Saving Water, Energy and Money using Irrigation Scheduling

Dr. Eric Harmsen

Professor, Dept. of Agricultural and Biosystems Eng., Univ. of Puerto Rico-Mayaguez

Eric.harmsen@upr.edu

(787)955-5102

The cost of our food in water

= 634 gallons

How much water is required for the hamberger bun?

- Assume 1 sq. ft of wheat is required to produce the bun.
- Assume typical wheat season is 135 days
- Assume average evapotranspiration is 2.5 mm/day
- Consider irrigation only (i.e., no post harvest processing)

$$\frac{2.5\ mm \cdot 1\ ft^{2}}{day} \cdot 135\ day = 31.35\ liter$$

= 8.26 gallons

Water Use for Alternative Fuels

The big shocker is that biodiesel doesn't look so "green" when considered in the context of water consumption. More than 180 000 L of water would be needed to produce enough soybean-based biodiesel to keep the lights on for one day in 1000 homes. Younos explains that it takes a lot of water to irrigate the soil in which the soybeans grow, and even more is used in turning the legumes into fuel.

Here are the Virginia Water Resources Research Center results by fuel source:

Fuel Source	Efficiency (liters per 1000 kilowatt-hours)
Natural gas	38
Synfuel: coal gasification	144–340
Tar sands	190–490
Oil shale	260–640
Synfuel: Fisher-Tropsch	530–775
Coal	530–2100
Hydrogen	1850–3100
Liquid natural gas	1875
Petroleum/oil-electric sector	15 500–31 200
Fuel ethanol	32 400–375 900
Biodiesel	180 900–969 000

Energy used by 2 house-holds in one month

http://spectrum.ieee.org/energy/environment/how-much-water-does-it-take-to-make-electricity

Seasonal Evapotranspiration and Irrigation Requirements for Crops Near Deming, New Mexico[a]

Crop	Length of Growing Season (days)	ET[b] (mm)
Alfalfa	197	915
Beans (dry)	92	335
Corn	137	587
Cotton	197	668
Grain (spring)	112	396
Sorghum	137	549

Beans: Average farm size in PR = 13 cuerda

335mm/0.75 x 0.003281 ft/mm * 43,560 cuerda/ft2 *7.48 gal/ft3

= 6.6 million gallons

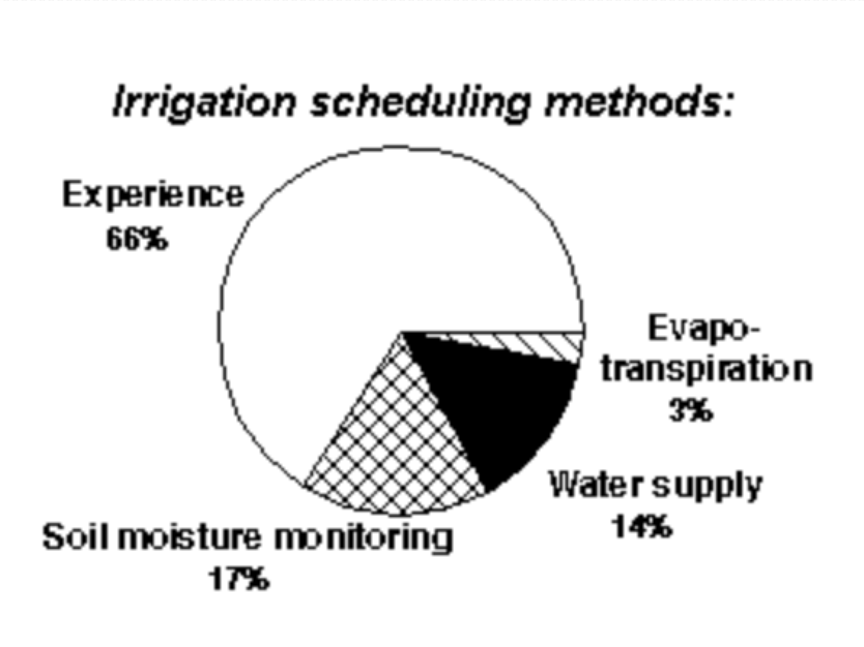
Cost of irrigation water by source

- PR Irrigation System (canals): $2 to $3 /acre-ft for farmers
- PRASA $84/acre ft
- Farmers are exempt from paying the Department of Natural and Environmental Resources fees if they have their own wells
- Municipal water: $2,400/acre-ft
- Municipal water is not an option for a farm!!

