President's Day Commercial Tree Fruit School

# Precision Farming: Progress with Sensing and Irrigation Technologies


**Long He**

Department of Agricultural and Biological Engineering
Fruit Research and Extension Center


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PennState College of Agricultural Sciences

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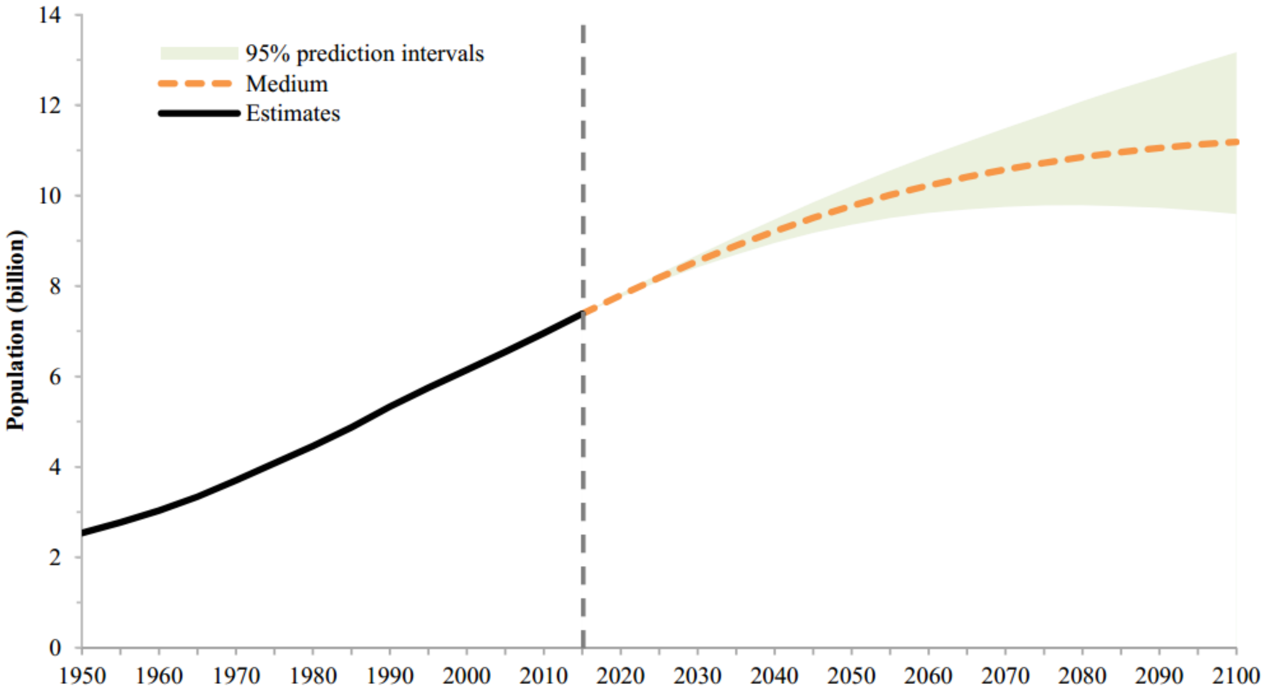
# Introduction

## Why Precision Farming?




*Source:* United Nations, Department of Economic and Social Affairs, Population Division (2017). *World Population Prospects: The 2017 Revision*. New York: United Nations.

- Population increase
- More food required
- Less available resources
- Precision farming is needed

# Precision Farming



Precision farming aims to develop a decision support system to improve efficiency and optimize returns with minimal inputs.

**Minimize Inputs**

Water Use
Energy Consumption
Labor Needed
Environment Impact

**Maximize Outputs**

Production yield
Crop Quality
Efficiency

# *Precision Farming*

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## Crop Sensing

- Sensors
- Cameras
- Drones
- Plants
- Soil
- Environment

## Decision Making

- Data
- Models
- Expert
- Algorithms
- Network
- Interface

## Field Operating

- Machinery
- Robotics
- Control system
- Autonomous
- Field operations

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# Crop Sensing

- Crop coverage detection
- Crop water stress detection
- Real-time crop load estimation
- Identification of pests and diseases infestation
- Soil mapping
- Crop nutrient deficiency detection

# Crop Sensing

## In-Field Sensing

Soil moisture sensor @ Meter Group Inc

Soil nutrient sensor @ Re:char

# Crop Sensing

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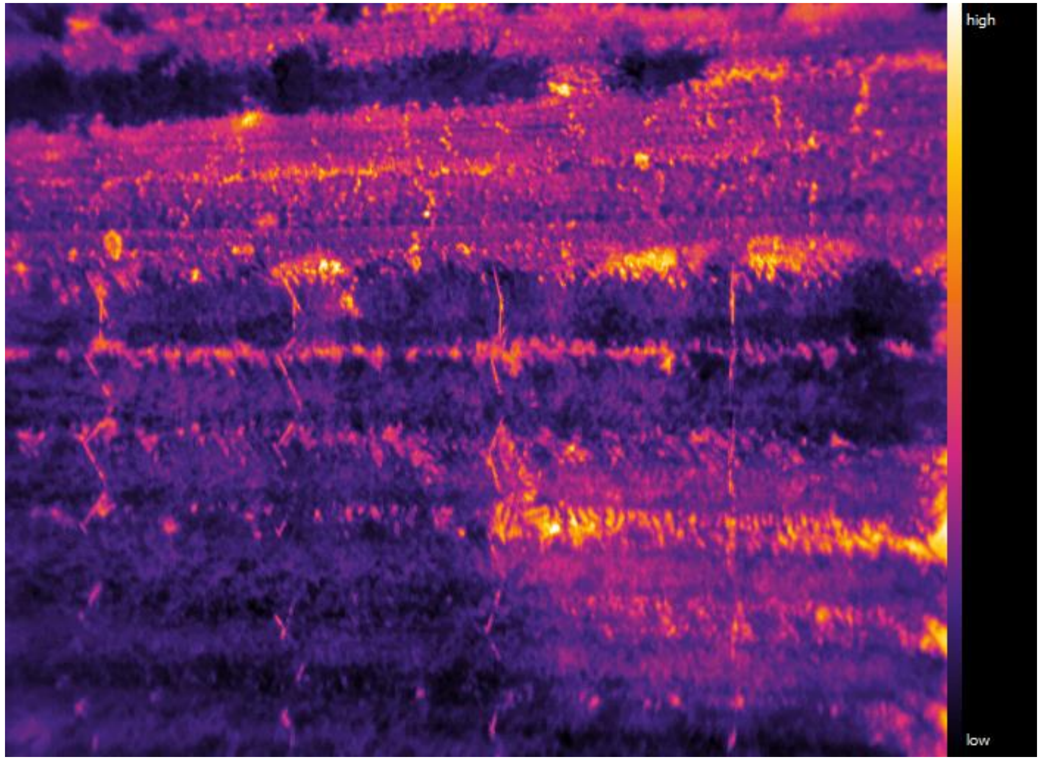
## UAV Based Sensing



