Vineyard Irrigation Proficiency Series – Part 2

Irrigation Water Management for Vineyards

January 22, 2021

Agenda

- Introduction to Evapotranspiration Concepts
- Calculating Irrigation Runtimes
- Overview of Soil Moisture Sensor Technologies
- Installation and Management of Soil Moisture Sensors

What is “ET”?

Evapotranspiration, ET

- Measurement of the total requirements of plants and crops
- The word evapotranspiration is a combination of the words “evaporation” and “transpiration”
- Very difficult to measure directly
- May be calculated using weather data

ET Weather Station

ET Theory and Current Practice

- Penman 1949 first proposed the “energy balance method” for determining plant water requirements
- This method required daily or hourly weather data: solar radiation, temperature, wind, and relative humidity
- ET is calculated for a single plant/crop which is used as a reference for determining the water requirements of all other plants/crop

Reference Evapotranspiration, ETo

- Alfalfa was the first reference crop used
- A cool season grass is now the standard reference plant
- The reference cool season grass is similar to a fescue, except that it is growing under idea conditions

Reference Evapotranspiration, ETo

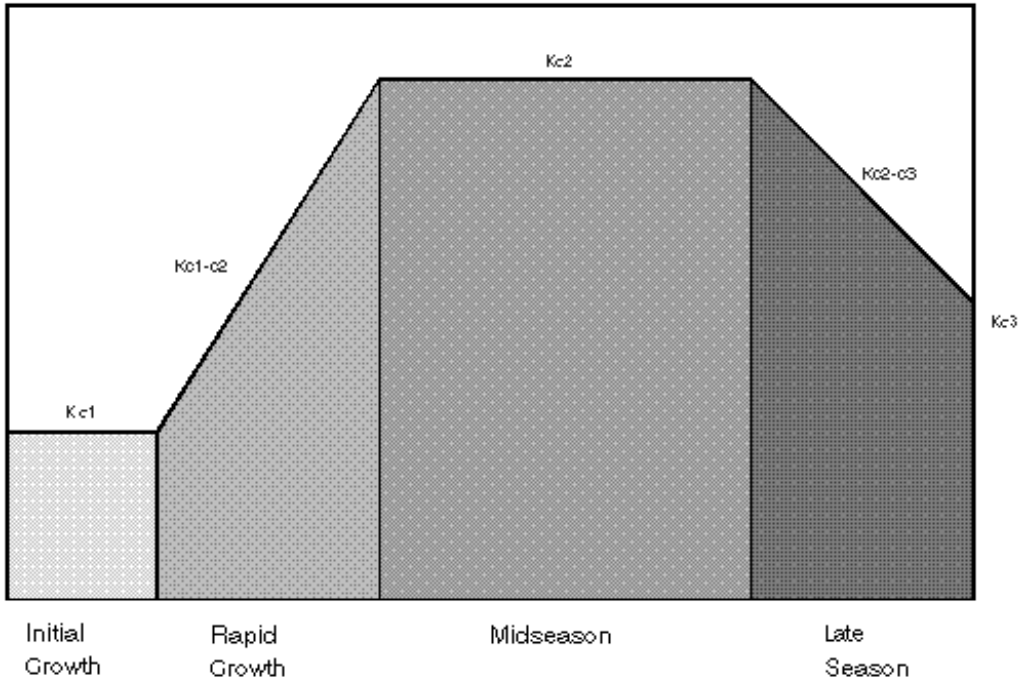
- Also is called the “Potential ET (PET)
- Used as a reference from which the water requirements of all other plants can be determined
- Note: ETo = PET
- ETo is the potential evapotranspiration (PET) of a cool season reference grass growing 4-inches tall under well watered conditions

Reference Evapotranspiration, ETo

- ETo for Central/North Texas usually peaks in July between 0.24 and 0.28 inches per day
- Lubbock: peak ETo = 0.33 – 0.36 in/day
- El Paso: peak ETo = 0.5 – 0.6 in/day

Crop Coefficient (Kc)

- Crop coefficients (Kc) are used to relate ETo to the water requirements of specific plants and crops
- Crop coefficients also change depending on the growth stage of the crop



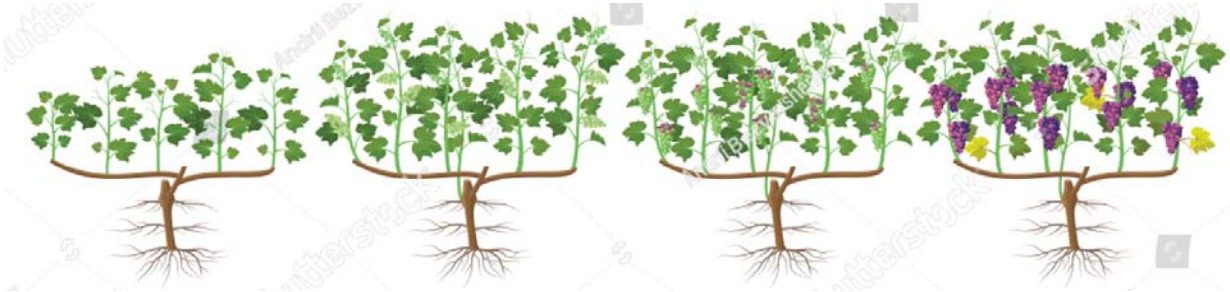
Crop Coefficient (Kc)

- Examples, at peak water use, the Kc of some common crops are:
  - Corn: Kc = 1.3
  - Cotton: Kc = 1.0
  - Sorghum: Kc = 1.10
  - Warm Season Turf: Kc = 0.6

Crop Coefficient (Kc)

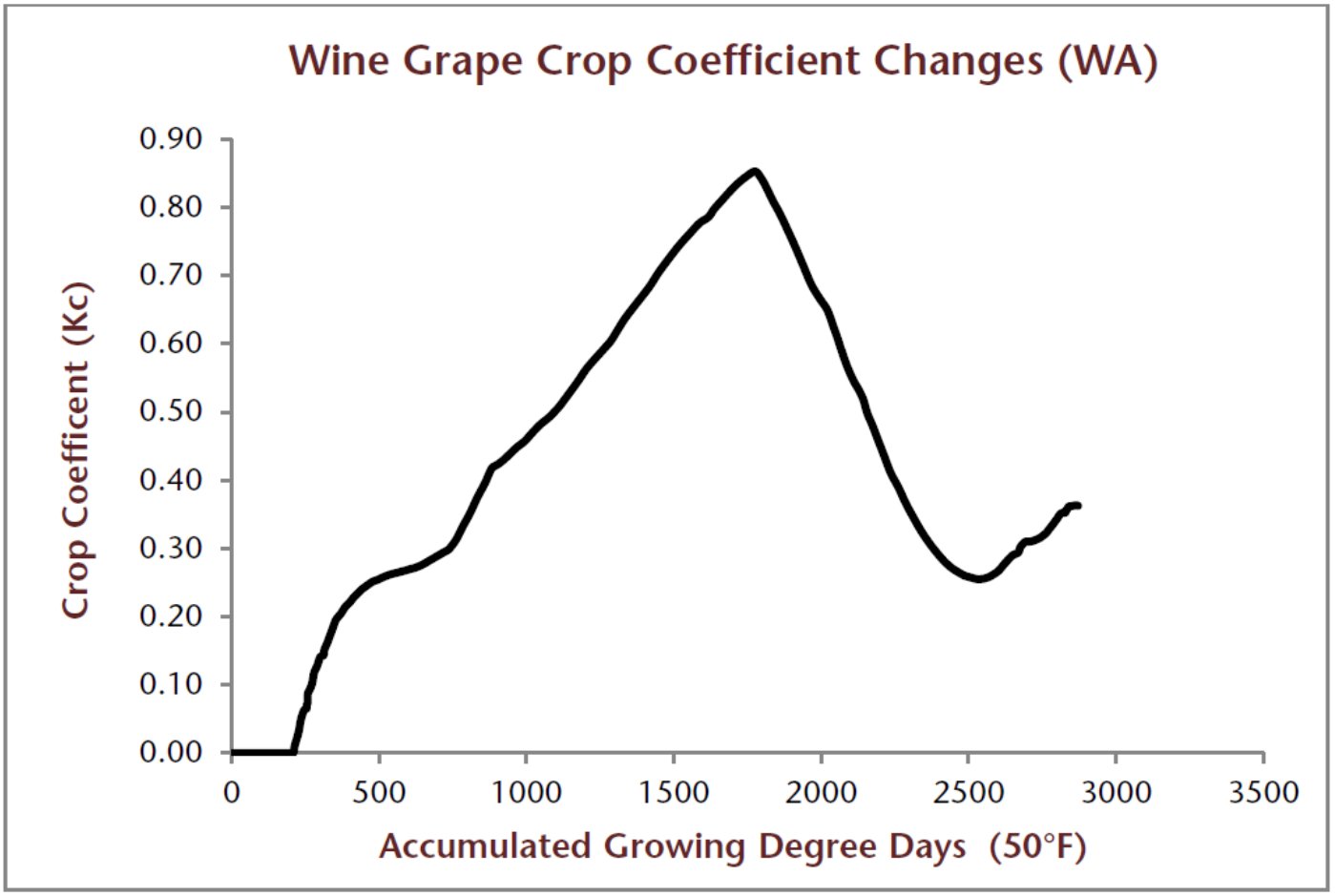
- What is the peak Kc for wine grapes??
- Wine Grapes: Kc = 0.8 (from California)