(Pricing information obtained from Ferdinand Quiñones)

Irrigation Scheduling - What is the problem?

- There is anecdotal evidence that most farmers do not use scientific methods for scheduling irrigation



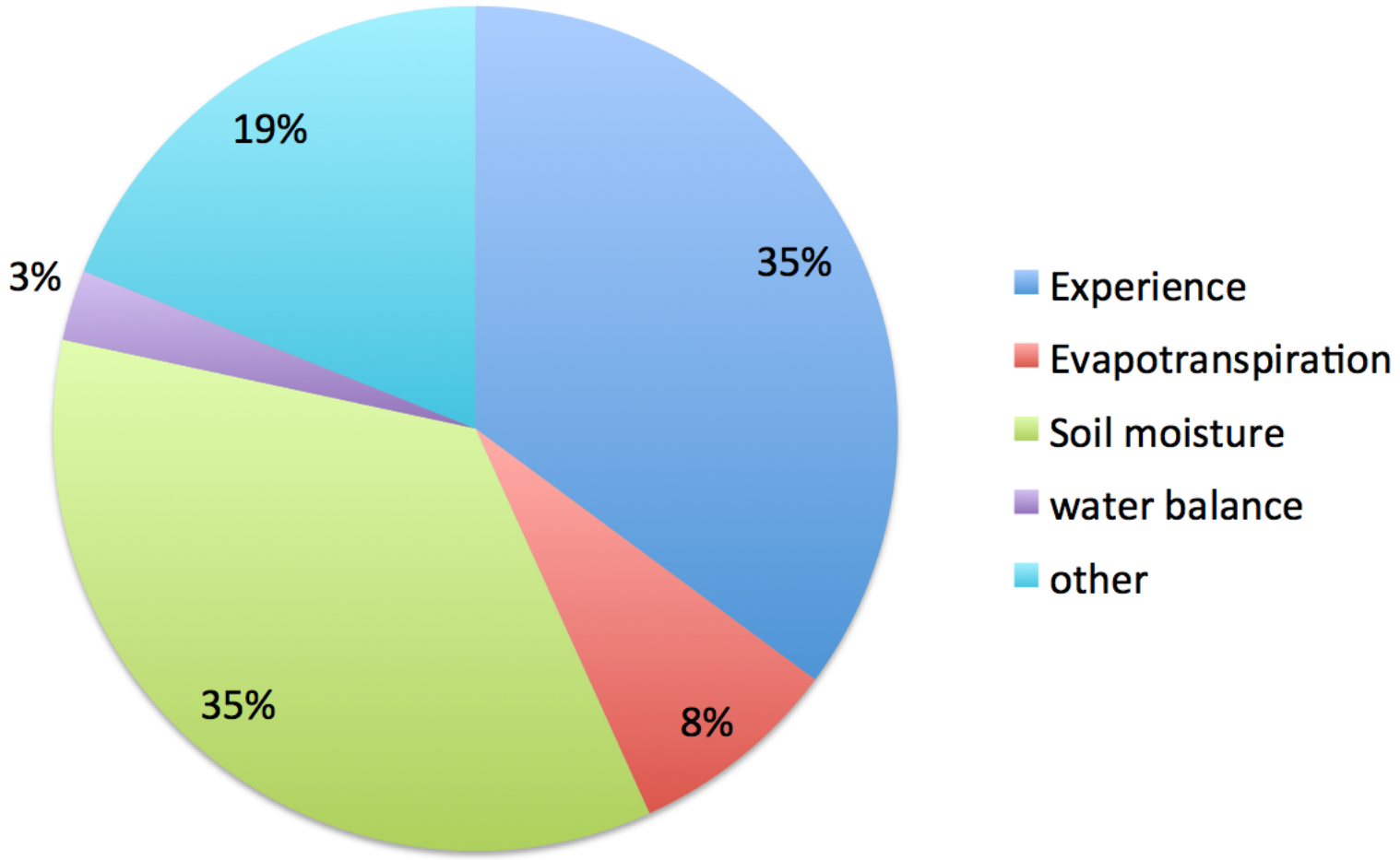
Data from Idaho, USA

http://www.webpages.uidaho.edu/~karenl/wq/wqbr/wqbr26.html

Definition

- What is irrigation scheduling*?*
  Irrigation Scheduling is the process used by irrigation system managers (farmers) to determine the **correct frequency and duration** of watering. (wikipedia.org)

