



# Irrigation Scheduling Methods: Weather and Sensor-based

**Younsuk Dong<sup>1</sup> and Lyndon Kelley<sup>2</sup>**

<sup>1</sup>Department of Biosystems and Agricultural Engineering

<sup>2</sup>Michigan State University Extension

Michigan State University

MSU Hop Spring Kickoff Meeting

Mar. 24. 2022



# Why Scheduling?

- Improve water use efficiency.
- Protect the environment.
- Maximize yield and quality.



“To maximize yield, hops require supplemental irrigation. Michigan State University (MSU) Extension recommends ***at least 6 gallons per plant per day during June and July when the plants are growing rapidly.*** (Sirrine, 2014).”

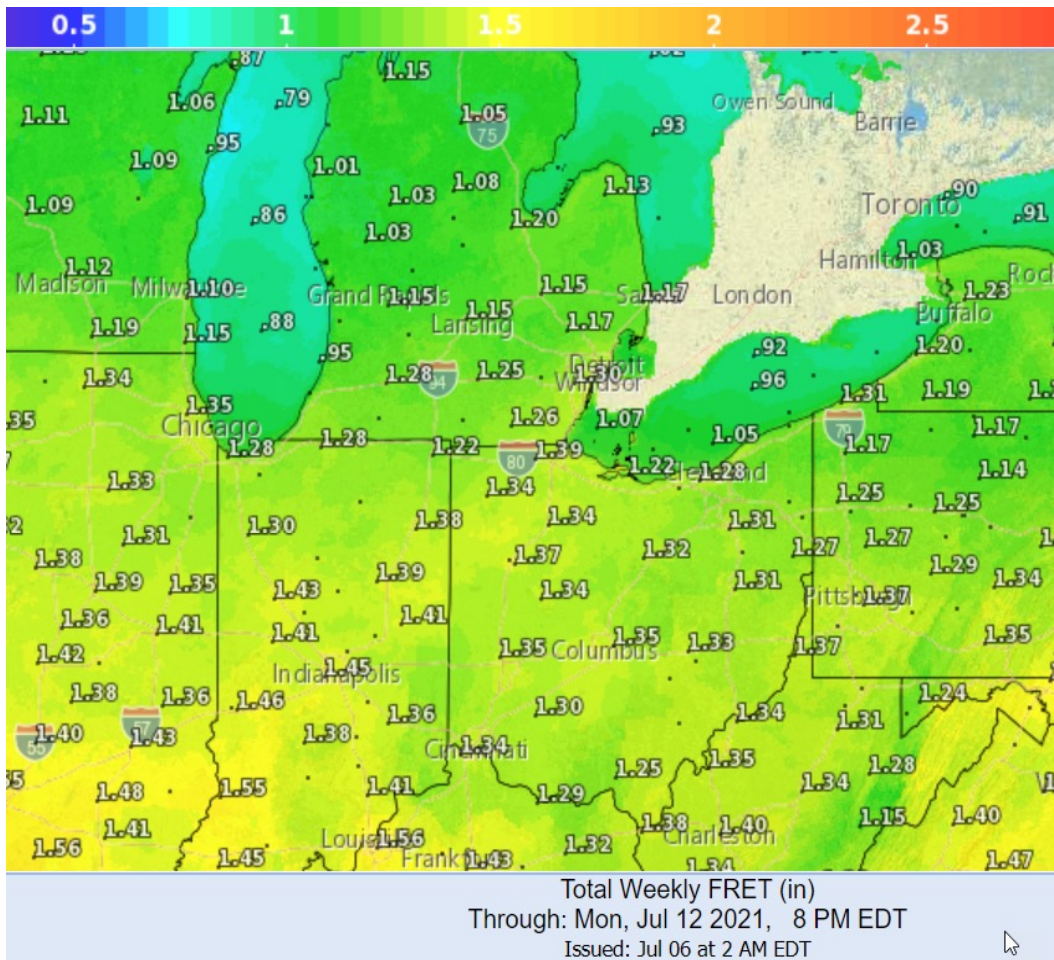
*“There was a **21 %** increase of yield on the average over the monitored years. The content of alpha bitter acids in the irrigated plants increased by **7 %** on the average in comparison with the non-irrigated group.*

*(Svoboda et al. 2008)”*

“Hop sensitively responds to supplementary irrigation, ***the application of which increases the yield by 20- 26 % in comparison with the non-irrigated plants*** (Slavík, Kopecký, 1997).”



