Tri-State G&T Irrigation Pumping Optimization for Energy and Water

Webcast A: Irrigation Scheduling Optimization @ 8:30-9:45am MST

Break @ 9:45-10:15am MST

Webcast B: Pump System Optimization @10:15-11:45am MST

February 20, 2019

www.epri.com

Welcome, and thanks for joining us today!

Reminder: please mute your phone when not speaking to reduce background noise.

This webcast is being recorded, including Q&A. By being on this call, you are providing your consent to be recorded.

The webcast recording and PDF of the presentation will be provided to Tri-State for distribution.

Question and Answer:

- Questions are welcome at any time throughout the webcast.
- You may type your question in the chat room if you prefer

Agenda

THURSDAY, FEBRUARY 20, 2019 (ALL TIMES MST)		
TIME	**TOPIC**	**PRESENTER**
8:30 a.m.	**Welcome & Background**	*Myles Jensen, Tri-State G&T*
8:35 a.m.	**Introductions & Learning Objectives**	*Sara Beaini & Micah Sweeney, EPRI*
8:40 a.m.	**Part A - Irrigation Scheduling Optimization**	*Dr. Lameck O. Odhiambo, Steven Melvin, Jonathan Aguilar, Irrigation Innovation Consortium*
9:30 a.m.	**Questions & Discussion**	*All*
9:45 a.m.	**Break**	
10:15 a.m.	**Part B - Pump System Optimization**	*Alex Kramer & Michael Michaud, Hydraulic Institute*
11:05 a.m.	**Adjustable Speed Drives (ASDs) for Energy Efficiency**	*Mark Stephens, EPRI*
11:20 a.m.	**Emerging Technologies**	*Sara Beaini & Micah Sweeney, EPRI*
11:25 a.m.	**Questions & Discussion**	*All*
11:40 a.m.	**Wrap-Up**	*EPRI and Tri-State G&T*

Why are we here?

- Tri-State and Member Systems engaging with our customers
  - Recent challenges for irrigators

- Tri-State experience with EPRI on resources for Motors/Drives/Pumps

- EPRI partners with Hydraulic Institute and Irrigation Innovation Consortium to support experience and resources for irrigation applications

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Objective: Provide Resources on Irrigation Pumping Optimization

Today's Webcast:

- Effective Irrigation Scheduling Practices
- Pump System Optimization for Irrigation
- Operational Costs and Prices: Measuring and Quantifying
- Emerging Energy and Water Efficiency Technology Considerations

Follow-on activities:

- Regional workshop or in-depth webinars
- Irrigation Resources Audit
  - Result: Irrigation Cost Worksheet

Intro to EPRI

ELECTRIC POWER RESEARCH INSTITUTE

BORN IN A BLACKOUT

Founded in 1972 as an independent, nonprofit center for public interest energy and environmental research

New York City, The Great Northeast Blackout, 1965

EPRI'S VALUE

To provide value to the public, our members, and the electricity sector

THOUGHT LEADERSHIP

INDUSTRY EXPERTISE

COLLABORATIVE MODEL

OUR MEMBERS…

- 450+ participants in more than 30 countries
- EPRI members generate approximately 90% of the electricity in the United States
- International funding – nearly 25% of EPRI's research, development, and demonstrations

ELECTRIC POWER RESEARCH INSTITUTE

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Irrigation Practices:

Irrigation Scheduling to Reduce Energy Costs

Irrigation Innovation Consortium

- The **Irrigation Innovation Consortium** (IIC) is a collaborative research effort to accelerate the development and adoption of water and energy efficient irrigation technologies and practices through public-private partnerships.
  - https://irrigationinnovation.org/

- The Consortium has five founding university partners (Colorado State University, University of Nebraska, Texas A&M Agricultural Research, California State University - Fresno, and Kansas State University) and eight founding industry partners.

- The Consortium seeks to address growing water scarcity domestically (e.g. western United States) and internationally by enhancing energy and water use efficiency in irrigated food systems and amenity landscapes.

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Review of Total Energy in Irrigated Agriculture

Total energy use in irrigated agriculture includes:

- Field operations and tillage
- Seed sources
- Chemicals
- Fertilizer
- Irrigation
- Harvest and drying

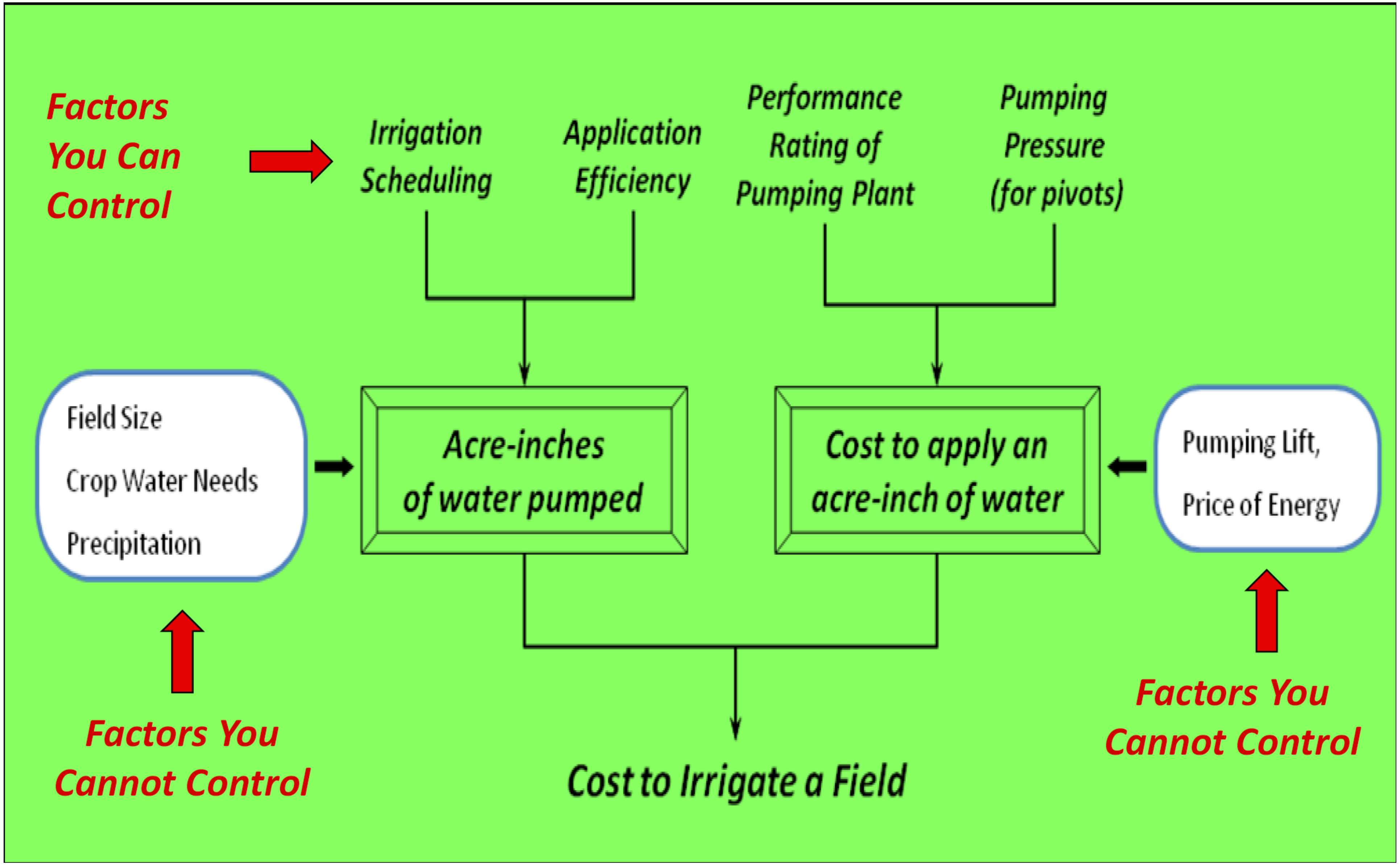
Review of Total Energy in Irrigated Agriculture

Total energy use in irrigated agriculture includes:

- Field operations and tillage
- Seed sources
- Chemicals
- Fertilizer
- Irrigation
- Harvest and drying

Irrigation systems use energy to deliver water from source and distribute it on the field. Thus improvements in the performance of the irrigation system components can result in significant energy savings

Factors Affecting Irrigation Energy Use

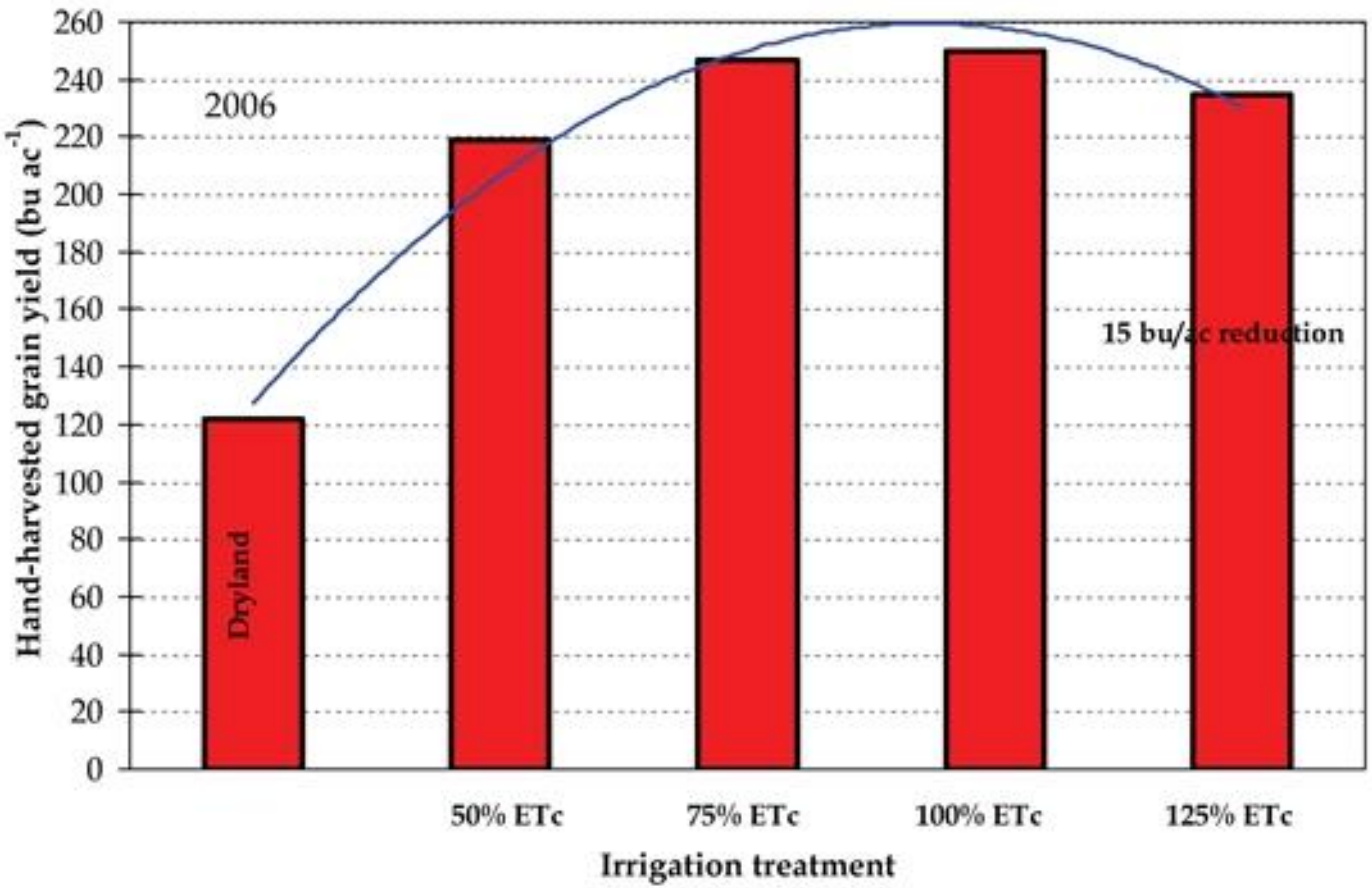


Source: Center Pivot Management Handbook

Why Should I Want To Do Irrigation Scheduling?

