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Center for Irrigation Technology


# Young Citrus Irrigation Scheduling and Nutrient Management

# THE CENTER FOR IRRIGATION TECHNOLOGY

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**California State University, Fresno** – The Center for Irrigation Technology

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**Project Title:** Young Orchard Irrigation and Nutrient Management Technical Assistance Program

**Lead Organization:** University of California Cooperative Extension, Moneim Mohamed

**Presentation Topic:** Young Citrus Irrigation Scheduling and Nutrient Management

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Center for Irrigation Technology, California State University- Fresno

## Agenda:

Factors affecting soil water reservoir

Soil water: Methods and Metrics

Soil water measurements and sensors

Soil parameters for irrigation scheduling

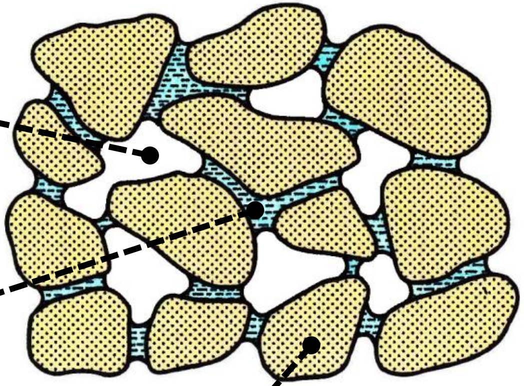
Management parameters for irrigation scheduling

Irrigation scheduling

Nutrient management

Conclusion

# Soil – Air – Water Continuum



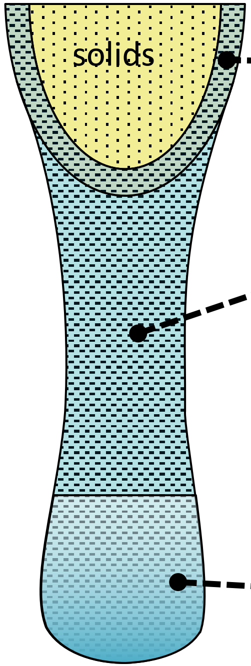
## Air
Moves easily through the soil. Some air will remain even when the soil is saturated

## Water
Surface tension attracts water to the surface of the solid fraction. As water moves through the soil it displaces the air.

## Solid
Tightly bound to soil particles. Not available to plants.

Image Source: Soil In The Environment, by Daniel Hillel, Fig 7.3

# Three 'kinds' of water

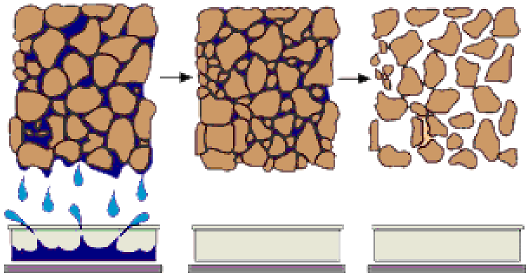



## Hygroscopic
This includes both the mineral portion and the **organic** portion

## Capillary
Surface tension attracts water to the surface of the solid fraction. Is available to plants but less so as it is depleted.

## "Gravity"
Moves quickly in large pores between soil particles. Does not remain in place for long. Only available to plants when it is present.

# Critical Moisture Levels



Saturation

All pores are full of water. Gravity drains the soil.

Field Capacity

Water content when drainage stops.

Permanent Wilting Point

None of the water remaining is available for plants

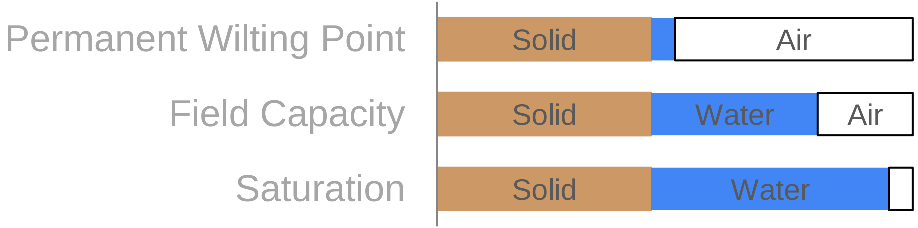
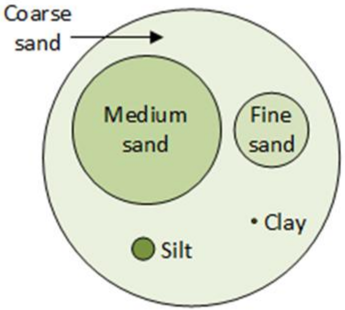


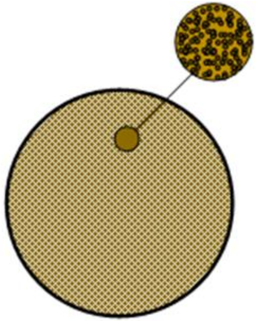

Image Credit: Prof. Blaskó Lajos, www.tankonyvtar.hu/hu/tartalom/tamop425/0032_talajtan/ch07s02.html

**Main factors affecting soil water storage capacity:** Soil texture, Structure, Organic Matter Content, Soil Compaction

| Soil Particle Size | | | | | | |
|---|---|---|---|---|---|---|
| Clay | Silt | Sand | | | | |
| | | Very Fine | Fine | Medium | Coarse | Very Coarse |
| <0.002 mm | 0.002 - 0.05 mm | 0.05 - 2.0 mm | | | | |
| <0.00008 inch | 0.00008 - 0.002 inch | 0.002 - 0.08 inch | | | | |



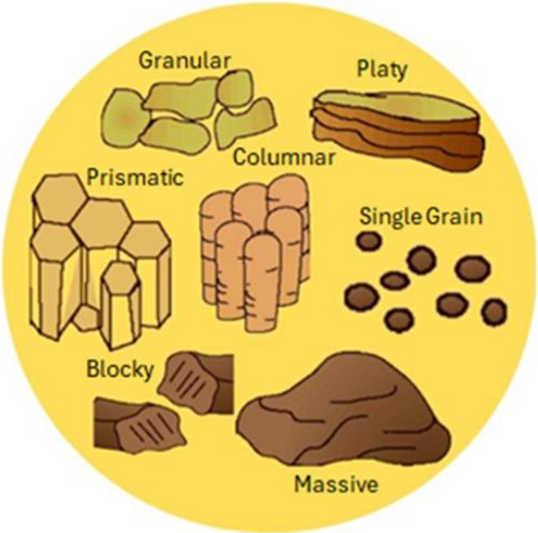

Relative Sand, Silt, and Clay Particle Size



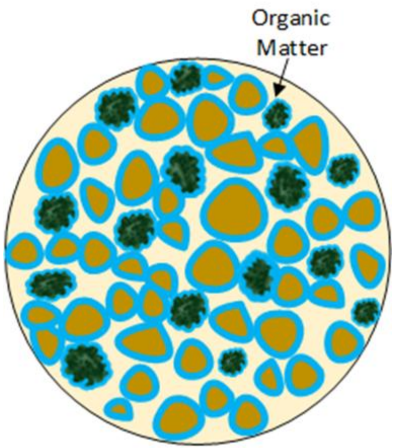
**Clay Soil**
Smaller Pores &
Greater Total Pore Volume

