

Irrigation Scheduling Based on Crop Modeling

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Team of University of Nebraska (UNL)



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Outline

- Crop modeling at UNL
- Irrigation scheduling based on crop models
- Remarks

Models for maize and soybean

- Hybrid-Maize model (Yang et al, 2004, 2006, 2017)
- Maize-N model (Yang et al, 2008, Setiyono et al, 2011)
- SoySim model (Setiyono et al, 2010)
- CornSoyWater (Yang et al, 2016)

Common functions/features:

- Need no info farmers don't know
- Farmers can use them easily, while scientists find them very powerful.
- Simulate daily crop development, biomass growth, crop stage, and final yield.
- Produce both numerical results as well as graphs.
- Scientifically transparent on parameter settings, math functions, and references.
- Tested and validated in reviewed publications
- Complete documentation



<https://hybridmaize.unl.edu/>

[illegible]

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Institute of Agriculture and Natural Resources

HYBRID-MAIZE

NebraskaHybrid-Maize

☰

ABOUT HYBRID-MAIZE

PURCHASE

UTILITIES & OTHER MODELS

MAIZE-N MODEL

⌵

What does the Hybrid-Maize model do?

Hybrid-Maize (current version: **2016**) is a computer program that simulates the growth of a corn crop (*Zea mays* L.) under non-limiting or water-limited (rainfed or irrigated) conditions based on daily weather data. Specifically, it allows the user to:

- Assess the overall site yield potential and its variability based on historical weather data;
- Evaluate changes in attainable yield using different combinations of planting date, hybrid maturity, and plant density;
- Explore options for optimal irrigation management;
- Conduct in-season simulations to evaluate actual growth up to the current date based on real-time weather data, and to forecast final yield scenarios based on historical weather data for the remainder of the growing season.

Hybrid-Maize does NOT allow assessment of different options for nutrient management nor does it account for yield losses due to weeds, insects, diseases, lodging, and other stresses.

Hybrid-Maize has been evaluated primarily in rainfed and irrigated maize systems of the US Corn Belt. Caution should be exercised when applying this model to other environments as this may require changes in some of the default model parameters.

As with all simulation models, **Hybrid-Maize** still represents a simplification of the ‘real-world’ system and, as such, model predictions may differ from actual outcomes. Therefore, the results of model simulations should be considered approximations and not taken as fact.

A new upgrade, version 2016 was released in Sept 2016. [Click here to know What's new.](#)

[Online Purchase](#)

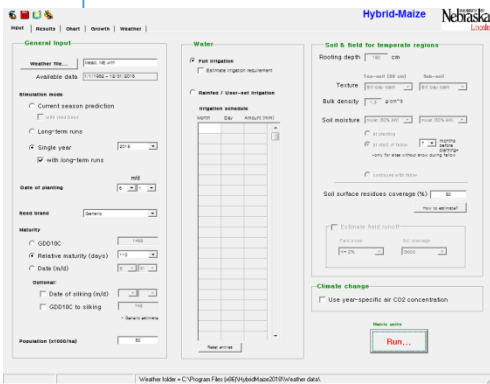
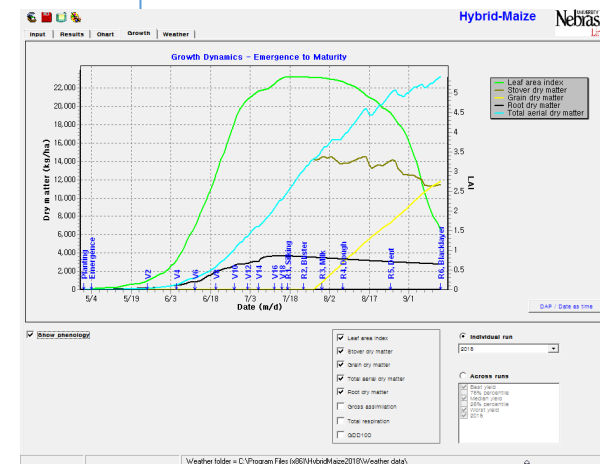
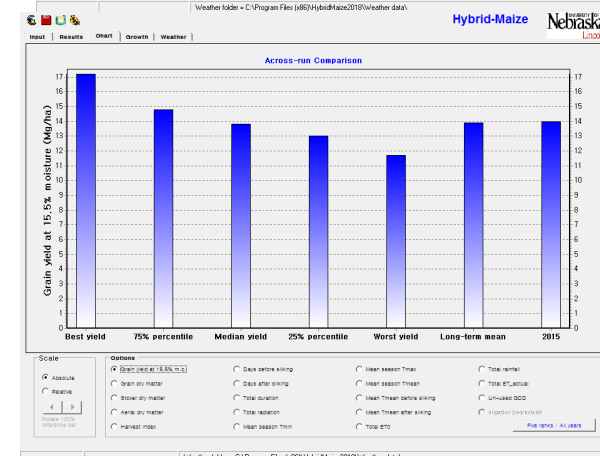
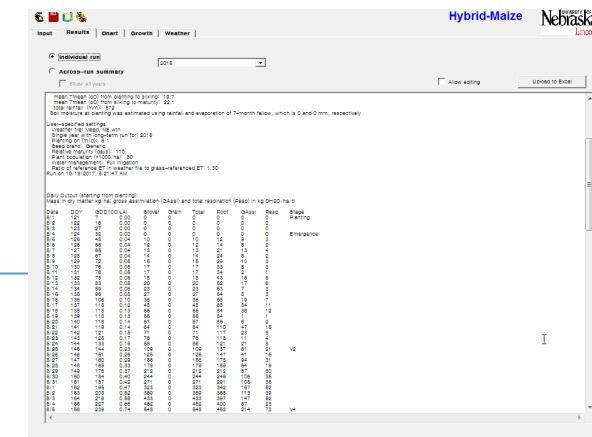
Hybrid-Maize model: inputs and outputs

