

Overview of Orchard Spraying

Production Impact

- Spray coverage
- Spray schedule
- Crop yield
- Crop quality

Economic Impact

- Pesticides cost
- Equipment cost
- Operation cost
- Income/return

Environmental Impact

- Ground water
- Soil
- Beneficial insects
- Residents

Operation/Maintenance

- Operator-friendly
- Easy to maintain
- Good service
- Educational programs



Orchard Sprayers



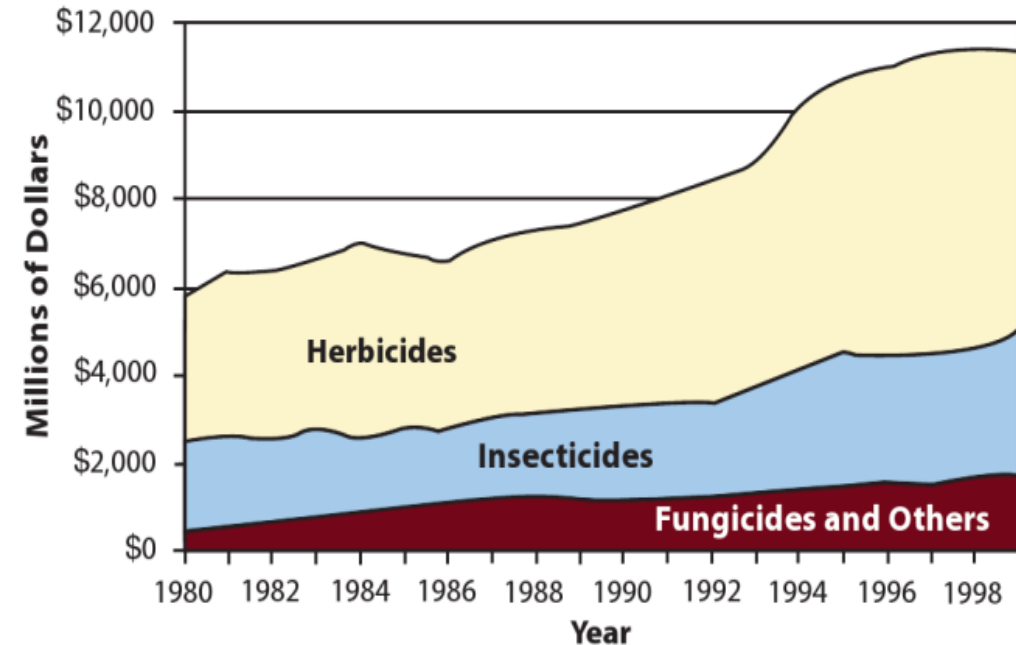
Need of Intelligent Sprayer

Conventional Methods:

- Non-precision and non-targeted
- Waste some chemicals (drift to air/ground, gaps)
(~ 30% of chemical on the tree canopy)
- Cause environmental issues

Intelligent Sprayer:

- Targeted spraying
- Save chemical
- Reduce production cost

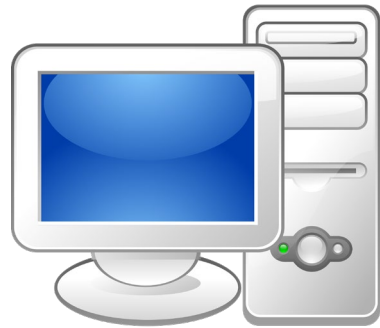


If the average of cost for pesticides is ***\$300-500 per acre*** for a growing season, and ***20%*** of saving is ***\$60-100***, and ***40%*** of saving is ***\$120-200***.

