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 ideal 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 = ET0 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?

**Daily**

- \( \text{ETgrape} = \text{ETo} \times Kc \)
- \( \text{ETgrape} = 0.28 \text{ in/day} \times 0.8 \)
- \( \text{ETgrape} = 0.22 \text{ in/day} \)
Water Requirements

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

**Weekly**

- $ET_{grape} = ETo \times 7 \text{ days} \times Kc$
- $ET_{grape} = 0.28 \text{ in/day} \times 7 \text{ days/week} \times 0.8$
- $ET_{grape} = 1.98 \text{ in/week} \times 0.8$
- $ET_{grape} = 1.57 \text{ in/week}$
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 ft²
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)
FIGURE 17. The larger the soil particle size, the lower the waterholding 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
## Soils

<table>
<thead>
<tr>
<th>Soil Texture</th>
<th>At Field Capacity</th>
<th>At Permanent Wilting Point</th>
<th>Soil Water Holding Capacity</th>
<th>Plant Available Water (@ MAD = 50%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>1.0-1.4</td>
<td>0.2-0.4</td>
<td>0.8-1.0</td>
<td>0.45</td>
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<tr>
<td>Sandy Loam</td>
<td>1.9-2.3</td>
<td>0.6-0.8</td>
<td>1.3-1.5</td>
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<td>Loam</td>
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<td>0.9-1.1</td>
<td>1.6-1.8</td>
<td>0.85</td>
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<tr>
<td>Silt Loam</td>
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<td>1.0-1.2</td>
<td>1.7-1.9</td>
<td>0.90</td>
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<tr>
<td>Clay Loam</td>
<td>3.0-3.4</td>
<td>1.1-1.3</td>
<td>1.9-2.1</td>
<td>1.00</td>
</tr>
<tr>
<td>Clay</td>
<td>3.5-3.9</td>
<td>1.5-1.7</td>
<td>2.0-2.2</td>
<td>1.05</td>
</tr>
</tbody>
</table>
Plant Available Water

\[ \text{PAW} = D \times \text{SWHC} \times \text{MAD} \]

- **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 Reflectometry, 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

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Sensor Type</th>
<th>Sensor Reading</th>
<th>Costs (Comparably)</th>
<th>Sensitive to Salinity</th>
<th>Affected by Temperature</th>
<th>Sensor Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Granular Matrix</td>
<td>Matric Potential</td>
<td>cBars</td>
<td>Low</td>
<td>Generally No</td>
<td>No</td>
<td>Slow</td>
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<tr>
<td>Capacitance</td>
<td>Volumetric Water Content</td>
<td>%</td>
<td>Moderate</td>
<td>Yes</td>
<td>No</td>
<td>Moderate-High</td>
</tr>
<tr>
<td>TDR/TDT</td>
<td>Volumetric Water Content</td>
<td>%</td>
<td>Moderate-High</td>
<td>Generally No</td>
<td>No</td>
<td>Moderate-High</td>
</tr>
</tbody>
</table>
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.
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

<table>
<thead>
<tr>
<th>Date</th>
<th>Sensor1</th>
<th>Sensor2</th>
<th>Sensor3</th>
<th>Irrig</th>
<th>Rain</th>
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<td>4”</td>
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<td>43</td>
<td>50</td>
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</table>
Demonstration Data

Gold Farms - Corn 2011

Soil moisture (bars)

Rainfall and irrigation (inches)

Legend:
- Rain
- Irrigation
- 1 Ft
- 2 Ft
- 3 Ft

Dates:
- 3/25/2011
- 4/2/2011
- 4/10/2011
- 4/18/2011
- 4/26/2011
- 5/4/2011
- 5/12/2011
- 5/20/2011
- 5/28/2011
- 6/5/2011
- 6/13/2011
Example Vineyard Sensor Data
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