Irrigation Water Management and Scheduling

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Biological Systems Engineering Dept.

BSE Boot Camp Training
November 3rd, 2017
Irrigation Water Management

So you want to irrigate ……

some questions you might ask:

- How often should I irrigate?

- How much water should I apply?

- How do I measure my soil moisture?

These are a few of the questions that will be discussed today.
Water in the Soil Profile

Source: Sprinkler Irrigation Systems, Midwest Plan Service, MWPS – 30, 1999
Definitions

- **Field capacity** (Fc) – soil moisture content after gravity drainage of water.

- **Permanent Wilting Point** (PWP) – moisture exiting plant is greater than water intake. Plant can no longer extract soil water.

- **Total Available Water** (TAW) – amount of water held in soil between field capacity and wilting point (Fc - PWP).

- **Management Allowed Depletion** (MAD) – portion of water easily extracted by plant without limiting growth.

- **Readily Available Water** (RAW) = TAW x MAD
Soil Moisture Primer

Gravitational Water

Total Available Water

Unavailable water

Saturation
Field Capacity

Management Allowed Depletion
(MAD ~ 0.5 TAW)

Plant water stress begins

Plant water stress increases

Permanent wilting point
(about 100 centibars)
Soil Water Pressure Plate Extraction Device

- Drain Line
- Soil Samples
**Soil- Water Release Curves**

mod. from Midwest Plan Service, MPWS 30

Soil Moisture Tension (Centibars or cb)
Which line above illustrates field capacity for this soil??
# Average Soil Water Properties
- By Textural Class -

<table>
<thead>
<tr>
<th>Soil Texture</th>
<th>Total Pore Space (% by volume)</th>
<th>Field Capacity (% by volume)</th>
<th>Permanent Wilting Point (% by volume)</th>
<th>Total Available Water (% by volume)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandy</td>
<td>38</td>
<td>15</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Sandy Loam</td>
<td>43</td>
<td>21</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>Loam</td>
<td>47</td>
<td>31</td>
<td>14</td>
<td>17</td>
</tr>
<tr>
<td>Clay loam</td>
<td>49</td>
<td>36</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>Silty clay</td>
<td>51</td>
<td>40</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Clay</td>
<td>53</td>
<td>44</td>
<td>21</td>
<td>23</td>
</tr>
</tbody>
</table>

Source: James, L.G. Principals of Farm Irrigation System Design
The effective root depth is that portion of the root zone where the crop extracts the majority of its water.

Source: NRCS National Engineering Handbook Section 15, Irrigation
Irrigation Management Depth

- Determined by Crop and Soil Properties -
Sensor Location

Shallow Location

- ~ 25 - 30% of root zone depth
- Used to know when to start irrigation

Deep Location

- ~ 65 - 80% of root zone depth
- Used to know amount of irrigation
- Penetration – is the irrigation water reaching lower roots?
- Watch for leaching events
### Irrigation Water Management Depth

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Broccoli &amp; cauliflower</td>
<td>24</td>
<td>12 - 18</td>
<td>12</td>
<td>20 - 24</td>
</tr>
<tr>
<td>Strawberry</td>
<td>12 - 24</td>
<td>12 - 18</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>Potatoes</td>
<td>24 - 36</td>
<td>12 - 18</td>
<td>8 -10</td>
<td>18</td>
</tr>
<tr>
<td>Tomato &amp; cantaloupe</td>
<td>36</td>
<td>12 - 24</td>
<td>18</td>
<td>36</td>
</tr>
<tr>
<td>Bush bean</td>
<td>24 - 36</td>
<td>18 - 24</td>
<td>10</td>
<td>18</td>
</tr>
<tr>
<td>Soybeans</td>
<td>48 - 60</td>
<td>30 - 36</td>
<td>12</td>
<td>24</td>
</tr>
<tr>
<td>Small grains</td>
<td>48</td>
<td>30 - 36</td>
<td>12</td>
<td>24</td>
</tr>
<tr>
<td>Sweet corn</td>
<td>24 - 36</td>
<td>24 - 36</td>
<td>12</td>
<td>24 - 30</td>
</tr>
<tr>
<td>Field Corn</td>
<td>48</td>
<td>30 - 36</td>
<td>12 -18</td>
<td>30 - 36</td>
</tr>
<tr>
<td>Pumpkins / Winter Squash</td>
<td>36 - 48</td>
<td>30 - 36</td>
<td>18</td>
<td>36</td>
</tr>
<tr>
<td>Established alfalfa</td>
<td>60</td>
<td>36 - 48</td>
<td>18</td>
<td>36</td>
</tr>
</tbody>
</table>

