Introduction to the Soil-Water-Plant Environment

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Irrigation Scheduling

- Process of maintaining an optimum water balance in the soil profile for crop growth and production

- Irrigation decisions are based on an accounting method on the water content in the soil

Reasons for Irrigation in Fruits and Vegetables

- Crop Growth and Development
  - Meeting the daily water use requirements
- Crop Establishment
  - Transplants need water in excess of normal crop water use
- Frost Protection
  - Sometimes requires more than one type – overhead for frost protection along with drip irrigation.
- Chemigation / Fertigation
- Herbicide Activation

Irrigation Scheduling

- Components
  - Plant Growth Stage and Water Use
  - Soil Water Holding Capacity
  - Evaporative Demand

- RECORDKEEPING

Irrigation Scheduling

- Levels of Accounting
  - 0 – Guessing (irrigate whenever)
  - 1 – Using the "feel and see" method
  - 2 – Using systematic irrigation (ex: ¾" every 4th day)
  - 3 – Using a soil moisture measuring tool to start irrigation
  - 4 – Using a soil moisture measuring tool to schedule irrigation and apply amounts based on a budgeting procedure
  - 5 – Adjusting irrigation to plant water use, using a dynamic water balance based on budgeting procedure and plant stage and growth, together with a soil water moisture measuring tool.

Irrigation Scheduling

- Components
  - **Plant Growth Stage and Water Use**
  - Soils and Water Holding Capacity
  - Evaporative Demand

- RECORDKEEPING

Plant Growth and Water Use

- Fundamentally crops use water to facilitate cell growth, maintain turgor pressure, and for cooling.
- Crop water use is driven by the evaporative demand of the atmosphere.
- Function of temperature, **solar radiation**, wind, relative humidity.
- Example, a fully developed corn crop in Michigan can use as high as 0.35 inches per day. (~9,500 gallons / acre)
- Generally, optimum crop growth and health occurs when the soil moisture content is held between 50 – 80% of the "plant available water"

Estimating Plant Water Use

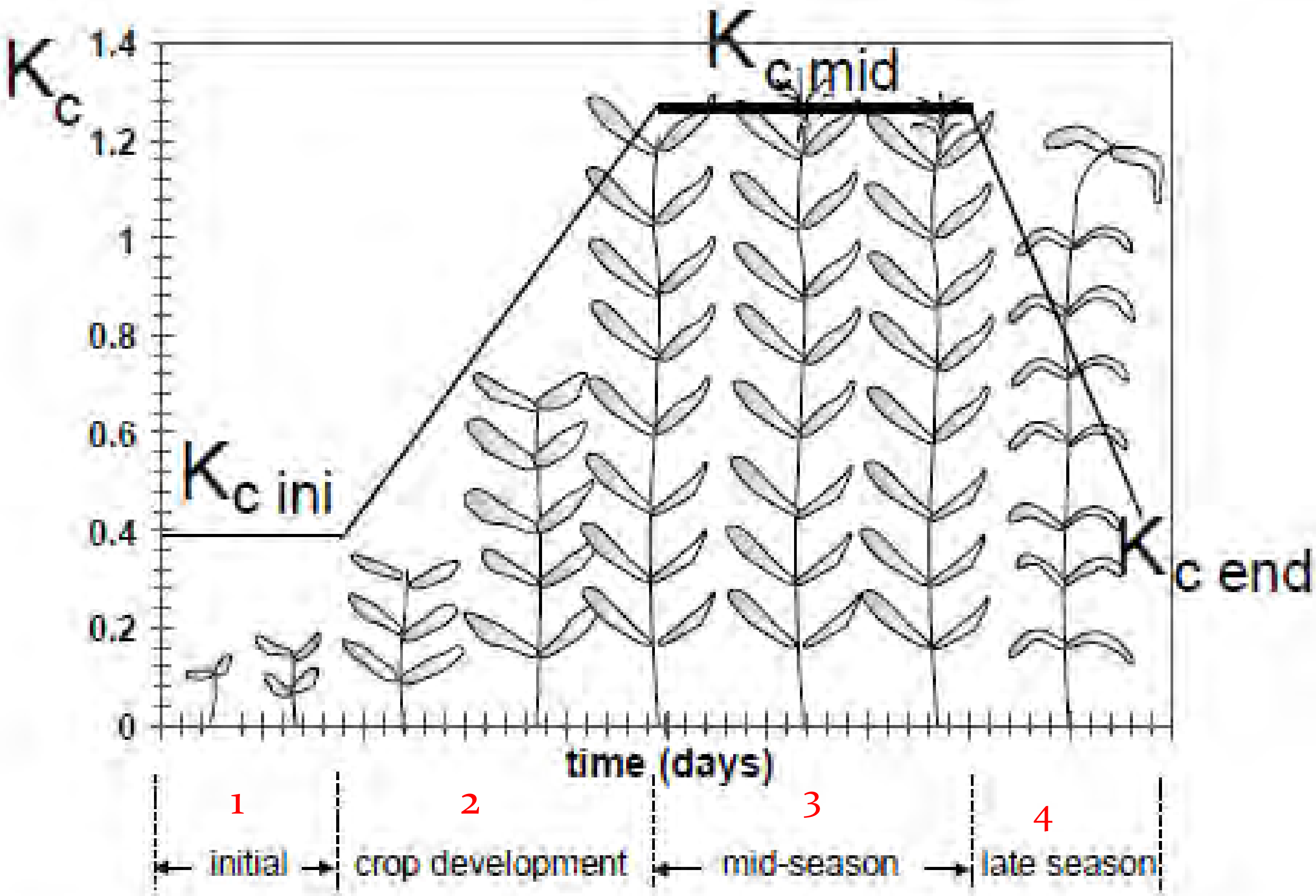
- Crop water use = Evapotranspiration (ET).
- A "potential reference ET (PET)" can be calculated based on weather conditions.
- The standard method – Penman – Monteith.
    - Based on temperature, solar, humidity, wind, rainfall
    - "Well watered grass"
- Michigan Agricultural Weather Network (MAWN) calculates hourly PET at each station and publishes the daily total value for irrigation use.
- http://www.enviro-weather.msu.edu/

