Irrigation and Nitrogen Management

Vasudha Sharma

Irrigation Specialist, Department of Soil, Water and Climate

University of Minnesota

Vasudha@umn.edu

Nutrient Management Conference- 2019

Overview

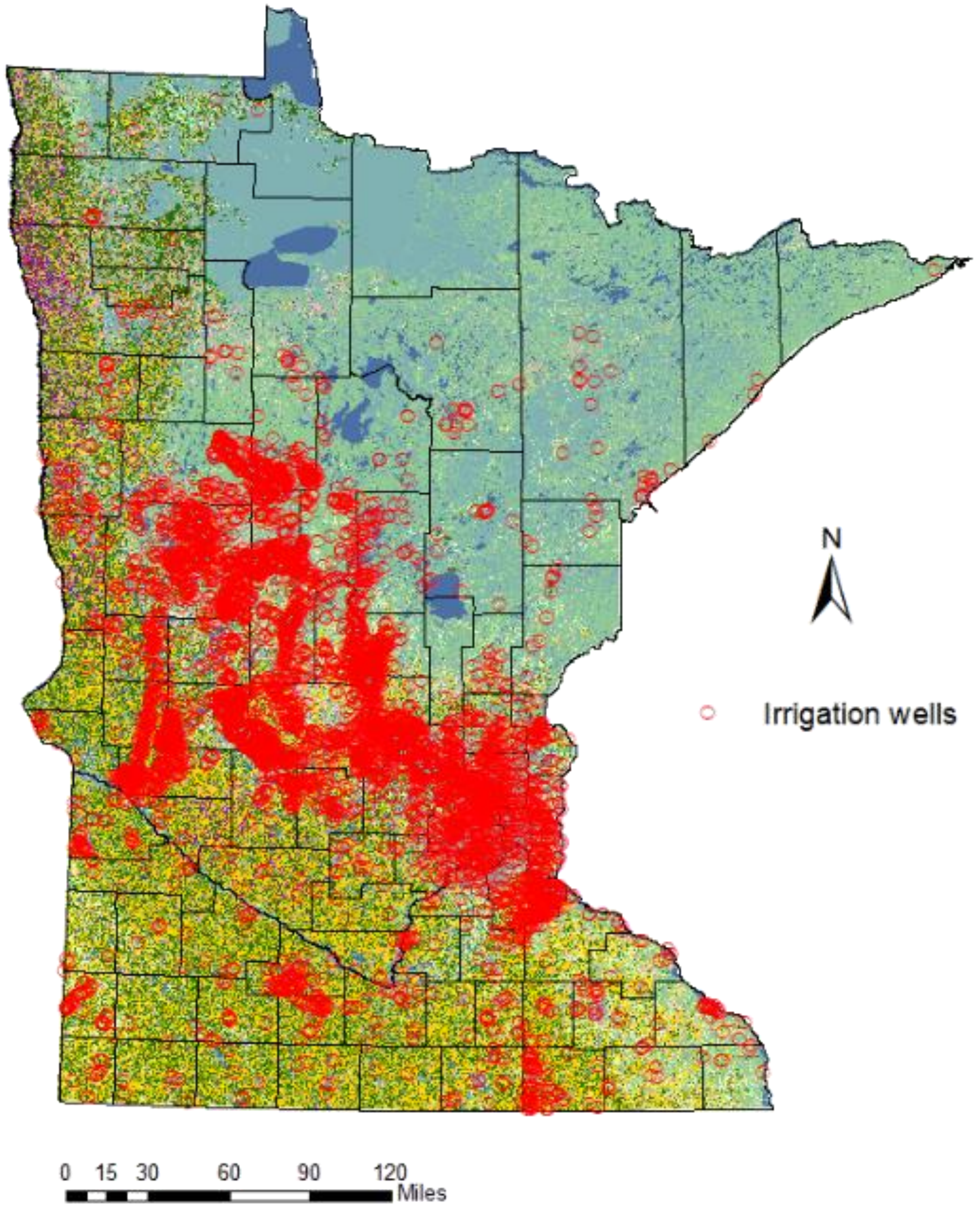
- Importance of Irrigation
- Irrigation Water Management
- Irrigation scheduling methods and tools
- Deficit irrigation management strategies
- Variable rate irrigation and fertigation

Why do we Irrigate?

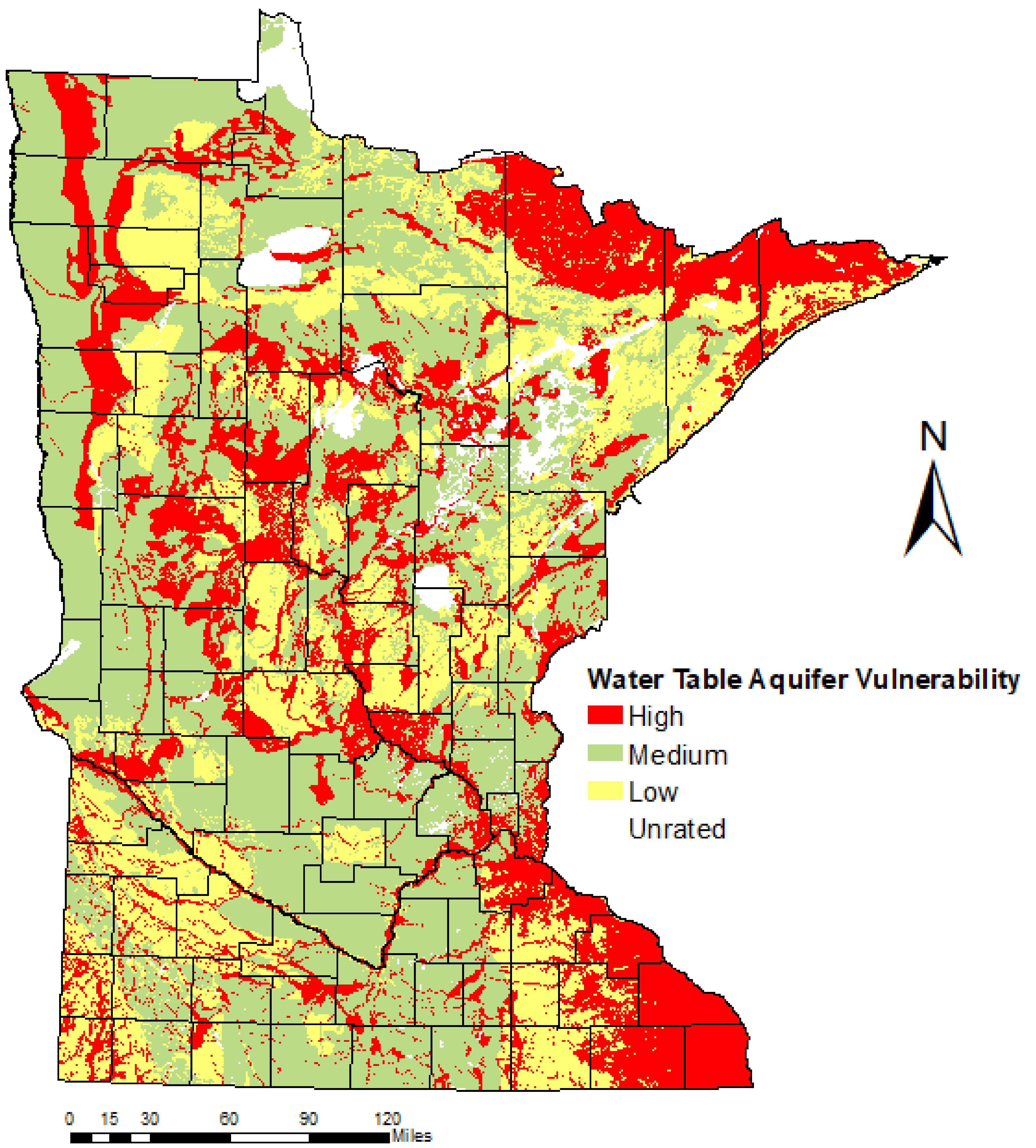
- When stored soil water in the root zone and precipitation during the growing season are not enough to meet the crop water demands (Evapotranspiration (ET)), irrigation is required.
- Under irrigation can:
  - Lead to plant stress and grain yield loss
  - Reduce grain quality
  - Reduce total biomass
  - Reduce net return ($ per ha)
- Over irrigation can:
  - Wastes water and increase energy cost
  - Decreases recharge to lakes and streams- Impact aquatic ecosystems
  - **Causes nutrients to leach from the rooting zone and contaminates ground water – nitrate leaching**

Minnesota Irrigation

Irrigation wells



Water Table Aquifer Vulnerability



Data: Minnesota Geospatial Commons

What is Irrigation Water Management?

- Irrigation water management is the act of timing and regulating irrigation water application in a way that will satisfy the water requirement of the crop without wasting water, energy, and **plant nutrients** or degrading the soil resource.
- This involves applying water according to **crop needs** in amounts that can be held in the soil and at rates consistent with the **intake characteristics of the soil**.
- Good water management will maximize yields and minimize the potential for pollution

Irrigation water management

- How can we manage irrigation efficiently?
  - Applying right amount of water at right time without wasting any.
- How can we determine that right amount and right time?
  - This is called ***Irrigation Scheduling***

Irrigation Scheduling Methods

- Maintain soil moisture within desired limit
  - Direct measurement- **Soil Moisture Monitoring**
  - Indirect measurement- accounting soil moisture using **Weather monitoring**
- Plant Monitoring
  - Canopy temperature, leaf color, leaf wilting

