Internet of Things (IoT) for Precision Irrigation Management in Tree Fruit Orchards

Long He

2021 Cornell NYS Tree Fruit Conference

February 4th, 2021

PennState College of Agricultural Sciences

PennState Extension

Importance of Precision Irrigation

PennState College of Agricultural Sciences · PennState Extension


Photo: Rayies Altaf

Challenges for Conventional Irrigation:

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

Precision Irrigation:

- Rely on data
- When and how much to irrigate

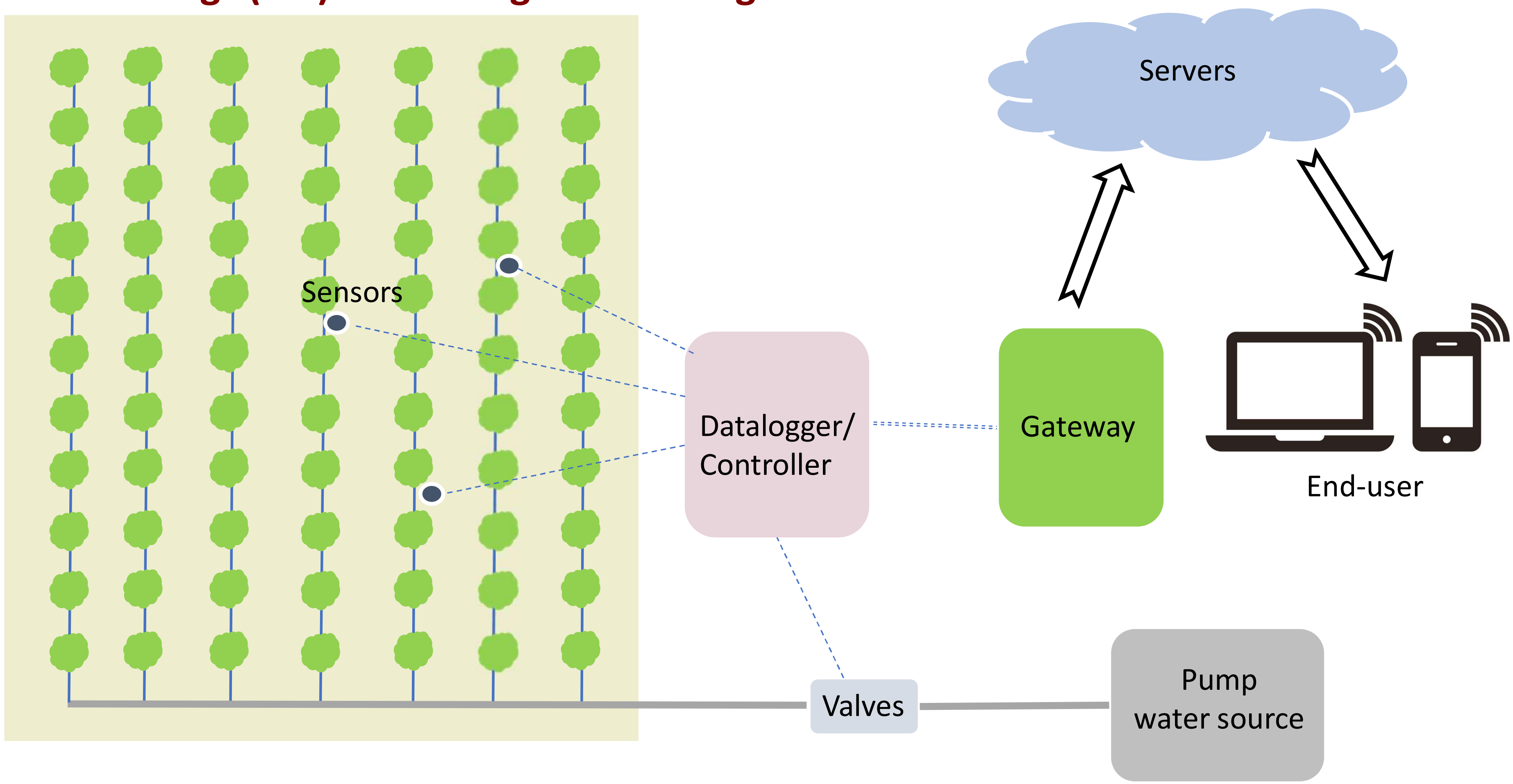

Photo: FarmersTrend, 2017

Benefit of Precision Irrigation:

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

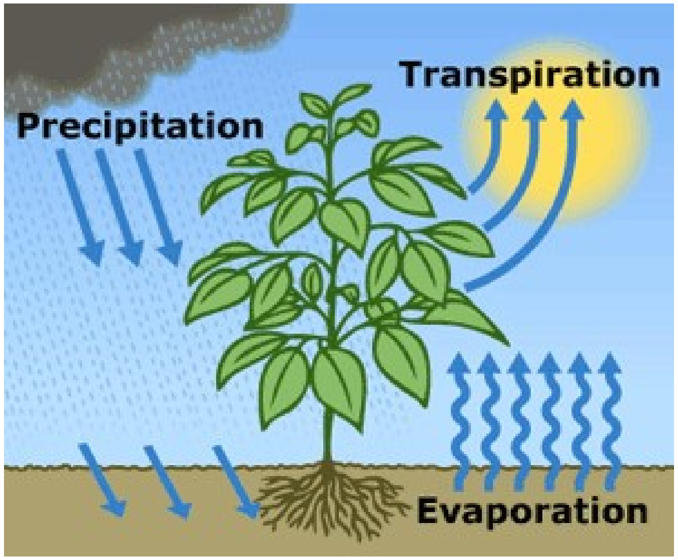
IoT for Precision Irrigation

Internet of Things (IoT) based Irrigation Management



Basics of Irrigation

Evapotranspiration (ET)



Penman–Monteith Model (P-M)