# Crop Sensing

## Proximal Sensing

Phenotyping sensing platform (Washington State University)

Crop load estimation (Dr. Daeun Choi, Penn State)

# Decision Making

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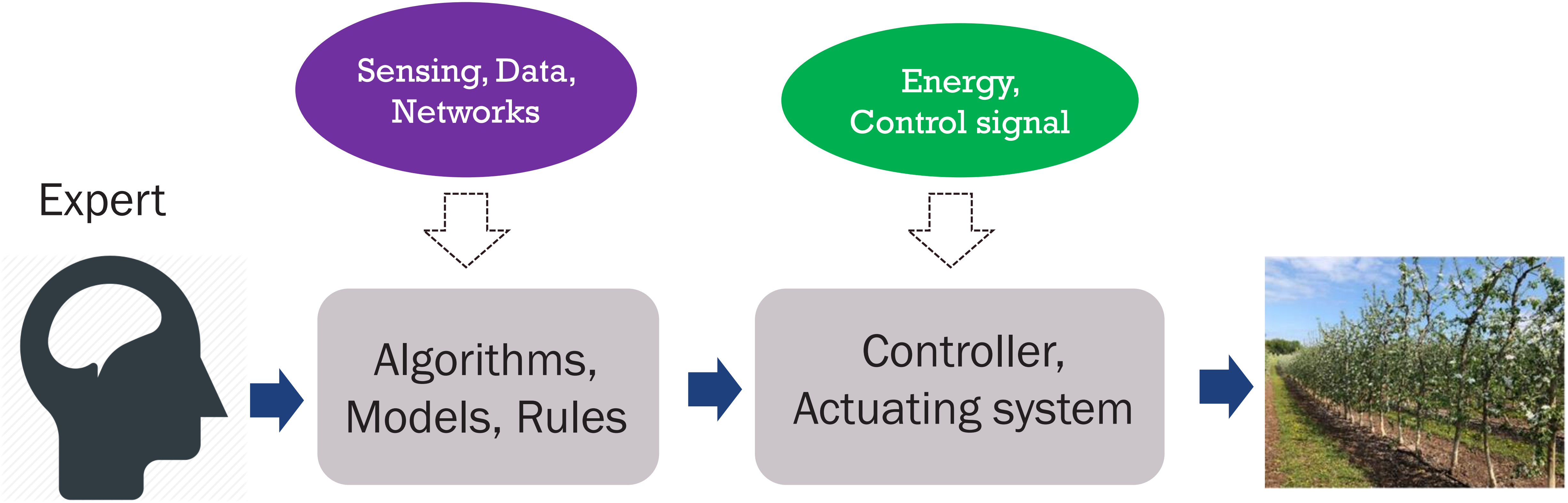
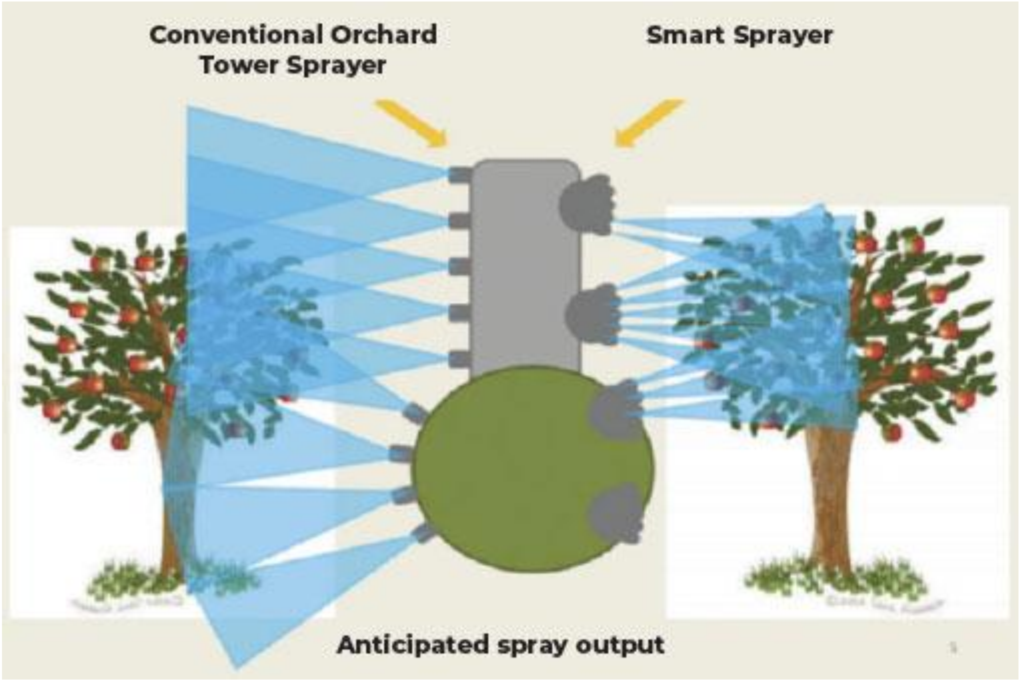


# Field Operating


*Time to start/stop the irrigation*




From: Ozkan, E. 2018. (Ohio State University)

# Case I: Sensor-Based Irrigation

## Importance of Irrigation

### Necessity:

- ❖ Mandatory for dry and semi-arid area
- ❖ Supplemental for drought days/uneven rainfall in humid area

### Proper irrigation:

- ❖ Increase yield
- ❖ Improve quality
- ❖ Conserve water
- ❖ Save energy
- ❖ Decrease fertilizer
- ❖ Reduce environmental impact

