Precision Irrigation Technology

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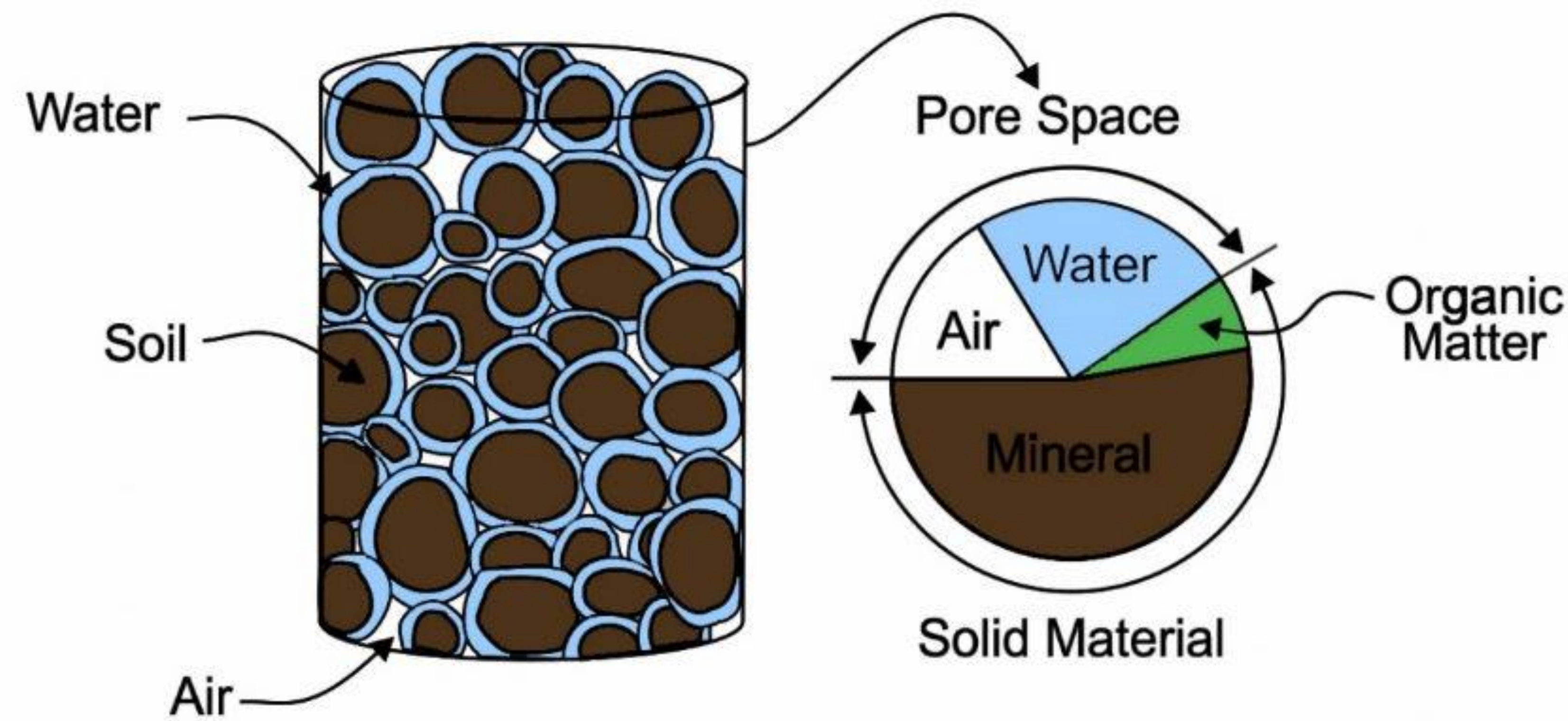
College of Agriculture

TENNESSEE STATE UNIVERSITY

TENNESSEE STATE UNIVERSITY

Cooperative Extension

Soil Composition

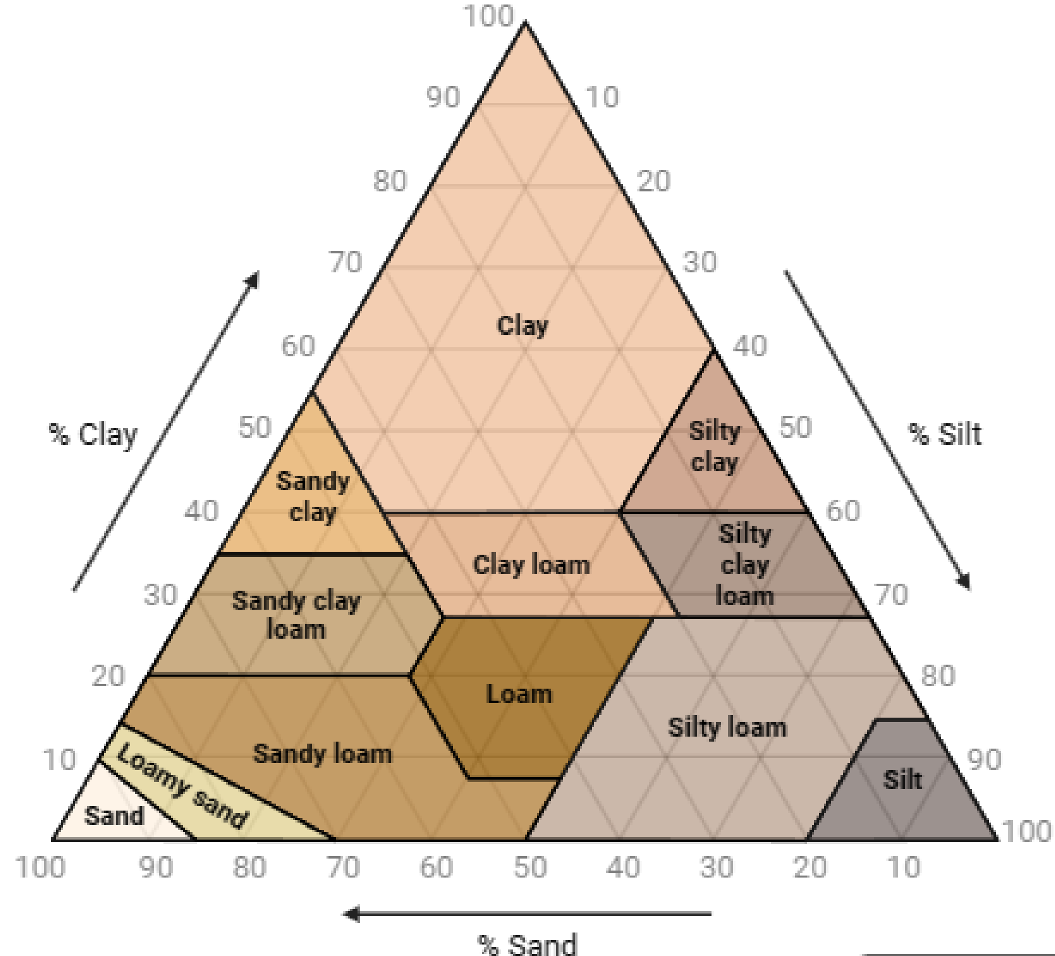


Soil texture and structure both influence the size of soil pores and total amount of pore space in a given volume of soil.

Soil Texture

Mineral fraction of soil and size:

- Clay < 0.00008 in.
- Silt 0.002 to 0.00008 in.
- Fine Sand 0.01 to 0.004 in
- Medium Sand 0.02 – 0.01 in
- Coarse Sand 0.04-0.02 in



Question: What is the texture class of a soil with 20% clay, 60% silt, and 20% sand?

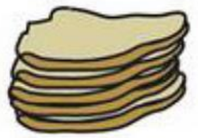
USDA equilateral Soil Texture Triangle

Soil Structure

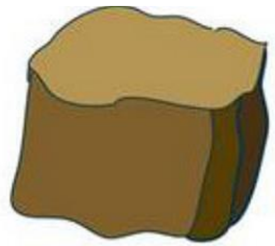
- Platy
- Massive

- Prismatic/columnar
- Blocky

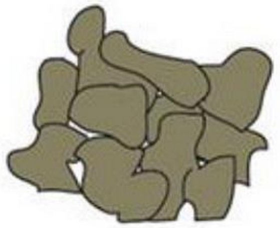
- Granular & crumb
- Single grain/aggregated



Platey (low permeability)



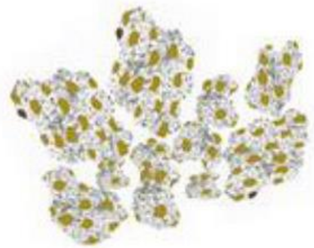
Massive (low permeability)



Blocky (moderate permeability)

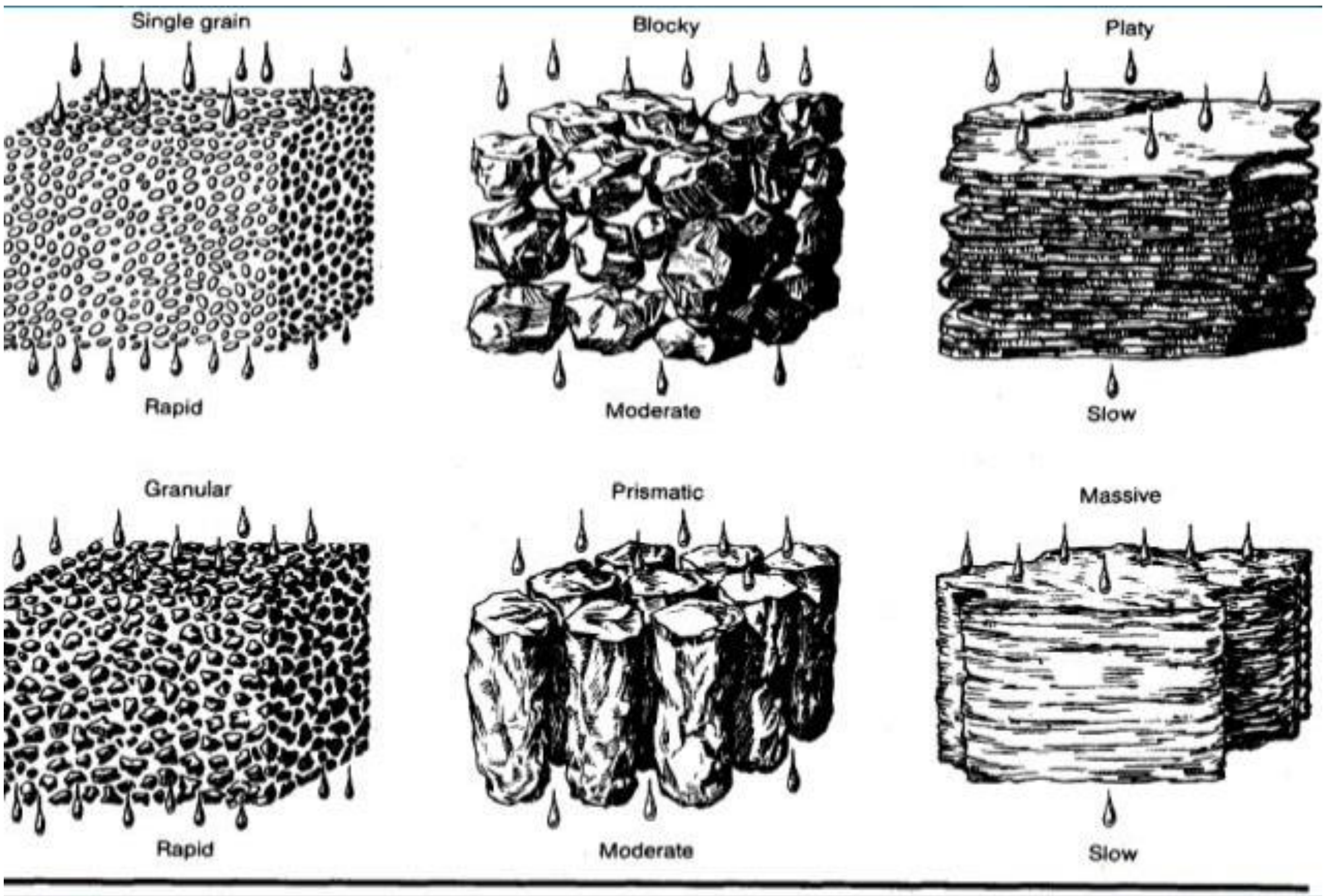
Columnar/prismatic (moderate permeability)

Granular (high permeability)

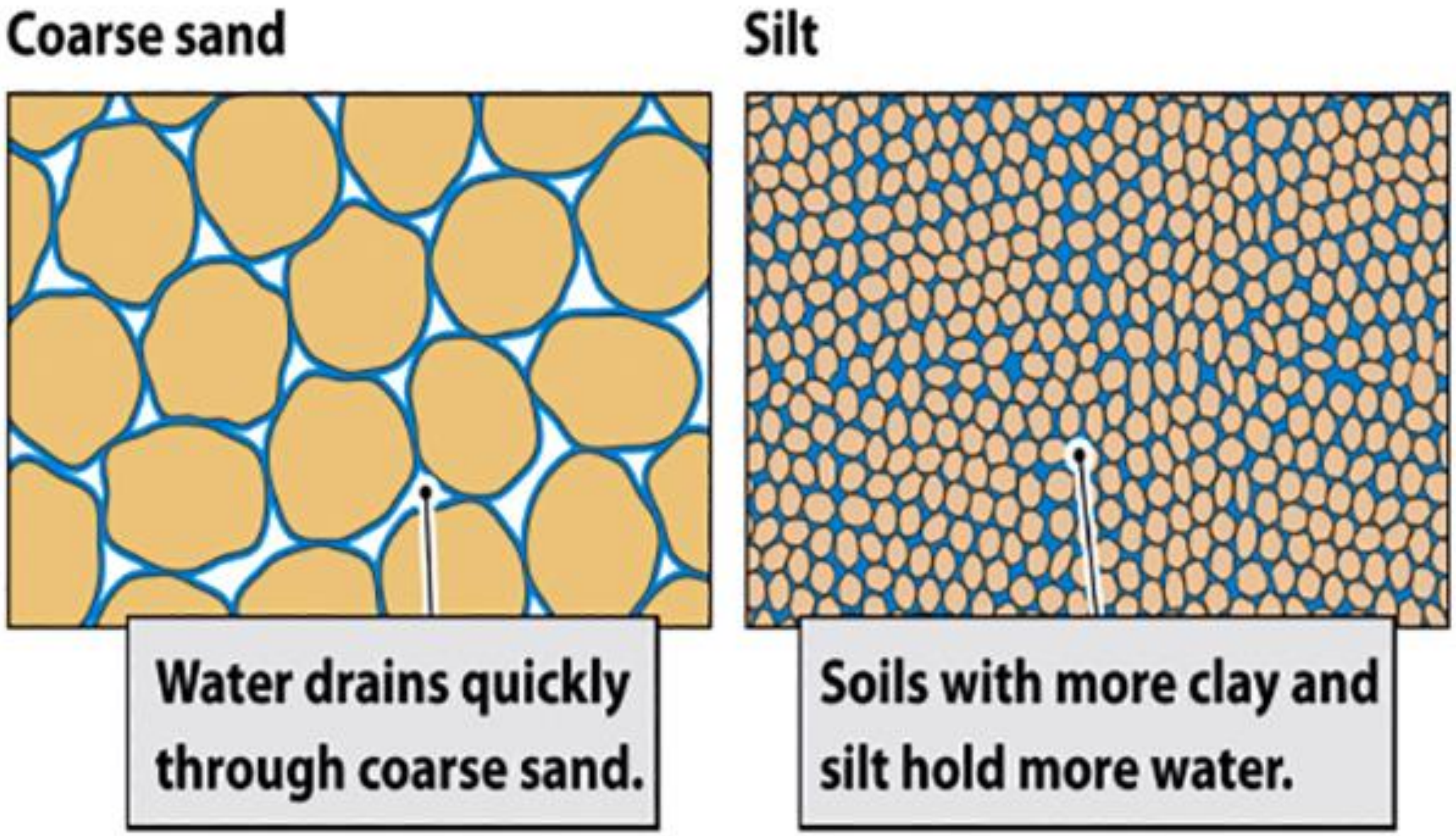


Aggregated (high permeability)

Effect of Soil Structures on the downward movement of water



Soil Particle Size and Pore Space



<u>Pore spaces</u>:

Coarse sand: 35%, Fine clay: 60%

Irrigation Scheduling for Variable Soil

- In which soil crop needs more water to grow?
- Which soil needs more frequent irrigation? How much?
- In which soil, crop shows water stress first?
- In which soil type are you going to have trouble imposing water stress?