**Sandy Soil**
Larger Pores &
Less Total Pore Volume

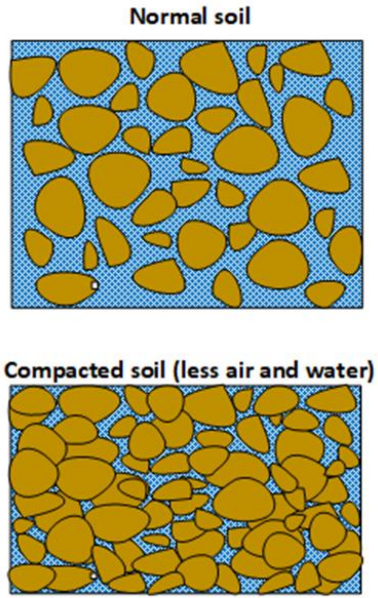
**Main factors affecting soil water storage capacity:** Soil texture, Structure, Organic Matter Content, Soil Compaction



Soil Structure



Soil Organic Matter



Soil Compaction

# Ways of quantifying moisture

- Volumetric :
  - Inches per Inch, inch per foot, percent
- Depth :
  - Inches = Volumetric x Soil Depth
- By Mass :
  - grams per gram
- By Force (aka Soil Water Potential):
  - centibars

## Soil Water Measurement Methods

**Soil water can be measured and expressed by gravimetric and volumetric water content, depth of water, and soil water potential**

**Gravimetric Water Content:** Usually directly measured in soil laboratories

**$\theta_m$ = Mass of Water / Mass of Dry Soil**

**Example:**

Moist soil weight = 120 grams

Oven-dried soil weight = 100 grams

Water weight = 20 grams

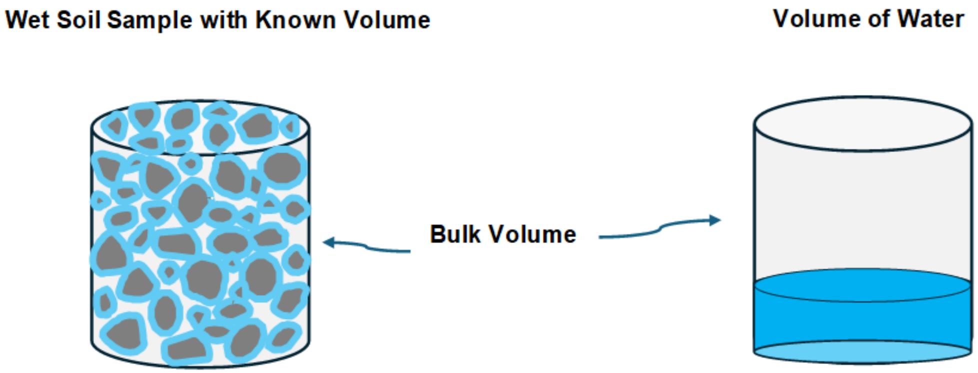
Gravimetric water content = (20/100) = 0.20 gram of water / gram of soil, or

Gravimetric water content = 0.20 x 100 = 20%

# Soil Water Measurement Methods

**Volumetric Water Content:** Difficult to measure directly in fields

**$\theta_v$ = Volume of Water / Bulk Volume**



## Soil Water Measurement Methods

**Volumetric Water Content:** Difficult to measure directly in fields

**$\theta_v = \theta_m$ x Bulk Density**

**Bulk Density ($g/cm^3$) = Dry Soil Weight (g)/ Soil Volume ($cm^3$)**

**Example:**

Gravimetric water content = 0.20 g/g

Bulk Density = 1.25 $g/cm^3$

Volumetric Water Content (VWC) = 0.20 x 1.25 = 0.25, or

Volumetric Water Content (VWC) = 0.25 x 100 = 25%

# Soil Water Measurement Methods

**Equivalent Depth of Water:** Volumetric water content multiplied by depth

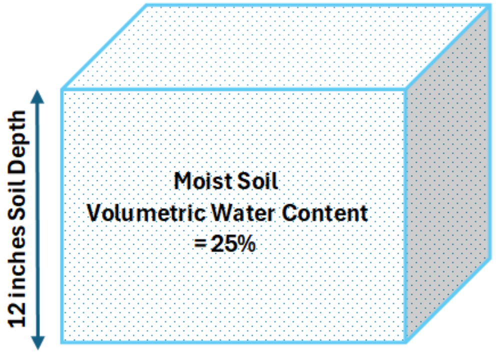
$\mathbf{d = \theta_v \times L}$

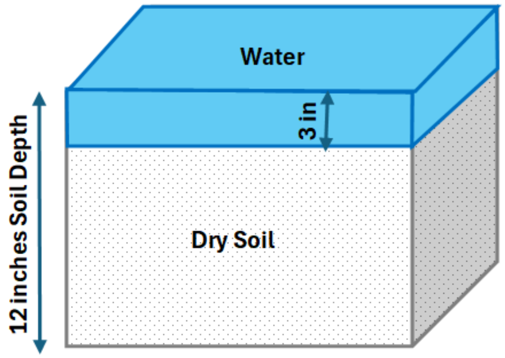
**Example:**

$\theta_v$ = Volumetric Water Content (VWC) = 25% = 0.25 fraction (inch per inch)

**L** = Soil Layer = one foot = 12 inches

**d** = Water Depth = 0.25 x 12 inches = 3.0 inches of water in one foot of soil



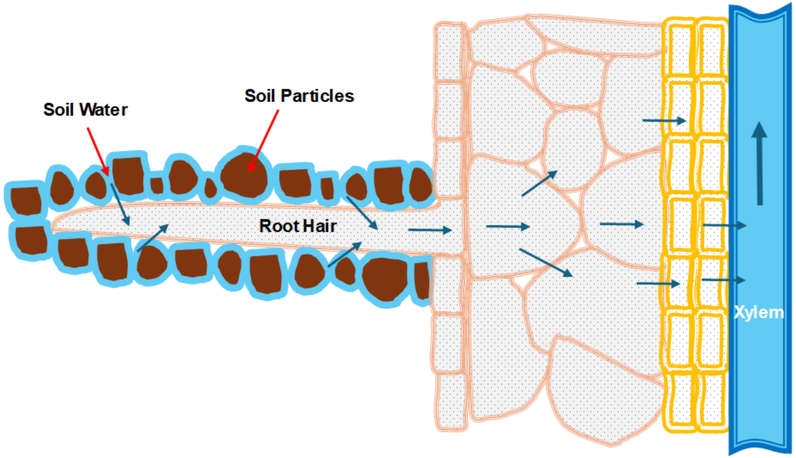



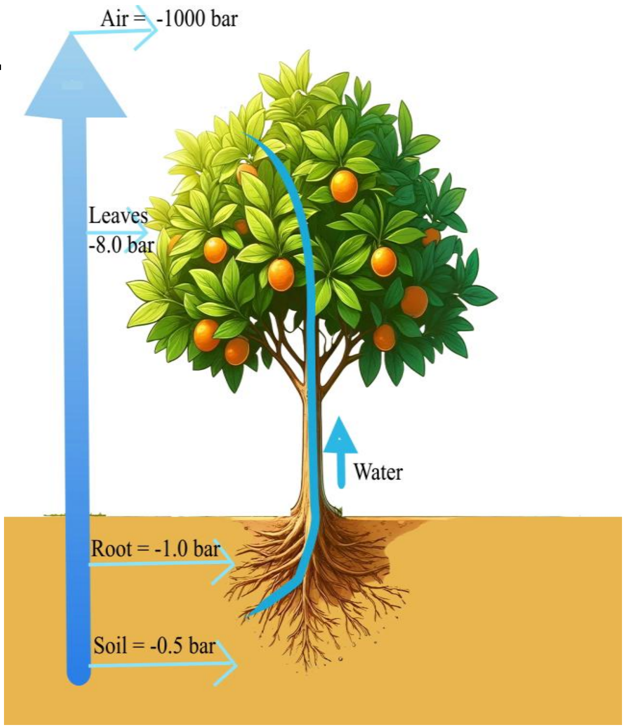
# Soil Water Measurement Methods

**Soil Water Potential:** A measure of the energy state of water in the soil

Water always moves from an area of higher potential to a lower potential

From soil to roots; to the canopy; to the atmosphere.