# Case I: Sensor-Based Irrigation

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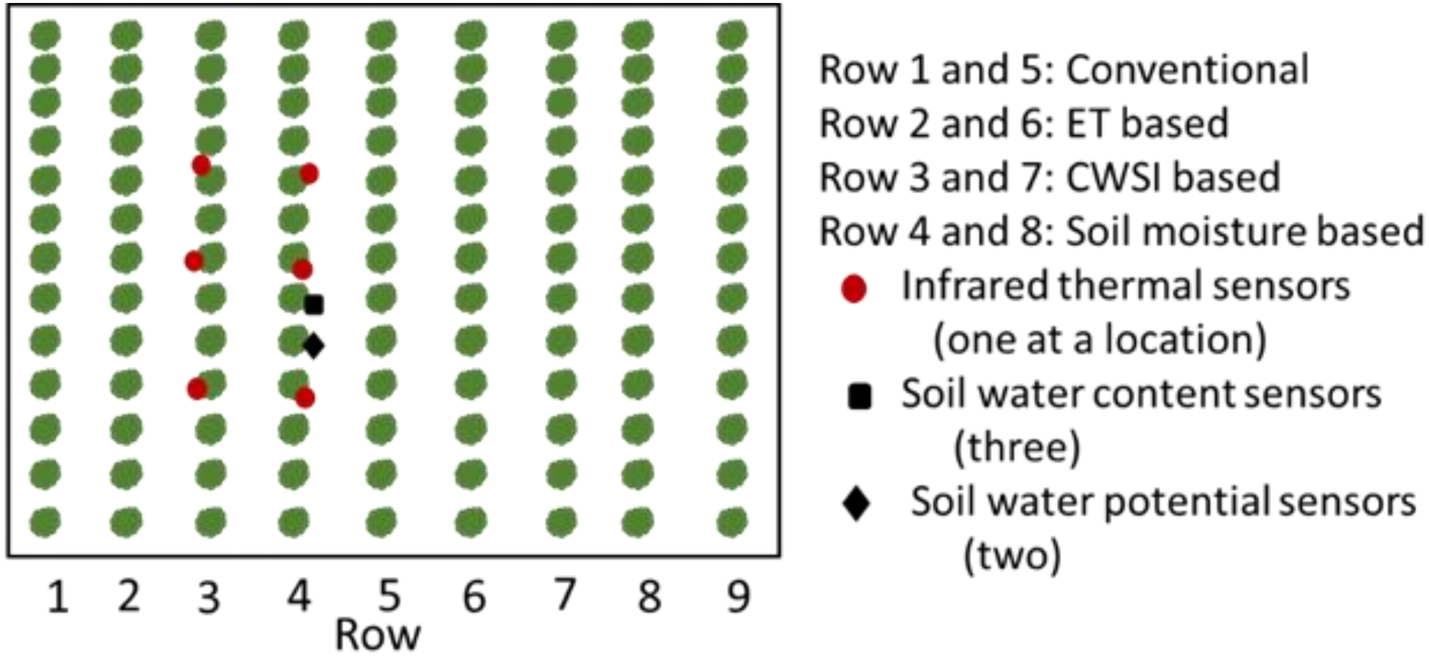
## *When to irrigate, and how much to irrigate?*

Orchard for test – Tall spindle Fuji trees




Schematic illustration of the experimental setup

# Case I: Sensor-Based Irrigation

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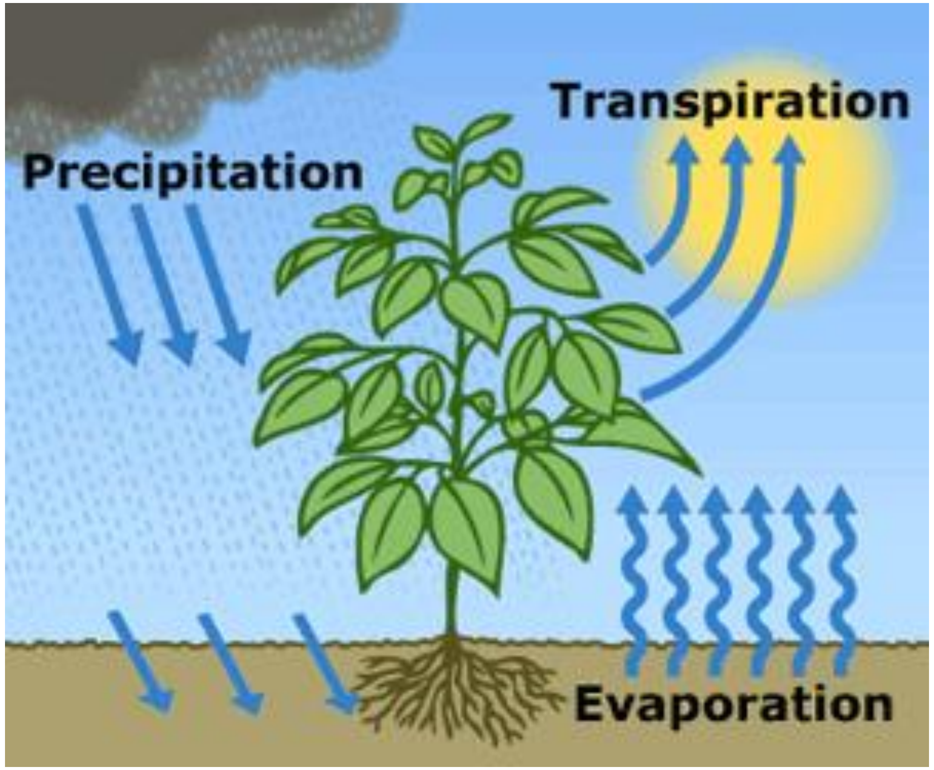
## Evapotranspiration (ET)-Base Irrigation



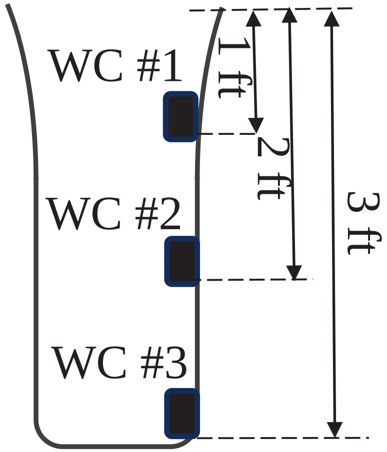

Penman–Monteith Model (P-M)

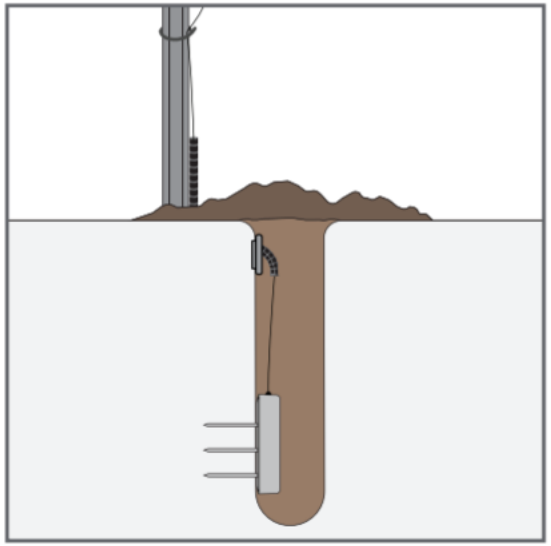
- Reference $ET_0$
- Estimated ET = Kc x $ET_0$