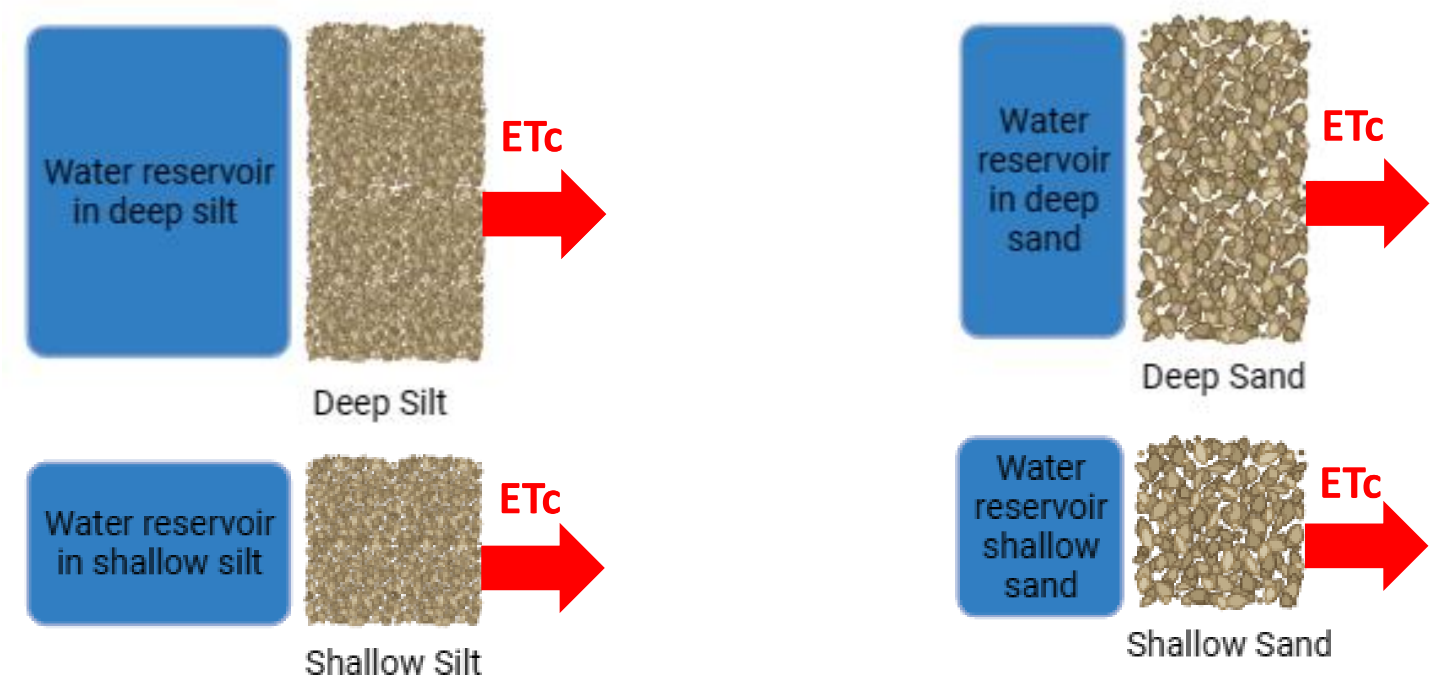
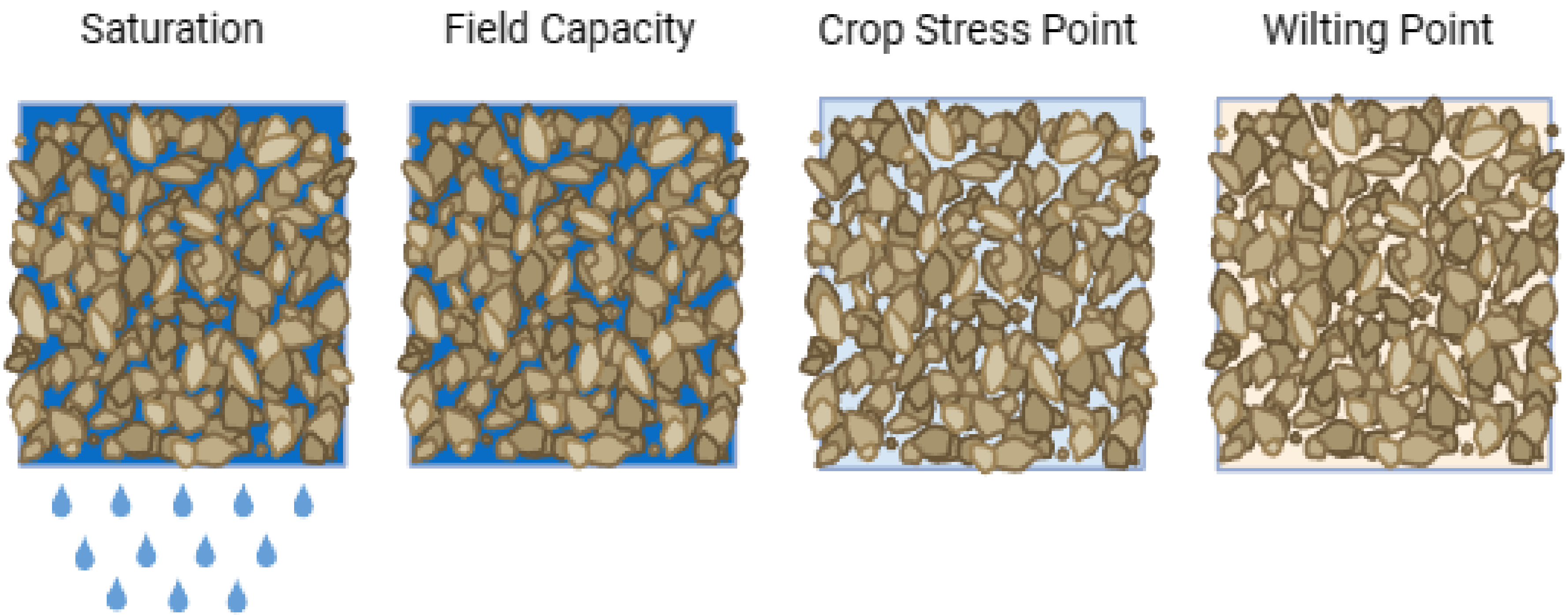


Image Created with BioRender.com by Behnaz Molaei

Soil-water thresholds



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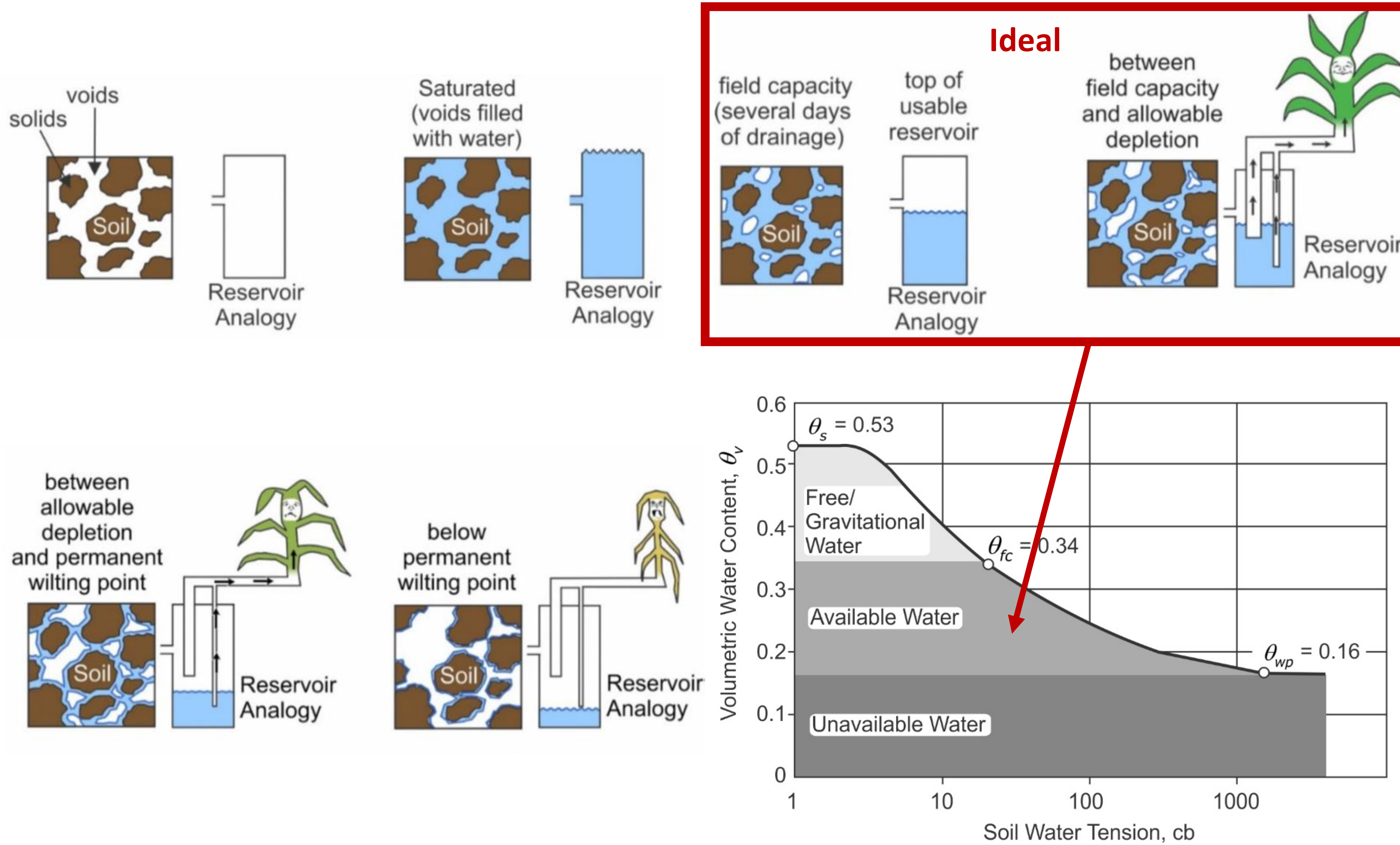
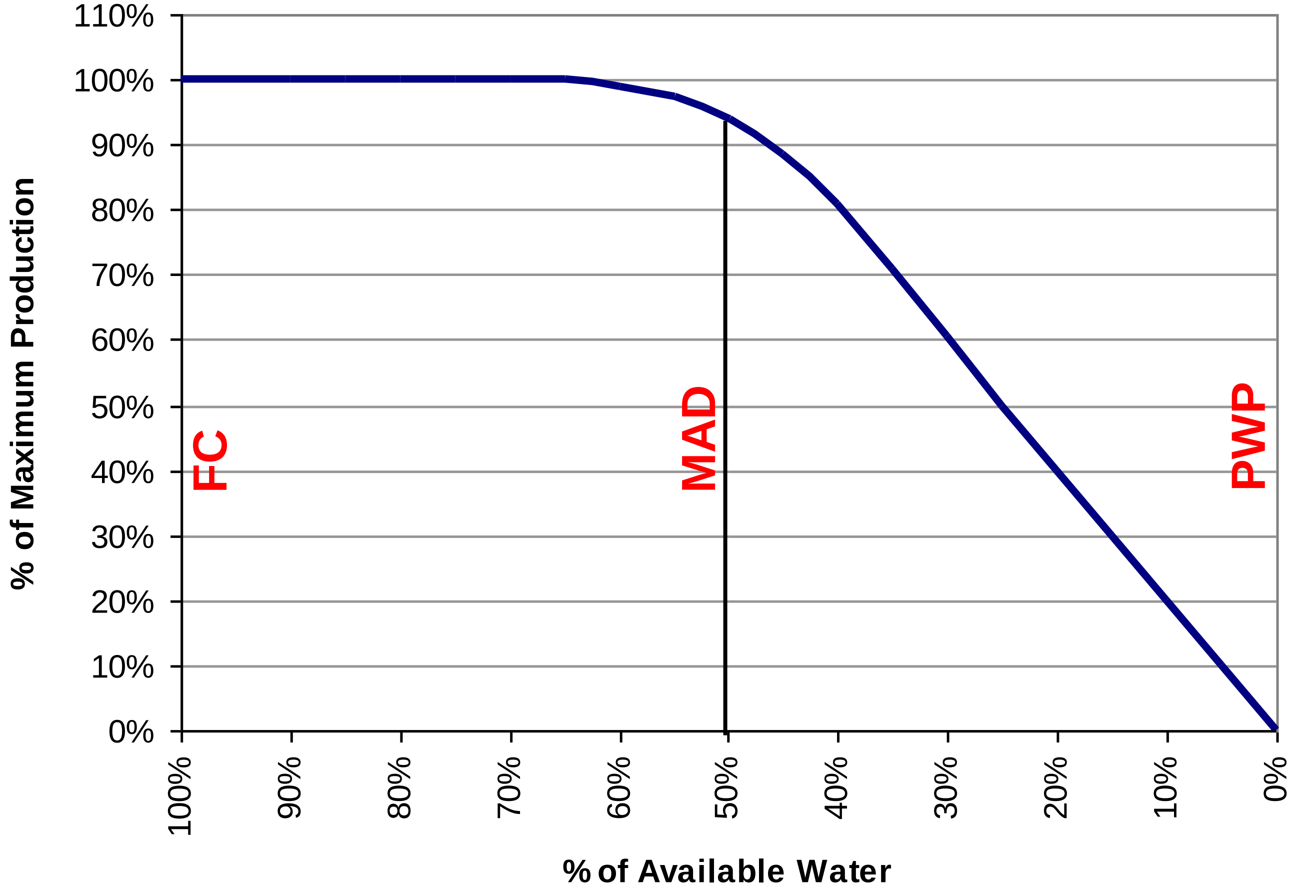
Soil is a Water and Nutrient Reservoir