- FAO Coefficient – Wine Grapes
  - Initial = 0.3
  - Rapid Growth = 0.5
  - Mid Season = 0.7
  - Late Season = 0.57
  - Harvest = 0.45



Crop Coefficients

- University of Washington Wine Grape Study



Water Requirements

Example, what is the peak water requirements (ET) for corn in Central Texas?

- ETcorn = ETo x Kc
- ETcorn = 0.28 in/day x 1.3
- ETcorn = 0.35 in/day

Water Requirements

Example 2, what are the daily and weekly peak water requirements (ET) for grapes in Central Texas?

<u>Daily</u>

- ETgrape = ETo x Kc
- ETgrape = 0.28 in/day x 0.8
- ETgrape = 0.22 in/day

Water Requirements

Example 2, what are the daily and weekly peak water requirements (ET) for grapes in Central Texas?

<u>Weekly</u>

- ETgrape = ETo x 7 days x Kc
- ETgrape = 0.28 in/day x 7 days/week x 0.8
- ETgrape = 1.98 in/week x 0.8
- ETgrape = 1.57 in/week

Irrigation System Runtime

- Precipitation Rate - measurement in inches per hour of how fast an irrigation system applies water

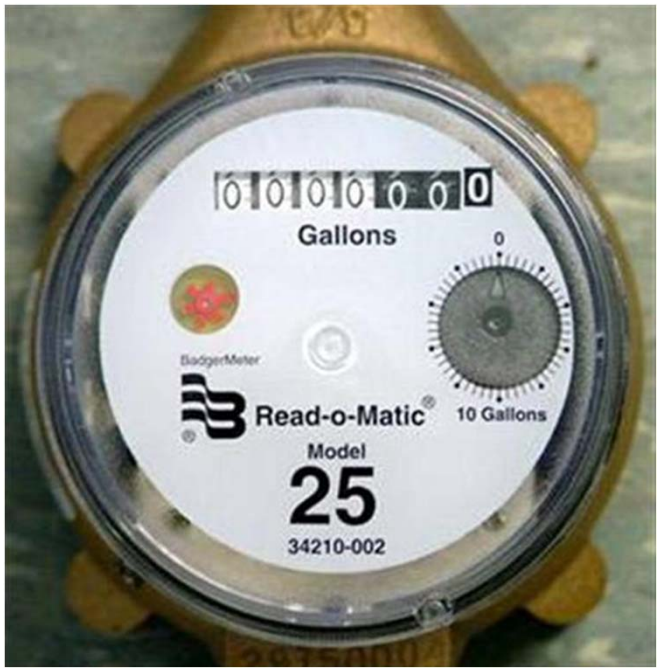
Precipitation Rate (in/hr)

$$PR = \frac{96.25 \times GPM}{Area}$$

- PR = Precipitation Rate, in/hr
- GPM = Total Flow in gallons per minute
- Area = wetted area in ft^2

Total Flow

- Measured directly with flow meter
- Estimated based on irrigation system design
  - Total of all the drip emitters used



Wetted Area

- Based on:
  - Grape row width, or
  - Total Area of the field

- Influenced by root zone area
  - Will roots spread out over time between rows of grapes?

*Note: 1 Acre = 43,560 ft^2

Example Wine Grape Rootzone

Irrigation System Runtime

$$RT = \frac{WR}{PR}$$

- RT – Station Runtime (hours)
- WR – Water Requirement (inches)
- PR – Precipitation Rate (inches per hour)

Irrigation System Runtime

Example: My drip irrigation system has a precipitation rate of 0.5 in/hr. How long will the irrigation set be to meet peak weekly water requirements of 1.57 in/week?

- RT = WR/PR
- RT = 1.57/ 0.5
- RT = 3.14 hours or 189 minutes

Web site demonstration
http://TexasET.tamu.edu

Irrigation Scheduling Worksheet

Irrigation Controller Management

Irrigation Controller Management

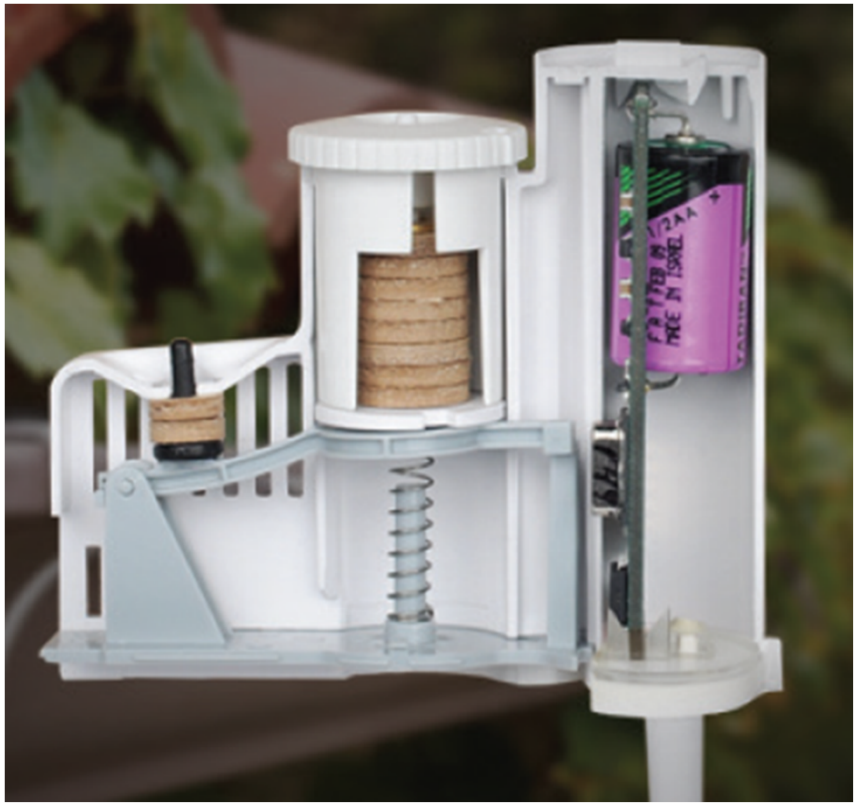
- Irrigation Controllers
  - Can incorporate weather sensors
    - Such as for ET Calculation/Estimation
  - Use of Rain Sensors
    - Avoid Irrigating during rain events
    - Incorporate total rainfall into schedule
  - Use of Soil Moisture sensors
  - Flow monitoring
  - Remote Control
    - WiFi or Cellular access for controller programming and operation

Rain Sensors

- Also called Rain Shut-off Device or Rain Switch
- Designed to interrupt a scheduled cycle of an automatic irrigation controller (timer device) when a certain amount of rainfall has occurred.
- 3 Models:
  - Utilize a receptacle to weigh the amount of water
    - Tipping Buckets
  - Utilize a receptacle to detect the water level
  - Use of a hygroscopic expanding material to sense the amount of rainfall
    - Most widely used method