Inputs

- Daily weather data
- Hybrid maturity
- Planting date
- Plant population
- Soil properties (texture, rooting depth, residues, slope, drainage)

Outputs

- Daily values:
 - GDD (growing degree day)
 - Crop stage
 - Biomass accumulation
 - LAI (leaf area index)
 - Root depth
 - Water use
 - Crop Water stress
- End of season results:
 - Yield, stover biomass
 - Total water use
 - Water balance



SoySim model: growth and yield

<https://soysim.unl.edu/>

Input

Weather

Results

General

Weather File...

Holdrege, NE.wth

Available Data

1988/1/1 to 2009/6/30

Simulation Mode

Current Season

Single Year

Long-term Runs

2008

Start from

Sowing

Emergence

Month

Day

5

10

Cultivar

Custom

Generic

Maturity Group

3.0

Stem Termination

Indeterminate

Plant Population Density (PPD)

at sowing

at emergence

300

x 1000 pl/ha

Early Growth Conditions

Optimum

SoySim

Soybean Growth Simulation Model

UNIVERSITY OF Nebraska Lincoln

Water

Yield is not water-limited

Yield can be water-limited

Estimate Irrigation Requirements

Max. Irrigation Capacity

38.1

mm/day

Irrigation Input

Month	Day	Amount
mm	dd	mm

Use Calibration

Max. LAI

m2/m2

Max. TDM

Mg/ha

Yield

Mg/ha

Soil

Max. Rooting Depth

m

Texture

Initial Moisture

Top-soil


Sub-soil

Unit

Metric

English

Run



Weather Folder = C:\SoySim2014\Weather\Holdrege, NE.wth

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SOYSIM - SOYBEAN GROWTH SIMULATION MODEL

Nebraska

SoySim - Soybean Growth Simulation Model

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SoySim - Soybean Growth Simulation Model



The SoySim model simulates soybean growth on a daily basis from emergence to full maturity (R8). This version of the program simulates soybean yield potential and water use plus irrigation requirements under non-limiting conditions, assuming both optimal nutrient supply and no yield losses from abiotic and biotic factors.

SoySim had been validated at irrigated research and field sites in Nebraska, Iowa, and Indiana at which agronomic inputs were optimized to allow a full expression of yield toward yield potential. The results indicated that the model was able to simulate above ground and seed dry matter with reasonable accuracy compared to other existing models. SoySim achieved desirable results even with far less cultivar-specific input parameters as compared to other models

More information for the model is provided in the [SoySim User Manual](#)

PURCHASE SOYSIM

Maize-N: N fertilizer rate for maize

<https://hybridmaize.unl.edu/Maize-N>

Input setting

Results

Weather data

Weather file Lincoln, May 31.wth
29 years of data included.
Weather data end on: 5/31/2015

The maize crop

☒ Irrigated ☐ Rainfed

Maturity ☒ CRM, days 110
☐ GDD10C

Date of planting (actual or scheduled) 5/ 1/2015

Plant population, x1000/ha 80

Price of maize per Mg 250

☐ Average yield of last 5 years, Mg/ha 12

Last crop

Type of crop Corn

Economic yield, Mg/ha 12

Total N applied, kg/ha 100

☐ User-set N fertilizer recovery rate, % 40

Date of maturity (approximate) 9/15/2014

Amount of crop residue left in field All

Root-zone soil moisture at crop maturity, % of field capacity 50%

N fertilizer

☒ N fertilizer already applied

Fertilizer Urea

N content, % 46
Price per Mg 300

Dose	Date	Amount, kg N/ha
1	5/ 1/2015	50
2	5/31/2015	0
3	6/ 7/2015	0
4	6/14/2015	0
5	6/21/2015	0
6	6/28/2015	0
7	7/ 5/2015	0
8	7/12/2015	0

To be applied

Fertilizer Urea

N content, % 46
Price per Mg 300

N from irrigation water, kg/ha 10

☐ User-set overall N recovery rate, % 40

☐ Applied slow release N

Date 5/ 1/2015
Amount, kg N/ha 0

Estimate N rate

Metric units

Tillage

Type of tillage Plow/disk

Date of operation (actual or scheduled) 4/20/2015

Soil

Top-soil organic matter content, % 1.5

Bulk density, g/cm3 1.3

Average rootzone texture Silt clay loam

Soil pH Neutral

Root zone depth, cm 100

☐ Measured root zone soil nitrate

Amount, kg N/ha 50
Date of sampling 4/ 2/2015

Manuring

Type of manure Beef manure

Organic N content, % in drymatter 2.4

Inorganic N content, % in drymatter 0.25

Moisture content, % 81

Fresh weight, Mg/ha 5

Date of application (actual or scheduled) 4/ 9/2015

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Nebraska Hybrid-Maize Maize-N model

ABOUT HYBRID-MAIZE PURCHASE UTILITIES & OTHER MODELS MAIZE-N MODEL

Maize-N Model

Purchase Maize-N

Maize-N is a computer program that simulates fertilizer requirement for Maize crop grown under intensive management.