# Irrigation Scheduling



**Weather-based Irrigation Scheduling**



**Sensor-based Irrigation Scheduling**



# Weather-based Irrigation Scheduling - Crop Evapotranspiration

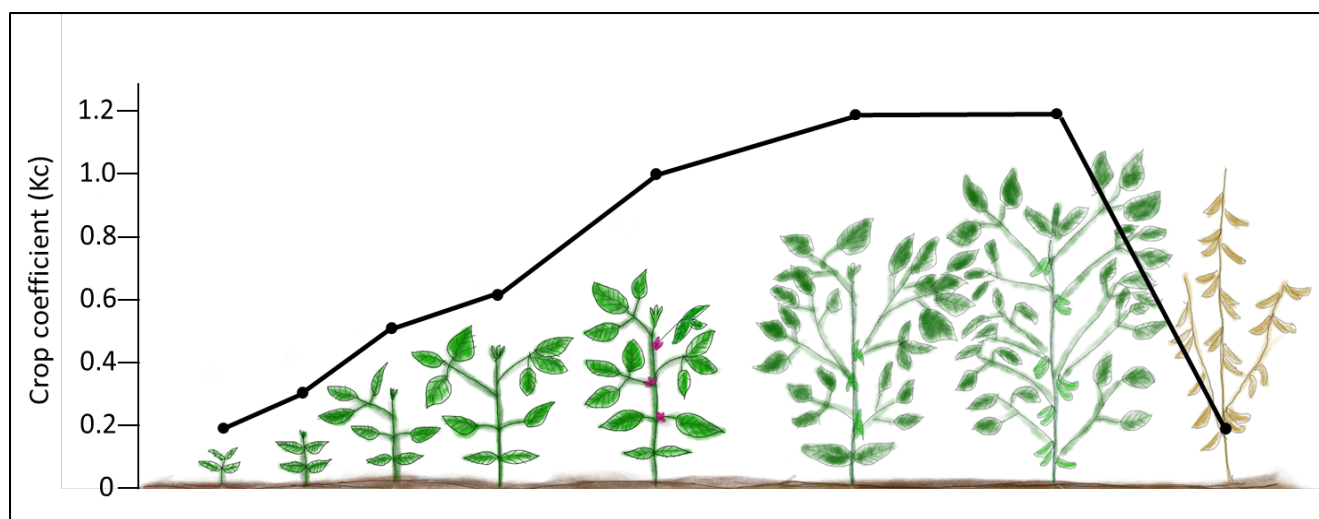
$$ET_C = K_C * rPET$$

Where,

$ET_C$  = Actual Crop Evapotranspiration (in/day)

$K_C$  = Crop Coefficient (unitless multiplier)

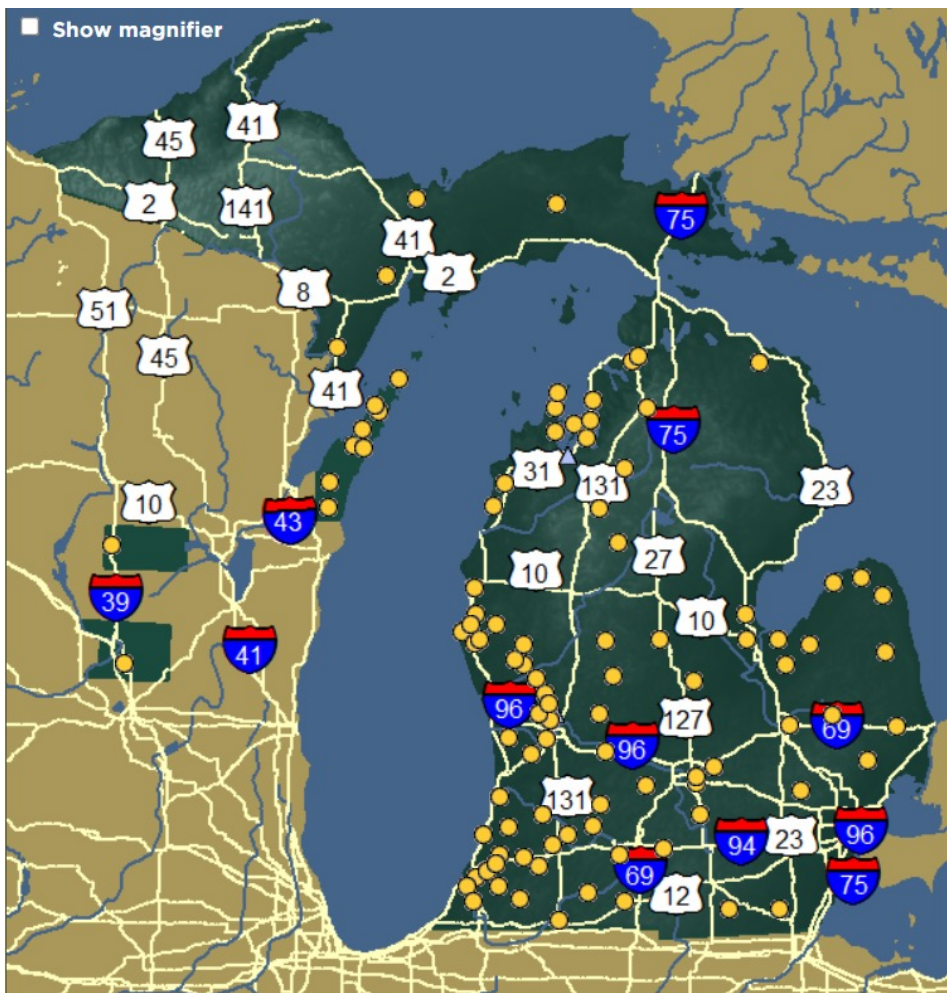
$rPET$  = Reference Potential Evapotranspiration (in/day)



Crop coefficient (Kc) changes as the soybean grows



# MSU Enviroweather Program



MICHIGAN STATE UNIVERSITY

## Enviroweather Test Version

Home | Weather | Crops | Information | SDL | Dashboard | V2 Keith Mason | Logout

Summary	Degree Day Tools	Maps	<b>Irrigation Tools</b>
Degree Day and Rainfall Summary	Regional Degree Day Summary	Growing Degree-Days (50)	Sign up for RPET Text Alerts
Meteogram	Degree Day Summary last 5 yr	Latest Observations	MSU Irrigation Scheduler
Overnight Temperatures	Regional Degree Day Comparison - alfalfa and corn	Temperature Inversion Potential	MSU Irrigation Resources
Soil Conditions	Degree Day Summary last 5 yr - alfalfa and corn	NOAA Radar - Great Lakes	Soil Water Balance Sheet (download pdf)
Degree Day and Rainfall Summary for Corn and Alfalfa			Potential Evapotranspiration Daily Summary
	Precipitation		
	Regional Rainfall Comparison		
	Rainfall Summary last 5 yr		

