Internet of Things (IoT) Sensor-Based Precision Irrigation and Decision Support Systems for the Optimal Management of Irrigation and Fertigation in Fresh-Market Tomato

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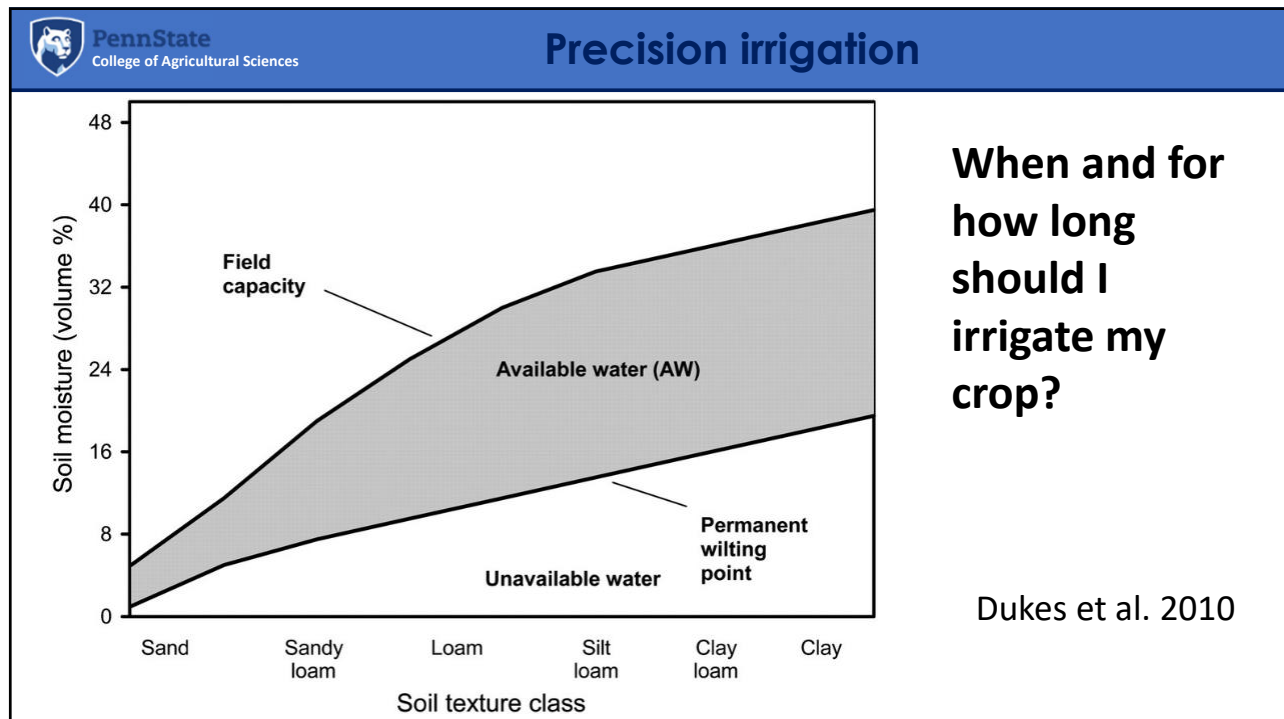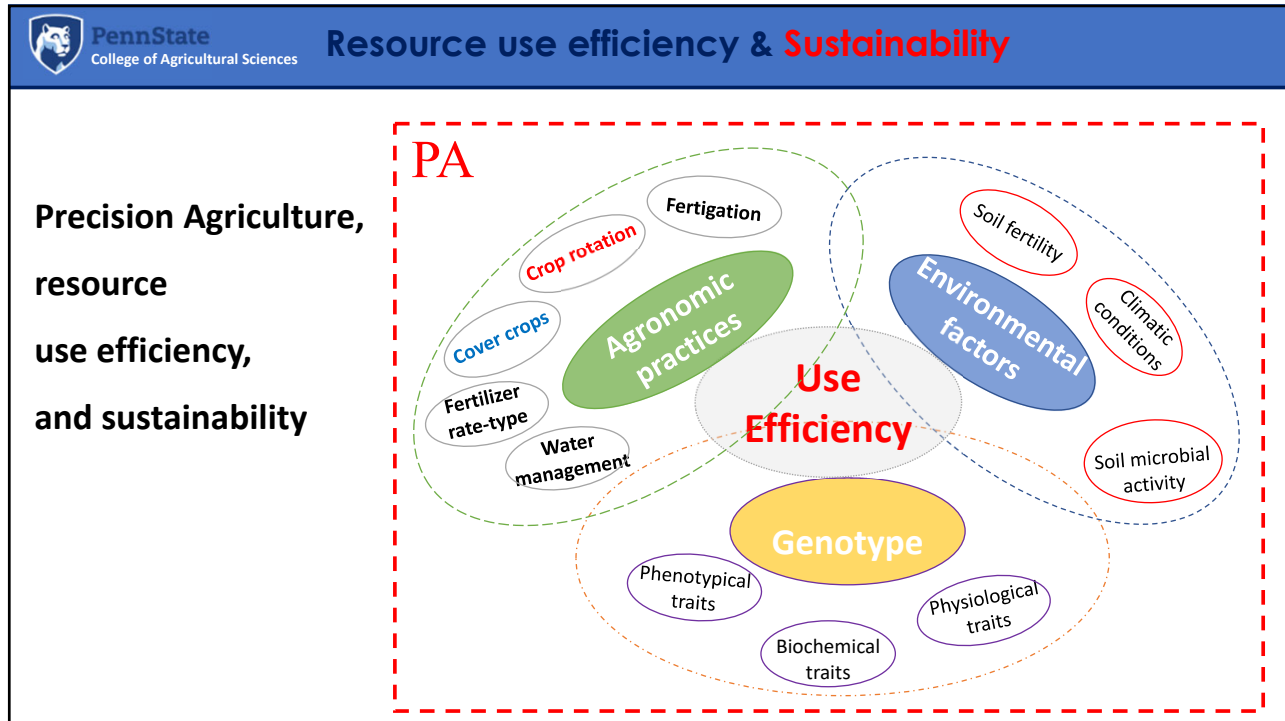**Antonio Elia** – Department of Agriculture, Food, Natural resources and Engineering, University of Foggia

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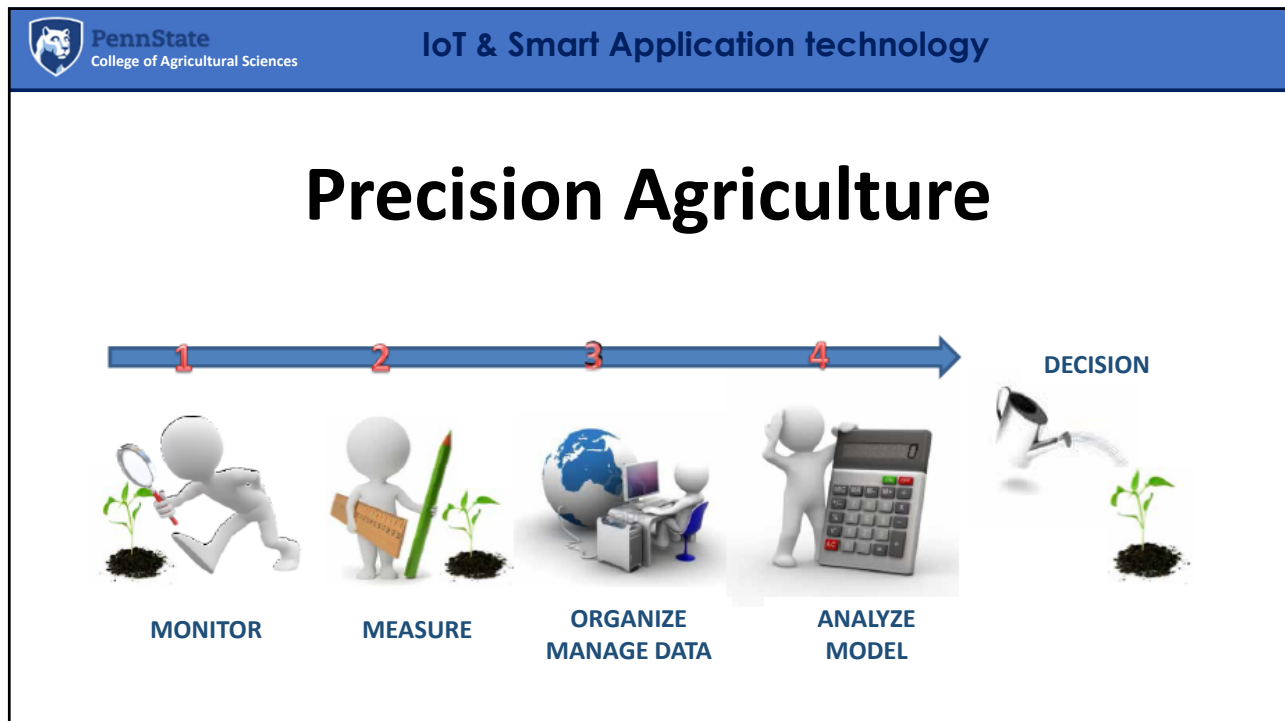Elevating Horticulture — ASHS 2021 Denver, Colorado August 5-9