- Assess the overall site yield potential and its variability based on historical weather data;
- Evaluate attainable yield, N uptake, and fertilizer N required based on climatic and management factors such as planting date, hybrid maturity, and plant density, N application method and timing, manuring, and soil characteristics.



The estimation of N fertilizer requirement in Maize-N is based on user input information on the current maize crop, last season crop, tillage and crop residue management, basic soil properties, fertilizer management and manuring, and long-term weather data of the field. The program first simulates maize yield potential (i.e., maximum yield with optimal water and nutrient supply and without stresses from diseases, insects and pests) and its year to year variation. It then simulates mineral N released from mineralization of soil organic matter, crop residues (roots and straw or stover) and manures. The program can also estimate recovery efficiency of applied N fertilizers. Finally, it estimates the economically optimal N rate (EON) of fertilizer for the current maize crop.

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CornSoyWater: irrigation scheduling for corn & soybean

cornsoywater.unl.edu

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CornSoyWater
A web-based irrigation tool for corn and soybean producers in Nebraska

Login Form


Your email address

Password

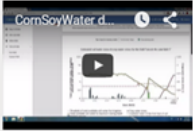
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Forgot password?

SIGN UP



Create an account and add a field



Analyzing the results

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ANDROID APP ON Google play

University of Nebraska Lincoln

Water, Energy and Agriculture Institute

Nebraska Corn Board

Water for Food

Soybeans Nebraska Soybean Board

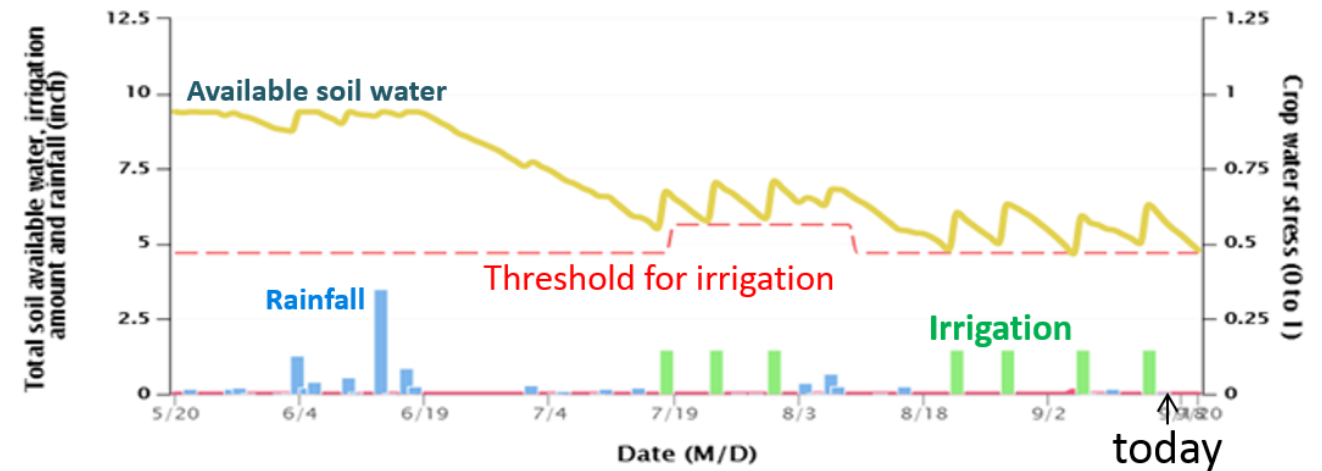


No crop water stress is projected for the next 3 days.

Crop water stress scales from 0 to 1, with 0 being no water stress and 1 being severe water stress. When simulated water stress has occurred or is predicted to occur within next three days, irrigation is recommended if no substantial rainfall is forecasted.

Time frame for showing results: ☐ For the last 7 days ☒ From planting date

Estimated soil water status & crop water stress for the field "HY"



Irrigation recommendation is nothing but to know:

- How much water is current in the soil rooting depth
- Threshold of water depletion for starting irrigation
- How many days it can go before next irrigation

Routine for irrigation decision making

- Get up
- Check weather on TV or internet
- Dress up for field work.
- Fire up the pickup, and drive to the field.....
- Walk into the field...
- Check plants, soil; walk around, look around...
- Make a decision: irrigate or not