Estimating ET for Different Crops

- Combining a "Crop Coefficient Curve" with the reference ET.
- Crop Curve is a relationship between the specific plants' growth characteristics and its water use relationship to the reference crop.

Crop Curve

FIGURE 25
Generalized crop coefficient curve for the single crop coefficient approach



Crop	Growth Stage	Crop Coefficient
All field-grown vegetables	1	0.20[1] to 0.40[2]
	2	Stage 1[3] value to Stage 3 value (Se
Legumes: snapbean, lima bean and southernpea	3	0.95[4]
	4	0.85[4]
Beet	3	1.00
	4	0.90
Cole crops:	3	1.00
broccoli, brussels sprouts	4	0.85
cabbage, cauliflower	3	0.95[4]
collards, kale	4	0.90[4]
mustard	3	1.00[4]
turnip	4	0.90[4]
Carrot	3	1.05
	4	0.75
Celery	3	1.05
	4	0.95
Cucurbits: cucumber, cantaloupe, pumpkin	3	0.90
squash, watermelon	4	0.70
Lettuce: endive,	3	0.95
escarole	4	0.90
Okra	3	1.00[4]
	4	0.90[4]
Onion (dry)	3	0.95
	4	0.75
Onion (green)	3	0.95
Parsley	3	1.00[4]

TABLE 25

Approximate reductions in K_c and surface evaporation and increases in transpiration for various horticultural crops under complete plastic mulch as compared with no mulch using trickle irrigation

Crop	Reduction in K_c (%)[1]	Reduction in evaporation (%)[1]	Increase in transpiration (%)[1]	Source
Squash	5-15	40-70	10-30	Safadi (1991)
Cucumber	15-20	40-60	15-30	Safadi (1991)
Cantaloupe	5-10	80	35	Battikhi and Hill (1988)
Watermelon	25-30	90	-10	Battikhi and Hill (1986), Ghawi and Battikhi (1986)
Tomato	35	not reported	not reported	Haddadin and Ghawi (1983)
Average	10-30	50-80	10-30	

[1] Relative to using no mulch

Irrigation Scheduling

- Components
  - Plant Growth Stage and Water Use
  - **Soils and Water Holding Capacity**
  - Evaporative Demand

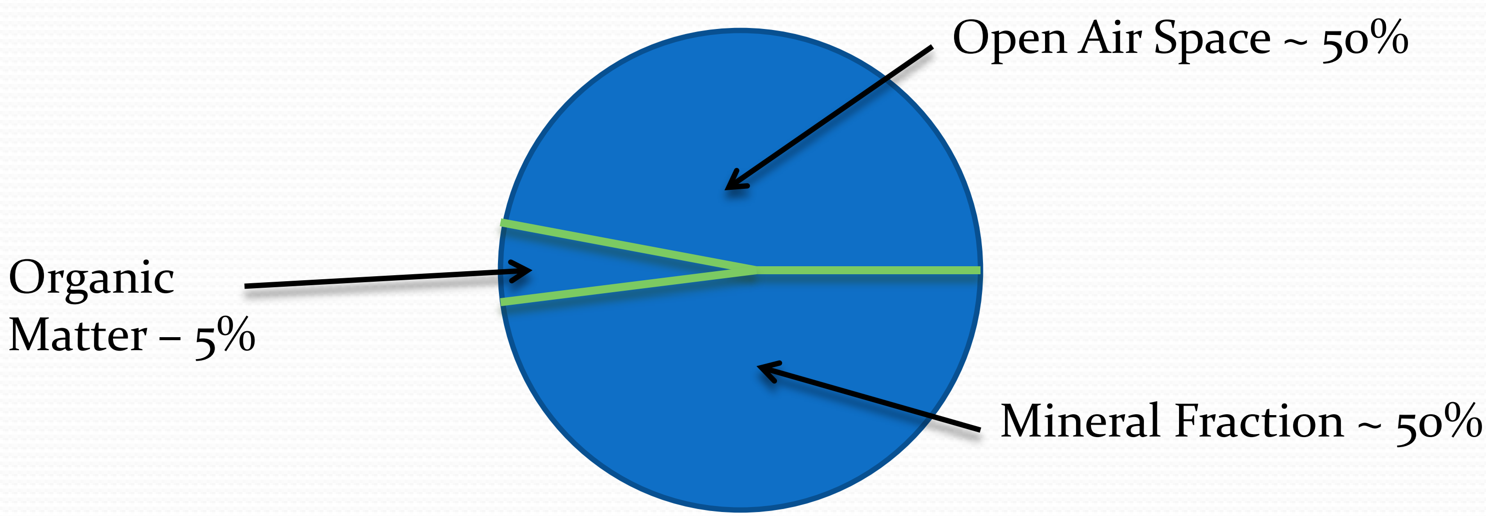
- RECORDKEEPING

Soils and Water Holding Properties

- In traditional agriculture soils act as the media in which plants are grown and harvested
- Soils can be very diverse spatially and with depth
- Understanding the basic components and properties of soils allows for effective management of water in a crop life cycle.

