Irrigation Scheduling Overview, Tools and Examples

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Michigan State University

NRCS Irrigation Training
Feb 2-3 and 9-10, 2010

Irrigation Scheduling

- Process of maintaining an optimum water balance in the soil profile for crop growth and production

- Irrigation decisions are based on an accounting method on the water content in the soil

Reasons for Irrigation

- Crop Growth and Development
  - Meeting the daily water use requirements
- Crop Establishment
  - Transplants need water in excess of normal crop water use
- Frost Protection
  - Sometimes requires more than one type – overhead for frost protection along with drip irrigation.
- Chemigation / Fertigation
- Herbicide Activation

Irrigation Scheduling

- Components
  - Plant Growth Stage and Water Use
  - Soil Water Holding Capacity
  - Evaporative Demand
  - Rainfall / Irrigation

- RECORDKEEPING

Irrigation Scheduling

- Levels of Accounting
  - 0 – Guessing (irrigate whenever)
  - 1 – Using the “feel and see” method
  - 2 – Using systematic irrigation (ex: ¾” every 4th day)
  - 3 – Using a soil moisture measuring tool to start irrigation
  - 4 – Using a soil moisture measuring tool to schedule irrigation and apply amounts based on a budgeting procedure
  - 5 – Adjusting irrigation to plant water use, using a dynamic water balance based on budgeting procedure and plant stage and growth, together with a soil water moisture measuring tool.

Irrigation Scheduling

- Components
  - **Plant Growth Stage and Water Use**
  - Soil Water Holding Capacity
  - Evaporative Demand
  - Rainfall / Irrigation

- RECORDKEEPING

Plant Growth and Water Use

- Fundamentally crops use water to facilitate cell growth, maintain turgor pressure, and for cooling.
- Crop water use is driven by the evaporative demand of the atmosphere.
- Function of temperature, **solar radiation**, wind, relative humidity.
- Example, a fully developed corn crop in Michigan can use as high as 0.35 inches per day. (~9,500 gallons / acre)
- Generally, optimum crop growth and health occurs when the soil moisture content is held between 50 – 80% of the "plant available water"

Estimating Plant Water Use

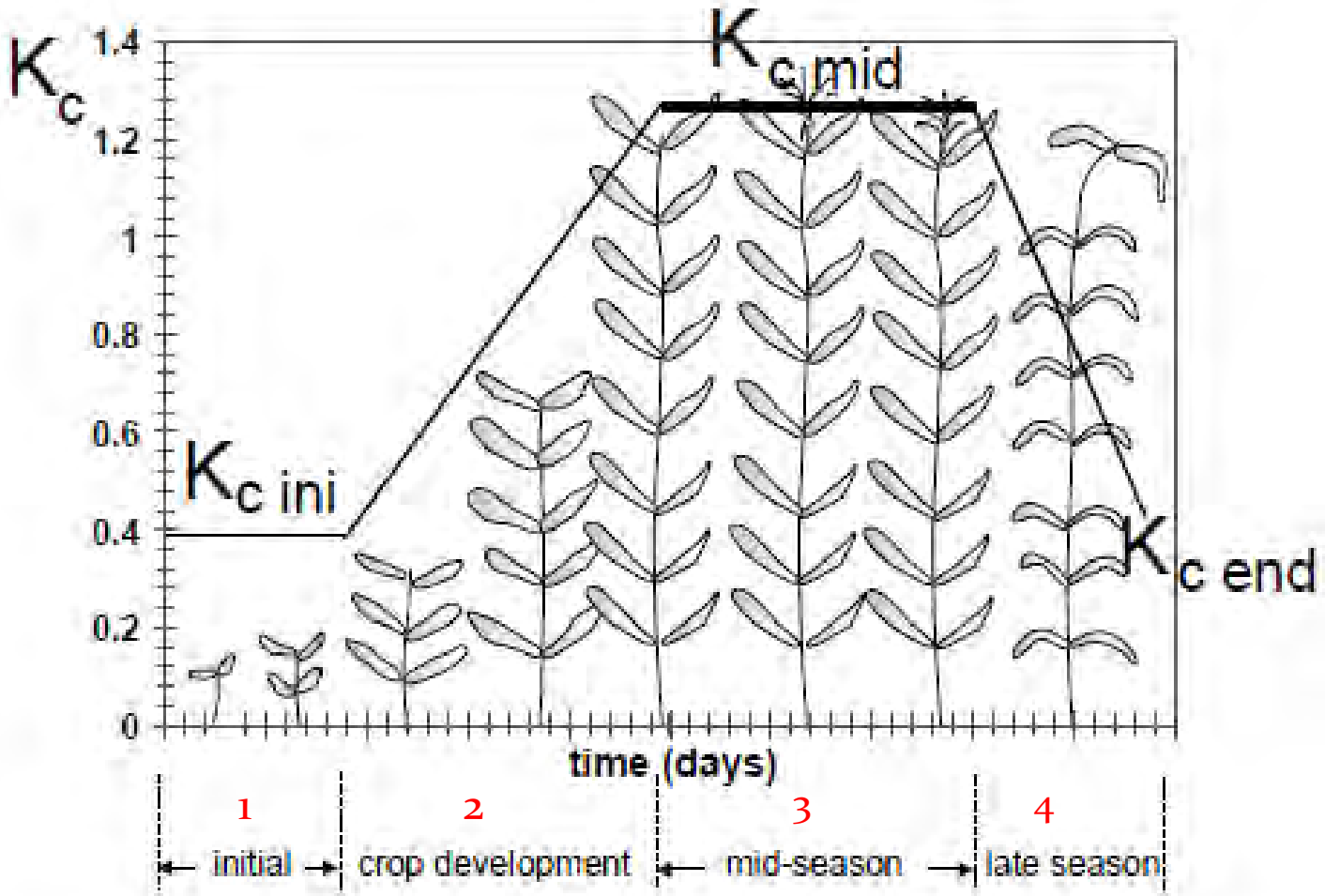
- Crop water use = Evapotranspiration (ET).
- A "potential reference ET (PET)" can be calculated based on weather conditions.
- The standard method – Penman – Monteith.
  - Based on temperature, solar, humidity, wind, rainfall
  - "Well watered grass"
- Michigan Agricultural Weather Network (MAWN) calculates hourly PET at each station and publishes the daily total value for irrigation use.
- http://www.enviro-weather.msu.edu/

Estimating ET for Different Crops

- Combining a “Crop Coefficient Curve” with the reference ET.
- Crop Curve is a relationship between the specific plants’ growth characteristics and its water use relationship to the reference crop.