Rain Sensors

- Rain Sensor
  (Rain Shutoff Device)



- Tipping Bucket

Rain Sensors

- Can delay irrigation until the sensor “drys out”
  - Some controllers can have a programmed timed delay (such as 48 hours) once a sensor is triggered to avoid the sensor re-activating too soon
- Can contain an internal tipping bucket that measures the amount of rainfall to adjust the water balance

Soil Moisture Management

Soil Moisture Management

- The concept is to:
  - wait to irrigate until the plants have depleted the water in the root zone
  - Run the irrigation system just long enough to fill back up the root zone

Definitions used in Soil Moisture Management

- Plant Available Water (PAW)
  - The amount of water in the root zone available for plant uptake
- Soil Water Holding Capacity (SWHC)
  - The amount of water that can be held or stored in the soil
- Managed Allowable depletion (MAD)
  - How dry the soil is allowed to become between irrigations (50% for most plants)


SAND
CLAY

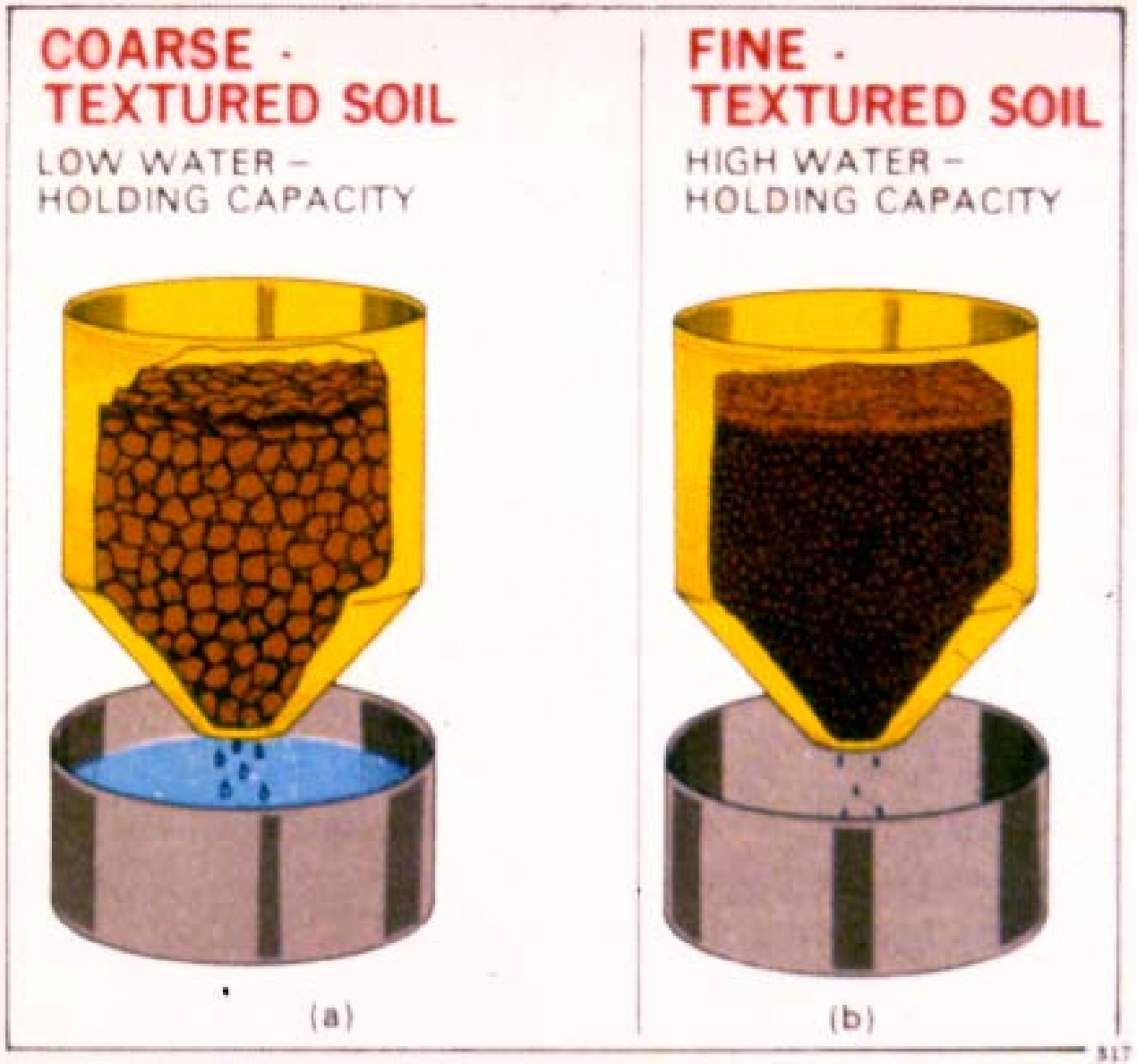


FIGURE 17. The larger the soil particle size, the lower the water-holding capacity. (a) A relatively small amount of water is held by coarse-textured soil as compared to (b) the amount held by fine-textured soil.