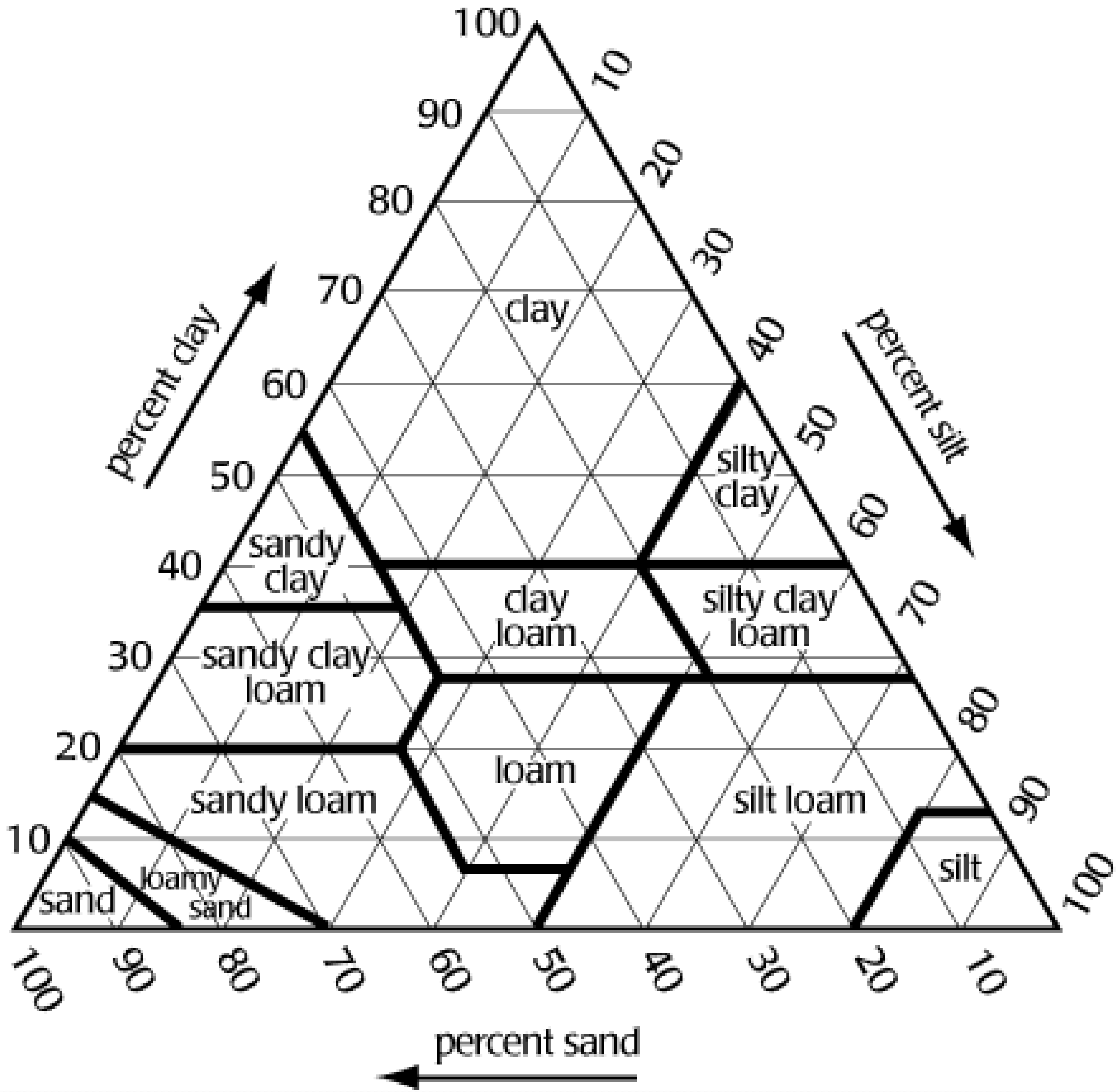
Ideal Soil

- Breakdown of an "ideal" soil
  - Mineral Component
  - Open Air Space – (porosity)
  - Organic Component