Crop Curve

FIGURE 25
Generalized crop coefficient curve for the single crop coefficient approach



Crop	Growth Stage	Crop Coefficient
All field-grown vegetables	1	0.20[1] to 0.40[2]
	2	Stage 1[3] value to Stage 3 value (See Figure 8-3)
Legumes: snapbean, lima bean and southernpea	3	0.95[4]
	4	0.85[4]
Beet	3	1.00
	4	0.90
Cole crops:	3	1.00
broccoli, brussels sprouts	4	0.85
cabbage, cauliflower	3	0.95[4]
collards, kale	4	0.90[4]
mustard	3	1.00[4]
turnip	4	0.90[4]
Carrot	3	1.05
	4	0.75
Celery	3	1.05
	4	0.95
Cucurbits: cucumber, cantaloupe, pumpkin	3	0.90
squash, watermelon	4	0.70
Lettuce: endive,	3	0.95
escarole	4	0.90
Okra	3	1.00[4]
	4	0.90[4]
Onion (dry)	3	0.95
	4	0.75
Onion (green)	3	0.95
Parsley	3	1.00[4]
Potato	3	1.10
	4	0.70
Radish	3	0.80
	4	0.75
Spinach	3	0.95
	4	0.90
Sweet corn	3	1.10
	4	1.00
Sweetpotato	3	1.10[4]
	4	0.70[4]

[1] low plant population; wide row spacing

[2] high plant population; close row spacing

[3] 0.20 or Kc value from Stage 1

[4] values estimated from similar crops

TABLE 25

Approximate reductions in K_c and surface evaporation and increases in transpiration for various horticultural crops under complete plastic mulch as compared with no mulch using trickle irrigation

Crop	Reduction in K_c (%)[1]	Reduction in evaporation (%)[1]	Increase in transpiration (%)[1]	Source
Squash	5-15	40-70	10-30	Safadi (1991)
Cucumber	15-20	40-60	15-30	Safadi (1991)
Cantaloupe	5-10	80	35	Battikhi and Hill (1988)
Watermelon	25-30	90	-10	Battikhi and Hill (1986), Ghawi and Battikhi (1986)
Tomato	35	not reported	not reported	Haddadin and Ghawi (1983)
Average	10-30	50-80	10-30	

[1] Relative to using no mulch

Measuring Soil Moisture

- Tensiometers and Watermarks
  - Measure soil tension - centibars
- Volumetric Probes
  - TDR
  - FDR
  - Capacitance Probes
- Moisture by Feel

Tensiometers and Watermarks

http://www.specmeters.com/Soil_Moisture/

Volumetric Moisture

http://www.campbellsci.com.au/hydrosense

Table 12. Guide for judging soil water deficit based on soil feel and appearance for several soil textures.

SOIL TEXTURE CLASSIFICATION					
Moisture deficiency	Coarse (loamy sand)	Sandy (sandy loam)	Medium (loam)	Fine (clay loam)	Moisture deficiency
in./ft.					in./ft.
.0	(field capacity) Leaves wet outline on hand when squeezed.	(field capacity) Appears very dark, leaves wet outline on hand, makes a short ribbon.	(field capacity) Appears very dark, leaves wet outline on hand, will ribbon out about one inch.	(field capacity) Appears very dark, leaves slight moisture on hands when squeezed, will ribbon out about two inches.	.0
.2	Appears moist, makes a weak ball.	Quite dark color, makes a hard ball.			.2
.4	Appears slightly moist, sticks together slightly.	Fairly dark color, makes a good ball.	Dark color, forms a plastic ball, slicks when rubbed.	Dark color, will slick and ribbons easily.	.4
.6	Appears to be dry, will not form a ball under pressure.	Slightly dark color, makes a weak ball	Quite dark, forms a hard ball.	Quite dark, will make thick ribbon, may slick when rubbed.	.6
.8		Lightly colored by moisture, will not ball.	Fairly dark, forms a good ball.	Fairly dark, makes a good ball.	.8
1.0	Dry, loose, single-grained flows through fingers. (wilting point)	Very slight color due to moisture, loose, flows through fingers. (wilting point)	Slightly dark, forms weak ball.	Will ball, small clods will flatten out rather than crumble.	1.0
1.2			Lightly colored, small clods crumble fairly easily.	Slightly dark, clods crumble.	1.2
1.4			Slight color due to moisture, powdery, dry, sometimes slightly crusted but easily broken down in powdery condition. (wilting point)	Some darkness due to unavailable moisture, hard, baked, cracked sometimes has loose crumbs on surface. (wilting point)	1.4
1.6					1.6
1.8					1.8
2.0					2.0

Irrigation Scheduling

- Components
  - Plant Growth Stage and Water Use
  - Soil Water Holding Capacity
  - **Evaporative Demand**
  - Rainfall / Irrigation

- RECORDKEEPING


Michigan Automated Weather Network - Windows Internet Explorer
http://www.agweather.geo.msu.edu/mawn/irrigation/
Michigan Automated Weather Network
MICHIGAN STATE UNIVERSITY
MAWN
Michigan Automated Weather Network
MAWN - Home Page
MSU Agricultural Weather Office
Michigan State Climatologist's Office
MSU Department of Geography
Enviro-Weather
Project GREEEN
MICHIGAN STATE UNIVERSITY EXTENSION
Michigan Agricultural Experiment Station
Irrigation Data - Support Files
Irrigation Checkbook (final rev)
Table of Crop Coefficients
http://www.agweather.geo.msu.edu/mawn/irrigation/
Irrigation Data - Individual Data Files
Albion
Bainbridge Center / Watervliet
Bath
Bear Lake
Belding
Benton Harbor / SWMREC
Benzonia
Ceresco
Chatham
Clarksville
Commerce Twp
Constantine
East Lansing / MSUHORT
East Lansing / MSUHTRC
East Leland
Eastport
Elk Rapids
Emmett
Entrican / Lakeview
Escanaba
Fairgrove
Fennville
Freeland
Fremont
Grand Junction
Hart
Hartford
Hawks
Hudson
Hudsonville
Ithaca
Kewadin
Lapeer
Lawton
Linwood
Ludington
Mendon
Munger
Northport
Old Mission
Petersburg / Dundee
Pigeon
Saginaw
Sandusky
Scottdale
South Haven
Sparta
Stephenson
Traverse City / NWMHRS
West Olive

MAWN Data

- Daily reference evapotranspiration is calculated by summing the hourly Penman-Monteith calculations from meteorological data at each station
- Considers temperature, **solar radiation**, humidity and wind speed
- International Standard for reference ET
  - Estimates the crop water use for a standing grass with ample water supply