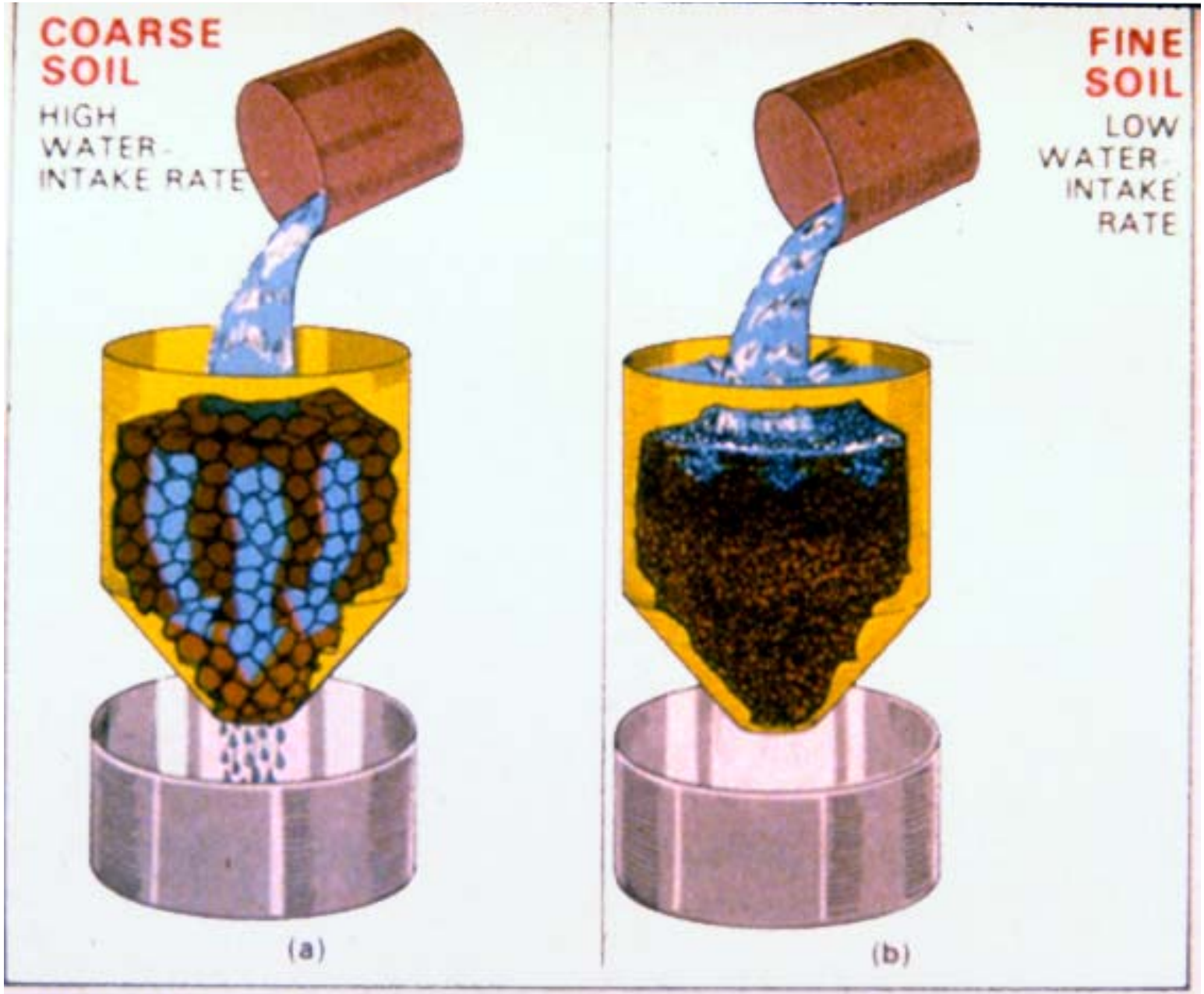
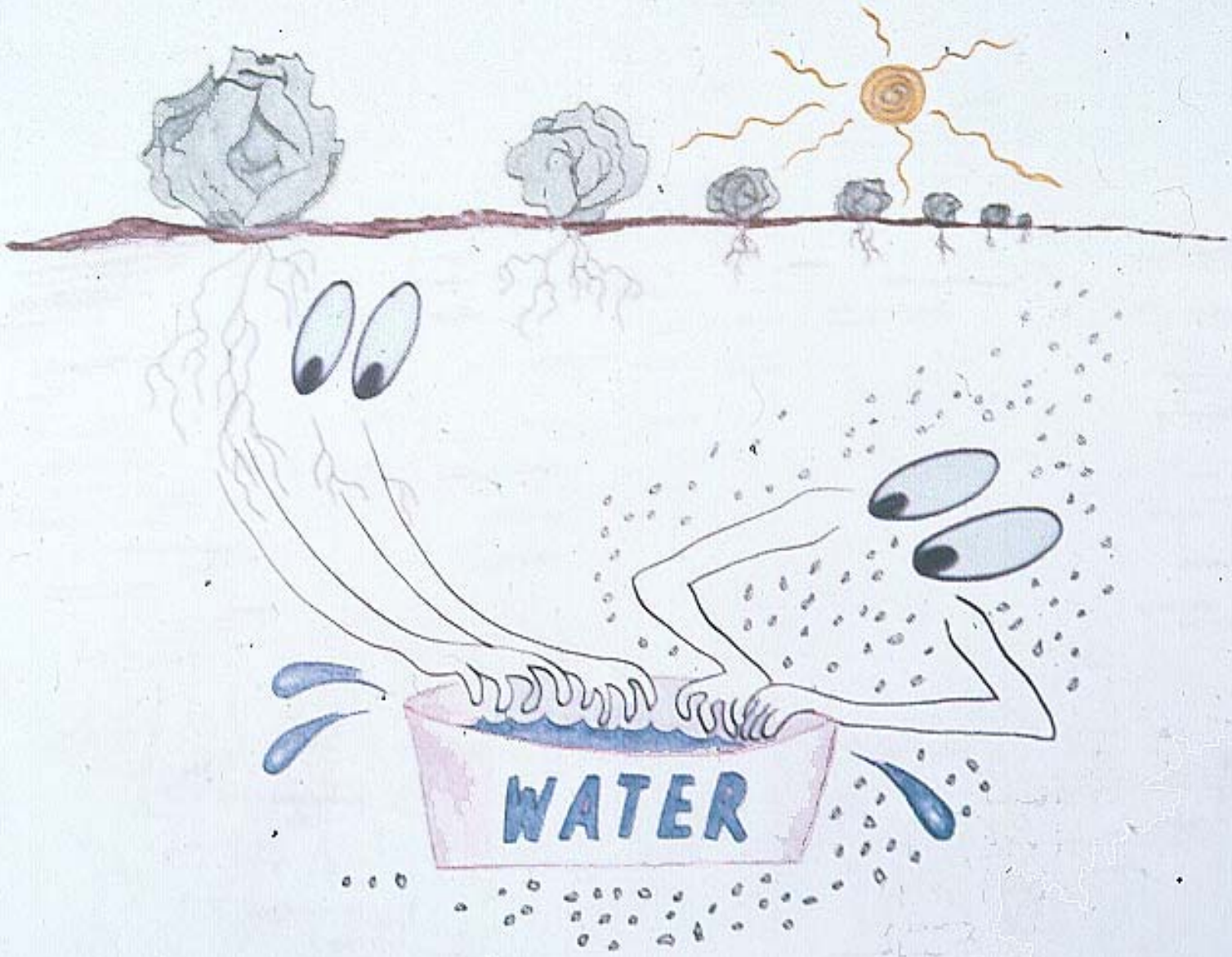


FIGURE 16. Generally, the larger the soil particle size, the faster the water-intake rate. (a) Water moves rapidly through coarse-textured soil. (b) Water moves slowly through fine-textured soil.

Soil Water Holding Capacity Demonstration Video


WATER

Soils

Typical Water Holding Capacity (inches of water per foot of soil)				
Soil Texture	At Field Capacity	At Permanent Wilting Point	Soil Water Holding Capacity	Plant Available Water (@ MAD = 50%)
Sand	1.0-1.4	0.2-0.4	0.8-1.0	0.45
Sandy Loam	1.9-2.3	0.6-0.8	1.3-1.5	0.70
Loam	2.5-2.9	0.9-1.1	1.6-1.8	0.85
Silt Loam	2.7-3.1	1.0-1.2	1.7-1.9	0.90
Clay Loam	3.0-3.4	1.1-1.3	1.9-2.1	1.00
Clay	3.5-3.9	1.5-1.7	2.0-2.2	1.05

Plant Available Water

$$PAW = D \times SWHC \times MAD$$

- PAW = Plant Available Water in root zone (inches)
- D = Root Zone Depth (feet)
  - about 3 feet for grapes unless limited by shallow soils
- SWHC = Soil Water Holding Capacity
  - Inches of water per foot of soil
- MAD = Managed Allowable Depletion
  - 50% for most crops, some use 65% for grapes

Soil Moisture Sensor Technology

Soil Moisture Sensor-Based Controllers

- Soil Moisture Sensor-Based Controllers function in 2 ways:
  - Provide Closed Loop Feedback
    - Similar to a home AC thermostat
    - Most Common Method
  - Give direct feedback to a controller
    - Large Central Control – Controller Technology
    - Allows for direct irrigation on demand

Soil Moisture Based Systems

- 2 Major Categories of Soil Moisture Sensors
  - Soil Water Content (Volumetric)
    - A sensor that measures volumetric content of water in a volume of soil, %
  - Soil Water Tension
    - A Sensor that measures the matric potential of water held in the soil
    - Sometimes referred to as Soil Water Potential or Soil Matric Potential
      - The force with which water is held by the soil matrix (soil particles and pore space)

Soil Moisture Sensor Operation

- Typically take the place of Rain Sensors on Controllers
  - Use of Sensor Ports or in Series with Common Wire/Port
- Operate by opening the circuit until the soil moisture content reaches a programmed deficit at which point the circuit is closed and the controller can begin its scheduled irrigation until the circuit is opened again.
- Most controllers will still require setting irrigation runtime, frequency, etc.

Using Soil Moisture Sensors

- Installing Multiple Sensors at Multiple Depths improves accuracy.
- Depth of Placement should be representative of the effective root zone.
- Difficult to obtain accurate readings in the top 2 inches of soil

Using Soil Moisture Sensors

- Can be expensive and challenging to use in large or elaborate landscapes/fields
  - Finding a representative to install location within the irrigation system
  - Often different plant materials will require their own sensors
    - Changes in Soil type
    - Different root zone depth
    - Irrigating grapes & grass??