Principle of Intelligent Spray

Detection and Control System

- Object detection
- Information processing
- Spraying control

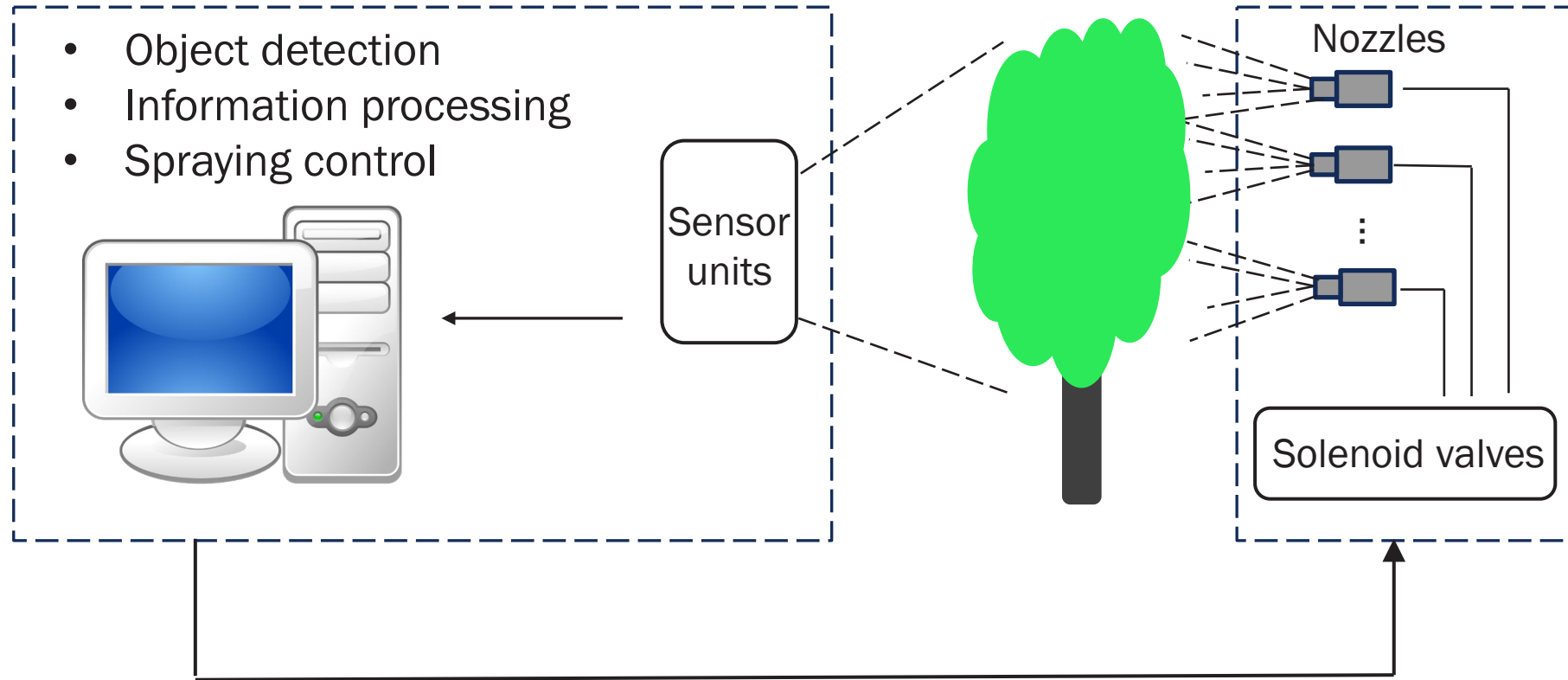


Sensor units

Spraying System

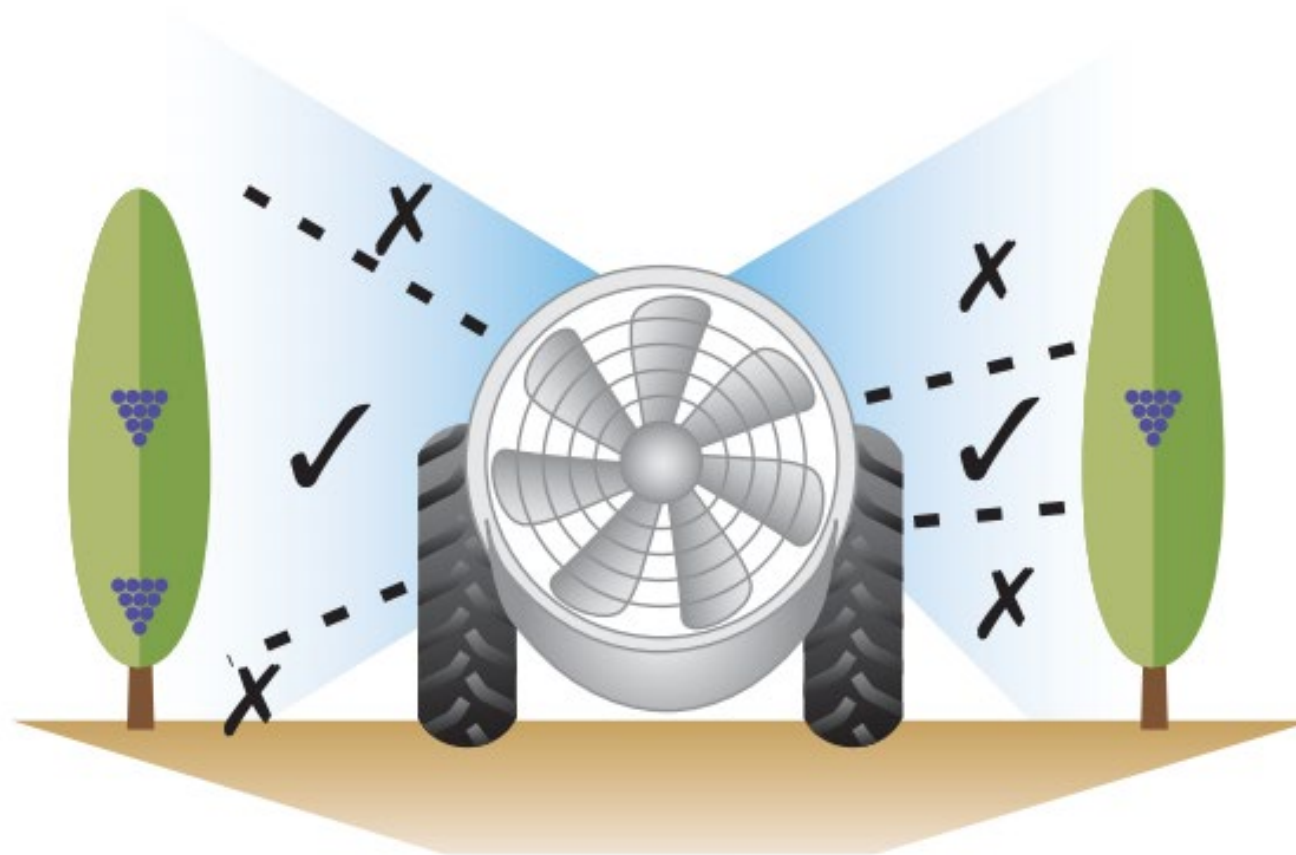
Nozzles

Solenoid valves



Core Tech. – Object Detection

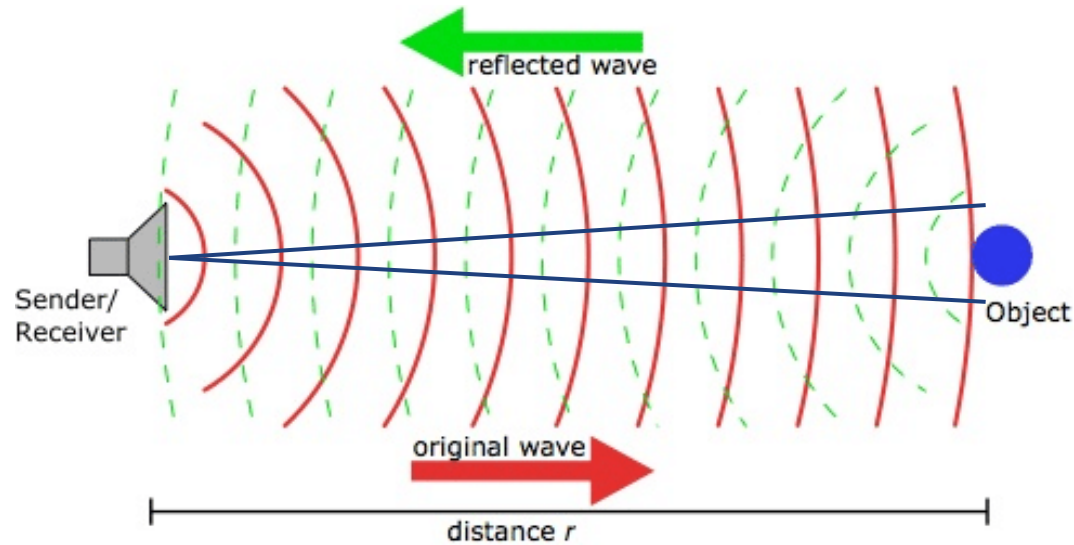
Canopy
location,
shape,
volume,
density



Blossoms,
fruits,
insects/
diseases

Airblast 101: Turn off nozzles that are not spraying the target.

Tree Canopy Detection – Ultrasonic Sensors



Measurement of distance to objects using sound waves



Pros

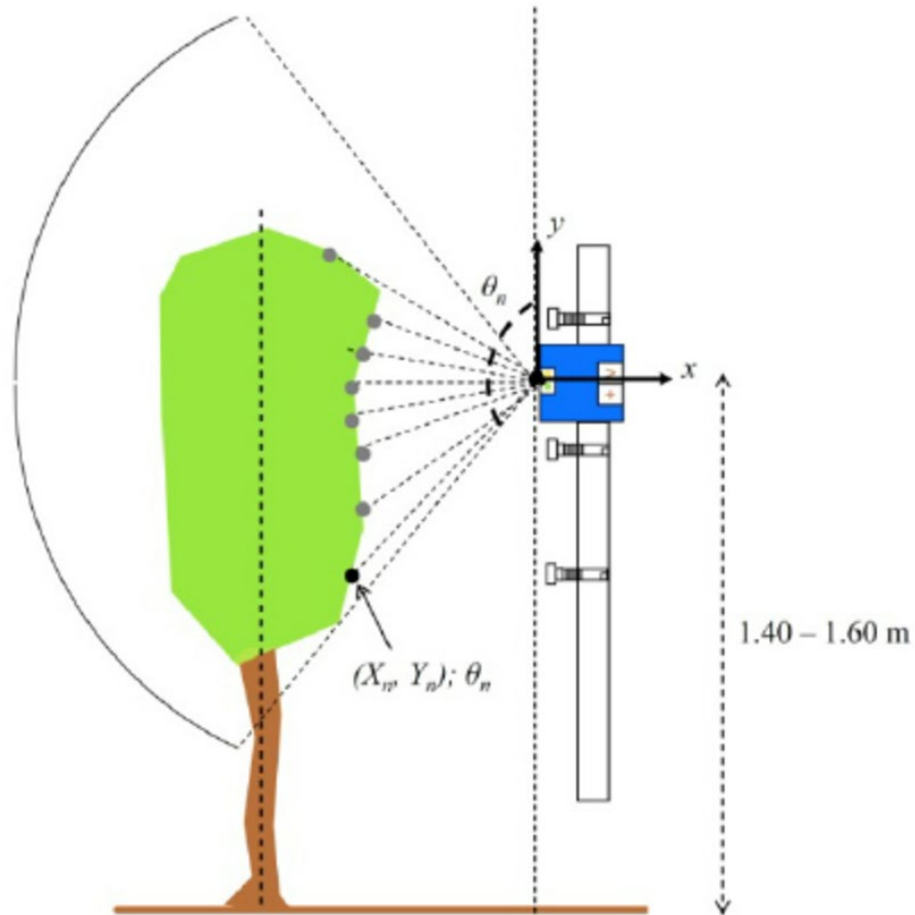
- Inexpensive
- Mid - long range
- Reliable in varying environment

Cons

- Small area detection
- Inaccurate at soft surface

Detection range: 20 mm to 8 m.