MAWN STATION NAME: bath

DATE	ET	PCPN	TMPX	TMPN
2007-03-01	0.014	0.54	38.5	29.2
2007-03-02	0.035	0.08	38.9	26.9
2007-03-03	0.035	0.00	31.0	23.7
2007-03-04	0.048	0.00	30.9	23.1
2007-03-05	0.046	0.00	29.1	10.3
2007-03-06	0.029	0.00	18.8	-0.0
2007-03-07	0.032	0.09	27.8	4.4
2007-03-08	0.052	0.01	34.4	0.8
2007-03-09	0.071	0.04	47.9	17.7
2007-03-10	0.064	0.15	47.5	34.9
2007-03-11	0.080	0.00	51.8	23.5
2007-03-12	0.067	0.04	52.9	28.1
2007-03-13	0.141	0.00	73.5	43.8
2007-03-14	0.053	0.00	63.9	34.8
2007-03-15	0.055	0.00	37.1	23.4
2007-03-16	0.056	0.00	34.6	21.4
2007-03-17	0.068	0.00	36.0	21.3
2007-03-18	0.061	0.00	39.9	20.8
2007-03-19	0.052	0.03	49.1	27.6
2007-03-20	0.067	0.00	38.6	22.0
2007-03-21	0.046	0.37	61.1	26.0
2007-03-22	0.099	0.72	64.1	36.9
2007-03-23	0.086	0.00	56.2	35.8

Irrigation Scheduling

- Components
  - Plant Growth Stage and Water Use
  - Soil Water Holding Capacity
  - Evaporative Demand
  - **Rainfall / Irrigation**

- RECORDKEEPING

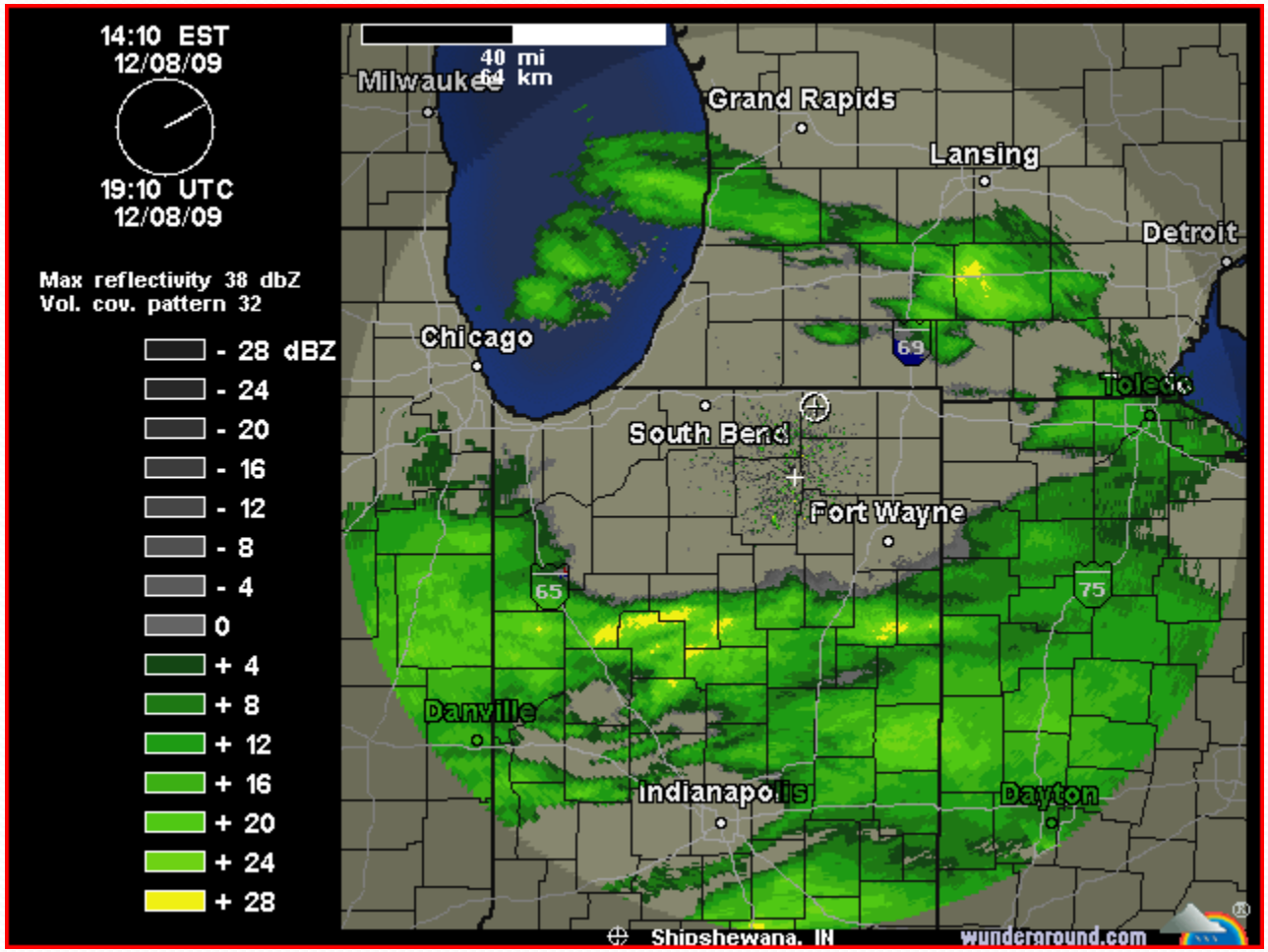
Rainfall measurement

- Measure in each field
- Should be read each day that a rain event occurs
- Record time reading is taken – should be consistent
- Keep Clean
- Install away from obstructions
- Basic gauges must not be allowed to freeze
- http://www.agweather.geo.msu.edu/mawn/

Rain Gauges

- Basic unit – 2 inch opening
- Cost less than $10.00
- 1-800-647-5368
- http://www.forestry-suppliers.com/product_pages/view_catalog_page.asp?id=5479