Types of Soil Moisture Sensors

- Granular Matrix Sensor
- Gypsum Blocks
- Tensiometer
- Capacitance Probe
- Time Domain Transmissometry, TDT
- Time Domain Reflectometry, TDR
- Frequency Domain Reflectrometry, FDR

Soil Moisture Sensor Technologies

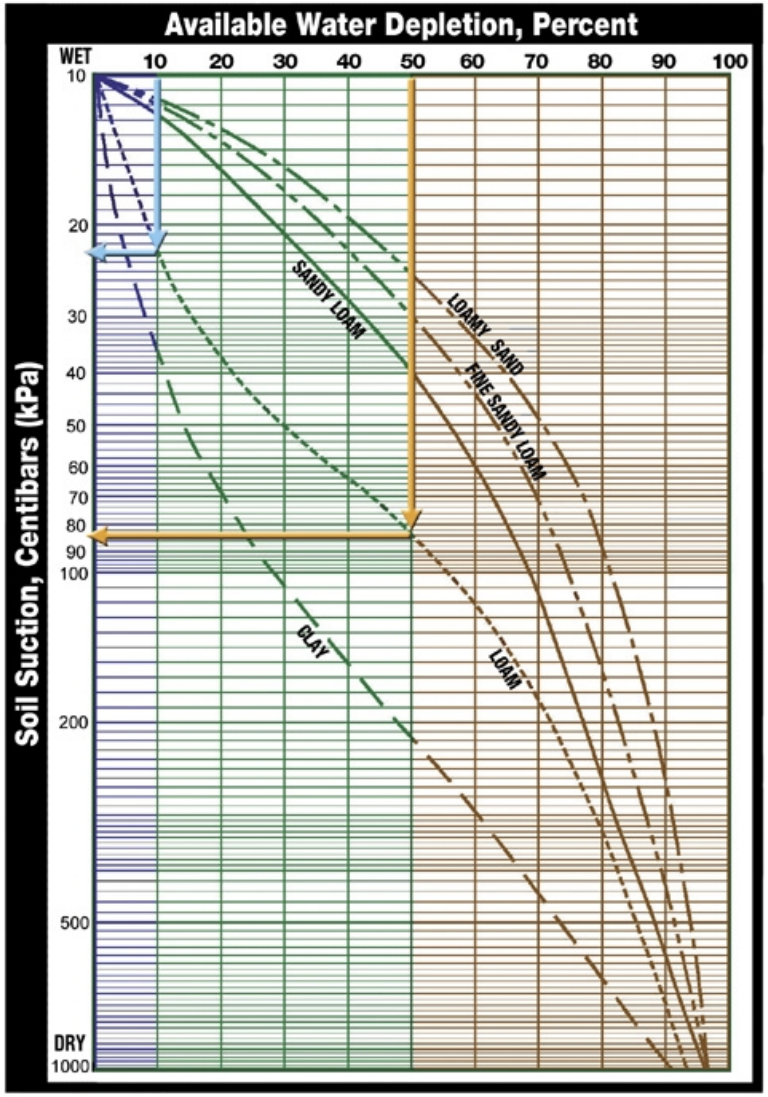
- Most Commonly Used in Field Irrigation
- Granular Matrix
- Capacitance
- TDR/TDT

Granular Matrix Sensors

- Contain a set of electrodes in a granular matrix material (combination of quartz & gypsum)
- Changes in soil electrical conductivity (resistance) are correlate to soil matric potential
  - i.e. the suction head as the soil wets and dries

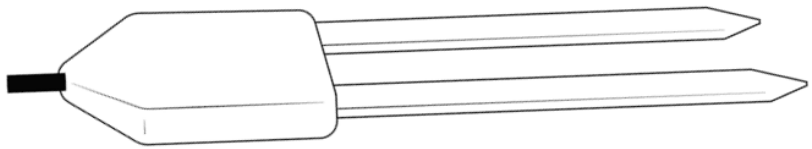
Reading Water Potential

- Available Water varies in the soil based on the matric potential (soil suction)
- Graph shows typical relationship of soil suction to available water depletion
- Most SMS products will simplify the range a sensor reads for irrigation mgmt.
  - Such as 1-10 threshold scale



Capacitance Sensors

- Capacitance: the ability to hold an electric charge – of the surrounding soil in order to obtain the dielectric permittivity of the soil
- Sensor determines the dielectric constant (Ka) by measuring the charge time of the capacitor, using the soil as the dielectric medium
  - Since Ka of Air = 1 and Water = 80, the capacitor uses a linear function to determine the dielectric permittivity of the soil



TDR/TDT

- TDR & TDT are similar in operation
- Operate using an electromagnetic wave passed through the soil via parallel rods from a transmission line.
  - With TDR, the speed and strength of the wave after it travels from one rod to another is directly related to the dielectric properties (soil moisture content) of the soil
  - With TDT, the rod is connected to the electrical source at the beginning and end of the rod to measure the travel time of the wave between rods

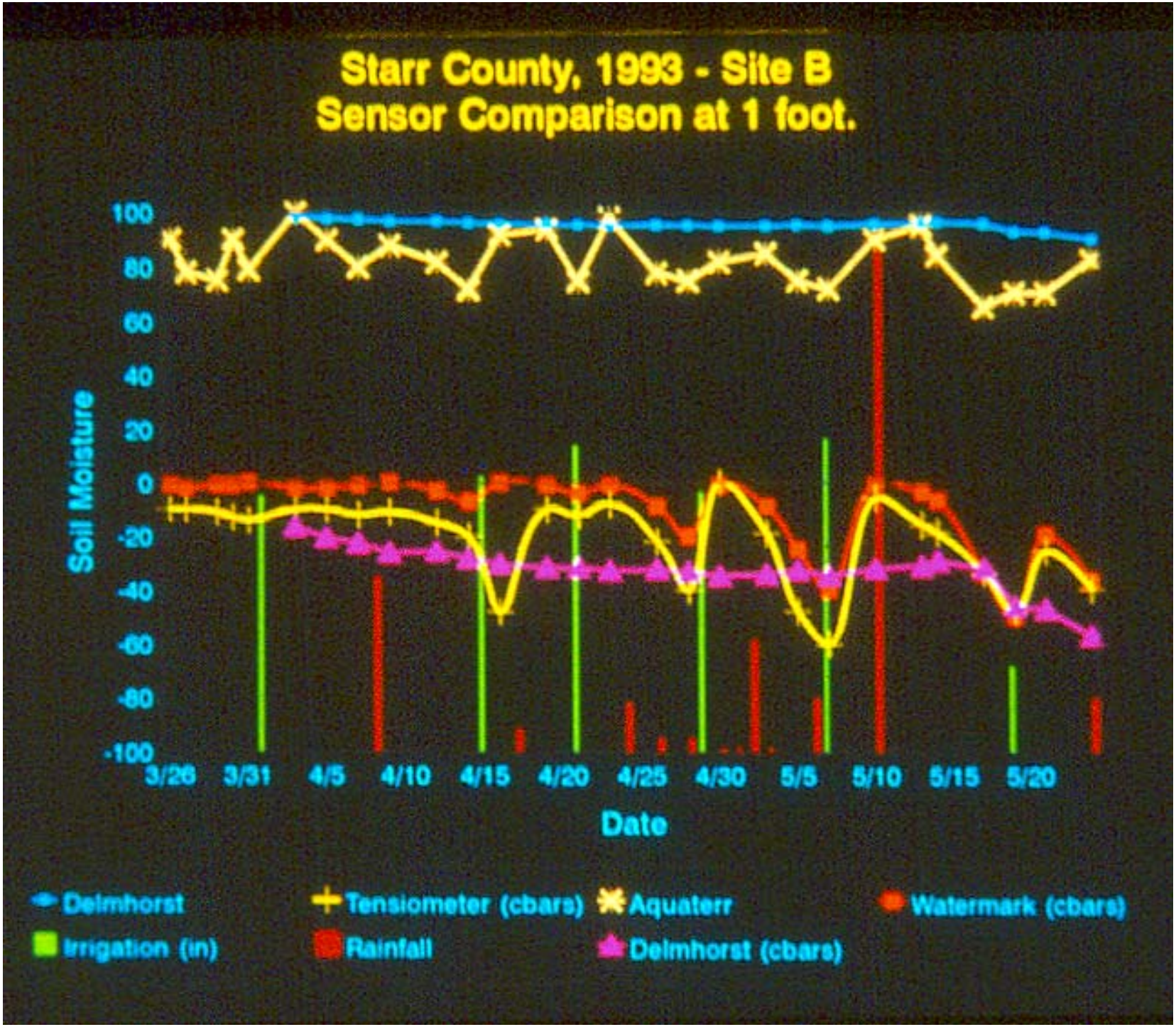
Sensor Technology Overview

Sensor	Sensor Type	Sensor Reading	Costs (Comparably)	Sensitive to Salinity	Affected by Temperature	Sensor Response
Granular Matrix	Matric Potential	cBars	Low	Generally No	No	Slow
Capacitance	Volumetric Water Content	%	Moderate	Yes	No	Moderate-High
TDR/TDT	Volumetric Water Content	%	Moderate-High	Generally No	No	Moderate-High