1. USDA – NRCS Part 652 - Irrigation Guide, 1997, Chapter 3, Table 3-4
2. Depth at which the soil water content should be managed for optimum crop production.
# Soil Moisture Management

<table>
<thead>
<tr>
<th>Crop</th>
<th>Managed Root Zone</th>
<th>Mgmt. Allowed Depletion</th>
<th>Critical Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potatoes</td>
<td>12 - 16”</td>
<td>35% - 50% 50%@ vine kill</td>
<td>Flowering and tuber formation to harvest</td>
</tr>
<tr>
<td>Peas</td>
<td>24”</td>
<td>50%</td>
<td>Start of flowering and when pods are swelling</td>
</tr>
<tr>
<td>Green Beans</td>
<td>24”</td>
<td>40%</td>
<td>Blossom through Harvest</td>
</tr>
<tr>
<td>Sweet Corn</td>
<td>24”</td>
<td>50% @ establish 40% until harvest</td>
<td>Tasseling thru silk stage until kernels are firm</td>
</tr>
<tr>
<td>Grain Corn</td>
<td>36 - 48”</td>
<td>50%</td>
<td>Tasseling thru silk stage until kernels are firm</td>
</tr>
</tbody>
</table>
How much water is the crop using?
- WI ET Estimates

Example: Crop ET values from the UW AGWX site

agweather.cals.wisc.edu/sun_water

- Based on Priestley - Taylor equation (Potential ET)

- Adjusted by canopy cover (%)

- Referenced by latitude and longitude

- Inputs = Solar radiation, air temperature, soil heat flux

Accuracy: +/- 15 - 20%
Precipitation Inputs
- Rain Gages -

• Accurate measurements of field conditions
• Three gages in every field is preferred
  - Records rain and irrigation
• Low evaporation rates
  - < 1% per week
How often should I Irrigate?
- Irrigation Scheduling -

Check Book Method
• Tracks daily soil water inputs (rain, irrigation), outputs (deep drainage, ET) and change in storage
• Only water when necessary
• Use enough to grow a high quality crop

Computer Program or Manual System (Paper)
• Manually track daily rainfall, irrigation and ET
• Use a irrigation scheduling software package
  WI Irrigation Scheduling Program (WISP)
How often should I Irrigate?
- Irrigation Strategy -

**Full Irrigation Strategy**
A full irrigation strategy fills the soil profile is back to field capacity

**Partial Irrigation Strategy**
A partial strategy does not fill the root zone to Fc with each irrigation, but makes unfilled soil water storage capacity available for natural rainfall
Irrigation Water Management Tools
- Web-based Scheduler WISP 2012 - Version 2.0 -

WISP: Wisconsin Irrigation Scheduling Program 2012 Version 2.0.0

WISP Home
Farm Status
Pivots, Fields, and Crops
Field Status
Field Groups
Multi-Edit Daily Data
User's Guide

REMINDER
WISP user input data will be purged on Feb. 15th each year.
To save current year data use the Create Report in CSV Form on the Field Status page prior to 2/15!

wisp.cals.wisc.edu/
The Pivot, Field and Crops Screen

Add new pivots directly into the table

Add fields directly into the table

Add data for a single crop directly into the table (no double cropping yet)

When selecting a pivot, the fields and crops for the selected field appear below.
Graph background color changes when RAW is depleted
How often should I Irrigate?
- Irrigation Scheduling -

**Irrigation scheduling can . . .**

- Reduce the chance of over irrigating
- Reduce the likelihood of N loss through leaching
- Help to provide more consistent root zone moisture throughout the growing season
- May reduce irrigation cost by taking better advantage of natural rainfall

**Irrigation scheduling can not . . .**

- Change the total plant consumptive water use
Irrigation Management in Wisconsin

The Wisconsin Irrigation Scheduling Program (WISP)

Scott Sardinha and John Panasich

Grown in Wisconsin irrigate about 475,000 acres of potatoes, vegetable, field, fruit, turf and nursery crops each year (2010-2012) to ensure profitable crop production. Irrigation improves both crop yield and quality. Yield responses are due to increased dry matter production, more plants per acre and increased numbers of vegetative parts (tubers, roots, stems, leaves) or reproductive parts (flowers, pods, fruits).