Traditional NEXRAD

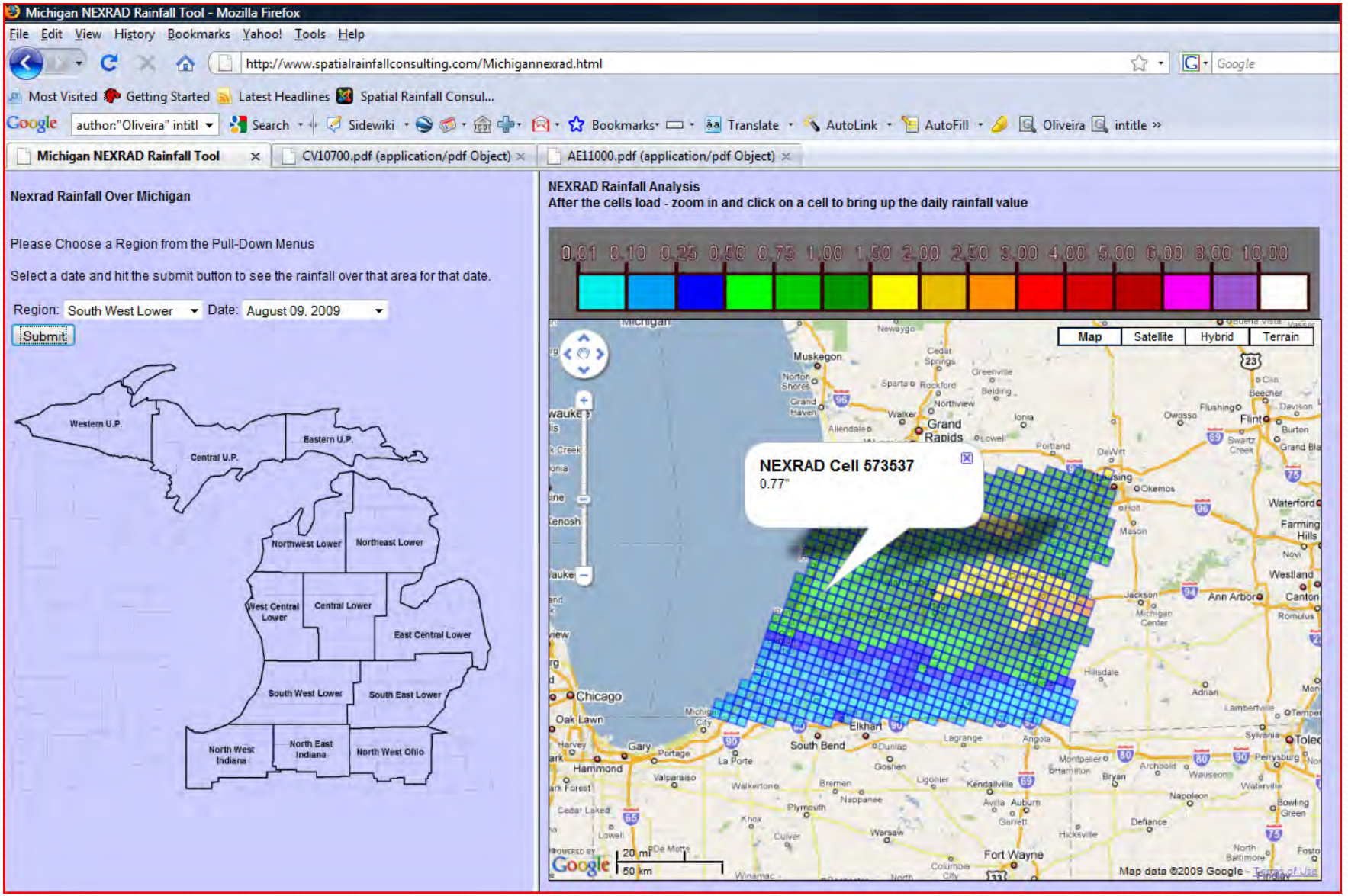


Michigan NEXRAD Tool

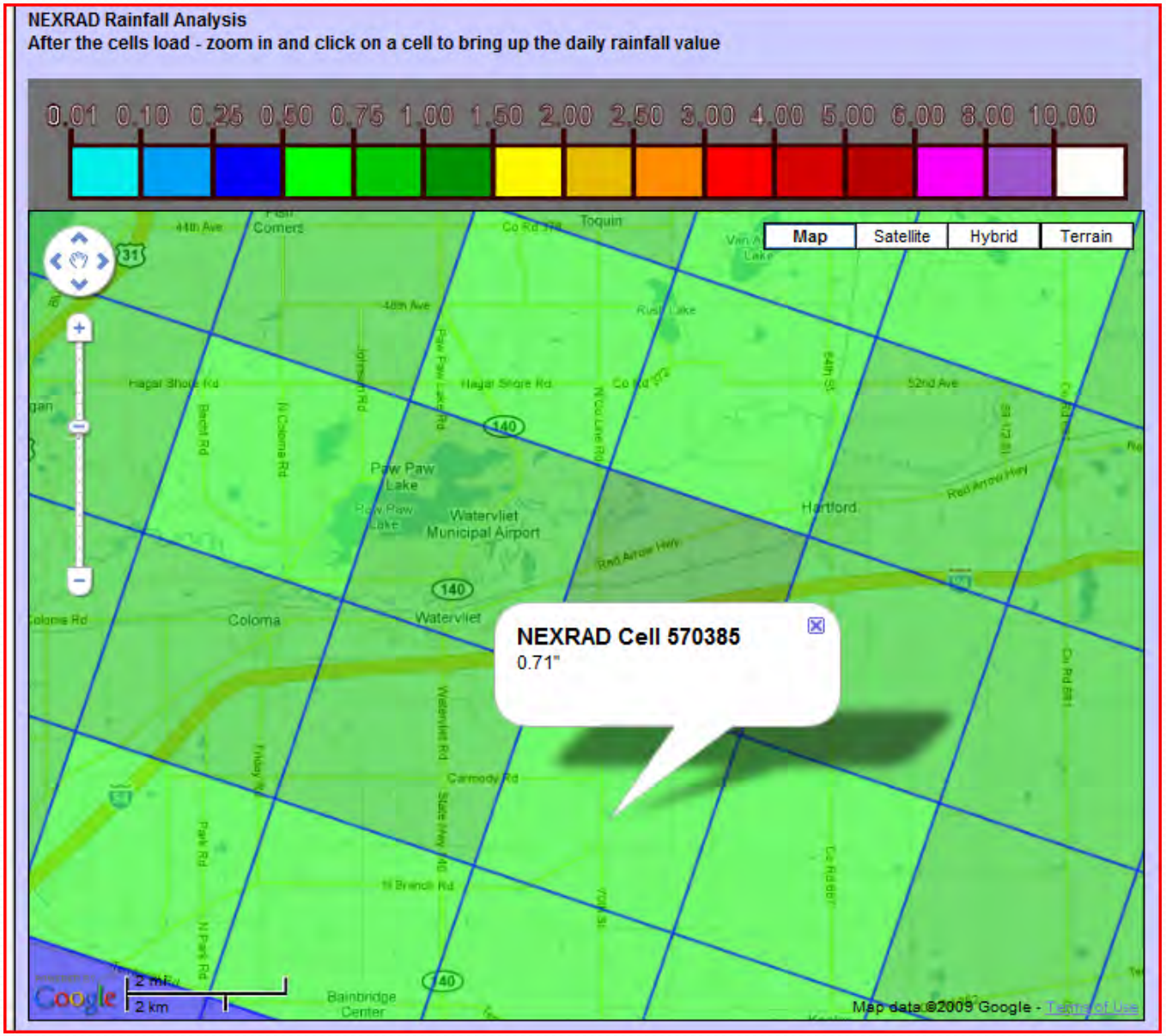
- Web –based tool
- Combines NWS Doppler Radar Network daily rainfall estimate with the power of Google Maps
- Site specific NEXRAD estimate of rainfall
- 2.5 mile resolution
- Base level is free to use
- Optional e-mail / text message data for a fee
- Other states are also available