Sensor Calibration

- All sensors require calibration based on sensor type
- Most manufacturers have simplified calibration for sensors used with landscape irrigation controllers
  - Calibration by:
  - Soil Type,
  - User Defined Threshold, or
  - Timed Calibration by irrigating the site to field capacity/saturation

Examples of Irrigation Sensors


Starr County, 1993 - Site B
Sensor Comparison at 1 foot.
Soil Moisture
100
80
60
40
20
0
-20
-40
-60
-80
-100
3/26
3/31
4/5
4/10
4/15
4/20
4/25
4/30
5/5
5/10
5/15
5/20
Date
Delmhorst
Tensiometer (cbars)
Aquaterr
Watermark (cbars)
Irrigation (in)
Rainfall
Delmhorst (cbars)

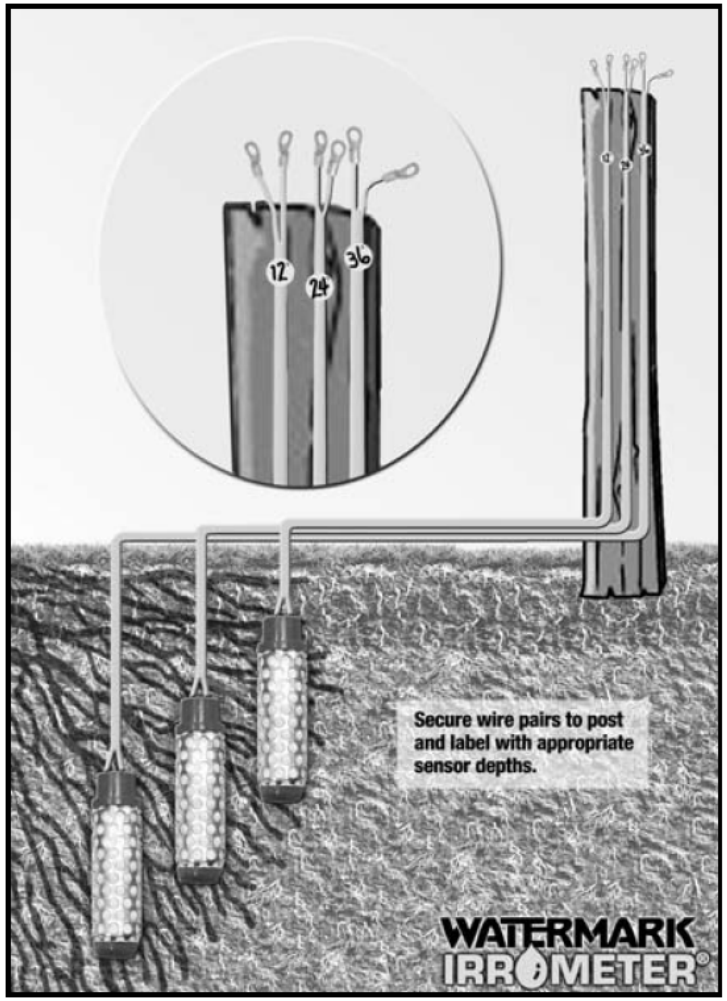
Using Soil Moisture Sensors

Equipment - Sensors

- Watermark Sensor
  - Inexpensive
  - Easy to use
  - No maintenance
  - Will not dissolve in soil

Sensor Installation

- Can be installed using a standard 5/8” soil probe
- Installing at multiple depth provides for best soil water management
- Typically installed at 1ft, 2ft & 3ft depths depending on depth of root system.

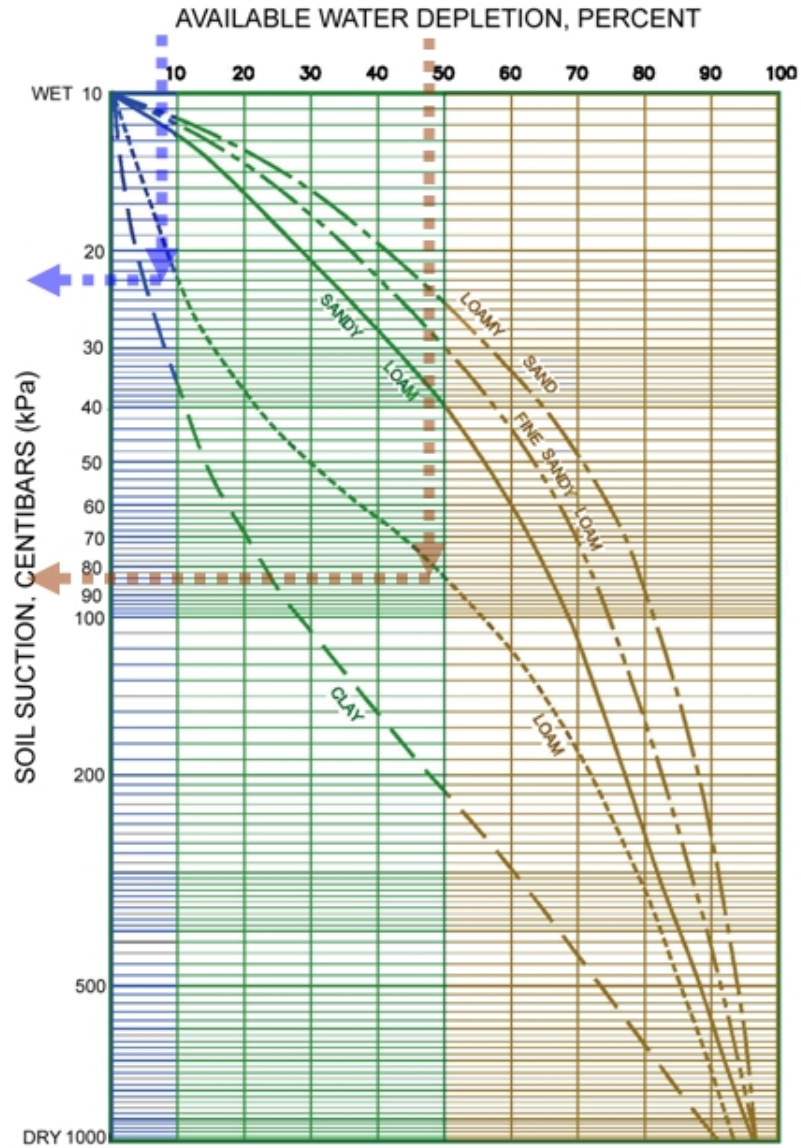


Equipment - Meter

- Watermark Meter
  - Quick and Easy to use
  - Inexpensive
  - Durable
  - Reads Soil Tension in CBARS
  - Need to reference a chart to determine soil moisture threshold

Defining the Threshold

- Soil Water Tension (CBARS) varies based on soil type.
- Water threshold is usually defined as 50% Available Water Depletion
- Simply Determine Soil Suction for your soil.
  - Ex. Loam @ 50% = 84 CBARS