<https://enviroweather.msu.edu/>



# Example – Crop Evapotranspiration Calculation

$$ET_C = K_C * rPET$$

$$ET_C = 1.05 * 0.83 \text{ in} = 0.87 \text{ in}$$

Where,

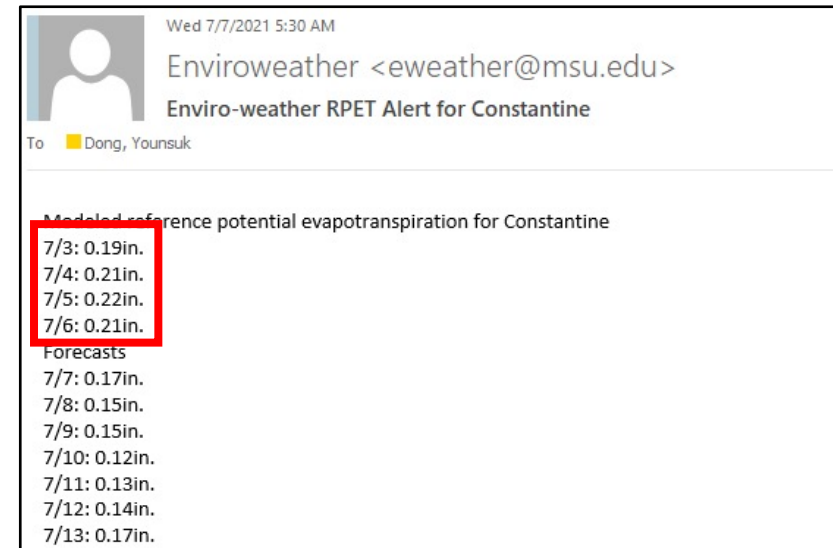
$ET_C$  = Actual Crop Evapotranspiration (in/day)

$K_C$  = Crop Coefficient (unitless multiplier)

$rPET$  = Reference Potential Evapotranspiration (in/day)

TABLE 12. Single (time-averaged) crop coefficients,  $K_C$ , and mean maximum plant heights for non stressed, well-managed crops in subhumid climates ( $RH_{min} \approx 45\%$ ,  $u_2 \approx 2 \text{ m/s}$ ) for use with the FAO Penman-Monteith  $ET_o$ .

	Kc_ini	Kc_mid	Kc_end
Hops	0.30	1.05	0.85





# MSU Irrigation Scheduler Program



**BAE - Irrigation**  
 Welcome to Biosystems & Agricultural Engineering Irrigation Research Group  
 Irrigation Scheduling  
 • Process of maintaining an optimum water balance in the soil profile for crop growth and production

**Center Pivot Sprinkler Irrigation System**

**Quick Links**

SENSOR

**MSU Irrigation Scheduler**

**Quick Links**

SENSOR

MSU Irrigation Scheduler

MSU Irrigation Scheduler Program -- Michigan State University Extension  
 (Version 4.0 - May 1, 2018) For Excel 2007-2016 & Office 365

Set Up This Irrigation Schedule (Field ID, Crop, Soil Type, Etc.)

View Plant Available Water By Plant Growth Stage in This Field

Download Weather Data From Enviroweather Station

Print Soil Moisture Graph For This Schedule

Enter Your Irrigation and Rainfall Data

Generate a Water Use Report for This Field

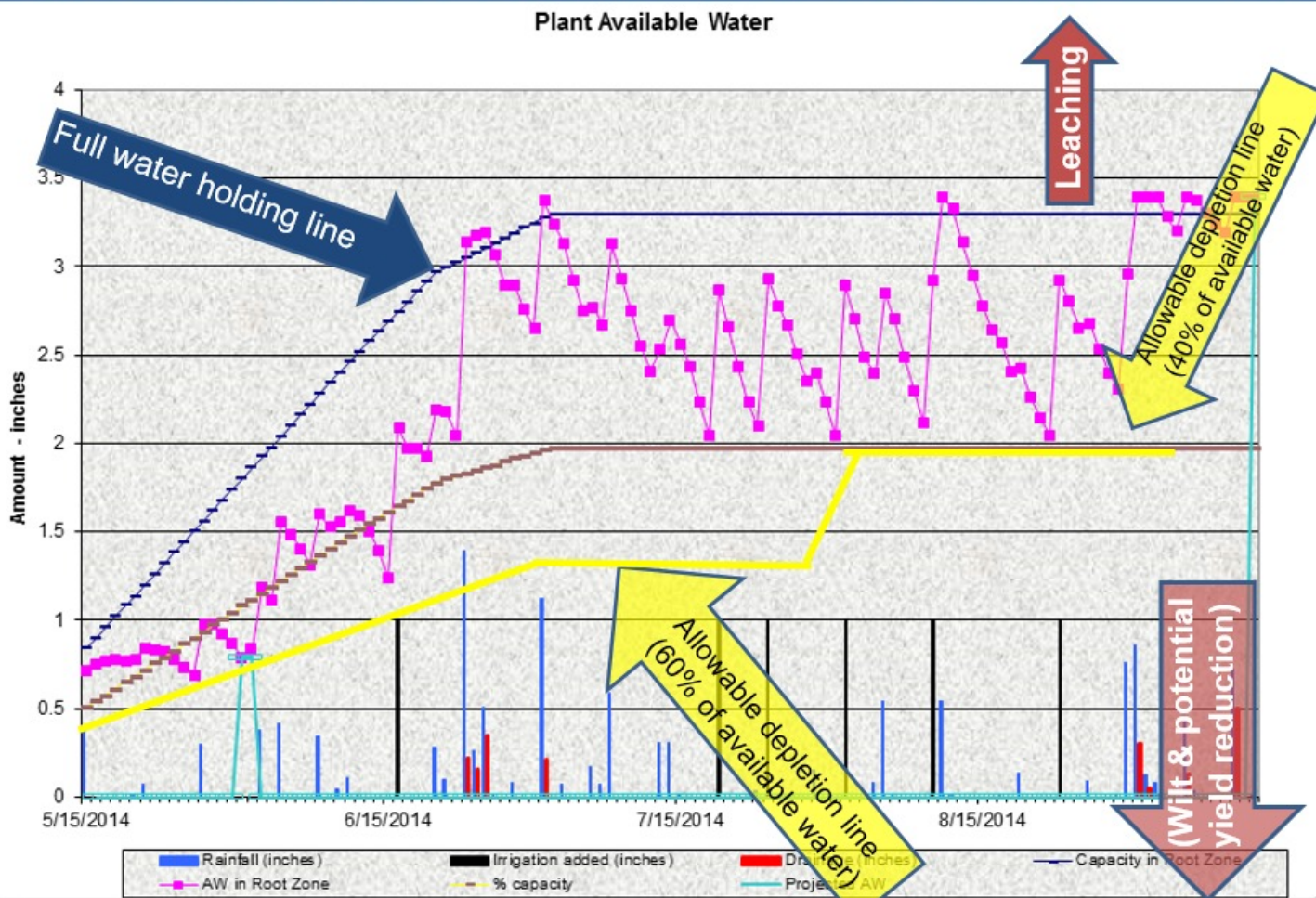
Generate Detailed Soil Moisture Report for Last 7 Days and 5 Day Forcast ET Outlook