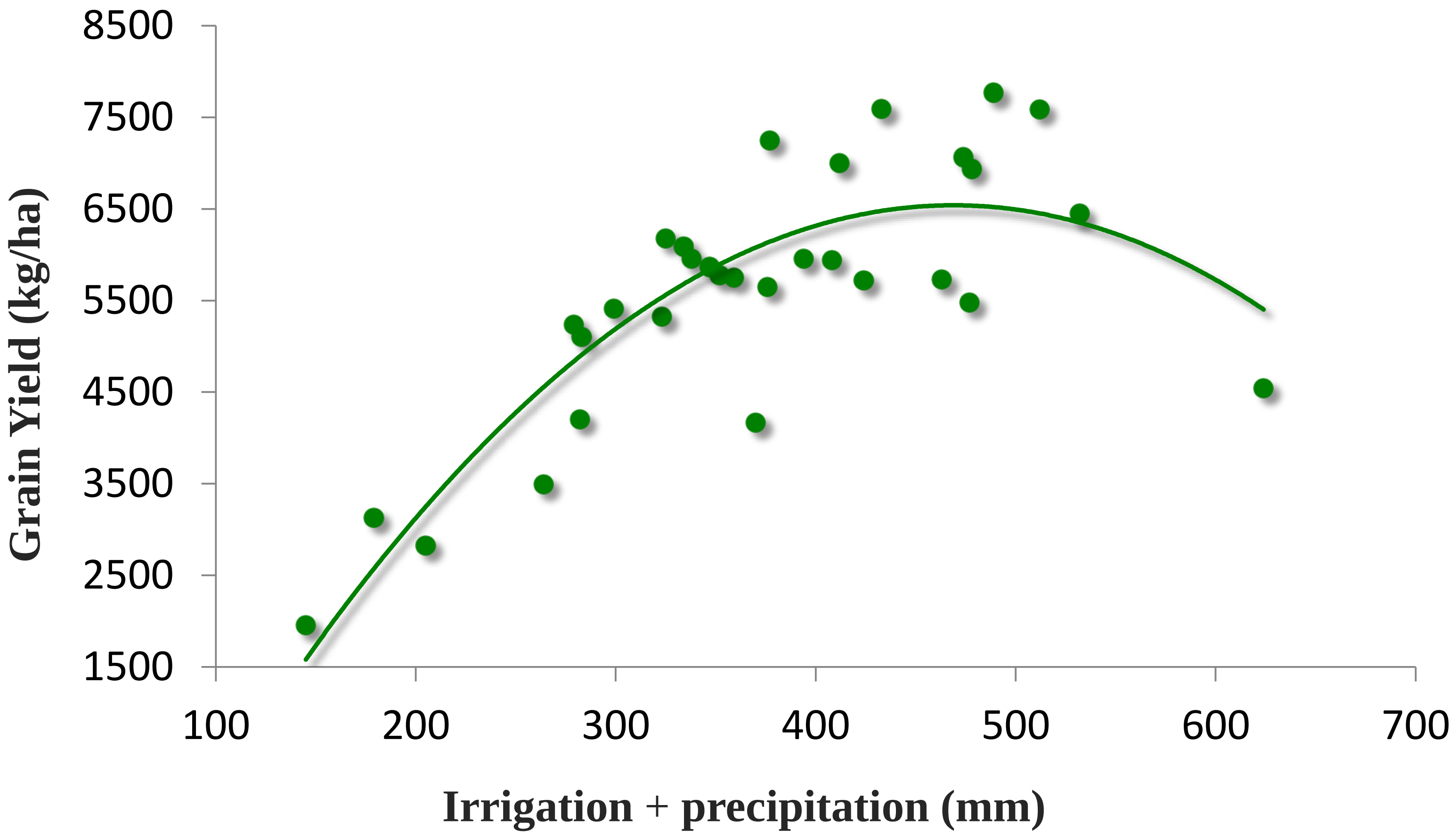
- To know when to start for the season
  - Save 1-2 inches of water
- To know when to irrigate during the irrigation season
  - Variation in rainfall, crop water use, and well capacity-may use more some years and save a lot on other years (-2 to 10 inches)
- To know how soon to begin delaying the start of the next irrigation to use up the stored soil water by crop maturity
  - Save 2 to 5 inches

Corn Yield Response to Total Applied Water



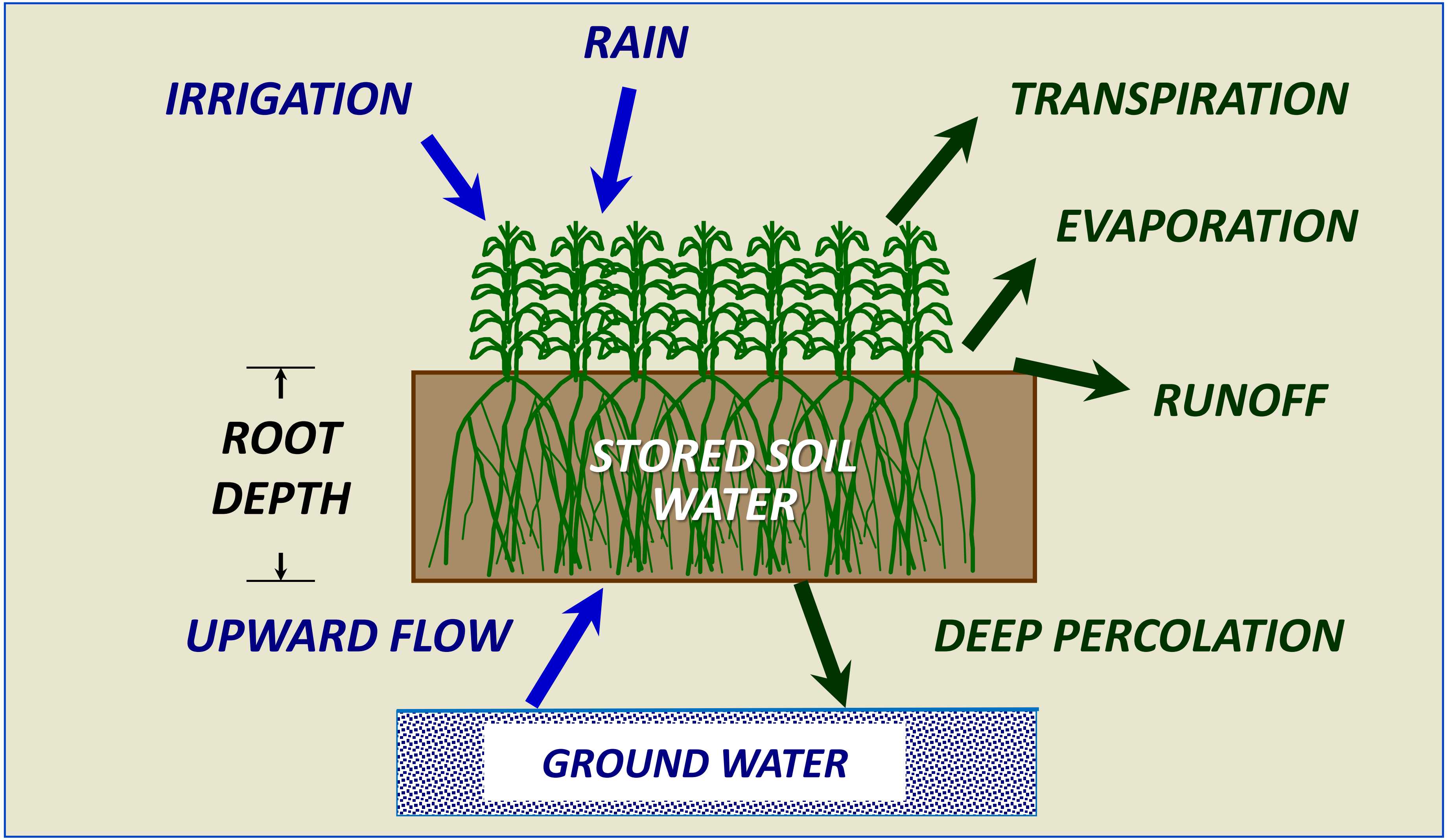
Data from Irmak and Rathje. 2008. Plant growth and yield as affected by wet soil conditions due to flooding or over-irrigation. University of Nebraska NebGuide G1904

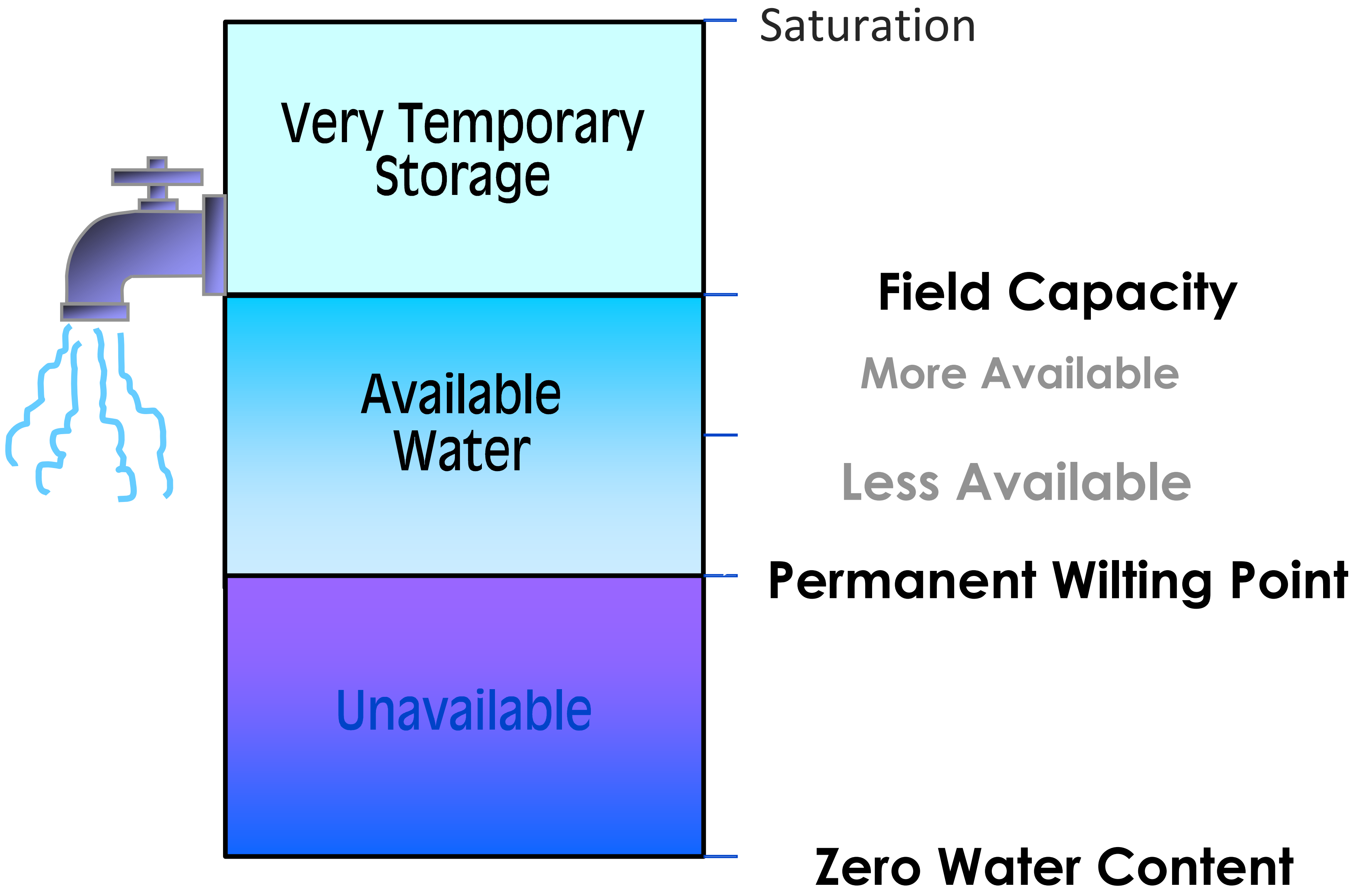
Wheat Yield Response to Total Applied Water