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

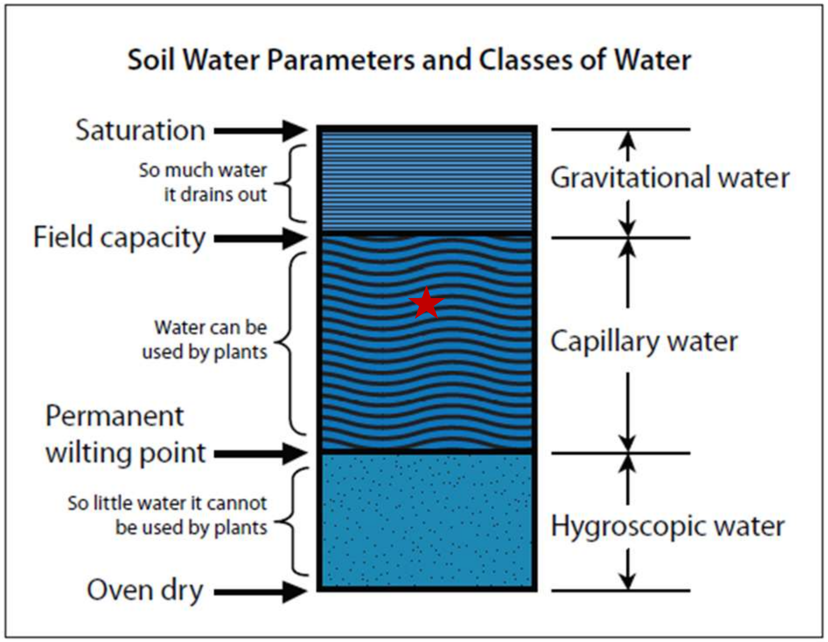
Parameters:

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

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

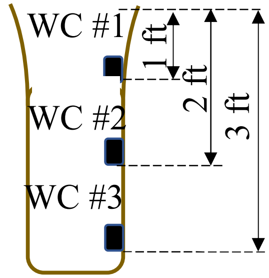
Soil Moisture Measurement

Fundamental Principles

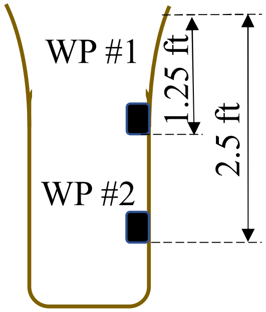


Soil Water Parameters (From: Texas A&M AgriLife Extension, E-618)