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Precision irrigation

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When and for how long should I irrigate my crop?

Dukes et al. 2010

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Resource use efficiency & Sustainability

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Precision Agriculture,

resource

use efficiency,

and sustainability

PA

Fertigation

Crop rotation

Cover crops

Agronomic practices

Fertilizer rate-type

Water management

Use Efficiency

Soil fertility

Environmental factors

Climatic conditions

Soil microbial activity

Genotype

Phenotypical traits

Physiological traits

Biochemical traits

3

IoT & Smart Application technology

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Precision Agriculture

1   2   3   4   DECISION

MONITOR   MEASURE   ORGANIZE MANAGE DATA   ANALYZE MODEL

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Sensor-based **precision** irrigation systmes
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USDA-NIFA 2019 NE SARE Research and Education grant:
"**Sensor-based precision irrigation system for tree fruit and vegetable crops**"
PI: Long He
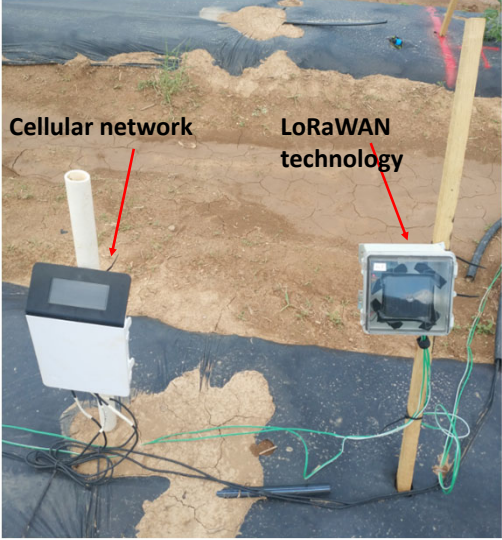Co-PI: Francesco Di Gioia, Daniel Weber, James Schupp, Tara Baugher

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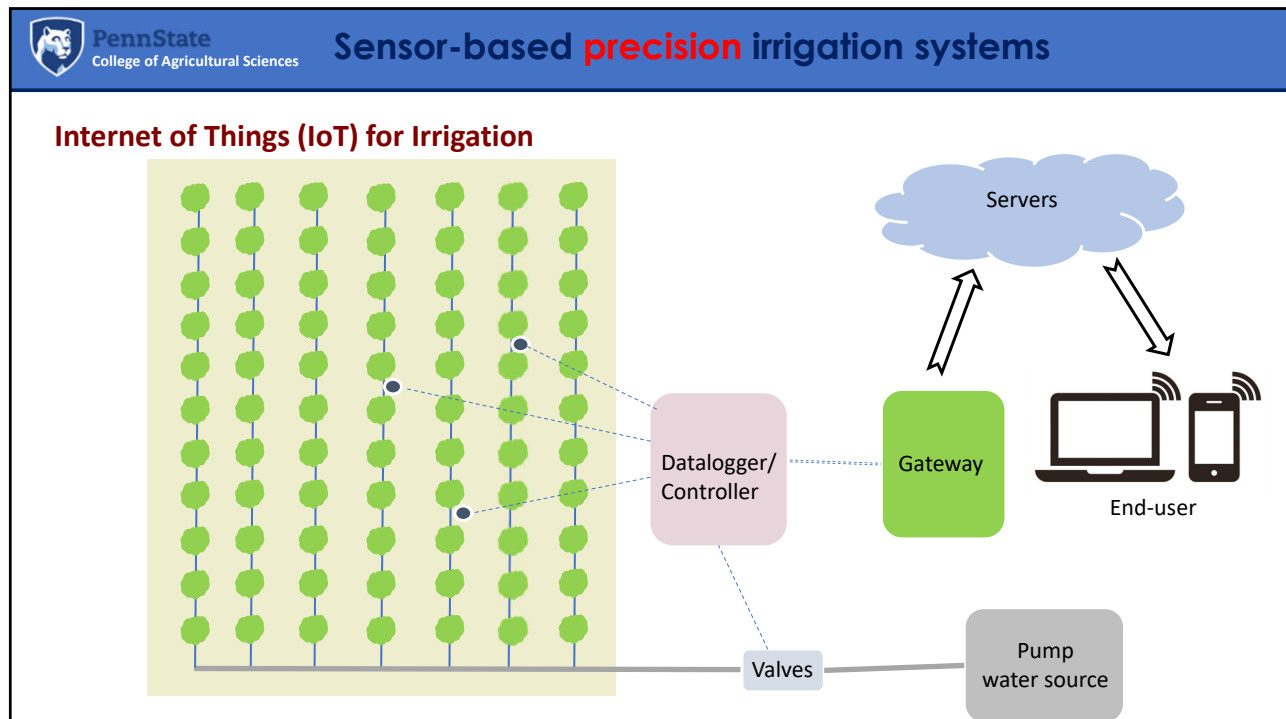
Sensor-based **precision** irrigation systems
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Internet of Things (IoT) for Irrigation

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Sensor-based **precision** irrigation systems

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Internet of Things (IoT) for Irrigation

Cellular network

LoRaWAN technology

❖ **Cellular network**
- Based on GSM network (2G/3G)
- Long distance application
- Remotely data access

❖ **LoRaWAN technology**
- Low Power Wide Range Network
- Communication through internet
- Remotely data access
- Remote/automated irrigation operation

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2019 precision irrigation study

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Photo by Di Gioia

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Teros 10 sensors
(Meter Group)

Soil Volumetric Water Content Sensors

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Teros 21 sensors
(Meter Group)

Soil Water Potential Sensors

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2019 precision irrigation study