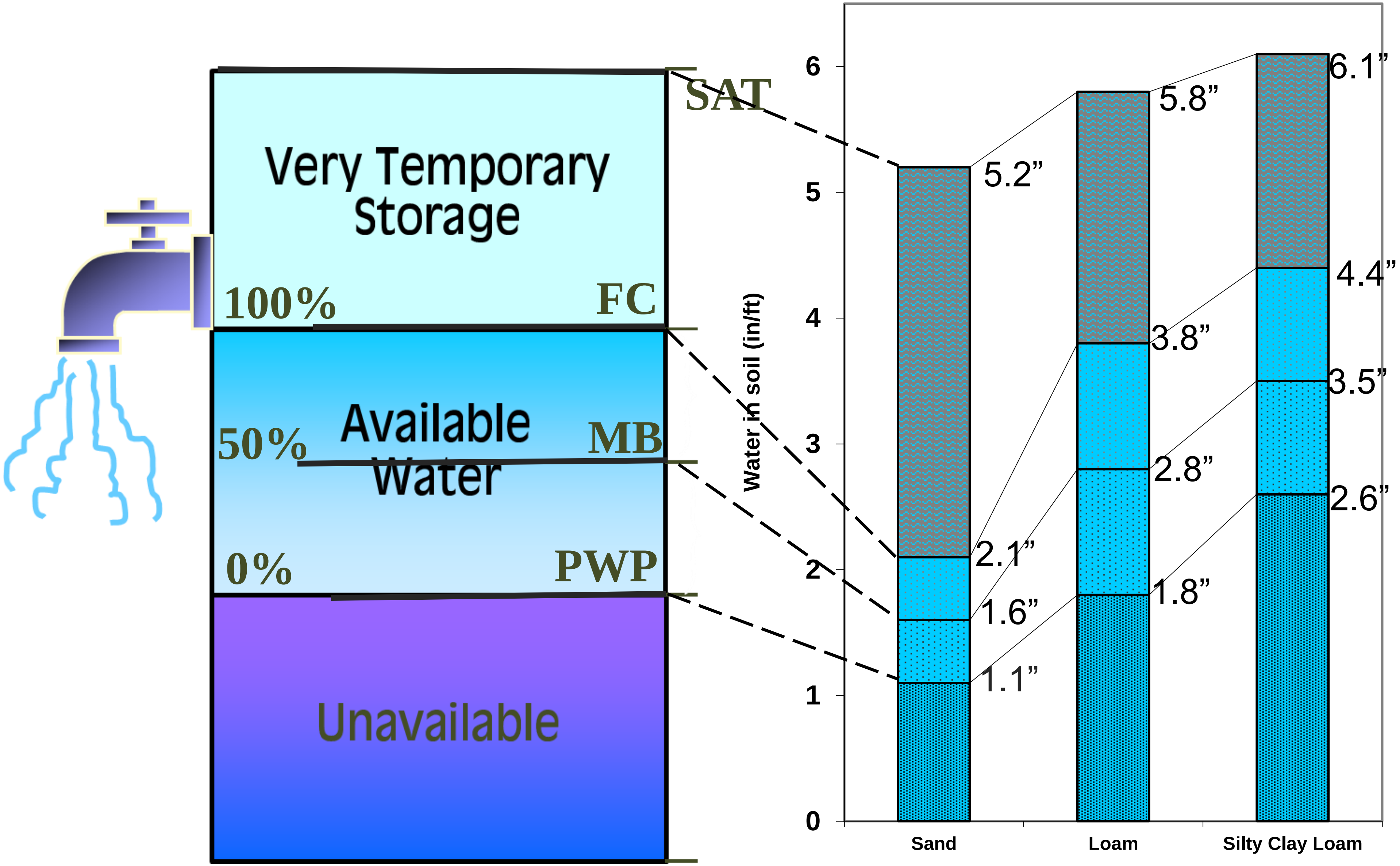


Data from Zhang et al. 2000. Management of supplemental irrigation of winter wheat for maximum profit. Food and Agricultural Organization of the United Nations

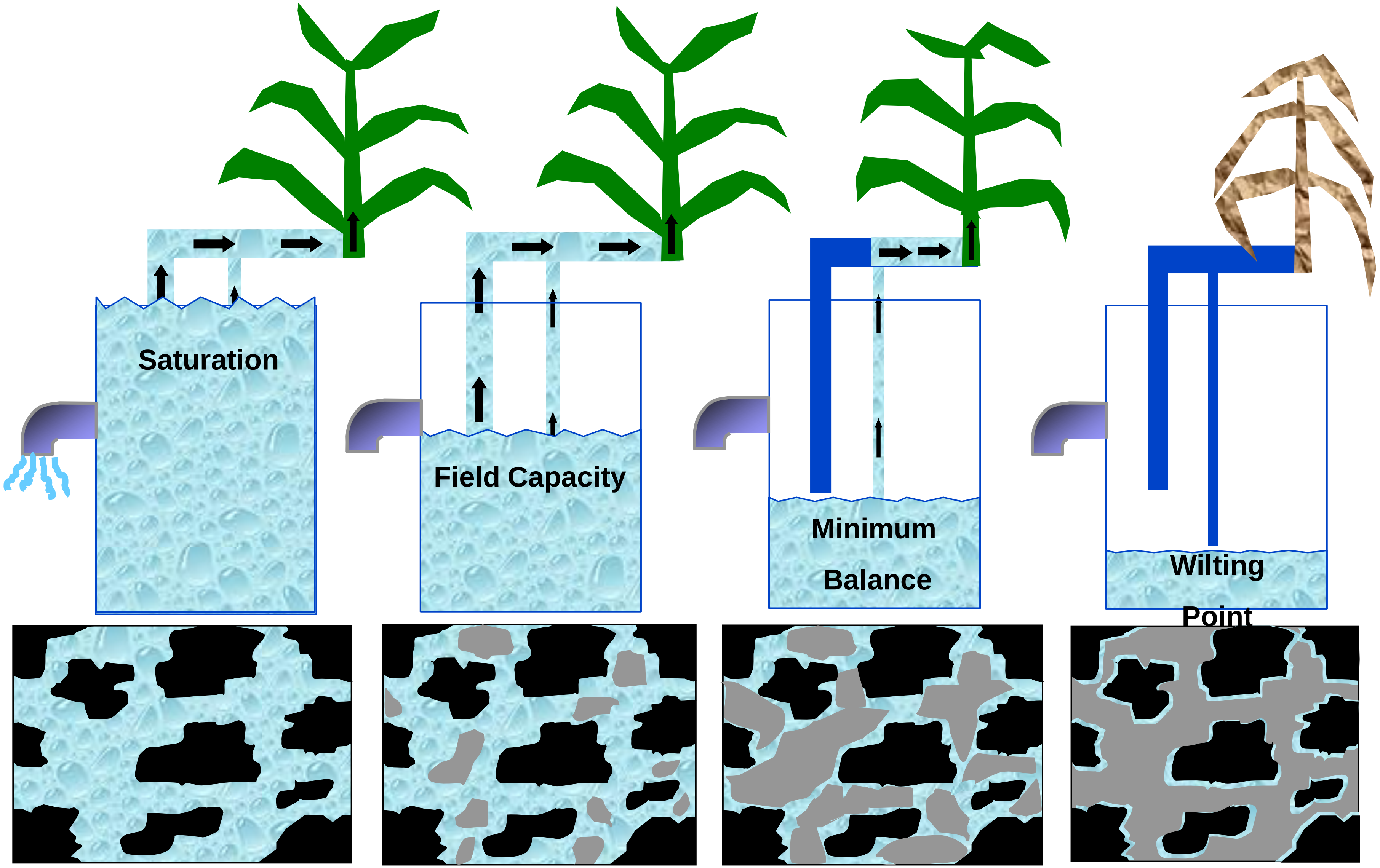
Soil Water Balance




Saturation
Very Temporary Storage
Field Capacity
More Available
Available Water
Less Available
Permanent Wilting Point
Unavailable
Zero Water Content