Irrigation enhances the quality of many crops by reducing moisture stress. A lack of moisture in a crop can produce misshapes fruit and tubers, poorly filled bean pods or size of corn, and low protein content in forages. Moisture stress can alter uniform crop maturity, which is important for efficient harvesting of processing vegetables.

Successful irrigation management uses a combination of rainfall and applied water to conserve energy, reduce cost and protect groundwater. Most of the areas in Wisconsin that are under sprinkler irrigation have sandy soils and groundwater that is close to the surface, so the potential for groundwater contamination by nutrients and pesticides in high. Over-irrigation and excessive or continuous rains can add more water than crops can use or soils can store. The excess water moves past the root zone (leached), carrying nutrients and pesticides into groundwater.

**Sprinkler irrigation**

Sprinkler irrigation is the most common type of irrigation in Wisconsin (98%). Drip irrigation is another type. Sprinkler irrigation waters crops through a sprinkler system of pipes and spray or impact nozzles. The objective is to apply the right amount of water at the right time.

Overhead sprinkler irrigation can do more than water crops. Properly designed and managed sprinkler systems can regulate soil moisture and temperature, apply fertilizers and pesticides, provide frost protection and apply liquid waste and separated liquid manure.

**Sprinkler irrigation of large crop acreages requires large volumes of water.** On the average summer day in central and southern Wisconsin an average crop plant will use approximately 0.25 inches in evapotranspiration, which is the combination of evaporation from soil and plant surfaces and transpiration of the amount of water that plants use to grow. On a per acre basis, 0.25 inches amounts to 0.750 gallons of water (27,154 gallons per acre-inch or 0.25 inch = 0.750 gallons). However, irrigation systems

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### LOW PRESSURE CENTER PIVOT:
Average nozzle pressure 20 psi, nozzle diameter 9/32 inch

<table>
<thead>
<tr>
<th>Air Temperature</th>
<th>% Relative Humidity</th>
<th>Wind Speed (mph)</th>
<th>% Evaporation Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>70 F</td>
<td>70%</td>
<td>7 mph</td>
<td>1.5%</td>
</tr>
<tr>
<td>70 F</td>
<td>30%</td>
<td>7 mph</td>
<td>2%</td>
</tr>
<tr>
<td>90 F</td>
<td>70%</td>
<td>7 mph</td>
<td>1.8%</td>
</tr>
<tr>
<td>70 F</td>
<td>70%</td>
<td>15 mph</td>
<td>2.2%</td>
</tr>
<tr>
<td>90 F</td>
<td>70%</td>
<td>15 mph</td>
<td>4.5%</td>
</tr>
</tbody>
</table>

### STANDARD PRESSURE CENTER PIVOT:
Average nozzle pressure 55 psi, nozzle diameter 7/32 inch

<table>
<thead>
<tr>
<th>Air Temperature</th>
<th>% Relative Humidity</th>
<th>Wind Speed (mph)</th>
<th>% Evaporation Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>70 F</td>
<td>70%</td>
<td>7 mph</td>
<td>4.7%</td>
</tr>
<tr>
<td>70 F</td>
<td>30%</td>
<td>7 mph</td>
<td>61%</td>
</tr>
<tr>
<td>90 F</td>
<td>70%</td>
<td>7 mph</td>
<td>5.5%</td>
</tr>
<tr>
<td>90 F</td>
<td>70%</td>
<td>15 mph</td>
<td>7.5%</td>
</tr>
<tr>
<td>90 F</td>
<td>30%</td>
<td>15 mph</td>
<td>16%</td>
</tr>
</tbody>
</table>

