Web Tool For Scheduling Irrigation in the Northern Caribbean Region

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What is the problem?

- There is anecdotal evidence that most farmers do not use scientific methods for scheduling irrigation.
- IRRIGATION SCHEDULING: the process used by irrigation system managers (farmers) to determine the correct frequency and duration of watering. (wikipedia.org)
Why do we care?

Over application of water

- Leads to the waste of
  - water
  - energy
  - chemicals
  - money
  - may lead to the contamination of ground and surface waters.
  - leaching of fertilizers past the root zone
  - water logging
  - lower crop yields.

Under-application of water

- Lead to
  - crop water stress
  - reduced crop yields
  - loss of revenue to the grower

“I wish I would have applied more irrigation.”
How much money are we talking about?

<table>
<thead>
<tr>
<th>Cultivo*</th>
<th>Relative Irrigation Applied</th>
<th>$ Lost / Cuerda</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.4</td>
<td>0.5</td>
</tr>
<tr>
<td>Gandules</td>
<td>47</td>
<td>32</td>
</tr>
<tr>
<td>Pepinillo</td>
<td>111</td>
<td>76</td>
</tr>
<tr>
<td>Repollo</td>
<td>256</td>
<td>174</td>
</tr>
<tr>
<td>Sandia</td>
<td>293</td>
<td>199</td>
</tr>
<tr>
<td>Platanos y Guineos, Plantilla</td>
<td>318</td>
<td>216</td>
</tr>
<tr>
<td>Calabaza</td>
<td>390</td>
<td>265</td>
</tr>
<tr>
<td>Cebolla</td>
<td>543</td>
<td>369</td>
</tr>
<tr>
<td>Pimiento</td>
<td>578</td>
<td>393</td>
</tr>
<tr>
<td>Barenjena</td>
<td>757</td>
<td>514</td>
</tr>
<tr>
<td>Platanos y Guineos, Reton~o</td>
<td>1,006</td>
<td>684</td>
</tr>
<tr>
<td>Melon, Cantaloupe y Honeydew</td>
<td>1,027</td>
<td>698</td>
</tr>
<tr>
<td>Raices y Tuberculos</td>
<td>1,041</td>
<td>707</td>
</tr>
</tbody>
</table>

*Based model budget data from the Conjunto Tecnológico, UPR Experment Station*
Objective

- To introduce a simple web-based method for scheduling irrigation in Puerto Rico
  - The method calculates the number of hours a farmer has to run his or her pump.

  - Available at http://pragwater.com/selected-publications-and-presentations/
How much water should be applied?

Plant Water Requirement = Crop Evapotranspiration (under well-watered conditions)
Cumulative $ET_c$ vs. Irrigation

- **Cumulative ET**
- **Cumulative Irrigation/Rainfall**

Date:
- 3/2/08
- 3/22/08
- 4/11/08
- 5/1/08
- 5/21/08
- 6/10/08

Cumulative ET or Irrigation/Rainfall (mm)
The most commonly used method for determining the Crop Water Requirement

\[ ET_c = K_c \cdot ET_o \]

where

- \( ET_c \) = evapotranspiration under well-watered conditions = crop water requirement
- \( K_c \) = Crop Coefficient (unique for every crop)
- \( ET_o \) = Reference Evapotranspiration (function of climate)
Many weather stations ($1,700 approx.) will calculate the daily reference evapotranspiration.
What if a farmer doesn’t have a weather station?

Here’s a relatively simple web-based method for scheduling irrigation:

1. Define problem (location, farm size, crop, etc.)
2. Determine \( \text{ET}_o \)
3. Estimate Crop Water Requirement:
   \[ \text{ET}_c = K_c \text{ET}_o \]
4. Determine average \( K_c \) for the time period
5. Determine rainfall from onsite gauge or NEXRAD
6. Determine the number of hours to run the pump:
   \[ T = 17.817 \times \frac{D \times A}{[Q \times \text{eff}]} \]

Detailed Example

- Determine the irrigation requirement for the 5 day period, February 15-19, 2012, for a tomato crop in Juana Diaz, Puerto Rico.

Required Hyperlinks

<table>
<thead>
<tr>
<th>Length of Growth Stages (Table 11) and Crop Coefficients (Table 12)</th>
<th><a href="http://www.fao.org/docrep/X0490E/x0490e00.htm">http://www.fao.org/docrep/X0490E/x0490e00.htm</a></th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily Reference ET Results for Puerto Rico⁴</td>
<td><a href="http://academic.uprm.edu/hdc/GOES-PRWEB_RESULTS/reference_ET/">http://academic.uprm.edu/hdc/GOES-PRWEB_RESULTS/reference_ET/</a></td>
</tr>
<tr>
<td>Daily NEXRAD Rainfall For Puerto Rico</td>
<td><a href="http://academic.uprm.edu/hdc/GOES-PRWEB_RESULTS/rainfall/">http://academic.uprm.edu/hdc/GOES-PRWEB_RESULTS/rainfall/</a></td>
</tr>
</tbody>
</table>
Step 1. Information used in example problem.