How farmers determine when to irrigate

Table 22. Methods Used in Deciding When to Irrigate: 2013

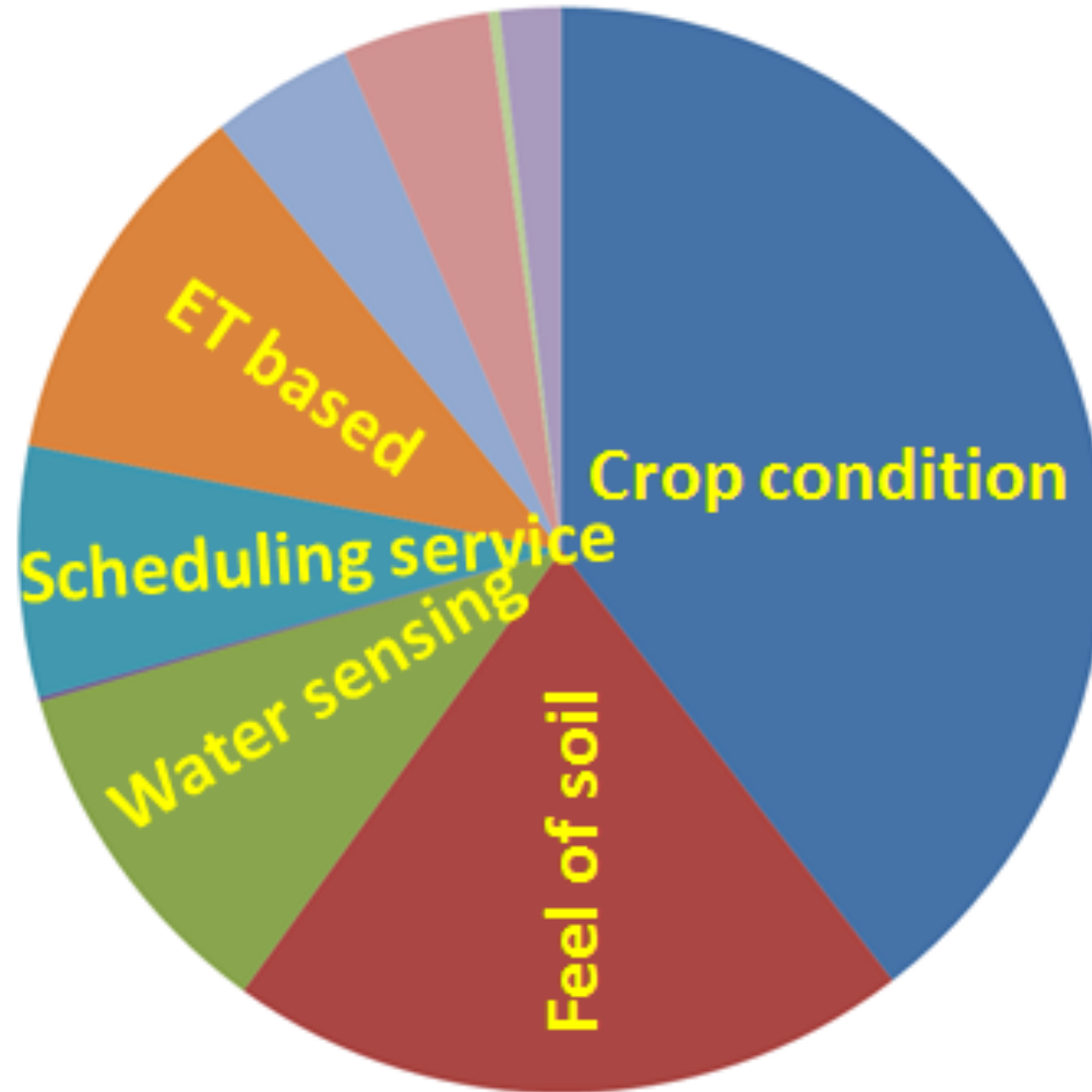
[Excludes institutional, research, and experimental farms. For meaning of abbreviations and symbols see introduction.]

Geographic area	All farms	Fa				
		Any method	Condition of crop	Feel of soil	Soil moisture sensing device	Plant moisture sensing device
United States	229,237	229,237	179,490	90,361	22,656	3,669
Alabama	1,022	1,022	919	426	70	1
Alaska	181	181	150	94	15	7
Arizona	4,380	4,380	3,171	1,964	174	21
Arkansas	4,212	4,212	3,978	1,452	222	53
California	44,347	44,347	33,163	18,097	7,429	2,127
Colorado	12,501	12,501	8,270	4,229	673	78
Connecticut	715	715	641	340	33	11
Delaware	396	396	354	192	60	10
Florida	8,120	8,120	6,865	2,971	803	181
Georgia	3,545	3,545	3,128	1,401	309	22
Hawaii	1,919	1,919	1,628	650	53	11
Idaho	14,092	14,092	10,025	5,867	521	61
Illinois	1,807	1,807	1,692	801	104	14
Indiana	1,893	1,893	1,770	845	151	29
Iowa	1,090	1,090	1,007	502	128	6
Kansas	5,243	5,243	4,340	1,646	596	50
Kentucky	1,212	1,212	1,046	465	80	9
Louisiana	2,130	2,130	1,936	695	62	17
Maine	946	946	818	352	19	11
Maryland	890	890	817	524	86	11
Massachusetts	1,398	1,398	1,233	739	122	-
Michigan	3,662	3,662	3,172	2,111	318	28
Minnesota	2,162	2,162	1,924	1,135	246	34
Mississippi	1,843	1,843	1,684	842	203	6
Missouri	2,569	2,569	2,436	1,159	162	22
Montana	7,384	7,384	5,674	2,393	446	26
Nebraska	15,747	15,747	13,491	6,957	3,599	45
Nevada	2,149	2,149	1,170	578	53	12
New Hampshire	528	528	483	262	32	1
New Jersey	1,255	1,255	1,118	569	175	36

Methods:

- Crop condition
- Feel of soil
- Soil moisture sensing
- Plant moisture sensing
- Scheduling service
- ET-based water use
- Personal calendar
- Computer model
- Look at neighbors

Nebraskan ways of determining when to irrigate



Challenge for making good decision on irrigation

- Get to the field
- Know how many spots to check
- Have knowledge and experience of:
 - judging **available** water in soil and how many days it can carry on.
 - detecting early crop water stress
 - crop water use in relation to crop stage
 - blend weather forecast into the decision.