Soils

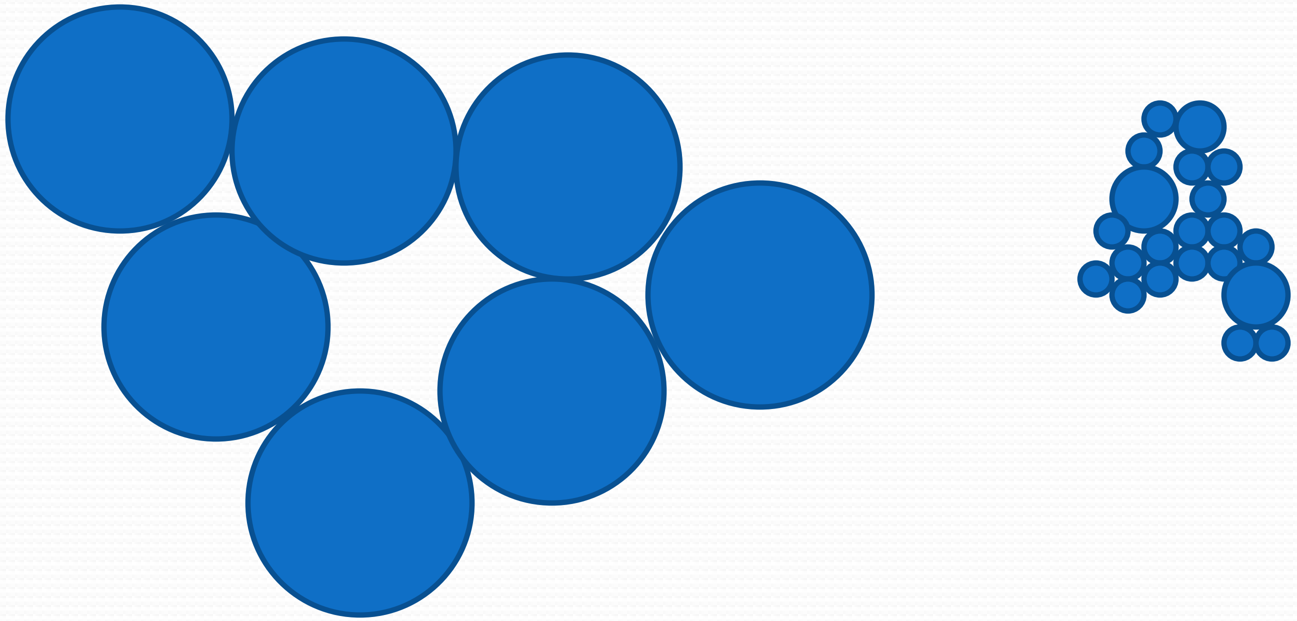
- Mineral Fraction
  - Composed of SAND, SILT, and CLAY
    - Sand (diameter > 2 mm)
    - Silt (2mm < diamter < 0.002 mm)
    - Clay (diameter < 0.002 mm)
- The distribution of these three components if referred to as the "Texture" of the soil.



percent clay
percent silt
percent sand
clay
silty clay
sandy clay
clay loam
silty clay loam
sandy clay loam
loam
sandy loam
silt loam
loamy sand
sand
silt
100
90
80
70
60
50
40
30
20
10

How does Texture affect water holding capacity?

- Soil particle size affects the size of the open pore spaces.



- Sand to Clay size is like comparing a grain of sand to a 6’ diameter beach ball.

Texture and Pore Space

- This is counterintuitive –
  - A sandy soil has a lower porosity than a clayey soil
    - Sands – porosity = 0.3 – 0.4 (30 – 40%) – Big Big Pores , but not many
    - Clays - porosity = as high as 0.6 (60%) – super tiny pores, but millions more than a sand

The Ideal soil has a porosity ~ 50%

Back to the Ideal Soil

- The Ideal soil has a textural distribution like "Goldilocks" not too many large pores, not too many small pores
- A good mixture of large pores for good water and air infiltration and small pores for water and nutrient holding capacity.
- Most irrigated soils are not like Goldilocks – you are irrigating because:
  - 1) not enough rainfall during the growing season
  - 2) not enough water holding capacity in the soil

Bulk Density

- Bulk Density is a useful value to know about a soil.
  - BD = Mass of Dry Soil / Total Soil Volume
    - Units are usually lbs/ ft^3 or grams / cm^3

- We can calculate the porosity of a soil if we know the bulk density

- Porosity = (1 – Bulk Density / Soil Solid Density)
  - Soil Solid Density = ~2.65 g/cm^3

Bulk Density

- Gives a good overall indication of soil structure and water holding capacity
  - Sandy Soils (BD ~ 1.5 – 1.7 g/cm^3)
  - Clayey Soils (BD ~ 1.1 g/cm^3)
  - The Ideal Soil has a bulk density of 1.33 g / cm^3

  0.50 = (1 – Bulk Density / 2.65g/cm^3)

Soil Water Holding Capacity

- Soil acts as a reservoir to hold water for plant use.
- The capacity for a soil to hold water is primarily based on the soils texture but can be modified by attributes such as soil organic matter.
- Example
  - Sandy soils have lower water holding capacity (Large pores that easily drain by gravity)
  - Clayey soils have higher water holding capacity (Microscopic pores that tightly hold water)

Determining Soil Moisture

- Two ways to refer to the moisture content of a soil
  - Gravimetrically
  - Volumetrically

Gravimetric Moisture Content

- Mass based calculation
  - W = Mass of water in the soil / Mass of dry soil
  - Weigh the soil when it is wet, dry it for 24 hours in a drying oven at 105 degrees C, weigh it when it is dry.
  - (Wet soil – Dry soil) / Dry Soil