Saturation, Field Capacity and Wilting point

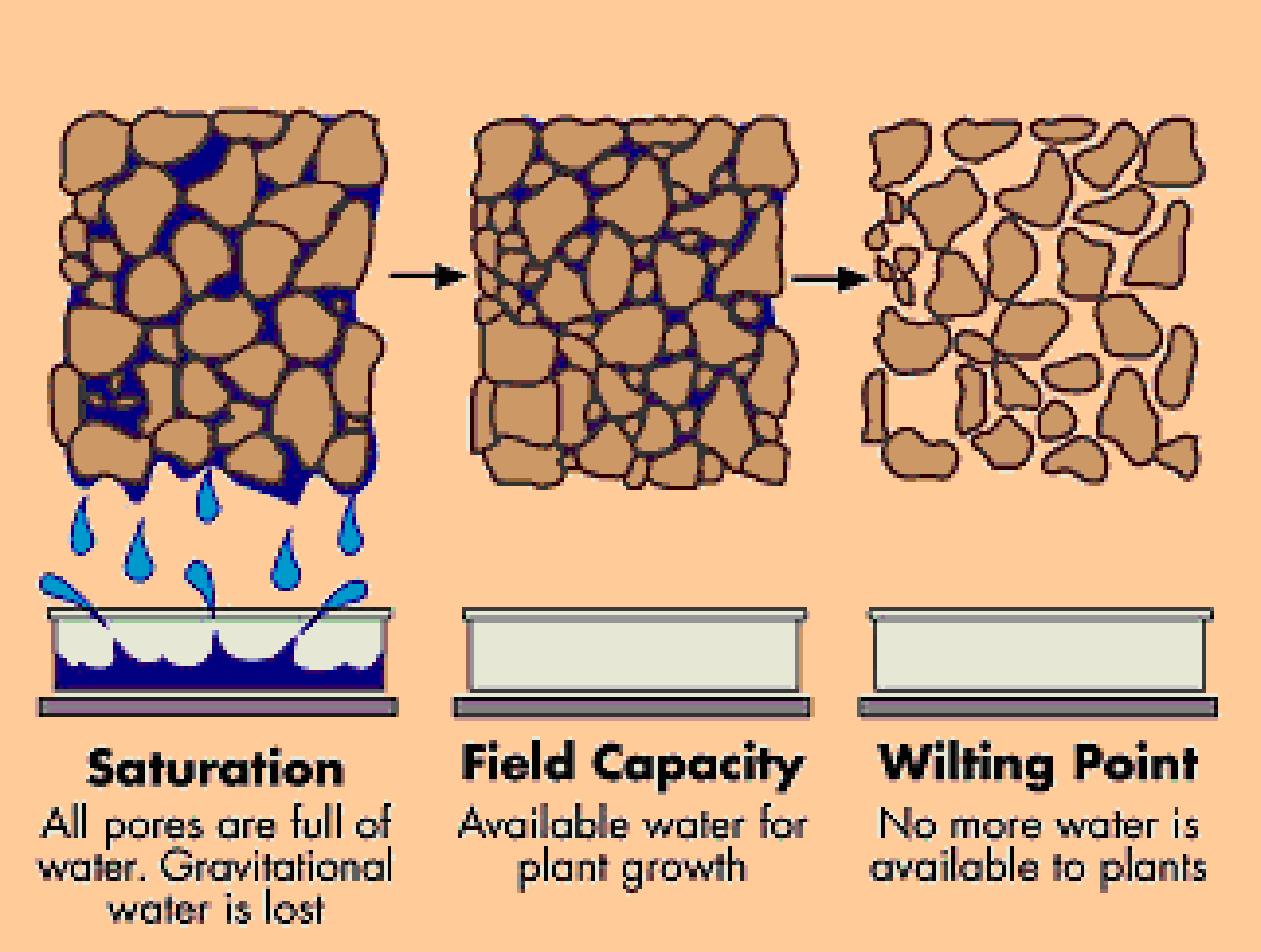
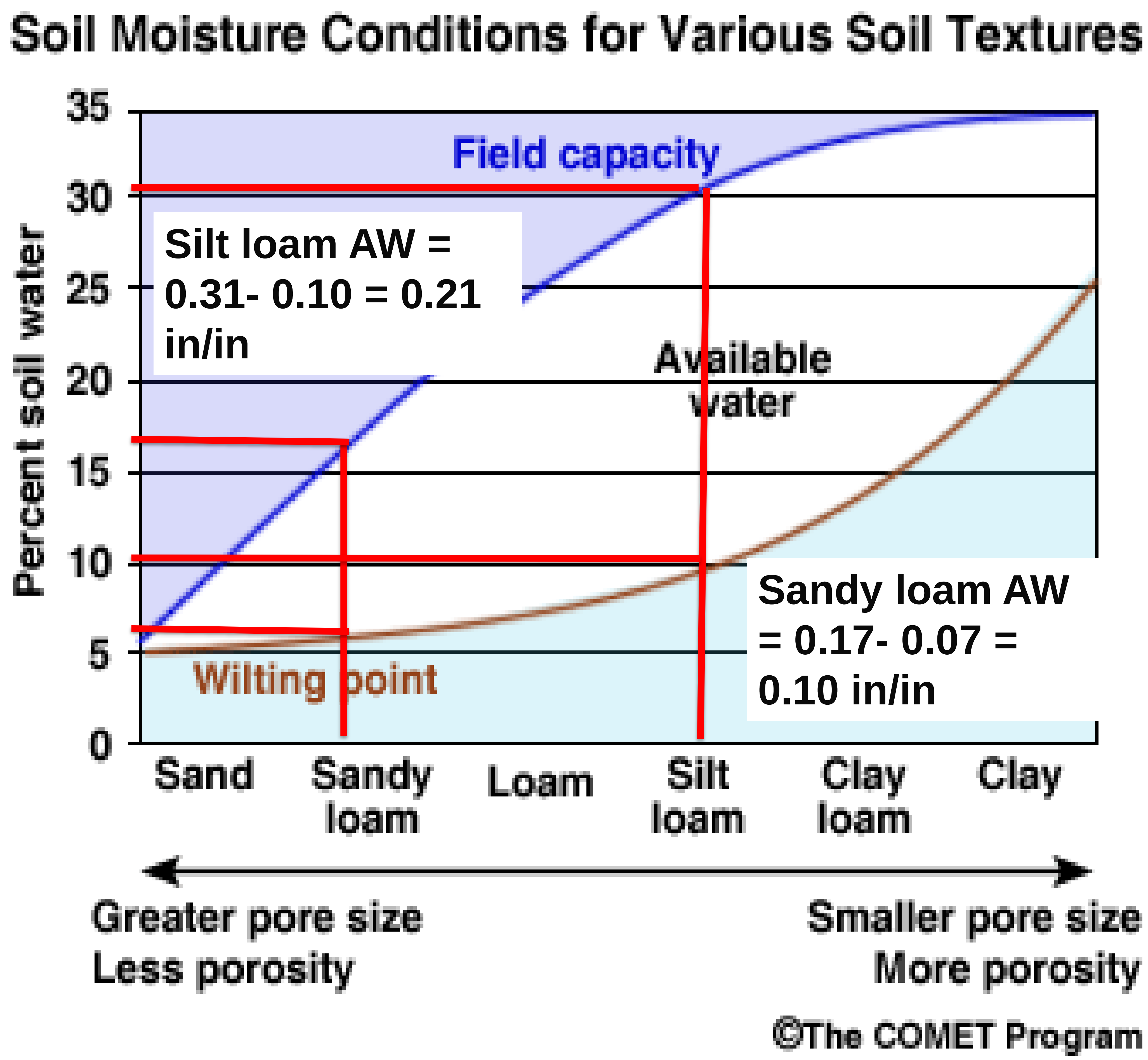
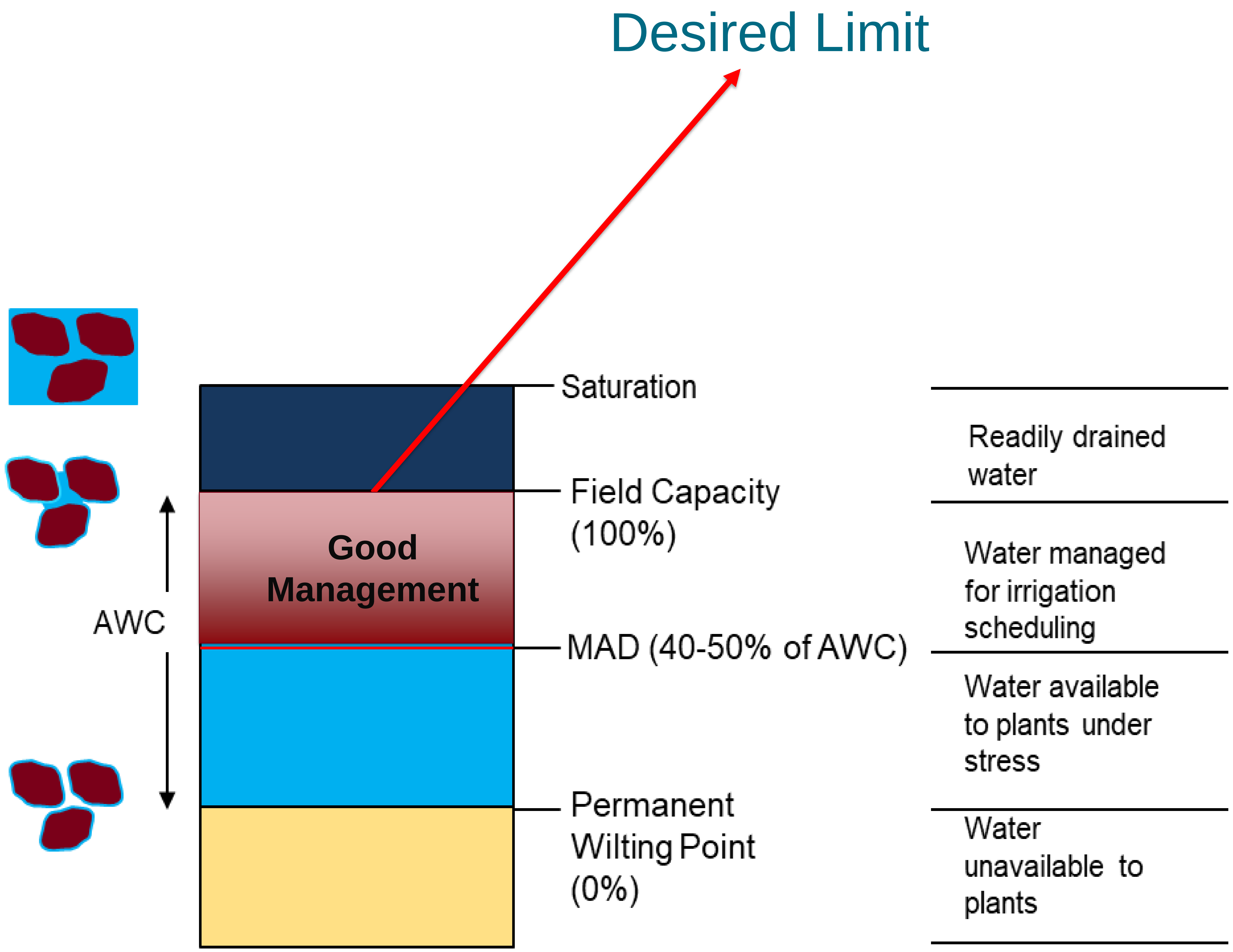


Image: https://www.tankonyvtar.hu/en/tartalom/tamop425/0032_talajtan/ch07s02.html

- **Saturation** is the soil water content when all pores are filled with water and excess water drains out with force of gravity.
- **Field capacity** is the soil water content after the soil has been saturated and allowed to drain freely for about 24 to 48 hours. When water stops draining, we know that the remaining water is held in the soil with a force greater than that of gravity.
- **Permanent wilting point** is the soil water content when plants have extracted all the water they can. At the permanent wilting point, a plant will wilt and not recover.

Soil Water for Irrigation Scheduling





Irrigation Scheduling Methods

- **Soil Moisture Monitoring**
- Weather Monitoring

Soil Moisture Monitoring

- Monitoring soil moisture and assuming what is happening in the soil is reflected in the crop

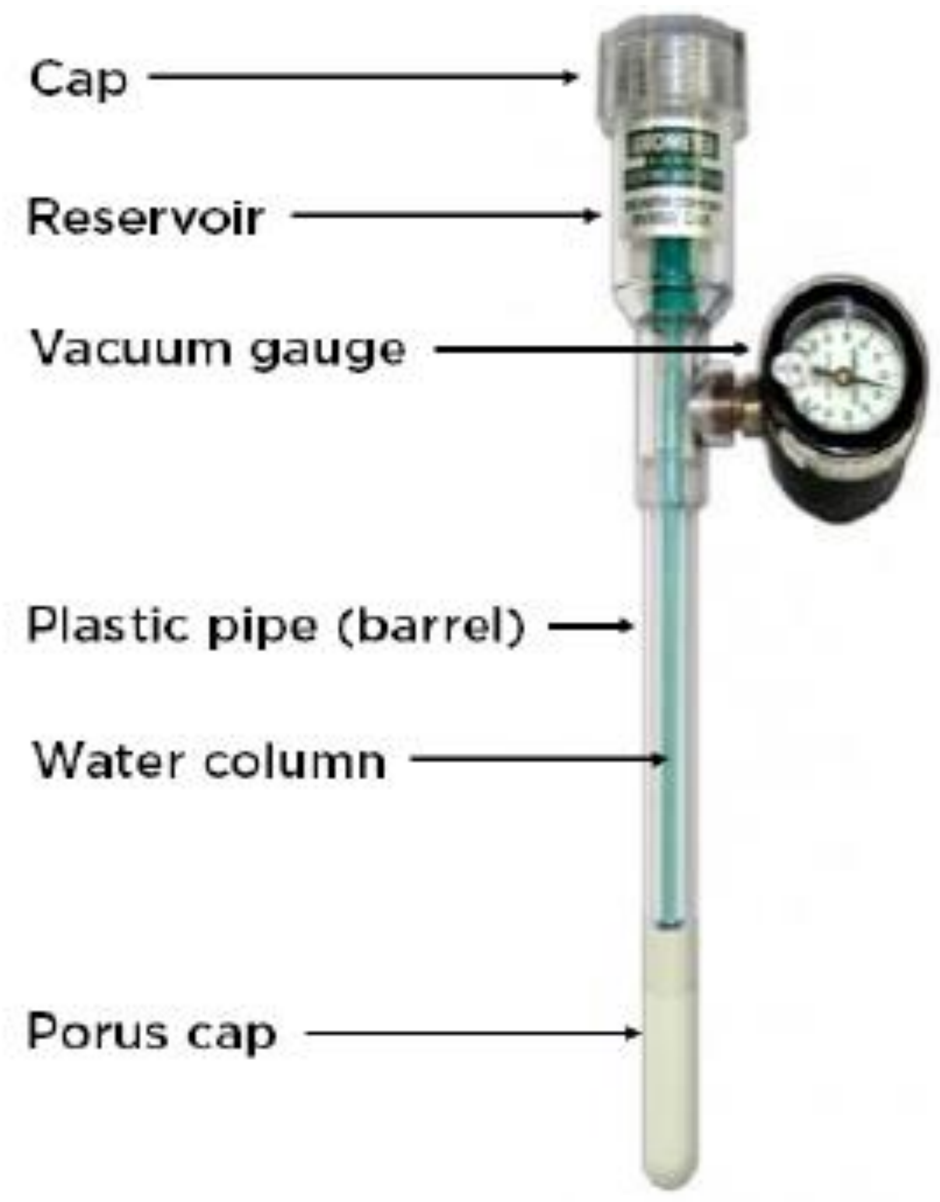
- Can give information about
  - Where the irrigation water is going?
  - Is it used by plant?
  - Is it in the root zone?
  - Is it below the root zone?
  - Are we Irrigating too little or too much?