Tree Canopy Detection – Laser Sensors



Pros

- Full canopy detection
- Long range
- Reliable in varying environment

Cons

- A bit expensive
- Real-time data processing

- 2D (one channel) and 3D (multiple channels)
- Detection range: up to 100 m or more
- Cost: ~ \$1,000 - \$10,000 or higher

Cameras based Object Detection



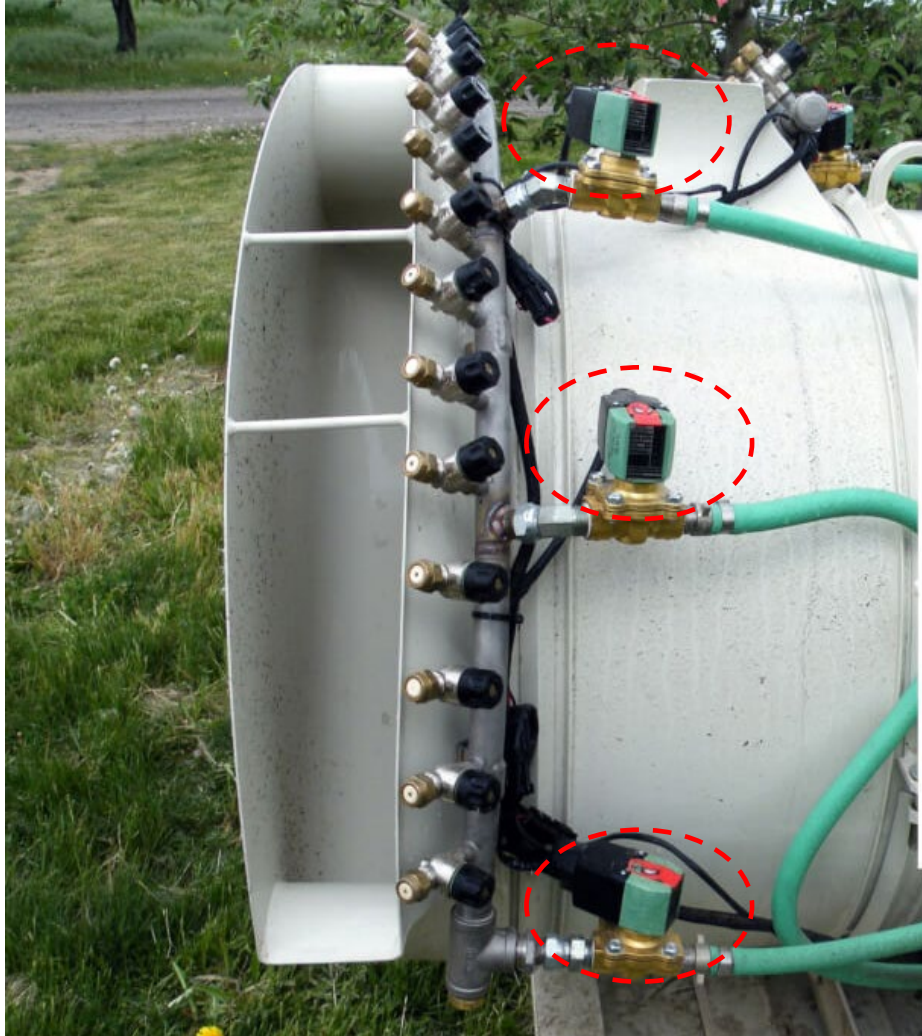
Karkee, WSU, 2014



Philippe Ambrozio Dias, 2018

- Very few studies on the camera based for tree orchard sprayer
- Some on the field crop detection (weed control or crop thinning)
- Specific disease/insect detection – Spot/targeted spraying?

Core Tech. – Nozzle Control





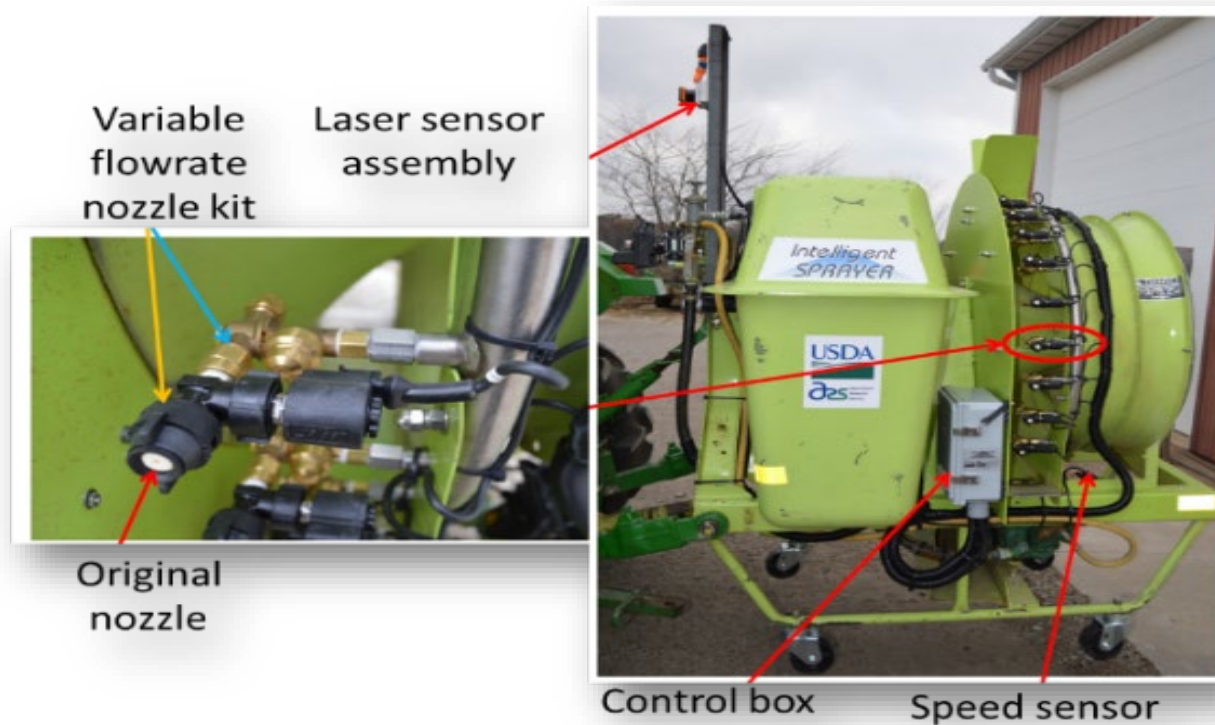
Smart Sprayer - Ultrasonic Sensor

- **Stajanko et al., 2012- apple orchard**
Save up to 48% pesticides
- **California almond and plum tests- Giles et al., 2011**
Reduced pesticides by 15-40%, and non-targeted orchard floor deposition by 5-72%.
- **Florida citrus tests- University of Florida Extension**
Average of 14% reduction in pesticides use.

Problems: valve clogged, control system failure, little saving on some sites.

Available Intelligent Sprayers

Smart Sprayer - Lidar Sensor

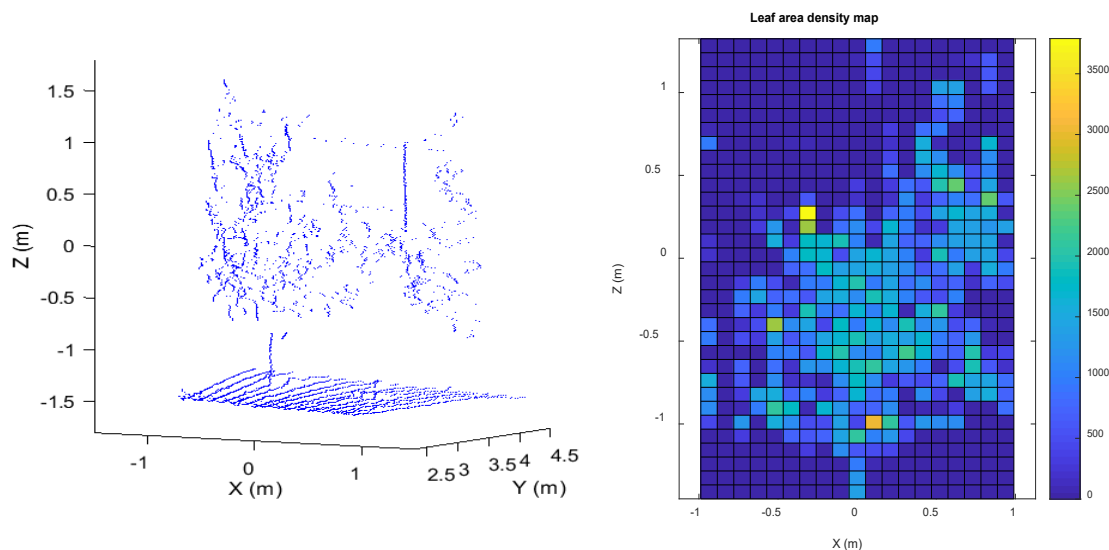


Intelligent sprayer kit

- *Studies from Dr. Heping Zhu's team: ~30-70% of chemical saving*
- *The intelligent sprayer kit could be retrofitted to existing sprayers.*

What We Are Doing?