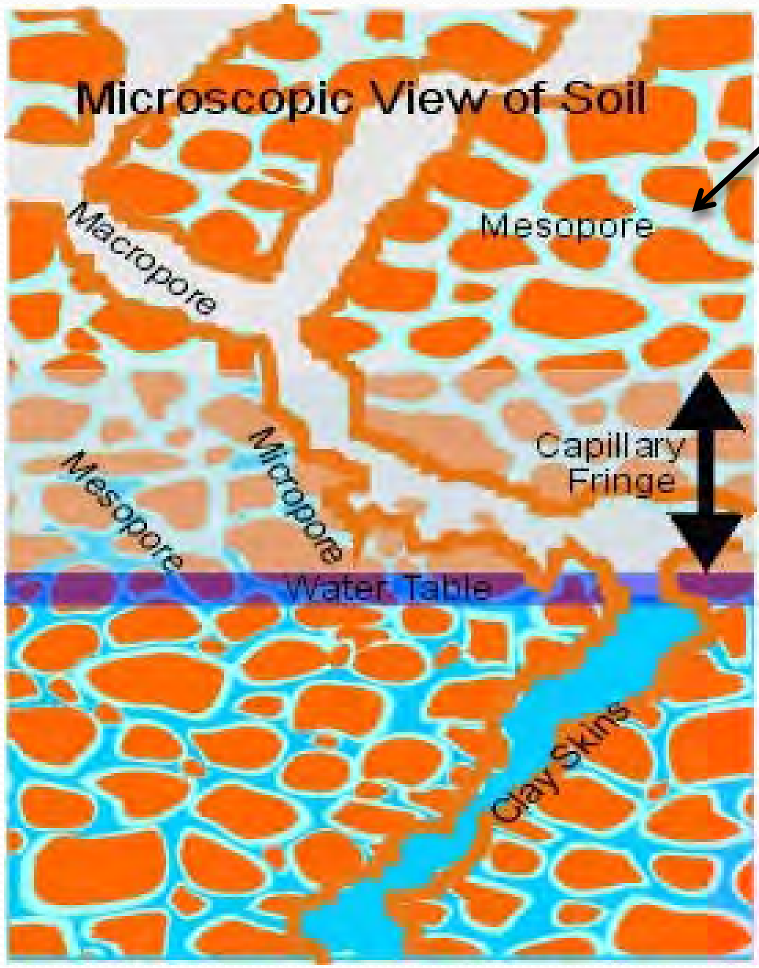
Volumetric Water Content

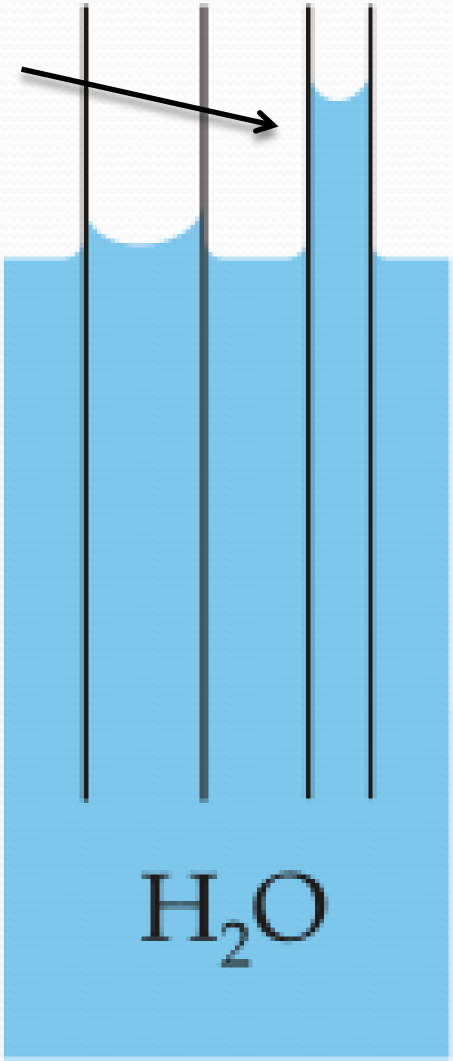
- Moisture based on the (you guessed it!) volume
  - Volume of water in the soil / Total volume of the soil
  - Much more tricky to determine but a little more useful in irrigation scheduling.
- Can relate Gravimetric moisture to Volumetric moisture using the soils' Bulk Density

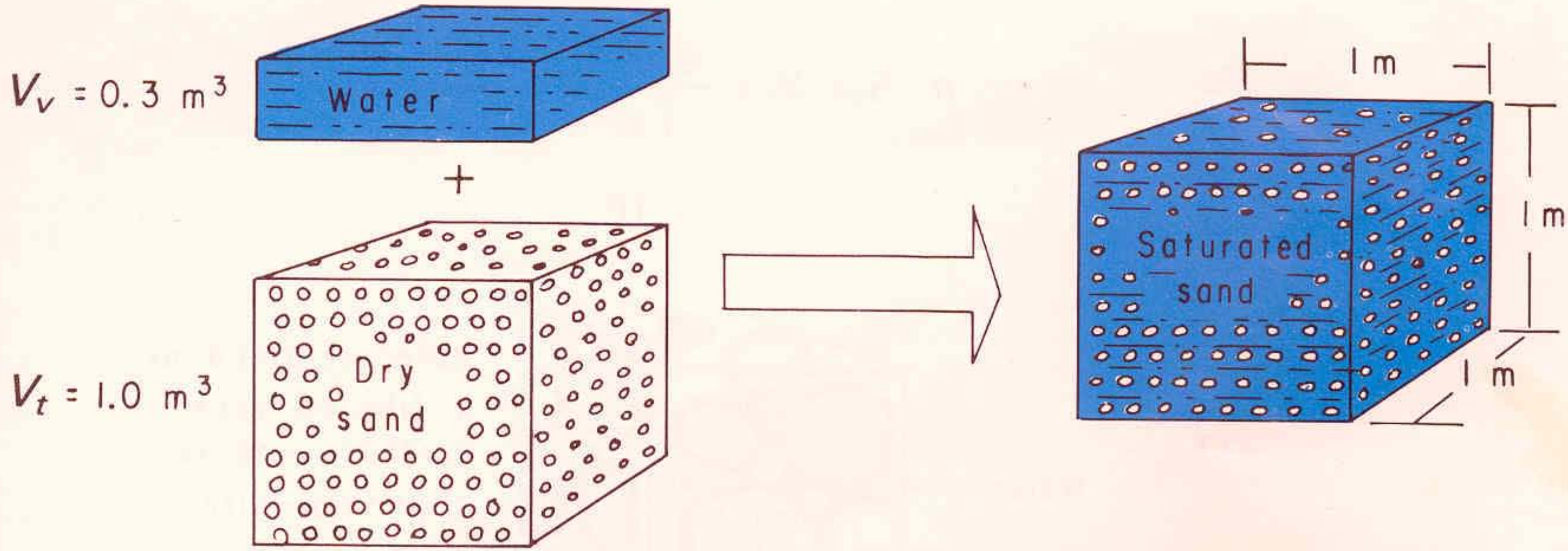
- Vol Moist = Grav. Moist * Bulk Density