Soil Moisture Monitoring Instruments

- Tensiometers
- Electrical resistance sensors
- Electromagnetic sensors
- Neutron probe

Soil Moisture Monitoring Instruments

- **Tensiometers and Electrical resistance blocks**
  - Tensiometers measure soil matric potential that is equivalent to the force or energy that a plant must exert to extract water from the soil.
  - Electrical resistance blocks also measure soil matric potential or soil tension. They operate on the principle water conducts electricity, and dry soil does not.

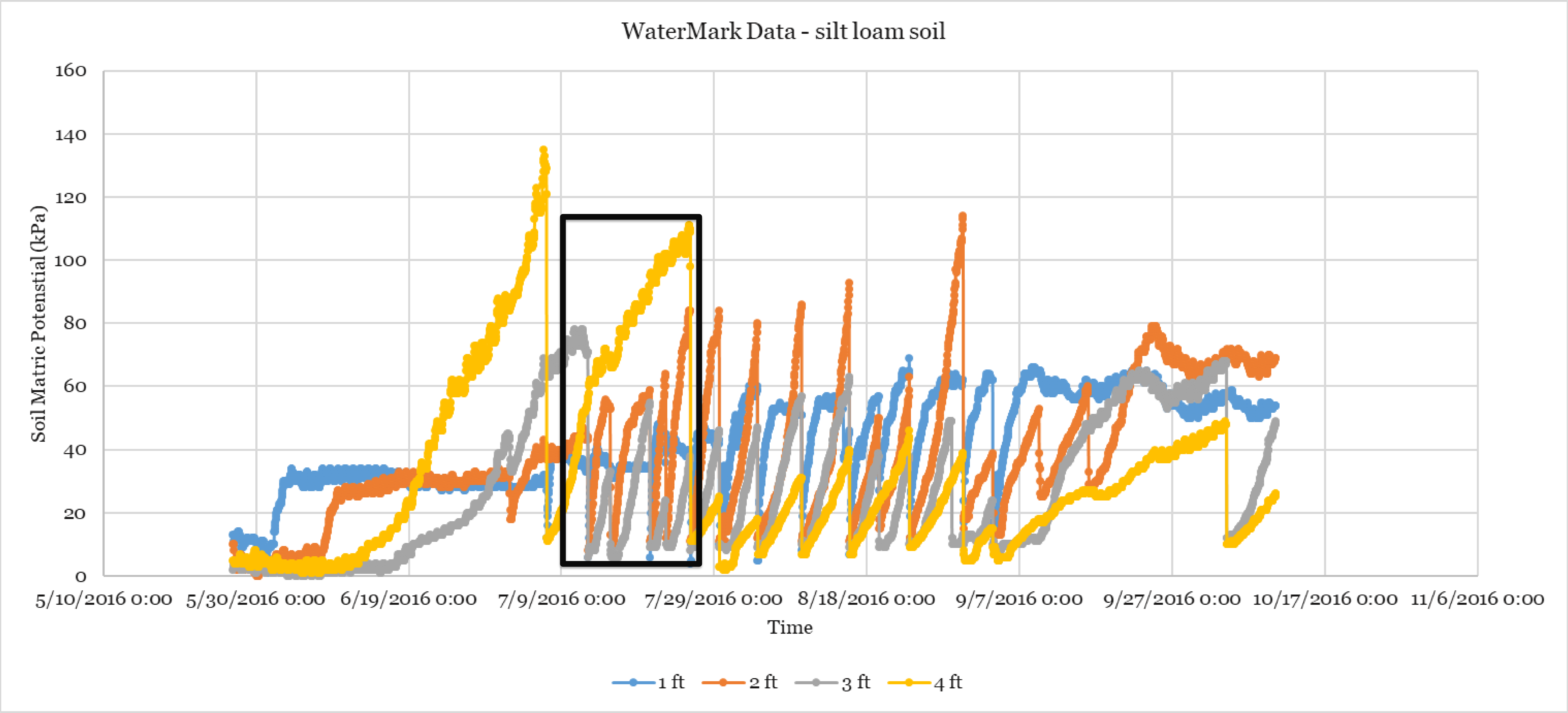


Tensiometer

Watermark sensor

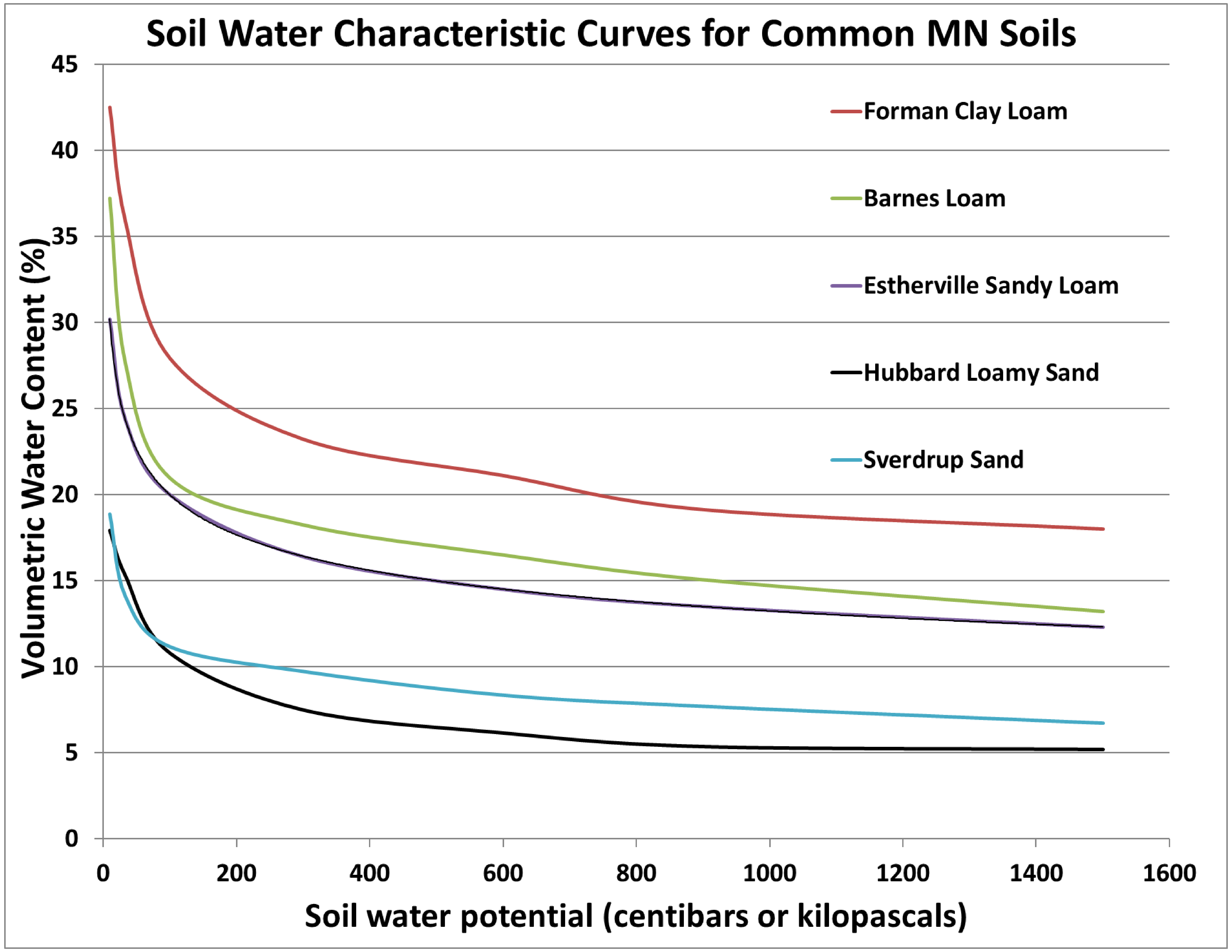
Soil Moisture Monitoring Instruments

- Watermark soil moisture data



Soil Moisture Monitoring Instruments

- **Tension and Volumetric water content (VWC)**
- **Tension**- How hard the plant has to work to extract water from soil
- **VWC** is the % of water held in the soil pores