Source: Irrigation Systems Management ASABE. doi:10.13031/ISM.2021

Management Allowable Depletion (MAD)



Production Reduction Function

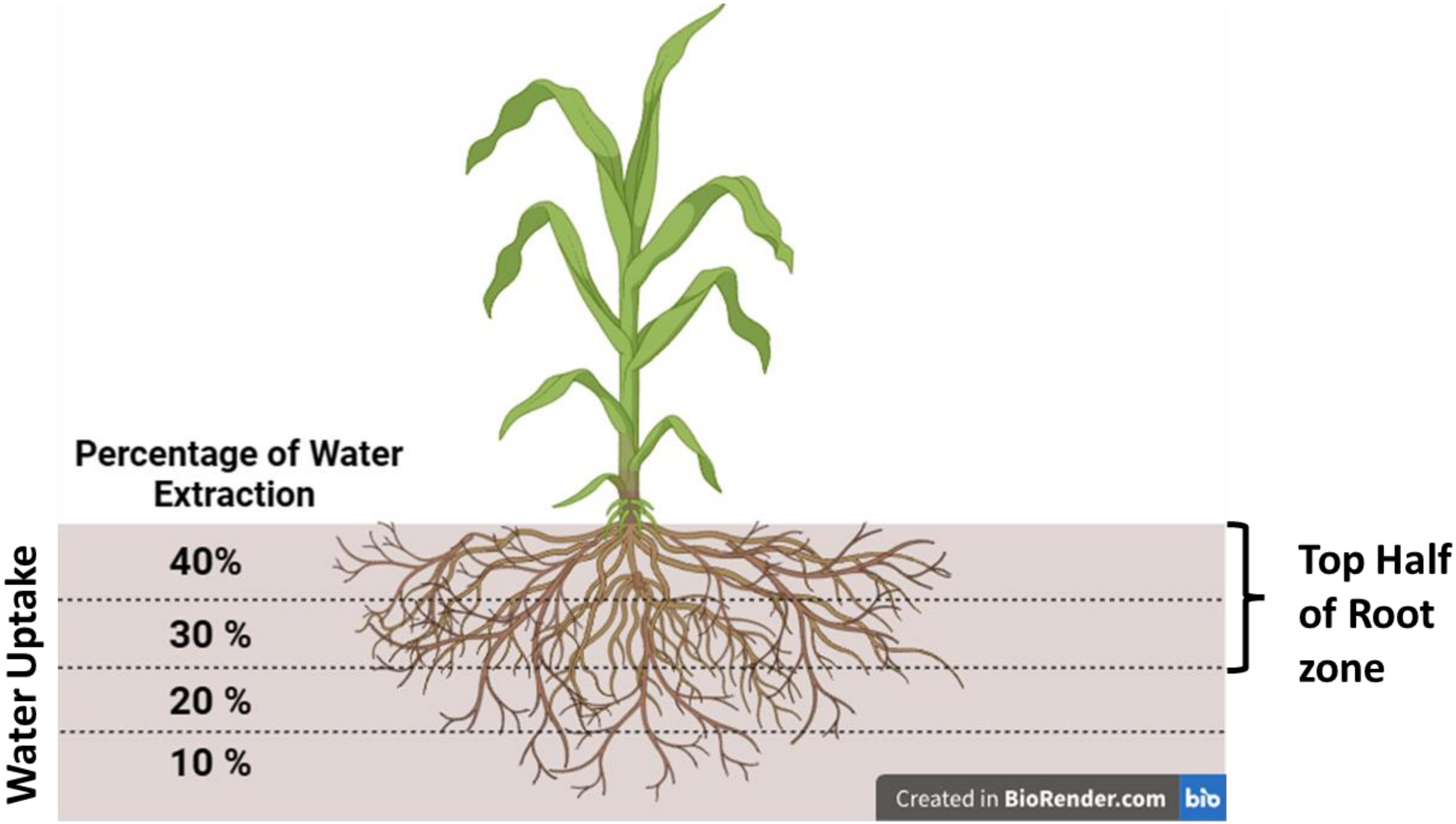
MAD % for different crops

Crop	MAD (%)
Alfalfa	65
Apples	50-65
Corn	65
Potato	25
Cotton	60-70
Mint	35
Winter Wheat	50-65

Selecting smaller MAD% means:

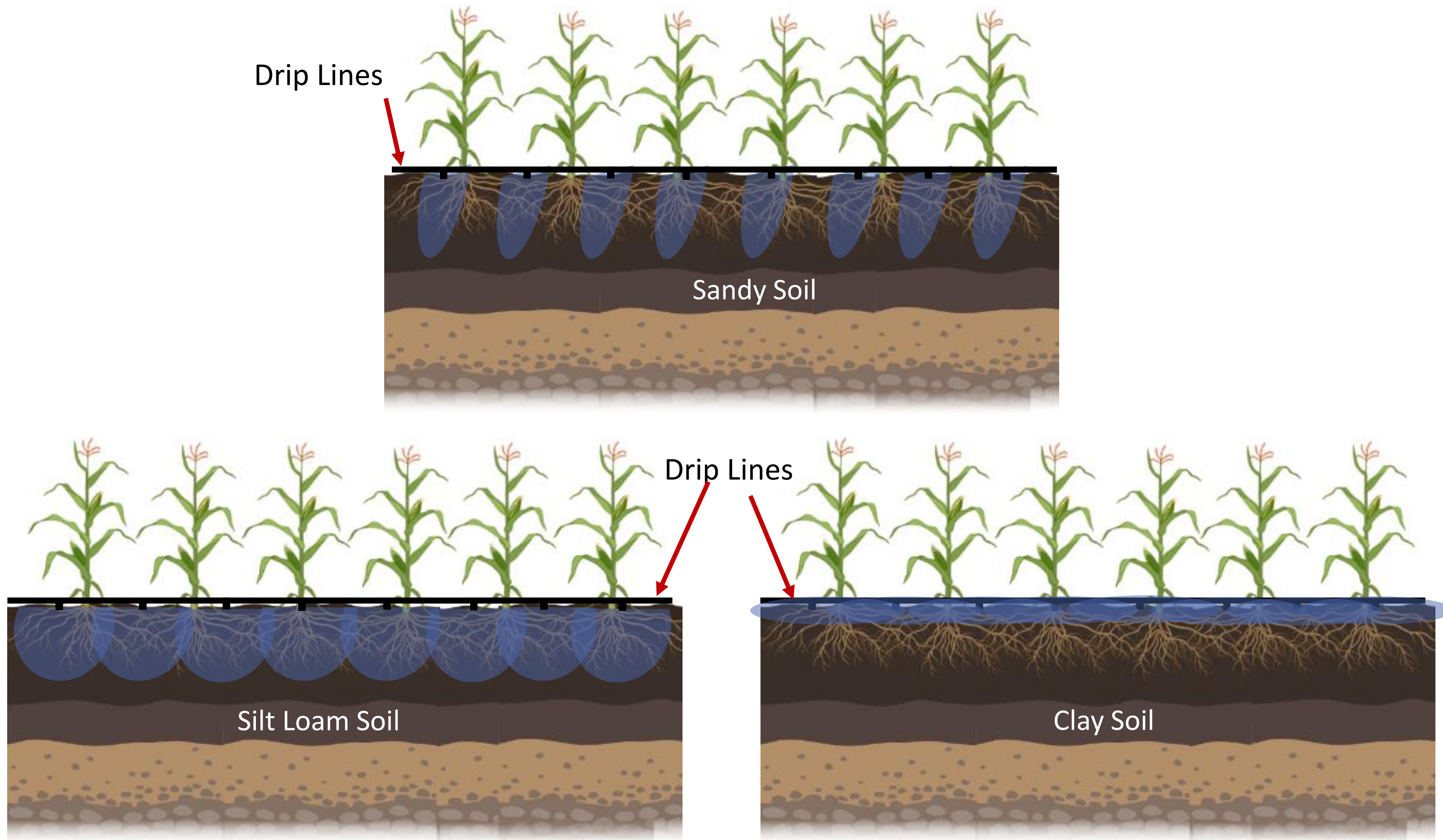
More frequent irrigation of smaller amount of water application

Root Zone & Effective Root Zone



Figures Created by Behnaz Molaei at BioRender.com

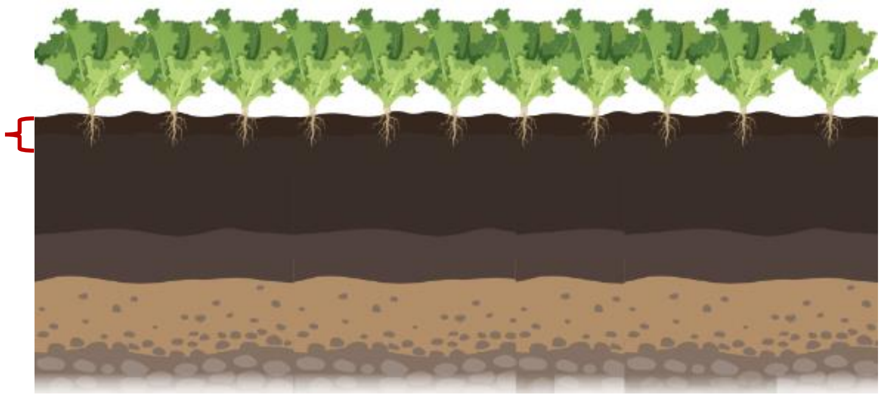
Wetting Pattern in Different Soil

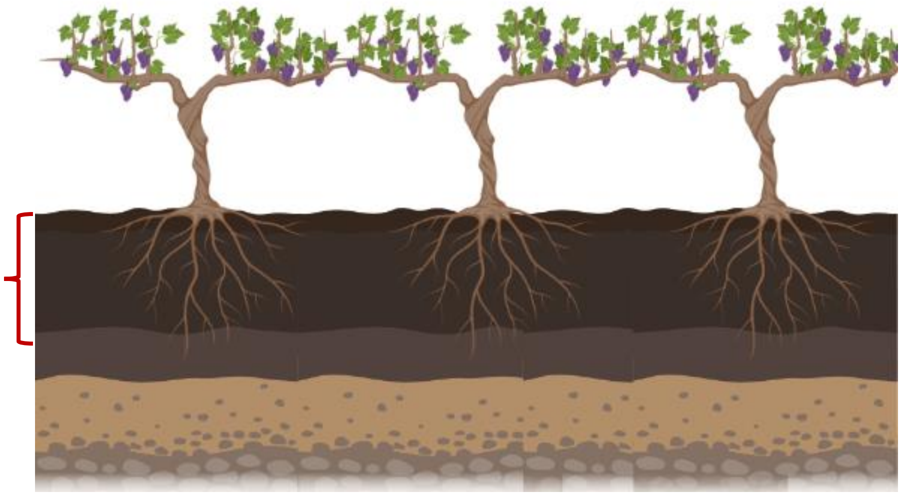


Figures Created at **BioRender.com** by Behnaz Molaei

Root Zone & Effective Root Zone

Crop	Effective Crop Root Depths (inches)
Lettuce	7 to 20
Carrot	15 to 23
Strawberry	11 to 20
Sweet Corn	16 to 24
Grapes	20 to 48

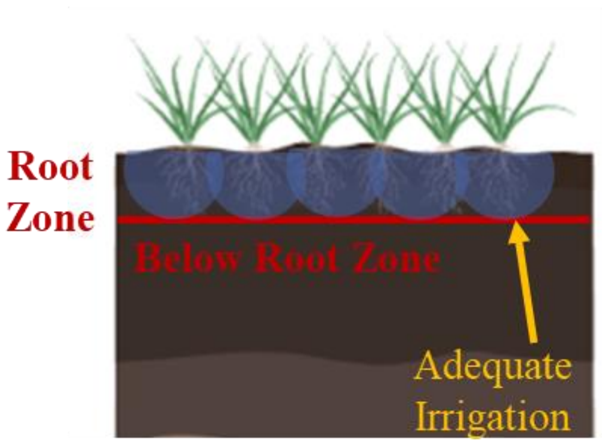




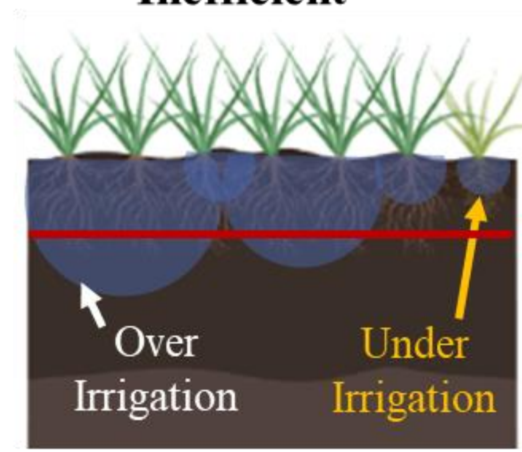
Figures Created by Behnaz Molaei at **BioRender.com**