Soil Moisture Sensors



Soil water content sensor: TEROS 12 @ QTY 3



Soil water potential sensor: TEROS 21 @ QTY 2

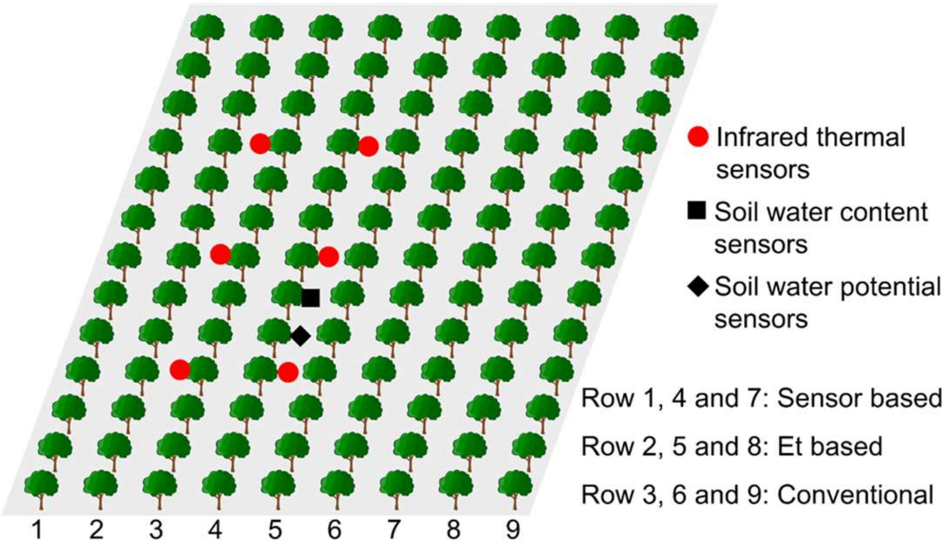
Precision Irrigation – Study One

PennState College of Agricultural Sciences   PennState Extension

Primary Goal

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

Experimental Setup



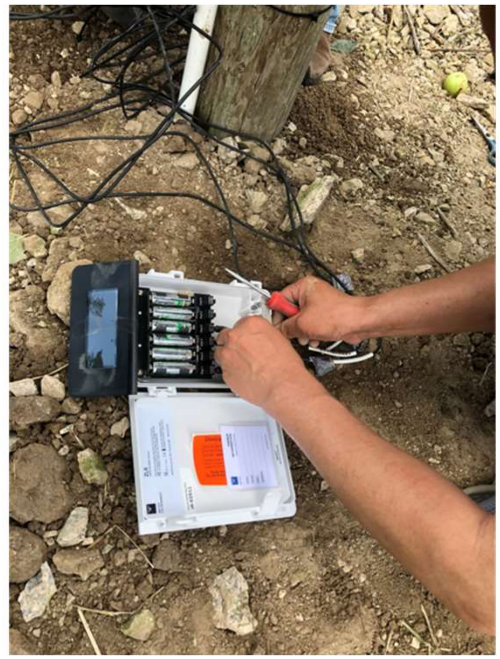
Precision Irrigation – Study One

PennState College of Agricultural Sciences

PennState Extension

A Cellular Network based IoT Irrigation System





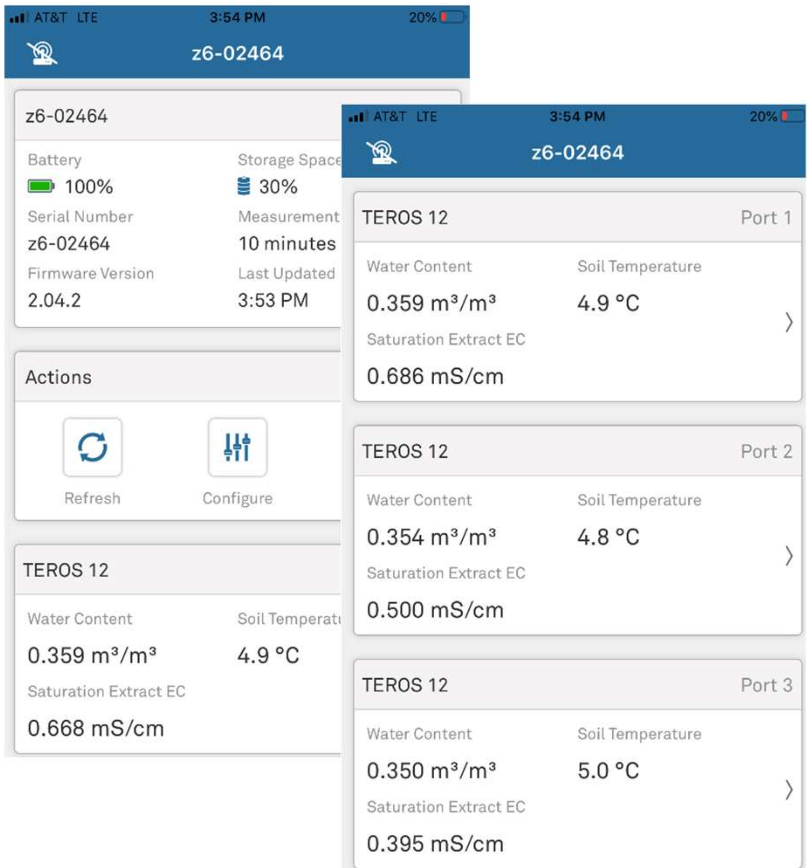

- Soil water content and Potential sensors
- Datalogger to record sensor data
- Cellular network for data communication (cloud server)

Precision Irrigation – Study One

PennState College of Agricultural Sciences

PennState Extension

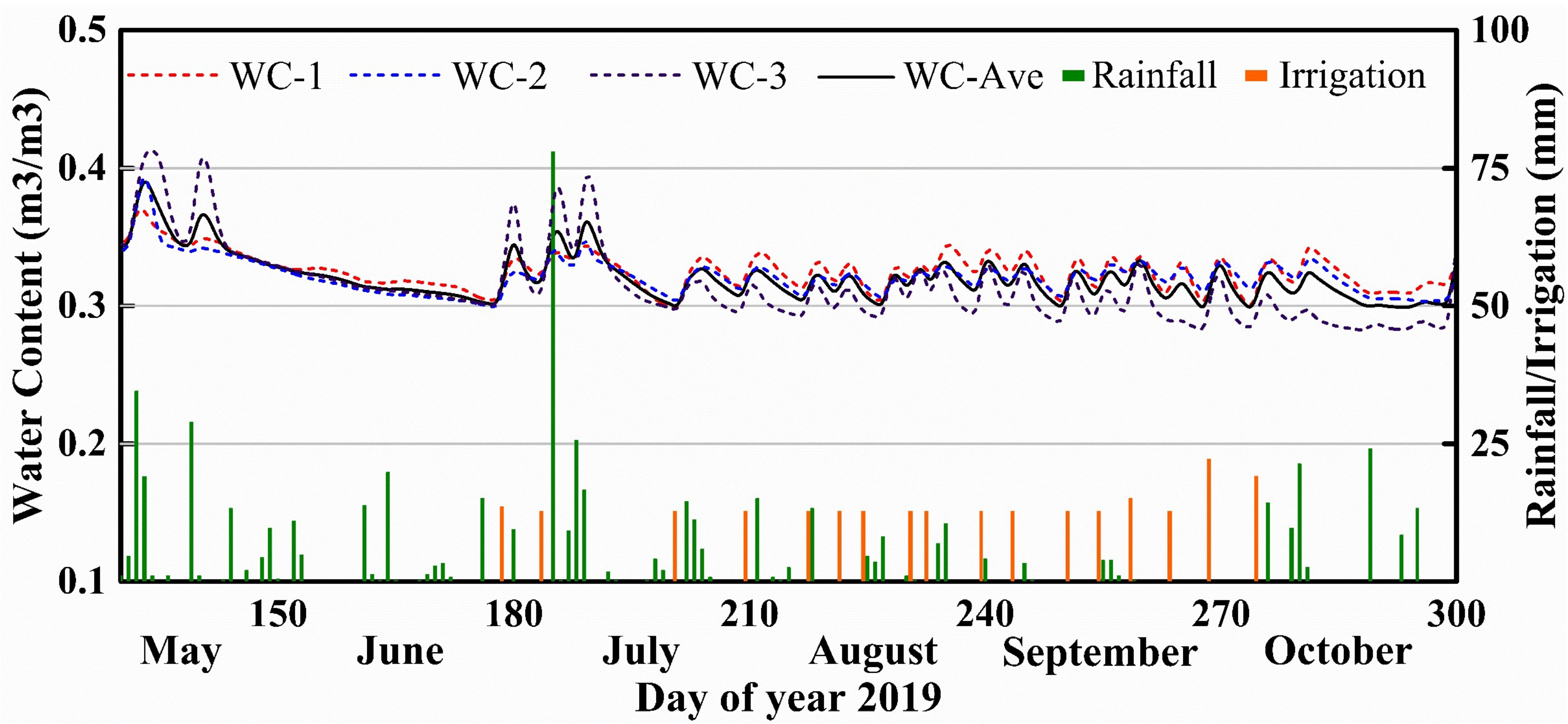
Soil Moisture Data Monitoring & Recording