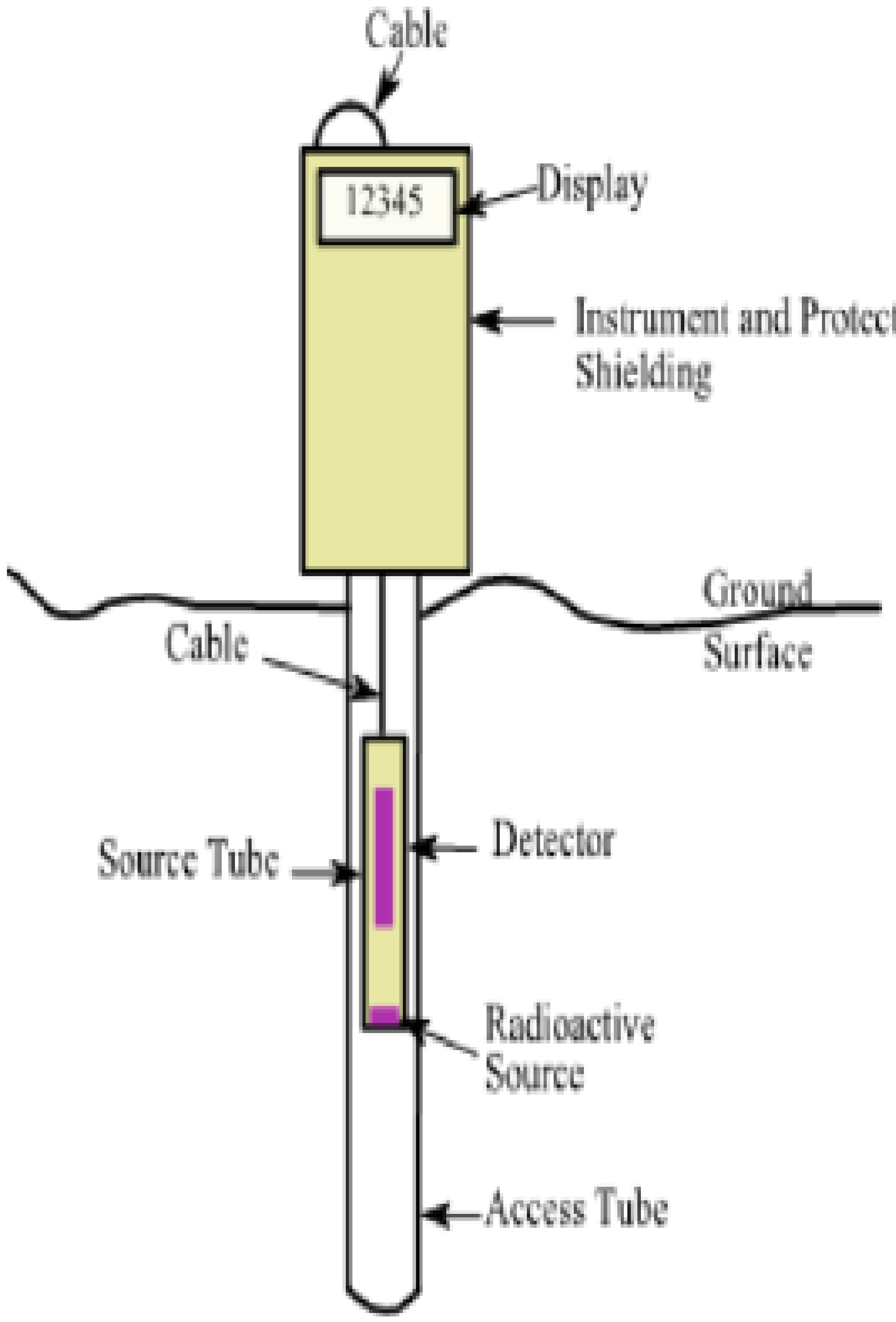


Graph developed by Joshua Stamper

Soil Moisture Monitoring Instruments

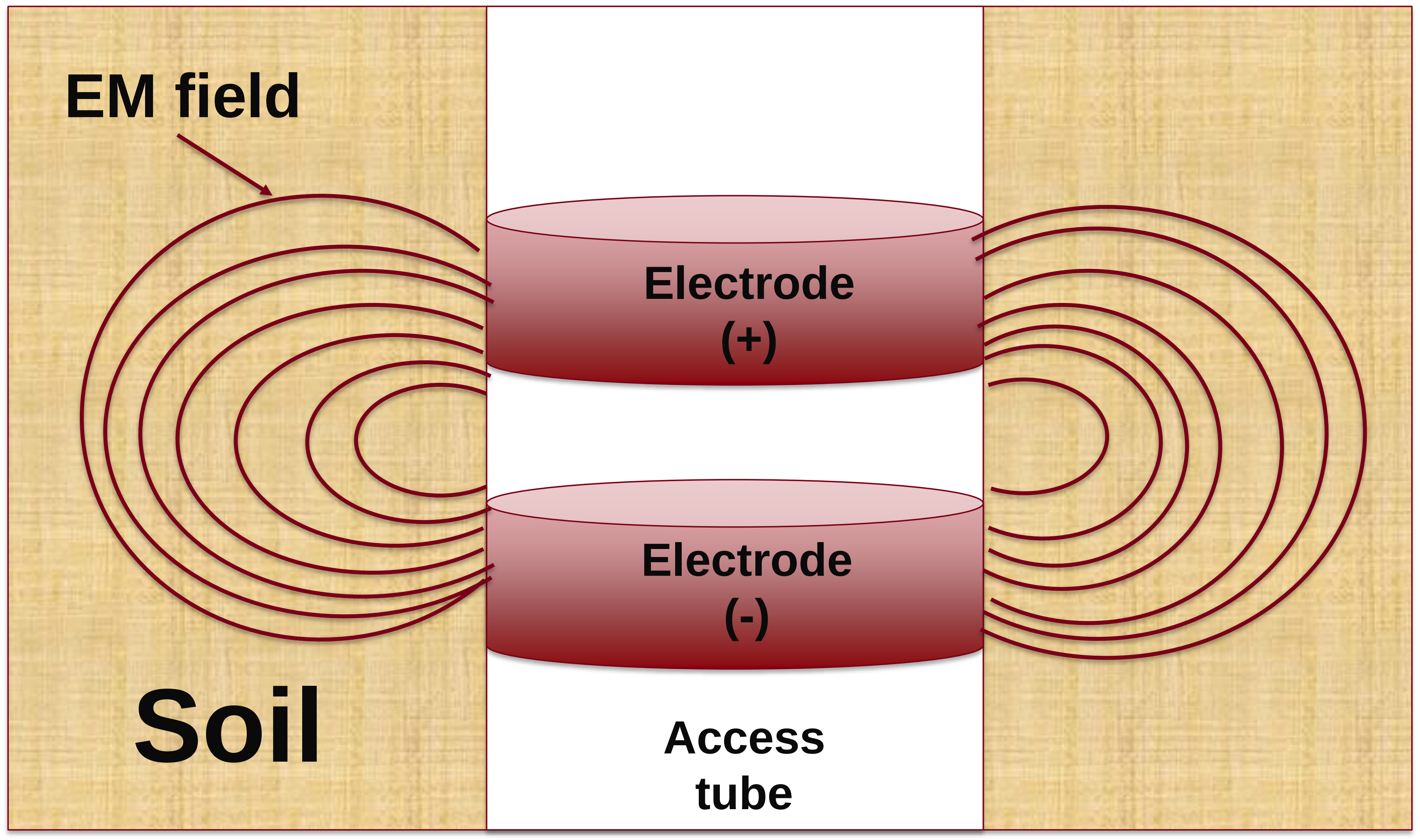
- **Neutron probe:** very accurate but expensive and has radioactive safety requirements

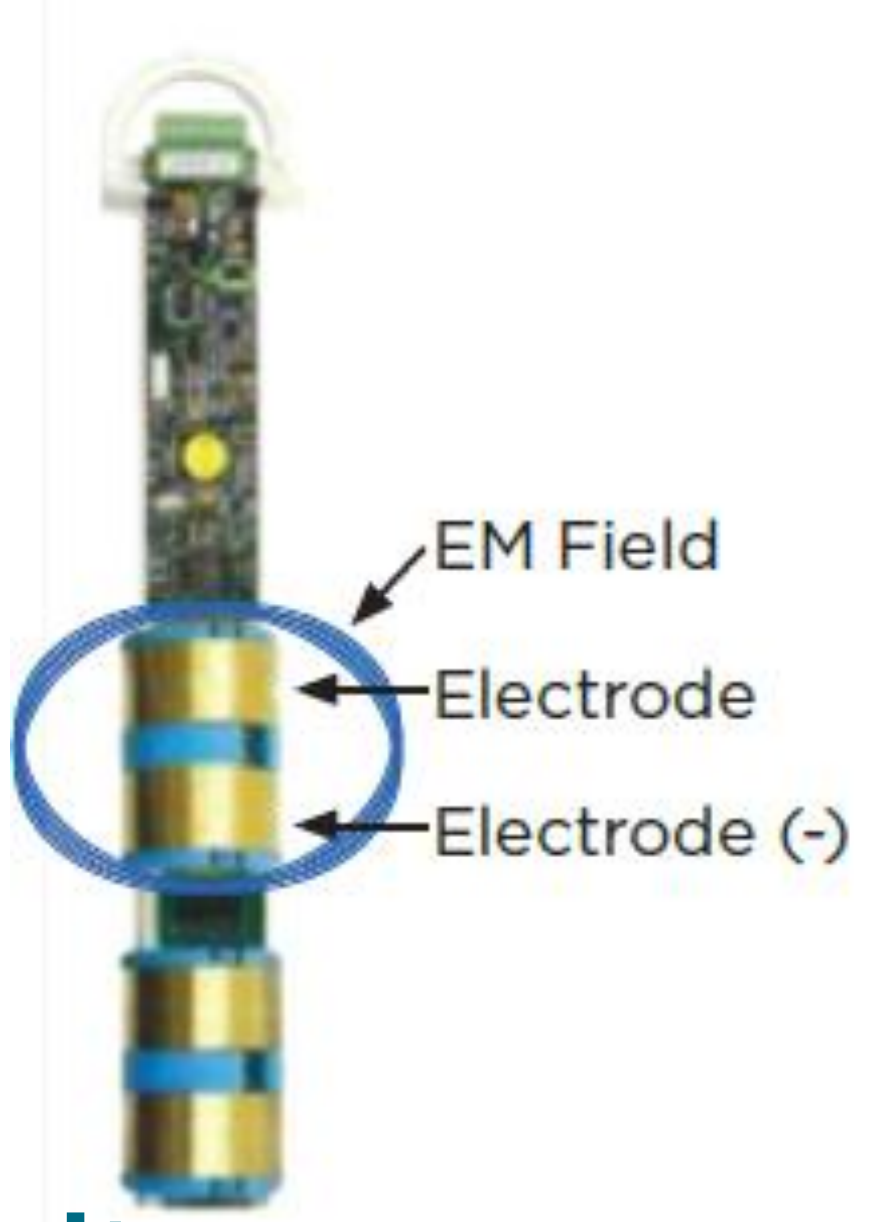
Neutron Probe



Soil Moisture Monitoring Instruments

- **Electromagnetic sensors:** Based on dielectric constant principle
  - Dielectric constant is a measure of the ability of the substance to store electrical energy in an electrical field.
  - Soil particles, water, and air, all have different dielectric constants.
  - Since the dielectric constant of water is much larger than that of other soil constituents, the total permittivity of the soil is mainly governed by the presence of soil water content.





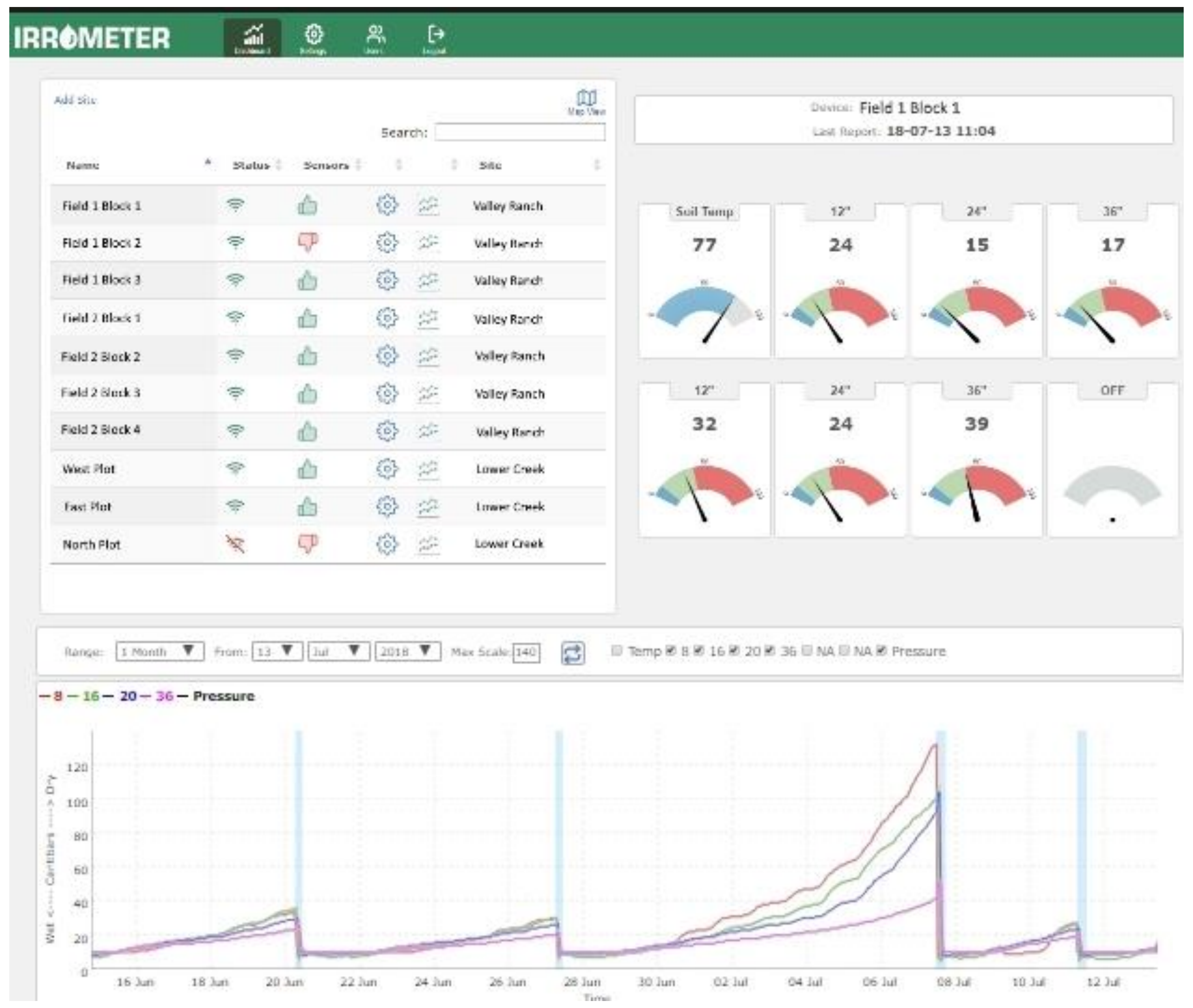
Capacitance sensor

Soil Moisture Monitoring Instruments

- Data can be logged (stored) from all these devices
- Many soil moisture monitoring services are available- like remote retrieval and you can access the information on password protected webpage
- More fancier the service, more it costs