Photo by Di Gioia
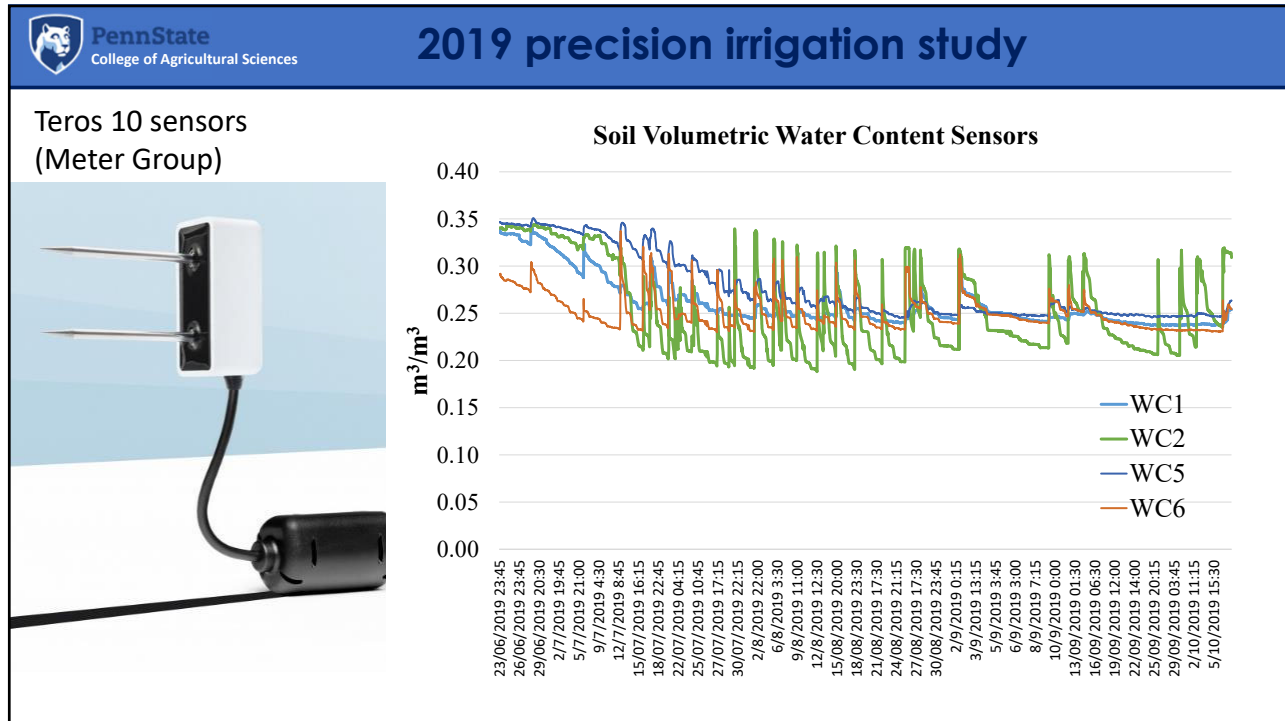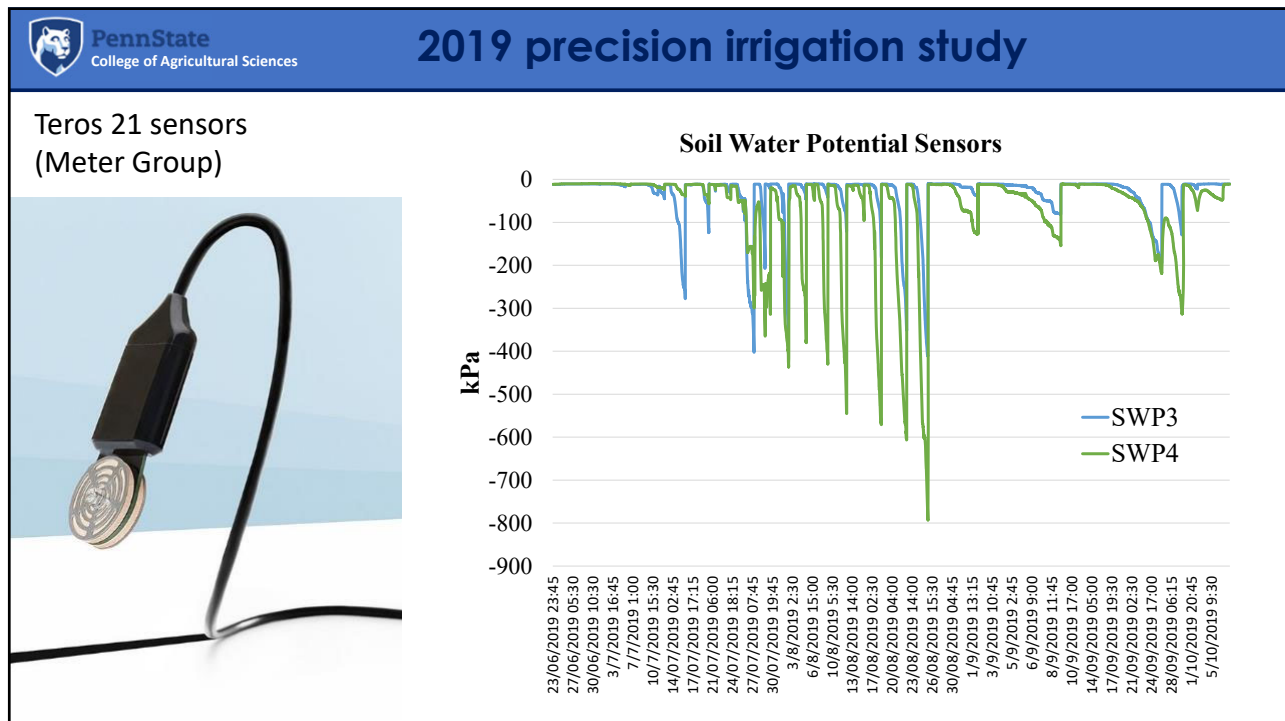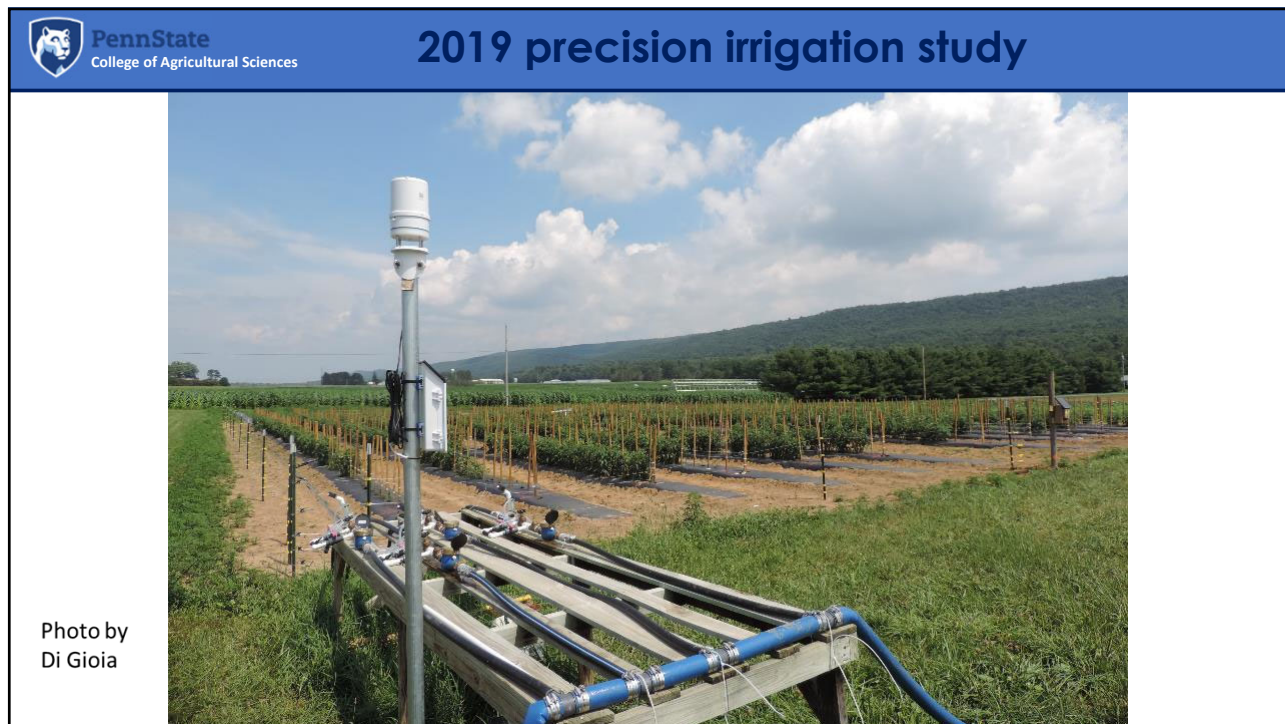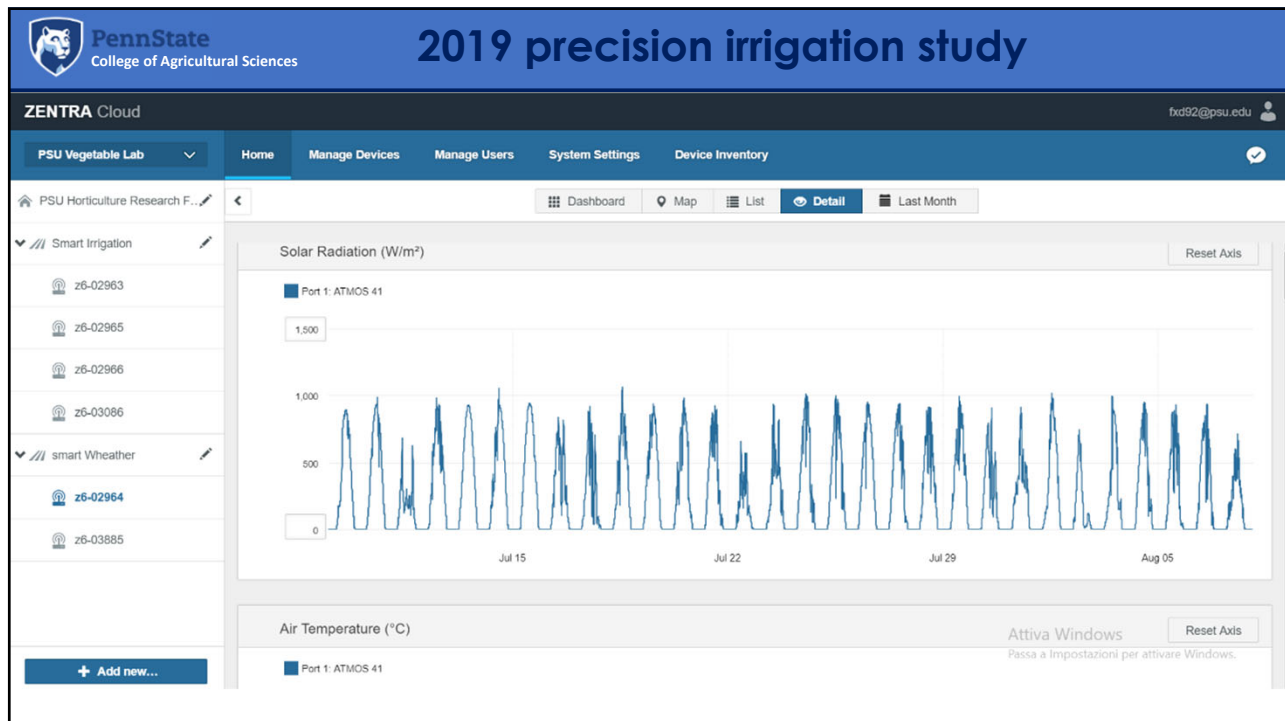