Irrigation Scheduling Methods used in Puerto Rico (preliminary data)



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

- Leads to
  - crop water stress
  - Reduced crop yield
  - loss of revenue to the grower

How much money are we talking about?

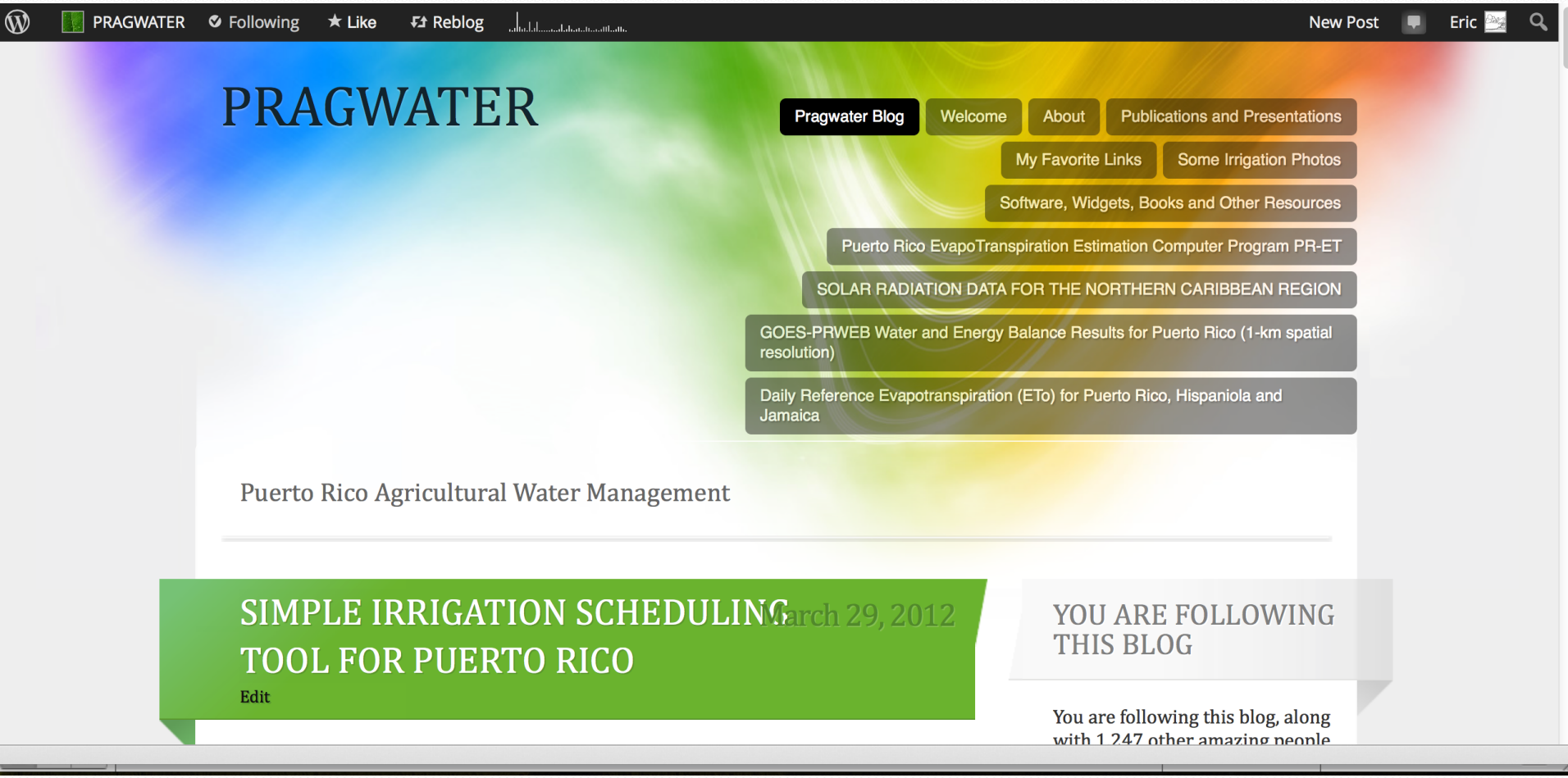
	Relative Irrigation Applied						
	0.4	0.5	0.8	1.0	1.3	1.5	1.8
Cultivo*	**$ Lost / Cuerda**						
Gandules	47	32	10	0	12	35	69
Pepinillo	111	76	25	0	15	56	124
Repollo	256	174	57	0	21	103	247
Sandia	293	199	65	0	23	114	277
Platanos y Guineos, Plantilla	318	216	71	0	24	122	299
Calabaza	390	265	87	0	27	146	359
Cebolla	543	369	121	0	34	195	490
Pimiento	578	393	129	0	36	206	519
Barenjena	757	514	169	0	44	264	670
Platanos y Guineos, Reton~o	1,006	684	225	0	76	388	945
Melon, Cantaloupe y Honeydew	1,027	698	229	0	56	352	899
Raices y Tuberculos	1,041	707	232	0	57	356	911