www.spatialrainfallconsulting.com/Michigannexrad.html

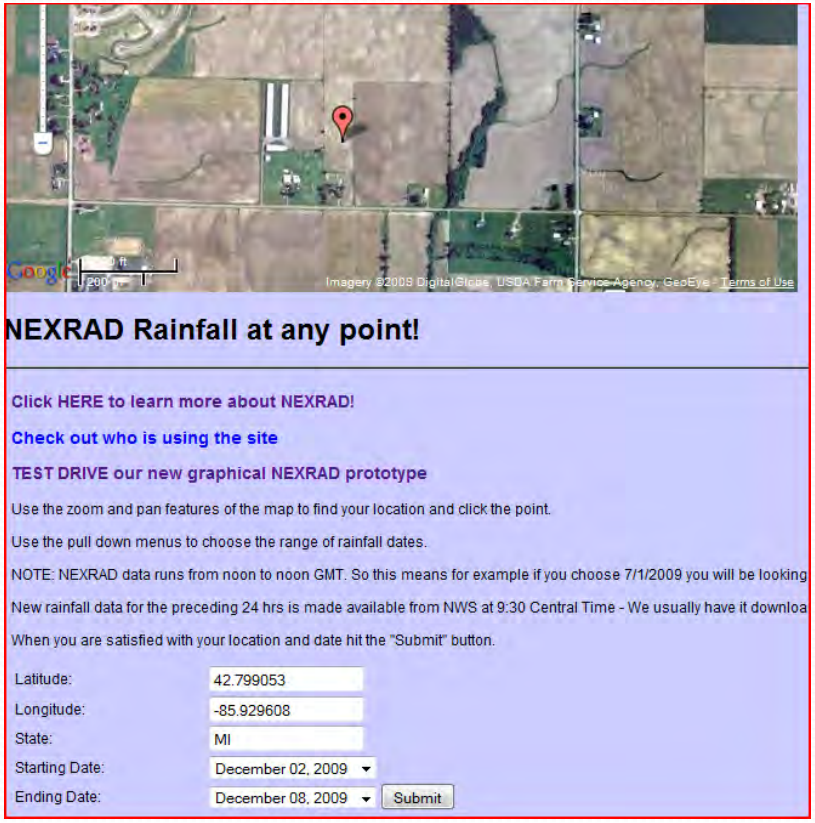
Michigan NEXRAD Tool

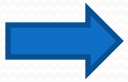


Michigan NEXRAD Tool



www.spatialrainfallconsulting.com/nexradrain.html





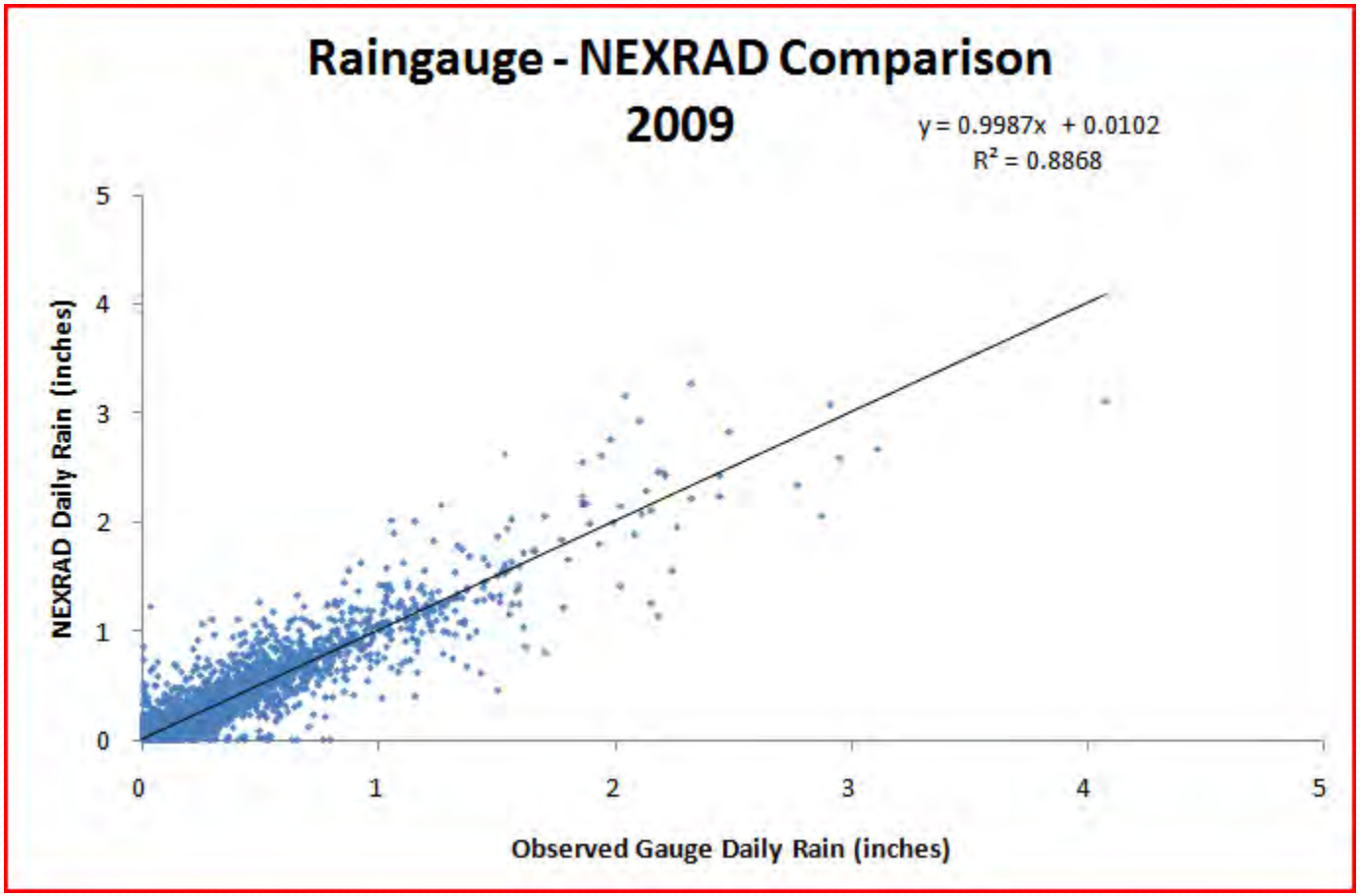
Latitude: 42.798959
Longitude: -85.929565
state: MI

The closest NEXRAD cell centroid to you is 589303 at a distance of 1.42029010566 km.