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

# Case I: Sensor-Based Irrigation

## Soil Water Content-Based Irrigation

# Case I: Sensor-Based Irrigation

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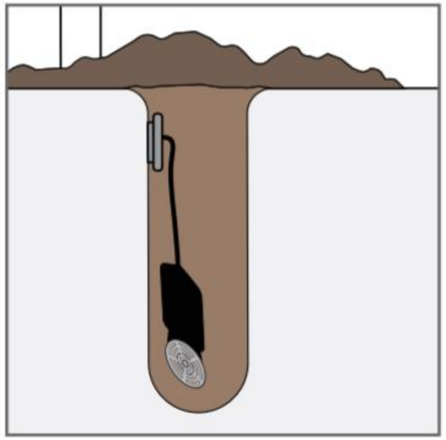
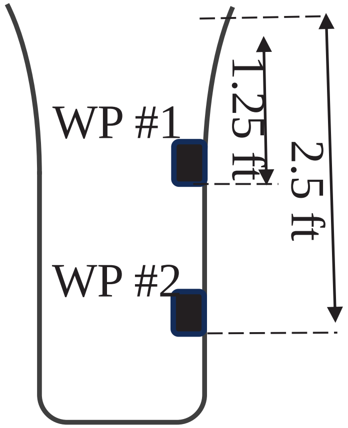
## Soil Water Potential-Based Irrigation

TEROS 21 @ QTY 2






# Case I: Sensor-Based Irrigation

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## Canopy Temperature-Based Irrigation (Crop Water Stress Index)

IR/t 3x @ QTY 6



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

# Case I: Sensor-Based Irrigation

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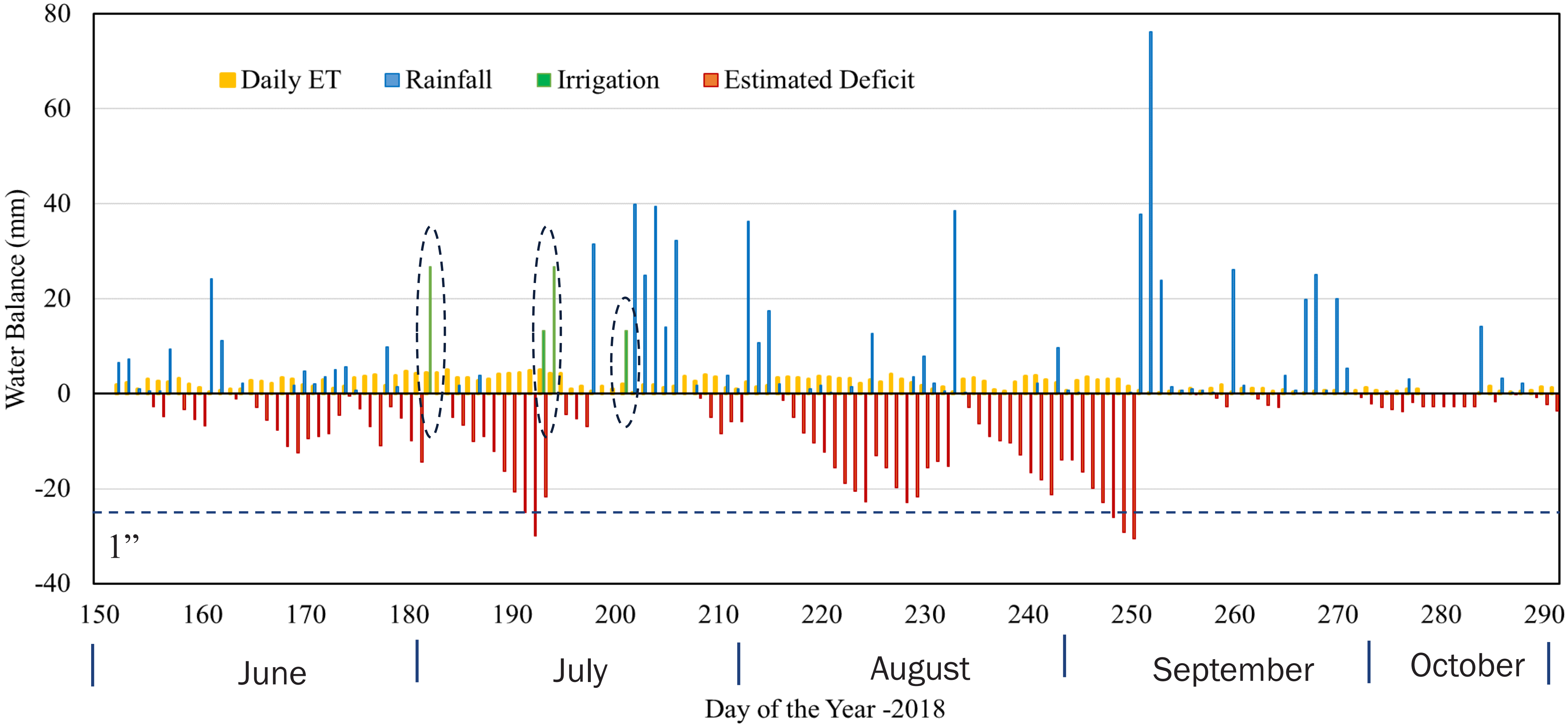
## Evapotranspiration (ET)-Based Irrigation



# Case I: Sensor-Based Irrigation

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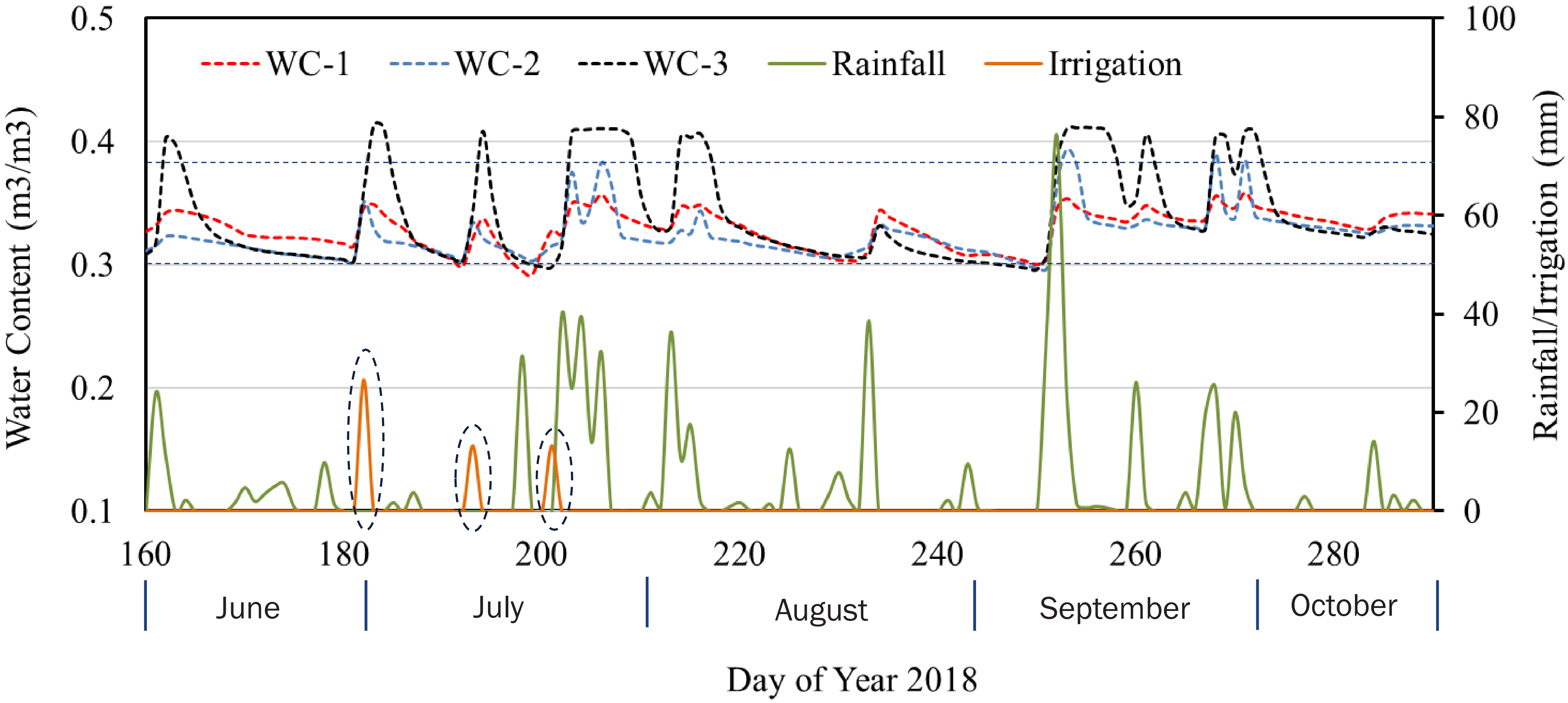
## Soil Water Content–Based Irrigation