Pore Size and Capillary Action

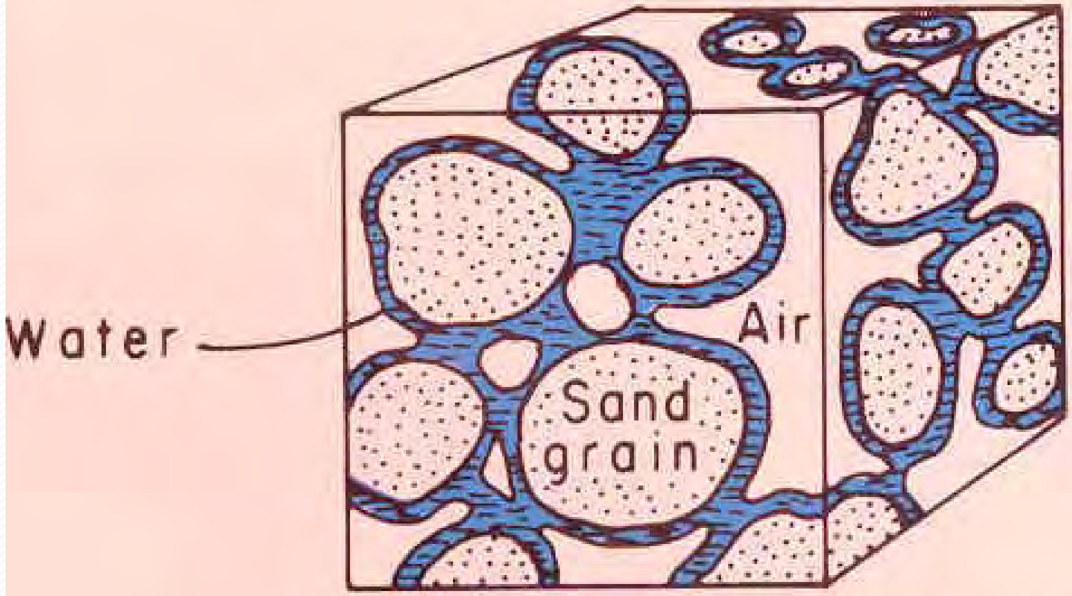
Surface Tension







$$\text{Porosity } (n) = \frac{\text{Volume of voids } (V_v)}{\text{Total volume } (V_t)} = \frac{0.3\ \text{m}^3}{1.0\ \text{m}^3} = 0.30$$



GRANULAR MATERIAL

Water retained as a film on rock surfaces and in capillary-size openings after gravity drainage.

Soil Water Holding Capacity

- The moisture content of a soil ranges along a continuum between absolutely saturated to completely dry
- There are specific points of interest along this continuum

- **KEY POINT – As a soil goes from wet to dry, the remaining water is going to be held tighter and tighter by the soil. We use the term "Tension" to describe the suction with units of Bars or Kilopascals**

Soil – Water Continuum

- Starting Point – Saturation
  - Every pore space is filled with water (think of a bathtub with the drain stopped up) TENSION = Zero Bars

- Volumetric water content = the soil porosity
- Bad situation for crops – plenty of water but no oxygen in the root zone

- Pull the plug! – Large pores begin to drain under the force of gravity

Soil – Water Continuum

- Large pores empty – Drainage stops – Smaller pores filled with water
- The force holding the water in the soil is equal to the force of gravity pulling it down
- This point is called "Field Capacity" or sometimes called "Upper Drained Limit"
- This represents that maximum amount of water the volume of soil can store for plant use.
- The TENSION (suction force) at this point is roughly 1/3 Bar.