Precision Irrigation – Study One

PennState College of Agricultural Sciences
PennState Extension

Results in Research Orchard - Soil Water Content

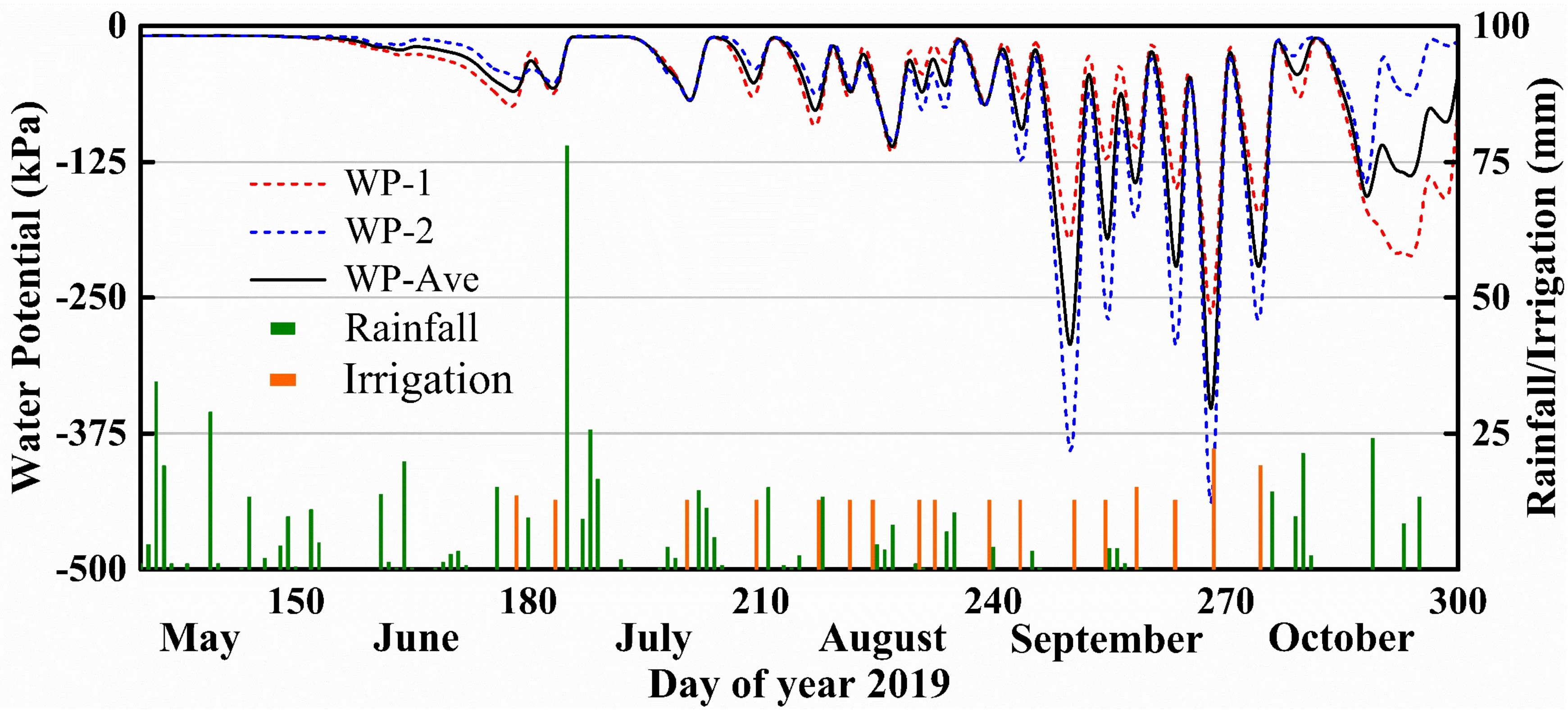


Precision Irrigation – Study One

PennState College of Agricultural Sciences

PennState Extension

Results in Research Orchard - Soil Water Potential

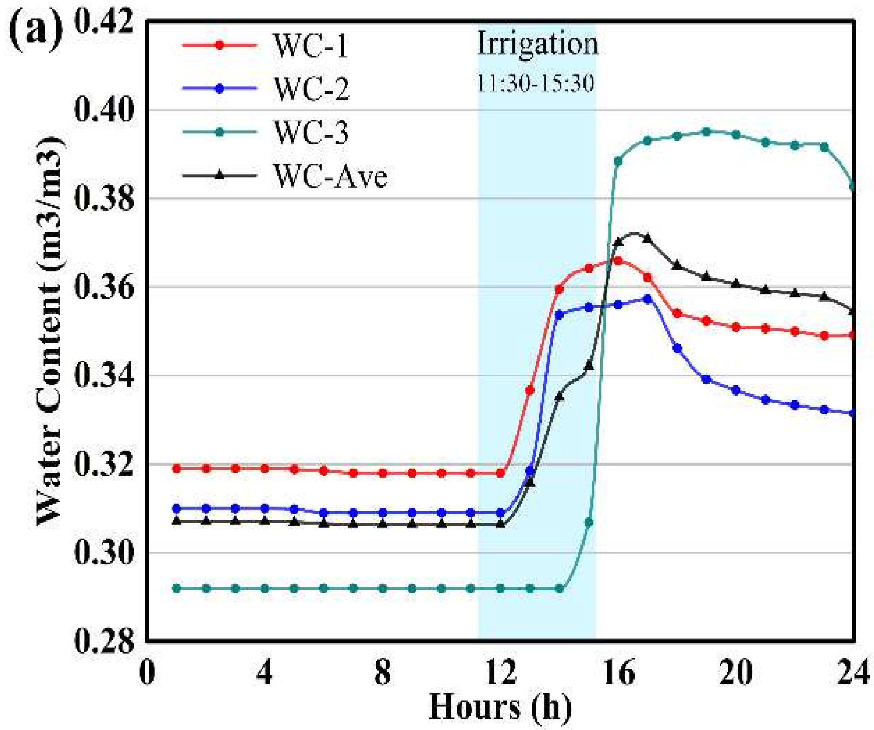


Precision Irrigation – Study One

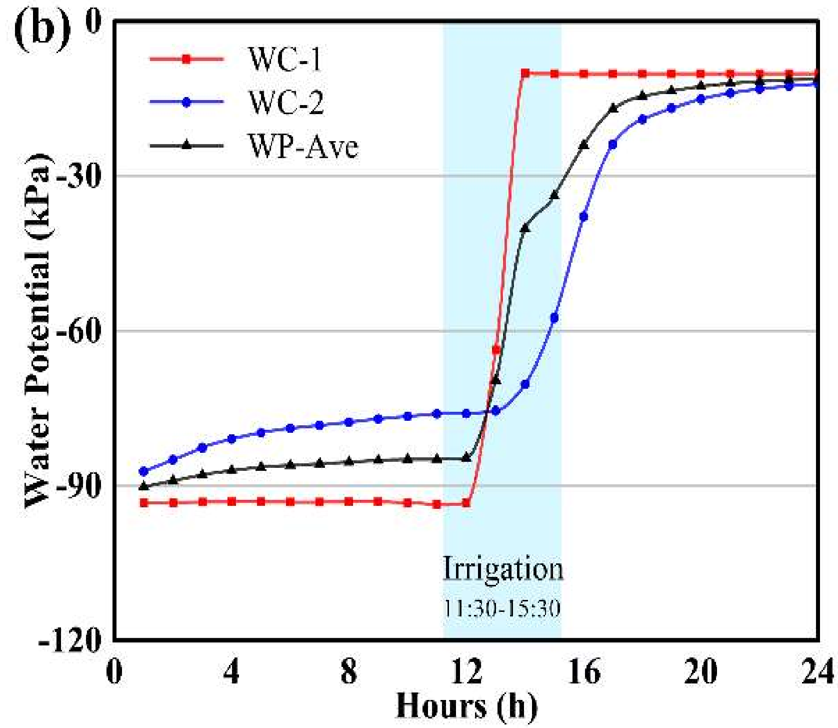
PennState College of Agricultural Sciences