Summary of Rainfall from NEXRAD

Date	Rainfall (in)
12/02/2009	0.00
12/03/2009	0.05
12/04/2009	0.47
12/05/2009	0.06
12/06/2009	0.18
12/07/2009	0.02
12/08/2009	0.02
Total	0.8

NEXRAD Rainfall



Michigan NEXRAD Tool

Quota status: 315.08 MB / 1024.00 MB (30.77%)

Inbox: Fwd: Summary of NEXRAD rain from 11/30/2009 - 12/06/2009 (1 of 597)

Mark as: | Move | Copy | This message to

Delete | Reply | Forward | Redirect | View Thread | Blocked List | Accepted List | Message Source | Save as | Print | Headers

Date: Tue, 8 Dec 2009 13:04:30 -0500 [01:04:30 PM EST]
From: "Bill Northcott" <bill.northcott1967@gmail.com>
To: northco2@msu.edu
Subject: Fwd: Summary of NEXRAD rain from 11/30/2009 - 12/06/2009

Show this HTML in a new window?

---------- Forwarded message ----------
From: <northco2@msu.edu>
Date: Mon, Dec 7, 2009 at 6:00 AM
Subject: Summary of NEXRAD rain from 11/30/2009 - 12/06/2009
To: bill.northcott1967@gmail.com

Date	Laingsburg	Onarga Farm	Onarga	Sheffield
11/30/2009	0.15	0.08	0.11	0.00
12/01/2009	0.00	0.00	0.00	0.00
12/02/2009	0.00	0.00	0.00	0.00
12/03/2009	0.22	0.01	0.01	0.00
12/04/2009	0.06	0.00	0.00	0.00
12/05/2009	0.00	0.00	0.00	0.00
12/06/2009	0.00	0.00	0.00	0.00

Delete | Reply | Forward | Redirect | View Thread | Blocked List | Accepted List | Message Source | Save as | Print | Headers

Mark as: | Move | Copy | This message to

Soil Water Balance

- Scheduling is very much a “checkbook” type method for accounting on a daily basis the following components
  - Rainfall / Irrigation in (Rain gage / Pumping Records)
  - Evapotranspiration out (Ref Et * Crop Coefficient)
  - Storage in the soil reservoir (H_2O capacity * Root Depth)
    - Water holding capacity
    - Increasing soil storage capacity with crop rooting depth

Tools Available

- Scheduling Tools
  - Checkbook registers
  - Scheduling software
- Daily ET estimates
  - Simple Estimates
  - Complex Estimates

Checkbook Register

SOIL WATER BALANCE SHEET

(Make copies as needed)

Field_____Crop_____Emergence date_____
Pumping Capacity_____gpm per acre=_____net application inches per day
Available Water Capacity_____inches in root zone of_____inches

Growth Stage	Vegetative	Critical Growth	Maturing
Allowable	_____%	_____%	_____%
Soil Water Deficit	_____inches	_____inches	_____inches

Week after emergence	Date	Soil water field reading		Maximum temperature	Add	Subtract		Soil water deficit	
		A	B		Crop water use	Rainfall	Net irrigation	A	B

Back to home

Enviro-weather

Weather-based pest, natural resource, and production management tools

MAWN Station: Coldwater

Commodity/Report: ....Crop ET estimates

Use default/current date

Change date range

Estimated crop evapotranspiration at Coldwater (Report issued 6/26/2009 9:35)

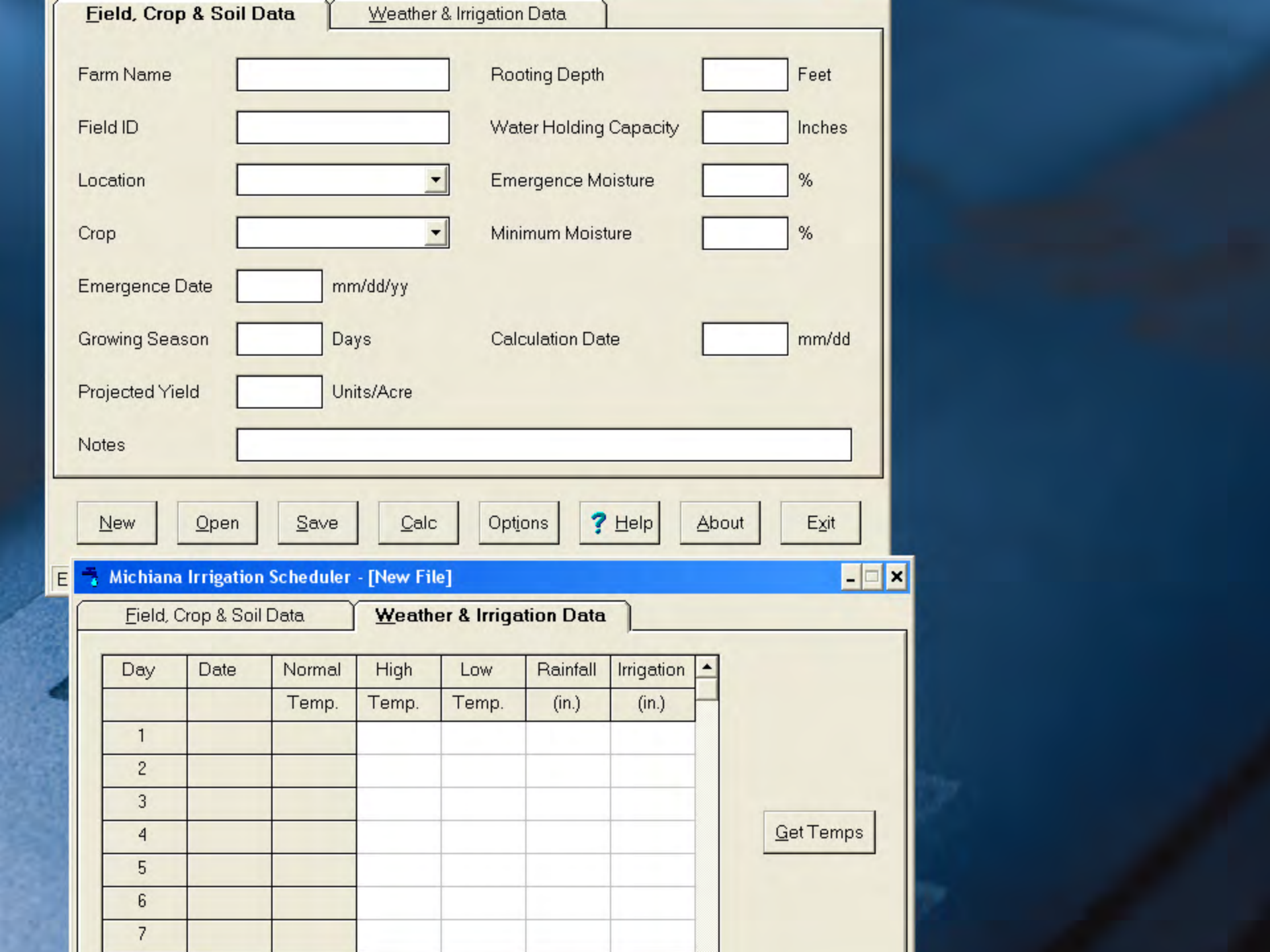
Change crop: Corn Emergence date: 5/20/2009