# Soil Water Measurement Methods

**Soil Water Potential:** A measure of the energy state of water in the soil

Soil water can be classified into three types based on energy state:

Gravitational: zero to -1/3 bar

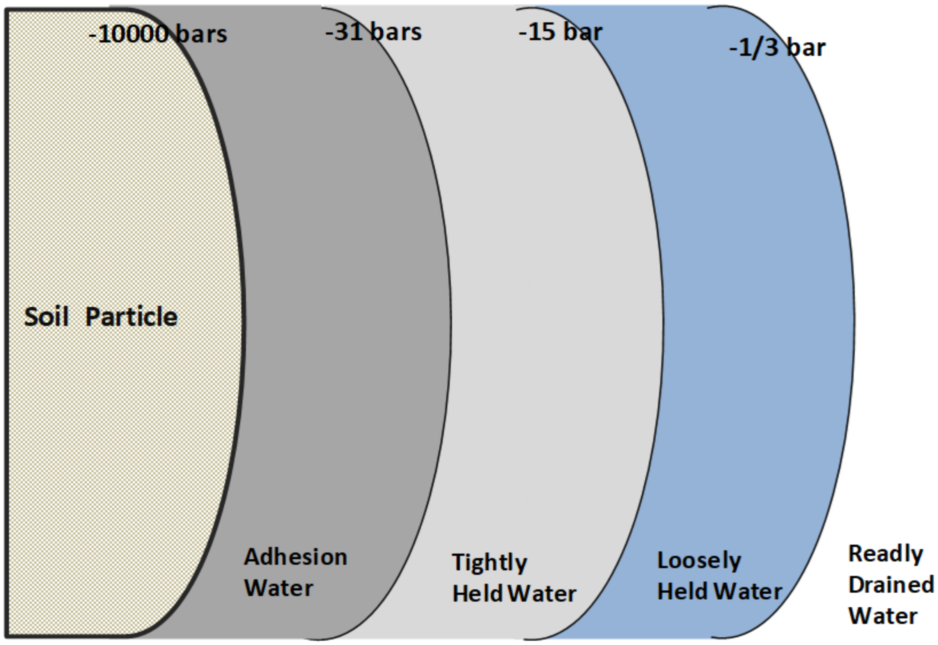
Capillary: -1/3 bar to -31 bar

Hygroscopic: Less than -31 bar

Plant Available Water: -1/3 to -15 bar

-1/3 bar = Field Capacity

-15 bar = Permanent Wilting Point



# Soil Water Measurements & Sensors

**Objective:** Measure and manage soil water to schedule irrigation.

**Direct methods:** time consuming, destructive- often not method of choice.

**Indirect methods:** Provide estimates of soil water by measuring soil properties.

Soil Water Content:

1. Neutron Probe
2. Dielectric Sensors (Capacitance & Time Domain Reflectometry (TDR)

Soil Water Potential:

1. Tensiometer
2. Resistance Block (e.g., Gypsum Block)
3. Granular Matrix

Many more methods and sensors are available to be included here.

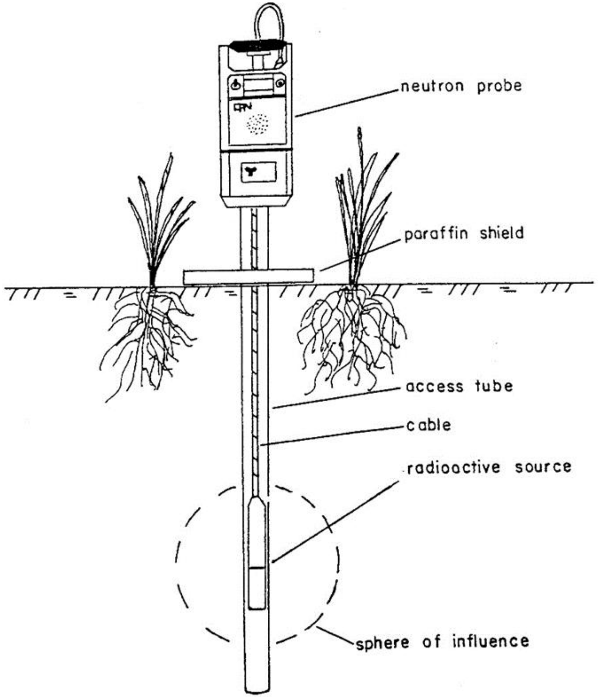
# Neutron Probe

## Strengths

- Accurate Volumetric Moisture
- Large soil sample area
- Not sensitive to temperature, salinity, or pH
- Easy to sample at different depths

## Weaknesses

- Radioactive material
- Must be licensed to own and operate
- Can’t leave in the field
- Expensive



# Capacitance & TDR Sensors

Measure the dielectric constant of soil to estimate the soil water content

Dielectric constant is primarily affected by the water content:

The constant is about 4 for dry soil, 1 for air, and 80 for water

Most common dielectric sensors are capacitance and TDR

Capacitance sensors measure changes in electrical capacitance caused by soil water

TDR sensors measure the travel time of electromagnetic waves transmitted into the soil