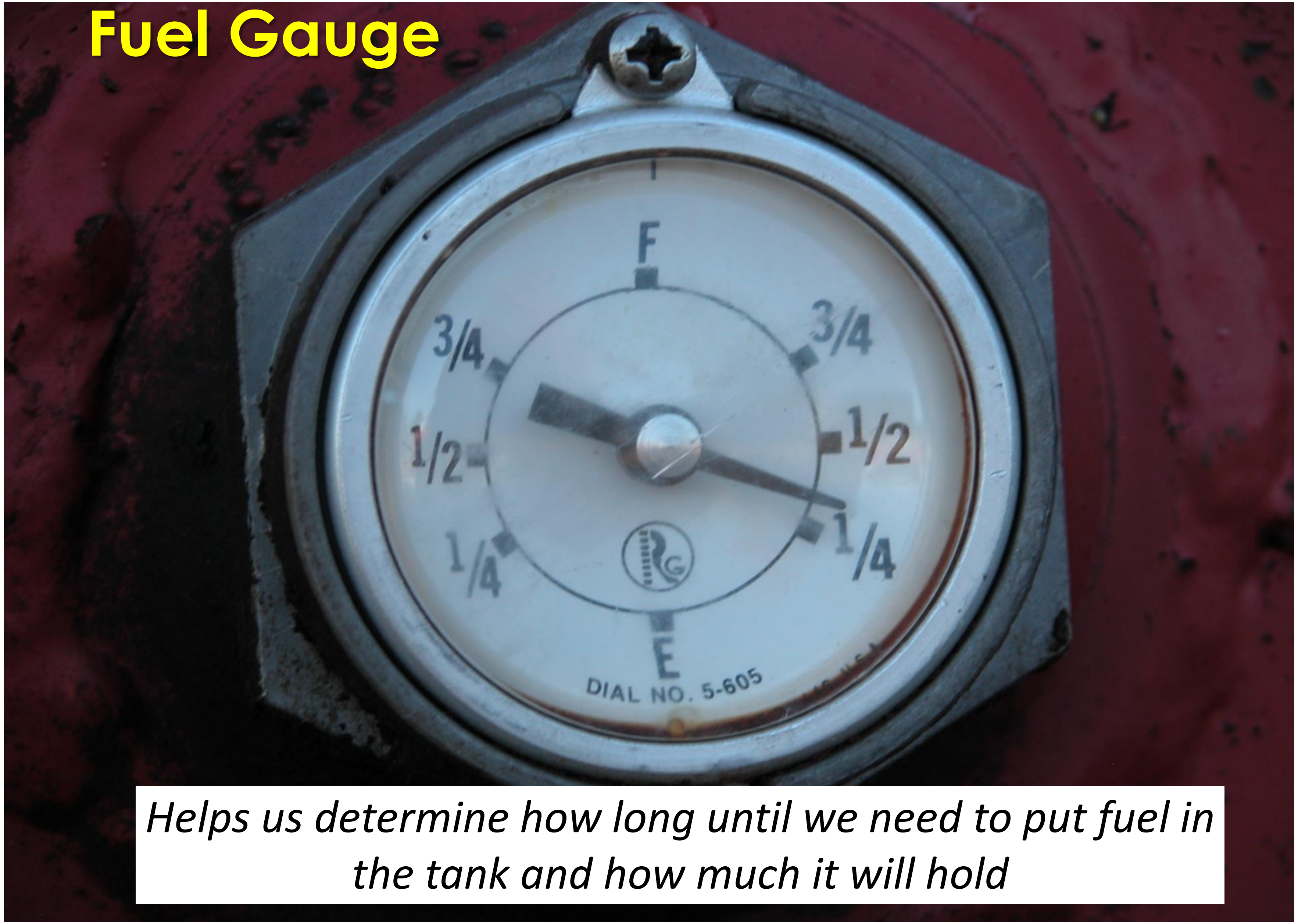


SAT
Very Temporary Storage
100%
FC
Available Water
50%
MB
0%
PWP
Unavailable
Water in soil (in/ft)
6
5
4
3
2
1
0
5.2”
5.8”
6.1”
4.4”
3.8”
3.5”
2.8”
2.6”
2.1”
1.8”
1.6”
1.1”
Sand
Loam
Silty Clay Loam



Source-University of Nebraska Lincoln-Extension

Fuel Gauge



Helps us determine how long until we need to put fuel in the tank and how much it will hold


Soil Water Gauge
F
3/4
1/2
1/4
E
Helps us directly determine how long until we need to irrigate and how much water the soil will hold

Irrigation Scheduling Requires Knowledge of the Following:

- The soil
- The soil-water status
- The crops
- The status of crop stress
- The potential yield reduction if the crop remains in a stressed condition

Irrigation Scheduling Requires Knowledge of the Following:

The soil

Each soil has a different moisture holding characteristics. Such characteristics include soil depth, available water holding capacity per foot of soil, and the relationship between soil water and matrix potential

Available Water and Minimum Water Balance to Maintain Evapotranspiration for Soil Textural Classes

Soil textural classification		*Minimum water balance[1] —% of available water—*			
		100% Available water	*75% Potatoes*	*60% Alfalfa, dry beans, cool season pasture, or small grains*	*50% Corn, warm season pasture, sorghum, soybeans, or sugarbeets*
		in/ft[2]			
Fine sand		1.0	0.8	0.6	0.5
Loamy sand		1.1	0.8	0.7	0.6
Sandy loam		1.4	1.0	0.8	0.7
Silty clay or clay		1.6	1.2	1.0	0.8
Fine sandy loam, Silty clay loam, or Clay loam		1.8	1.4	1.1	0.9
Sandy clay loam		2.0	1.5	1.2	1.0
Loam, Very fine sandy loam, or Silt loam topsoil	Silty clay loam or silty clay subsoil	2.0	1.5	1.2	1.0
Loam, Very fine sandy loam, or Silt loam topsoil	Medium textured subsoil	2.5	1.9	1.5	1.3

[1]Lower minimum water balances may be desirable during some crop growth stages in water-short areas or if pumping costs are high. A minimum water balance of 40 percent is generally recommended for late season water management.
[2]Inches of water per foot of active root zone.

Approximate Water Use Rates by Stage of Growth for Various Crops

Water use rate in/day	*Corn*	*Grain sorghum*	*Soybeans*	*Alfalfa**	*Dry beans*	*Sugarbeets*	*Winter wheat*
0.18						June 15	Spring growth
0.20							
0.22			Full bloom			July 1	
0.24	12 leaf				Rapid vegetative growth		Joint
0.26		Flag leaf	Begin pod				
0.28	Early tassel	Boot		June 15			
0.30	Silking	Half bloom	Full pod	July 1	Flowering and pod devevelopment	July 15	Boot
0.28				August 1			
0.26	Blister	Soft dough				August 1	
0.24	Milk		Seed fill	August 15			
0.22				Sept 1			Dough
0.20	Begin dent						
0.18	Full dent	Hard dough			Pod fill and maturation		

*Alfalfa water use rates should be multiplied by 0.50 during the first 10 days following cutting and by 0.75 for the 10th to 20th days following cutting.

Chart from EC709 Irrigation Scheduling: Checkbook Method

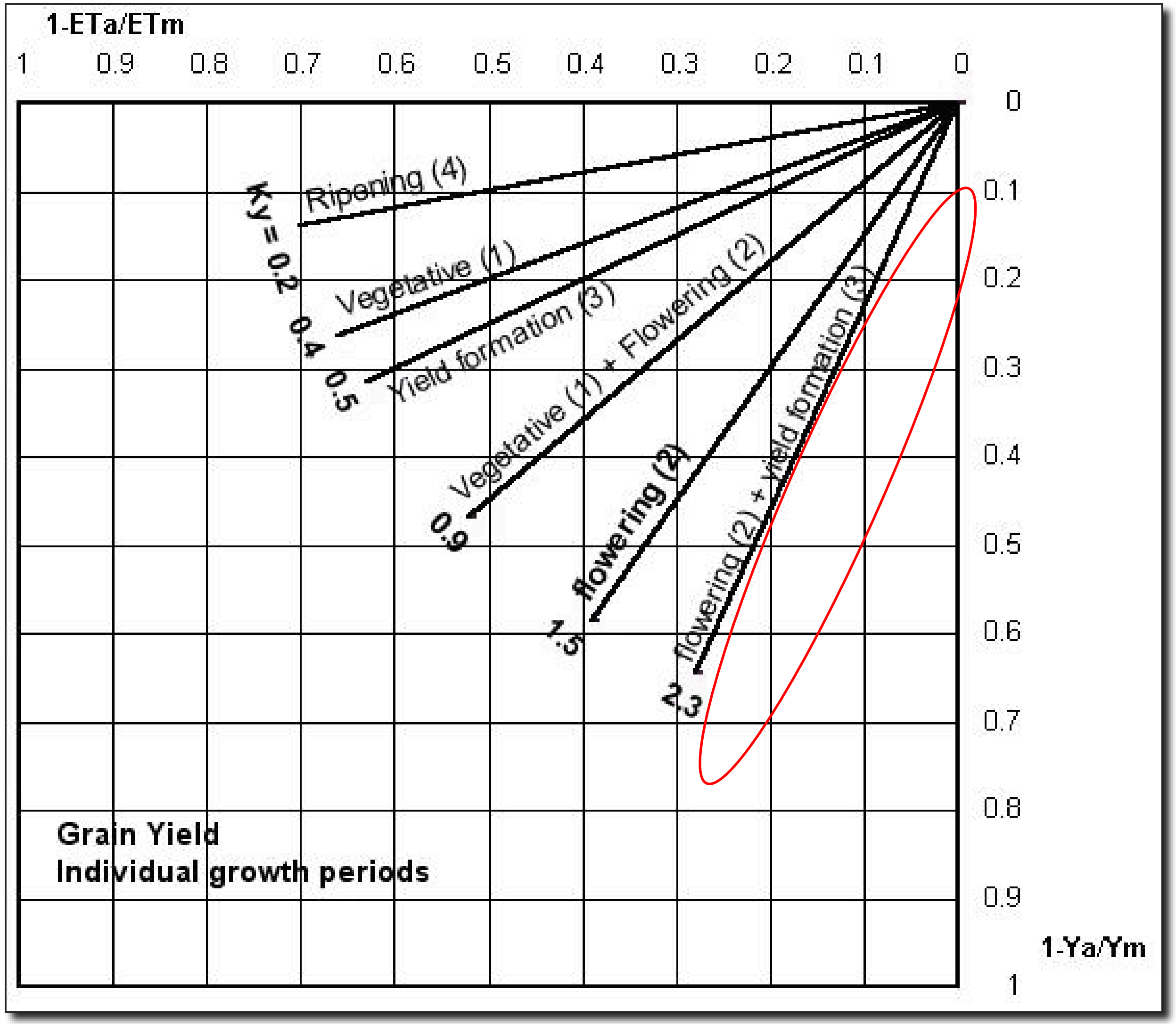
Suggested Root Depth at Various Stages of Growth for Irrigation Scheduling

Root Depth (ft)	*Corn*	*Soybeans*	*Grain sorghum*	*Spring grains*	*Winter wheat*	*Alfalfa*	*Sugarbeets*	*Dry beans*	*Established pasture*	*Potatoes*
1.0	Vegetative	Vegetative	Vegetative					Vegetative		Seeding
1.5								Initial flower pod set		Bloom
2.0	12 leaf	Early bloom			Fall growth		June 1	Beginning pod fill	Cool season	
2.5	16 leaf	Full bloom	Flag leaf	Joint	Spring growth		July 1	Full seed fill		Maturity
3.0	Silking	Pod elongation	Boot	Boot	Joint		July 15		Warm season	
3.5	Blister		Bloom	Flowering	Boot		Aug. 1			
4.0	Beginning dent	Full seed fill	Dough	Dough	Dough	Established stand	Sept. 1			

Irrigation Scheduling Requires Knowledge of the Following:

- The potential yield reduction if the crop remains in a stressed condition

Evapotranspiration Deficit Impact on Corn Yield



Graph from Crop Water Management, AGLW Water Management Group, FAO

Some Basic Techniques that Farmers Use for Irrigation Scheduling

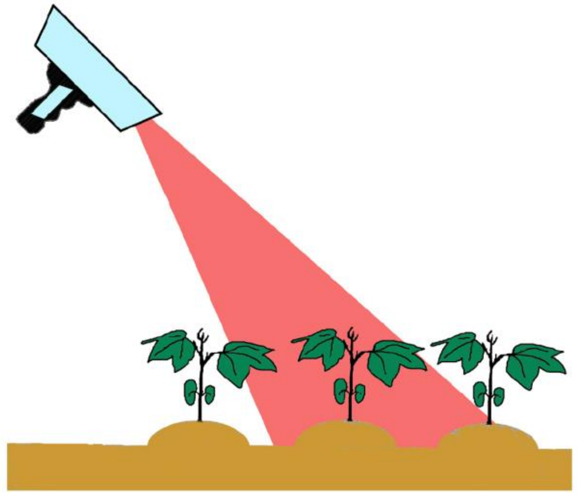
1. Irrigation calendar method
2. Crop stress indicators
3. Soil water tension indicators
4. Soil volumetric water content measurements
5. Evapotranspiration data (ET) for irrigation scheduling
6. Estimate soil-water using accounting approach (check book method)