https://aquaspy.com/

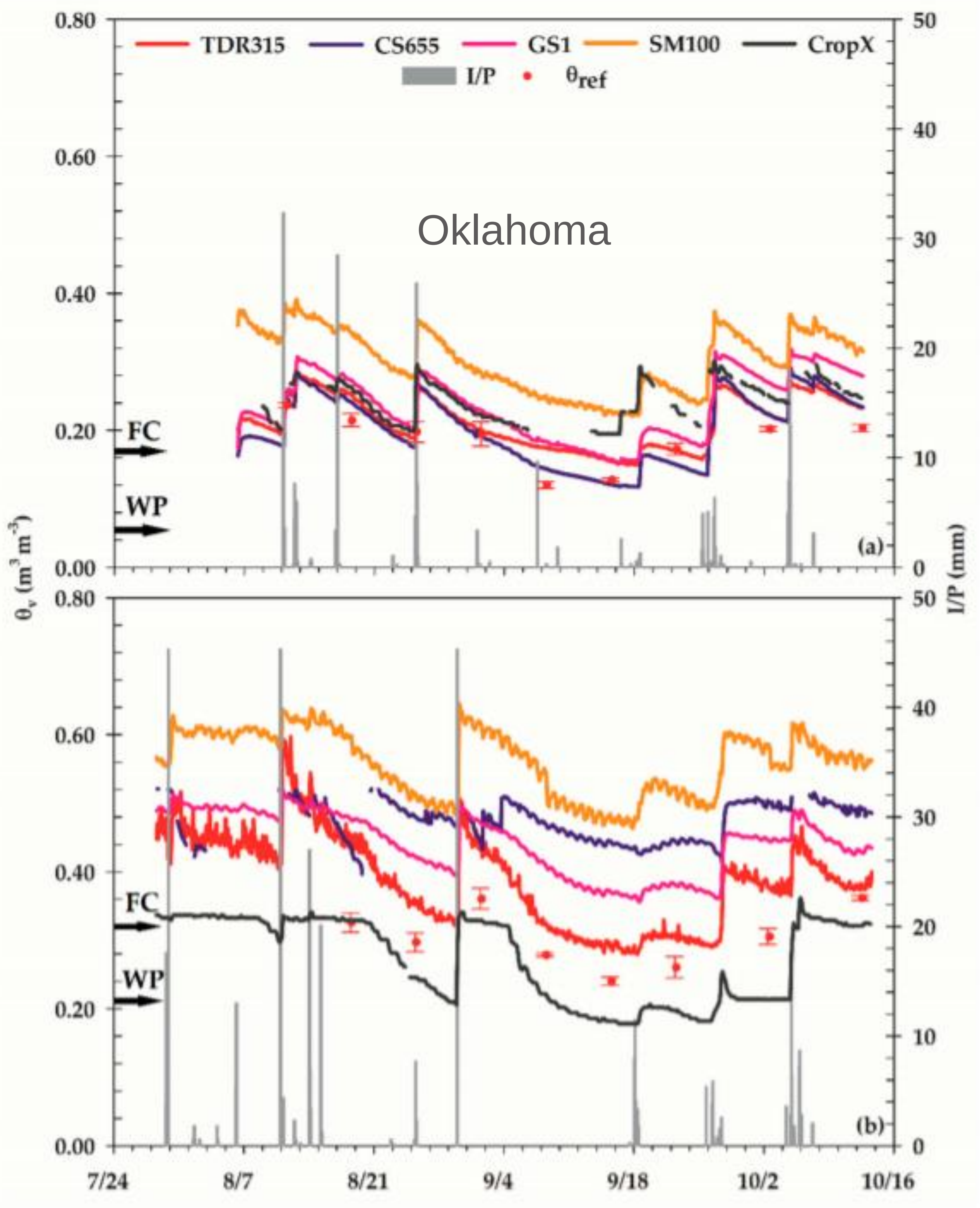
https://www.cropx.com/



http://www.irrometer.com/loggers.html

Soil Moisture Monitoring Instruments

- Things to watch out when using soil moisture sensors
  - Moisture sensors are soil sensitive and many of them require in-field calibration
  - Its not always accurate



Datta et al. 2018. Performance Assessment of Five Different Soil Moisture Sensors under Irrigated Field Conditions in Oklahoma. Sensors 2018, 18, 3786; doi:10.3390/s18113786

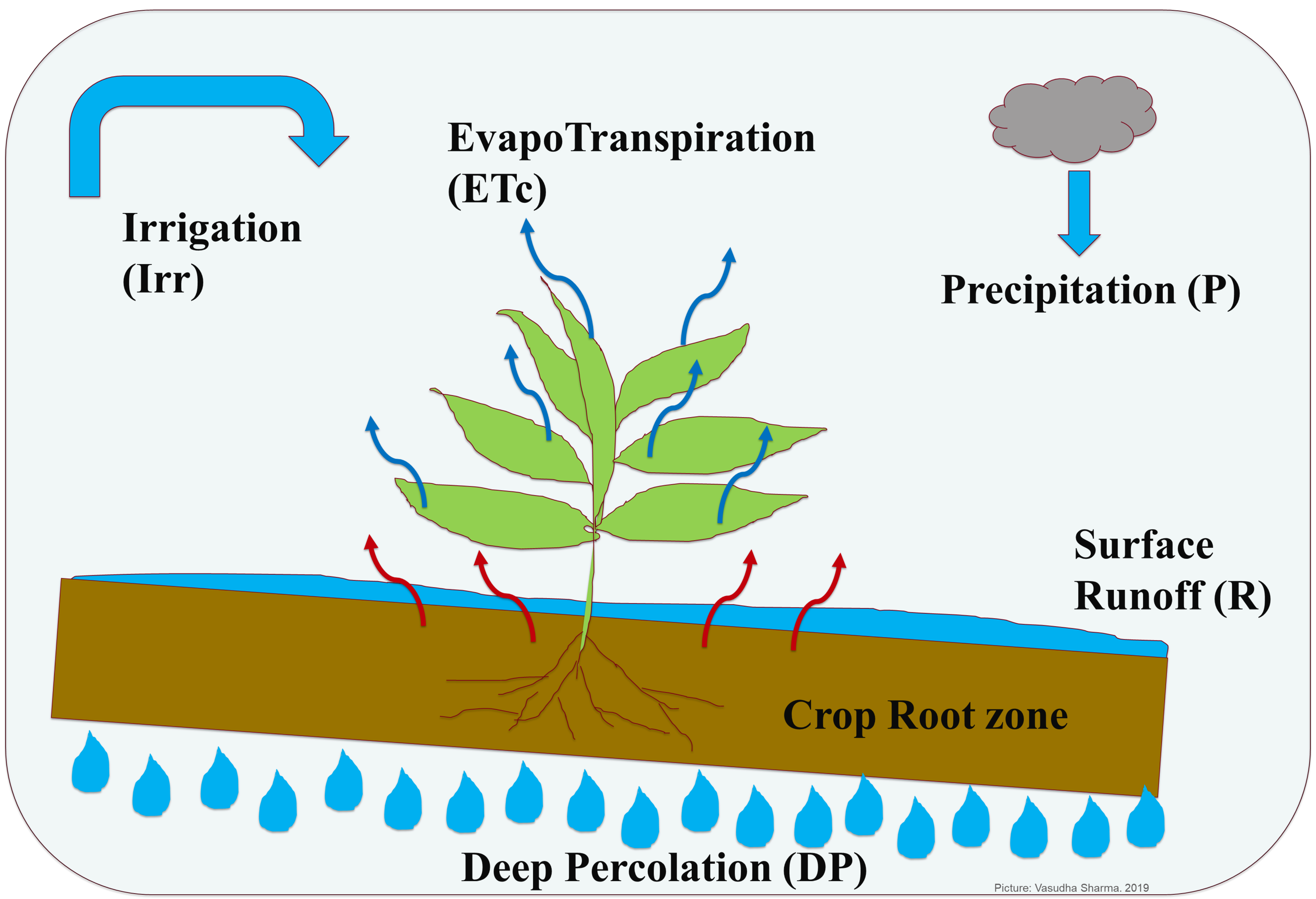
Irrigation Scheduling Methods

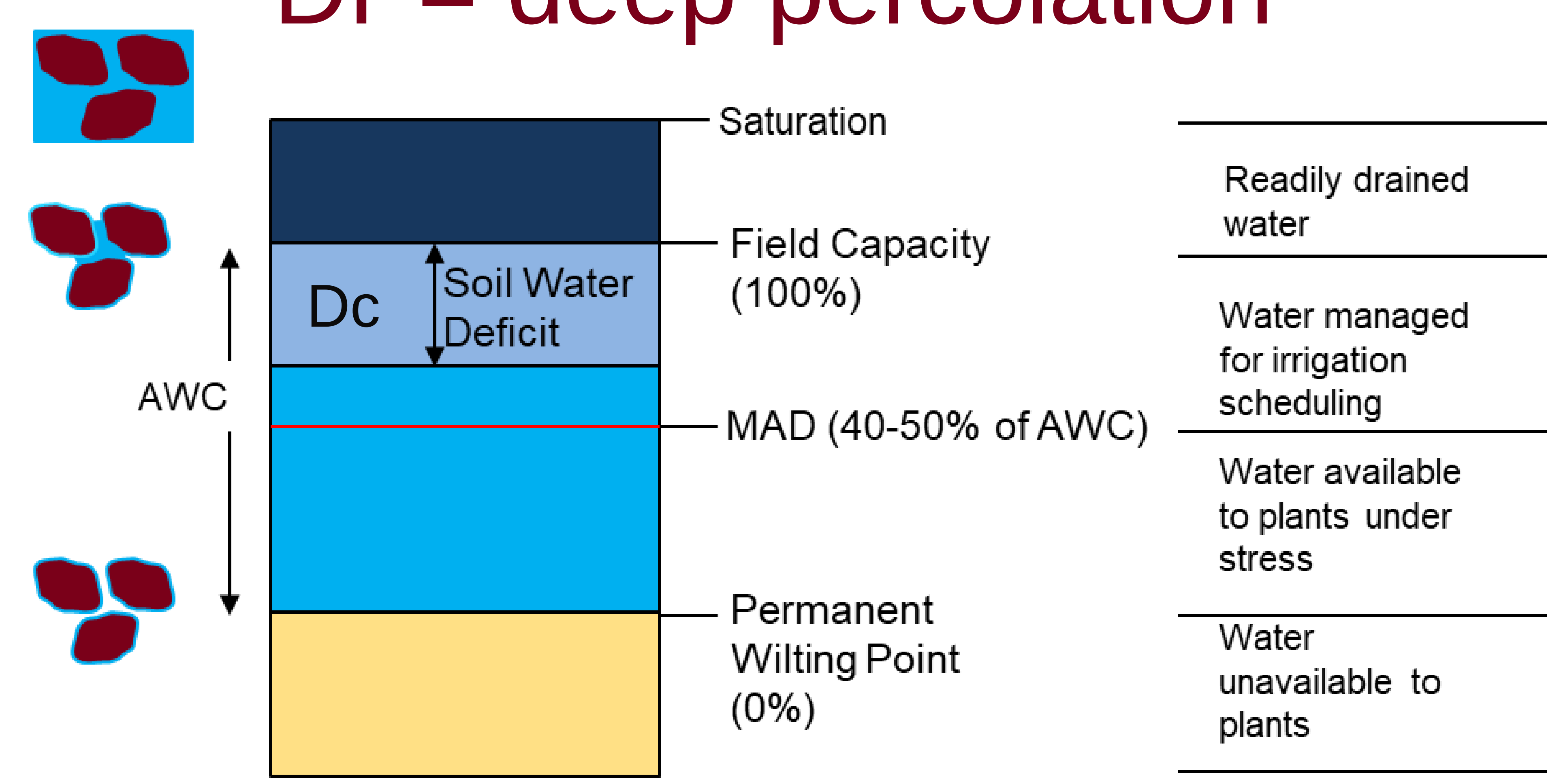
- Soil Moisture Monitoring
- **Weather Monitoring**

Weather Monitoring

- Daily Water balance of Soil Profile
  - Dc = Dp + ETc – P – Irr + R + DP

Dc = current deficit (IWR)
Dp = previous deficit
ETc = crop evapotranspiration
P = precipitation
Irr = Irrigation
R= surface runoff
DP= deep percolation

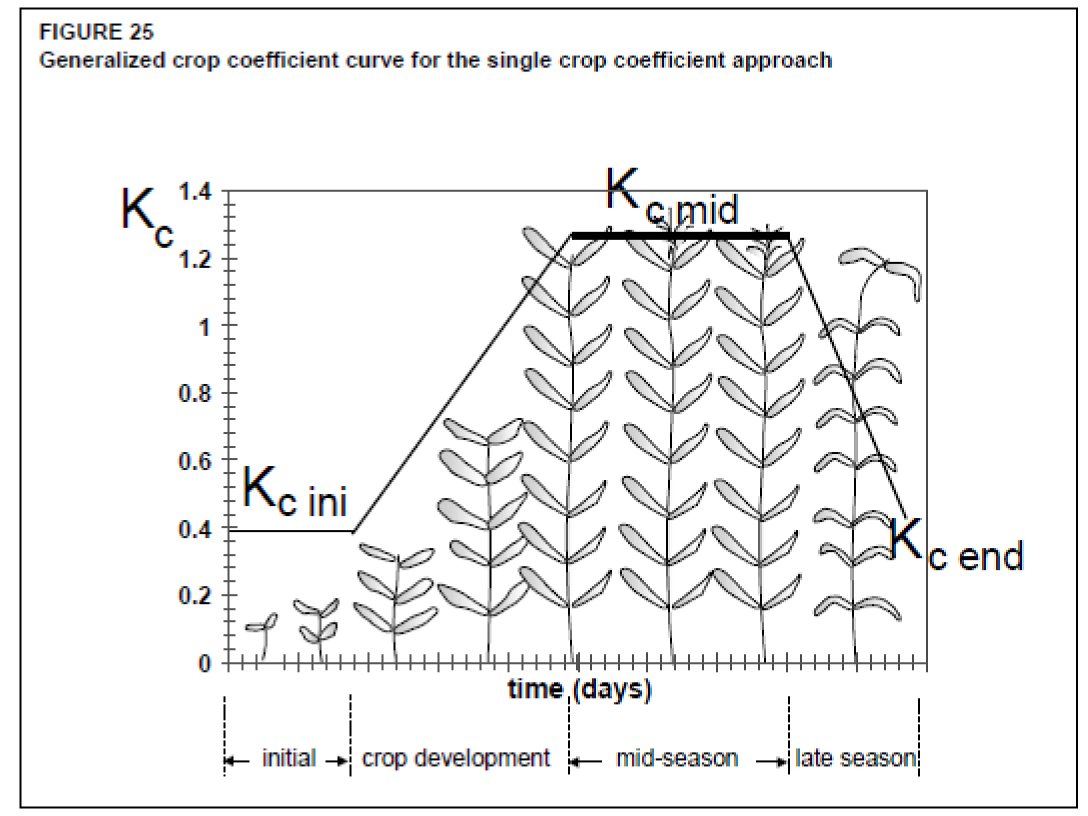




Weather Monitoring

Reference ET i.e., full cover grass or alfalfa crop ET

X



=

Actual crop ETc

$$ET_{ref} = \frac{0.408\Delta(R_n - G) + \gamma \frac{C_n}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + C_d u_2)}$$