Uniformity and Efficiency

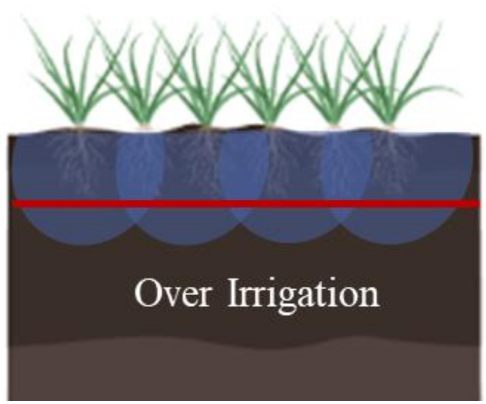
Uniform & Efficient



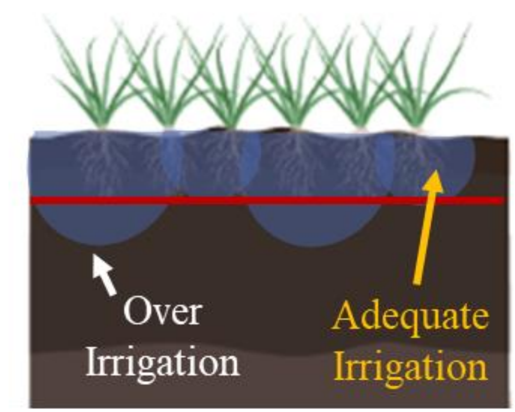
Non-Uniform & Inefficient



Uniform & Inefficient

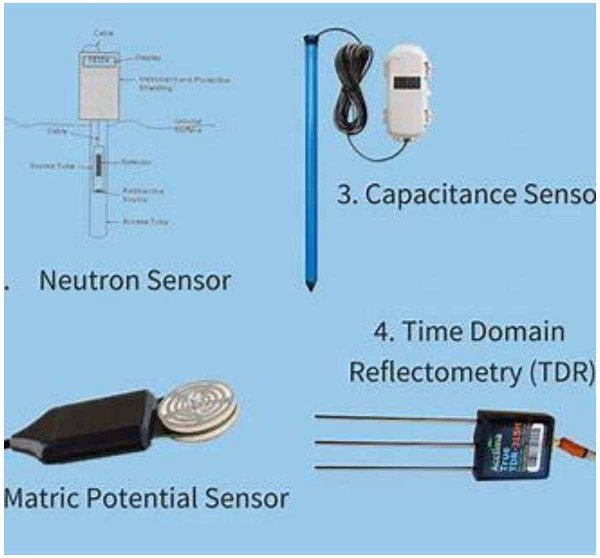


Non-Uniform & Inefficient

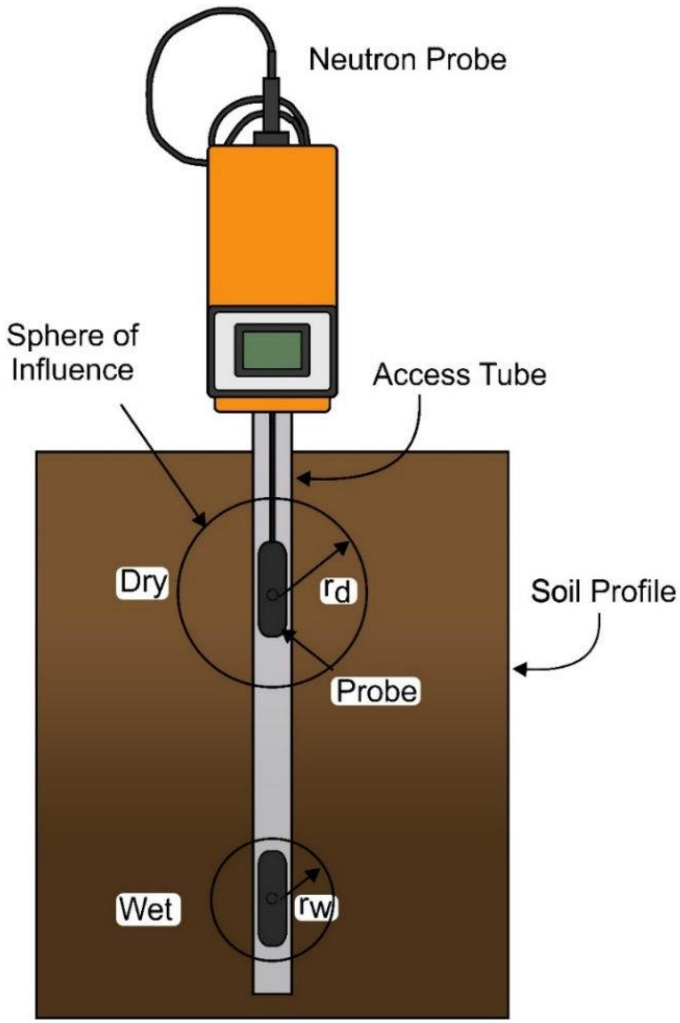


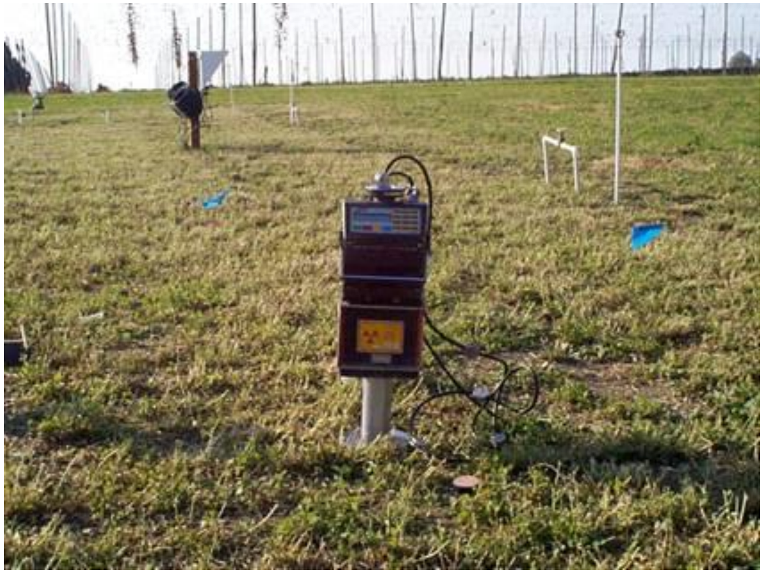
Figures Created at **BioRender.com** by Behnaz Molaei

What is Precision Irrigation Management?



Neutron Probe





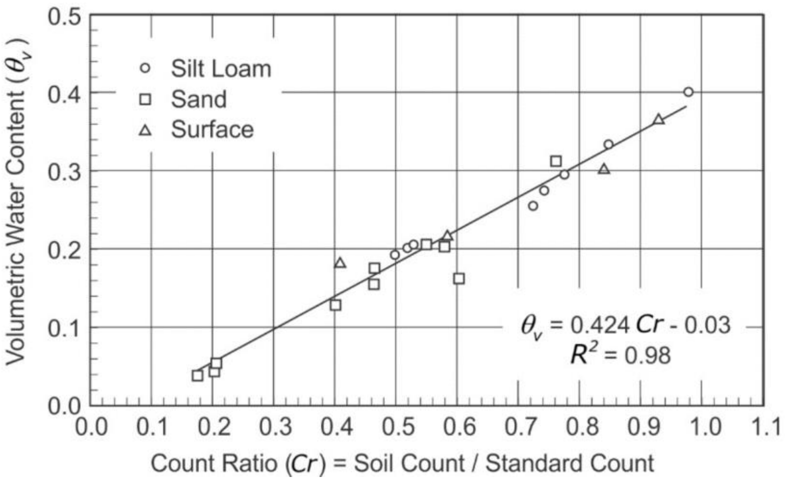
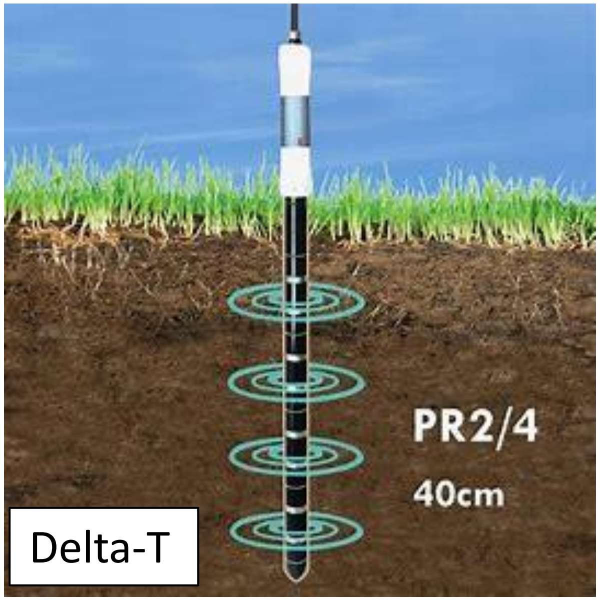


Image Source: Irrigation Systems Management, ASABE. doi:[10.13031/ISM.2021](10.13031/ISM.2021)

Time Domain Reflectometry (TDR)

Capacitance Probes or Frequency Domain Reflectometry

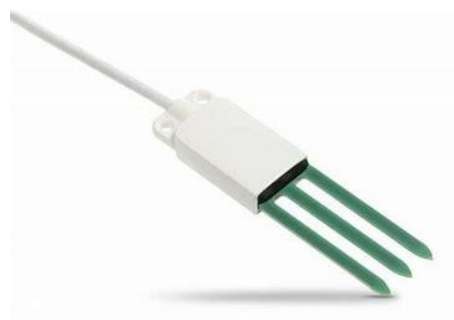
In-direct: using access tube

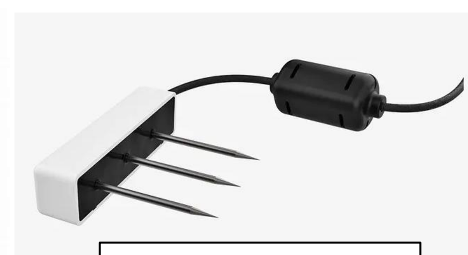


Delta-T

Image:
Irrigation Lab,
WSU-IAREC

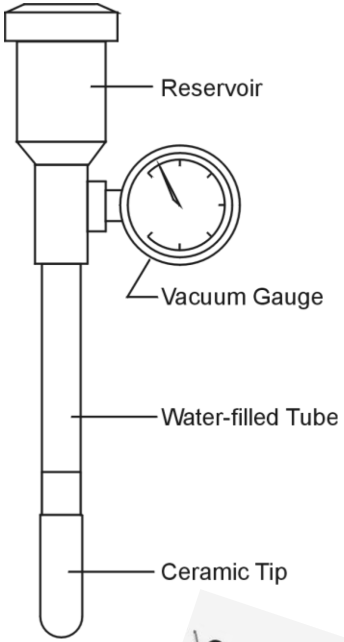
Direct Measurement

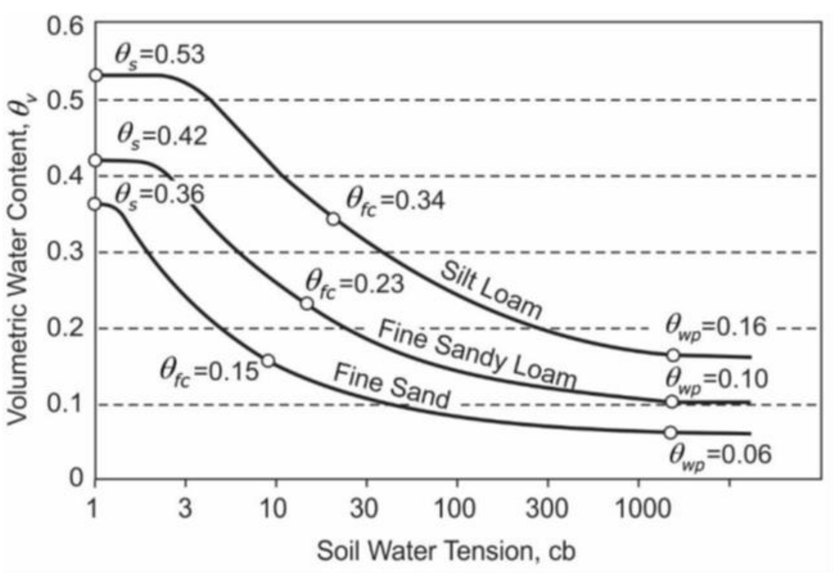




METER Group

Tensiometers



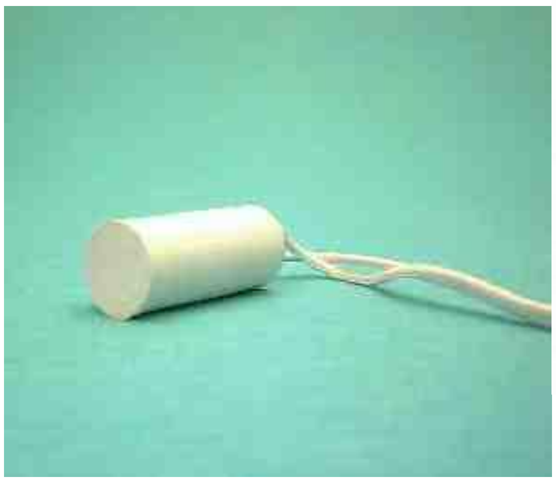


IRROMETER

METER Group

Image Source: METER Group, and IRROMETER Companies

Electrical Resistance Blocks & Granular Matrix Sensors



Resistance Block

Granular Matrix Sensors
0-200 cb range

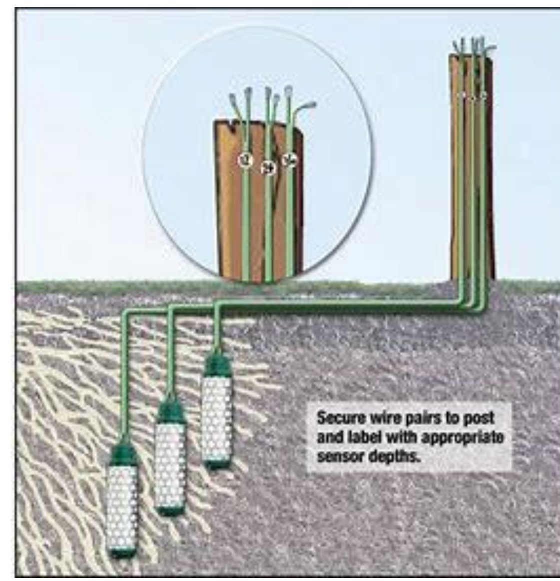
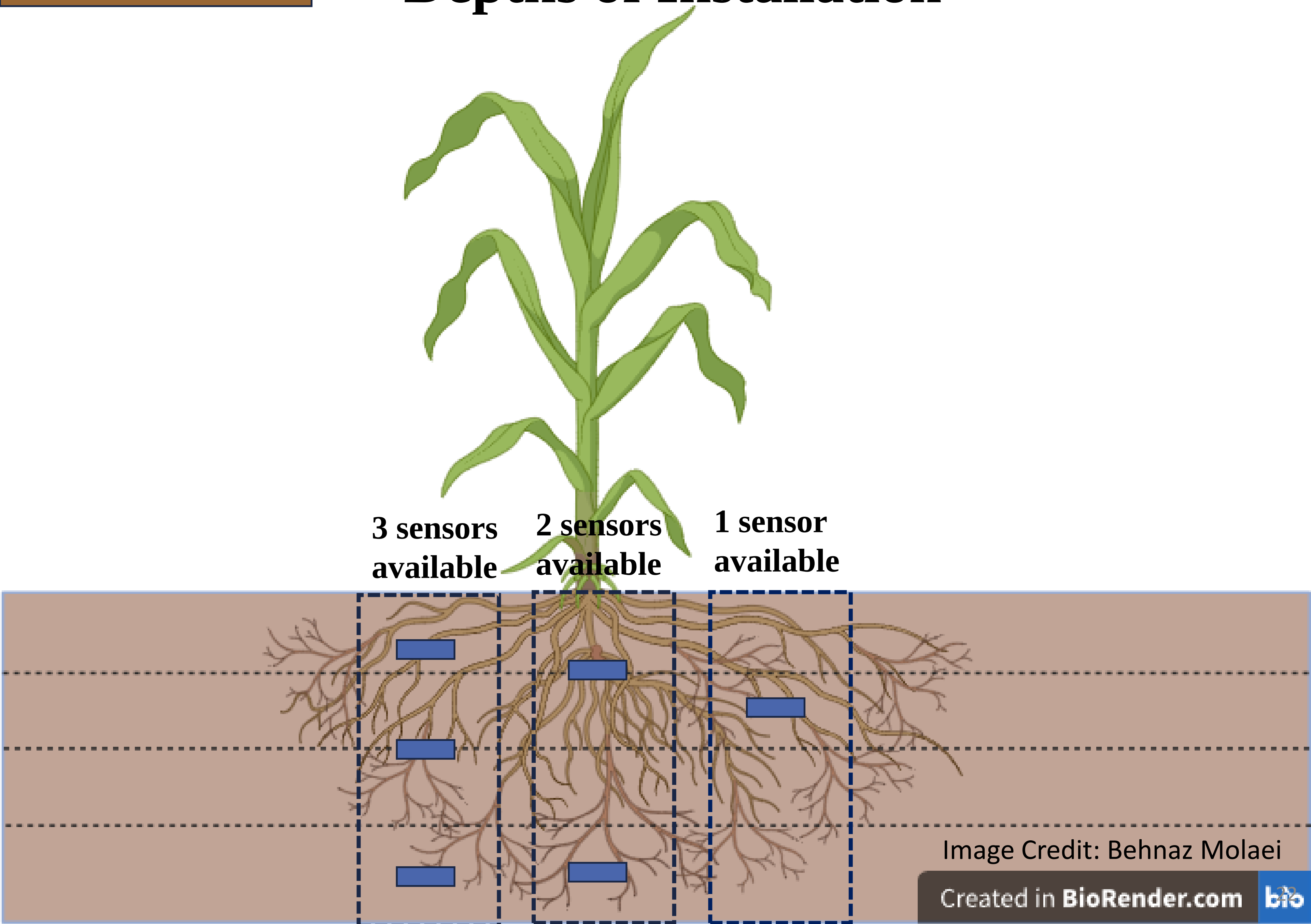