Some Basic Techniques that Farmers Use for Irrigation Scheduling

Crop stress indicators

These methods do not say how much to irrigate, but only show that the plant is under stress. Stress indicators include:

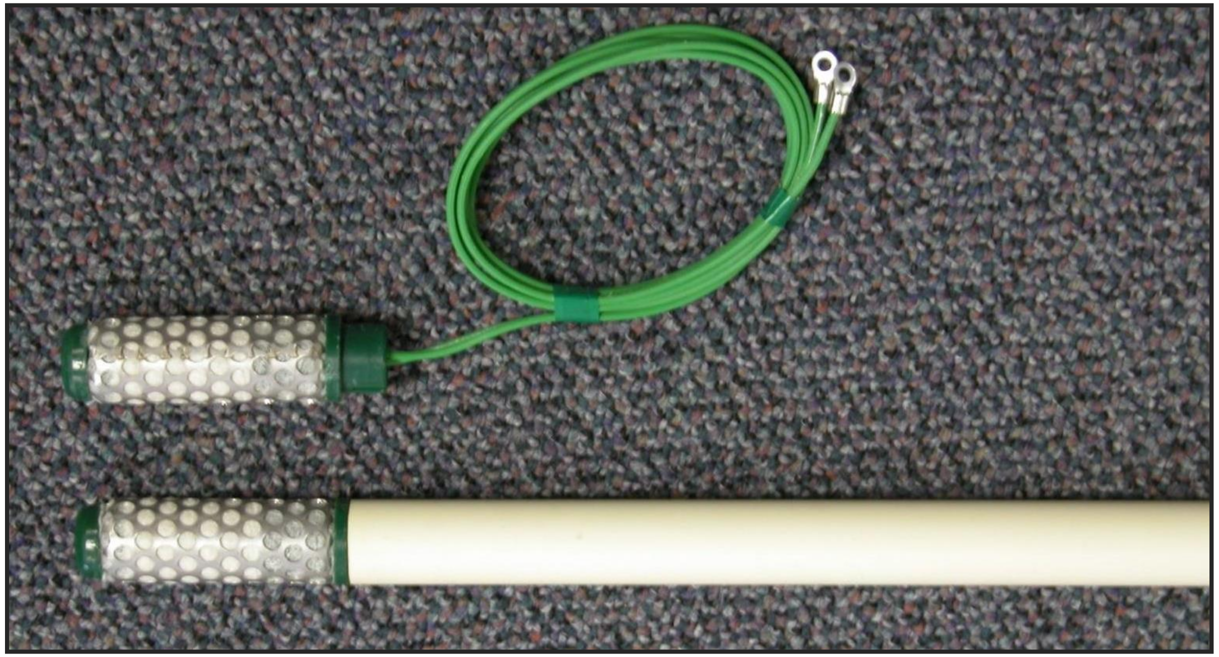
- IRT (Infrared Thermometer)
- Change of color
- Curling of leaves (corn, wheat etc.)



Plant Science Infrared thermometer

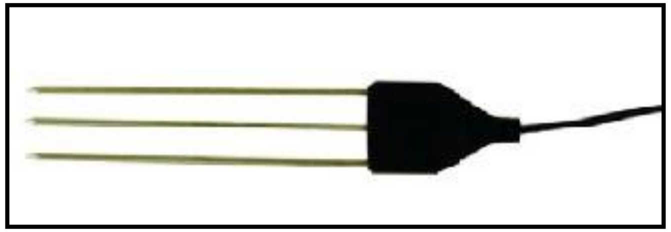
Granular Matrix Sensors

- Soil water potential
- Watermark

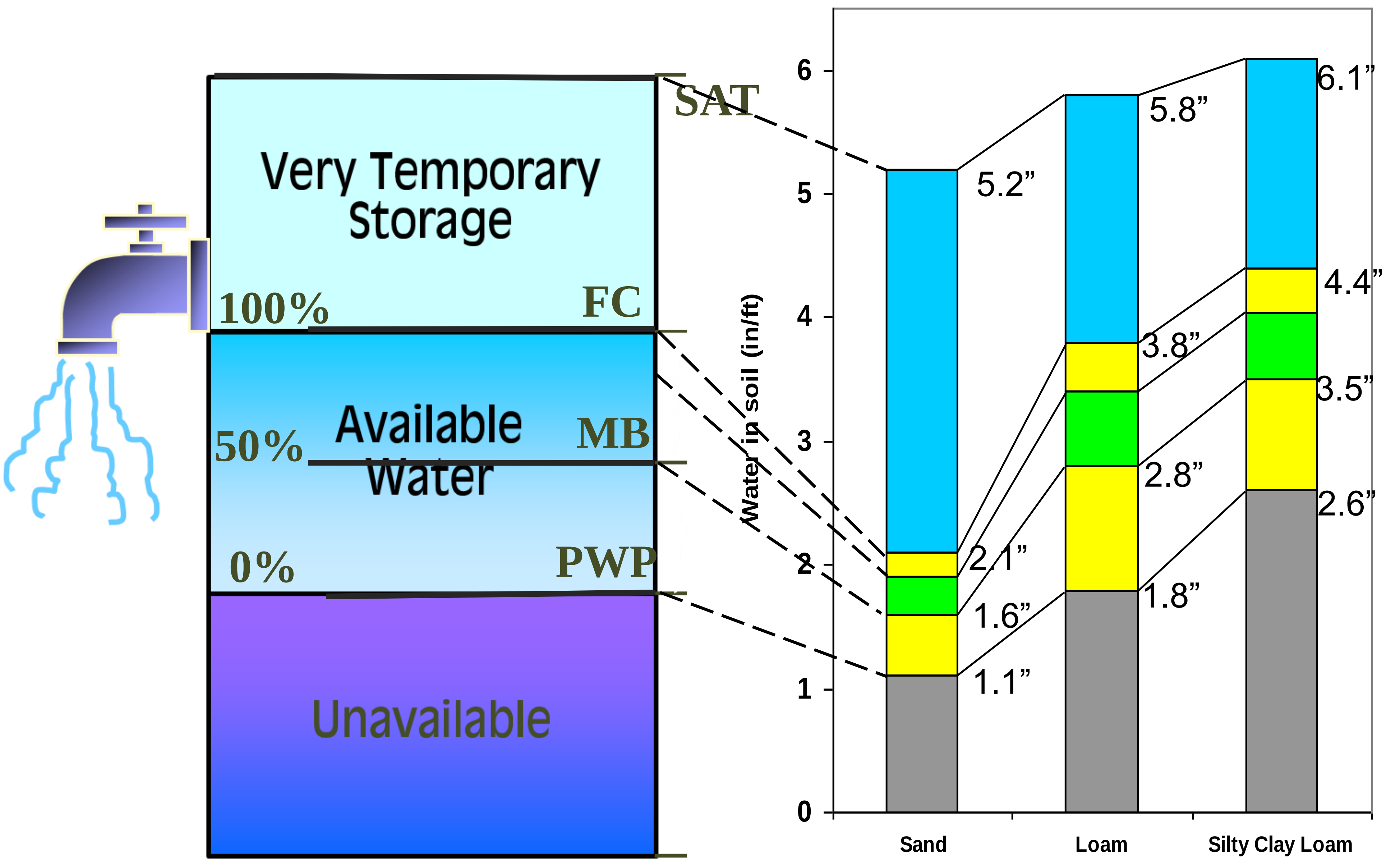


Volumetric Water Content Sensors

- TDR
- TDT
- Capacitance Probes
- Others



- Real-time monitoring
- Can be integrated into apps for pivot monitor and control


SAT
Very Temporary Storage
100%
FC
Available Water
50%
MB
0%
PWP
Unavailable
Water in soil (in/ft)
6
5
4
3
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5.2”
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1.8”
6.1”
4.4”
3.5”
2.6”
Sand
Loam
Silty Clay Loam