Crop coefficients
(Crop specific and change
with location)- kind of correction factor (FAO-56)

- Reference ET values can be obtained from nearest weather stations.
- If weather station is not near by, Atmometers can be used.
- An atmometer (or ETgage) can give reasonable estimates of reference ET

http://agweathernetwork.com/

Image: ETgage company

Weather Monitoring

Irrigation Scheduling by the Checkbook Method | Instructions | Internal Links | External Links | Authors

Minnesota ET Tables, Conventional Units. | Crops & Soils | NDAWN | Disclaimer

Crop: **Corn** | ET Tables | Web Soil Survey | Revisions

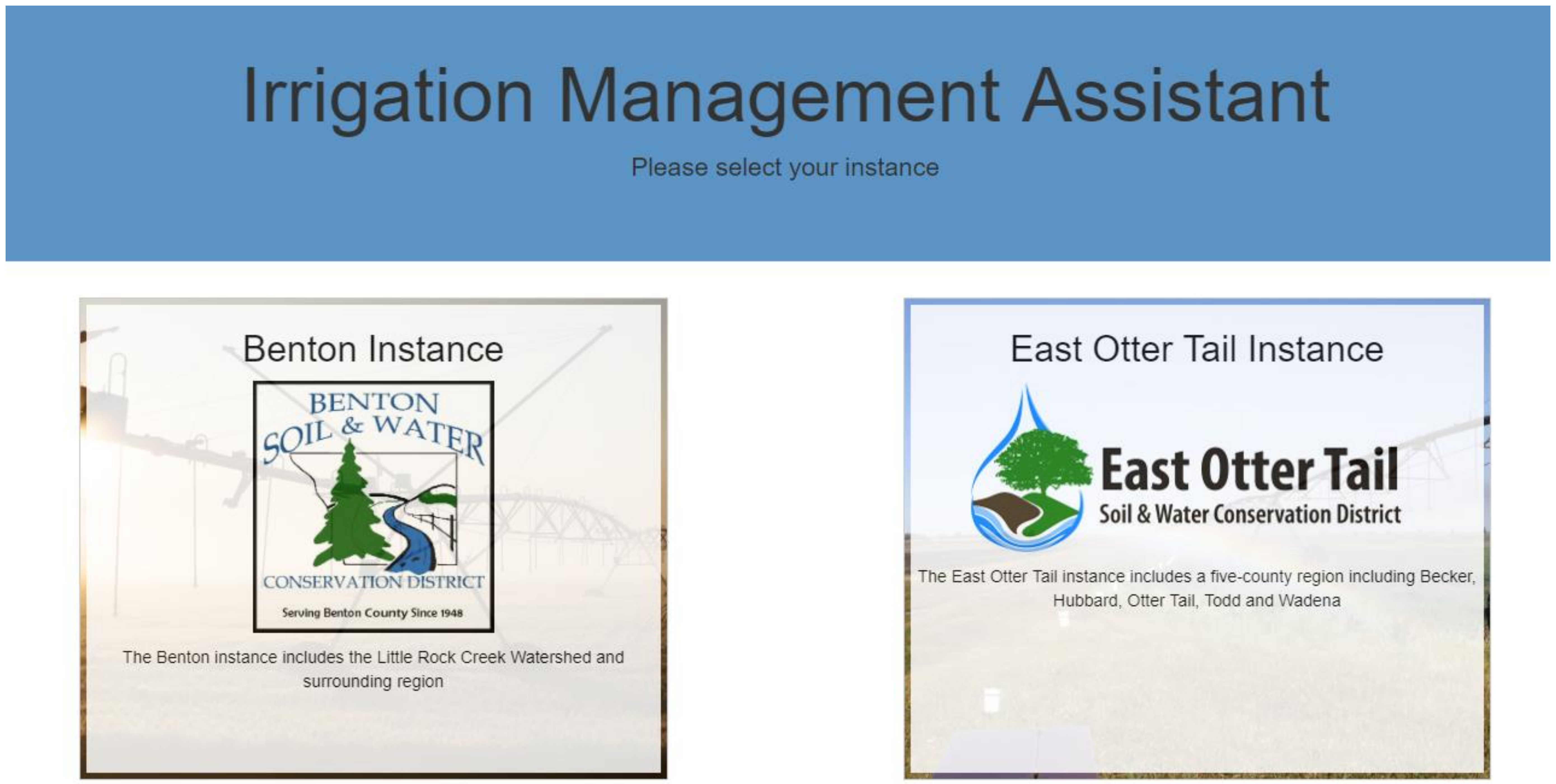
Field: **Smith's NE 29, Madison Twp,** | Emergence: **5/1/2009** | Charts | Ver. 2.5

Date	Daily Maximum Temper-ature (T_{max})	Week Past Emer-gence (WPE)	ET for all Crops Except Cut Alfalfa (ET)	Effective Rain (R)	Effective Irrigation (I)	Soil-Water Deficit (SWD)	Soil-Water Deficit Percent (SWDP)	Soil-Water Deficit Percent (Adjusted) ($SWDP_{adj}$)	Water Losses (Deep Percolation or Runoff); (WL)	Root Zone Depth (RZ)	Available Water Holding Capacity for the Root Zone ($AWHC_{RZ}$)	Cumulative Values: Total ET	Cumulative Values: Total Rain	Cumulative Values: Total Irrigation	Cumulative Values: Total Water Losses	Notes	Manage ment Allowed Depletion (MAD)
-	°F	-	in.	in.	in.	in.	%	%	in.	in.	in.	in.	in.	in.	in.		%
4/30/2009	49	0	0.00	0.06		0.00	0%	0%	0.00	4.0	0.28	0.00	0.06	0.00	0.00		50%
5/1/2009	54	1	0.01	0.01		0.00	0%		0.00	4.0	0.28	0.01	0.07	0.00	0.00		50%
5/2/2009	64	1	0.02	0.11		0.00	0%		0.09	4.8	0.35	0.03	0.18	0.00	0.09		50%
5/3/2009	50	1	0.00	0.00		0.00	0%		0.00	5.5	0.42	0.03	0.18	0.00	0.09		50%
5/4/2009	41	1	0.00	0.00		0.00	0%		0.00	6.3	0.49	0.03	0.18	0.00	0.09		50%
5/5/2009	63	1	0.02	0.00		0.02	4%		0.00	7.0	0.55	0.05	0.18	0.00	0.09		50%
5/6/2009	73	1	0.03	0.00		0.05	8%		0.00	7.8	0.62	0.08	0.18	0.00	0.09		50%
5/7/2009	78	1	0.03	0.04		0.04	6%		0.00	8.6	0.71	0.11	0.22	0.00	0.09		50%
5/8/2009	72	2	0.04	0.10		0.00	0%		0.02	9.3	0.81	0.15	0.32	0.00	0.11		50%
5/9/2009	64	2	0.03	0.00		0.03	3%		0.00	10.1	0.91	0.18	0.32	0.00	0.11		50%
5/10/2009	53	2	0.02	0.00		0.05	5%		0.00	10.9	1.01	0.20	0.32	0.00	0.11		50%
5/11/2009	55	2	0.02	0.00		0.07	6%		0.00	11.6	1.11	0.22	0.32	0.00	0.11		50%
5/12/2009	61	2	0.03	0.00		0.10	8%		0.00	12.4	1.22	0.25	0.32	0.00	0.11		50%

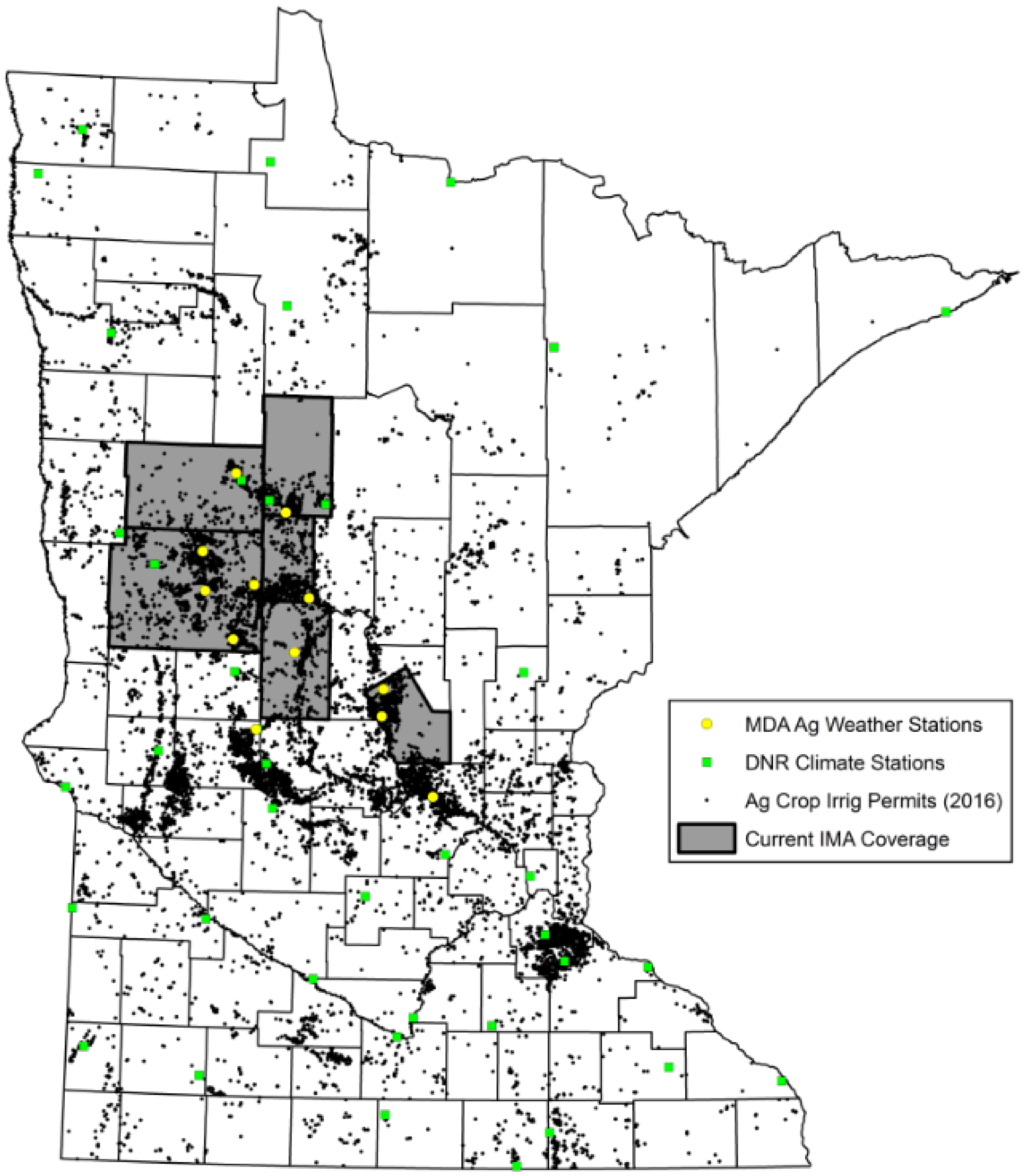
Table 2. Average water use for CORN in inches/day

Temperature F	Week after emergence: 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
50-59	.01	.02	.03	.04	.05	.06	.08	.09	.09	.10	.10	.10	.09	.07	.06	.05	.04	.03
60-69	.02	.03	.04	.06	.08	.09	.11	.12	.13	.15	.14	.14	.13	.11	.09	.07	.06	.04
70-79	.03	.04	.05	.07	.10	.12	.15	.16	.17	.19	.19	.18	.17	.14	.11	.09	.07	.05
80-89	.03	.05	.07	.09	.13	.15	.18	.20	.22	.24	.23	.22	.21	.17	.14	.11	.09	.06
90-99	.04	.06	.08	.11	.15	.18	.21	.24	.26	.28	.27	.26	.25	.20	.17	.13	.11	.07
Corn growth stages		↑ 3 leaf			↑ 8 leaf			↑ 1st tassel	↑ silk		↑ blister kernel			↑ early dent	↑ dent			