# Capacitance & TDR Sensors





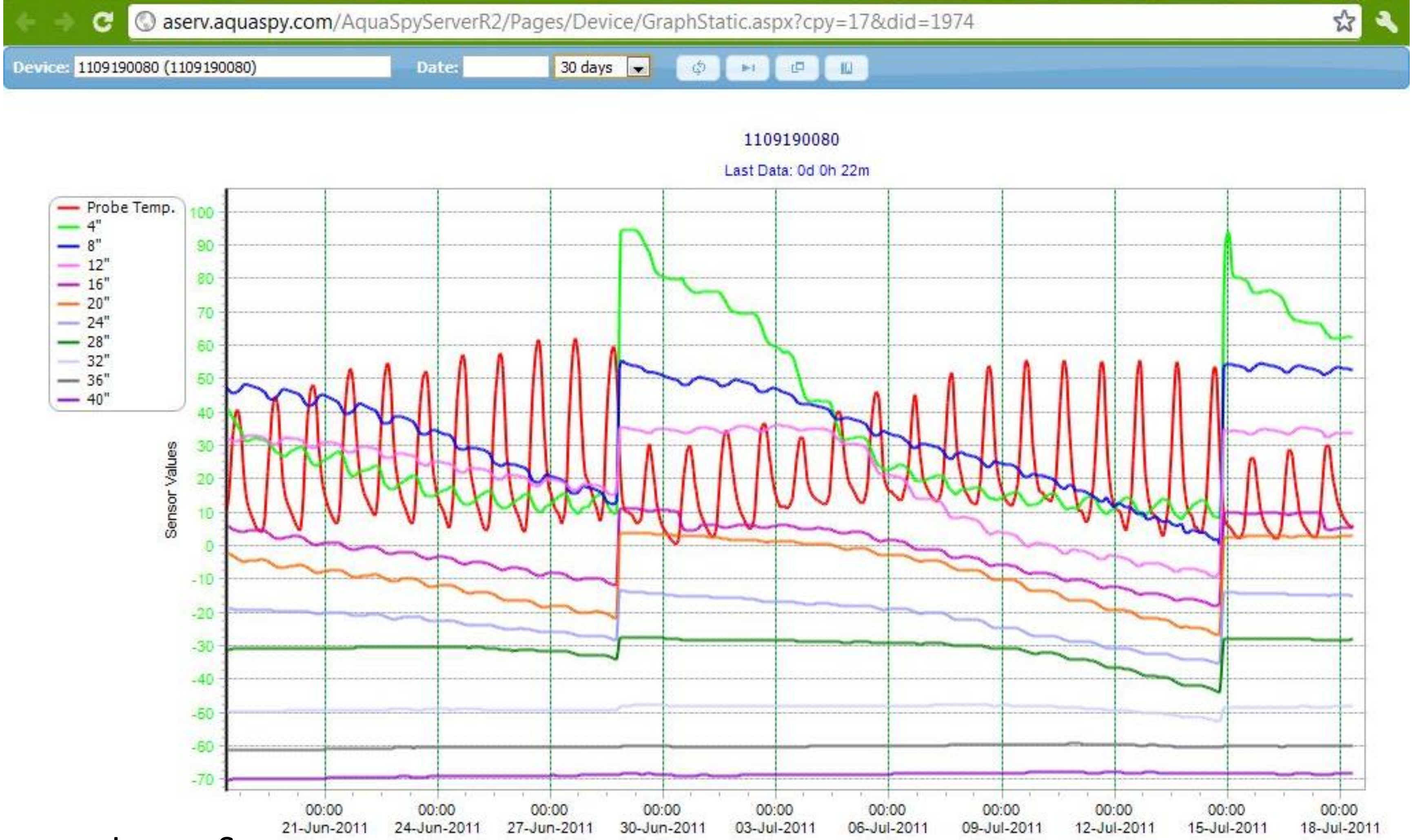




Image Source: www.aquaspy.com

# Capacitance & TDR Sensors

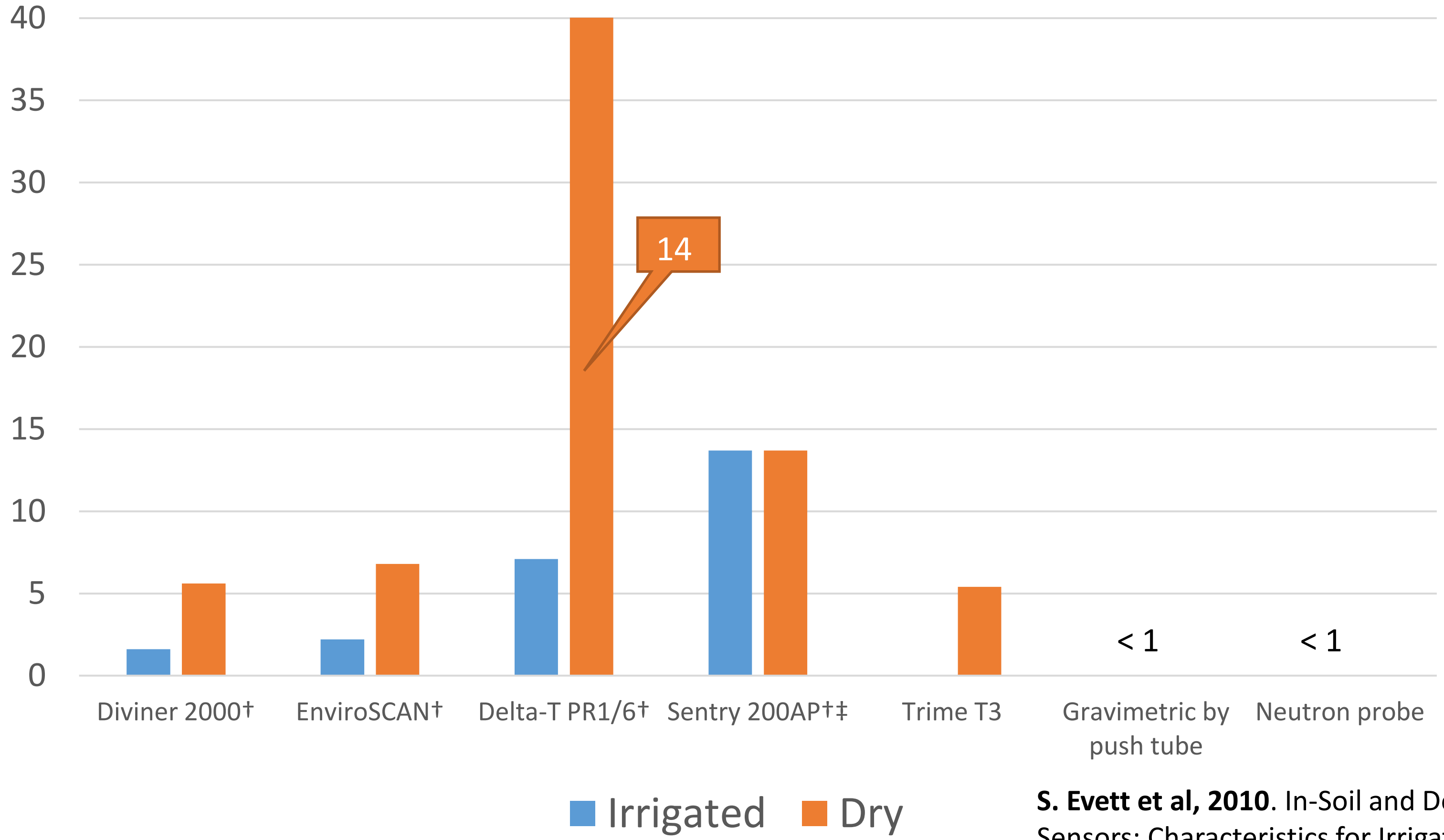
**Strengths:**

- Continuous measurements
- Repeatability of measurements
- Sensitivity to small changes in soil water content
- Usable trends

**Weaknesses:**

- Sensitive to air gap, so need proper installation
- Imperfect accuracy
- Small area of measurement
- Affected by soil texture and salinity

# Calculation of number of access tubes needed to find the mean water content in a field to 0.02 (m3 m-3)




**S. Evett et al, 2010**. In-Soil and Down-Hole Soil Water Sensors: Characteristics for Irrigation Management.

# Water Potential Sensors- Tensiometer

**Strengths**

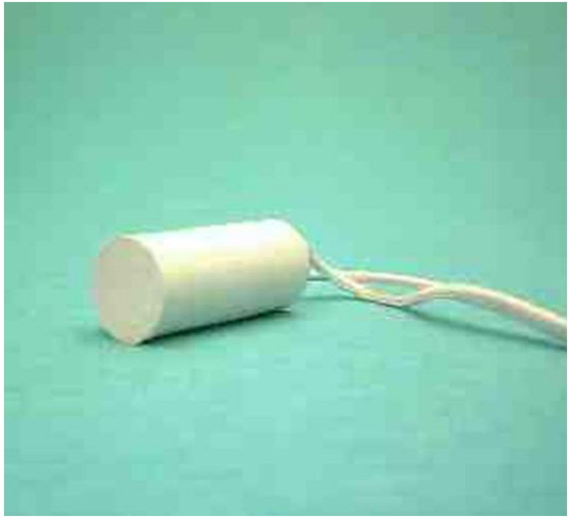
- Soil water tension (same as plant sees)
- Less expensive
- Widely used, studied and accepted
- Not affected by salinity