Preparing Soil Moisture Sensors Video Demonstration

Installing Soil Moisture Sensors Video Demonstration

Reading Soil Moisture Sensors Video Demonstration

Interpreting Soil Moisture Sensor Readings

Interpreting Sensor Readings

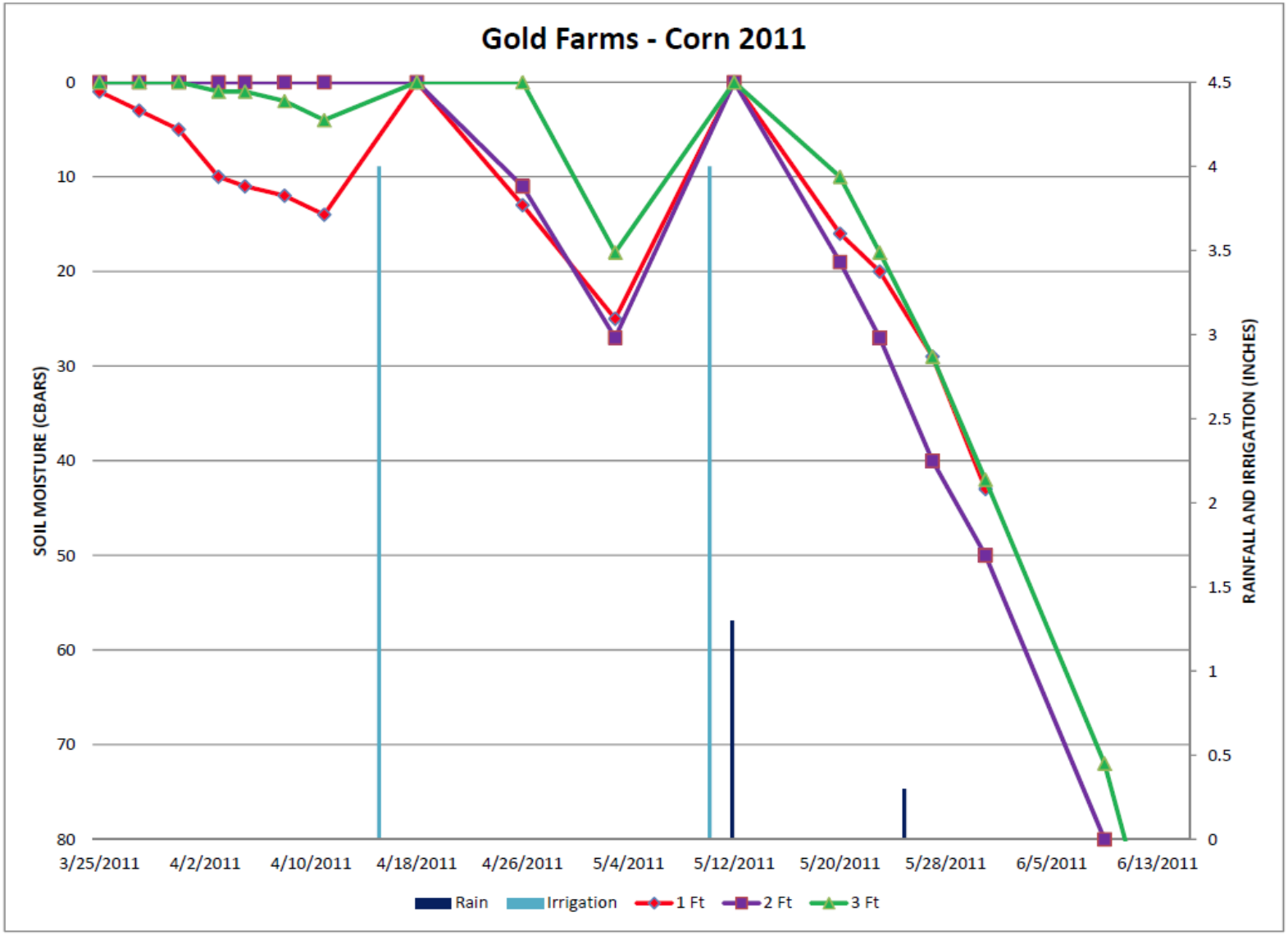
- Graphing sensor readings will help create a visual of moisture conditions in the soil
  - Trends of moisture at each sensor level
  - Effectiveness of rainfall events
    - Do you need to irrigate after rain?
  - Adequacy of irrigation events
    - Are you irrigating too frequently?
    - Are you applying enough irrigation to refill the root zone?

Demonstration Data

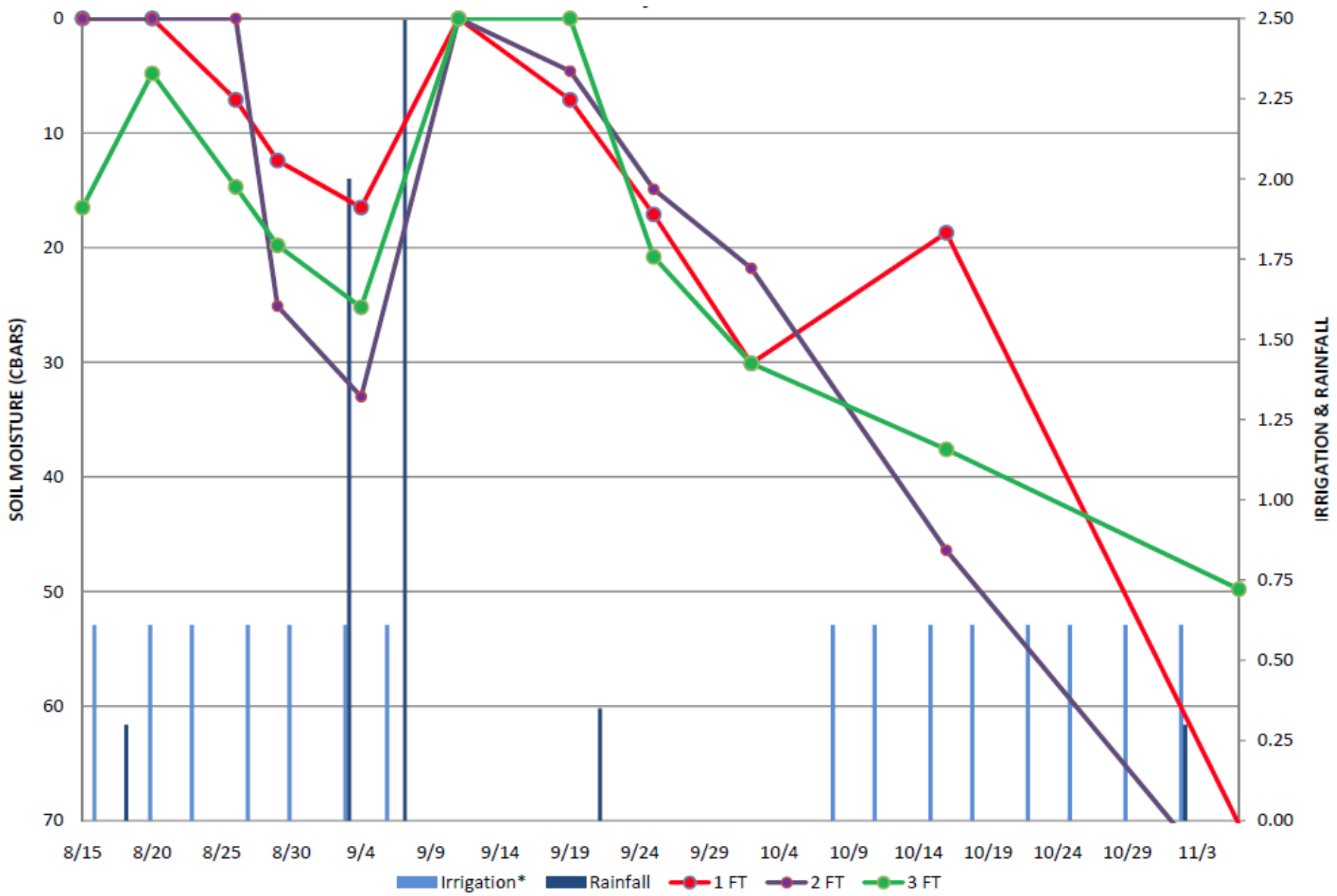
Gold Farms

Date	Sensor 1	Sensor 2	Sensor 3	Irrig	Rain
3/25	1	0	0		
3/28	3	0	0		
3/31	5	0	0		
4/3	10	0	1		
4/5	11	0	1		
4/8	12	0	2		
4/11	14	0	4		
4/15				4"	
4/18	0	0	0		
4/26	13	11	0		
5/3	25	27	18		
5/10				4"	
5/12	0	0	0		1.3"
5/20	16	19	10		
5/23	20	27	18		
5/25					0.3"
5/27	29	40	29		
5/31	43	50	42		