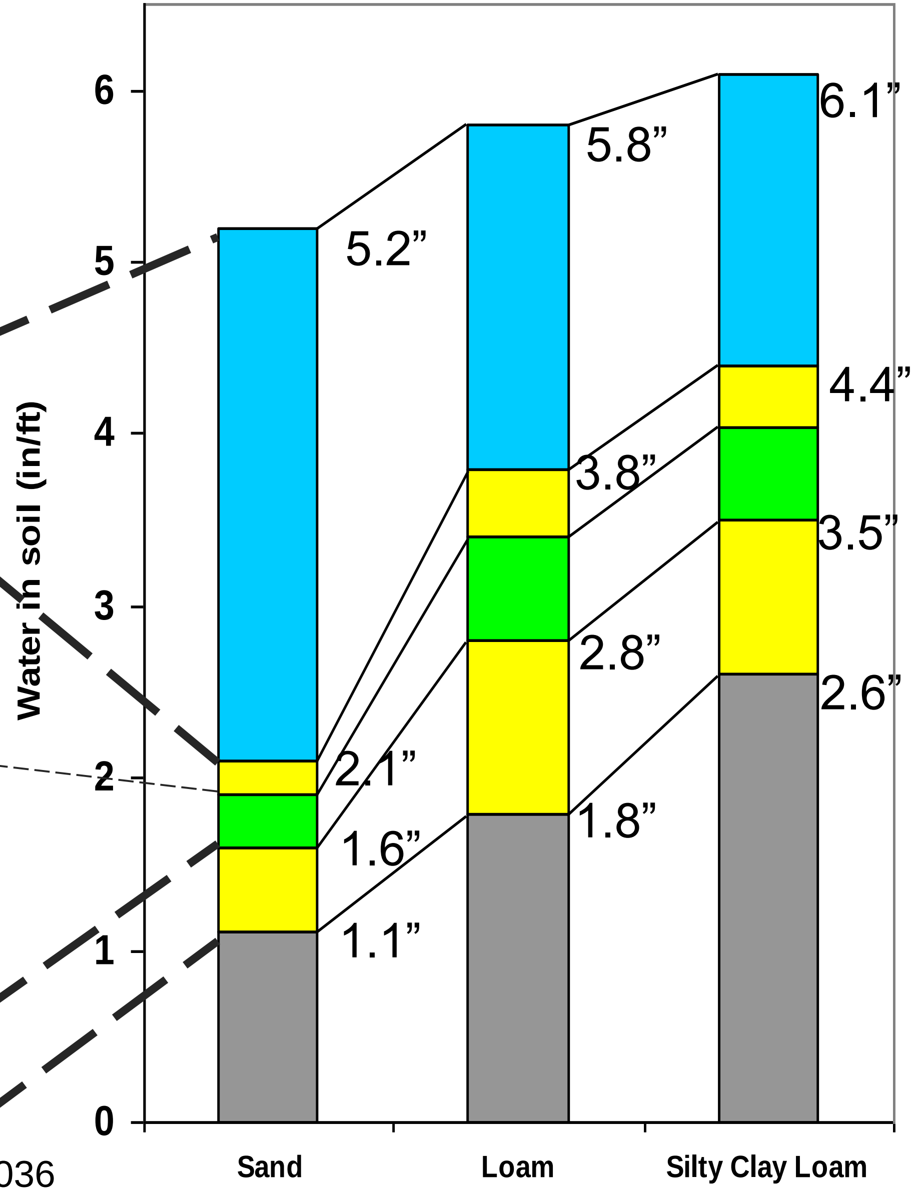
Nebraska Lincoln EXTENSION IANR

Watermark Sensor Chart

Silt Loam

Water Holding Capacity, inches/foot = 2.00

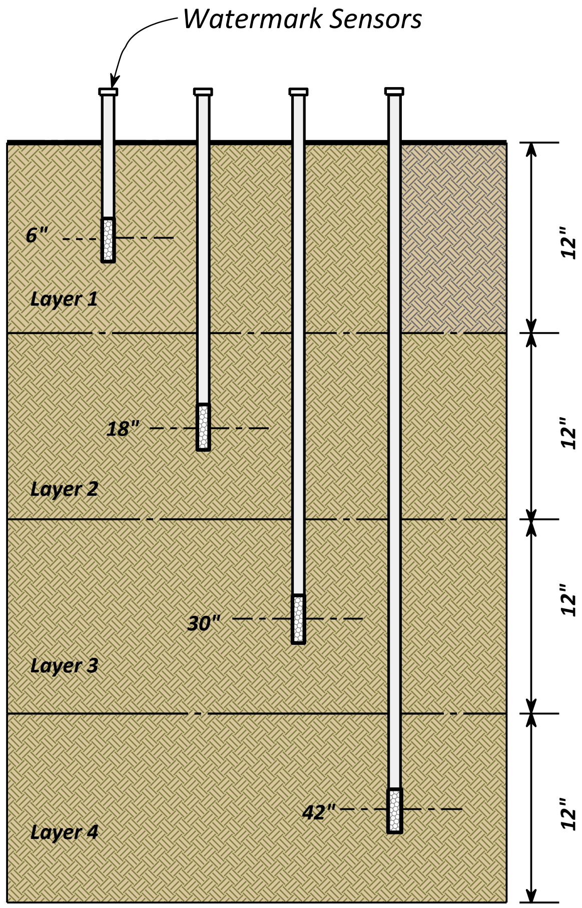
Watermark Reading Centibars	Plant Available Water, %	Soil Water Above(+)/Below(-) Field Capacity, inches/foot	Management Zone
5	157	1.14	**High Drainage Water Zone**
10	139	0.78	Top soil layer may get this wet
15	125	0.50	from rain or irrigation, but do not
20	114	0.28	irrigate deep layers to this level.
25	106	0.11	
29	100	0.00	**Field Capacity**
30	99	-0.03	**Rain Storage Zone**
35	93	-0.15	
40	88	-0.25	Keep a one-foot layer of
45	83	-0.33	soil dryer than this to store rain.
50	80	-0.41	
55	76	-0.48	
60	73	-0.54	**Desired Water Zone**
70	68	-0.64	Keep the deeper soil layers in this
80	63	-0.73	range. The goal is to dry out the
90	60	-0.81	lower layers through out the
100	56	-0.87	summer and be in the low water
120	51	-0.98	zone by crop maturity.
140	47	-1.07	
160	43	-1.14	**Low Water Zone**
180	40	-1.20	Keep a one-foot layer wetter than
200	37	-1.26	this range to avoid stress.



Irrigation Scheduling Strategies When Using Soil Water Data, EC3036

Depths to Place Sensors

- There are no right or wrong intervals to install sensors
- The Soil Water Sensor Conversion Charts are designed to be used with sensors representing a 1 foot layer of soil
- Thus it is the most convenient to install sensors at 6, 18, 30, and 42 inches
- Only use readings from the sensors in the currently active root zone of the crop



Location of Soil Moisture Sensors & Installation

- The location of the sensors should have soil water holding characteristics that represent the whole field or to be more conservative
- In cases where a single field contains both heavy and light soils, it is recommended that the area containing each soil type be monitored and managed for irrigation as a separate unit
- Use field mapping technologies to help identify differences in water holding capacity
- Place the sensors between plants within a crop row at their desired depths.
- Flag the sensors so that they are not damaged during field operations

Using Management Chart with Hansen Logger

Irrigation Scheduling Using the Chart Management Zones

Advantages

- Simple and easy to make very quick decisions
- Do not need to look at the number or do any calculations

Disadvantages

- Less accuracy than calculating water levels
- Need some experience to make good decisions

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Watermark Sensor Chart

Silt Loam

Water Holding Capacity, inches/foot = 2.00

Watermark Reading Centibars	Plant Available Water, %	Soil Water Above(+)/Below(-) Field Capacity, inches/foot	Management Zone
5	**157**	**1.14**	**High Drainage Water Zone** Top soil layer may get this wet from rain or irrigation, but do not irrigate deep layers to this level.
10	**139**	**0.78**	
15	**125**	**0.50**	
20	**114**	**0.28**	
25	**106**	**0.11**	
29	**100**	**0.00**	**Field Capacity**
30	**99**	**-0.03**	**Rain Storage Zone** Keep a one-foot layer of soil dryer than this to store rain.
35	**93**	**-0.15**	
40	**88**	**-0.25**	
45	**83**	**-0.33**	
50	**80**	**-0.41**	
55	**76**	**-0.48**	
60	**73**	**-0.54**	**Desired Water Zone** Keep the deeper soil layers in this range. The goal is to dry out the lower layers through out the summer and be in the low water zone by crop maturity.
70	**68**	**-0.64**	
80	**63**	**-0.73**	
90	**60**	**-0.81**	
100	**56**	**-0.87**	
120	**51**	**-0.98**	
140	**47**	**-1.07**	
160	**43**	**-1.14**	**Low Water Zone** Keep a one-foot layer wetter than this range to avoid stress.
180	**40**	**-1.20**	
200	**37**	**-1.26**	

Irrigation Scheduling Using the Chart Management Zones

Example	**Corn-silk stage**
Top foot	15 CB
Second foot	100 CB
Third foot	70 CB
Fourth foot	33 CB

Root Depth (ft.)	Corn
1.0	Vegetative
1.5	
2.0	12 leaf
2.5	16 leaf
3.0	Silking
3.5	Blister
4.0	Beginning dent

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Watermark Sensor Chart

Silt Loam

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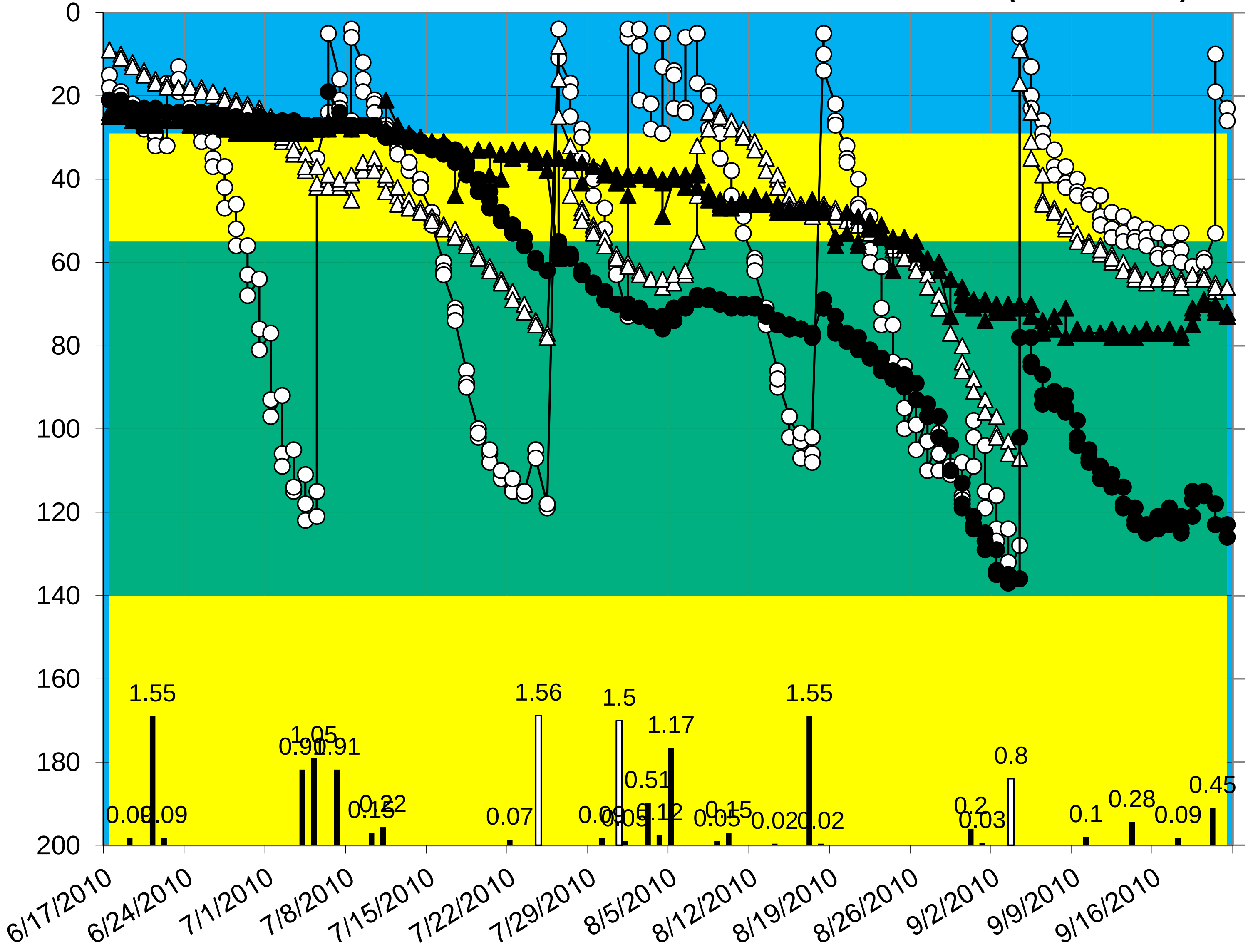
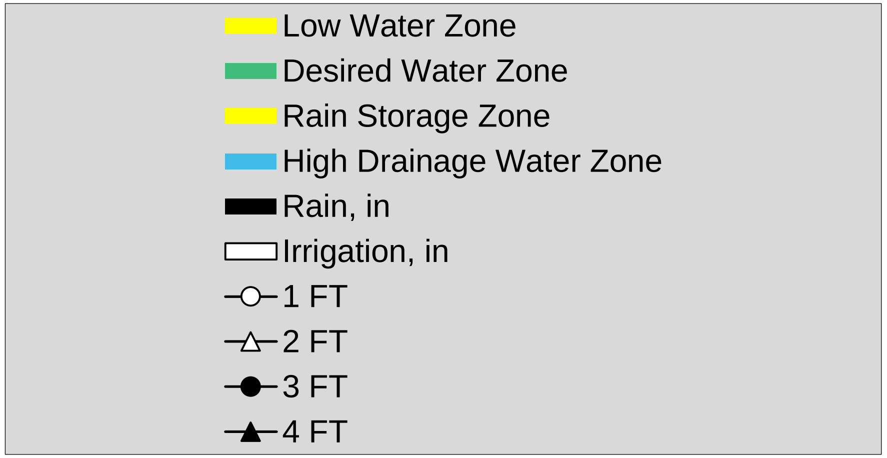
180	**40**	**-1.20**	Keep a one-foot layer wetter than
200	**37**	**-1.26**	this range to avoid stress.