Weather Monitoring



MDA & DNR Weather Stations

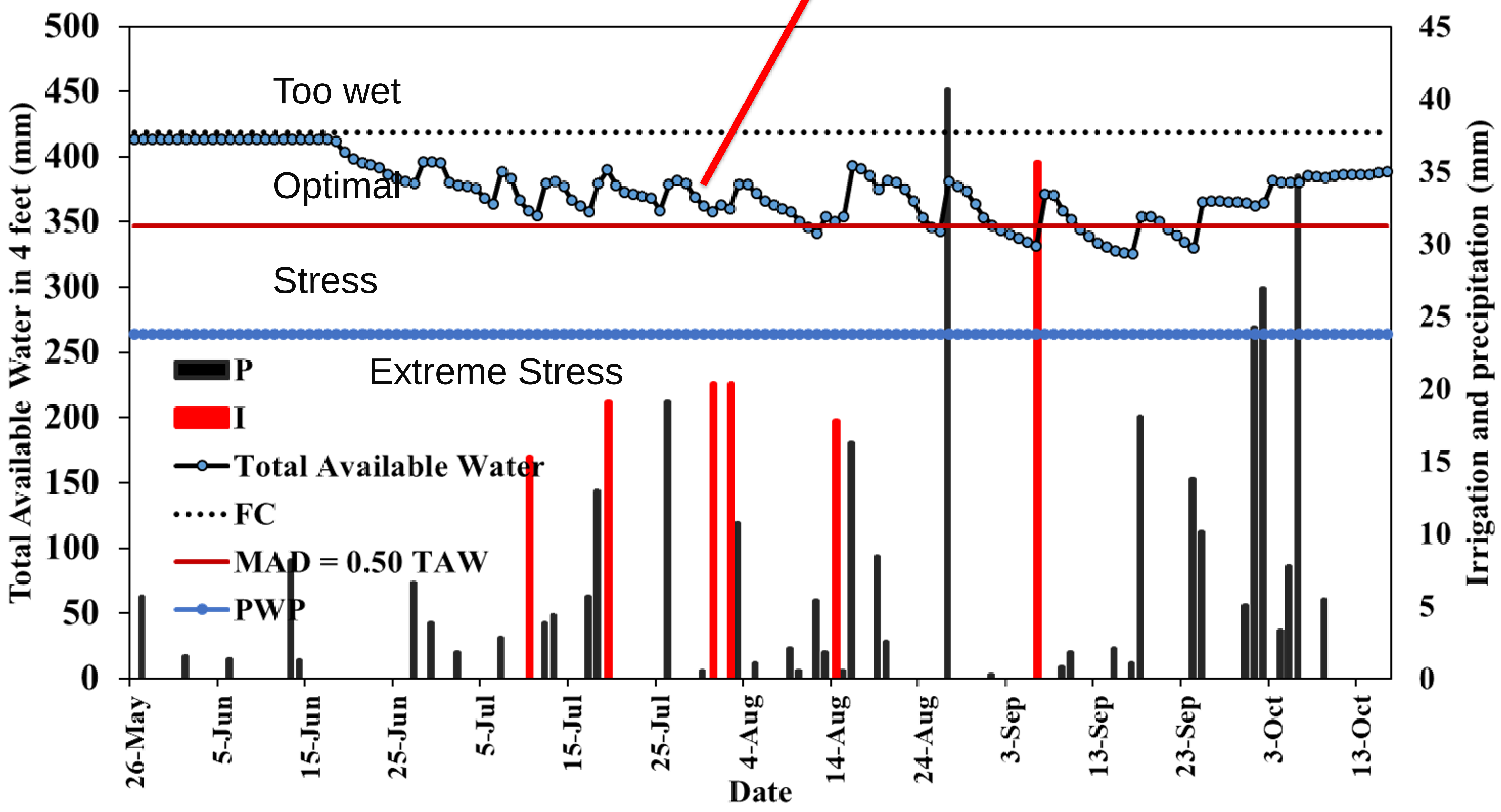


Source: ima.respec.com

Irrigation scheduling- Things you need to know

- Know available soil water for each depth of soil
- Know the rooting depth for each crop
- Know allowable soil moisture depletion at each stage of plant growth- using soil moisture measurement or estimation
- Use evapotranspiration data to estimate crop water use
- Measure rainfall in each field

Soil moisture depletion can be measured using soil moisture sensors and can be estimated using weather data



Irrigation Management Strategies

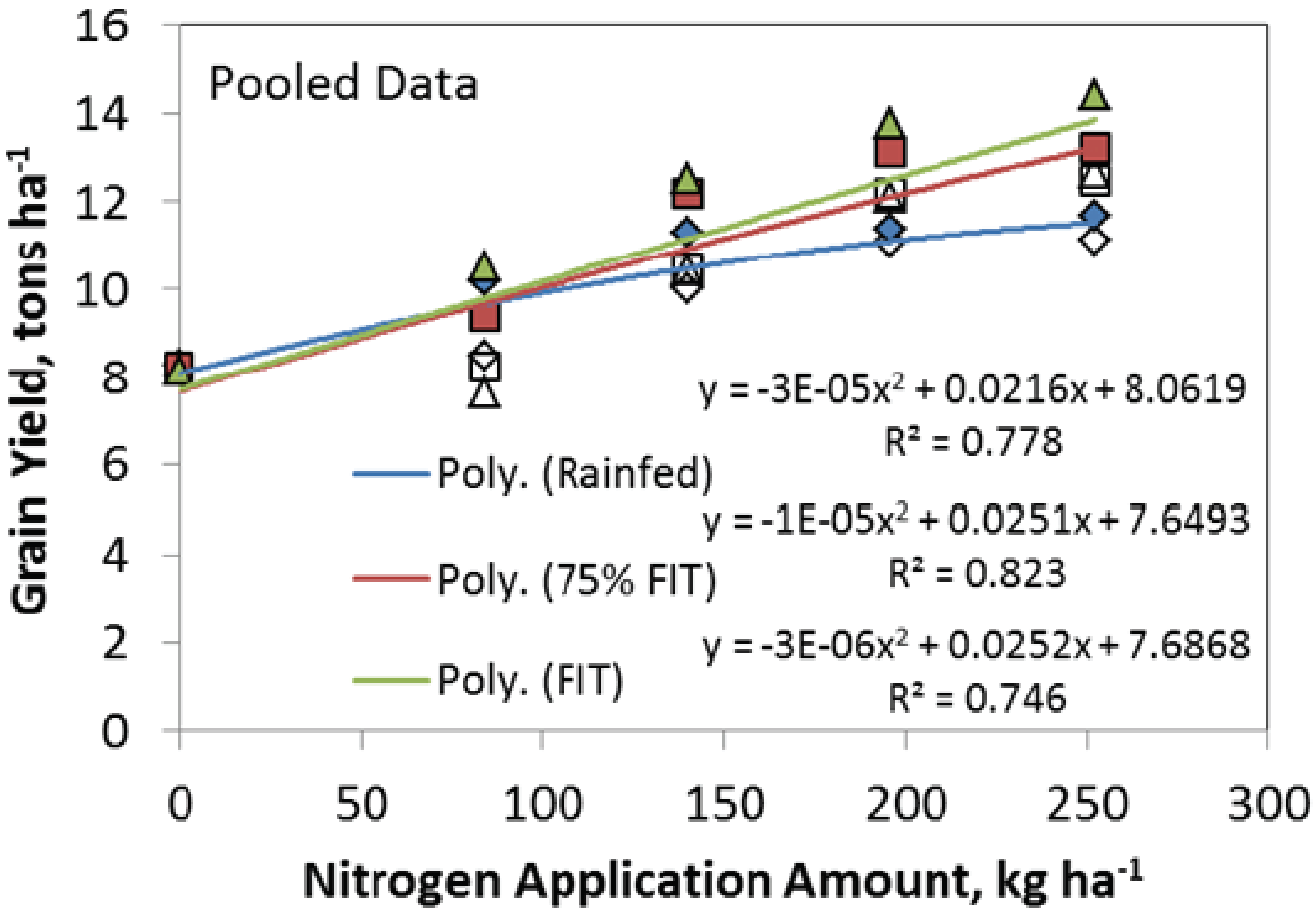
- Deficit Irrigation Management
- Variable rate Irrigation and fertigation

Deficit Irrigation Management

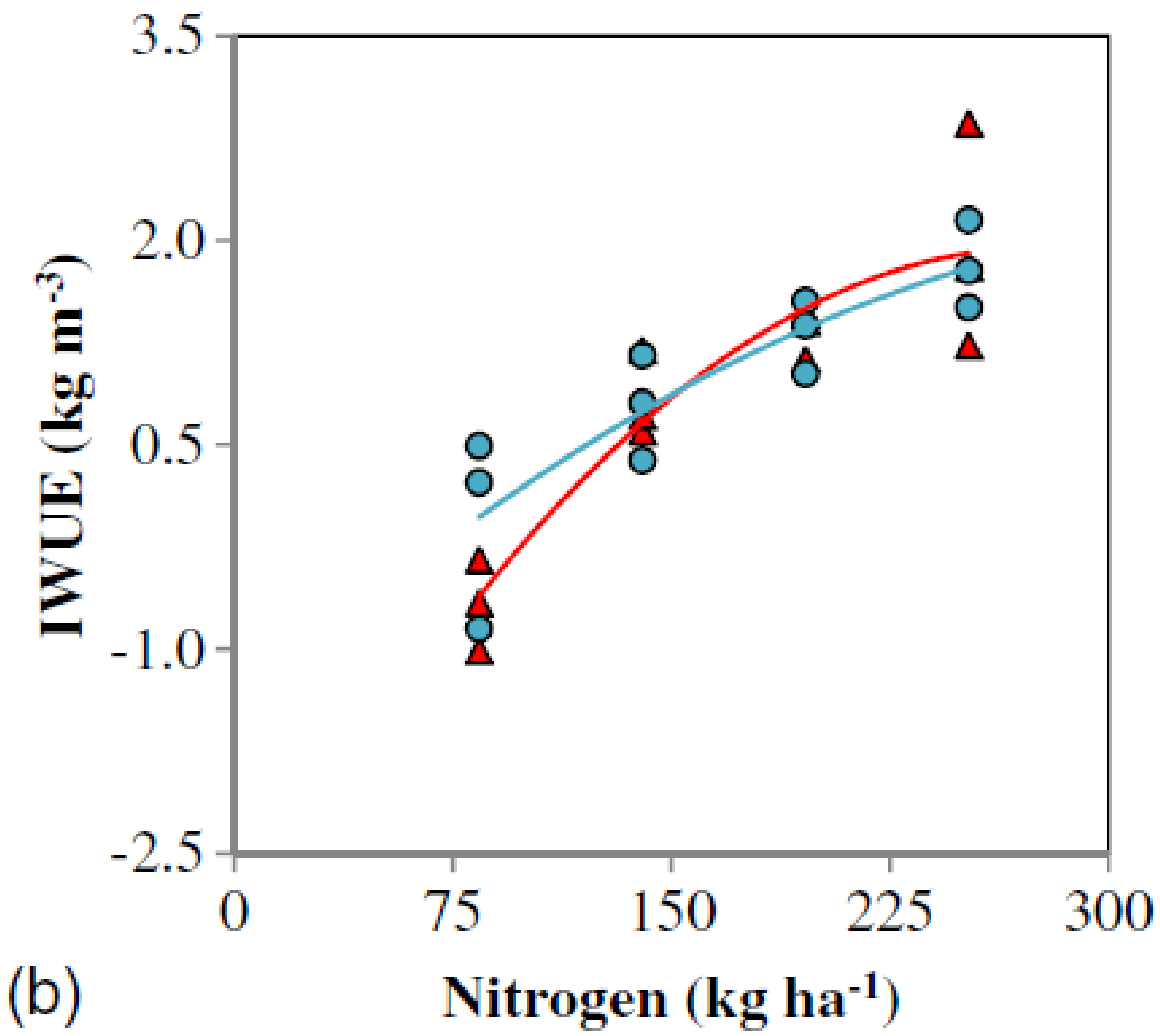
- Deficit irrigation is one way of maximizing water use efficiency (WUE) for higher yields per unit of irrigation water applied.