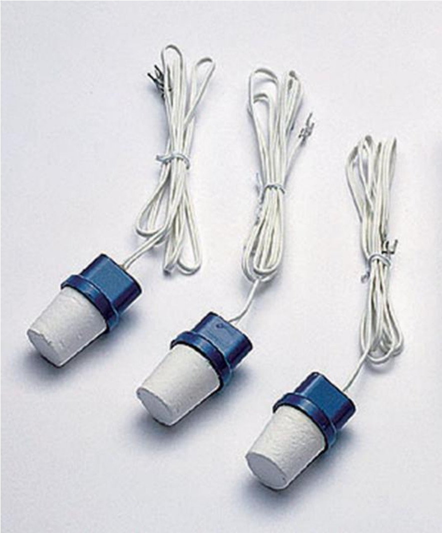
**Weaknesses**

- Small sample area
- Maintenance

# Water Potential Sensors- Resistance Blocks

**AKA Gypsum Blocks**





## Strengths

- Give soil water potential
- Inexpensive
- Usable trends
- Easy to log data

## Weaknesses

- Affected by salinity
- Imperfect accuracy
- Samples small area
- Gypsum dissolves eventually
- Calibration changes over time
- Sensitive to soil chemistry

# Water Potential Sensors- Granular Matrix

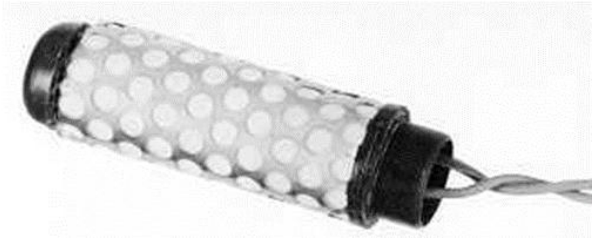
Similar principle to Gypsum Block


## Strengths

- Give soil water potential
- Inexpensive
- Usable trends
- Easy to log data

## Weaknesses

- Affected by salinity
- Imperfect accuracy
- Samples small area



# Irrigation Scheduling

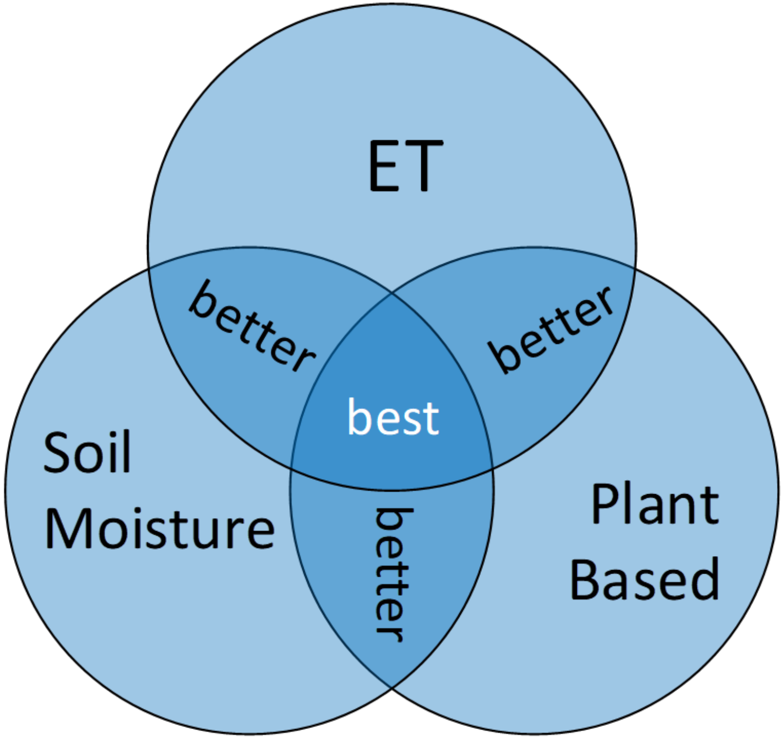
Methods of Irrigation Scheduling:

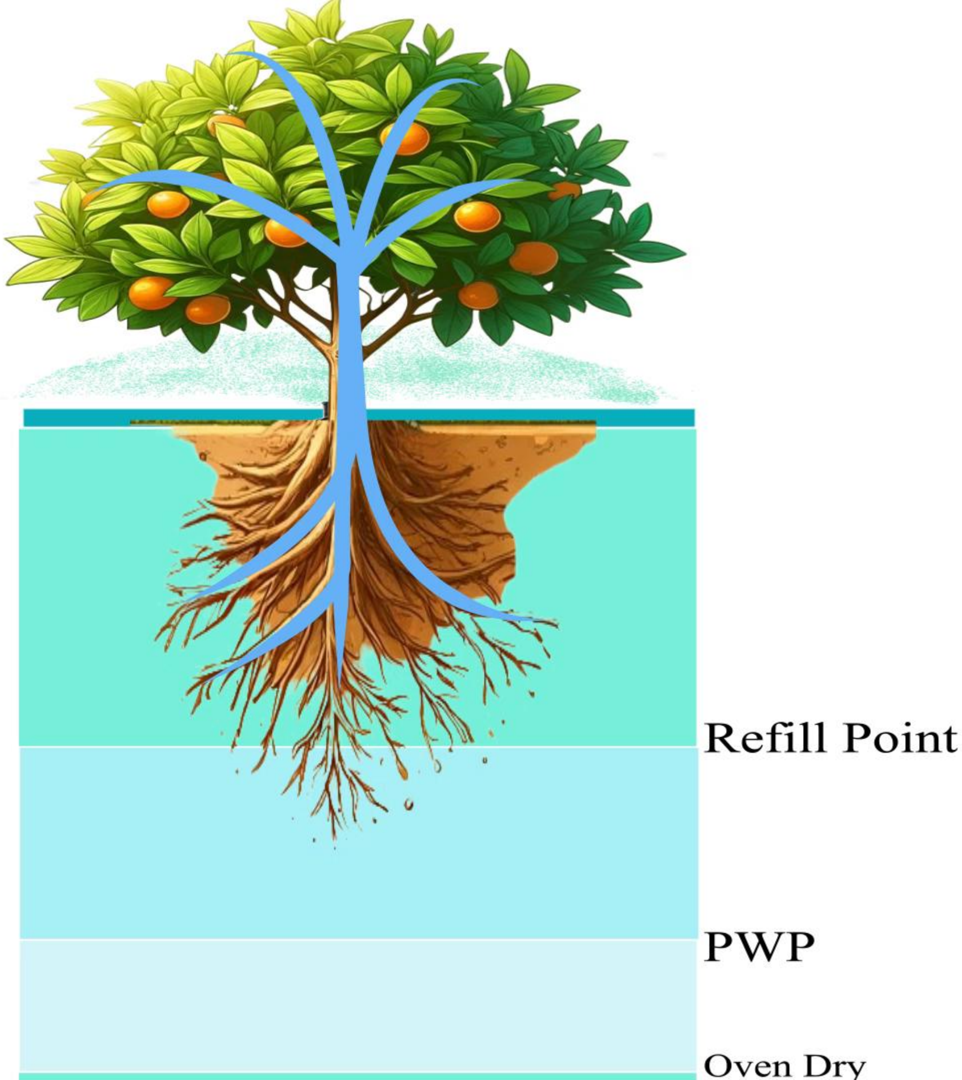
- Plant-based
- Soil-based
- Weather-based (Evapotranspiration)

To minimize under-irrigation or over-irrigation:

A combination of methods is best.