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

Experience Method

- “I apply 1 inch of water to my crop every week.”
- “The soil looks dry so I am going to irrigate.”
- “The crop looks stressed so I am going to irrigate.”

IRRIGATION SCHEDULING TOOL



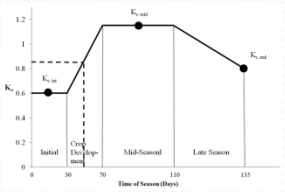
http://pragwater.com/2012/03/29/simple-irrigation-scheduling-tool-for-puerto-rico/

Web-based method for irrigation scheduling in PR

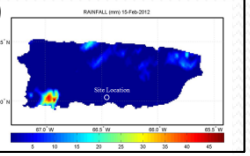
Start

Define problem (location, farm size, crop, etc.)

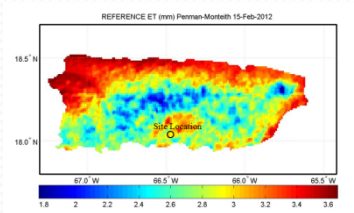
Determine average K_c for the time period



Determine rainfall from onsite gauge or NEXRAD



Determine ET_o

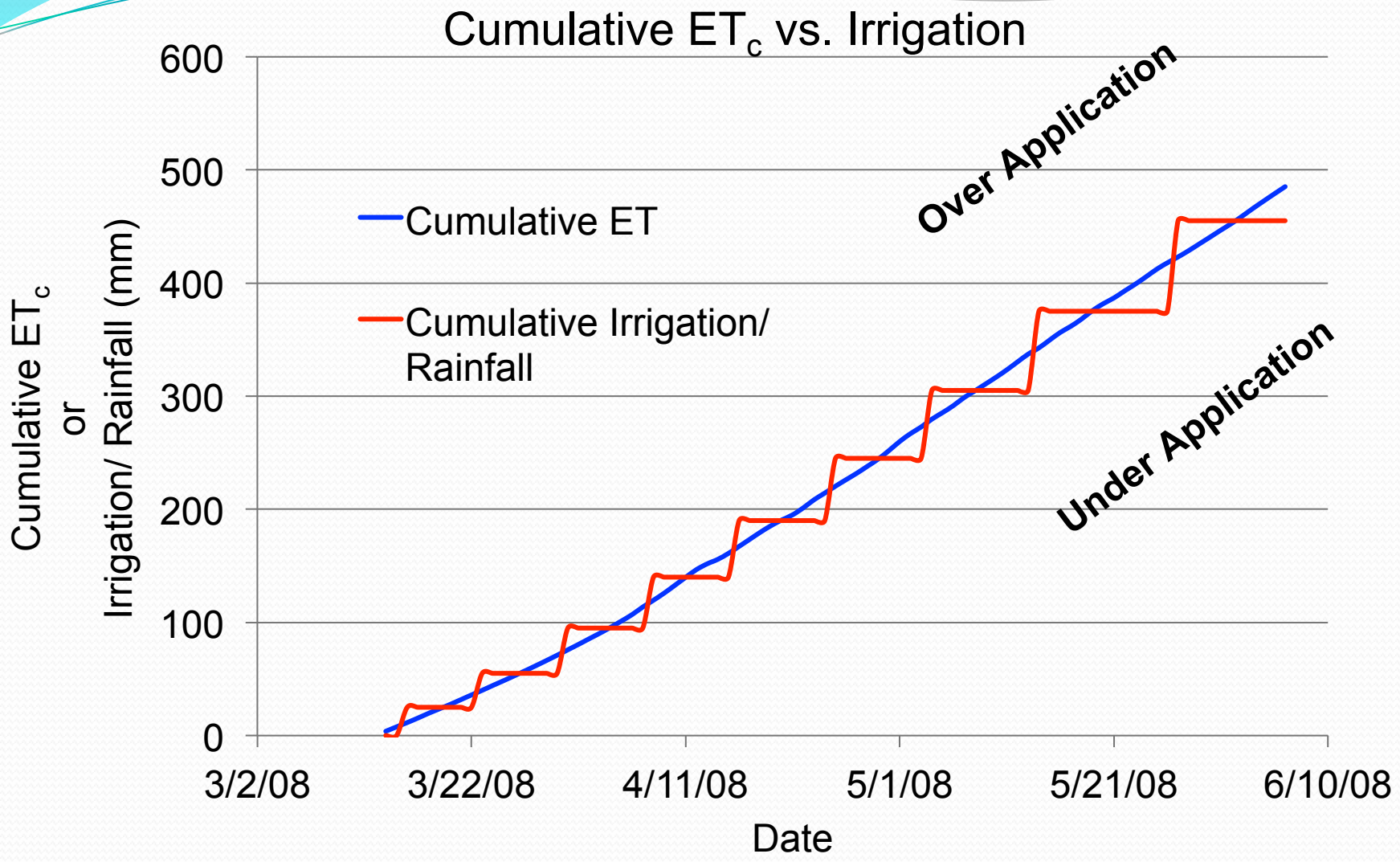


Estimate Crop Water Requirement

$$ET_c = K_c\ ET_o$$

Estimate Irrigation Requirement and required hours of pumping

Harmsen E.W., 2012. TECHNICAL NOTE: A Simple Web-Based Method for Scheduling Irrigation in Puerto Rico J. Agric. Univ. P.R. 96 (3-4) 2012.


Cumulative ETc vs. Irrigation
Cumulative ETc or Irrigation/ Rainfall (mm)
600
500
400
300
200
100
0
Cumulative ET
Cumulative Irrigation/ Rainfall
Over Application
Under Application
3/2/08
3/22/08
4/11/08
5/1/08
5/21/08
6/10/08
Date

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

Length of Growth Stages (Table 11) and Crop Coefficients (Table 12)	http://www.fao.org/docrep/X0490E/x0490e00.htm
Daily Reference Evapotranspiration (ETo)	http://academic.uprm.edu/hdc/GOES-PRWEB_RESULTS/rainfall
Daily NEXRAD Rainfall for Puerto Rico	http://academic.uprm.edu/hdc/GOES-PRWEB_RESULTS/reference_ET/

Step 1. Information used in example problem.

Location	Juana Diaz, Puerto Rico
Site Latitude	18.02 degrees N
Site Longitude	66.52 degrees W
Site Elevation above sea level	21 m
Crop	Tomato
Planting Date	1-Jan-12
Rainfall information	A rain gauge is not available on or near the farm
Type of irrigation	Drip
Irrigation system efficiency	85%
Field Size	10 acres
Pump capacity	300 gallons per minute

Step 2. Crop growth stage and crop coefficient data for example problem.