Tree Canopy Detection



Geo-reference and Orchard Terrain

- Initial measurement Unit (IMU) – orchard terrain
- RTK GPS – Geo-reference



Intelligent Sprayer Integration and Evaluation

- Ordered an intelligent sprayer unit
- Integrate the sprayer and intelligent unit (March 2020)
- Orchard evaluation (2020 season)

Soil Moisture Sensors for Precision Irrigation

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

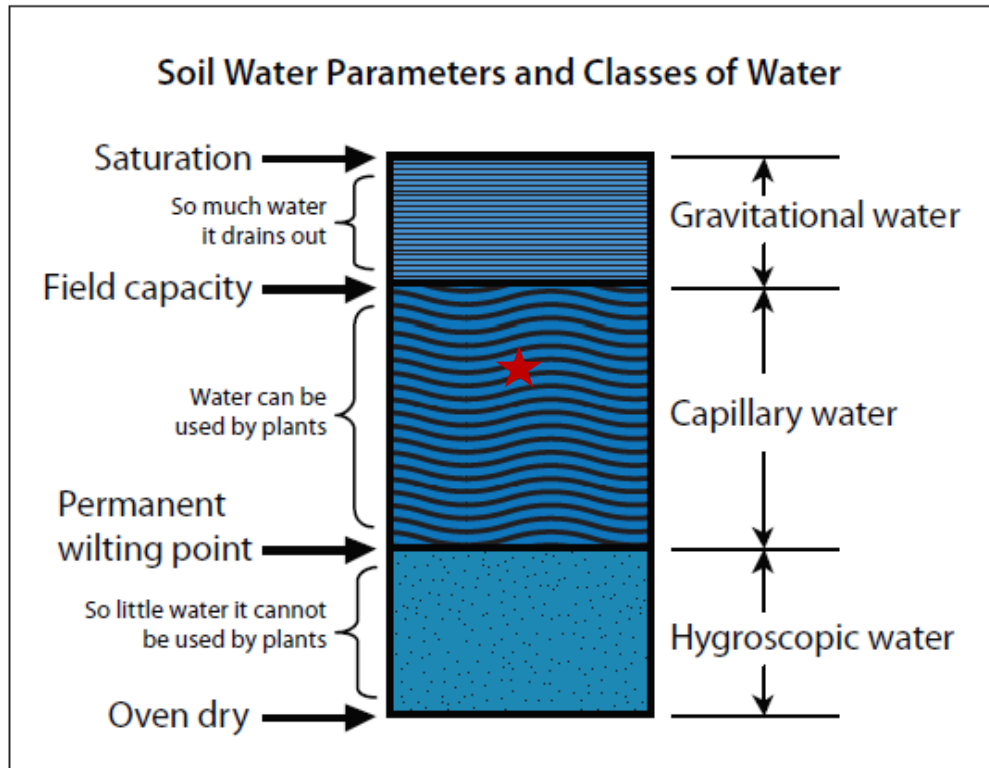
Benefit of Precision Irrigation:

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



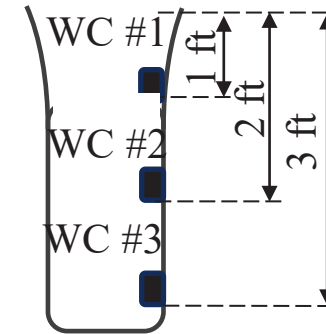
Soil Moisture Measurement

Fundamental Principles

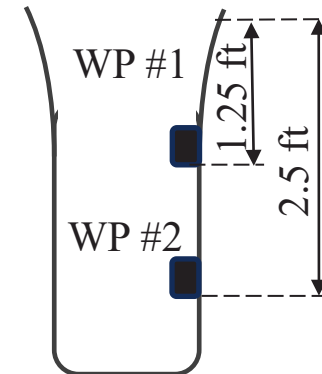


Soil Water Parameters (From: Texas A&M AgriLife Extension, E-618)

Soil Moisture Sensors



Soil water content sensor: TEROS 12 @ QTY 3



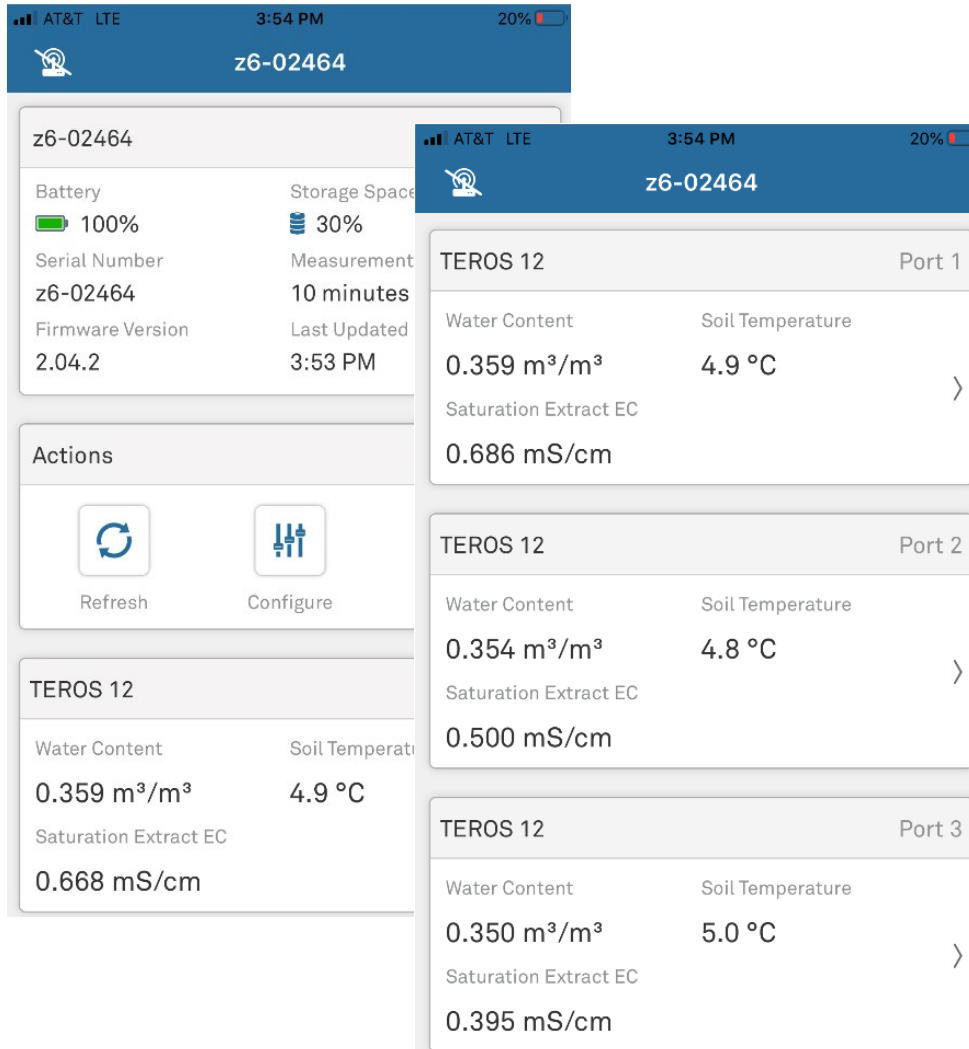
Soil water potential sensor: TEROS 21 @ QTY 2

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



Mobile app interface for device z6-02464. The interface shows device details, actions, and sensor data for three ports.