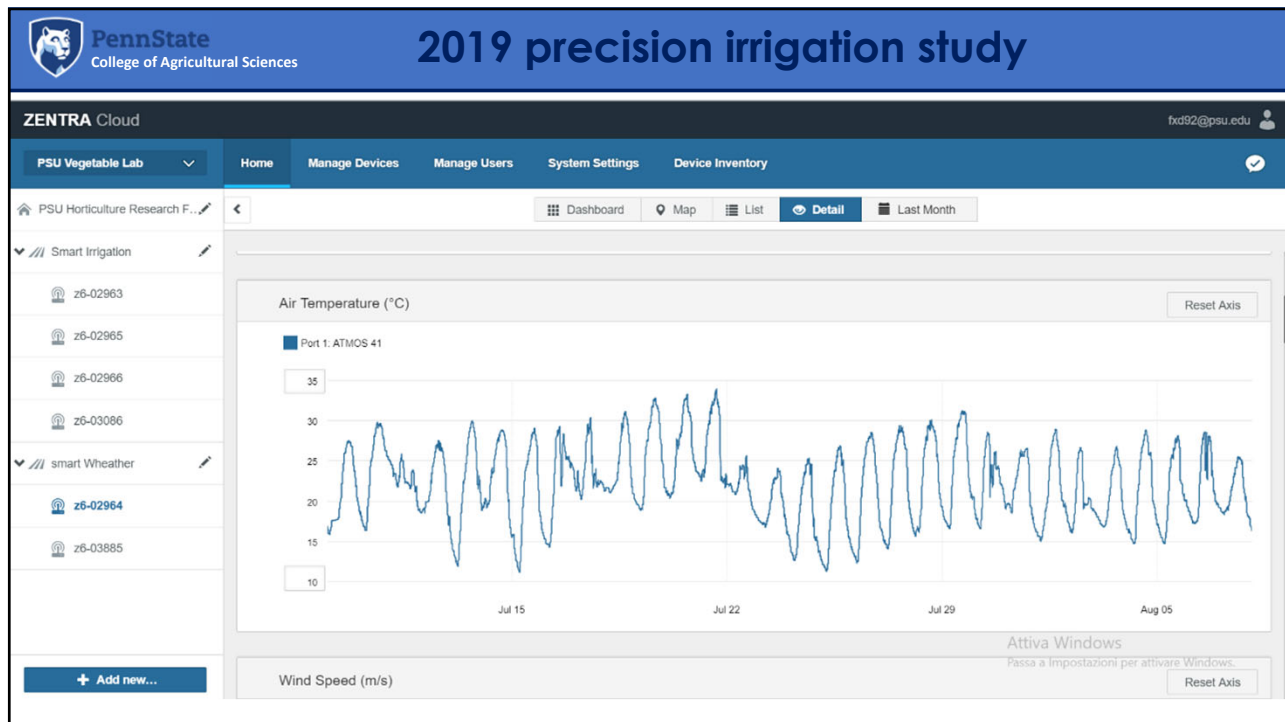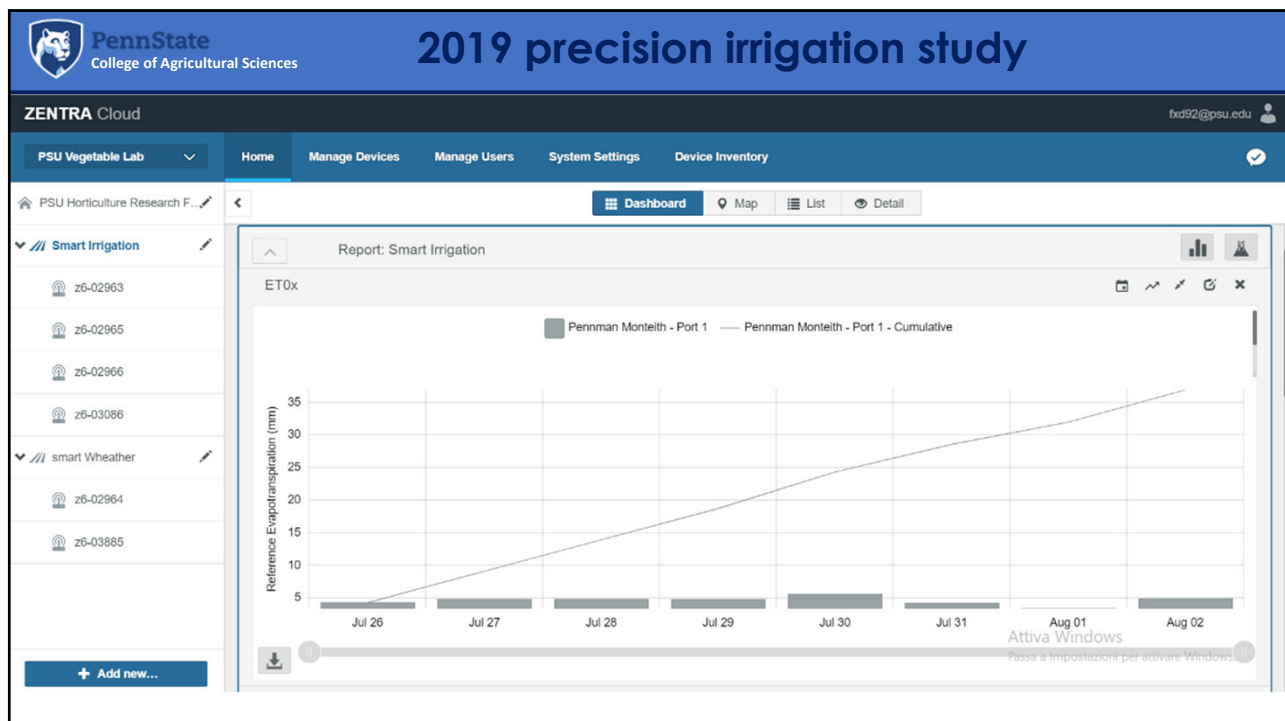
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2019 precision irrigation study