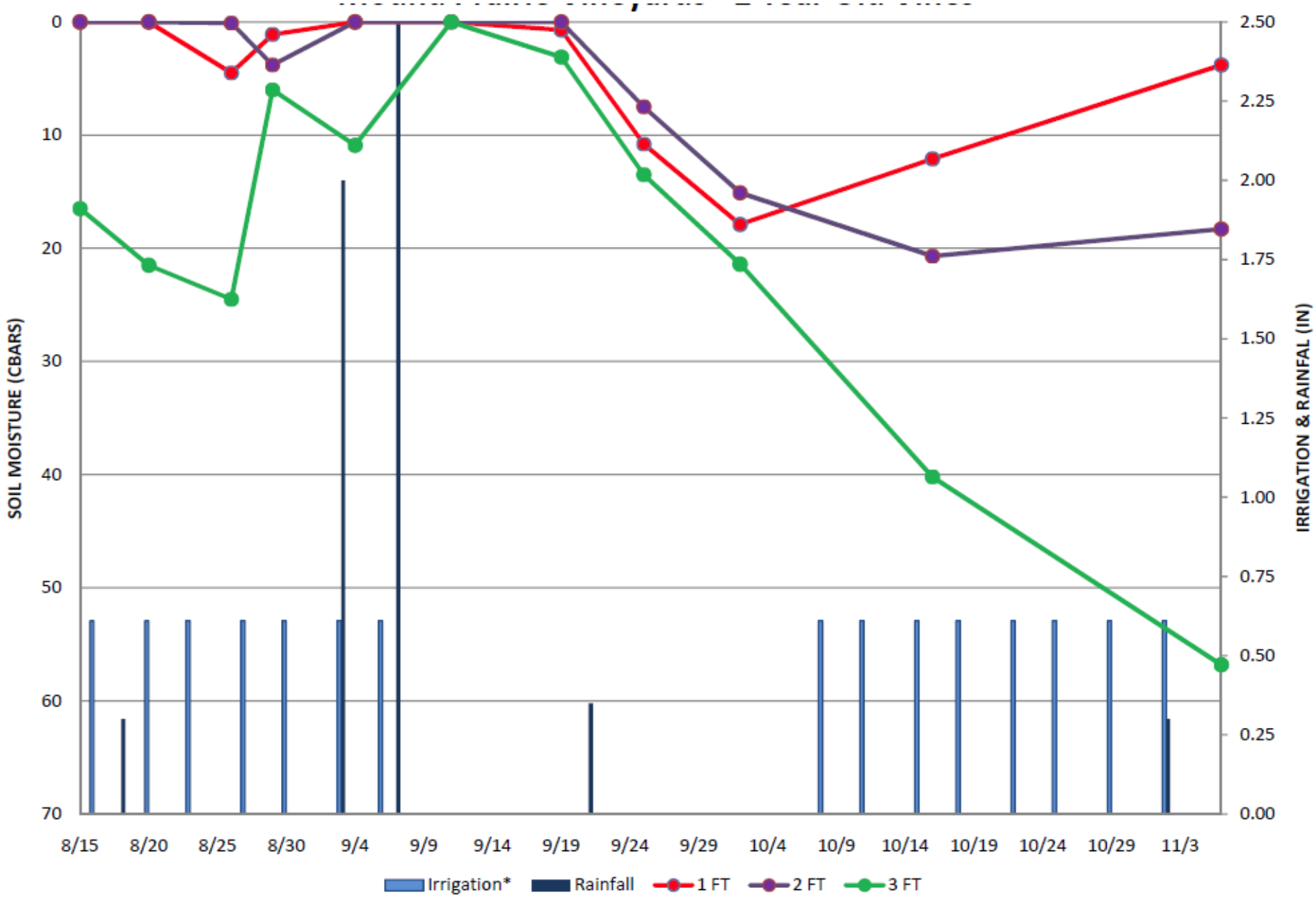
Demonstration Data



Example Vineyard Sensor Data



*Irrigation Volume Estimated Based On Flow



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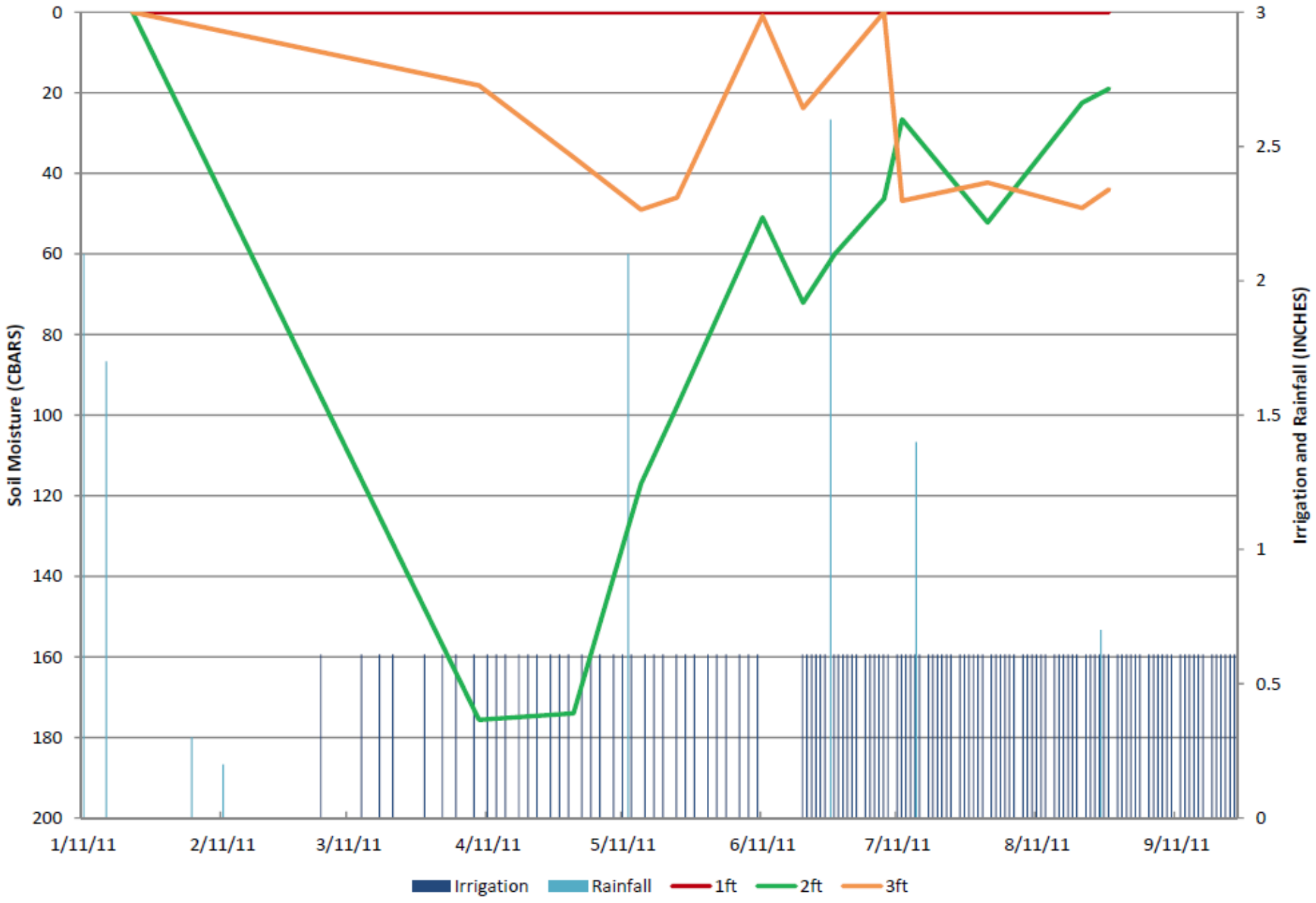
Soil Moisture (CBARS)
Irrigation and Rainfall (INCHES)
0
20
40
60
80
100
120
140
160
180
200
3
2.5
2
1.5
1
0.5
0
1/11/11
2/11/11
3/11/11
4/11/11
5/11/11
6/11/11
7/11/11
8/11/11
9/11/11
Irrigation
Rainfall
1ft
2ft
3ft

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