# Case I: Sensor-Based Irrigation

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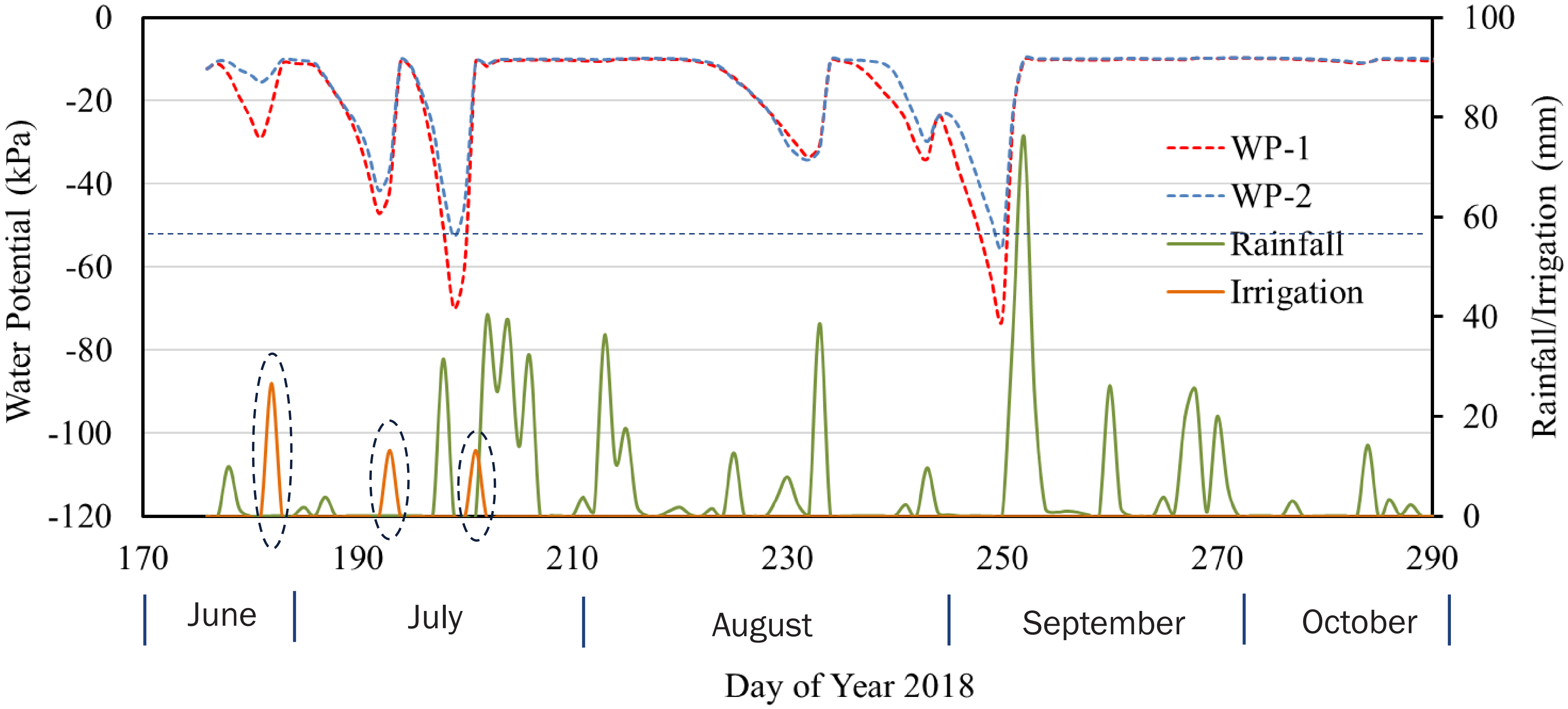
## Soil Water Potential-Based Irrigation