Device Details:

- Battery: 100%
- Storage Space: 30%
- Serial Number: z6-02464
- Firmware Version: 2.04.2
- Measurement Interval: 10 minutes
- Last Updated: 3:53 PM

Actions: Refresh, Configure

Port 1 Data:

- TEROS 12
- Water Content: 0.359 m³/m³
- Soil Temperature: 4.9 °C
- Saturation Extract EC: 0.686 mS/cm

Port 2 Data:

- TEROS 12
- Water Content: 0.354 m³/m³
- Soil Temperature: 4.8 °C
- Saturation Extract EC: 0.500 mS/cm

Port 3 Data:

- TEROS 12
- Water Content: 0.350 m³/m³
- Soil Temperature: 5.0 °C
- Saturation Extract EC: 0.395 mS/cm



ZENTRA Cloud web interface showing historical data for a 2009 Fuji sensor. The interface includes a navigation menu, a location selector, and two data visualization charts.

Navigation: Home, Manage Devices, Manage Users, Device Inventory, Manage Calibrations

Location: 2009 Fuji

Chart 1: Water Content (m³/m³)

This chart displays water content over time from July to December. The y-axis ranges from 0.25 to 0.35. The data shows a clear seasonal cycle with peaks in late summer/early fall and troughs in late winter/early spring.

Chart 2: Matric Potential (kPa)

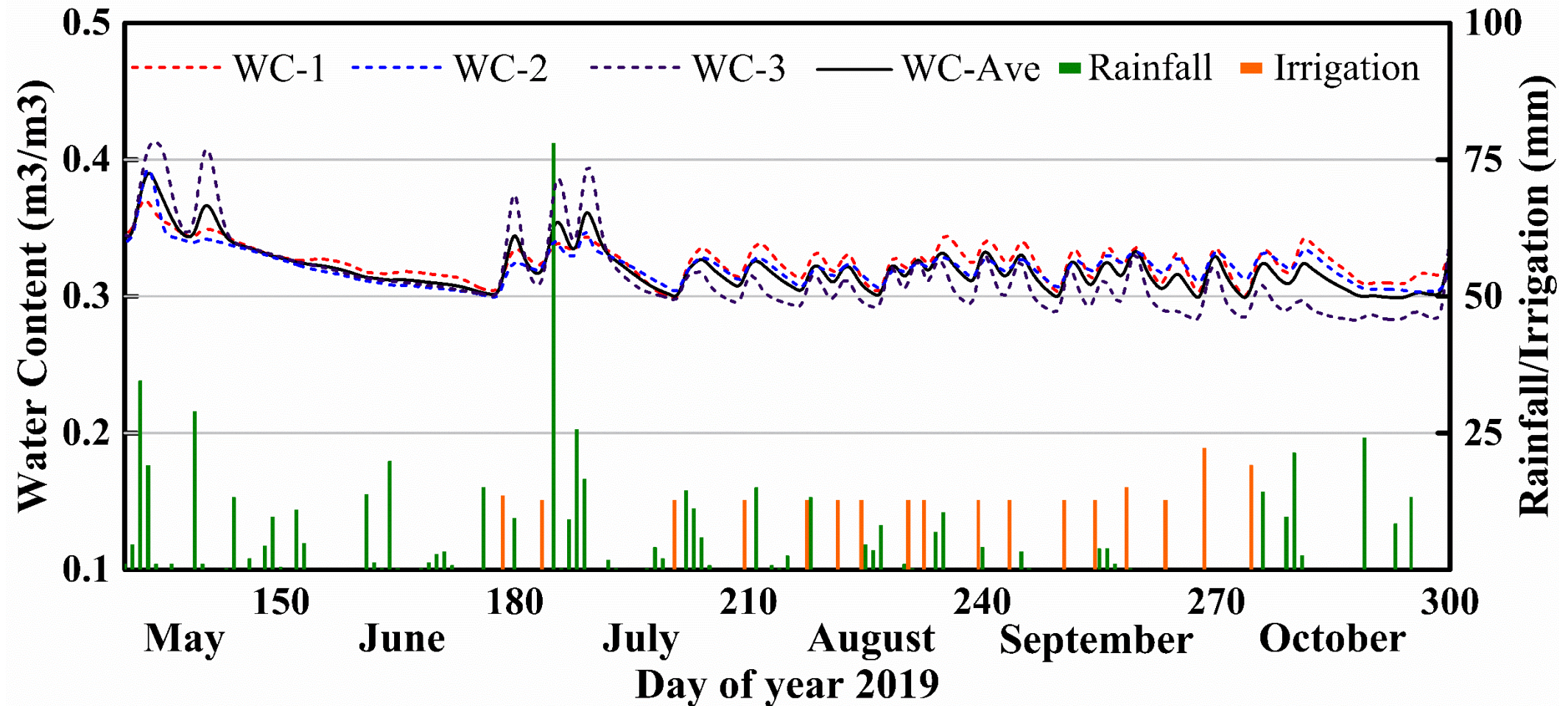
This chart displays matric potential over time from July to December. The y-axis ranges from -400 to 0. The data shows a clear seasonal cycle with values near 0 kPa in late summer/early fall and values near -400 kPa in late winter/early spring.

Legend: Port 4: TEROS 21 (Green), Port 5: TEROS 21 (Orange)

Buttons: Dashboard, Map, List, Detail, Last 6 Months, + Add new...