PennState Extension

Sensor Data in an Irrigation Event



a). Soil water content



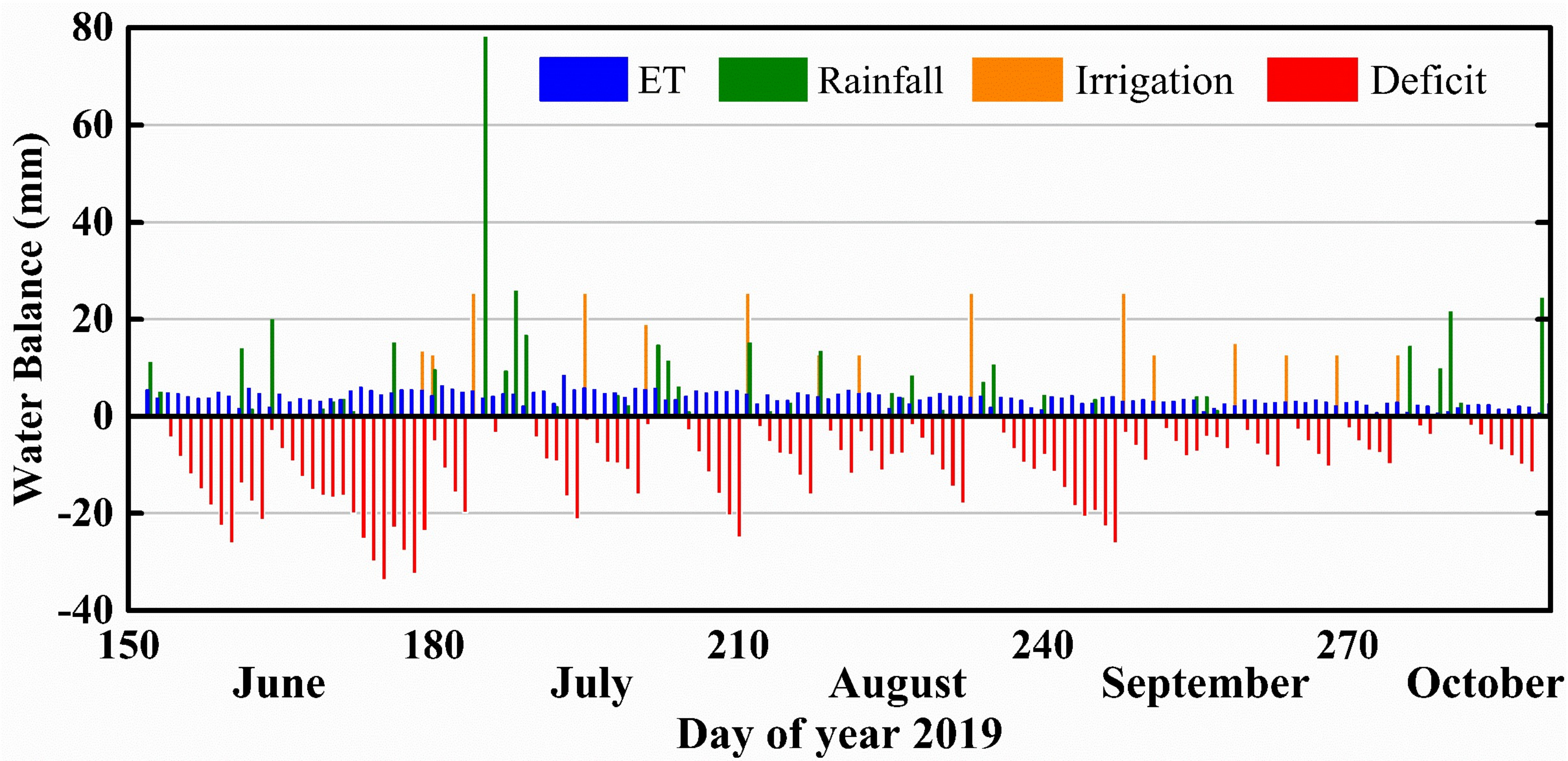
b). Soil water potential

Precision Irrigation – Study One

PennState College of Agricultural Sciences

PennState Extension

Results in Research Orchard - Evapotranspiration (ET)



Performance among Different Irrigation Methods

Irrigation strategies	Overall water use (mm)	Crop yield/tree (kg) (Mean±sd)	Crop size (g) (Mean±sd)	Hardness (kg) (Mean±sd)	Soluble solids (oBrix) (Mean±sd)
Moisture-based	**235**	**24.4±3.5a**	243.1±22.9a	8.2±0.6a	16.1±0.7a
ET-based	264	23.4±4.9ab	264.4±19.1a	8.2±0.4a	16.0±1.0a
Conventional	247	20.9±3.1b	258.2±15.3a	8.4±0.5a	15.9±0.8a

Precision Irrigation – Study One

PennState College of Agricultural Sciences

PennState Extension

Test in Commercial Orchards

Hollabaugh Bro. Inc
(Honey Crisp)

Mt. Ridge Farms
(Fuji)

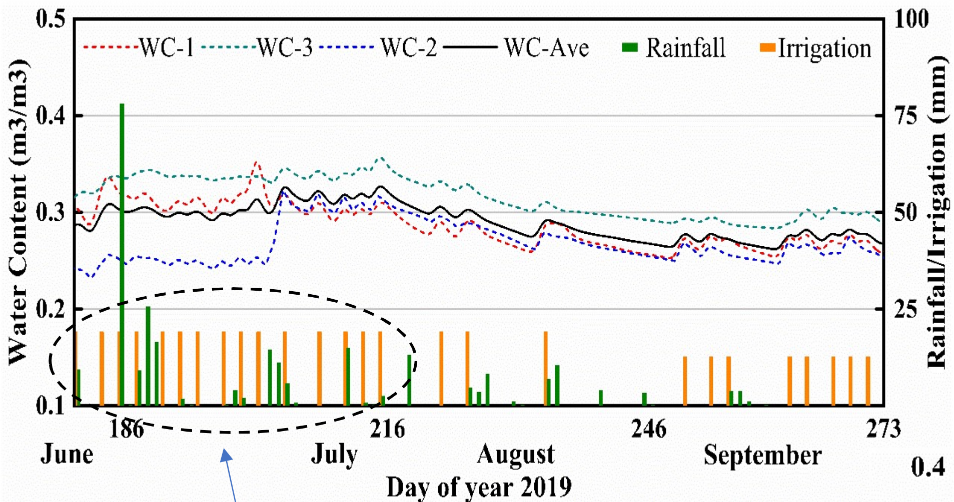
Twin Springs Fruit Farm
(Crimson Crisp)