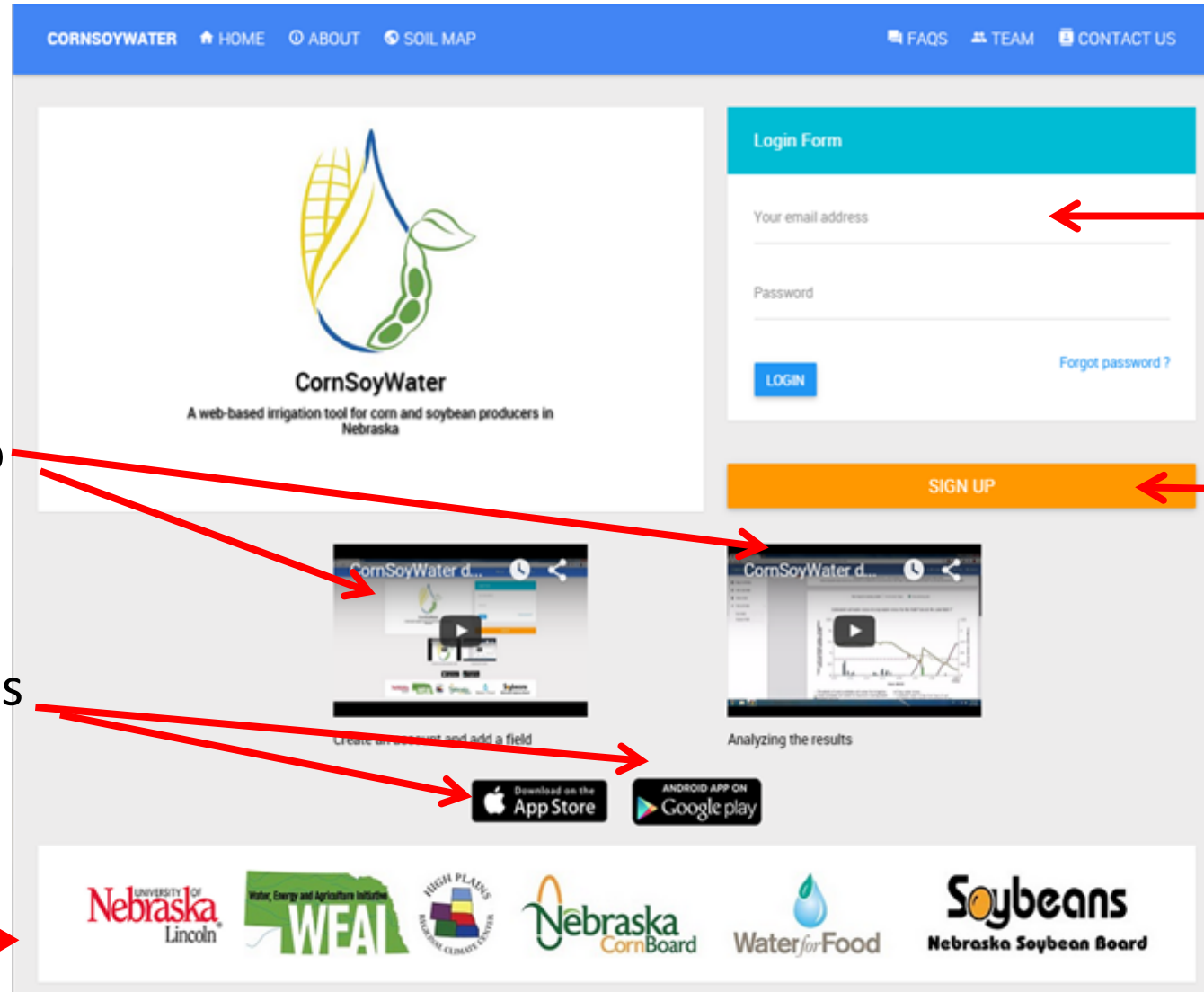
It is a challenge every day, every field, and every season!

Conventional methods are:

- Empirical
- Not quantitative
- Depends much on experience
- Either too early, too much, or too late
- Time and label consuming, not fun!