Soil – Water Continuum

- Soil continues to dry (Evaporation or Transpiration)
- Plant roots are like drinking straws
- They can only suck with a tension or vacuum of about 15 Bars
- At the 15 Bar point – plants can no longer win the tug-of-war with the soil and reach the “Permanent Wilting Point”

Soil – Water Continuum

- From that the PWP – soil continues to dry until the moisture content becomes in equilibrium with the relative humidity of the atmosphere.
- Call "Hygroscopic Point" or "Air Dry Soil"
- Tension equals roughly 31 Bars
- Represents a volumetric water content of ~ 2 – 3%
- Anything dryer requires baking in an oven – to an "Oven Dry Soil"
- Only 1 layer of water molecules remain – 10,000 Bars

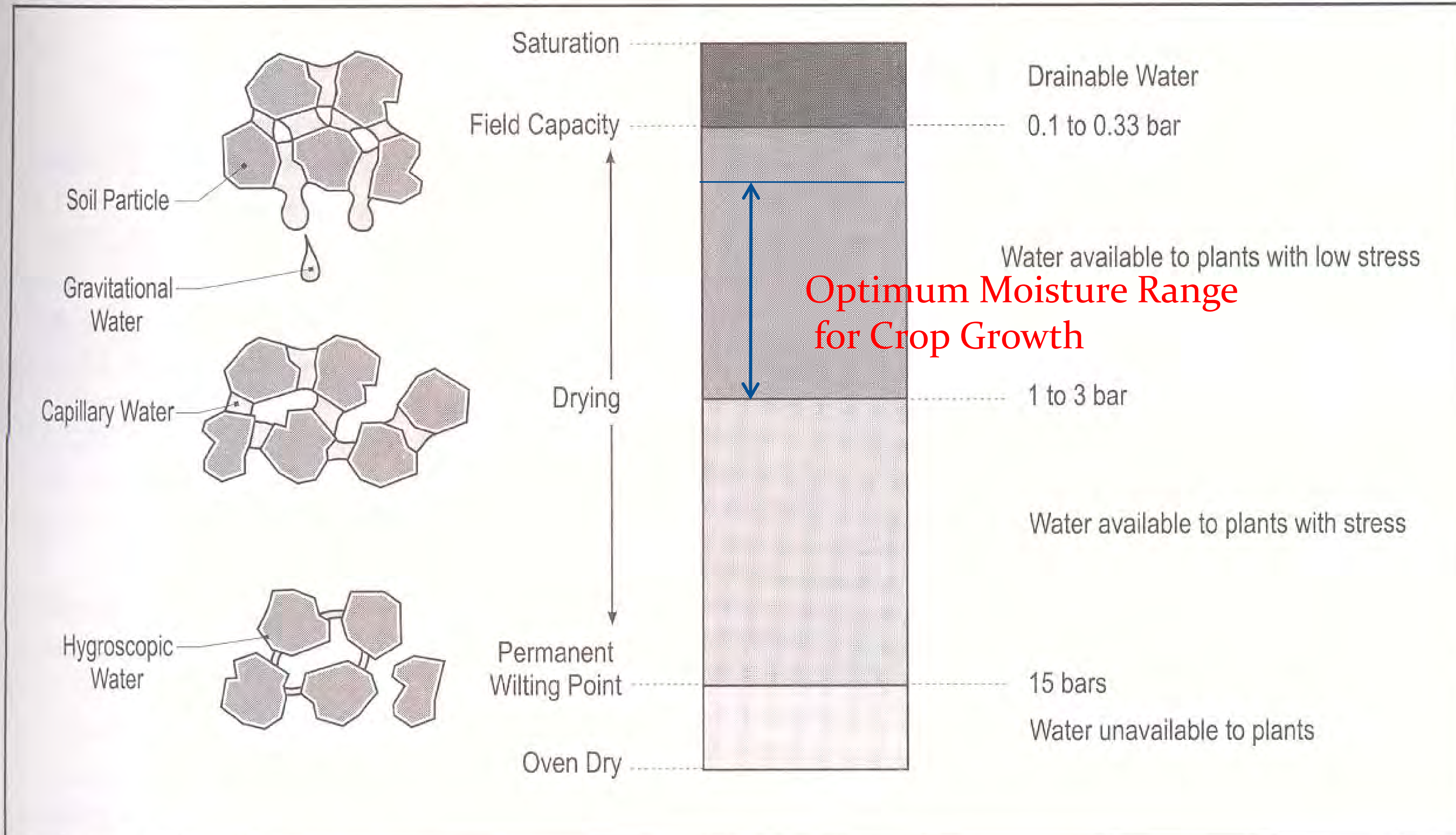
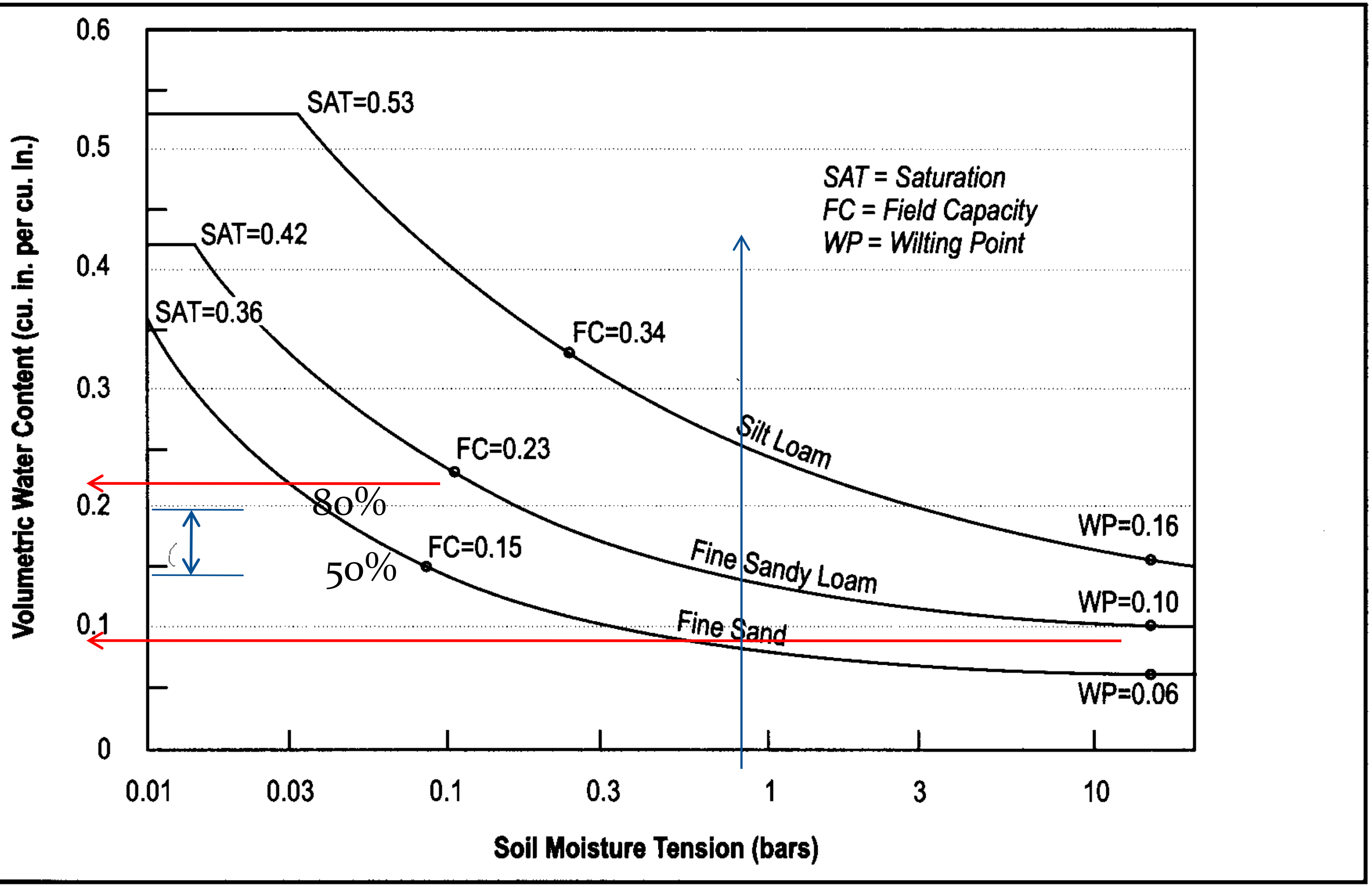