El Vista Orchards
(Gala)

Precision Irrigation – Study One

PennState College of Agricultural Sciences | PennState Extension

Soil Water Content/Irrigation/Rainfall

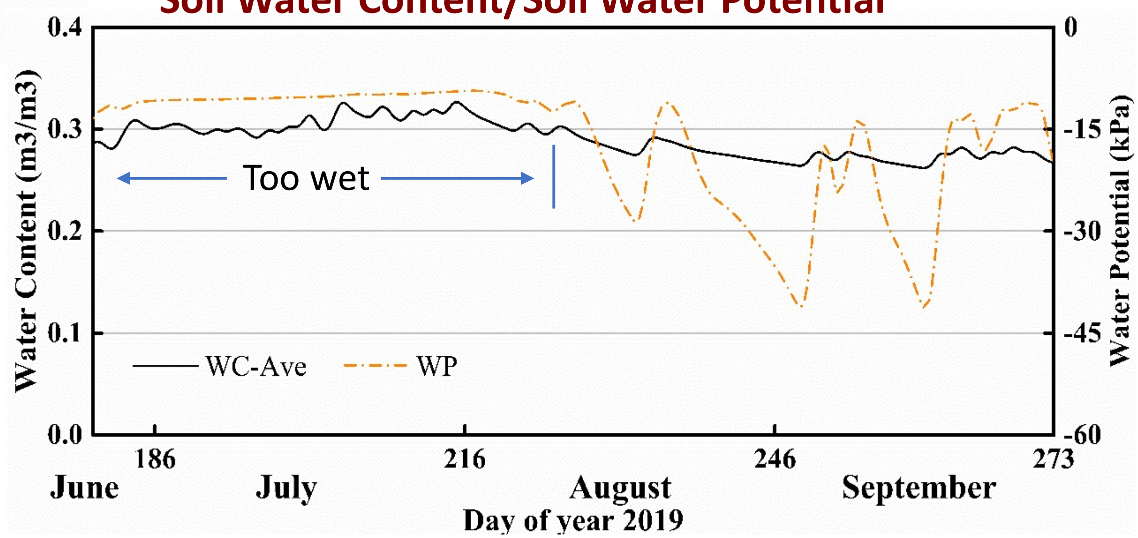


Three times/week (Timer)
6 hours each time

Data in A Commercial Orchard

2019 Season

Soil Water Content/Soil Water Potential

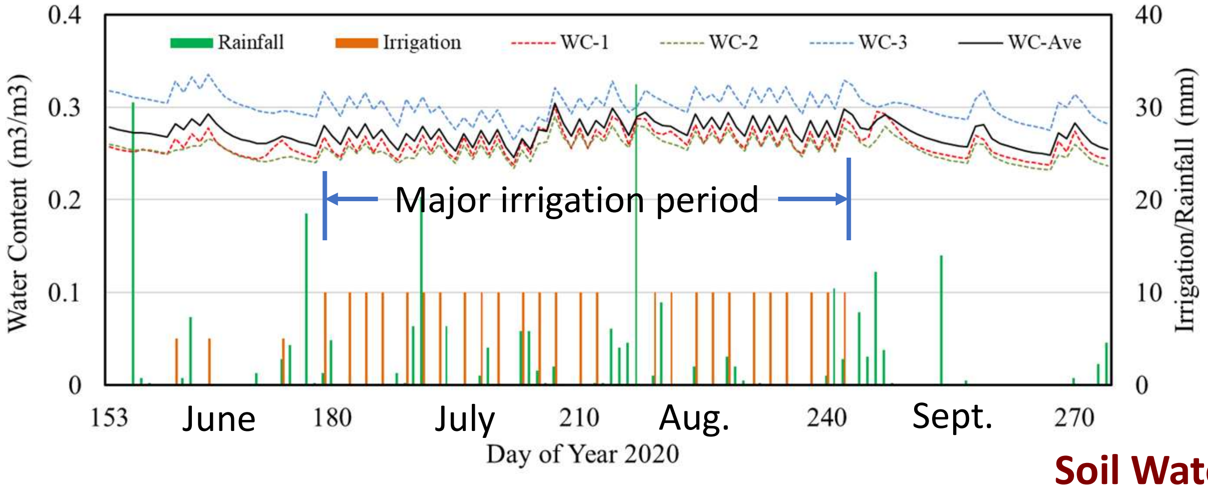


Precision Irrigation – Study One

PennState College of Agricultural Sciences

PennState Extension

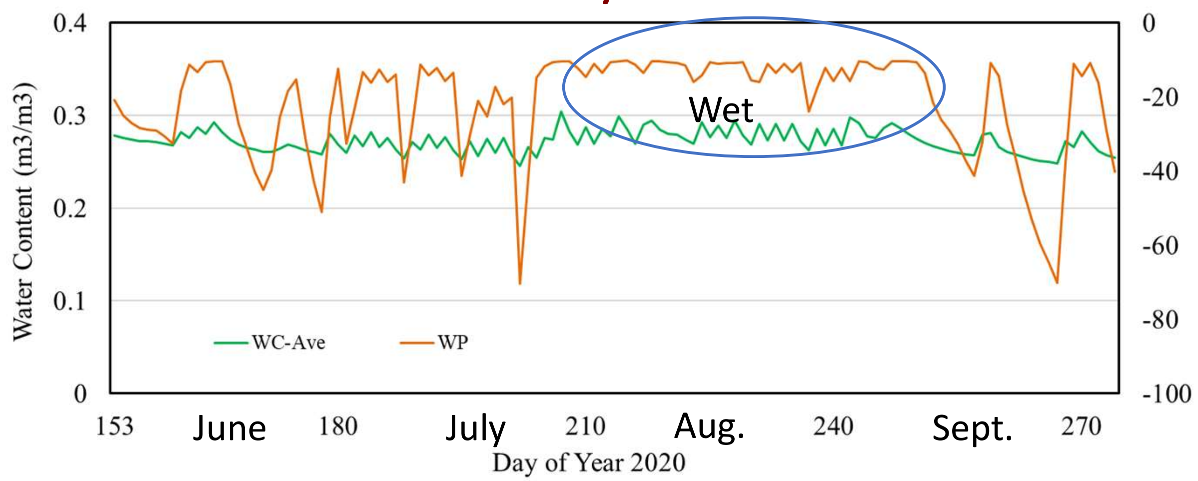
Soil Water Content/Irrigation/Rainfall



Data in A Commercial Orchard

2020 Season

Soil Water Content/Soil Water Potential



Precision Irrigation – Study Two

PennState College of Agricultural Sciences · PennState Extension

LoRa (Long Range) IoT Irrigation System