CornSoyWater: model-based irrigation decision support for farmers



youtube demo

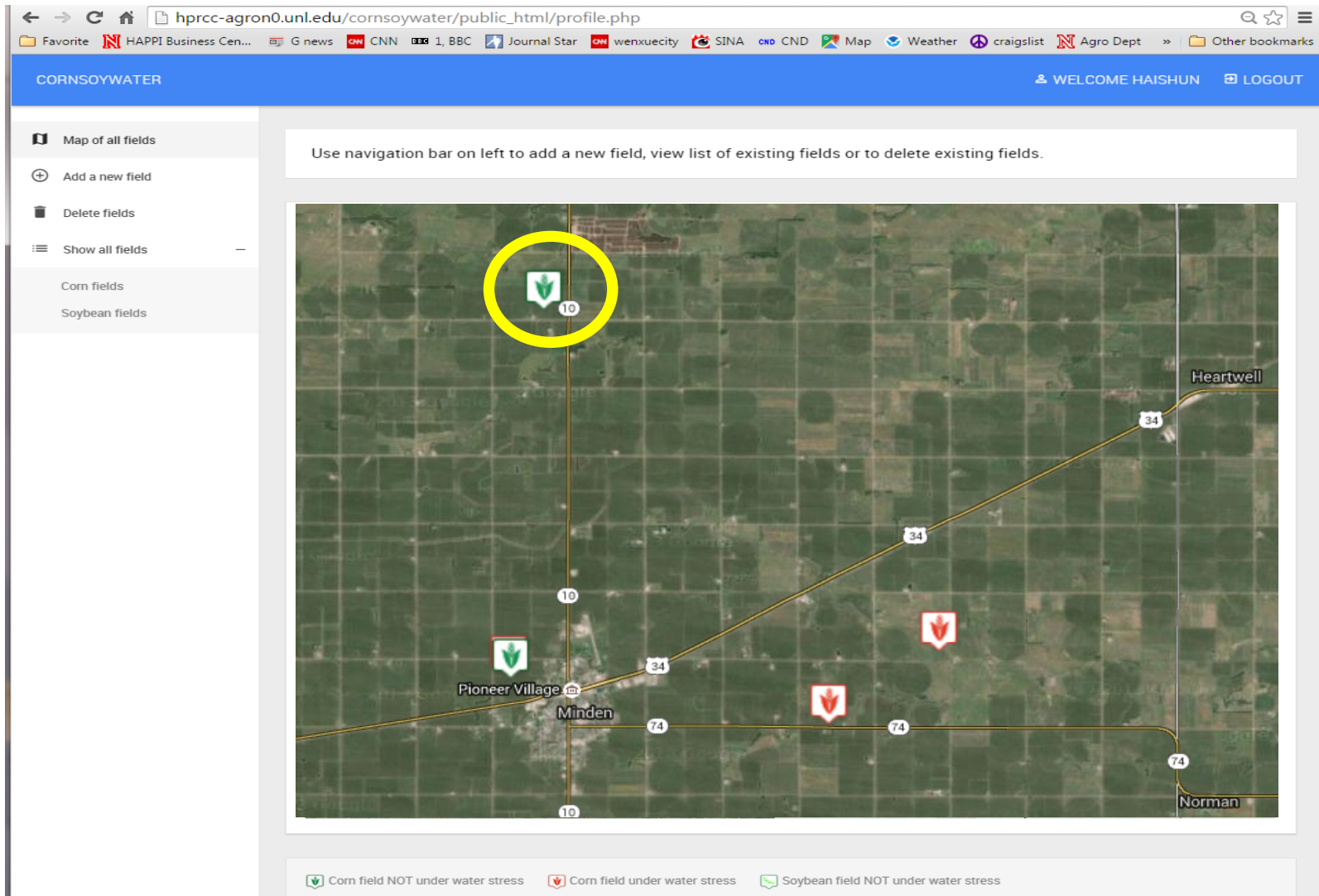
Smartphone apps

Funding support

Sign in

Sign up (free)

Upon log in: your fields are shown in green or red



No need for
irrigation



Need for
irrigation

**You know where
you should go
before leaving your
home**

Soil water and crop condition assessment

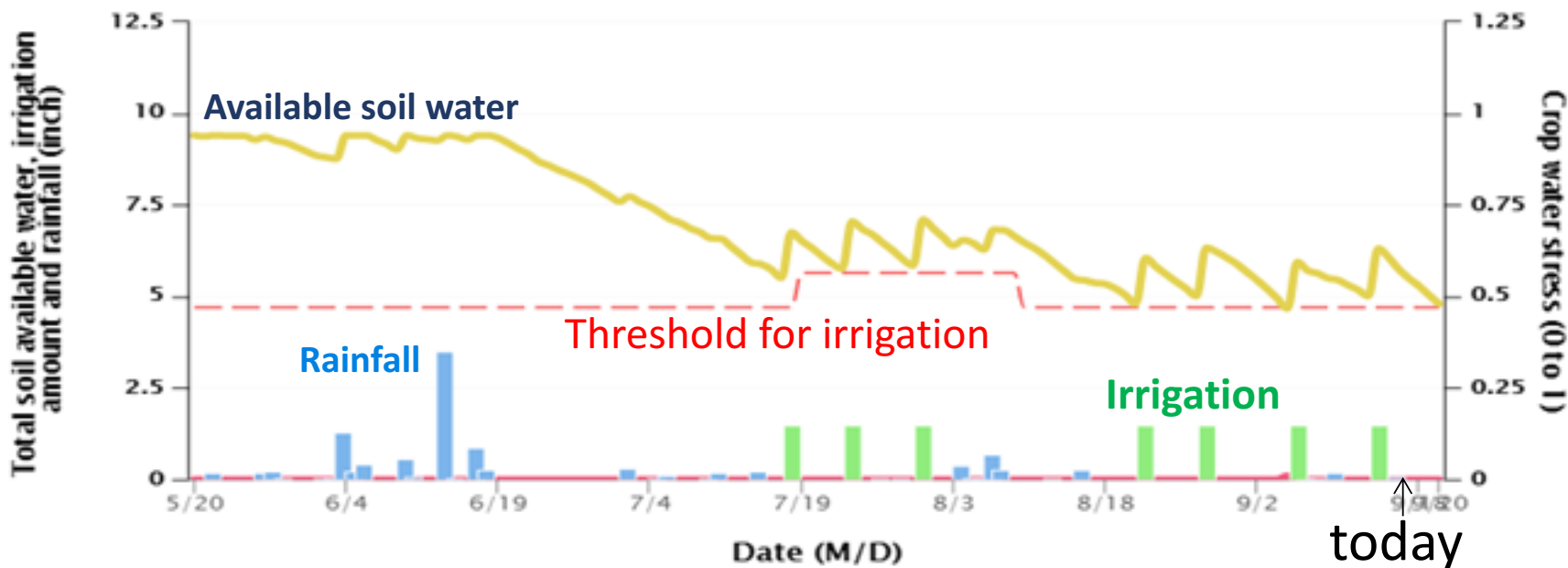


No crop water stress is projected for the next 3 days.

Crop water stress scales from 0 to 1, with 0 being no water stress and 1 being severe water stress.
When simulated water stress has occurred or is predicted to occur within next three days, irrigation is recommended if no substantial rainfall is forecasted.