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2019 precision irrigation study

GesCoN Fertigation manager module

www.ecofert.it

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2019 precision irrigation study

GesCoN Fertigation manager module

Simulation output Penn State University 2019 fresh market tomato trial

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2019 precision irrigation study

Preliminary study conducted in high tunnel in the fall of 2019 using cabbage as a test crop

Zhang et al. 2020 ASABE

Photo by Di Gioia

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2020 precision irrigation study

Overall Experimental Setup

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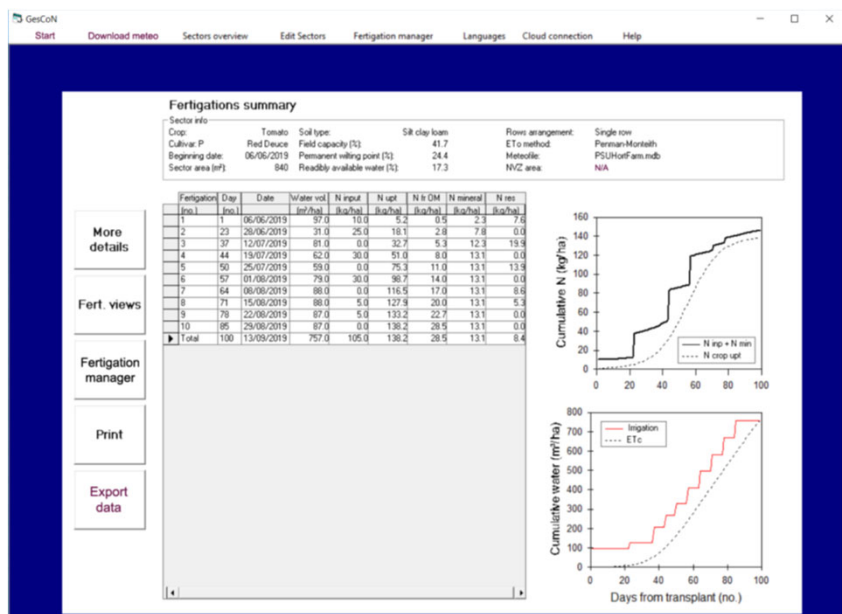- ❖ There were 48 sections with 20 plants at each section
- ❖ Sub-surface drip irrigation
- ❖ Same nutrient level applied to the whole field
- ❖ Harvest dates: 8/7; 8/19; 9/1; 9/11; and 9/23
- ❖ Randomized complete block design

❖ 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

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Irrigation System Setup

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Solenoid Valves and Pressure Sensors

❖ Solenoid Valves
 - One for each treatment
 - DC power

❖ Pressure Sensors
 - After each valve
 - Indicate the water pressure

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Fertilizer Injectors, Pressure Regular Valves, and Gauges

❖ Fertilizer was applied evenly for the four treatments

❖ Pressure was set to 13 psi to the driplines

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Flow Meters

❖ Water use amount was recorded for every irrigation event

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Planting
May 21, 2020

Initially plants
went through
cold and
harsh
weather

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2020 precision irrigation study

June 10, 2020
Soil moisture
sensors
installation

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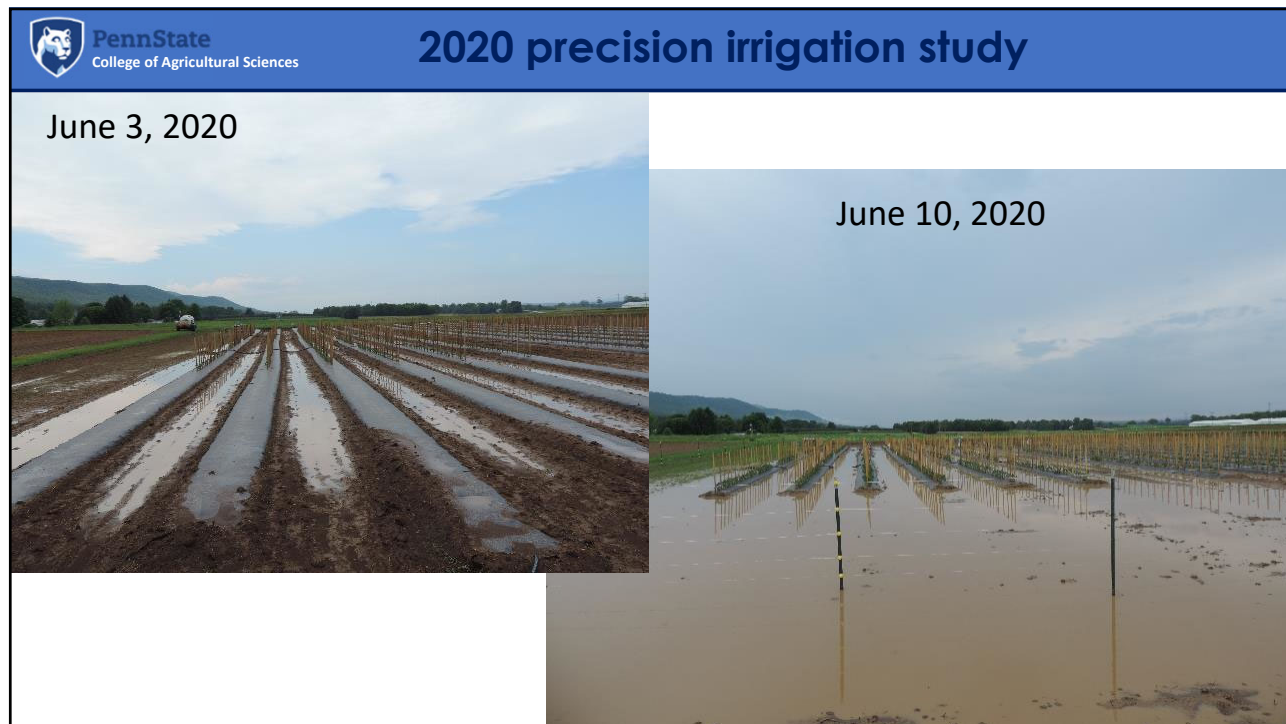
2020 precision irrigation study
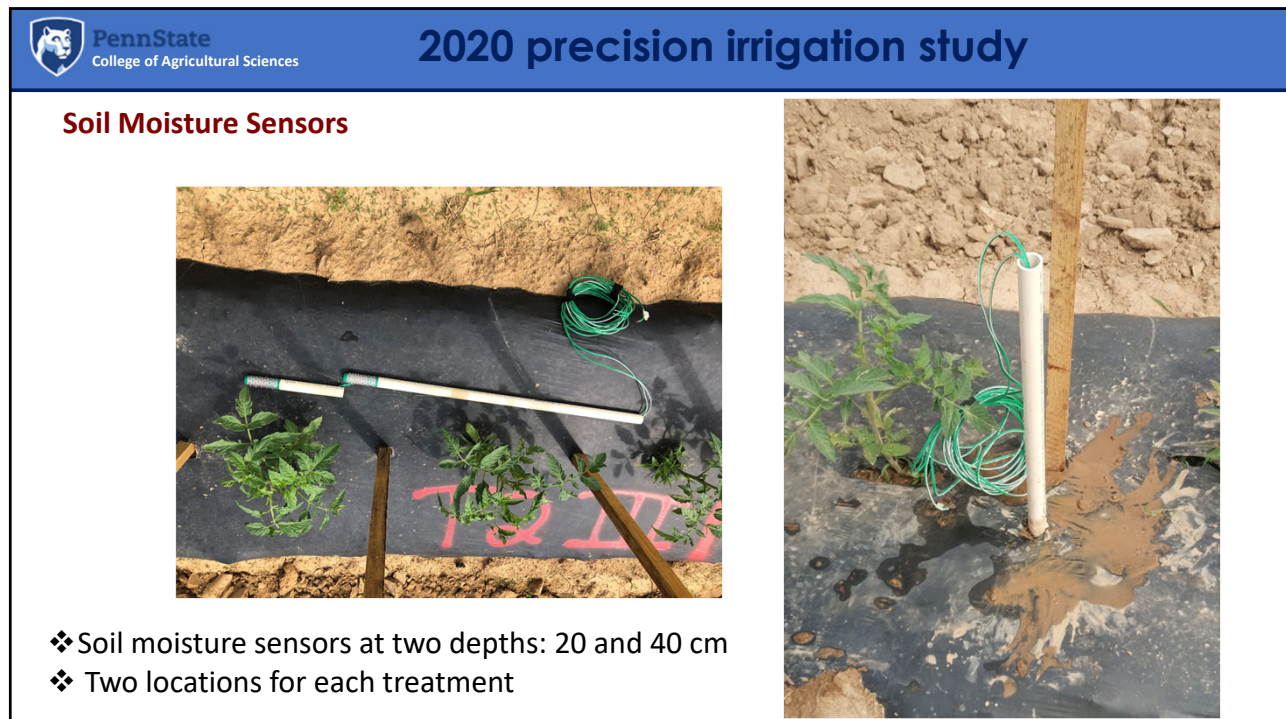
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June 3, 2020