Irrigation scheduling objectives:
how much and when to apply water




Refill Point
PWP
Oven Dry

# Soil & Management Parameters for Irrigation Scheduling

**Soil Parameters:**

Field Capacity (FC)

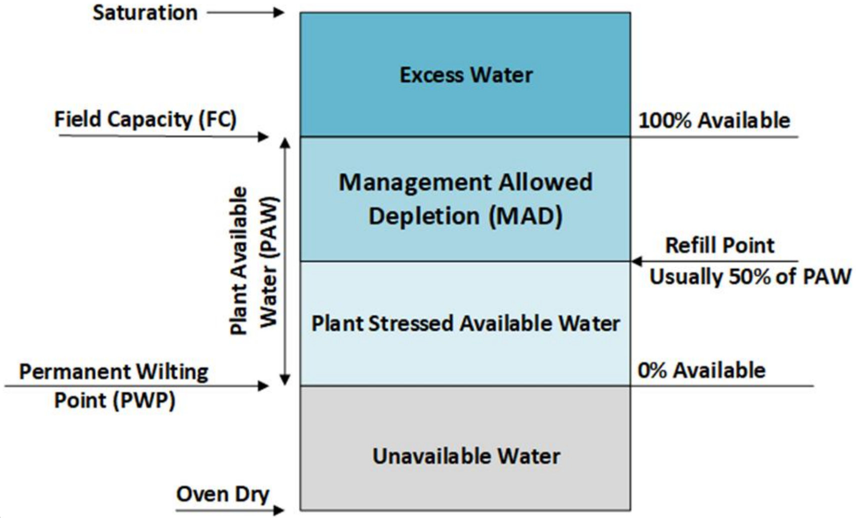
Permanent Wilting Point (PWP)

Plant Available Water (PAW)

**Management Parameters:**

Management Allowed Depletion (MAD)

Managed Rooting Depth



# Soil & Management Parameters for Irrigation Scheduling

## Plant Available Water for different soil texture

| Soil Texture | Plant-Available Water Holding Capacity (inches of water per foot of soil) |
|---|---|
| Very coarse sands | 0.4 - 0.75 |
| Coarse sands, fine sands, loamy sands | 0.75 - 1.25 |
| Sandy loams, fine sandy loams | 1.25 - 1.75 |
| Very fine sandy loams, loams, silt loams | 1.50 - 2.30 |
| Clay loams, silty clay loams, sandy clay loams | 1.75 - 2.50 |
| Sandy clays, silty clays, clays | 1.60 - 2.50 |
| Source: Schwankl, L.J. and T. Prichard. 2009. University of California Drought Management | |

Find your soil with SoilWeb https://casoilresource.lawr.ucdavis.edu/gmap/

# Soil & Management Parameters for Irrigation Scheduling

**Management Allowed Depletion (MAD)**

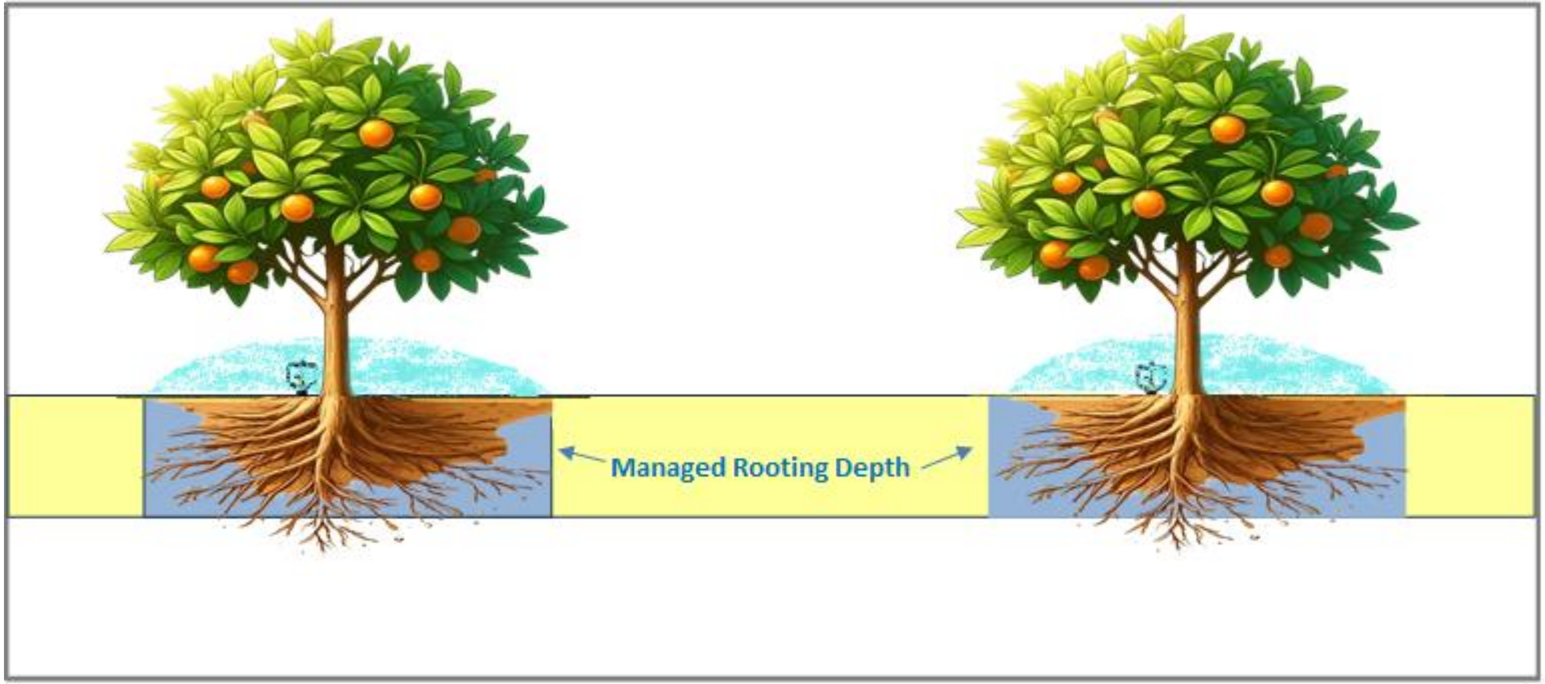
Average MAD = 50% for mature citrus (general guideline)

Lower MAD level may be desired for:

- Lighter soil texture to ensure soil does not dry out too quickly leading to stress.
- Hotter, drier climate conditions to reduce stress during peak hours.
- Younger citrus trees could benefit from a more consistent soil moisture.