<table>
<thead>
<tr>
<th>Location</th>
<th>Juana Diaz, Puerto Rico</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site Latitude</td>
<td>18.02 degrees N</td>
</tr>
<tr>
<td>Site Longitude</td>
<td>66.52 degrees W</td>
</tr>
<tr>
<td>Site Elevation above sea level</td>
<td>21 m</td>
</tr>
<tr>
<td>Crop</td>
<td>Tomato</td>
</tr>
<tr>
<td>Planting Date</td>
<td>1-Jan-12</td>
</tr>
<tr>
<td>Rainfall information</td>
<td>A rain gauge is not available on or near the farm</td>
</tr>
<tr>
<td>Type of irrigation</td>
<td>Drip</td>
</tr>
<tr>
<td>Irrigation system efficiency</td>
<td>85%</td>
</tr>
<tr>
<td>Field Size</td>
<td>10 acres</td>
</tr>
<tr>
<td>Pump capacity</td>
<td>300 gallons per minute</td>
</tr>
</tbody>
</table>
Step 2. Crop growth stage and crop coefficient data for example problem.

(http://www.fao.org/docrep/X0490E/x0490eoo.htm)

### Tomato Growth Stages and Crop Coefficients

<table>
<thead>
<tr>
<th>Stage</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Crop Growth Stage</td>
<td>30 days</td>
</tr>
<tr>
<td>Crop Development Growth Stage</td>
<td>40 days</td>
</tr>
<tr>
<td>Mid-Season Growth Stage</td>
<td>40 days</td>
</tr>
<tr>
<td>Late-Season Growth Stage</td>
<td>25 days</td>
</tr>
<tr>
<td>Total Length of Season</td>
<td>135 days</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stage</th>
<th>$K_{c\text{ ini}}$</th>
<th>$K_{c\text{ mid}}$</th>
<th>$K_{c\text{ end}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.6</td>
<td>1.15</td>
<td>0.8</td>
</tr>
</tbody>
</table>
Crop Coefficient

- The average $K_c$ value of 0.85 for the five day period was obtained.

Crop coefficient curve for the example problem. The heavy dashed line applies to the example problem with day of season 46-50 (i.e., Feb 15-19) corresponding to an approximate crop coefficient of 0.85 (vertical axis).
Step 3. Rainfall
(http://academic.uprm.edu/hdc/GOES-PRWEB_RESULTS/rainfall/)

- Inspection of the rainfall maps at the URL provided indicates that there was no rainfall during the five day period.

- Therefore, all of the crop water requirement will have to be satisfied with irrigation.
Step 4. Reference Evapotranspiration ($ET_o$)

(http://academic.uprm.edu/hdc/GOES-PRWEB_RESULTS/reference_ET/)

- Inspection of the $ET_o$ maps at the URL provided above indicates that there was 16.1 mm of $ET_o$ during the five day period.
REFERENCE ET (mm) Penman-Monteith 15-Feb-2012

Site Location
Step 5. Crop Water Requirement

- The crop water requirement ($ET_c$) for the time period can now be estimated as follows:

$$ET_c = K_c \cdot ET_o = (0.85)(16.1 \text{ mm}) = 13.7 \text{ mm}$$
Step 6. Number of hours to run the pump

- Pumping time is estimated from a form of the well-known irrigation equation (Fangmeier et al., 2005) can be used:

$$T = 17.817 \times \frac{D \times A}{Q \times \text{eff}}$$

- where $T$ is time in hours, $D$ is depth of irrigation water ($=\text{ET}_{c}$) in mm, $A$ is effective field area in acres, $Q$ is flow rate in gallons per minute and eff is irrigation system efficiency.
Number of hours to run the pump to satisfy the crop water requirement for the example problem.

- Using $D = ET_c = 13.7$ mm
- $A = 10$ acres
- $Q = 300$ gallons per minute
- $\text{eff} = 0.85$, yields:

$$T = 17.817 \times [13.7 \times 10] / [300 \times 0.85] = 9.57 \text{ hours}.$$
Daily Reference Evapotranspiration (ETo) for Puerto Rico, Hispaniola and Jamaica

PRAGWATER

Puerto Rico Agricultural Water Management

Daily Reference Evapotranspiration (ETo) for Puerto Rico, Hispaniola and Jamaica

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www.pragwater.com
Archived Reference ET for Puerto Rico, Hispaniola and Jamaica
(www.pragwater.com)
In Conclusion

• Many farmers do not systematically schedule irrigation.
• Application of the wrong quantity of water can lead to losses in water, fuel, chemicals, yield, and money.
• A simple web-based method was introduced for scheduling irrigation on farms without weather stations.
• The approach presented here is relatively simple and the near-real-time data is available to any farmer in Puerto Rico with internet access.
• The method can also be used in Hispaniola and Jamaica, but on-site rainfall measurement would be required.