# Case I: Sensor-Based Irrigation

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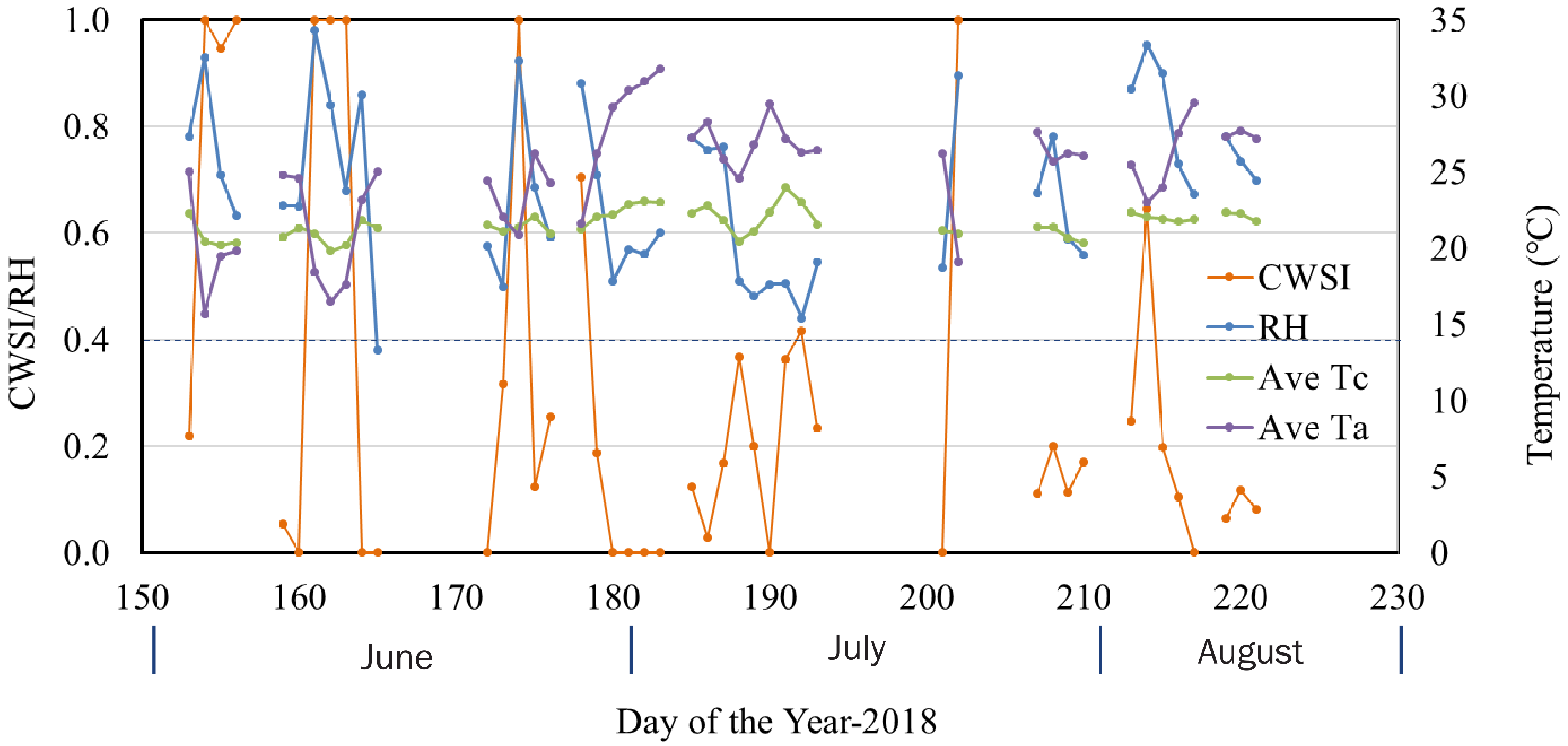
## Canopy Temperature–Based Irrigation



# Case I: Sensor-Based Irrigation

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## Comparation of the Tested Methods

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

*Water use?*

*Crop production?*

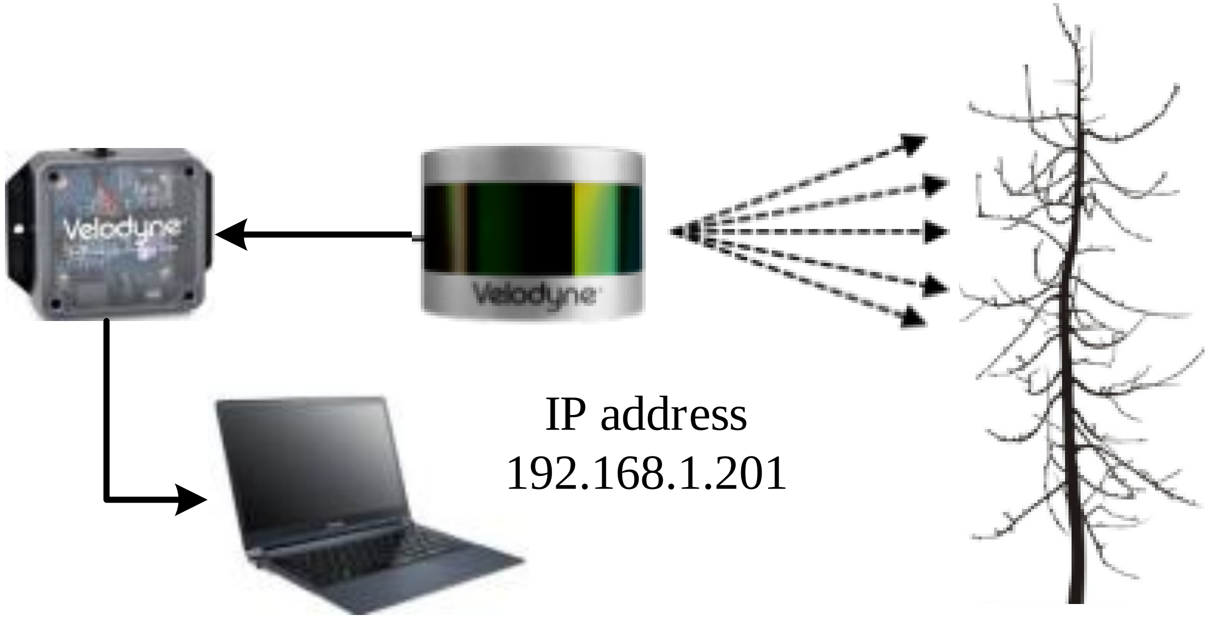
# Case II: Canopy Estimation using 3D LiDar

## 3D Canopy Reconstruction

- ❖Mechanical summer pruning
- ❖Precision spraying
- ❖Orchard platform auto guidance

# Case II: Canopy Estimation using 3D LiDar

## Experimental Setup



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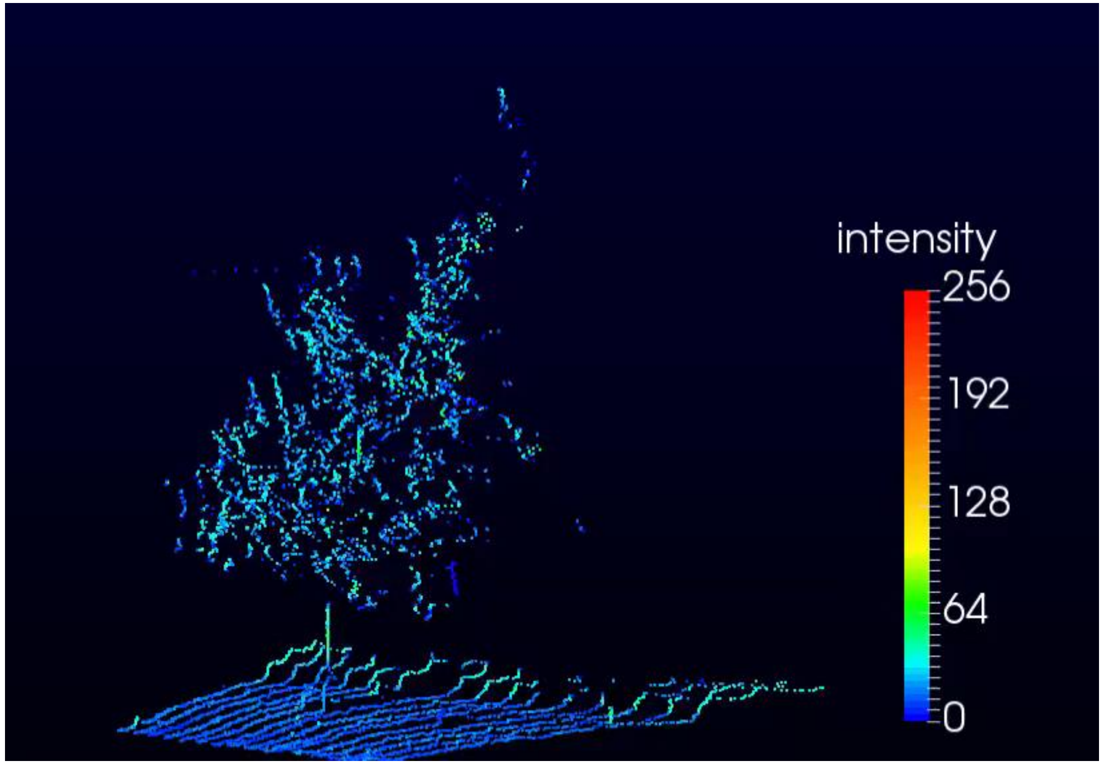
# Case II: Canopy Estimation using 3D LiDar