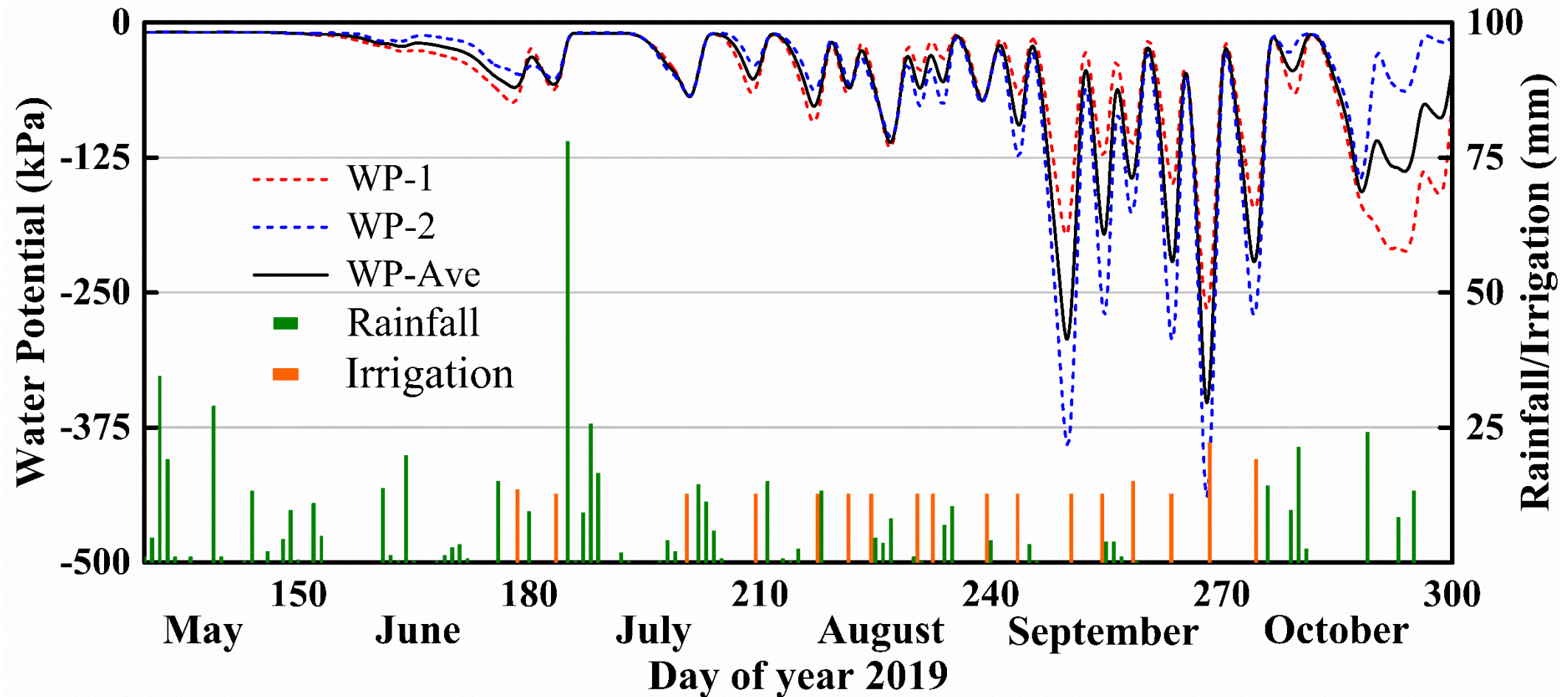
Results – Irrigation Strategies

Soil Water Content



Results – Irrigation Strategies

Soil Water Potential



Test in Commercial Orchards



Hollabaugh Bro. Inc
(Honey Crisp)



Mt. Ridge Farms
(Fuji)

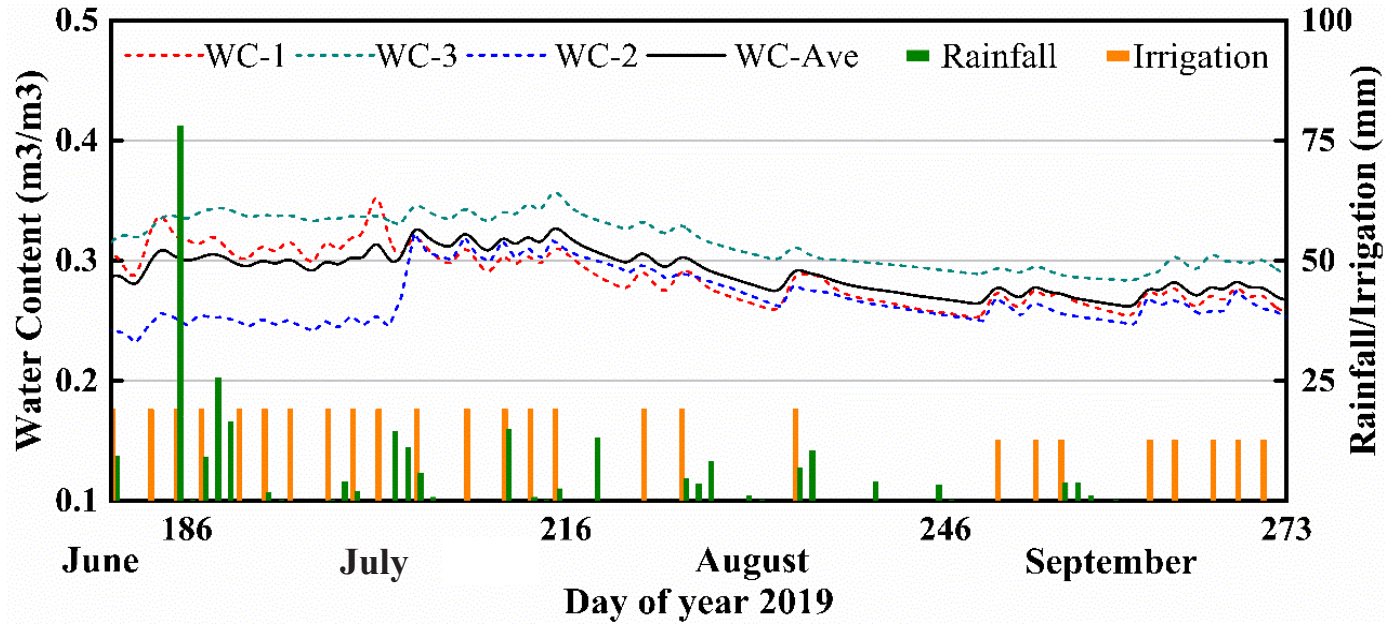


Twin Springs Fruit Farm
(Crimson Crisp)

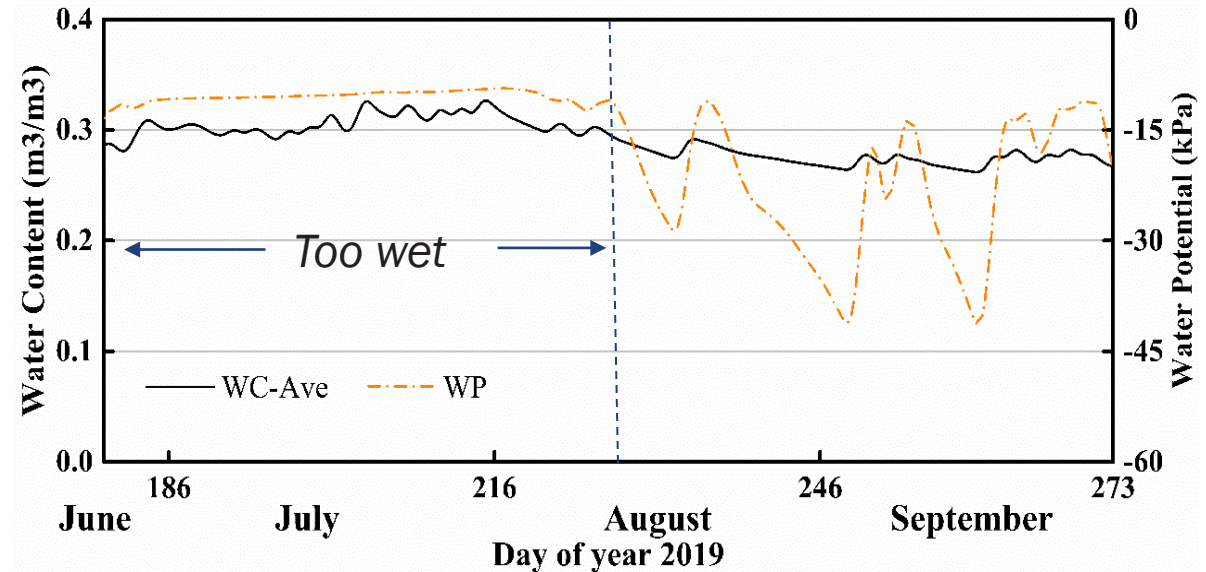


El Vista Orchards
(Gala)