June 10, 2020

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Soil Moisture Sensors

❖ Soil moisture sensors at two depths: 20 and 40 cm
❖ Two locations for each treatment

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2020 precision irrigation study

June 10, 2020
Soil moisture sensors installation

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2020 precision irrigation study

June 10, 2020
Soil moisture sensors installation

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Meter Group datalogger

LoRaWAN datalogger Sensor-Box

PVC-pipe collecting wires of soil water potential sensors

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Dataloggers/Controllers

Connect to soil moisture sensors

Connect to valves and pressure sensors

Wire connections

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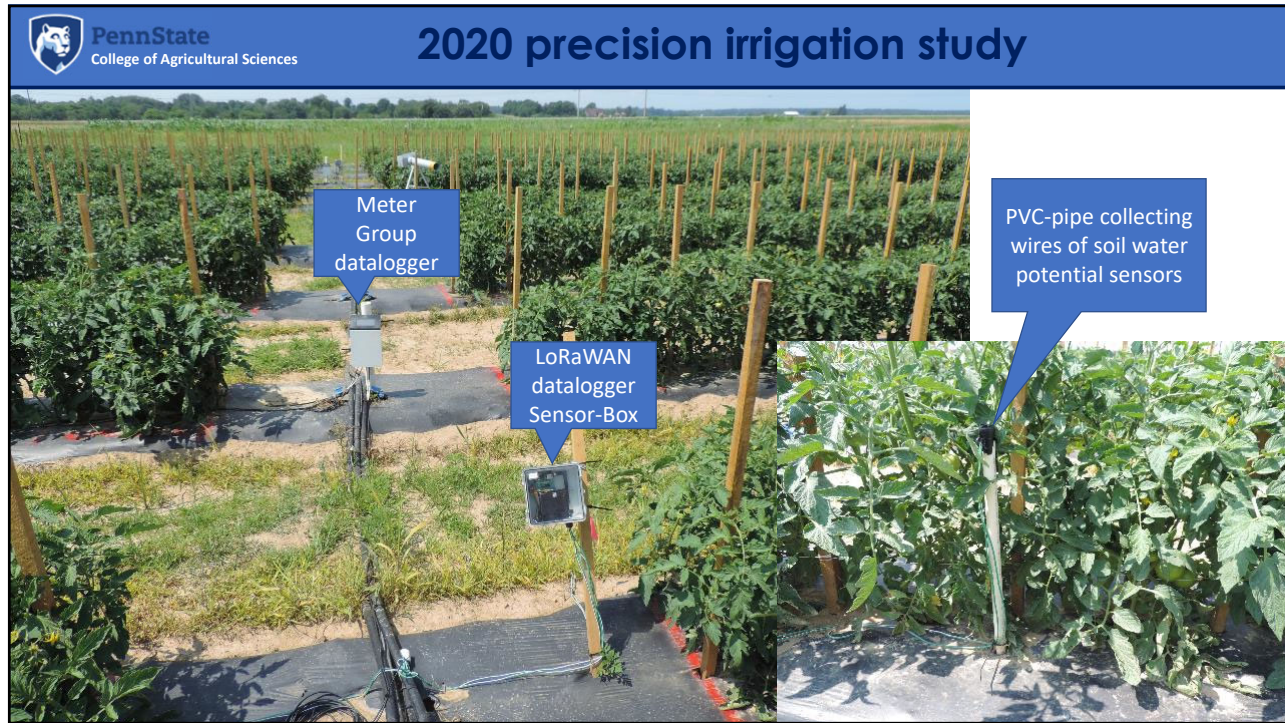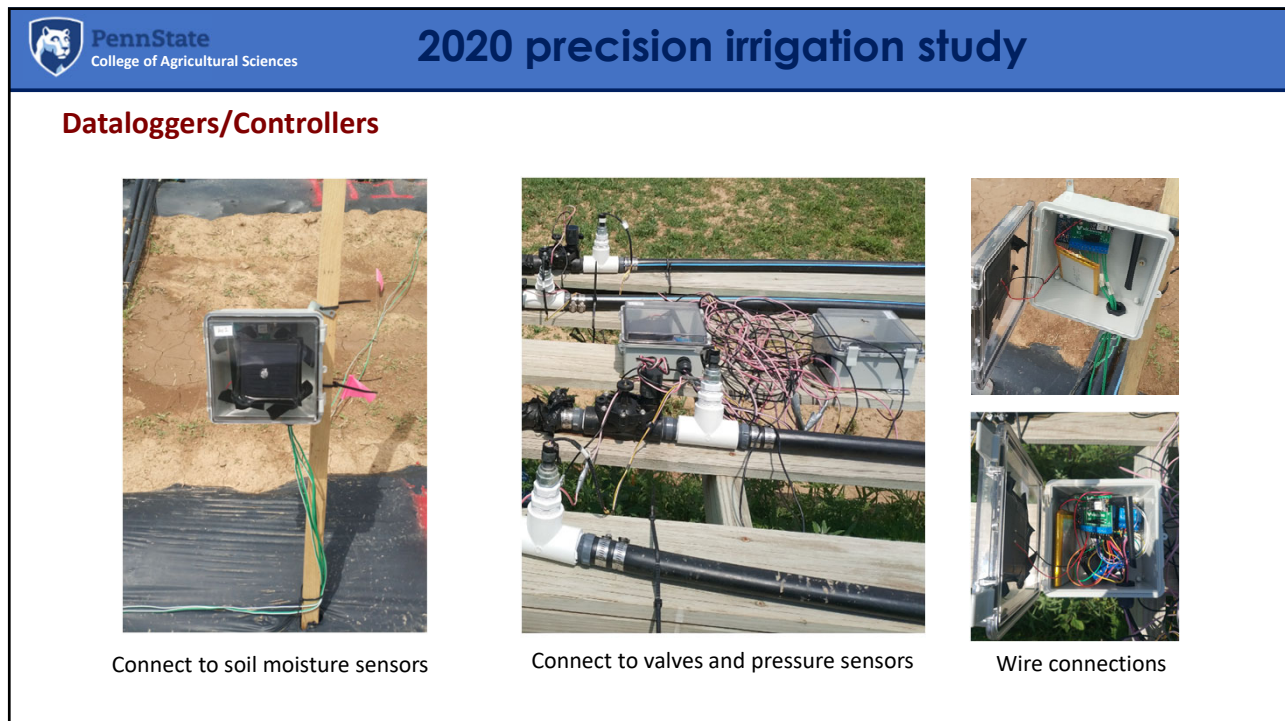
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Internet of Things (IoT) System Configuration