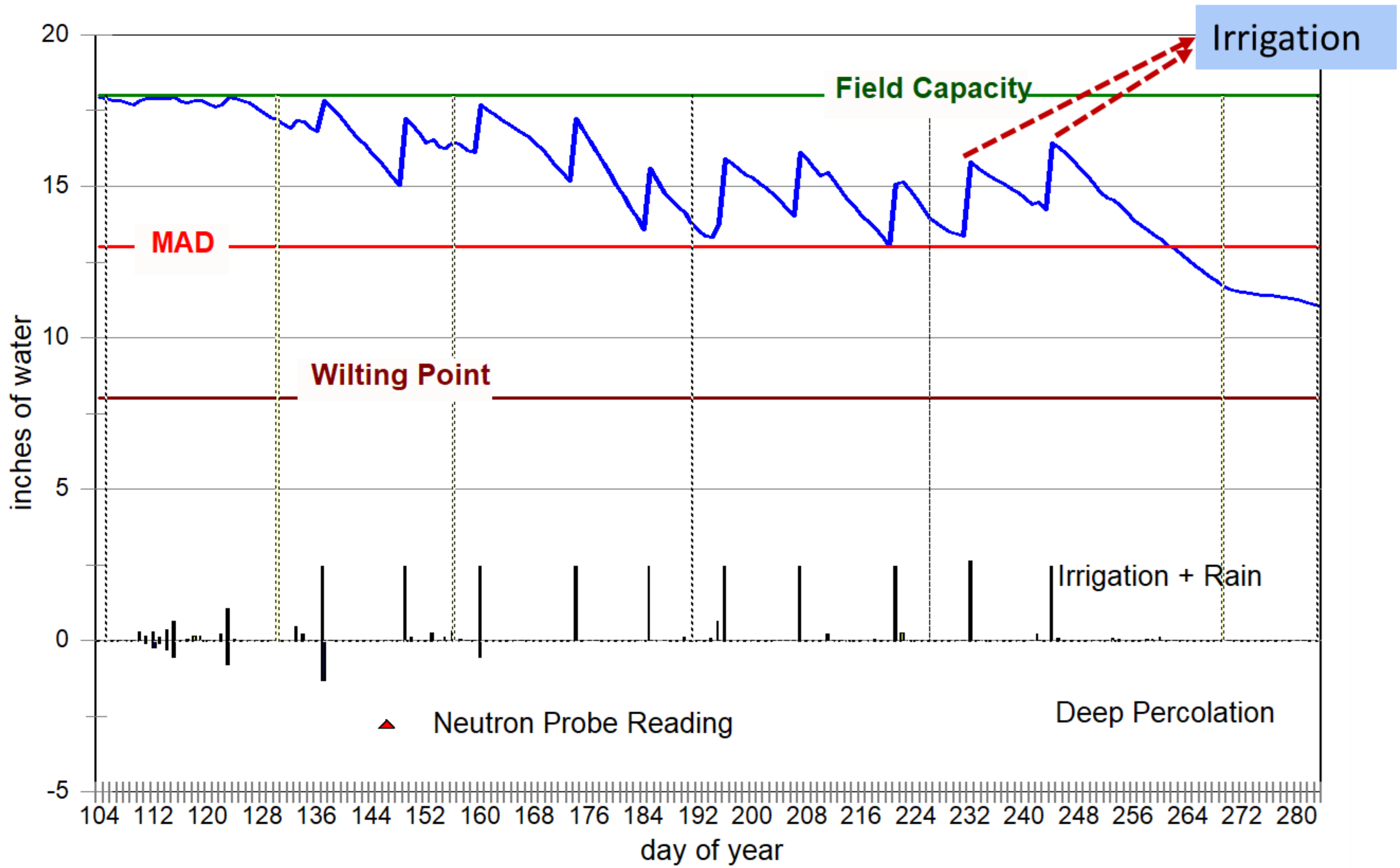
Image Source: IRROMETER

Soil-based Methods

Depths of Installation

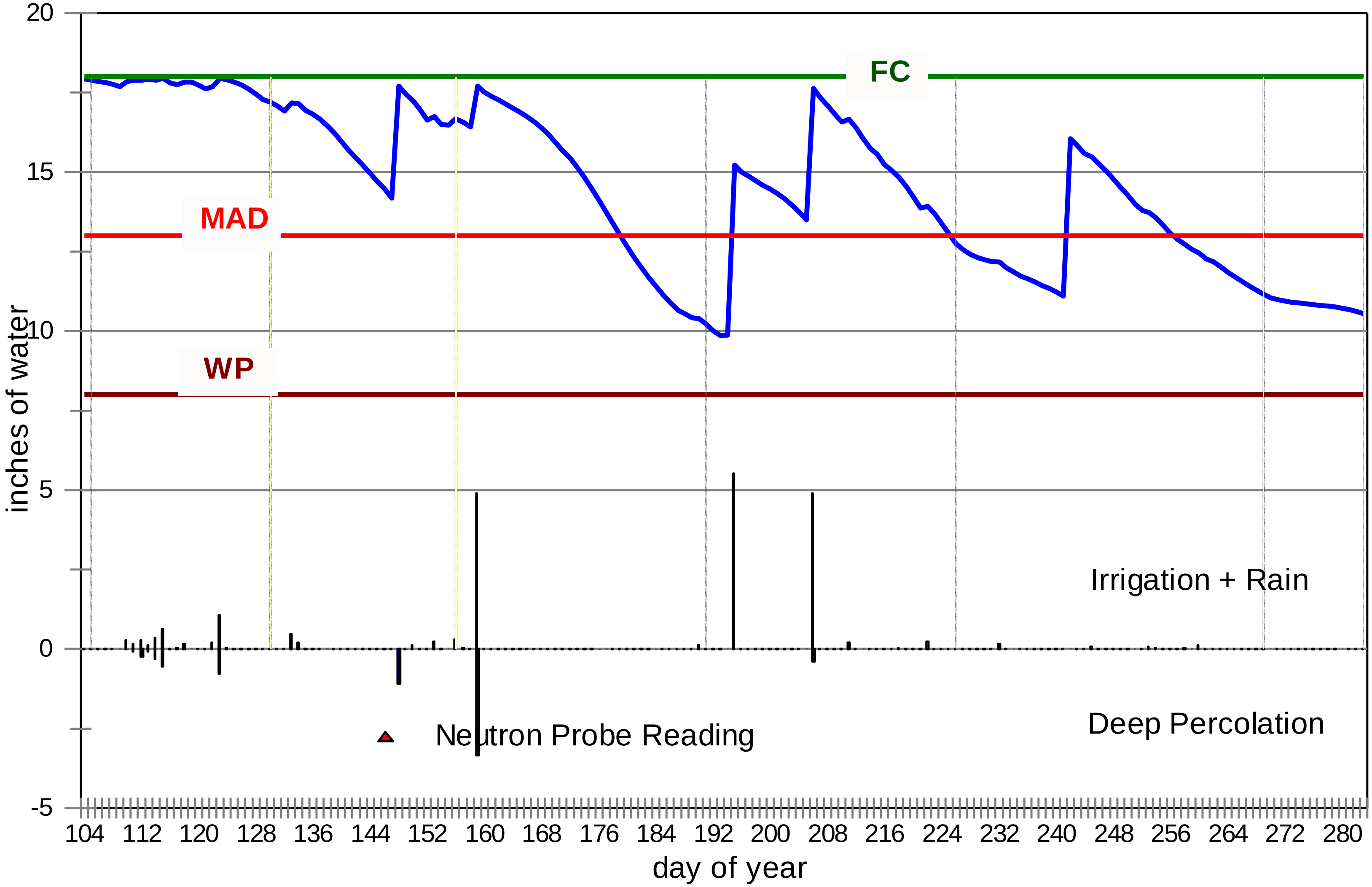


Irrigation Management to Minimize Stress



Credit: Irrigation Lab, WSU-IAREC

Poor Irrigation Scheduling



Credit: Irrigation Lab, WSU-IAREC

Soil Water Balance

$$P + I + CR = E + T + RO + DP + \Delta\theta$$

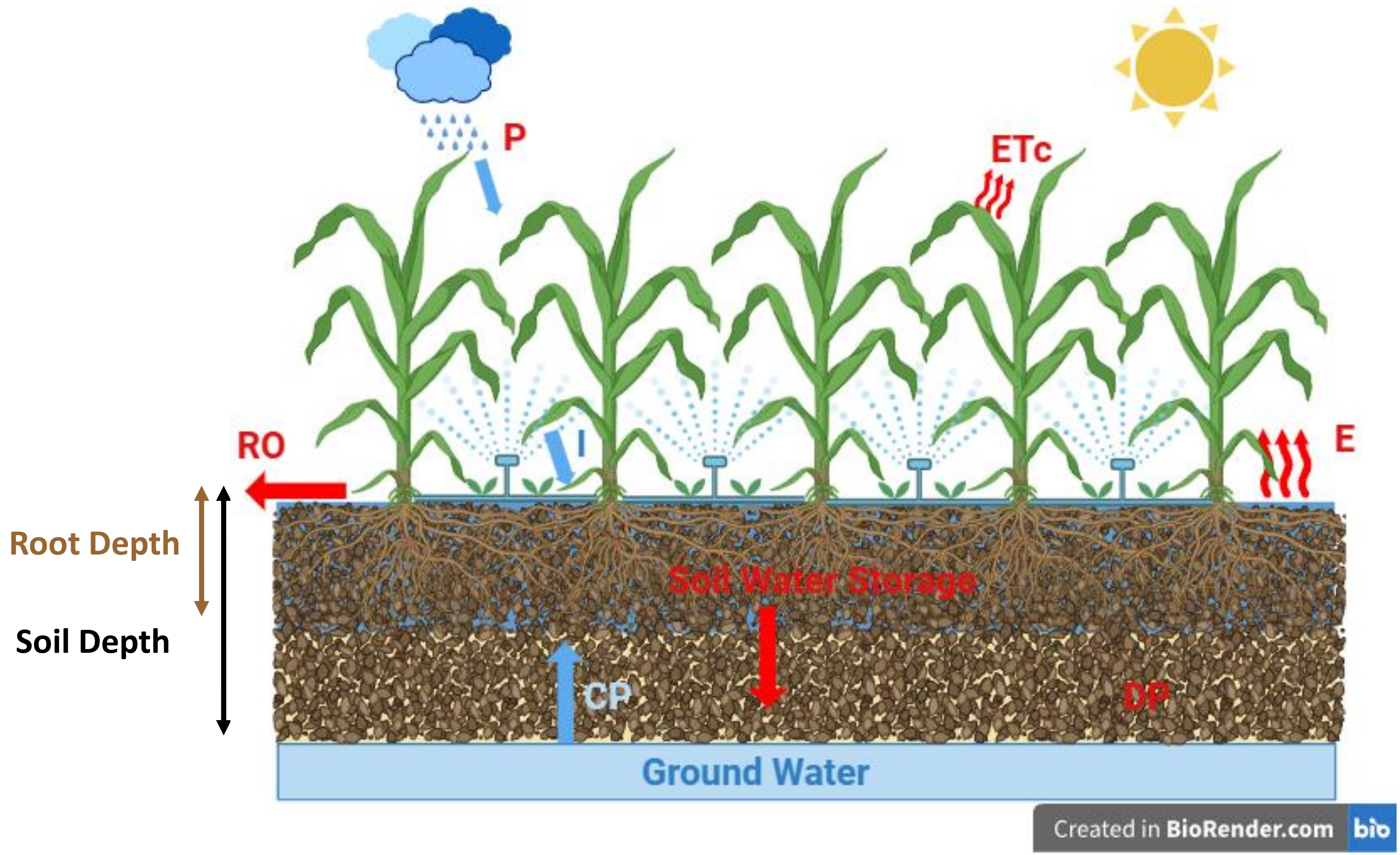
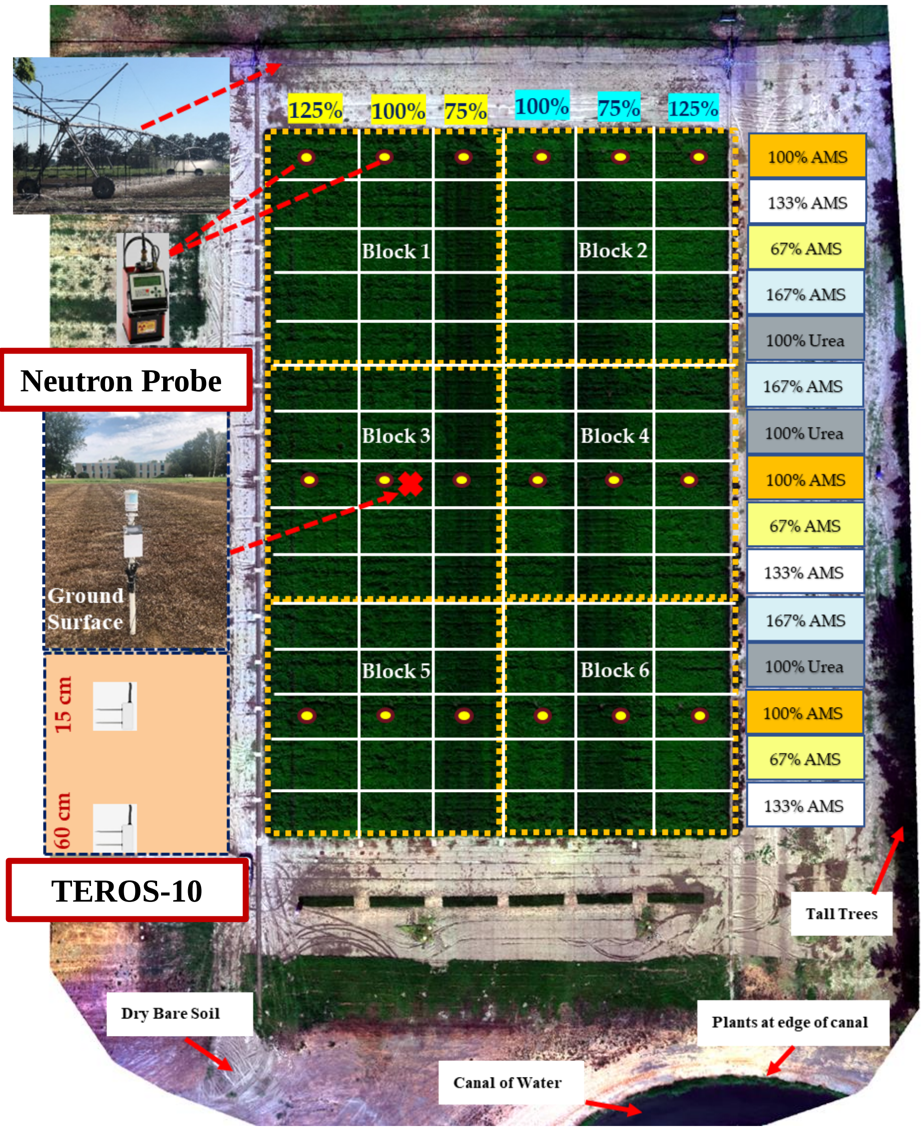
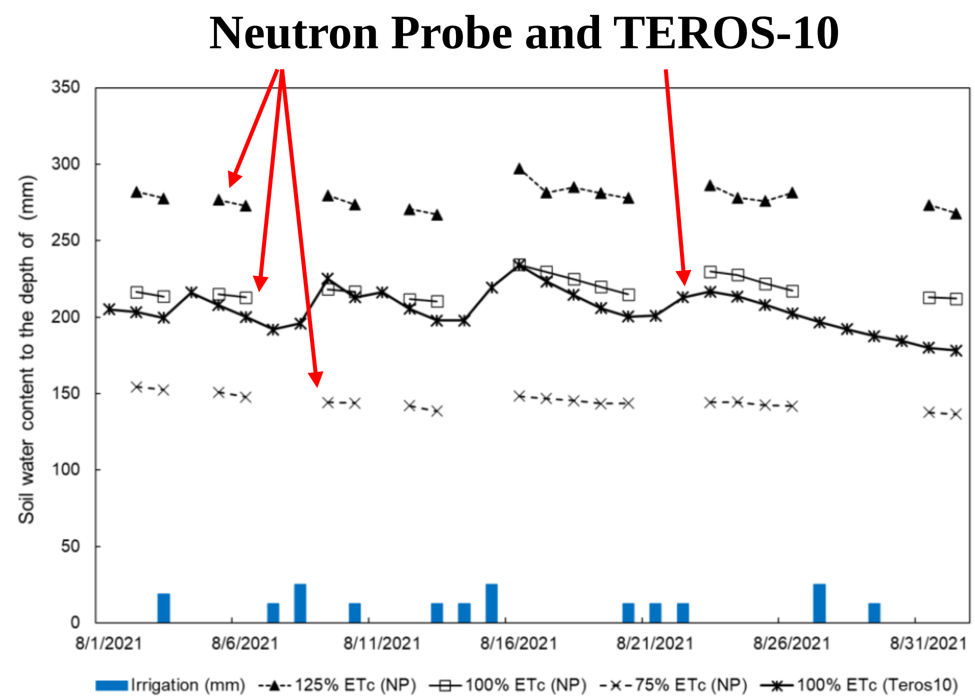