2400 GDD (86/50 method) Calendar days

2009		Temperature (F)		GDD	Rainfall	Reference PET						
Day	Date	Min	Max	86/50 method	(in.)	(in.)	GDD since 5/20	Percent total growth	Kc(coefficient)	PET today	PET since 5/20	Rainfall since 5/20
Fri	6/19	63.8	80.6	22.2	1.75	0.1	475	19%	0.73	0.07	2.36	4.87
Sat	6/20	66.1	82.3	24.2	0.64	0.18	499	20%	0.76	0.14	2.5	5.51
Sun	6/21	63.2	87.3	24.6	0	0.19	524	21%	0.79	0.15	2.65	5.51
Mon	6/22	64.3	84.4	24.4	0	0.22	548	22%	0.81	0.18	2.83	5.51
Tues	6/23	64.9	89.1	25.5	0	0.21	574	23%	0.84	0.18	3.01	5.51
Wed	6/24	68.5	95.4	27.3	0	0.24	601	25%	0.9	0.21	3.22	5.51
Thu	6/25	69.2	91.8	27.6	0	0.22	629	26%	0.92	0.2	3.42	5.51

Forecast data:

Day	Date	Min	Max	86/50 method	(chance)	(in.)	GDD since 5/20	Percent total growth	Kc(coefficient)	PET today	PET since 5/20	Rainfall since 5/20
Fri	6/26	67	86	26.5	32%	0.24	655	27%	0.95	0.23	3.65	5.51
Sat	6/27	59	83	21	7%	0.2	676	28%	0.98	0.2	3.85	5.51
Sun	6/28	65	79	22	82%	0.21	698	29%	1	0.21	4.06	5.51
Mon	6/29	60	71	15.5	58%	0.15	714	29%	1	0.15	4.21	5.51
Tues	6/30	56	72	14	51%	0.15	728	30%	1.03	0.15	4.36	5.51
Wed	7/1	58	79	18.5	22%	0.2	746	31%	1.05	0.21	4.57	5.51
Thu	7/2	63	82	22.5	41%	0.17	769	32%	1.06	0.18	4.75	5.51


Field, Crop & Soil Data
Weather & Irrigation Data
Farm Name
Field ID
Location
Crop
Emergence Date
mm/dd/yy
Growing Season
Days
Projected Yield
Units/Acre
Notes
Rooting Depth
Feet
Water Holding Capacity
Inches
Emergence Moisture
%
Minimum Moisture
%
Calculation Date
mm/dd
New
Open
Save
Calc
Options
Help
About
Exit
Michiana Irrigation Scheduler - [New File]
Field, Crop & Soil Data
Weather & Irrigation Data
Day
Date
Normal Temp.
High Temp.
Low Temp.
Rainfall (in.)
Irrigation (in.)
1
2
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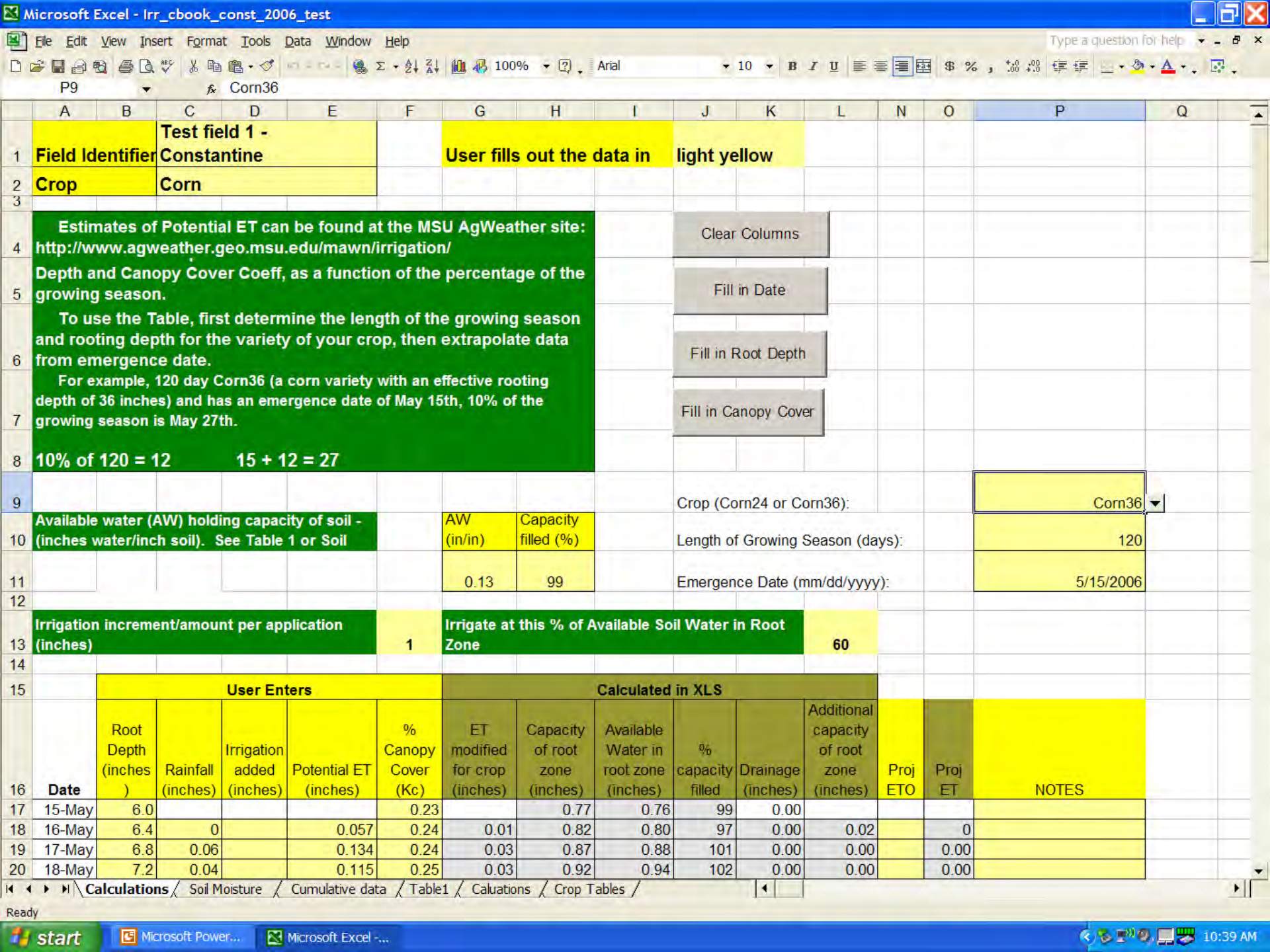
Get Temps



Microsoft Excel - Irr_cbook_const_2006_test

File Edit View Insert Format Tools Data Window Help

P9 Corn36

Field Identifier	Test field 1 - Constantine	User fills out the data in light yellow
Crop	Corn	

Estimates of Potential ET can be found at the MSU AgWeather site: http://www.agweather.geo.msu.edu/mawn/irrigation/

Depth and Canopy Cover Coeff, as a function of the percentage of the growing season.