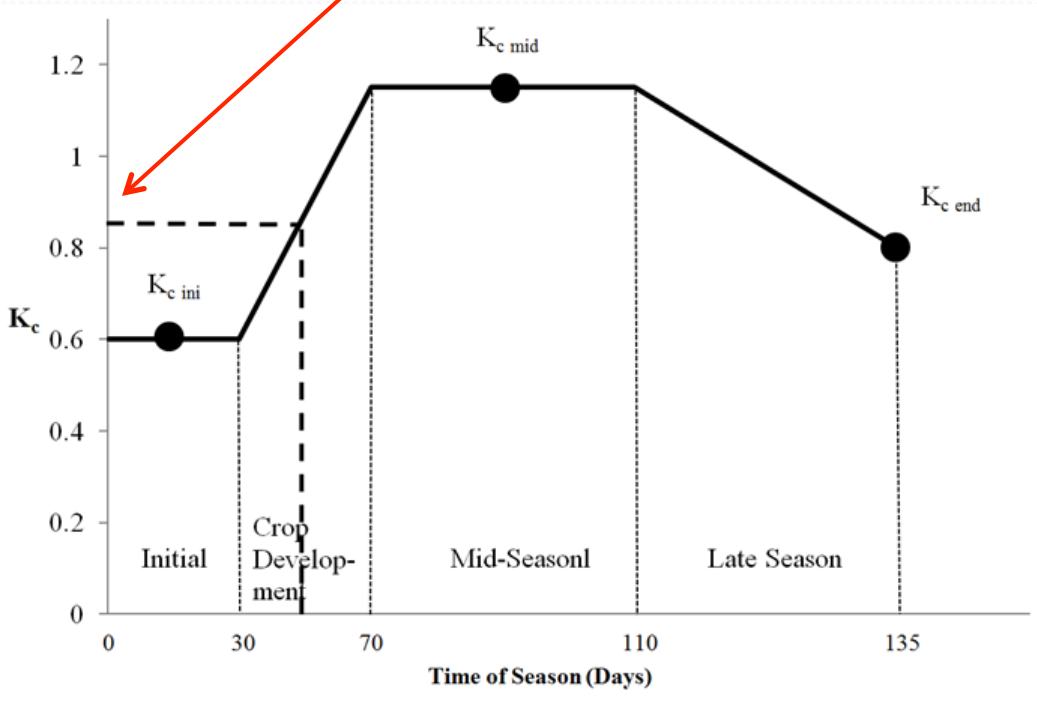
http://www.fao.org/docrep/X0490E/x0490e00.htm

Tomato Growth Stages and Crop Coefficients

Initial Crop Growth Stage	30 days
Crop Development Growth Stage	40 days
Mid-Season Growth Stage	40 days
Late-Season Growth Stage	25 days
Total Length of Season	135 days
$K_{c\ ini}$	0.6
$K_{c\ mid}$	1.15
$K_{c\ end}$	0.8