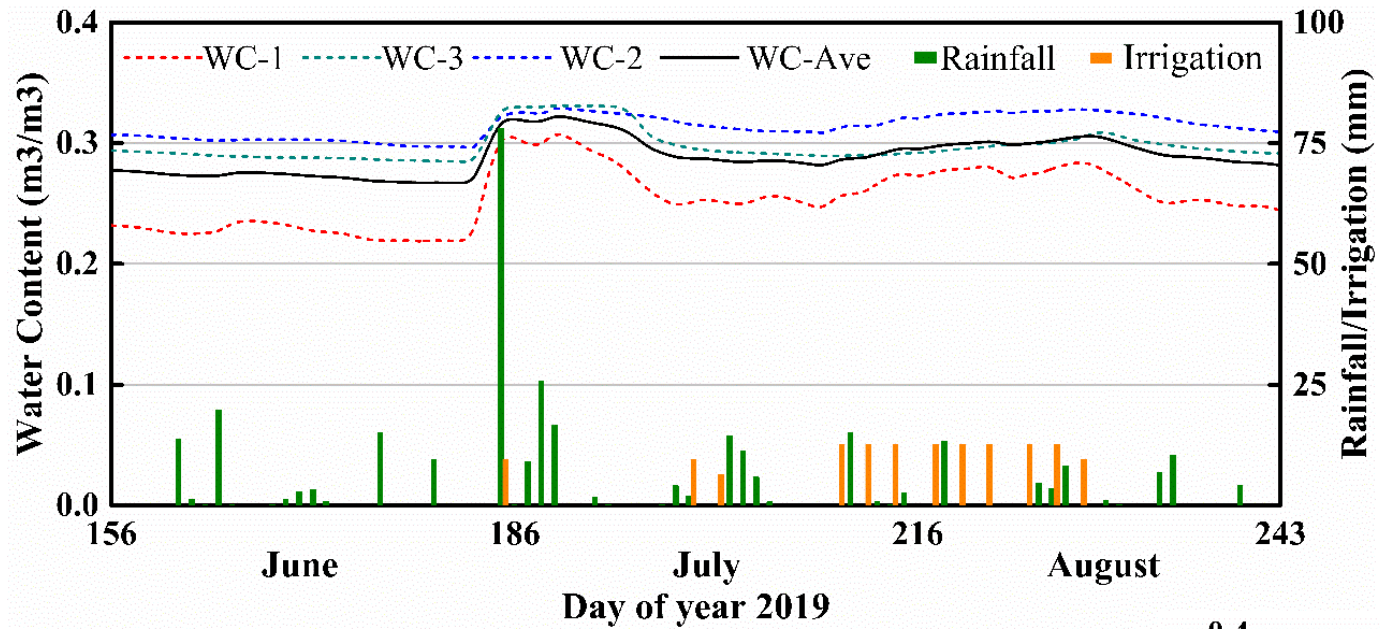
Test in Commercial Orchards



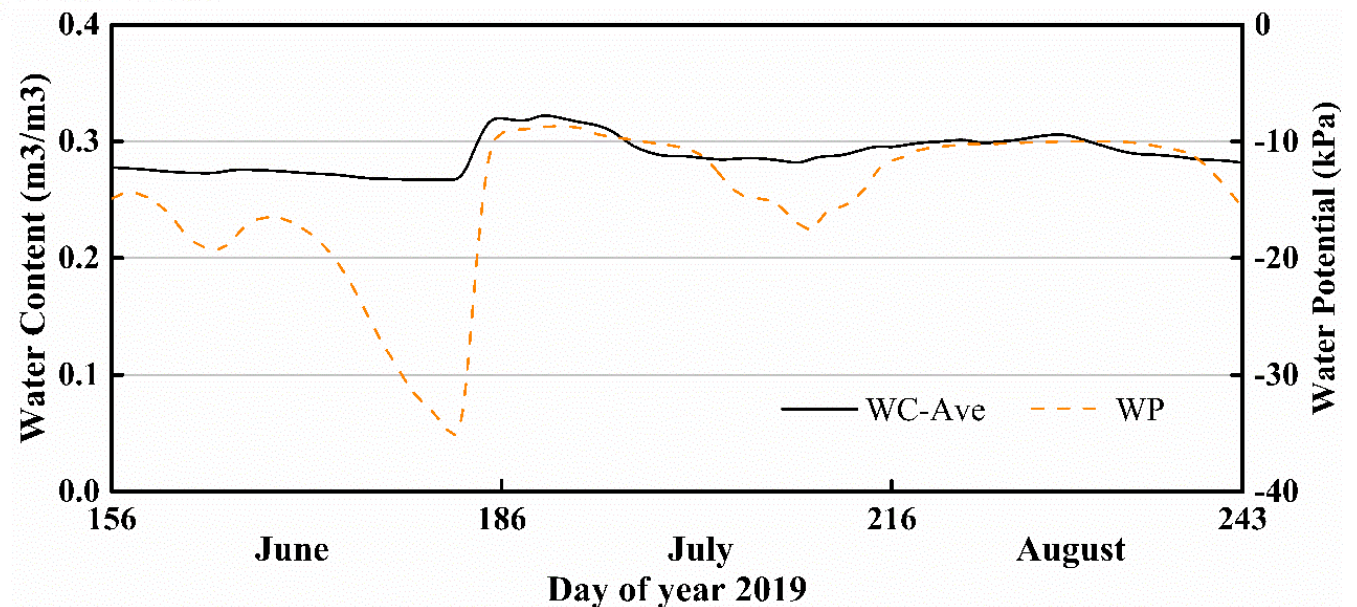
**Twin Springs Fruit Farm
(Crimson Crisp)**



Test in Commercial Orchards

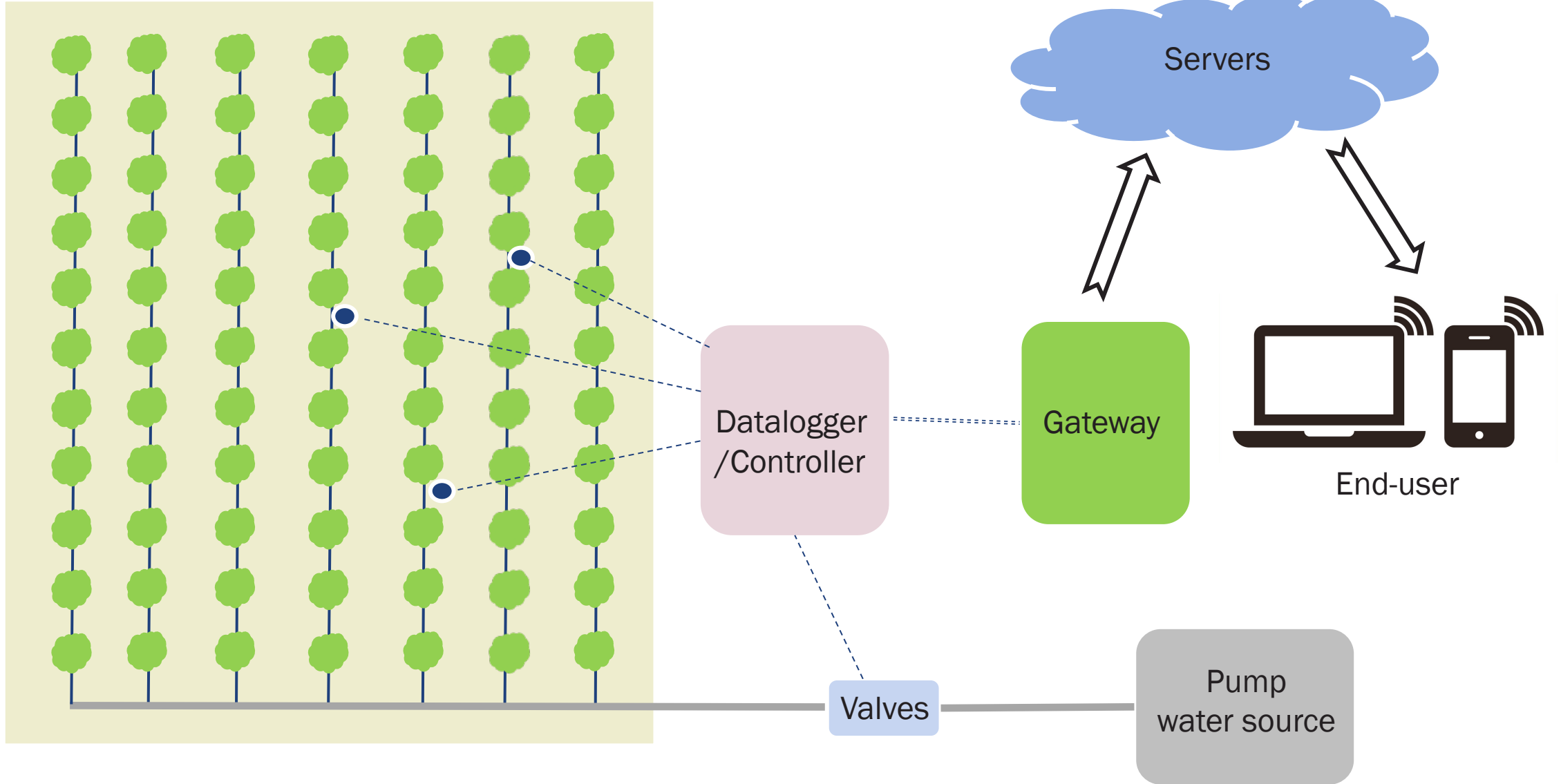


**Hollabaugh Bro. Inc
(Honey Crisp)**

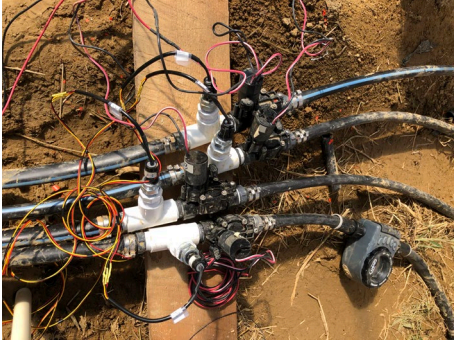


Automated Irrigation System

Automated Irrigation with Internet of Things (IoT)