Enter Your Irrigation and Rainfall Data-Easy Sytem



# MSU Irrigation Scheduler Program

## MSU Excel Irrigation Schedule Checkbook Method - Mendon 2014



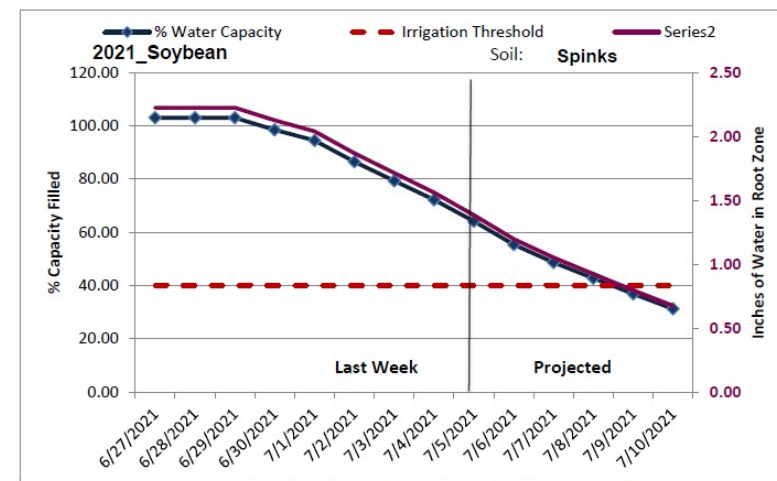
St. Joseph County Soil and Water Conservation District Irrigation Scheduling Service  
Weekly Water Balance Report and Et Outlook for Next 5 Days

Generated: 07/06/21

MSU Irrigation Scheduler

Field Name	2021_Soybean	
Crop:	Soybeans24	Emergence Date: 5/16/2021

Date	Rainfall	Irrigation	Crop Et	Forecasted Et	Drainage	AW Above Threshold	Additional Capacity
6/27/2021	0.16		0.06		0.02	1.30	0.00
6/28/2021	0.32		0.11		0.21	1.30	0.00
6/29/2021	1.18		0.11		1.07	1.30	0.00
6/30/2021	0.02		0.12		0.00	1.26	0.03
7/1/2021	0		0.09		0.00	1.18	0.12
7/2/2021	0		0.17		0.00	1.00	0.29
7/3/2021	0		0.15		0.00	0.85	0.45
7/4/2021	0		0.15		0.00	0.70	0.60
7/5/2021	0		0.18		0.00	0.52	0.77
7/6/2021		0.1888			0.00	0.33	0.96
7/7/2021				0.15	0.00	0.19	1.11
7/8/2021				0.13	0.00	0.06	1.24
7/9/2021				0.13	0.00	-0.07	1.36
7/10/2021				0.12	0.00	-0.19	1.49
Totals	1.68	0	1.14	0.52	1.30		