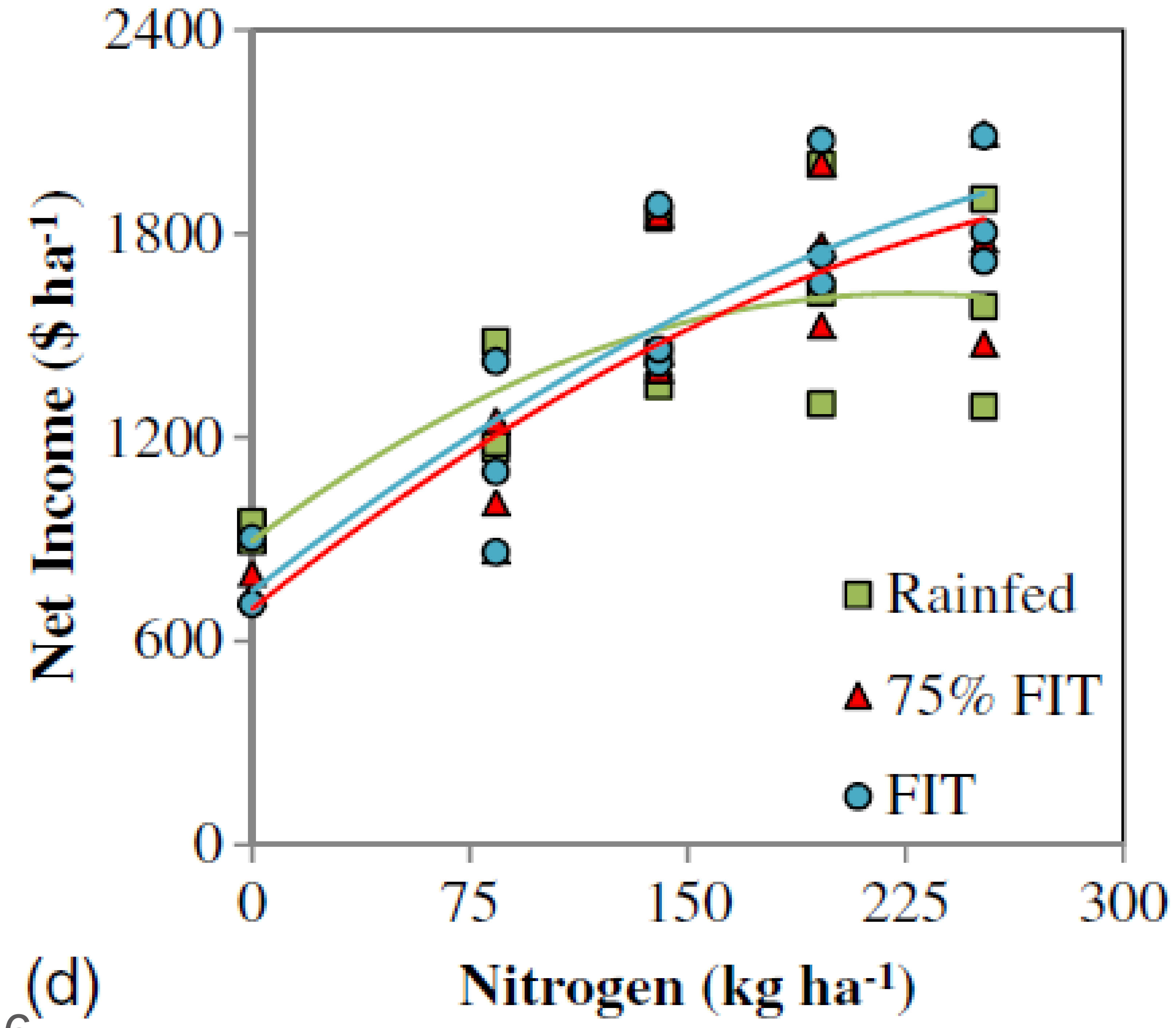
- The crop is exposed to a certain level of water stress either during a particular growth period or throughout the whole growing season, without significant reduction in yields.

Deficit Irrigation Management



Rudnick and Irmak, 2013





Rudnick et al. 2016

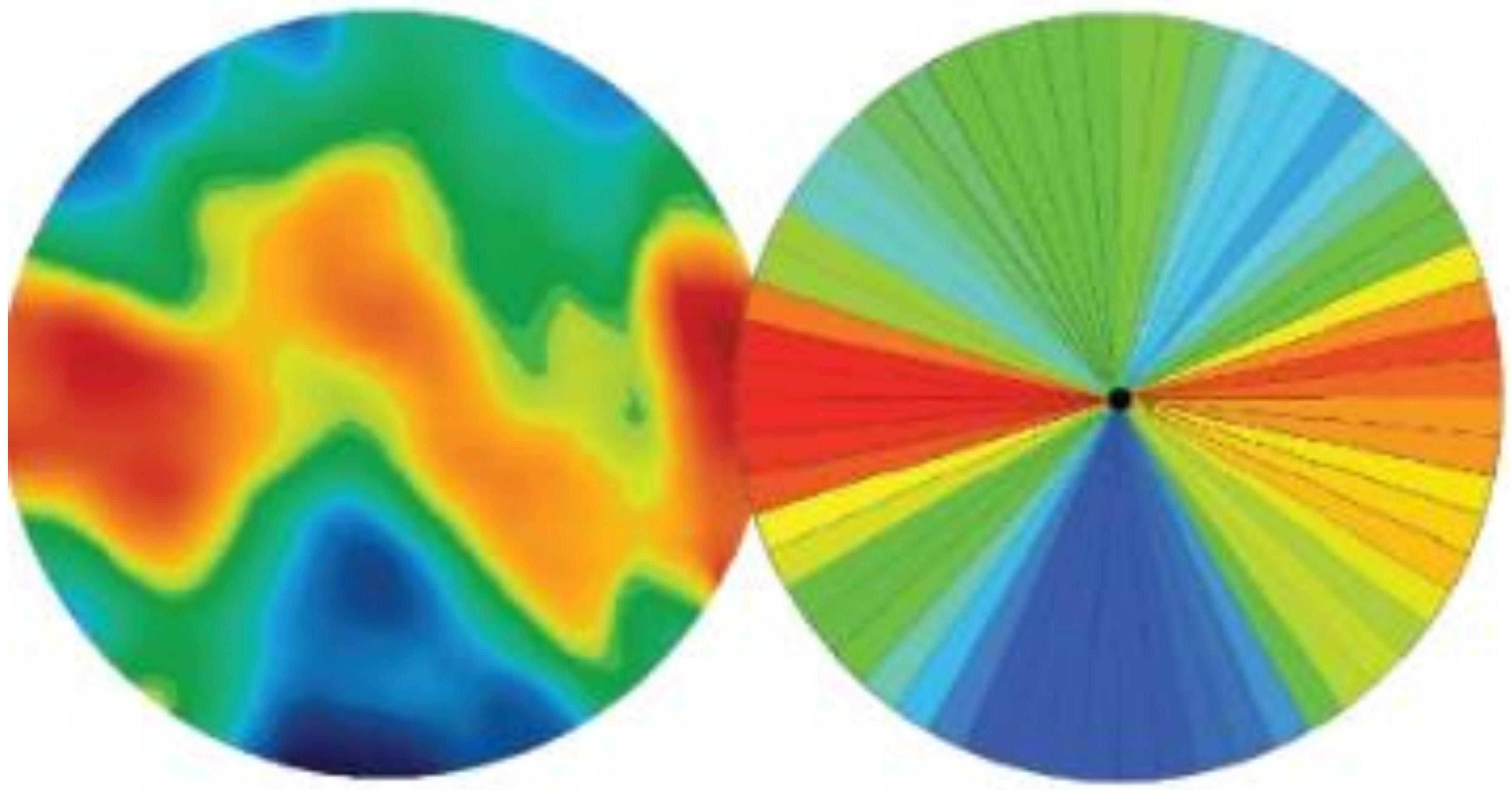
Deficit Irrigation study in Minnesota

- Three Irrigations: 100% (i.e., all irrigations), 75% (i.e., skipped 1 irrigation) and 50% (i.e., skipped two irrigations)
- Three Planting Populations: 20, 30 and 40 thousand plants per acre
- 2017 results

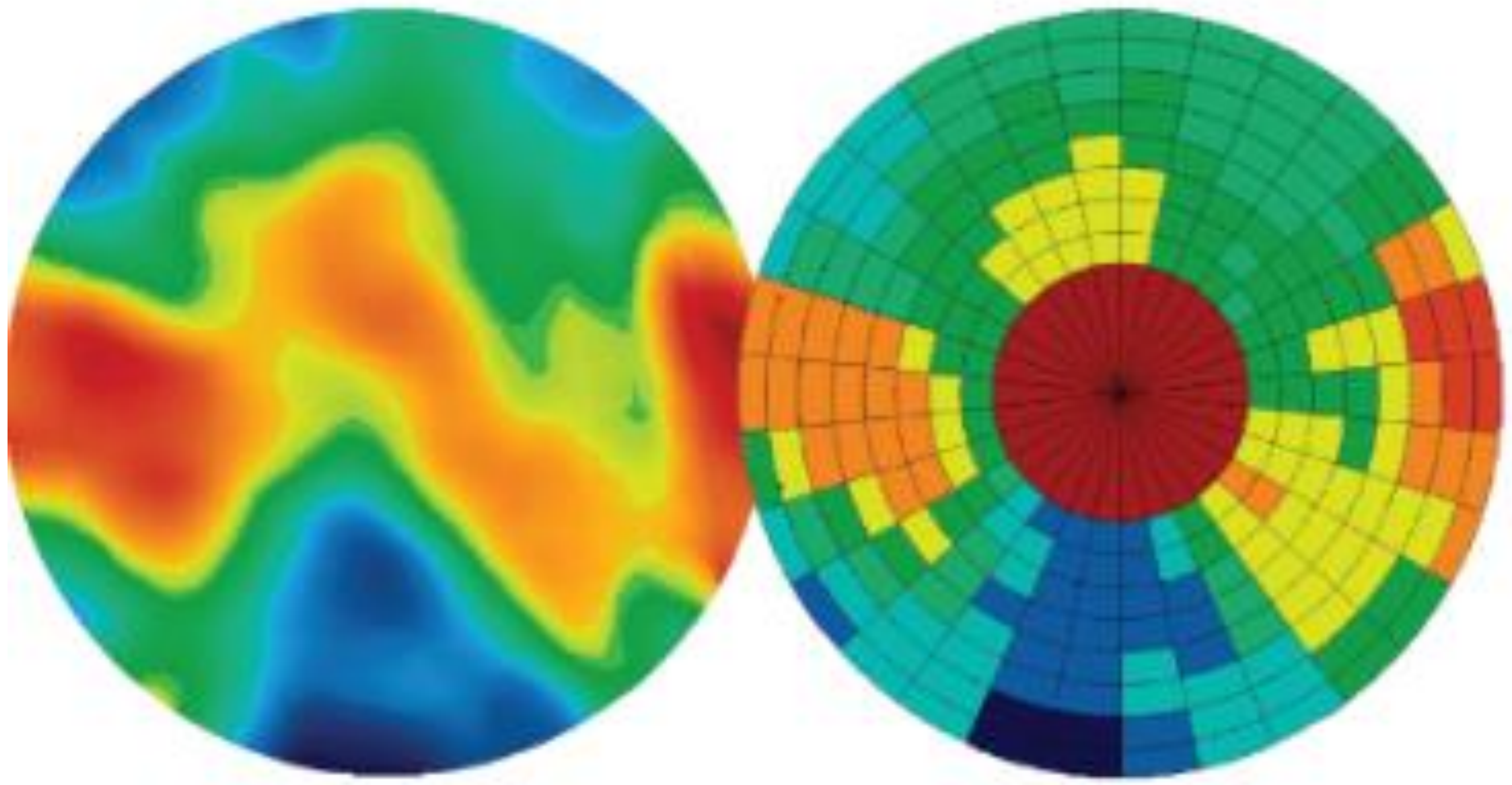
Irrigation (%)	Planting population (x1000 plants/ac)	Yield (bu/ac) @ 15.5 %	Avg. Yield (bu/ac)	Stat. Diff.
50	20	186.40	198.71	A
50	30	203.59		
50	40	206.13		
75	20	205.00	215.47	B
75	30	220.15		
75	40	221.26		
100	20	209.70	221.56	B
100	30	222.36		
100	40	232.61		

Variable Rate Technology

- Changing the rate of water and chemicals to different areas in the field
- VRI can be
  - Speed control and Zone control
    - In zone control: Bank of nozzles are controlled or individual nozzles can be controlled



Sector Control or Speed Control



Zone Control

Picture: Reinke irrigation

Variable Rate Technology

- Few studies at commercial field scale
- Need to develop user friendly management tools

- **Variable rate irrigation and fertigation study in Nebraska**
- **Objectives:**
  - Quantifying irrigation reduction and yield potential with VRI as compared to uniform and rainfed treatments

Conclusion

- Managing soil water in the root zone is critical to plant growth
- Accurate control of soil water enables accurate control of nutrients and other inputs
- Modern soil moisture sensing and weather monitoring enable automated soil moisture tracking
- By keeping soil water content between field capacity and management allowable depletion, irrigation can be managed
- Putting these steps to work can increase farm profits with reduced environmental impacts

THANK YOU !
Questions???

The mention of any trade name or commercial products in this presentation does not constitute an endorsement or recommendation for use by author and the University of Minnesota