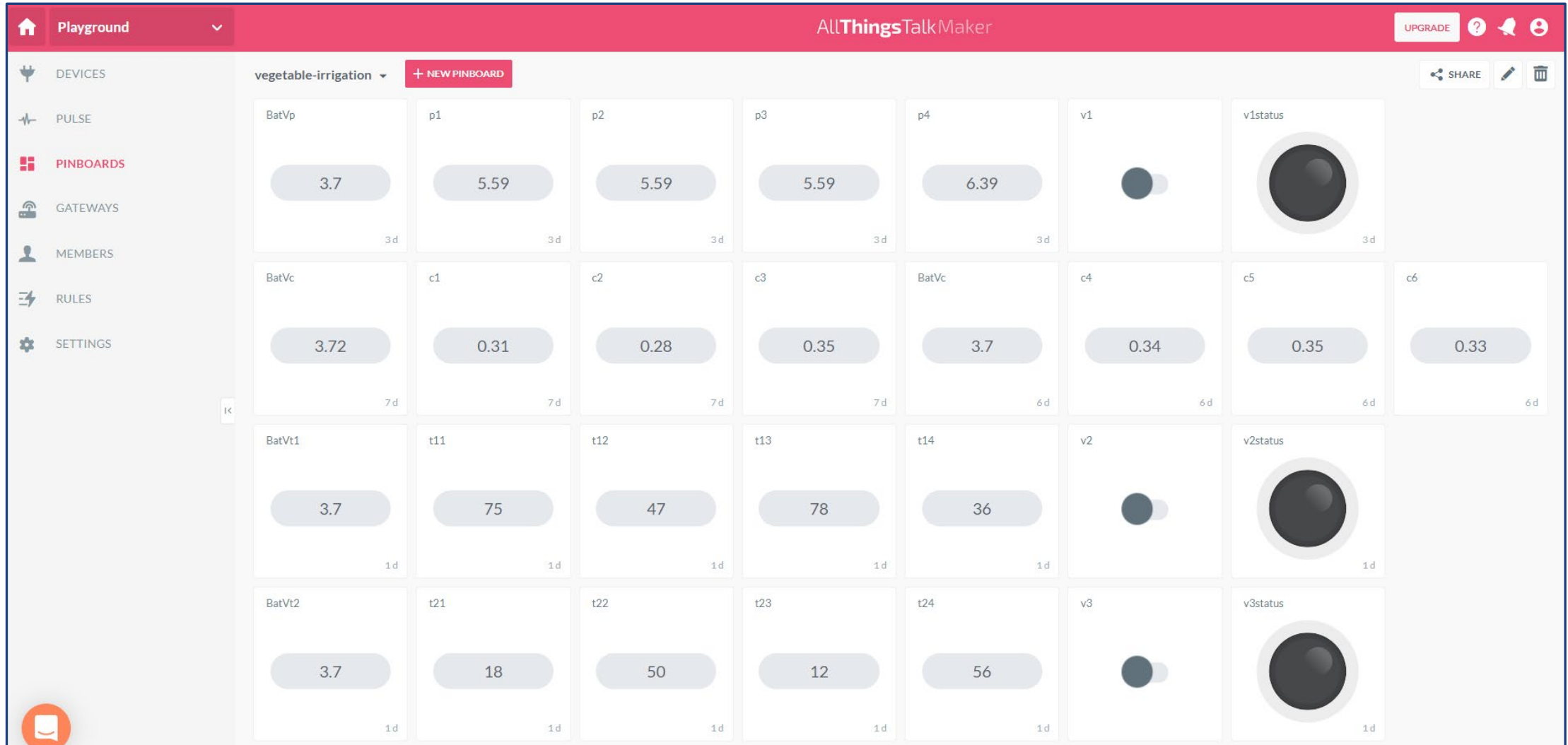


Automated Irrigation System



Automated Irrigation System

Interface of IoT irrigation System



The screenshot shows the AllThingsTalkMaker interface for a 'vegetable-irrigation' system. The dashboard is organized into a grid of data cards, each representing a different sensor or control element. The cards are arranged in four rows and seven columns. The first row contains cards for BatVp (3.7), p1 (5.59), p2 (5.59), p3 (5.59), p4 (6.39), v1 (toggle), and v1status (circular gauge). The second row contains cards for BatVc (3.72), c1 (0.31), c2 (0.28), c3 (0.35), BatVc (3.7), c4 (0.34), c5 (0.35), and c6 (0.33). The third row contains cards for BatVt1 (3.7), t11 (75), t12 (47), t13 (78), t14 (36), v2 (toggle), and v2status (circular gauge). The fourth row contains cards for BatVt2 (3.7), t21 (18), t22 (50), t23 (12), t24 (56), v3 (toggle), and v3status (circular gauge). The interface includes a sidebar with navigation options: DEVICES, PULSE, PINBOARDS, GATEWAYS, MEMBERS, RULES, and SETTINGS. The top navigation bar shows 'Playground', 'AllThingsTalkMaker', and 'UPGRADE'. A '+ NEW PINBOARD' button is visible in the top right of the main content area.

Card Label	Value	Update Time
BatVp	3.7	3 d
p1	5.59	3 d
p2	5.59	3 d
p3	5.59	3 d
p4	6.39	3 d
v1	Toggle (Off)	
v1status	Gauge	3 d
BatVc	3.72	7 d
c1	0.31	7 d
c2	0.28	7 d
c3	0.35	7 d
BatVc	3.7	6 d
c4	0.34	6 d
c5	0.35	6 d
c6	0.33	6 d
BatVt1	3.7	1 d
t11	75	1 d
t12	47	1 d
t13	78	1 d
t14	36	1 d
v2	Toggle (Off)	
v2status	Gauge	1 d
BatVt2	3.7	1 d
t21	18	1 d
t22	50	1 d
t23	12	1 d
t24	56	1 d
v3	Toggle (Off)	
v3status	Gauge	1 d

What Growers Can Use?

Soil Water Potential using Watermark Sensors



\$45/piece (Watermark)



\$250 (Digital meter)

OR



\$880 (Monitor + seven sensors)

Soil Moisture Measurement (Meters Group, Inc)

Soil moisture sensors



\$120/piece (Water content)
\$225/piece (Water content + Temp,
Water potential)



Sensor datalogger: \$650

ZentraCloud



Data service:
\$180/season

- Three sensors (one node) in different depths for fruit trees
- Number of nodes in an orchard depends on the size and variation of the orchard
- Data can be monitored through ZentraCloud, or can be read and manually downloaded from the datalogger

What Growers Can Use?

IoT based automated irrigation system

Soil Moisture Sensor



Datalogger & Gateway



Valve Control



IoT Platform



- Soil moisture sensors: \$50-\$225 per piece
- Datalogger and Gateway: \$500-\$1,000
- Solenoid valves: ~\$100
- IoT platform: Free or data fee if using some commercial services

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

Please contact me or your local extension educator if you are interested in applying sensor-based irrigation or want to know more about it.

Funding Sources:

State Horticultural Association of Pennsylvania (SHAP)
Northeast SARE, Project No. 19-378-33243
USDA-NIFA CPPM (2019-70006-30440)

Project Personnel:

Long He, Dana Choi, James Schupp, Kari Peter, David Biddinger, Greg Krawczyk
Daniel Weber, Tara Baugher

Thank you!