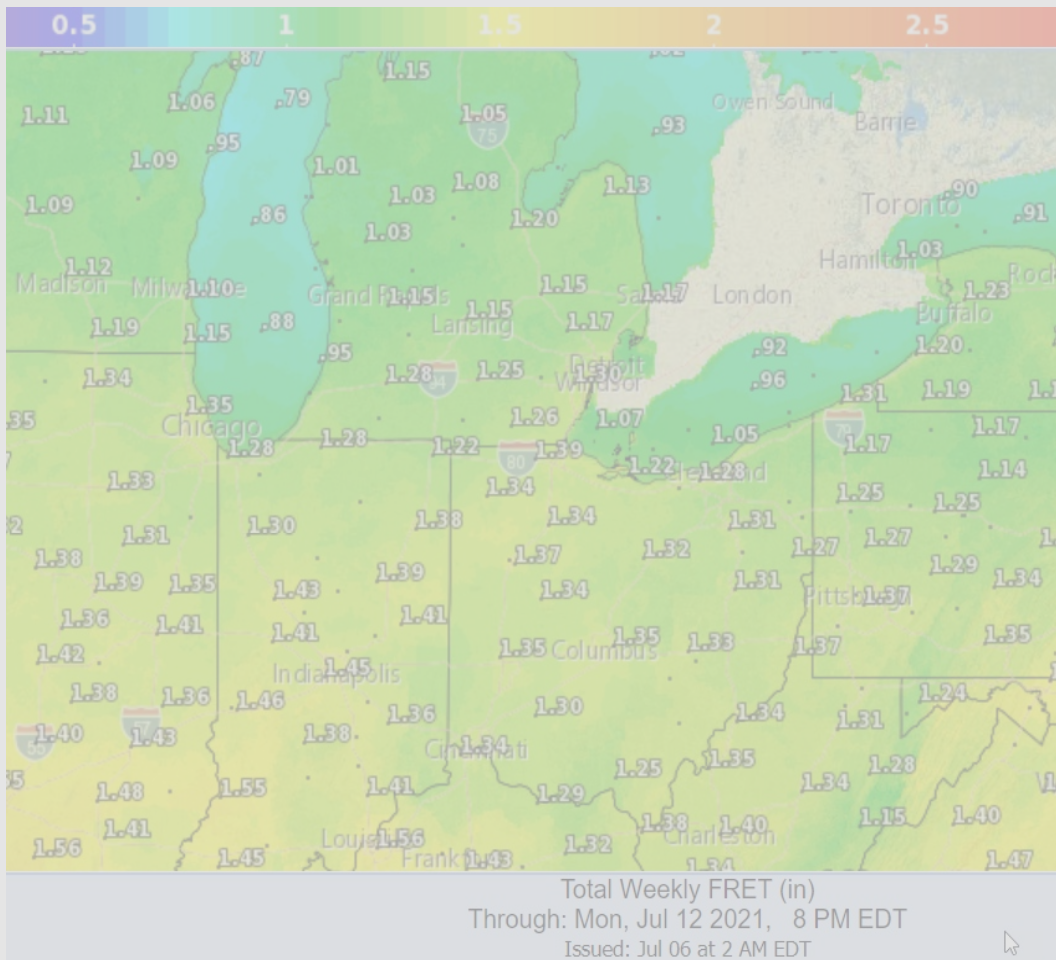


Please note: projected values do not include forecasted rainfall, only the outlook Et values.  
Irrigation Threshold: Dropping below this level may cause yield loss. To avoid, initiate irrigation.  
Enviroweather Station Selected: Constantine





# Irrigation Scheduling



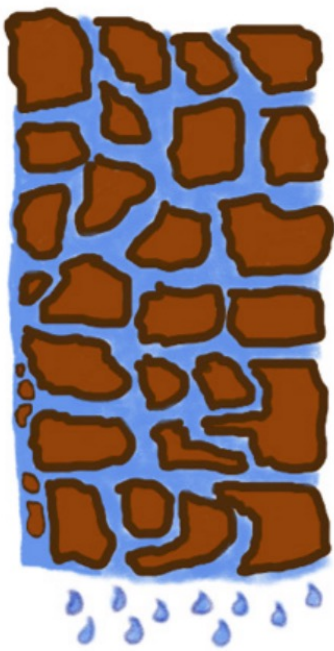
**Weather-based Irrigation Scheduling**



**Sensor-based Irrigation Scheduling**

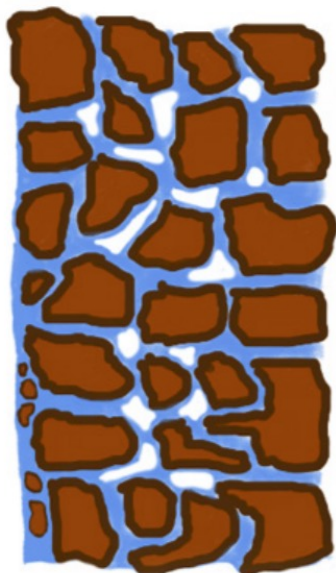


# Terminology for Irrigation Scheduling



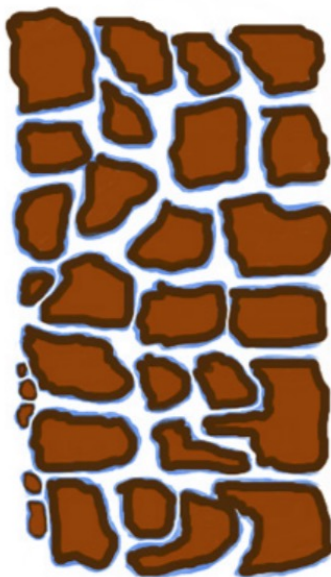
## Saturation

All soil pore spaces are filled with water.