## Field Test with a Utility Vehicle

# Case II: Canopy Estimation using 3D LiDar

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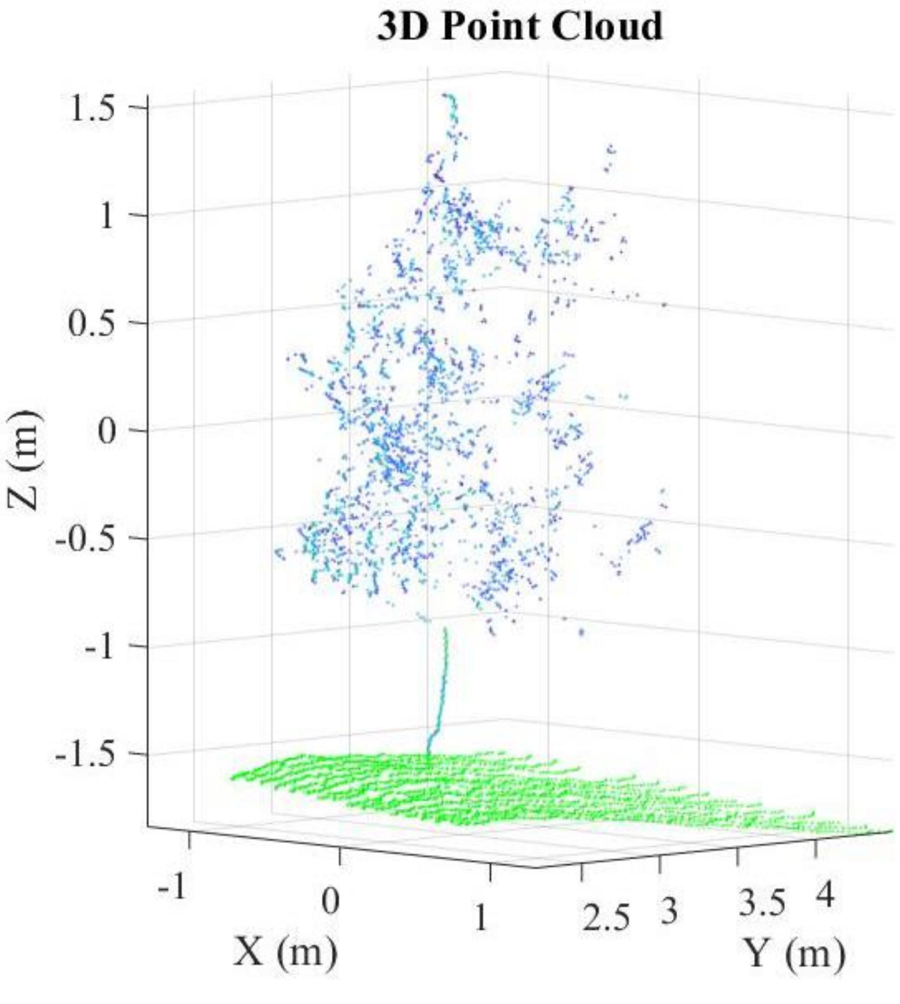
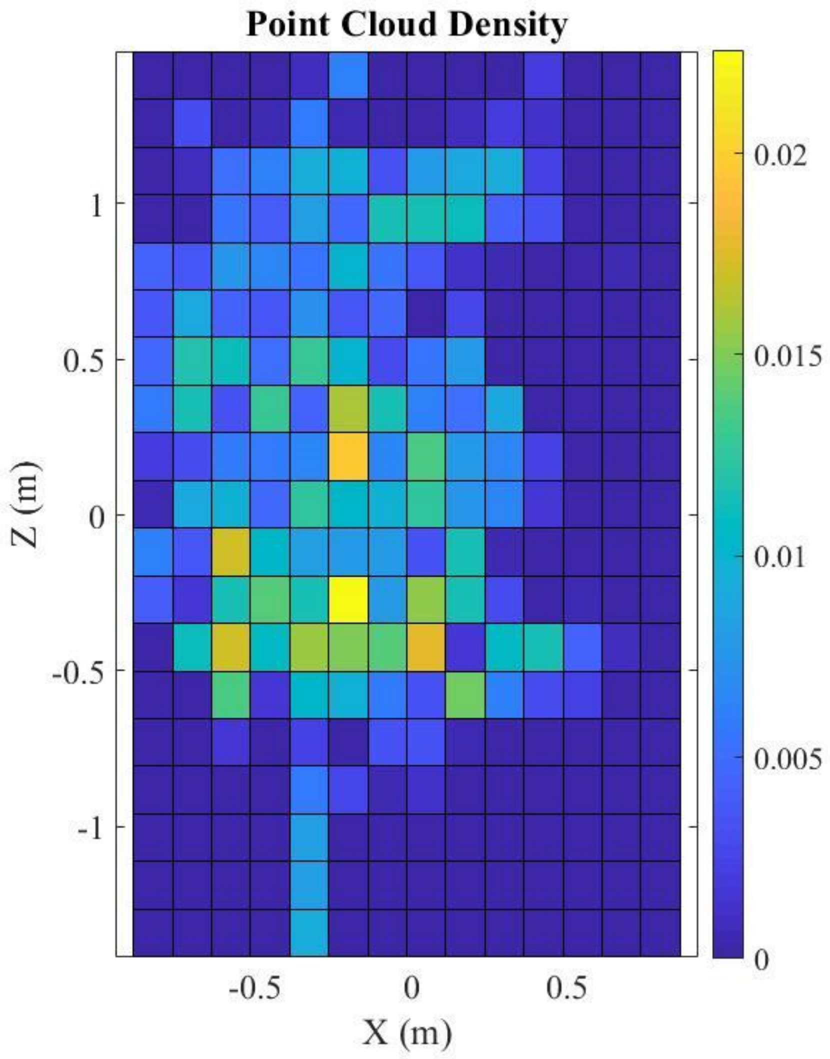
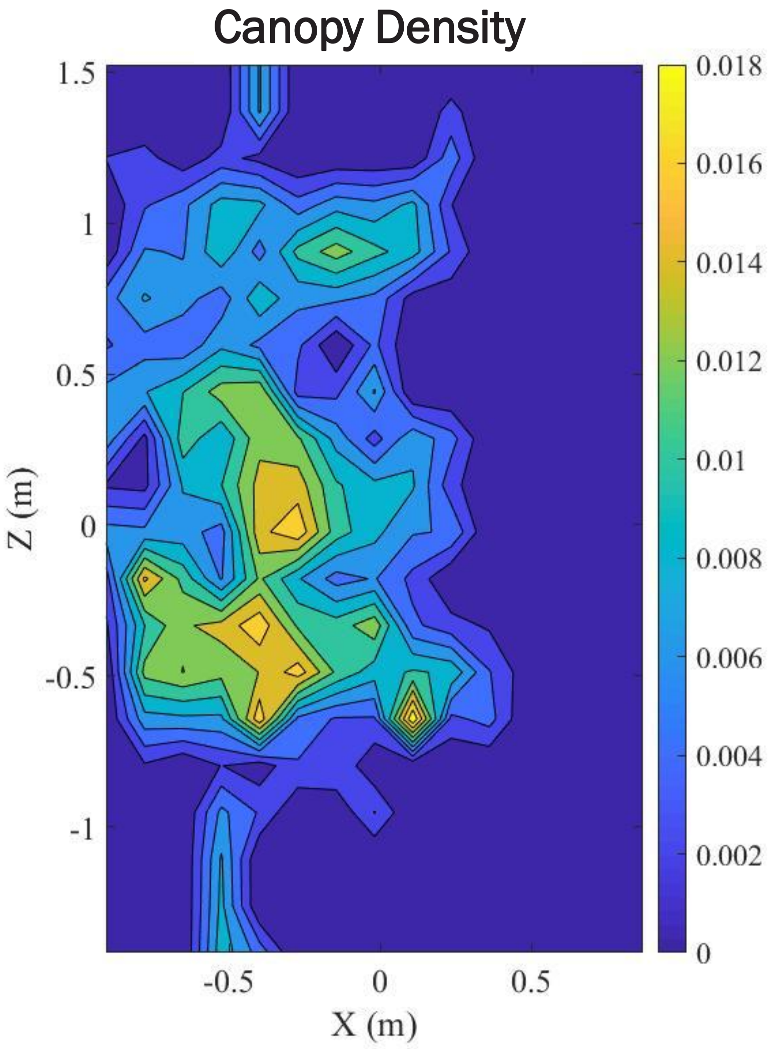
## Point Cloud of a Tree Canopy