2020 precision irrigation study

Internet of Things (IoT) Platform Interface

'AllThingsTalk' IoT platform
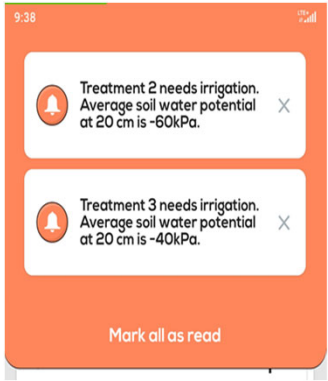
2020 precision irrigation study

Irrigation Operation

- ❖ Solenoid valves for all treatments were controlled remotely

- ❖ Alerts were received for T2 and T3 (Soil moisture irrigation)

- ❖ Irrigation scheduling for T1 is based on the ET calculation

- ❖ Irrigation scheduling for T4 is based on the Gescon (App)

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Biometric
assessment at
113 Days After
Planting

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Irrigation management effect on plant growth at 113 days after planting

Irrigation treatment	Plant dry biomass (g/plant)			
	Leaves	Stems	Fruit	Total
T1-ETc	189.75 ab	82.88 ab	184.44	457.06
T2-60 kPa	194.50 a	87.25 a	160.23	441.98
T3-40 kPa	**166.94 b**	**75.38 b**	151.99	394.30
T4-GesCoN	204.56 a	89.44 a	198.96	492.96
P-value	*0.02*	*0.05*	*0.19*	*0.06*

Means separation by Fishers LSD test at P = 0.05

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Harvest was done from 10 contiguous plants in the center row of each experimental unit

First harvest

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First harvest

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Irrigation management effect on fruit yield

Irrigation treatment	First Harvest (lbs/acre)					
	XL	L	M	Cull	TMY	TY
T1-ETc	3283	625	205	**1811 b**	4122	**5933 b**
T2-60 kPa	3685	633	80	**1276 b**	4390	**5656 b**
T3-40 kPa	3756	660	232	**3105 a**	4648	**7753 a**
T4-GesCoN	4193	696	134	**1320 b**	5014	**6326 b**
P-value	*0.69*	*0.92*	*0.30*	***0.001***	*0.68*	***0.03***

Means separation by Fishers LSD test at P = 0.05

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Irrigation management effect on fruit yield

Irrigation treatment	First and Second Harvest (lbs/acre)					
	XL	L	M	Cull	TMY	TY
T1-ETc	14203 a	758	259	8056 ab	15221 a	23277
T2-60 kPa	15479 a	919	80	5639 b	16479 a	22117
T3-40 kPa	**11331 b**	901	375	**10447 a**	**12606 b**	23054
T4-GesCoN	15096 a	839	134	6897 b	16068 a	22965
P-value	***0.03***	*0.71*	*0.08*	***0.03***	***0.03***	*0.90*

Means separation by Fishers LSD test at P = 0.05

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Third harvest 9/1/2020

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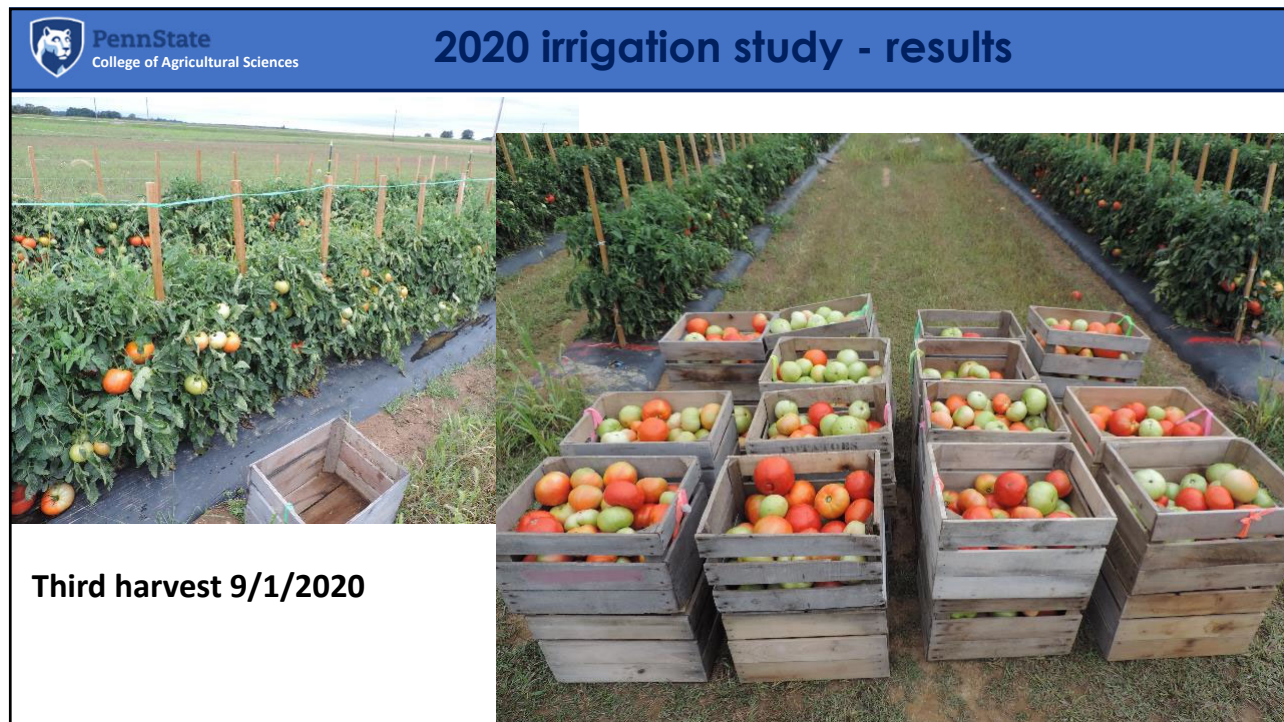
Irrigation management effect on fruit yield

Irrigation treatment	First to Third Harvest (lbs/acre)					
	XL	L	M	Cull	TMY	TY
T1-ETc	**30334 b**	1365	357	19021 a	32056 b	51077 a
T2-60 kPa	**33385 ab**	2106	285	16577 a	35785 ab	52353 a
T3-40 kPa	**21814 c**	1285	375	19378 a	**23473 c**	**42851 b**
T4-GesCoN	**35999 a**	2177	303	**13222 b**	38480 a	51693 a
P-value	*0.002*	*0.11*	*0.89*	*0.003*	*0.001*	*0.01*

Means separation by Fishers LSD test at P = 0.05

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Irrigation management effect on fruit yield

Irrigation treatment	First to Fourth Harvest (lbs/acre)					
	XL	L	M	Cull	TMY	TY
T1-ETc	36017 b	1767	571	21760 ab	38364 b	60115 b
T2-60 kPa	42120 ab	3167	401	19806 b	45697 a	65504 a
T3-40 kPa	**26462 c**	1847	419	**22849 a**	**28737 c**	**51586 c**
T4-GesCoN	44778 a	2837	517	16336 c	48133 a	64469 a
P-value	*0.0008*	*0.16*	*0.87*	*0.001*	*0.0004*	*0.0005*

Means separation by Fishers LSD test at P = 0.05

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Irrigation management effect on fruit yield

Irrigation treatment	Total Harvest (lbs/acre)					
	XL	L	M	Cull	TMY	TY
T1-ETc	**41352 bc**	4033 b	2980	22956 ab	**48365 bc**	71330
T2-60 kPa	**47027 ab**	5763 a	2909	21109 b	**55699 ab**	76808
T3-40 kPa	**34046 c**	4845 ab	3346	**24526 a**	**42236 c**	66762
T4-GesCoN	**50604 a**	5308 a	3140	**17844 c**	**59053 a**	76906
P-value	*0.01*	*0.04*	*0.66*	*0.002*	*0.01*	*0.06*

Means separation by Fishers LSD test at P = 0.05

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Effect of early **freezing temperatures** on September 19 and 20, 2020