Figure 2-2. Soil moisture tension.



ure 2-4. Soil water content-moisture tension relationship.

rce: *Irrigation Systems Management.*

Problem # 1

- You are given a sandy loam soil sample with a volume of 10cm X 10cm X 10cm = 1,000 cubic cm.
- The sample was taken within a day of a good long soaking rainfall event.
- The wet weight of the soil is 2,250 grams
- The oven dry weight is 1,850 grams
- Determine the Bulk Density, Porosity, Gravimetric Moisture Content, and Volumetric Moisture Content

Problem work area

Soil Texture	Available Water	
	Range in./in.	Average in./in.
Very coarse-textured sands and fine sands	0.04-0.08	0.06
Coarse-textured loamy sands and loamy fine sands	0.06-0.10	0.08
Moderately coarse-textured sandy loams and fine sandy loams	0.10-0.15	0.13
Medium textured very fine sandy loams, loam and silt loams	0.13-0.19	0.16
Moderately fine-textured sandy clay loams, clay loams, and silty clay loams	0.15-0.21	0.18
Fine-textured sandy clays, silty clays, and clay	0.13-0.21	0.17

Reference: USDA, NRCS, *Engineering Field Manual*

Available water for each soil group by soil horizon from NRCS Soil Surveys

Where can I get soil specific data

- **County Soil Survey**
  - Table 16 – Physical and Chemical Properties of the Soils

- Two Important Characteristics
  - **Soil Permeability (inches / hr)**
    - Is this soil at risk for runoff during irrigation events?
  - **Available Water Capacity (inch / inch)**
    - How many inches of water can be stored for plant use per inch of soil profile?

Example – Oshtemo Soil

Available water (AW) holding capacity of soil - (inches water/inch soil). See Table 1 or Soil Survey.								
Depth Range (in)	0 - 6	6 - 12	12 - 18	18 - 24	24 - 30	30 - 36	36 - 42	42 - 48
AW (in/in)	0.125	0.125	0.125	0.150	0.084	0.070	0.070	0.030

Soil Example

- Tomatoes on a Oshtemo soil
  - Available water is 0.13 in/in

- 2 foot effective rooting zone

- Total available water storage in the soil profile at full crop development
  - 24 inches * 0.13 in / in = <u>3.12 inches</u>

Oshtemo Soil Example

Depth (inches)	Storage per Layer	Cumulative Storage (inches)
0 - 6	6" * 0.125" water storage / " soil	0.75
0 - 12	6" * 0.125" water storage / " soil	1.5
0 - 18	6" * 0.125" water storage / " soil	2.25
0 - 24	6" * 0.150" water storage / " soil	3.15

Measuring Soil Moisture

- Tensiometers and Watermarks
  - Measure soil tension - centibars
- Volumetric Probes
  - TDR
  - FDR
  - Capacitance Probes
- Moisture by Feel