Fully Watered, Curtis

(Hall silt loam)



- *Rain at Curtis during the growing season was just over 18 inches*
- *Total rain from 10/1/2009 to 9/20/2010 was over 30 inches*
- *Total irrigation on the Full Watered was 3.9 inches*
- *Demonstration plot yield (Not replicated) 217 bu/a*



Irrigation Scheduling using Percent of Available Water

Advantages

- A very intuitive number to use
- Very simple to determine using the charts
- Provides a good indication of the adequacy of water for the crop

Disadvantages

- Less accuracy than calculating the volume of water in the root zone
- Requires some calculations

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Watermark Sensor Chart

Silt Loam

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60	73	-0.54	**Desired Water Zone** Keep the deeper soil layers in this range. The goal is to dry out the lower layers through out the summer and be in the low water zone by crop maturity.
70	68	-0.64	
80	63	-0.73	
90	60	-0.81	
100	56	-0.87	
120	51	-0.98	
140	47	-1.07	
160	43	-1.14	**Low Water Zone** Keep a one-foot layer wetter than this range to avoid stress.
180	40	-1.20	
200	37	-1.26	

Irrigation Scheduling using Percent of Available Water

University of Nebraska Lincoln EXTENSION — IANR

Watermark Sensor Chart

Silt Loam

Water Holding Capacity, inches/foot = 2.00

Watermark Reading Centibars	Plant Available Water, %	Soil Water Above(+)/Below(-) Field Capacity, inches/foot	Management Zone
5	**157**	**1.14**	**High Drainage Water Zone**
10	**139**	**0.78**	Top soil layer may get this wet
15	**125**	**0.50**	from rain or irrigation, but do not
20	**114**	**0.28**	irrigate deep layers to this level.
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29	**100**	**0.00**	**Field Capacity**
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35	**93**	**-0.15**	
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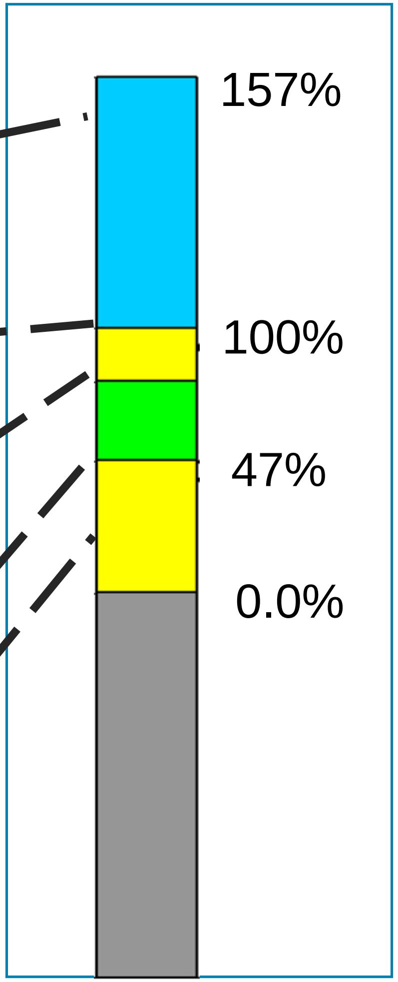

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Irrigation Scheduling using Percent of Available Water

Nebraska Lincoln EXTENSION — IANR

Watermark Sensor Chart

Silt Loam

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180	**40**	**-1.20**	Keep a one-foot layer wetter than
200	**37**	**-1.26**	this range to avoid stress.

Example	**Corn-silk stage**
Top foot	15 CB
Second foot	100 CB
Third foot	70 CB
Fourth foot	33 CB

Irrigation Scheduling using Percent of Available Water

University of Nebraska Lincoln EXTENSION — IANR

Watermark Sensor Chart

Silt Loam

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Example	**Corn-silk stage**
Top foot	15 CB
Second foot	100 CB
Third foot	70 CB

Example I.

Available Water, Percentage

Top foot	125
Second foot	+ 56
Third foot	+ 68
Total	249
Average	249/3=83%

Irrigation Scheduling using Inches of Available Water

Advantages

- Provides the most accuracy
- Simple to determine using the charts
- Determines how much water is left, how much it will hold, and how quickly irrigation needs to be started
- Provides a must have number to determine how much water is needed at the end of the season

Disadvantages

- Requires some calculations and a little more time

Nebraska Lincoln EXTENSION IANR

Watermark Sensor Chart

Silt Loam

Water Holding Capacity, inches/foot = 2.00

Watermark Reading Centibars	Plant Available Water, %	Soil Water Above(+)/Below(-) Field Capacity, inches/foot	Management Zone
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15	125	0.50	
20	114	0.28	
25	106	0.11	
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Irrigation Scheduling using Inches of Available Water

Nebraska Lincoln EXTENSION — IANR

Watermark Sensor Chart

Silt Loam

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Example	**Corn-silk stage**
Top foot	15 CB
Second foot	100 CB
Third foot	70 CB

Example I.

Available Water,	**%**	**In/ft**
Top foot	125	(+0.50)
Second foot	+ 56	+(-0.87)
Third foot	+ 68	+(-0.64)
Total	249/3	-1.01
Average	83%	

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Irrigation Scheduling using Inches of Available Water

Nebraska Lincoln EXTENSION — IANR

Watermark Sensor Chart

Silt Loam

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200	**37**	**-1.26**	

Example I. **Available Water, Percent**

Top foot	125
Second foot	+ 56
Third foot	+ 68
Total	249
Average	83%

Example II. **Available Water, Inches**

Column 2	Column 3
@ 83 %	(-0.33) in/ft
	x 3 ft root zone
Total	-0.99 in
	below field capacity

Irrigation Scheduling using Inches of Available Water

Nebraska Lincoln EXTENSION — IANR

Watermark Sensor Chart

Silt Loam

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180	40	-1.20	
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Example I. **Available Water, Percent**

Top foot	125
Second foot	+ 56
Third foot	+ 68
Total	249
Average	83%

Example III. **Remaining Water, Inches**

Column 2	Column 3
Used @ 83 %	(-0.33) in/ft
Used @ 50%	-(-0.98) in/ft
Remaining water	0.65 in/ft
	x 3 ft root zone
Total	1.95 in
	of water remaining

Approximate Water Use Rates by Stage of Growth for Various Crops

Water use rate in/day	*Corn*	*Grain sorghum*	*Soybeans*	*Alfalfa**	*Dry beans*	*Sugarbeets*	*Winter wheat*
0.18						June 15	Spring growth
0.20							
0.22			Full bloom			July 1	
0.24	12 leaf				Rapid vegetative growth		Joint
0.26		Flag leaf	Begin pod				
0.28	Early tassel	Boot		June 15			
0.30	Silking	Half bloom	Full pod	July 1	Flowering and pod devevelopment	July 15	Boot
0.28				August 1			
0.26	Blister	Soft dough				August 1	
0.24	Milk		Seed fill	August 15			
0.22				Sept 1			Dough
0.20	Begin dent						
0.18	Full dent	Hard dough			Pod fill and maturation		

*Alfalfa water use rates should be multiplied by 0.50 during the first 10 days following cutting and by 0.75 for the 10th to 20th days following cutting.

Chart from EC709 Irrigation Scheduling: Checkbook Method

Irrigation Scheduling using Inches of Available Water

Nebraska Lincoln EXTENSION IANR

Watermark Sensor Chart

Silt Loam

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180	**40**	**-1.20**	
200	**37**	**-1.26**	

Example III. **Remaining Water, Inches**

Column 2	Column 3
Used @ 83 %	-0.41 in/ft
Used @ 50%	-0.98 in/ft
Remaining water	0.65 in/ft
	x 3 ft root zone
Total	1.95 in
	of water remaining

Example IV. **Days Until Irrigation is Required**

Remaining available water	1.95 in water
Estimated daily water use	÷ 0.3 in/day
Days until irrigation is required	6.5 days

Irrigation Scheduling for Late Season Needs

- Today's date is August 10th
- Corn is at the R4 (Dough) stage
- Allow soil to dry to 40% plant available water
- Location is central Buffalo County

Nebraska Lincoln EXTENSION — IANR

Watermark Sensor Chart

Silt Loam

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140	47	-1.07	
160	43	-1.14	**Low Water Zone** Keep a one-foot layer wetter than this range to avoid stress.
180	40	-1.20	
200	37	-1.26	

Example III. **Remaining Water, Inches**

Column 2	Column 3
Used @ 68%	(-**0.64) in/ft**
Used @ 40%	-(-**1.20) in/ft**
Remaining water	**0.56 in/ft**
	x 4 ft root zone
Total	**2.24 in of water remaining**

Example IV. **Days Until Irrigation is Required**

Remaining available water	**2.24 inches**
Estimated daily water use	**÷ 0.18 in/day**
Days until irrigation is required	**12 days**

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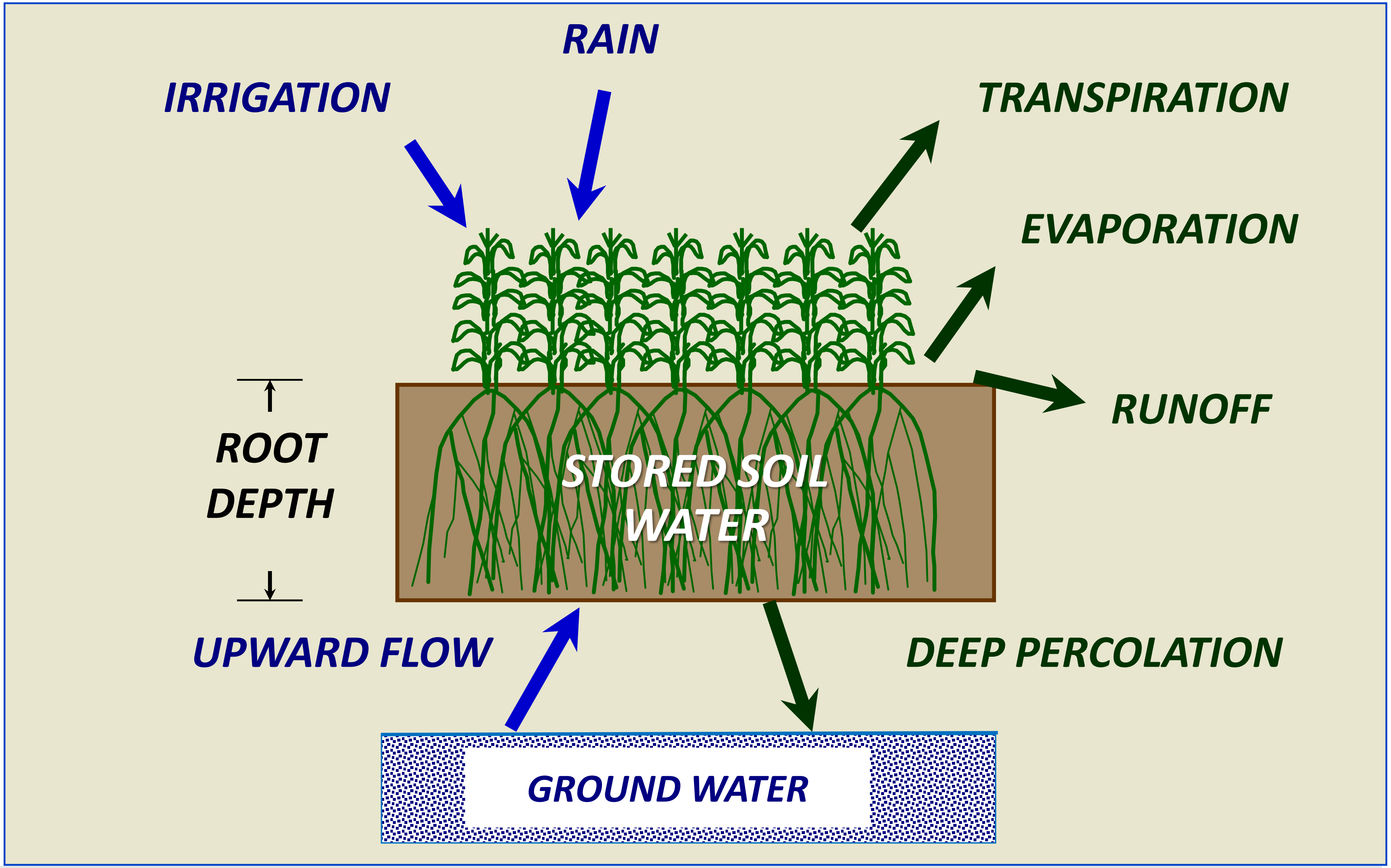
Some Basic Techniques that Farmers Use for Irrigation Scheduling

Evapotranspiration (ET) based irrigation scheduling

Three types of ET data can be used for scheduling irrigation in the field.