Image credit: Behnaz Molaei, TSU

Example of Soil Water Balance





Crop: Spearmint

Irrigation Levels: Stressed, Fully Irrigation and Overirrigation

Credit: Molaei et al. 2022

Weather Stations for Irrigation Scheduling

Image Credit: METER Group, AgWeatherNet_WSU, Campbell Scientific

Reference ET from Weather Measurements

Standardized ASCE Penman-Monteith

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

Solar Radiation

Temperature

Wind Speed

Humidity

Equation is for your information

Credit: Richard Allen, University of Idaho

Crop Coefficient Curve

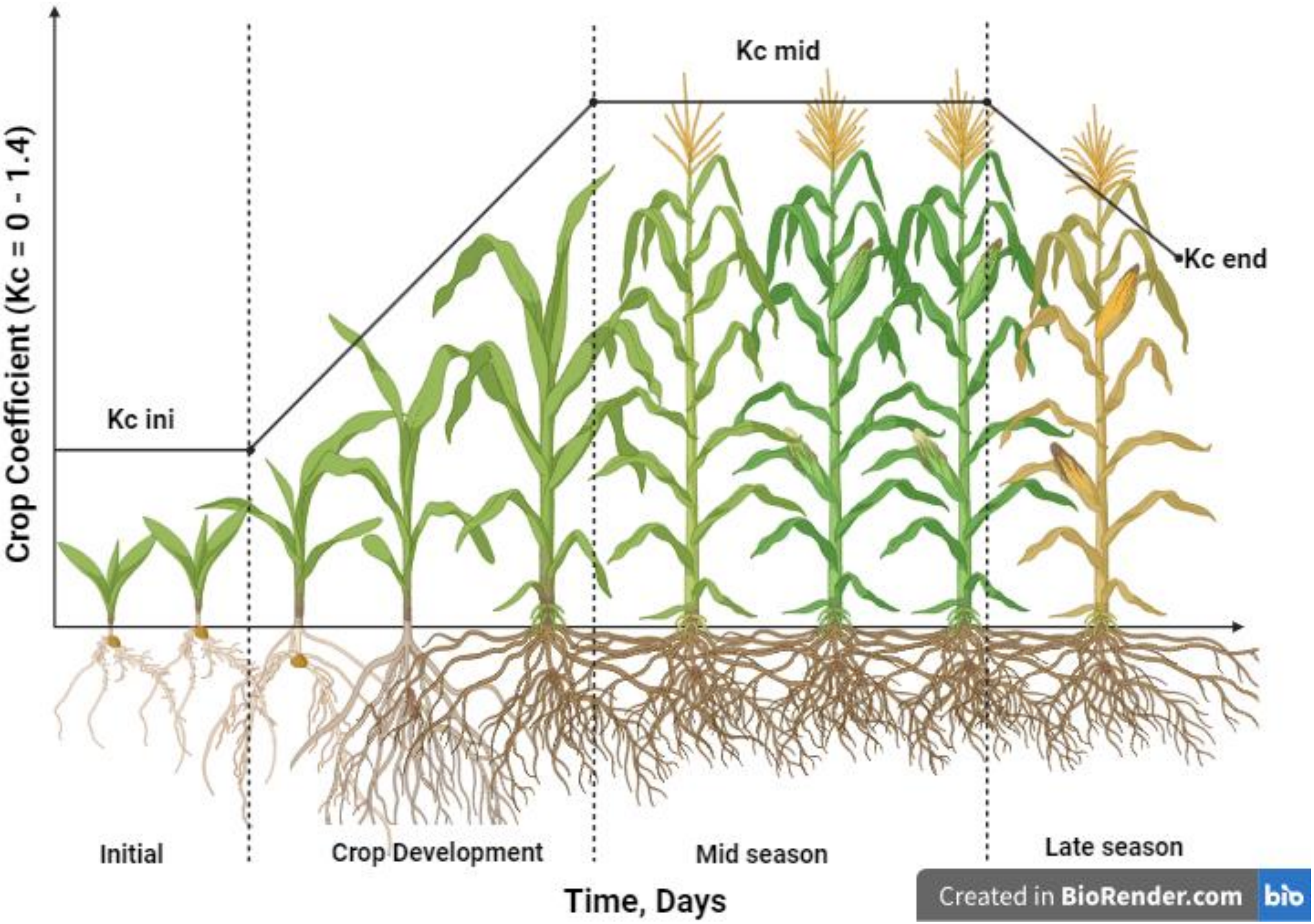


Image credit: Behnaz Molaei, TSU

How do we use weather data for estimating crop water use

$$ET_c = ET_{r-o} \times K_c$$

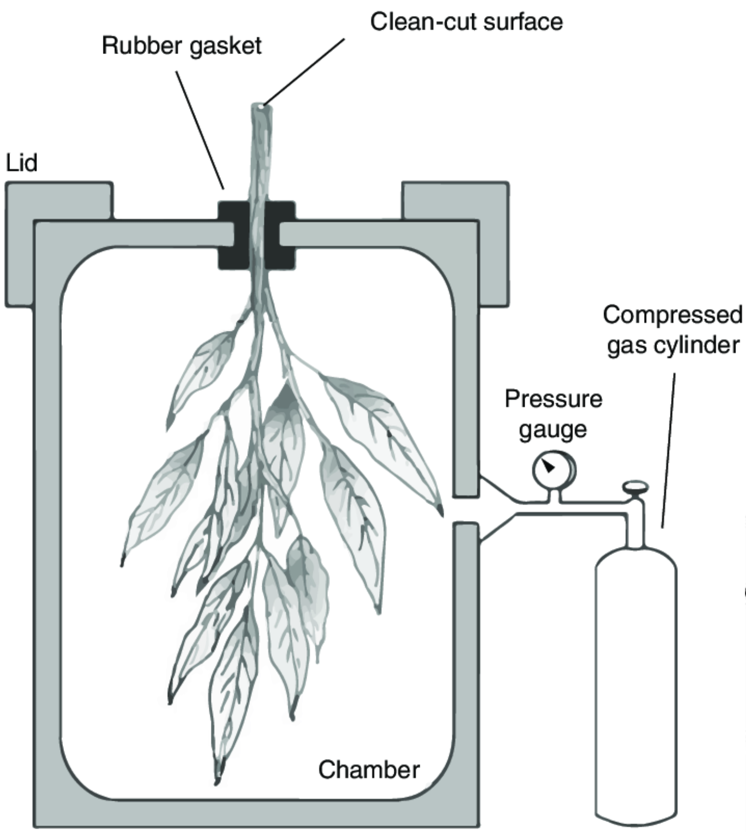
ET_c = Crop Evapotranspiration

ET_r or ET_o = Evapotranspiration rate of a reference crop. *Function of the weather*

ET_r is alfalfa based and ET_o is grass based

K_c = Crop coefficient. *Function of the plants*

Leaf Water Potential/Pressure Chamber



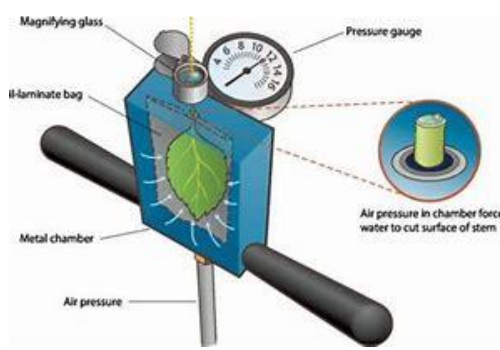


Image: PMS Instrument Company

**Image: Behnaz Molaei,
WSU-IAREC smart vineyard**

LWP of the well water plants is higher (less negative in value) than that of plants under water stress