Time frame for showing results: ☐ For the last 7 days ☒ From planting date

Estimated soil water status & crop water stress for the field "HY"



Irrigation is called if water stress is likely to occur

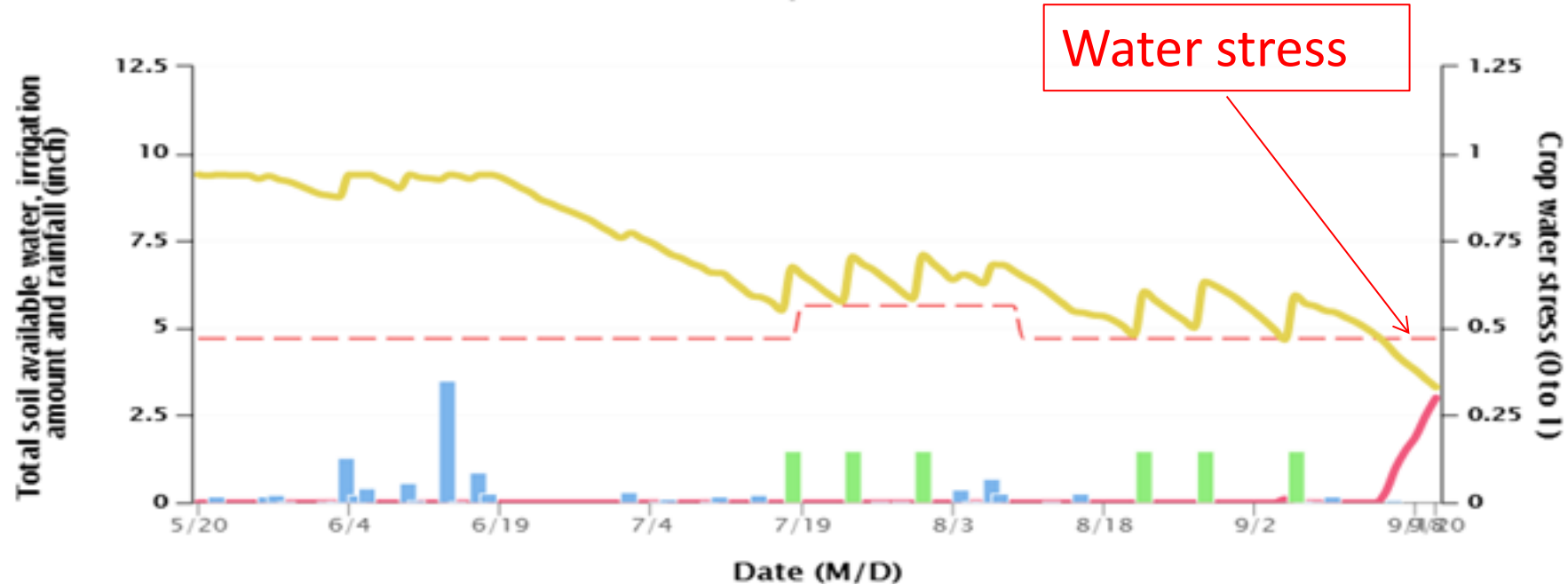


Crop is currently under water stress.
Irrigation is recommended if no significant rainfall is expected for the next 3 days.

Crop water stress scales from 0 to 1, with 0 being no water stress and 1 being severe water stress.
When simulated water stress has occurred or is predicted to occur within next three days, irrigation is recommended if no substantial rainfall is forecasted.

Time frame for showing results: ☐ For the last 7 days ☒ From planting date

Estimated soil water status & crop water stress for the field "HY"



Current crop stage is also predicted

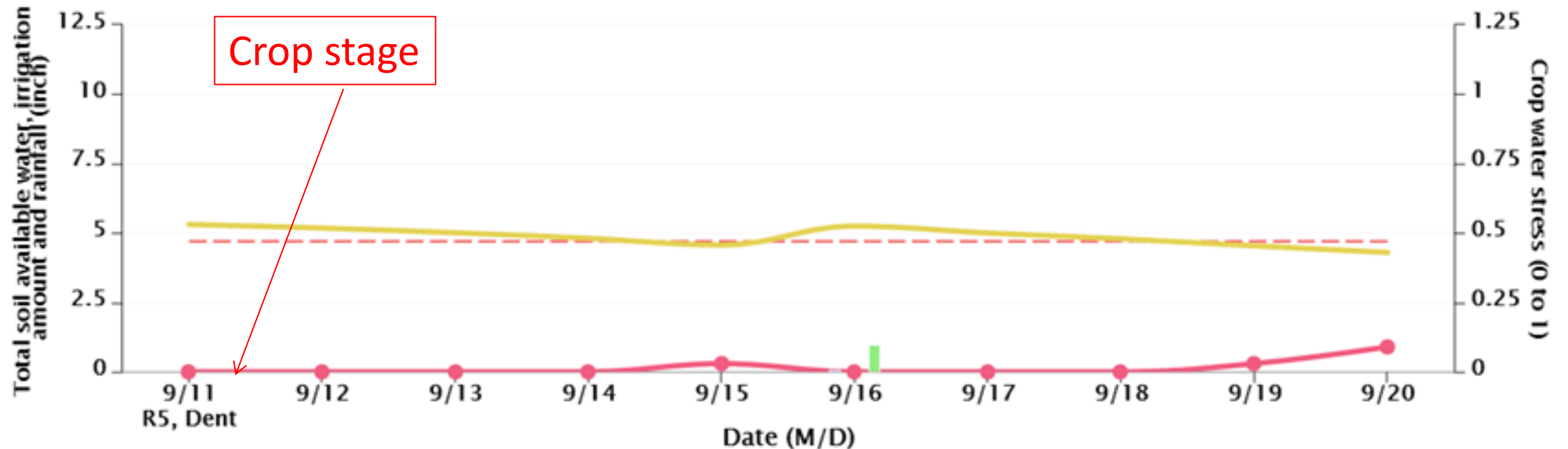


**Crop water stress is projected for the next 3 days.
Irrigation is recommended if no significant rainfall is expected for the next 3 days.**