Crop Coefficient

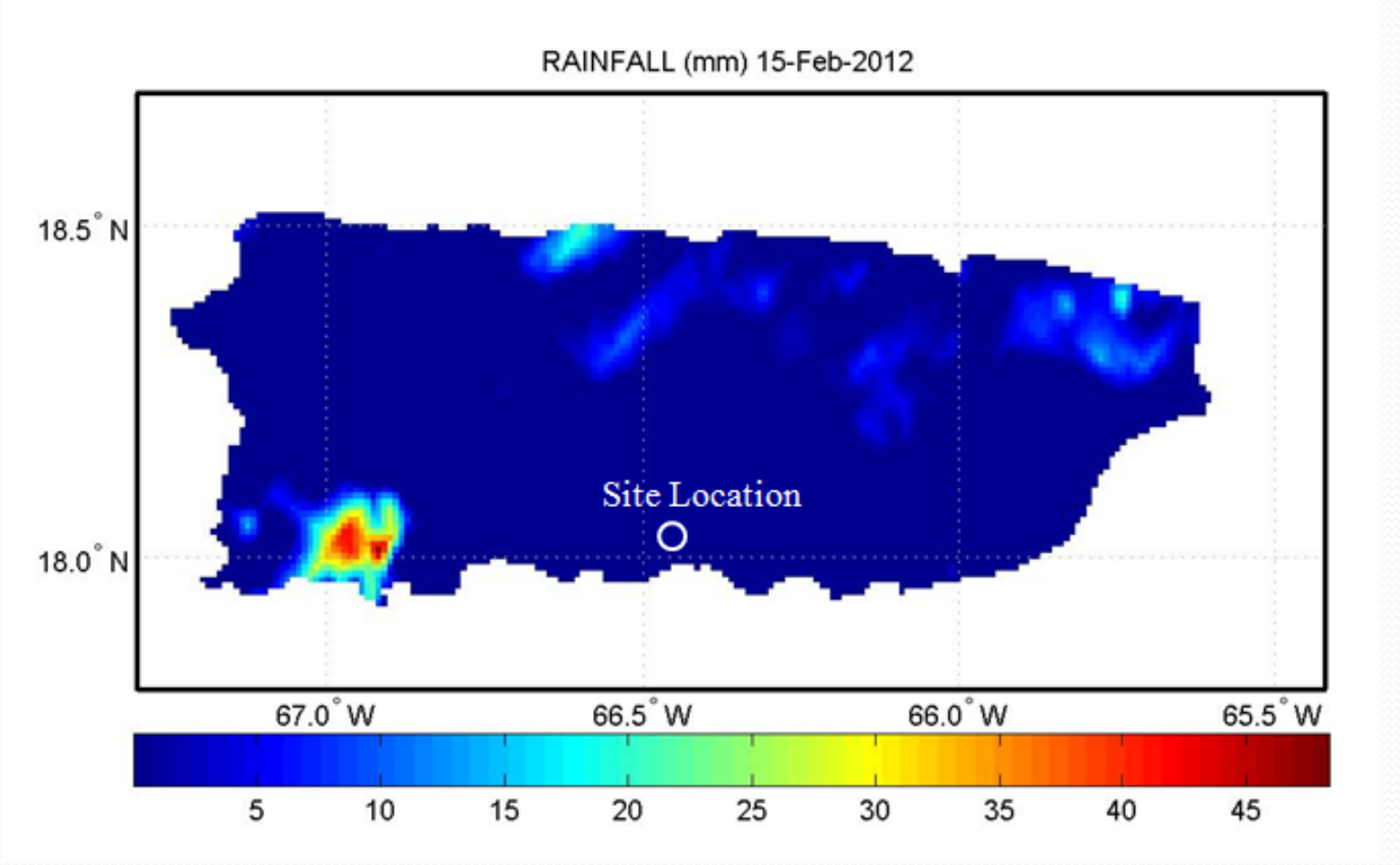
- The averge K_c value of 0.85 for the five day period was obtained.