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Irrigation management effect on cumulative marketable yield (lbs/acre)

Means separation by Fishers LSD test at P = 0.05
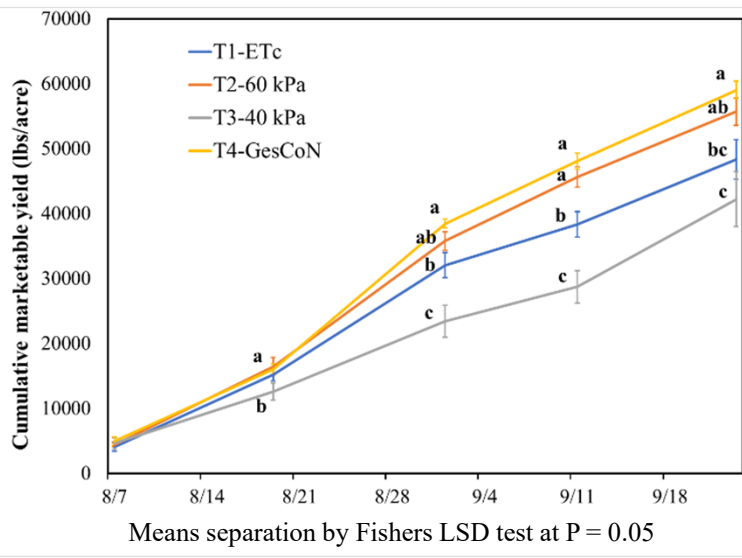
	Total marketable yield (%)	% variation
T1-ETc	100	**0**
T2-60 kPa	115	**15**
T3-40 kPa	87	**-13**
T4-GesCoN	122	**22**

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Irrigation management effect on irrigation water use efficiency (iWUE)

	Seasonal irrigation volume (gal/acre)	Irrigation volume reduction (%)
T1-ETc	260,888	
T2-60 kPa	251,934	**- 3.4**
T3-40 kPa	181,171	**- 31.6**
T4-GesCoN	250,069	**- 6.0**

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Irrigation management effect on fruit quality

Irrigation treatment	TSS (°Brix)	Dry matter (g/100 g FW)	TSS (°Brix)	Dry matter (g/100 g FW)
	2nd harvest		3rd harvest	
T1-ETc	4.9	**3.6 b**	4.7	2.6
T2-60 kPa	5.1	**3.6 b**	4.7	2.5
T3-40 kPa	5.1	**4.5 a**	4.7	2.7
T4-GesCoN	4.9	**4.2 ab**	4.4	2.6
p-value	*0.36*	***0.04***	*0.17*	*0.42*

Means separation by Fishers LSD test at P = 0.05

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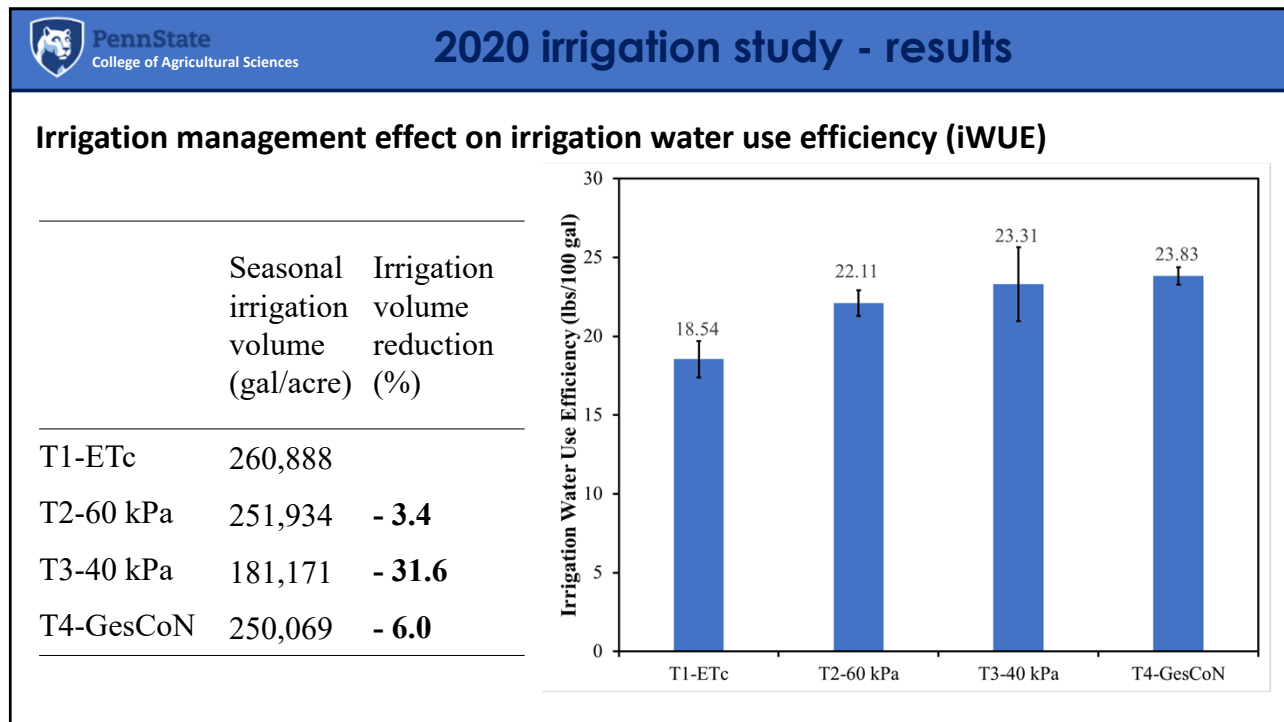
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Conclusions

➢The LoRaWAN sensor-based precision irrigation systems (with the exception of T3) and the Decision Support System GesCoN demonstrated to be effective solution for the precision management of irrigation in fresh-market tomatoes allowing to save water and fertilizer while increasing yield.

➢Failure of T3 demonstrated that sensor placement and distribution across the field are critical for the correct management of the irrigation.

➢Benefits may derive from integrating IoT sensor-based precision irrigation systems and Decision support systems

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Acknowledgements

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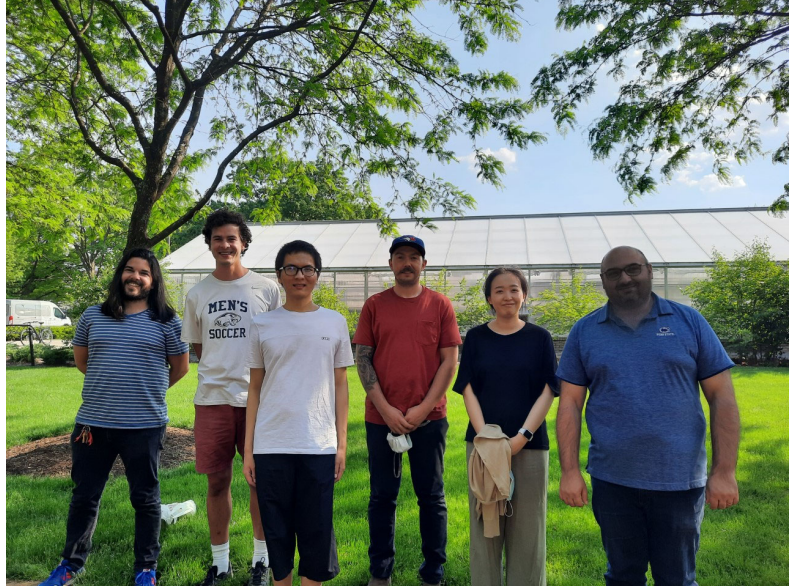
Acknowledgements
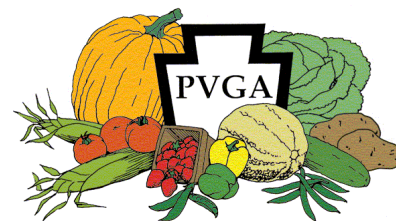
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Trevor Johnson
Andrew Blunk
Raymond Barbosa

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Thank You!!!

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