Soil Moisture Sensor

Datalogger &Gateway

Valve Control

IoT Platform

THE THINGS NETWORK

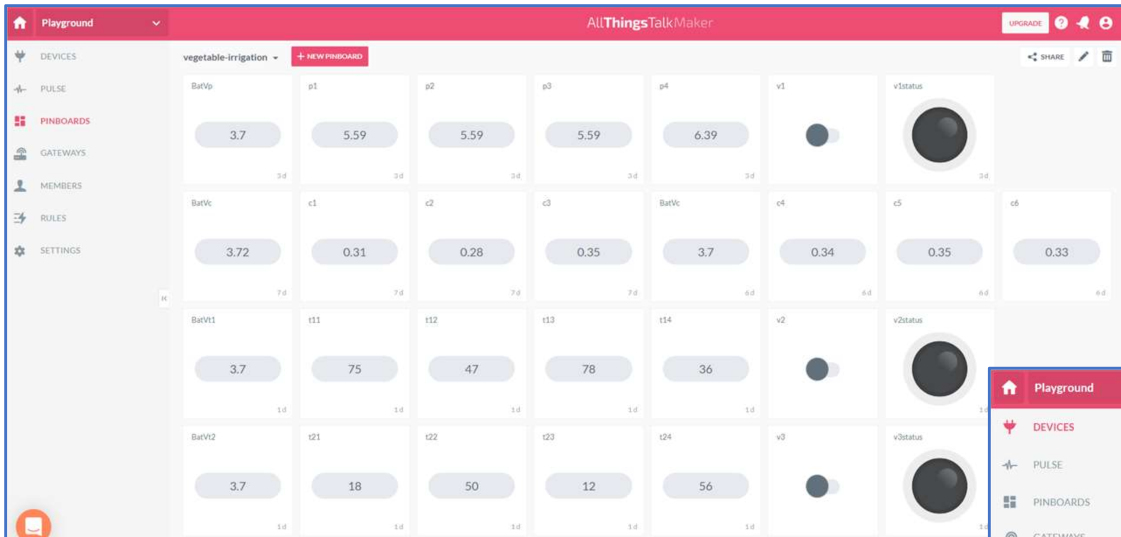
AllThingsTalk

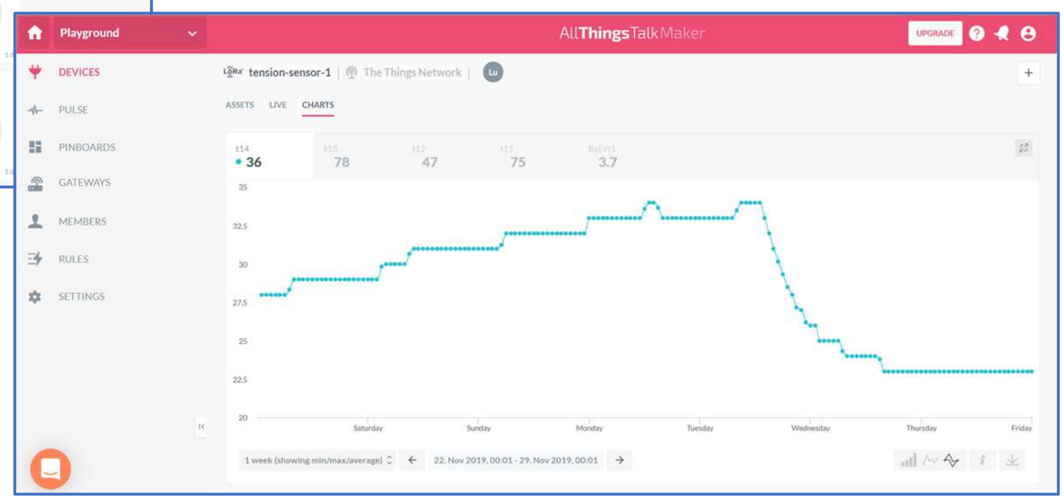
Precision Irrigation – Study Two

PennState College of Agricultural Sciences

PennState Extension

Interface of the IoT irrigation System





Remote/Automated Irrigation Operation!

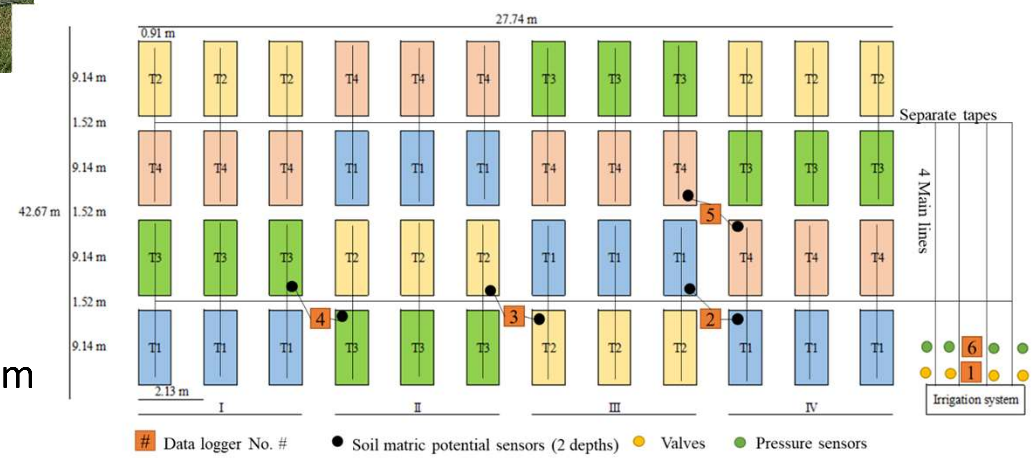
Precision Irrigation – Study Two

PennState College of Agricultural Sciences | PennState Extension

Field Test in A Tomato Field

- Tomatoes were transplanted on May 21st, 2020
- There were 48 sections with 20 plants at each section
- Sub-surface drip irrigation
- Same nutrient level applied to the whole field
- Harvest dates: 8/7; 8/19; 9/1; 9/11; and 9/23