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

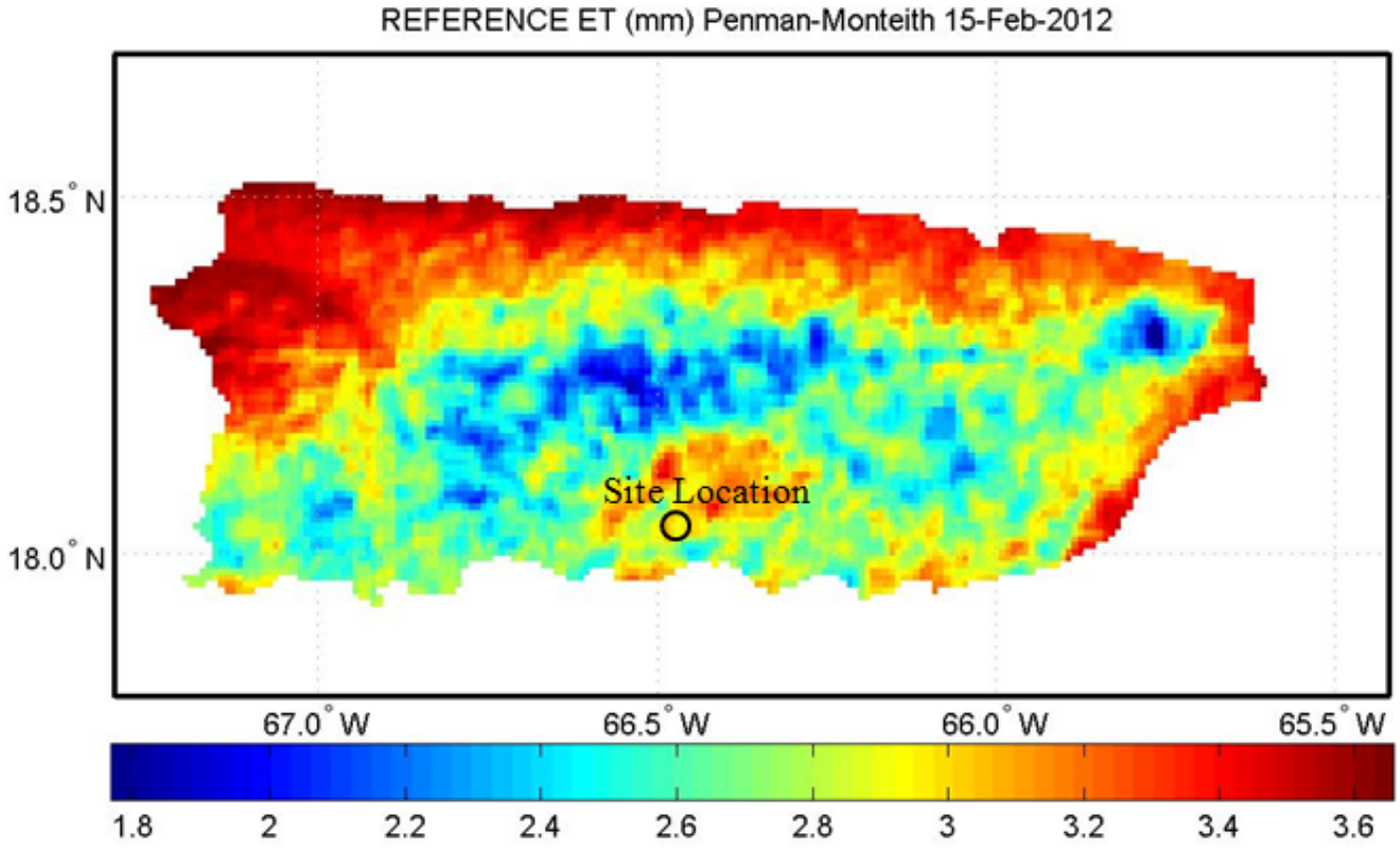
http://academic.uprm.edu/hdc/GOES-PRWEB_RESULTS/rainfall/



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

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.

Step 5. Crop Water Requirement

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

$$ET_c = K_c\, ET_o = (0.85)(16.1\ mm) = 13.\ 7\ mm$$

Step 6. Calculation of Irrigation Requirement and duration of pumping

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

- Irrigation Requirement (volume)

13.7 mm x 10 cuerda x 1044 / 0.85

= **168,260 gallons**

- Pumping time:

168,260 gal/300 gal/min *60 min/hr = **9.35 hours**

Web-based Irrigation Scheduling Tool

- Students from the Computer Engineering Department are developing ***desktop and mobile apps*** of the web-based irrigation scheduling procedure.
- The user will be able to create an account, which will remember the user's irrigation history
- Everything will be automated
- The apps should be ready for use in approximately 3 months.

Assignment

Determine the irrigation requirement for the 2-day period, June 1 and 2, 2014, for a pepper crop. Assume the following:

- Farm area is 20 acres
- Pump flow rate is 500 gallons per minute.
- Planting date is Jan 2, 2013
- Irrigation efficiency 70%

- Perform the analysis for a pueblo with the same letter as your first name. For example, Pedro could use Ponce, Peñuelas, etc. Jomira could use Juana Diaz, Juncos, etc.

Use the web-based irrigation schedule tool presented in class on Nov. 13, 2013.

Length of Growth Stages and Crop Coefficients
http://www.fao.org/docrep/X0490E/x0490e00.htm

Daily Reference ET Results for Puerto Rico
http://academic.uprm.edu/hdc/GOES-PRWEB_RESULTS/reference_ET/

Daily NEXRAD Rainfall For Puerto Rico
http://academic.uprm.edu/hdc/GOES-PRWEB_RESULTS/rainfall/