Sap flow Gauges







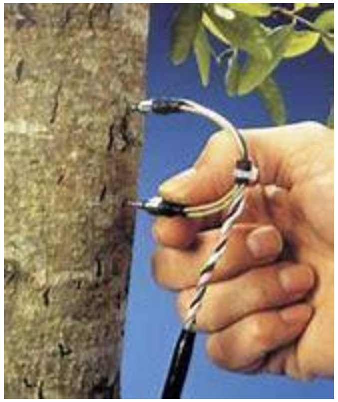


Image: Dynamax Company

Infrared Temperature Sensor

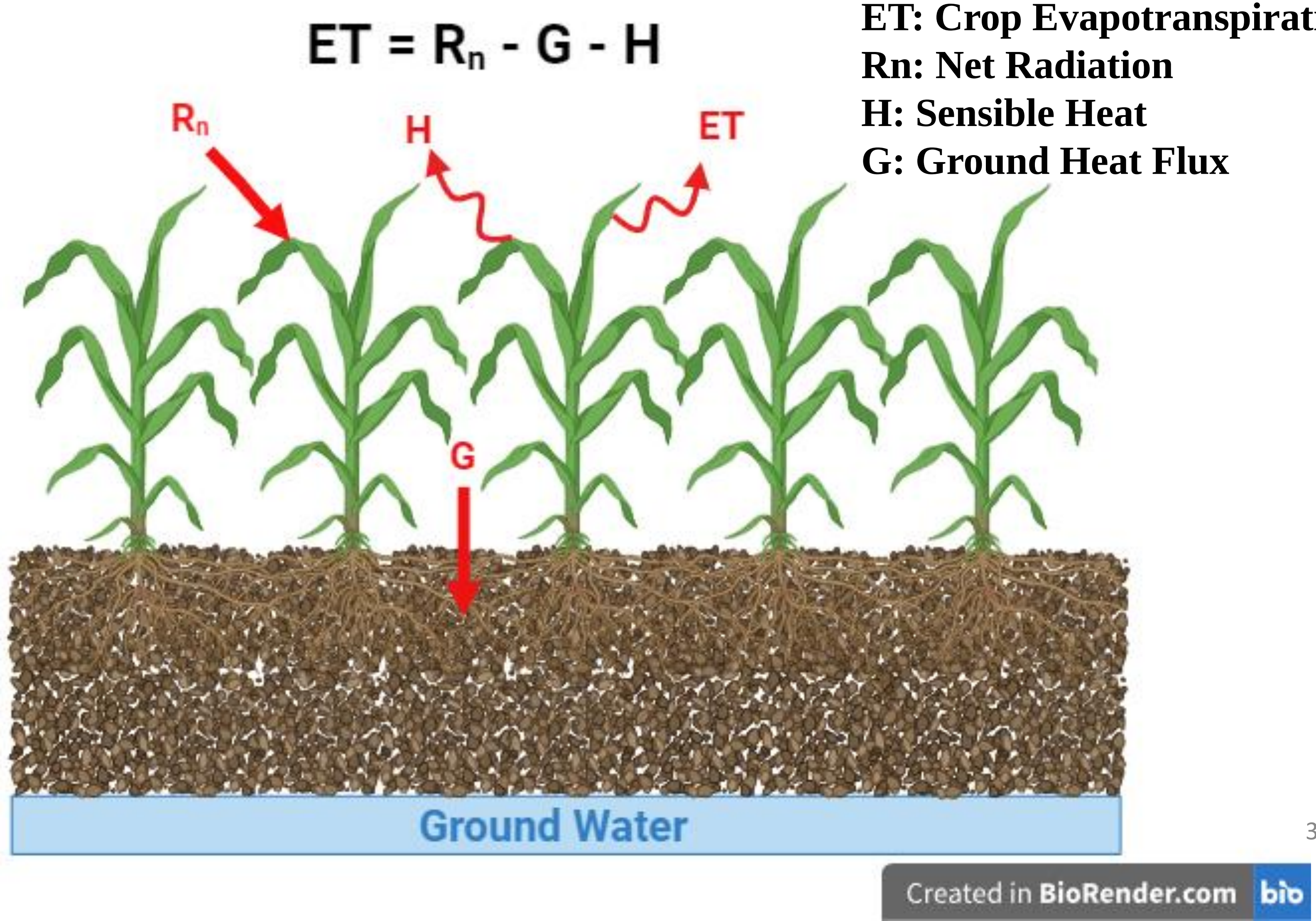
Farms of the Future

Apogee Instruments

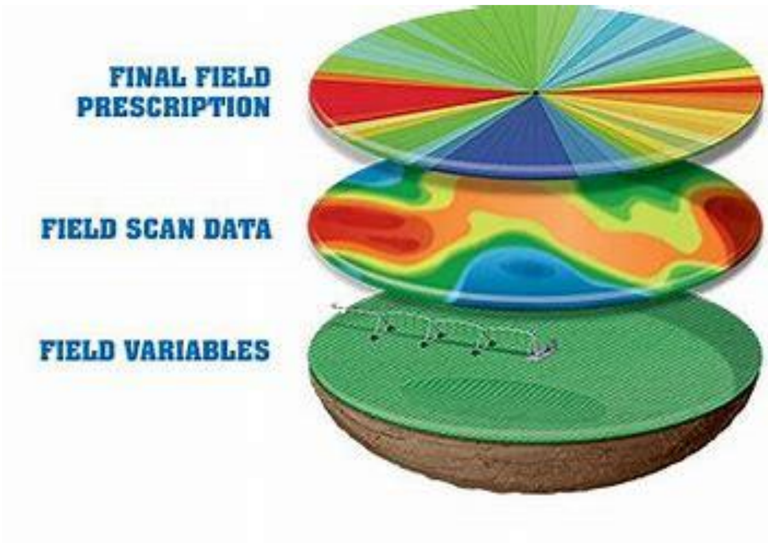
Infrared Temperature Sensors on the Pivot
Dr. Heeren Research at
University of Nebraska-Lincoln

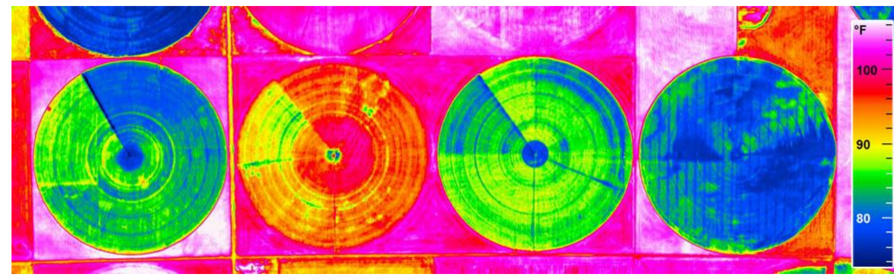
Energy Balance for Estimating ETc

ET: Crop Evapotranspiration
Rn: Net Radiation
H: Sensible Heat
G: Ground Heat Flux



ET_c maps for Prescription maps for Variable Rate Irrigation

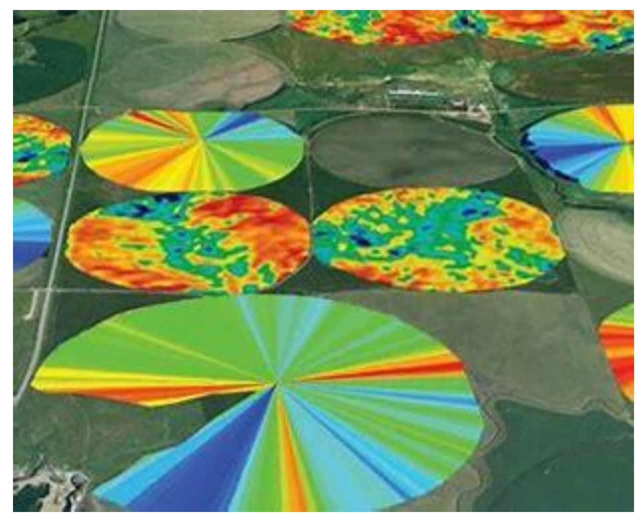




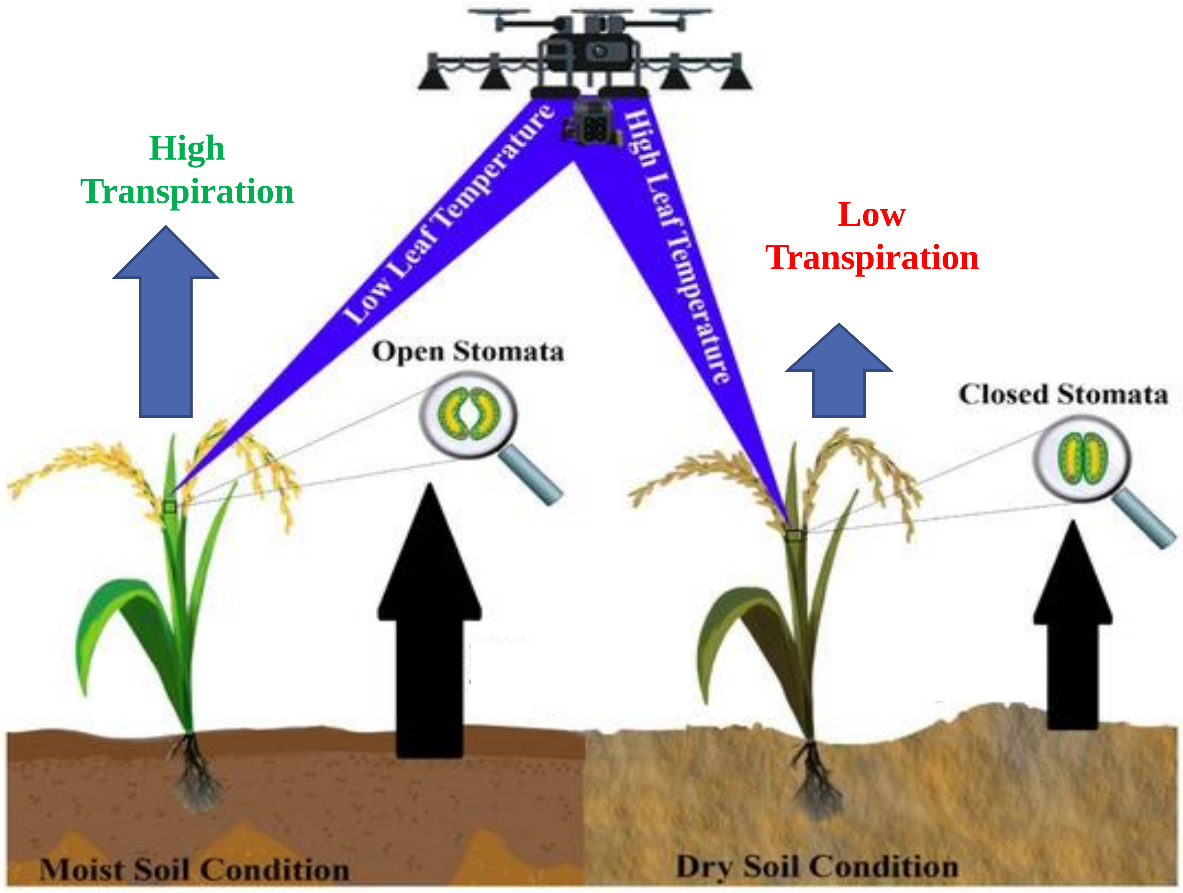
Cornerstone MAPPING
AN AERIAL SURVEY COMPANY

Variable Rate Irrigation on Pivots

- Variable Speed Irrigation
- Variable Zone Irrigation



Leaf Temperature: Indicator of Crop Water Status



Well Watered Crop is cooler than water stressed crop

Image: Ahmed et al., 2021, Remote Sens. 13(20)

Smart Vineyard, WSU-IAREC

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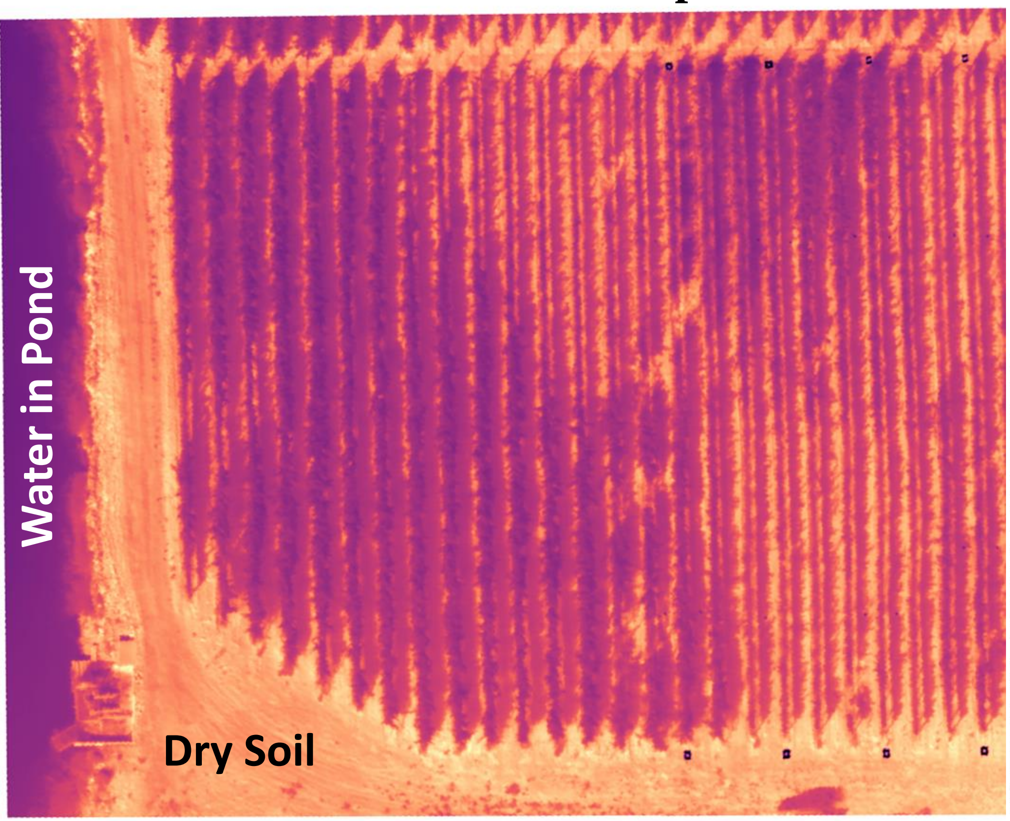
AI Institute for Transforming Workforce & Decision Support

https://agaid.org/

Remote Sensing-based Methods

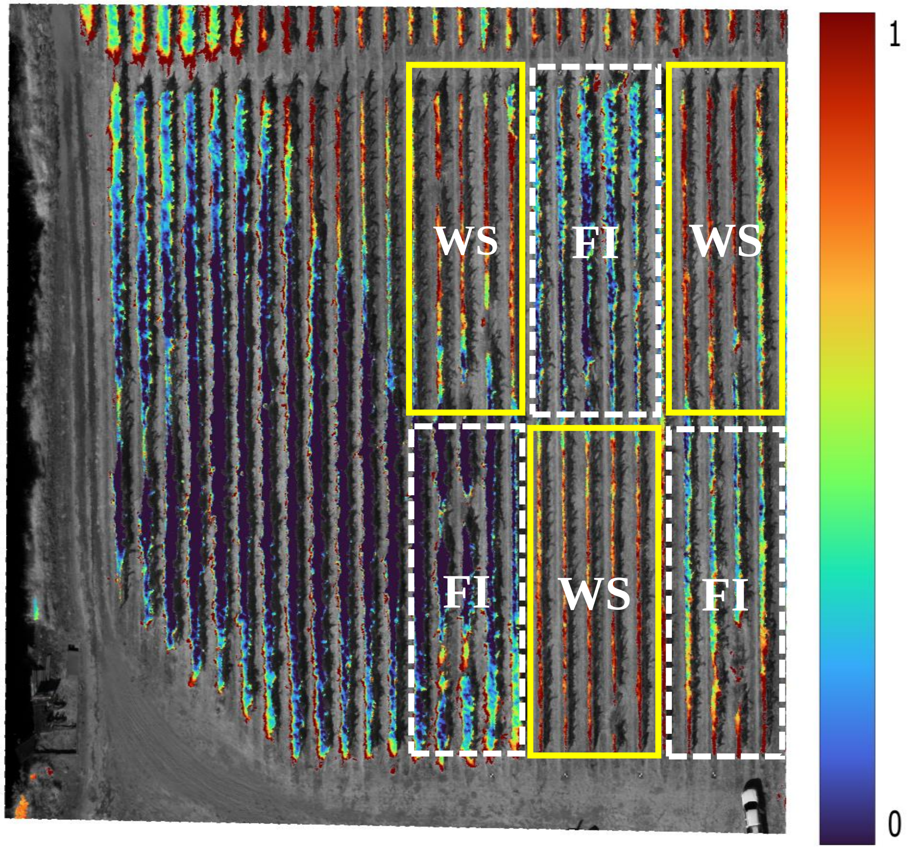
Thermal maps for Crop Water Stress Index