Crop water stress scales from 0 to 1, with 0 being no water stress and 1 being severe water stress.
When simulated water stress has occurred or is predicted to occur within next three days, irrigation is recommended if no substantial rainfall is forecasted.

Time frame for showing results: ☒ For the last 7 days ☐ From planting date

Estimated soil water status & crop water stress for the field "HY"



Up-to-date soil water balance summary

Results Summary

3.3	Current available water balance down to the maximum soil rooting depth (inch)
9.4	Initial available water down to the maximum soil rooting depth at planting (inch)
11.0	Total rainfall amount since planting (inch)
9.0	Total irrigation amount (inch)
20.0	Water consumption (i.e., total crop ET) since planting (inch)
6.0	Water losses, including canopy interception and drain below the maximum soil rooting depth (inch)

Don't forget to enter your irrigation record!

Irrigation Events

Irrigation Date(MM/DD/YYYY)

Irrigation Amount

ADD

Irrigation Date	Irrigation Amount
07/18/2015	1.5
07/24/2015	1.5
07/31/2015	1.5
08/22/2015	1.5
08/28/2015	1.5
09/06/2015	1.5

Free sign up, easy field registration for
CornSoyWater

Registering a field: using the mouse to mark your field



Tell the program about your field & crop

Field Information	
HY	Field Name
5/20/2015	Date of Planting (MM/DD/YYYY)
115	Relative Maturity (Days)
34	Plant Population (x1000/acre)
60	Soil Rooting Depth (inch)
50	Soil Surface Residues Coverage (%)
1.3	Top Soil Bulk Density
Very wet (100% Available water)	Top Soil (1 foot) Moisture at Planting
Very wet (100% Available water)	Sub Soil (below 1 foot) Moisture at Planting
Loamy Sand	Top Soil (1 foot) Texture
Loamy Sand	Sub Soil (below 1 foot) Texture

- Hybrid maturity
- Date of planting
- Plant population
- Soil rooting depth
- Surface residues %
- Soil texture
- Soil moisture at planting

How CornSoyWater works

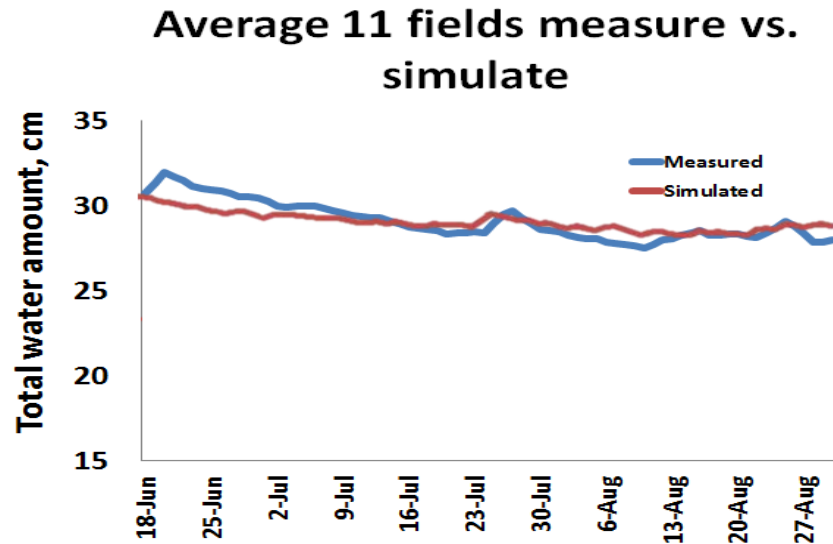
- It selects the nearest weather station for a field, and sets up simulation based on crop and soil info from user.
- Each time one logs in, it runs the model to simulate, in real time with 10-day projection:
 - Crop stage and growth (GDD, LAI, biomass, etc)
 - Crop water use
 - Soil water balance
 - Crop water stress

It calls for irrigation if water stress is likely to occur in coming days.

How good is the simulation?

CornSoyWater uses the Hybrid-Maize model (<http://hybridmaize.unl.edu/>,

Yang et al 2004, 2006, 2014, 2016, 2017; Grassini et al, 2011, 2012; Liu et al, 2015, Meng et al 2015)



Key to good results

- Representative soil texture for the field
- Good rainfall data
- Good irrigation record.

However,

- Don't lose your common sense.
- We continue improving it to make it better every day!

The CornSoyWater project team

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- Greg Kruger (Co-PI), Assistant Professor, Dept of Agronomy & Horticulture
- Jenny Rees (co-PI), Associate Extension Educator
- Ken Hubbard, Professor, SNR and HPRCC.
- Derek Heeren, Assistant Professor, Dept of Biological System Engineering
- Group of senior students of Dept of Computer Sciences

Remarks: two challenges

- Accurate rainfall amount of a field
- Representative soil moisture content of a field

Thanks