- Four Treatments:
  - Treatment #1 (T1): ET based irrigation
  - Treatment #2 (T2): Soil water potential (-40 kPa)
  - Treatment #3 (T3): Soil water potential (-60 kPa)
  - Treatment #4 (T4): GesCon decision support system



Precision Irrigation – Study Two

PennState College of Agricultural Sciences

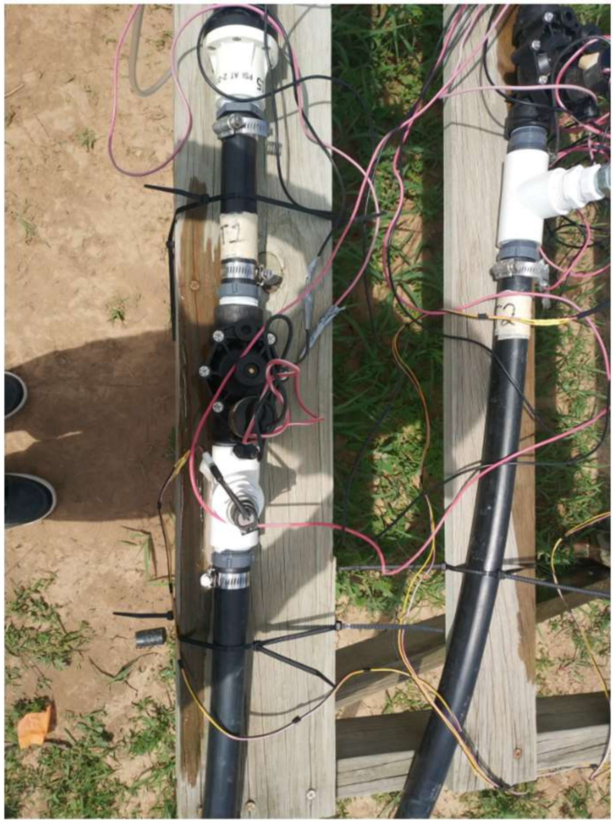
PennState Extension

Irrigation System Setup

Precision Irrigation – Study Two

PennState College of Agricultural Sciences PennState Extension

Sensing/Control System Setup



Precision Irrigation – Study Two

Experiment Results

❖ Water Use Efficiency

Treatment	T1	T2	T3	T4
Water use efficiency (kg/m^3)	22.22	26.49	27.94	28.30

❖ Crop Yield and Quality

Treatment	Total Harvest ($Mg\ ha^{-1}$)					
	XL	L	M	Cull	TMY	TY
T1	46.35	4.52	3.34	25.73	54.21	79.95
T2	52.71	6.46	3.26	23.66	62.43	86.09
T3	38.16	5.43	3.75	27.49	47.34	74.83
T4	56.72	5.95	3.52	20.00	66.19	86.20

XL – extra large; L – large; M – medium; TMY – total market yield; TY – total yield

Precision Irrigation – Study Two

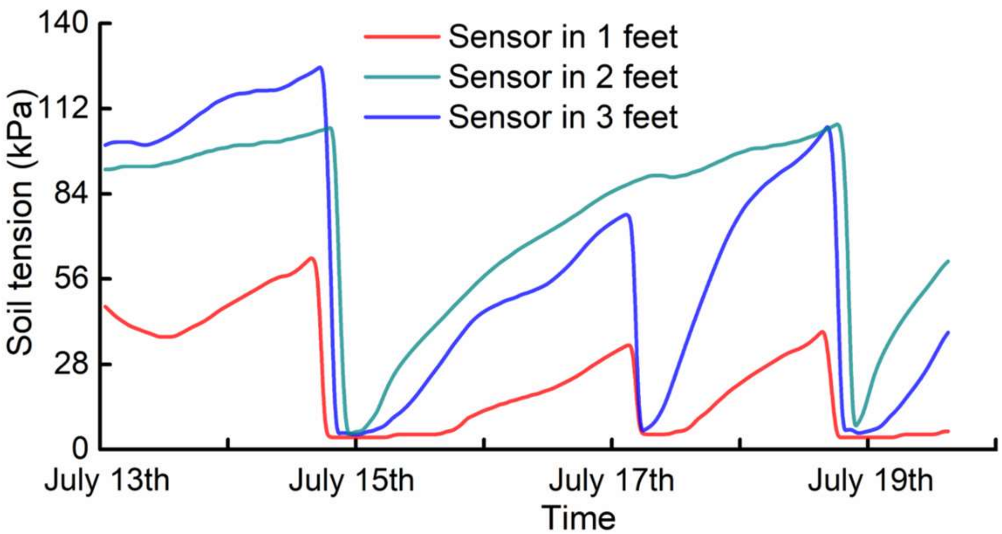
PennState College of Agricultural Sciences

PennState Extension

A Preliminary Study in A Peach Orchard

Precision Irrigation – Study Two

A Preliminary Study in A Peach Orchard



- ❖ Water supply with an electric pump controller
- ❖ Tested the irrigation with soil moisture level
- ❖ Remotely controlled the valve
- ❖ A water pressure valve shows the status of the valve (on/off)
- ❖ Possible to run automatically

IoT Based Precision Irrigation

PennState College of Agricultural Sciences   PennState Extension

Conclusions

- Soil moisture is an easy and direct measurement for precision irrigation
- Soil moisture levels in the field can be accessed remotely through an IoT system
- Soil moisture-based irrigation was proved to be effective

A Few other thoughts:

- The cost of the system
- The location of the sensors to represent the crop root zoom
- Variation in soil types and orchard terrains
- Fully automated irrigation

Acknowledgement

Funding Sources:

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

Thanks to: Dr. Francesco Di Gioia and his students, Dr. Daniel Weber, Dr. Lihua Zeng, Haozhe Zhang, Xiaohu Jiang.