Thermal UAS Map



Map of Vineyard from 100 ft height

CWSI Maps of Smart Vineyard WSU

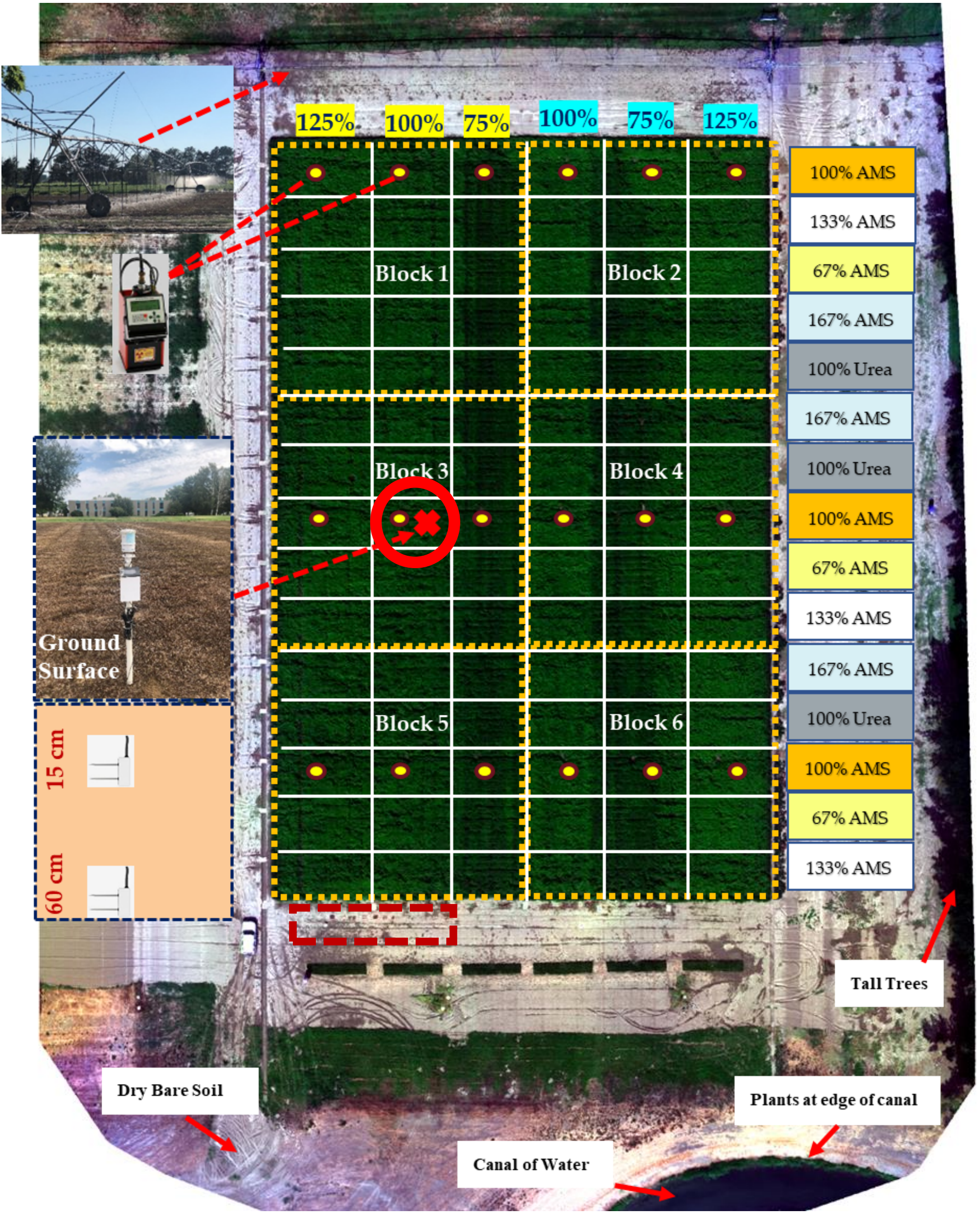


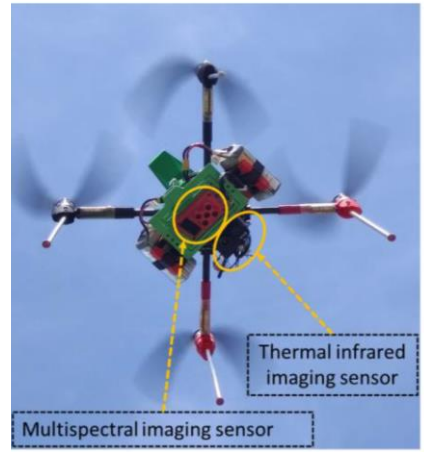
Water Stressed (WS)

Fully Irrigated (FI) Vines

Image and Data Analysis: Behnaz Molaei

Combination of All Methods





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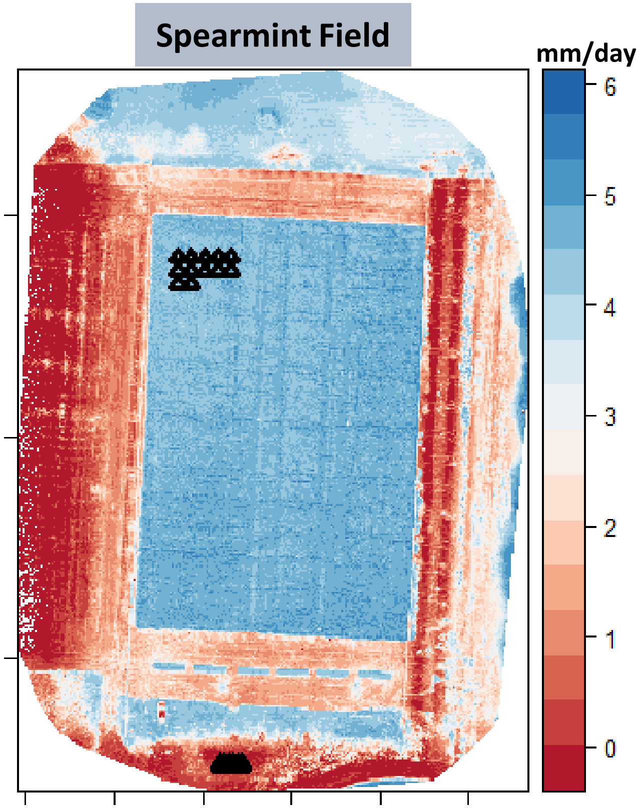
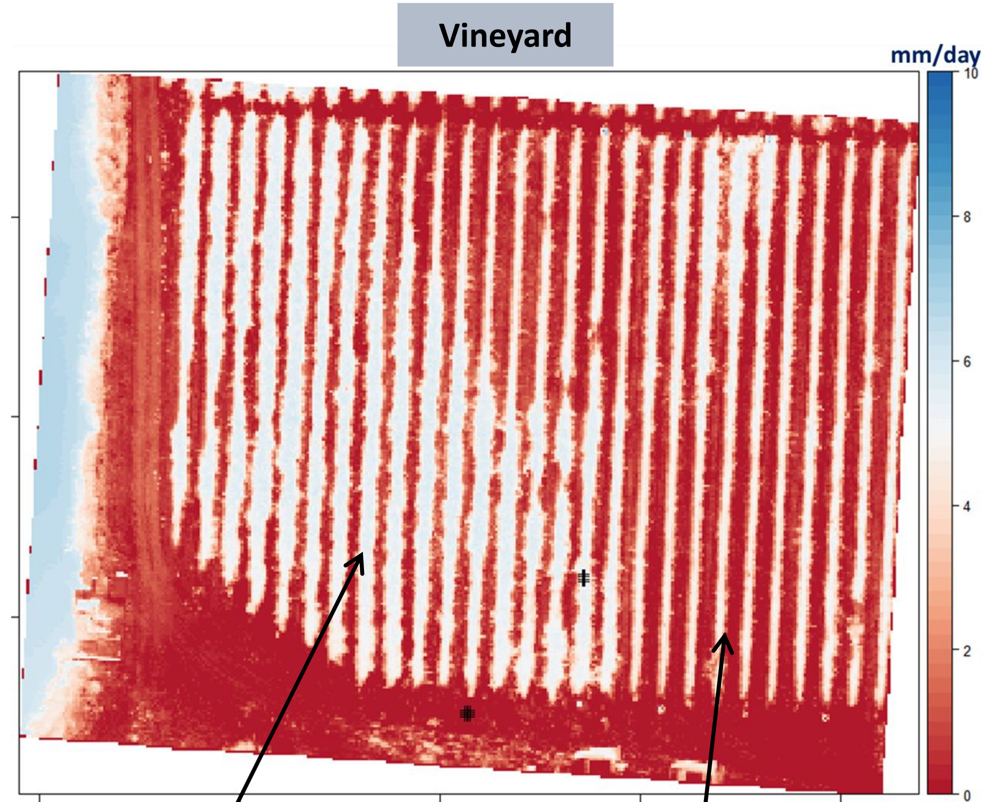
Prosser Irrigated Agriculture Research & Extension Center 1919 100 YEARS 2019

Generating ETc Maps using UAS-METRIC

ET maps resolution: 4 cm/pixel





Crop water use of fully irrigated vines

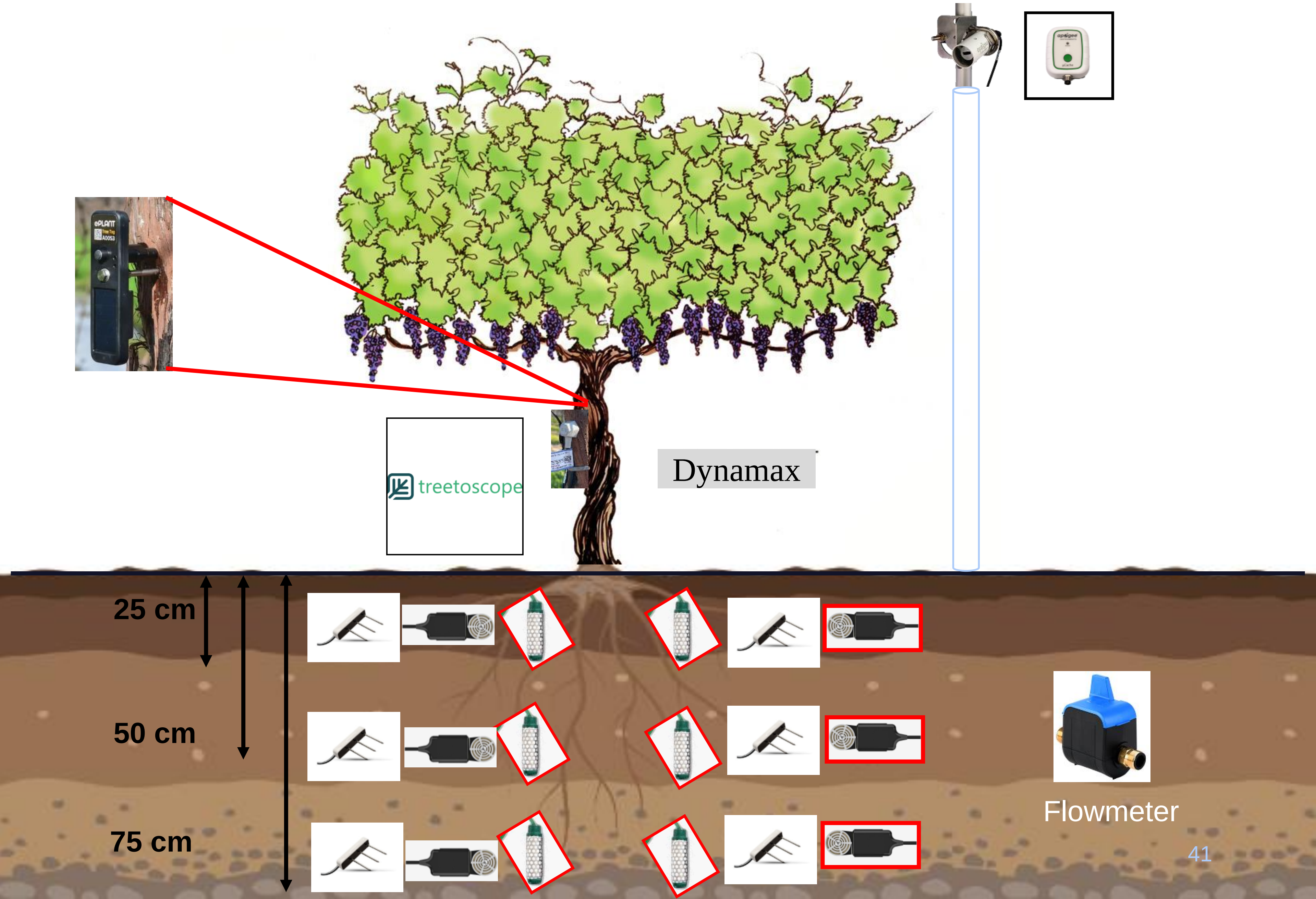
Crop water use of stressed vines

Data Acquisition: Precision Ag. Lab WSU
Image Analysis: Behnaz Molaei's work at WSU

Combination of All Methods

Center for Precision & Automated Agricultural Systems

AgAID AI Institute for Transforming Workforce & Decision Support



Combination of All Methods

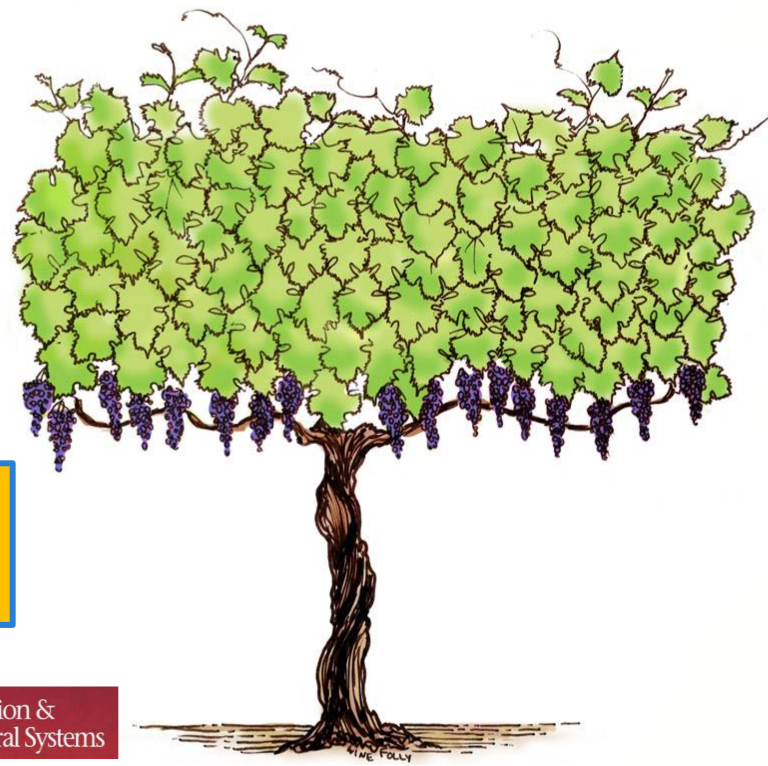
Smart Vineyard 2022

UAS-based Imagery Thermal and Multispectral
8 days of data acquisition

UAS-based Imagery RGB, for 3D maps
2 days of data acquisition

LI-191 R Line quantum sensor measures PAR (Photosynthetically Active Radiation)
2 days of data acquisition

Leaf Water Potential
Predawn (4 am, 8 data point)
Afternoon (2 pm, 24 data point)



Gas Exchange (LCi T)
14 days of leaf measurements

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