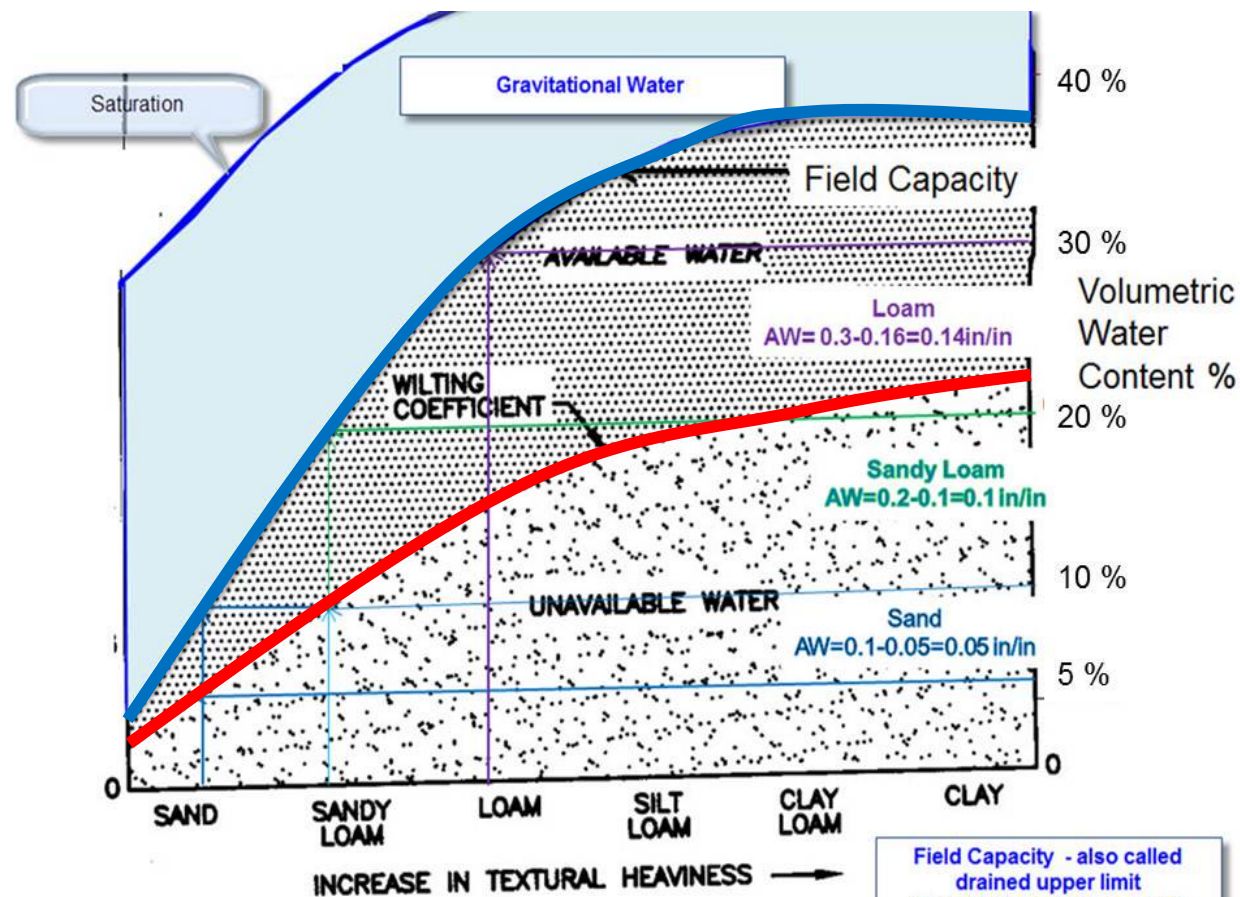
## Field Capacity

Maximum amount of water that soil can hold after drainage.



## Wilting Point

Soil moisture level where there is no available water for the crop.



Ref: USDA, NRCS, *Engineering Field Manual*  
 Additional graphics add by Steve A Miller, Michigan State University



## Field Capacity, Wilting Point, and Available Water

Soil texture	FC (%)	WP (%)	AW (%)
Sand	9.4	5	4.4
Loamy sand	12	5.7	6.3
Sandy loam	17.9	8.1	9.8
Loam	31	14	17

Irmak, S., Payero, J. O., VanDeWalle, B., Rees, J., & Zoubek, G. (2014). Principles and operational characteristics of Watermark granular matrix sensor to measure soil water status and its practical applications for irrigation management in various soil textures.



# Calculating Water Holding Capacity

Soil Name	Depth Inches	Available water holding capacity	Average Available water holding capacity	Ave. Available water holding capacity ( 24 in.)	Ave. Available water holding capacity ( 36 in.)
Oshtemo	0 - 14	0.10 – 0.15	0.125	14" x 0.125=1.75	14" x 0.125= 1.75
	14 – 35	0.12 – 0.19	0.155	10" x 0.155=1.55	21" x 0.155= 3.26
	35 - 60	0.06 – 0.10	0.08	----- = 3.3	1" x 0.08 = 0.08 ----- = 5.09
Spinks	0 – 10	0.08 – 0.10	0.09	10" x 0.09= 0.9	10" x 0.09= 0.9
	10 – 26	0.08 – 0.10	0.09	14" x 0.09= 1.26	16" x 0.09= 1.26
	26 - 60	0.04 – 0.08	0.06	----- = 2.16	8" x 0.06= 0.48 ----- = 2.64