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Also available at:
Learningstore.uwex.edu/
Measuring Soil Moisture
The Hand Feel Method

- Estimate only
- Quantitative accuracy not possible
- Investment is only a soil probe or shovel
- It is best to have accurate soil moistures to perfect your judgment
Tensiometer

- Works like a mechanical root
- Readings in centibars of vacuum
- Indication of water extraction rate
- Water equilibrates with soil moisture
- Accurate up to 85 centibars (~12 psi)
- Installed for growing season
- Maintenance may be required – refill with distilled water, color agent
- Different lengths
- Cost $82 - 92/each
# Interpreting Soil Tension Readings

## Soil Tension (Vacuum) Readings

<table>
<thead>
<tr>
<th>Range</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 10 centibar *</td>
<td>Saturated soils</td>
</tr>
<tr>
<td>10 - 20 centibar</td>
<td>Field capacity</td>
</tr>
<tr>
<td>30 - 60 centibar</td>
<td>Usual range for to start irrigation</td>
</tr>
<tr>
<td>70 - 100 centibar</td>
<td>Heavy soils and crops requiring dry down between irrigations.</td>
</tr>
<tr>
<td>100 - 200 centibar</td>
<td>DRY!!</td>
</tr>
</tbody>
</table>

Centibar = 0.01 bar = 0.145 psi
Remember for soil tension, higher = dryer
Electrical Resistance Block

- Solid state
- Good soil contact important
- Cost
  - Sensor: $35 - 45
  - Meter: $300
- Temperature sensitive
- Sensitive to high saline or acid soils
- Withstands freezing, can be re-use
Watermark Calibration Curves
Time Domain Reflectivity (TDR)

- Measures dielectric constant of soil
- Comes from technology was used to find breaks in underground phone cables
- Available as hand probe and buried sensor
- Reads directly in percent moisture
- Cost: $800 - 1200 – Theta Probe
Capacitance Sensor

- **Cost:**
  - Sensor ~ $110
  - Hand held meter ~ $200, Five channel data logger ~ $400

- Measures volumetric soil moisture to ± 3% for all mineral soils.

- Low sensitivity to salinity and temperature

- The sensor can be left in over the winter
Multi-Depth Stationary Systems

- Measure at multiple depths at once
- Uploads data in real time (web, local)
- Often linked with VRI software
- Most costly system $2,500 and up.
Moisture Measurement Methods

Sensor Configuration Options

Portable Hand-held Probe (Capacitance, TDR)
- Very portable, can cover a lot of area
- A little more difficult to track subsurface moisture over time (need to dig a hole)

In-place Sensor (tensiometer, resistance blocks)
- Good to monitor moisture at several depths simultaneously
- Limited to a single location
Simple Data Logger

- Monitoring over time
  - Typically readings every 15 to 60 minutes
- Display data or download to computer
- Two sensor system: $329
Irrigation Water Management Tools
- Irrigation Water Management Publication -
Welcome to the University of Wisconsin-Extension Crop Irrigation Website.

This website has resources that can help growers better understand crop irrigation.

Growers in Wisconsin irrigate about 473,000 acres of potato, vegetable, field, fruit, turf and nursery crops each year to ensure profitable crop production. Irrigation improves both crop yield and quality. Successful irrigation management uses a combination of rainfall and applied water to conserve energy, reduce cost and protect groundwater. Most of the areas in Wisconsin that are under sprinkler irrigation have sandy soils and groundwater that is close to the surface, so the potential for groundwater contamination by nitrates and pesticides is high. Over-irrigation and excessive or untimely rains can add more water than crops can use or soil can store. The excess water moves past the root zone (leaches) carrying nitrates and pesticides into groundwater.

Find resources about crop irrigation on this website.

Photo credit: USDA NRCS.

This material is based upon work that is supported from the Sustainable Agriculture Research and Education (SARE) program, funded by the National Institute of Food and Agriculture, U.S. Department of Agriculture (NIFA-USDA). Any opinions, findings, conclusions, or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the view of SARE or the U.S. Department of Agriculture. U.S. Department of Agriculture is an equal opportunity provider and employer.
QUESTIONS ? ? ? ?