# Soil & Management Parameters for Irrigation Scheduling

**Managed Rooting Depth**



# Irrigation Scheduling

## How much water to apply:

Readily Available Water (RAW):

Total Available Water (TAW) = (FC - PWP) x Root Depth

Readily Available Water = MAD x TAW

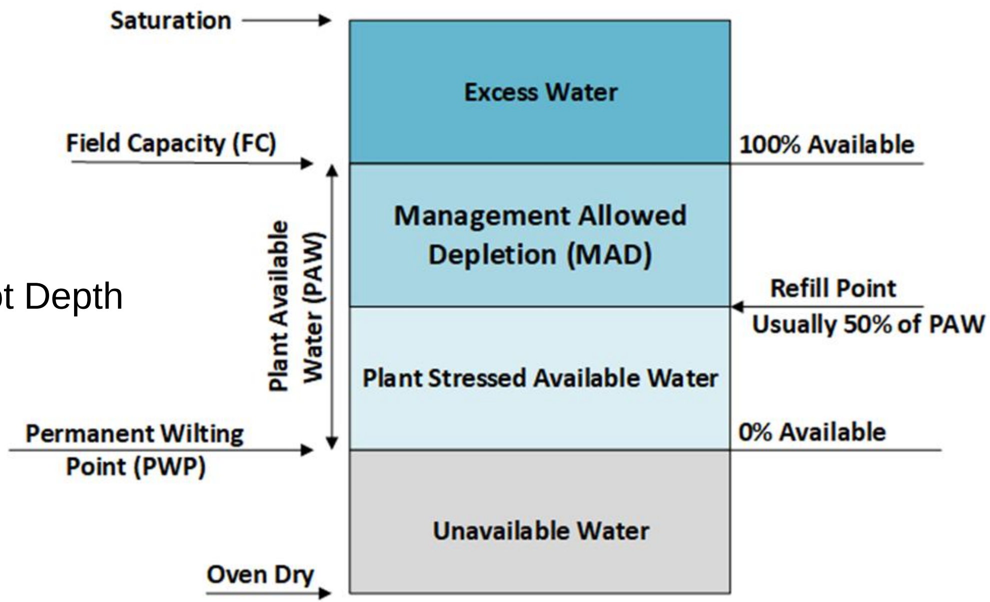
**Example:**

TAW = 1.5 inches/foot, a sandy loam soil

MAD = 50%, management choice

Managed Rooting Depth = 2 feet, management choice

Readily Available Water (RAW) = 1.5 in/ft x 2 ft x 50/100 = 1.5 inches



# Irrigation Scheduling

## Measuring/Calculating/Estimating components of water balance

SWD = calculated using other components, or measured  for verification/adjustment:

Example:
Volumetric water content at field capacity = 23% = 0.23 fraction, inch/inch

Current/measured volumetric water content = 17% = 0.17 fraction, inch/inch

Rooting depth  = 2 feet = 24 inches

SWD measured =   (0.23 - 0.17 ) x 24 = 1.44 inches

ETc = estimated using reference evapotranspiration and crop coefficients

DP = calculated as the residual of water balance

I = measured with flow meter, or estimated based on irrigation runtime

P = measured at the orchard or estimated from the local weather station

RO = estimated, if any

# Irrigation Scheduling

## When to to apply:

Requires direct soil water measurement and/or checkbook accounting/water balance approach to keep track of Soil Water Deficit (SWD).

Components of root zone water balance:

$SWD_i = SWD_{i-1} + ETc_i + DP_i - I_i - (P - RO)_i$

$SWD_i$ = Soil Water Deficit on the current day

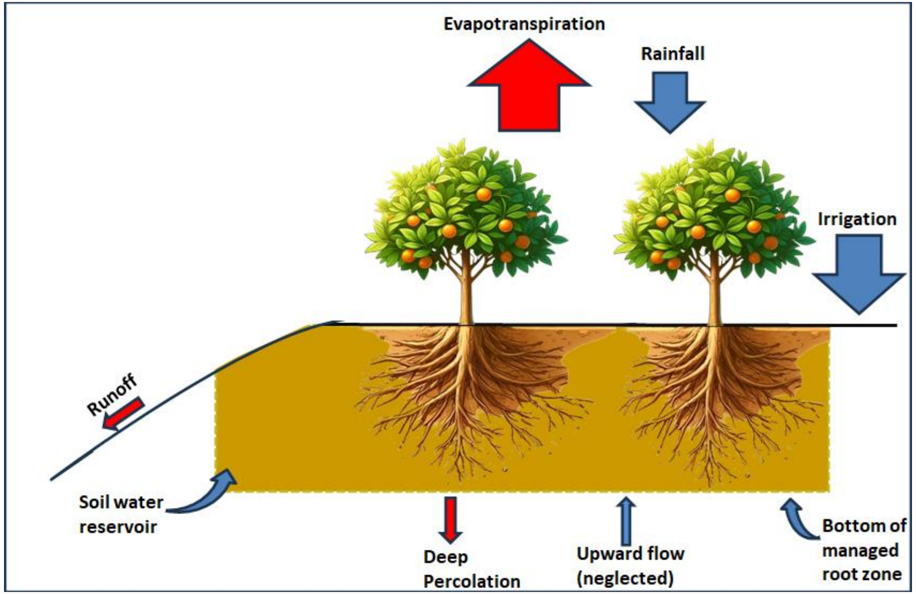
$SWD_{i-1}$ = Soil Water Deficit on the previous day

$ETc_i$ = Crop evapotranspiration on the current day

$DP_i$ = Deep percolation on the current day

$I_i$ = Net irrigation application on the current day

$(P - RO)_i$ = Precipitation less runoff on the current day



# Irrigation Scheduling

## Estimating crop evapotranspiration (ETc)

ETc = Reference Evapotranspiration (ETo) x Crop Coefficient (Kc)

ETo = Available from CIMIS weather stations

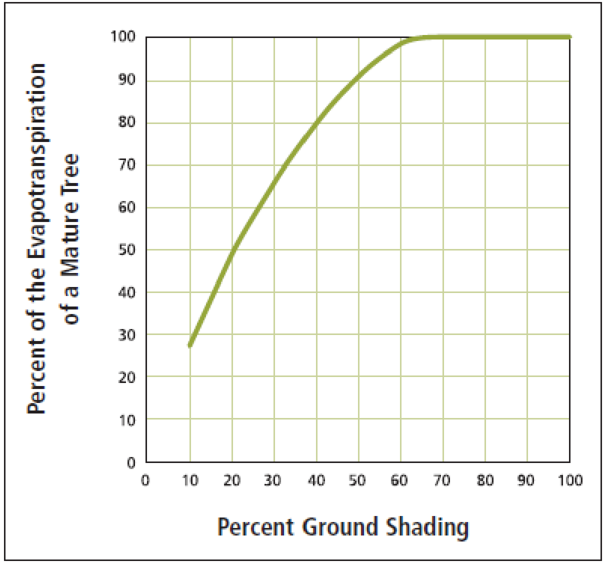
Kc = Available from UC research data

Kc for full grown citrus orchard ~ 0.65 - 0.70

Maximum ETc occurs at 60% to 70% ground shading

Kc for young orchard:

A fraction of full depending on the percent ground cover




Source: UC Publication 8212

# Irrigation Scheduling

## Citrus historical crop evapotranspiration estimates (inches during period)

Apply additional water for account for

Distribution Uniformity, and

Leaching requirements as needed

| Date | Orange Cove | Lindcove | Kern County |
|---|---|---|---|
| Mar 16–31 | 1.04 | 0.83 | 1.07 |
| Apr 1–15 | 1.17 | 1.14 | 1.37 |
| Apr 16–30 | 1.46 | 1.56 | 1.66 |
| May 1–15 | 1.66 | 1.77 | 1.98 |
| May 16–31 | 2.29 | 2.18 | 2.28 |
| June 1–15 | 2.34 | 2.39 | 2.50 |
| June 16–30 | 2.44 | 2.50 | 2.60 |
| July 1–15 | 2.63 | 2.60 | 2.67 |
| July 16–31 | 2.91 | 2.81 | 2.80 |
| Aug 1–15 | 2.83 | 2.81 | 2.80 |
| Aug 16–31 | 2.71 | 2.70 | 2.70 |
| Sept 1–15 | 2.44 | 2.39 | 2.37 |
| Sept 16–30 | 2.05 | 1.98 | 2.05 |
| Oct 1–15 | 1.66 | 1.66 | 1.69 |
| Oct 16–31 | 1.46 | 1.35 | 1.46 |
| Nov 1–15 | 1.07 | 0.94 | 1.14 |
| Nov 16–30 | 0.68 | 0.62 | 0.81 |

Source: UC Publication 8212

# Nutrient Management Plan

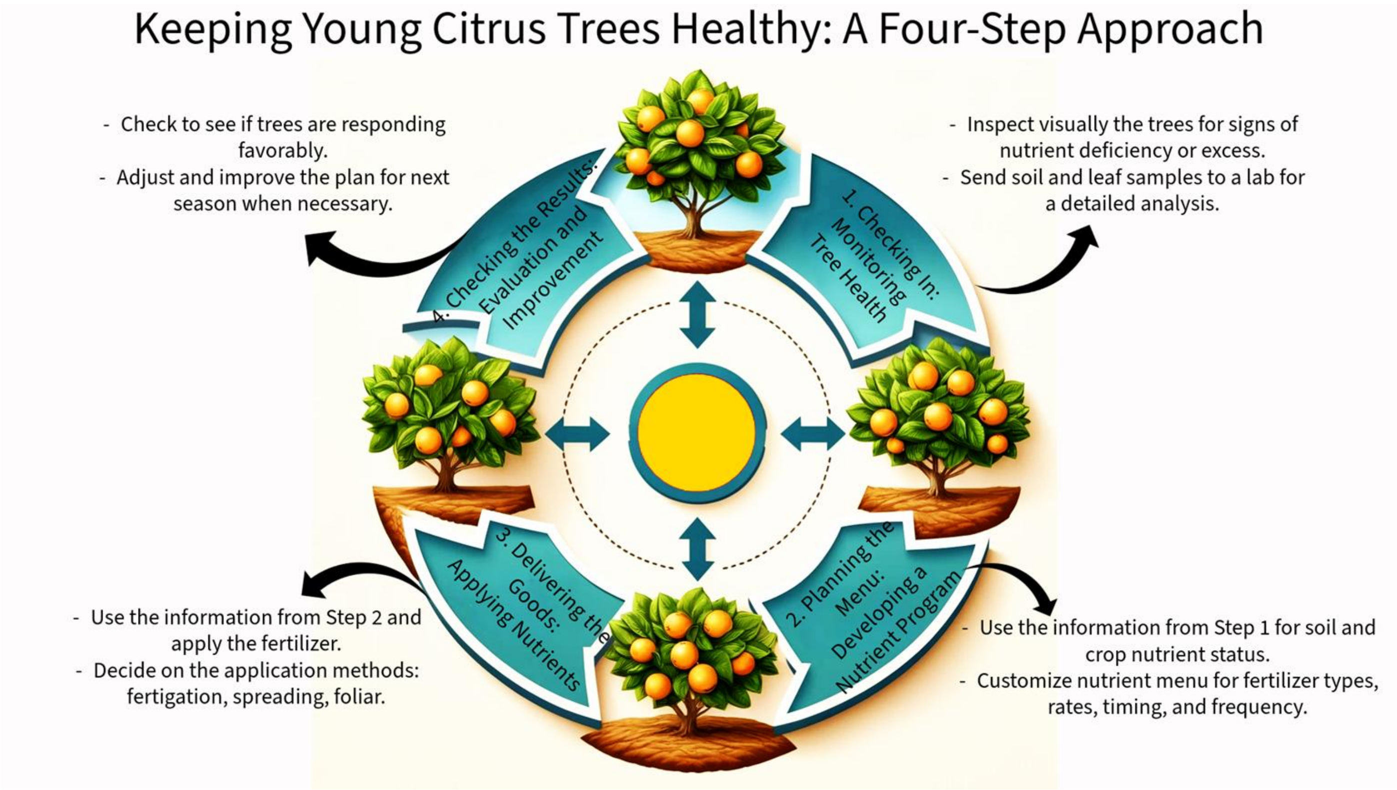
1. Test: soil and plant tissues

2. Schedule: types, rate, timing

3. Execute: fertilizer application

4. Evaluate: tree response

# Nutrient Management Plan



# Nutrient Management- Fertilizer Application

Young citrus trees need a balanced pool of macro and micronutrients

Nutrient accumulation can occur in soil with repeated applications over the years.

# Nutrient Management- Nitrogen Application

The nitrogen application rates vary depending on the soil's nitrogen supplying capacity.

Leaf analyses are recommended to assess if the nitrogen application rates are sufficient.

Recommended N application rates to young citrus trees for California, Florida and Arizona

| Tree age (years) | Foothills, CA | Florida | Arizona |
|---|---|---|---|
| | Application rate (lbs N/tree/year) | | |
| 1 | 0.13 - 0.25 | 0.15 - 0.30 | 0 |
| 2 | 0.25 - 0.50 | 0.30 - 0.60 | 0.15 |
| 3 | 0.50 - 0.75 | 0.45 - 0.90 | 0.23 |

Source: https://www.cdfa.ca.gov/is/ffldrs/frep/FertilizationGuidelines/Citrus.html

# Nutrient Management- Phosphorus Application

The UC does not offer specific guidelines for phosphorus fertilization in citrus orchards.

Initial soil test analyses should guide phosphorus applications to young trees.

The recommended phosphorus application rates for young trees in Florida's citrus production.

| Tree age (years) | Soil test P | | | | |
|---|---|---|---|---|---|
| | very low | low | medium | high | very high |
| | Application rate (lbs $P_2O_5$/tree/year) | | | | |
| 1 | 0.15 - 0.30 | 0.11 - 0.23 | 0.08 - 0.15 | 0 | 0 |
| 2 | 0.30 - 0.60 | 0.23 - 0.45 | 0.15 - 0.30 | 0 | 0 |
| 3 | 0.45 - 0.90 | 0.34 - 0.68 | 0.23 - 0.45 | 0 | 0 |

Source: https://www.cdfa.ca.gov/is/ffldrs/frep/FertilizationGuidelines/Citrus.html

# Nutrient Management- Potassium Application

The UC does not offer specific guidelines for potassium fertilization in citrus orchards.

Initial soil test analyses should guide phosphorus applications to young trees.

The recommended phosphorus application rates for young trees in Florida's citrus production.

| Tree age (years) | very low K availability $K_2O$ lbs/tree/year |
|---|---|
| 1 | 0.15 - 0.30 |
| 2 | 0.30 - 0.60 |
| 3 | 0.45 - 0.90 |

Source: https://www.cdfa.ca.gov/is/ffldrs/frep/FertilizationGuidelines/Citrus.html

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