# Soil Moisture Sensors



**EC-5**



**Soil Watch 10**



**SoilVUE10**



**10HS**



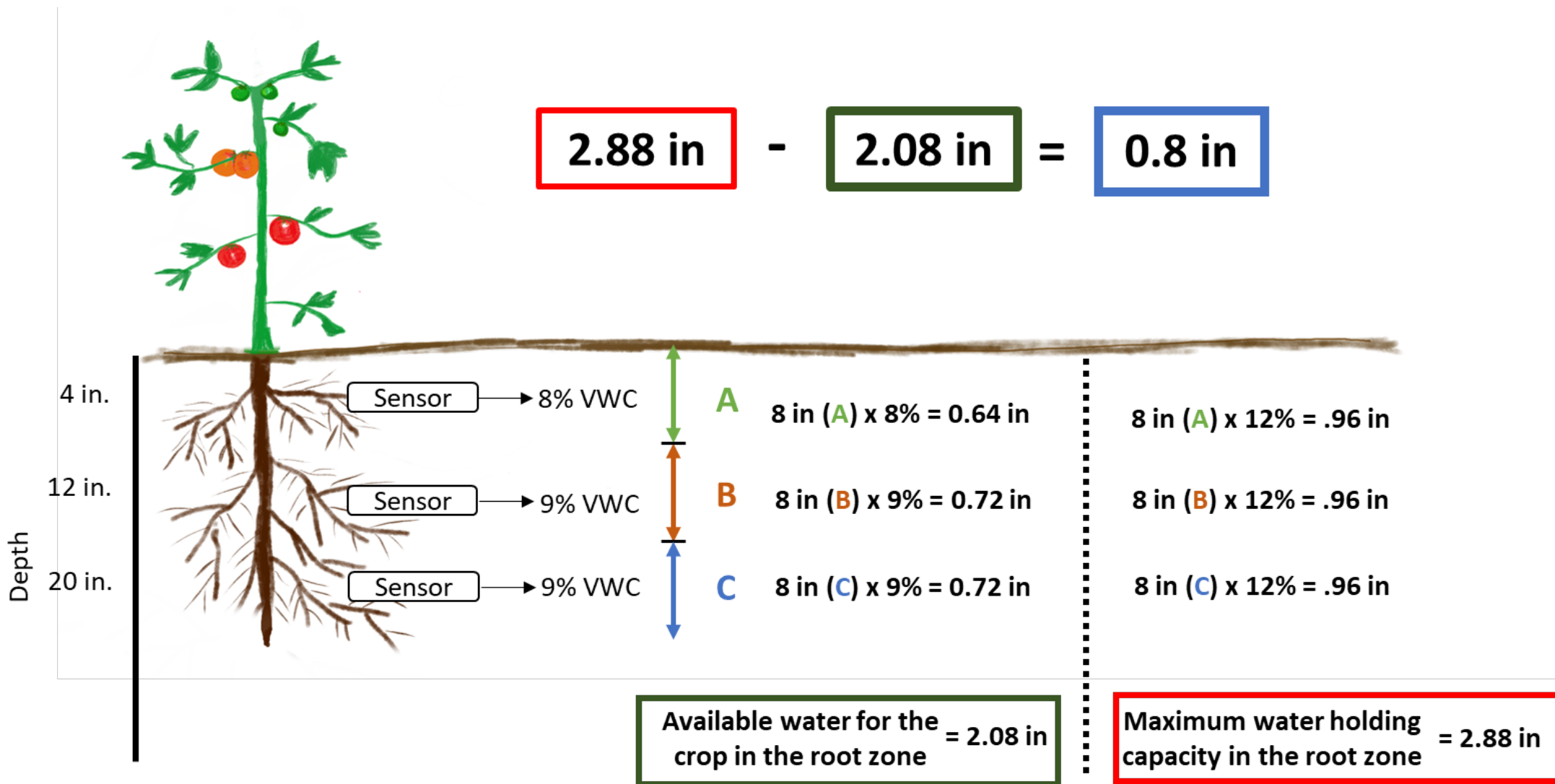
**Teros 12**



**WATERMARK**

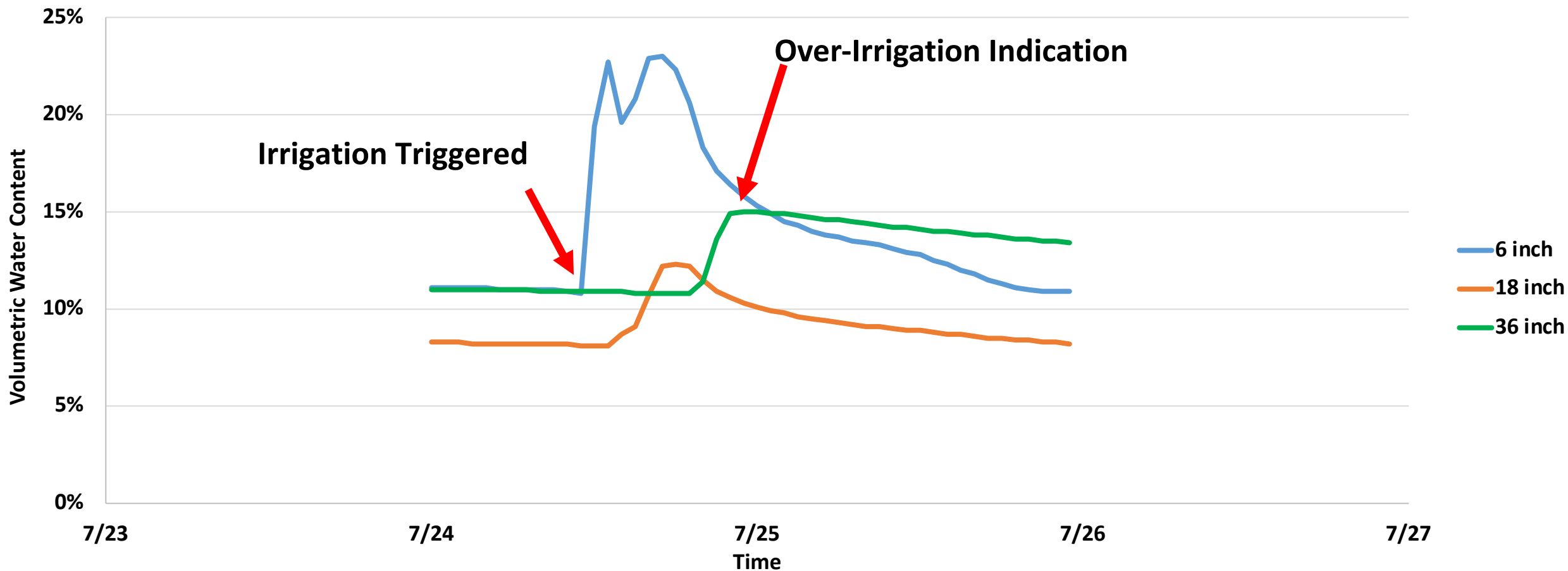


# Example – Irrigation Amount



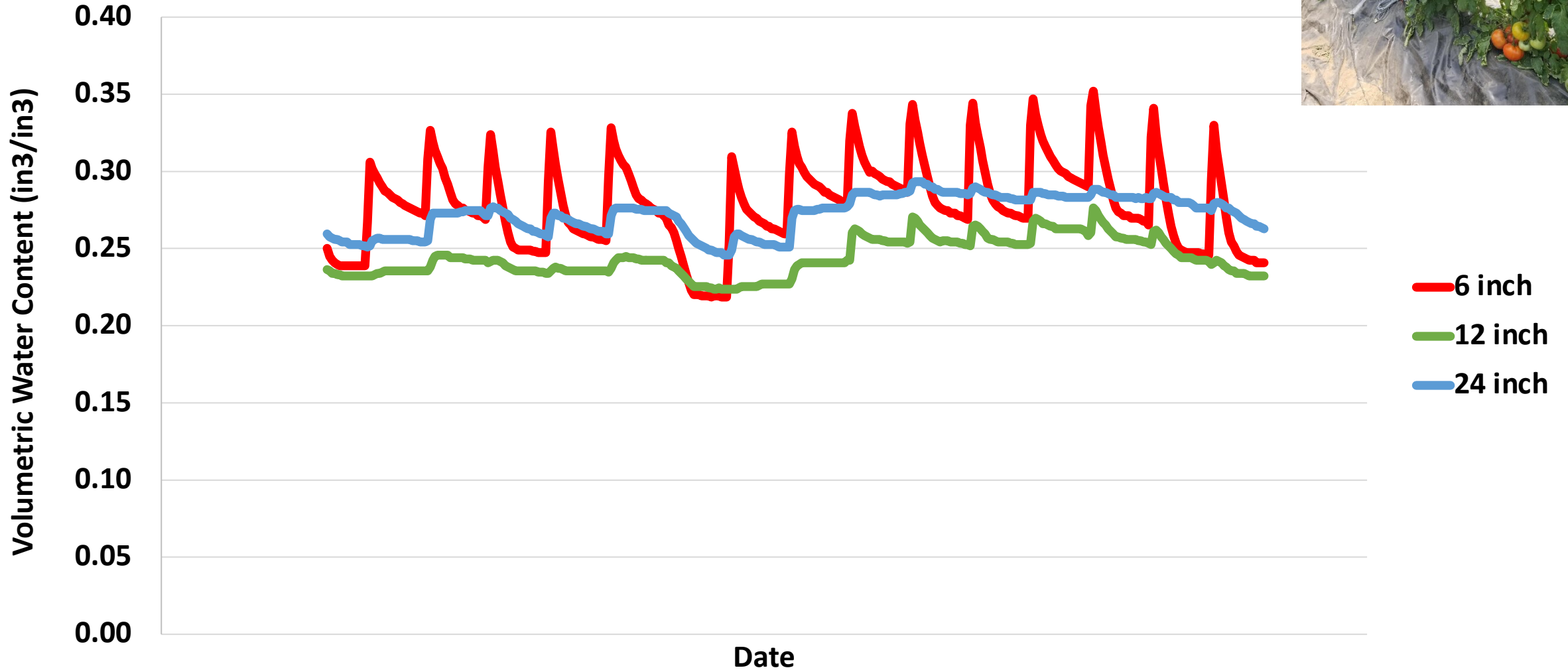


# Example – Over Irrigation





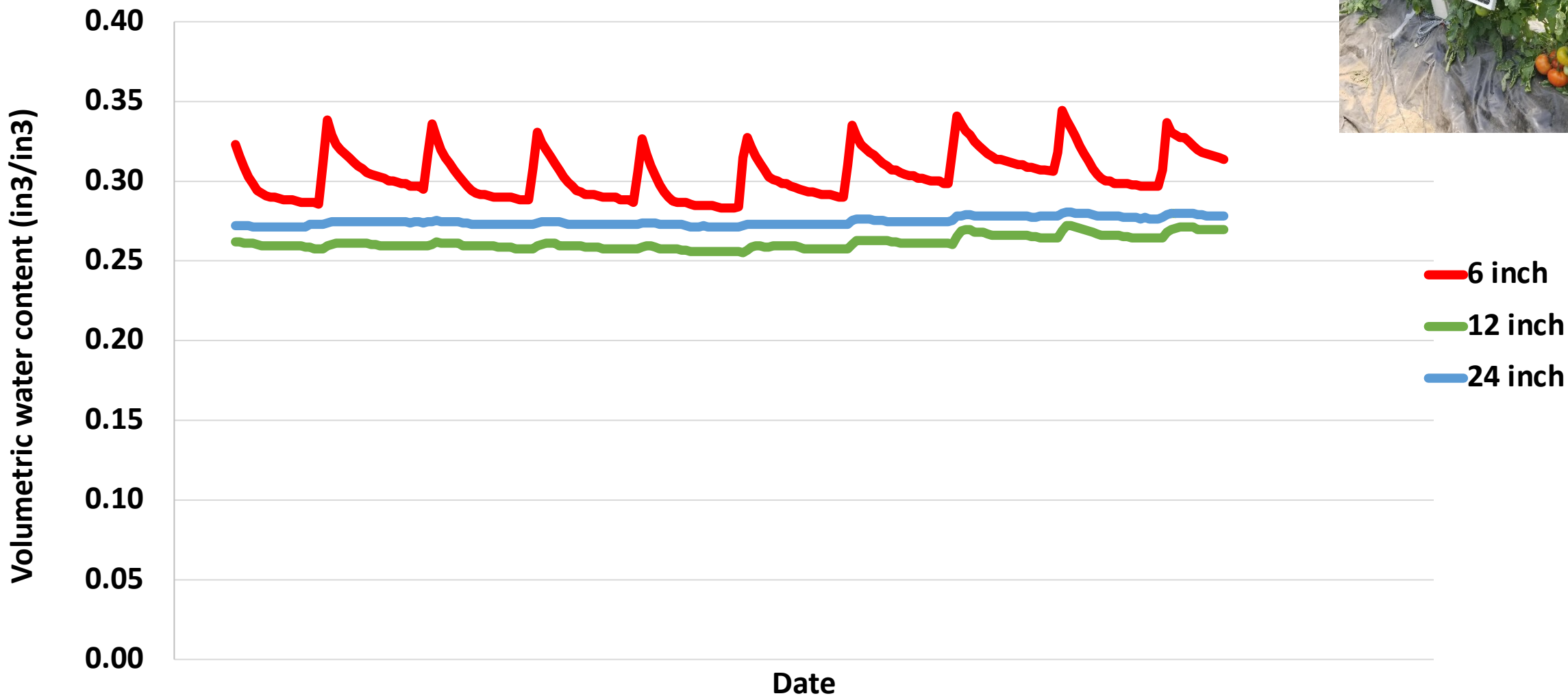
# Tomato – Drip Irrigation







# Tomato – Drip Irrigation (After adjustment)



# Sensor Installation Considerations

- Root depth.
- Wetting zone.
- No air gap.





**Younsuk Dong**  
[dongyoun@msu.edu](mailto:dongyoun@msu.edu)



**Lyndon Kelley**  
[Kelleyl@msu.edu](mailto:Kelleyl@msu.edu)

**Biosystems and Agricultural Engineering – Irrigation**

<https://www.egr.msu.edu/bae/water/irrigation/>

**MSU Extension – Irrigation**

<https://www.canr.msu.edu/irrigation>