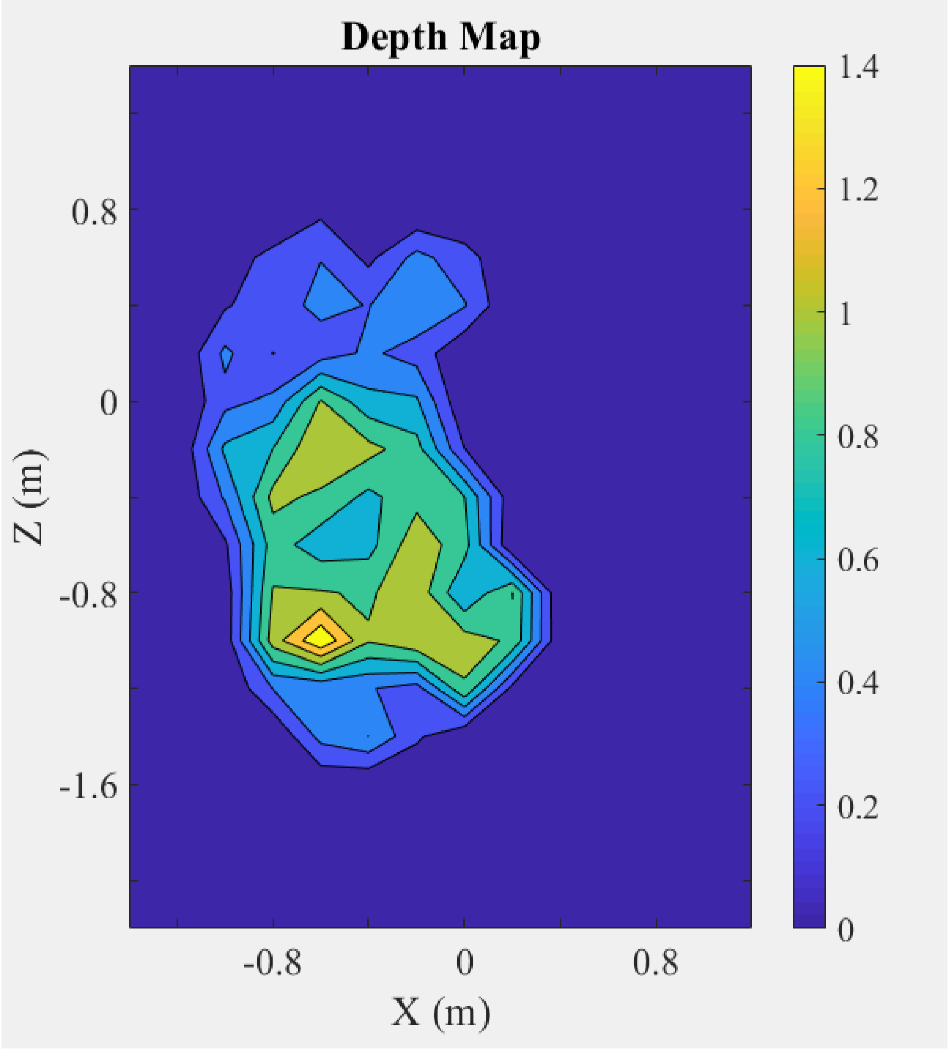


# Case II: Canopy Estimation using 3D LiDar





# Planning Project

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## Precision Spraying Technologies for Pest Management

From: USDA-ARS Dr. Heping Zhu

From: DJI MG-1S Sprayer Drone

### ❑ Activities

- Preliminary studies: pest/disease detection; variable rate sprayer
- Workshop/seminar: pest management, intelligent spraying, drone sprayer
- Seeking collaboration

# Acknowledgement

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- **Funding Agency**
  - State Horticultural Association of Pennsylvania (SHAP)
  - Penn State College of Agricultural Science
  - Penn State Extension
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  - Tara Baugher, Daniel Weber
- **Field Setup/Data Acquisition**
  - Azlan Zahid
  - Lihua Zeng

# Thank you !