To use the Table, first determine the length of the growing season and rooting depth for the variety of your crop, then extrapolate data from emergence date.

For example, 120 day Corn36 (a corn variety with an effective rooting depth of 36 inches) and has an emergence date of May 15th, 10% of the growing season is May 27th.

10% of 120 = 12 **15 + 12 = 27**

Clear Columns

Fill in Date

Fill in Root Depth

Fill in Canopy Cover

Crop (Corn24 or Corn36):	Corn36
Length of Growing Season (days):	120
Emergence Date (mm/dd/yyyy):	5/15/2006

Available water (AW) holding capacity of soil - (inches water/inch soil). See Table 1 or Soil	AW (in/in)	Capacity filled (%)
	0.13	99

Irrigation increment/amount per application (inches)	1	Irrigate at this % of Available Soil Water in Root Zone	60

	User Enters					Calculated in XLS								
Date	Root Depth (inches)	Rainfall (inches)	Irrigation added (inches)	Potential ET (inches)	% Canopy Cover (Kc)	ET modified for crop (inches)	Capacity of root zone (inches)	Available Water in root zone (inches)	% capacity filled	Drainage (inches)	Additional capacity of root zone (inches)	Proj ETO	Proj ET	NOTES
15-May	6.0				0.23		0.77	0.76	99	0.00				
16-May	6.4	0		0.057	0.24	0.01	0.82	0.80	97	0.00	0.02		0	
17-May	6.8	0.06		0.134	0.24	0.03	0.87	0.88	101	0.00	0.00		0.00	
18-May	7.2	0.04		0.115	0.25	0.03	0.92	0.94	102	0.00	0.00		0.00	

Calculations / Soil Moisture / Cumulative data / Table1 / Caluations / Crop Tables

Ready

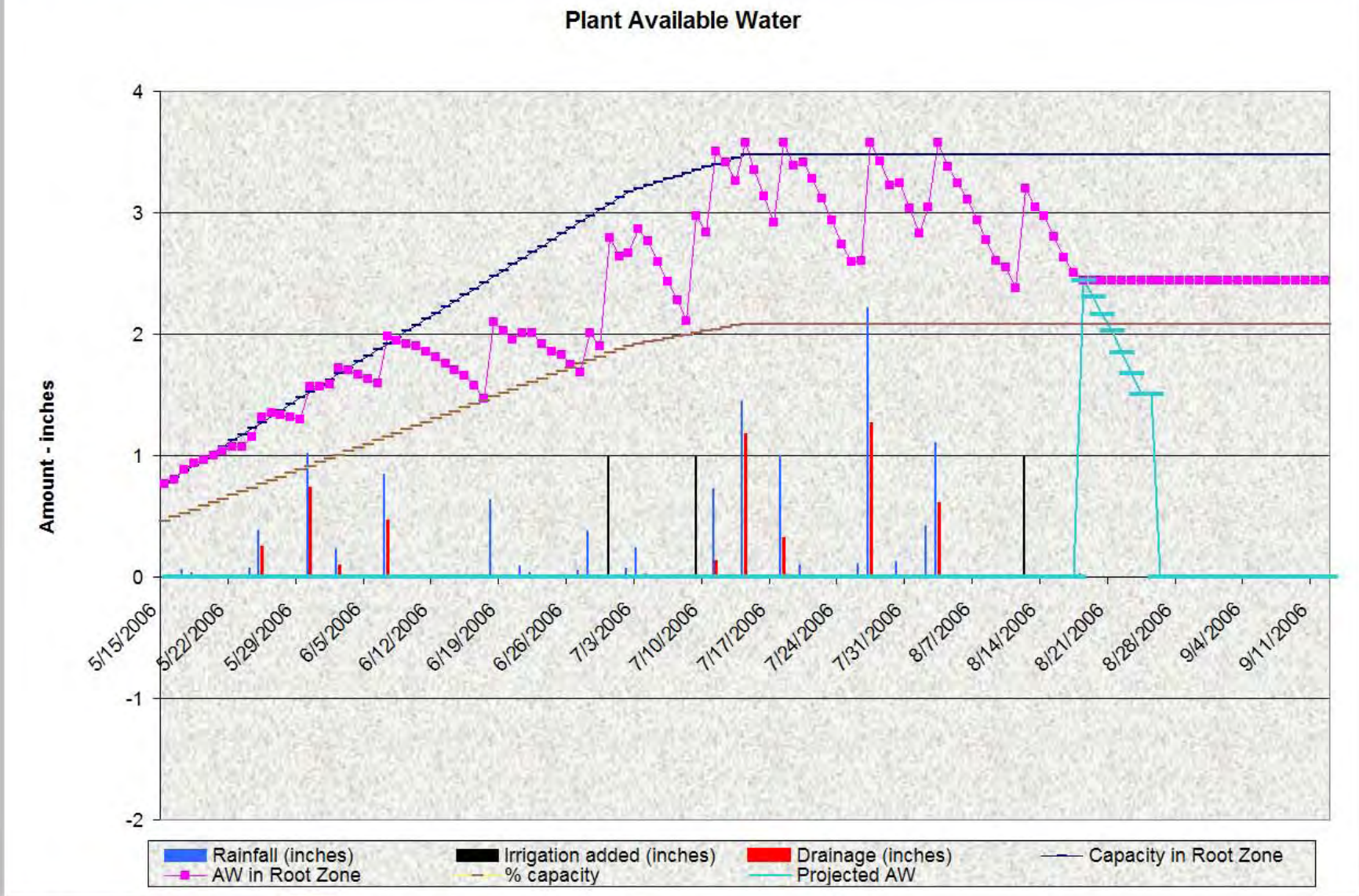
start Microsoft Power... Microsoft Excel -... 10:39 AM

Microsoft Excel - Irr_cbook_const_2006_test

File Edit View Insert Format Tools Chart Window Help

Type a question for help

109%



Legend

Calculations | Soil Moisture | Cumulative data | Table1 | Caluations | Crop Tables

Ready

Example Problem

Questions

Summary of Websites

- **Irrigation Scheduling Checkbook Method – U. of Minnesota Extension**
- http://www.msue.msu.edu/stjoseph
- **MSU Irrigation Page**
- www.msu.edu/~northco2/irrigation/
- **Michiana Irrigation Scheduler www.agry.purdue.edu/irrigation/IrrDown.htm**
- **MSU Excel Version of Scheduler http://**
- www.agweather.geo.msu.edu/mawn/irrigation/
- **Irrigation Scheduler V 4.0** http://www.agweather.geo.msu.edu/mawn/
- **Michigan NEXRAD Tool**

  www.spatialrainfallconsulting.com/Michigannexrad.html