- Published daily ET data
- Measured ET data using ET-gage or other devices
- Historical ET data

Soil Water Balance



Some Basic Techniques that Farmers Use for Irrigation Scheduling

Published data for ET for irrigation scheduling

Published ET values can be used for irrigation scheduling. Sometimes, published ET values can be for reference grass or alfalfa evapotranspiration (ETo). If it is ETo, it must be changed to crop evapotranspiration (ETc) using crop coefficients (Kc) as follows:

$$ETc = ETo \times Kc$$

Some Sources of Published ET Data for the Tri-State Region

1. Kansas State University Weather Data Library (http://mesonet.k-state.edu/)

2. The High Plains Regional Climate Center Automated Weather Data Network (AWDN, serving Colorado, Iowa, Kansas, Minnesota, Missouri, Montana, North Dakota, Nebraska, South Dakota and Wyoming (http://www.hprcc.unl.edu/awdn/)

3. The North Dakota Agricultural Weather Network (NDAWN, serving North Dakota, Montana and Minnesota, http://ndawn.ndsu.nodak.edu/)

4. Oklahoma Agweather (http://agweather.mesonet.org/)

5. Colorado climate center - CoAgMET (www.coagmet.com)

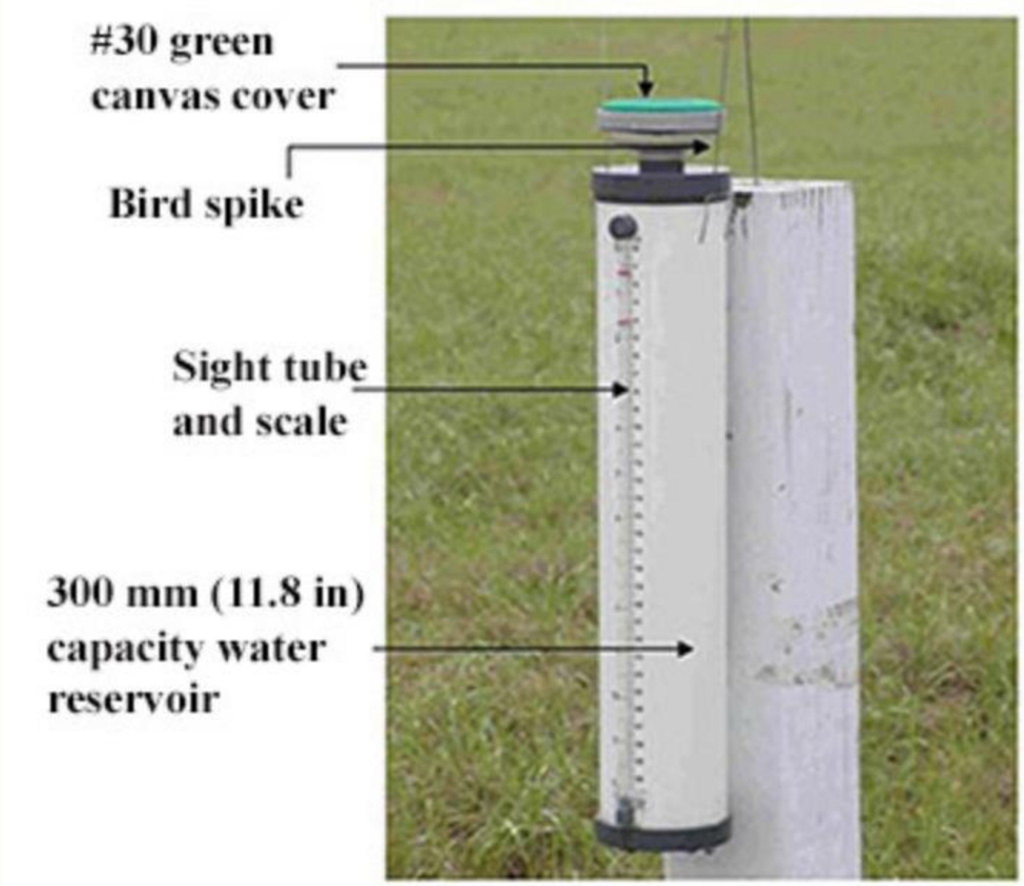
6. The Texas High Plains Evapotranspiration Network (TXHPET, http://txhighplainset.tamu.edu)

7. CropWatch (https://cropwatch.unl.edu/gdd-etdata)

Some Basic Techniques that Farmers Use for Irrigation Scheduling

Measured ET Using Atmometers (ETgage)

- Low cost ($400)
- ETgage is used to estimate reference crop evapotranspiration (ETo)
- ETgage readings is recorded daily or weekly
- Crop water use or evapotranspiration (ETc) is obtained as ETc = ETo x Kc

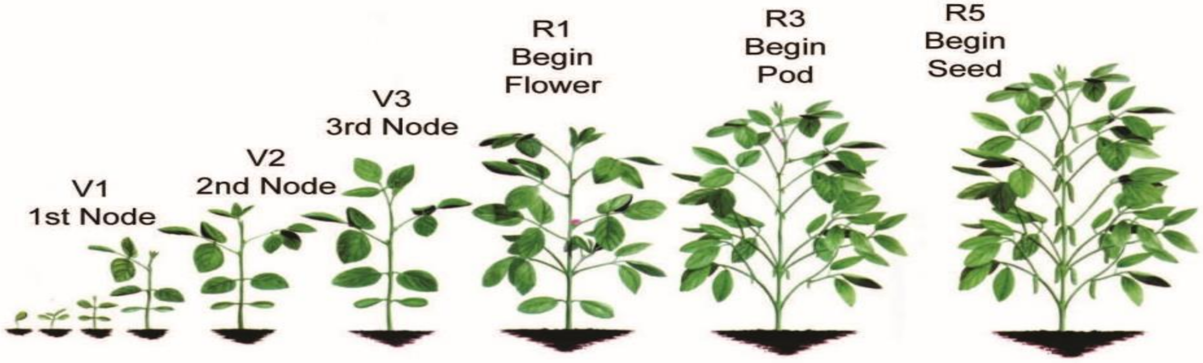


Crop Water Use by Growth Stage – Soybeans

Nebraska Lincoln EXTENSION

Soybean Growth Stages

VC: Cotyledon leaves with unifoliate leaves unrolled.
V1: 1st node containing trifoliolate leaf fully expanded.
V2: 2nd node containing trifoliolate leaf fully expanded.
V2: 3rd node containing trifoliolate leaf fully expanded.
R1: At least one flower on any node.
R3: A pod 3/16 inch on one of four uppermost nodes.
R5: Seed is 1/8 inch long in a pod of the upper four nodes.
Begin Maturity: one brown leaf on main stem.



Weekly ETgage® Change in Inches

Crop Stage	Kc	1.00	1.10	1.20	1.30	1.40	1.50	1.60	1.70	1.80	1.90	2.00	2.10	2.20	2.30	2.40	2.50	2.60	2.70	2.80	2.90	3.00
VC Cotyledon	0.10	0.10	0.11	0.12	0.13	0.14	0.15	0.16	0.17	0.18	0.19	0.20	0.21	0.22	0.23	0.24	0.25	0.26	0.27	0.28	0.29	0.30
V1 1st Node	0.20	0.20	0.22	0.24	0.26	0.28	0.30	0.32	0.34	0.36	0.38	0.40	0.42	0.44	0.46	0.48	0.50	0.52	0.54	0.56	0.58	0.60
V2 2nd Node	0.40	0.40	0.44	0.48	0.52	0.56	0.60	0.64	0.68	0.72	0.76	0.80	0.84	0.88	0.92	0.96	1.00	1.04	1.08	1.12	1.16	1.20
V3 3rd Node	0.60	0.60	0.66	0.72	0.78	0.84	0.90	0.96	1.02	1.08	1.14	1.20	1.26	1.32	1.38	1.44	1.50	1.56	1.62	1.68	1.74	1.80
R1 Begin Bloom	0.90	0.90	0.99	1.08	1.17	1.26	1.35	1.44	1.53	1.62	1.71	1.80	1.89	1.98	2.07	2.16	2.25	2.34	2.43	2.52	2.61	2.70
R2 Full Bloom	1.00	1.00	1.10	1.20	1.30	1.40	1.50	1.60	1.70	1.80	1.90	2.00	2.10	2.20	2.30	2.40	2.50	2.60	2.70	2.80	2.90	3.00
Begin Pod Full Pod R5 Begin Seed Full Seed	1.10	1.10	1.21	1.32	1.43	1.54	1.65	1.76	1.87	1.98	2.09	2.20	2.31	2.42	2.53	2.64	2.75	2.86	2.97	3.08	3.19	3.30
Begin Mature	0.90	0.90	0.99	1.08	1.17	1.26	1.35	1.44	1.53	1.62	1.71	1.80	1.89	1.98	2.07	2.16	2.25	2.34	2.43	2.52	2.61	2.70
Full Mature	0.20	0.20	0.22	0.24	0.26	0.28	0.30	0.32	0.34	0.36	0.38	0.40	0.42	0.44	0.46	0.48	0.50	0.52	0.54	0.56	0.58	0.60
Mature	0.10	0.10	0.11	0.12	0.13	0.14	0.15	0.16	0.17	0.18	0.19	0.20	0.21	0.22	0.23	0.24	0.25	0.26	0.27	0.28	0.29	0.30

This chart can be used with readings from an ETgage® or other ET reference. First, identify the change in the ET rate across the horizontal row and then identify the current growth stage in the left column. Follow the two columns to the point where they intersect to identify the ET rate to use in your irrigation scheduling. When planning irrigation, account for soil moisture, precipitation, weather conditions, and the ET rate for growth stage of your crop.

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ET-Based Scheduling Implementation

2. A strategy for ET based irrigation scheduling is the checkbook irrigation scheduling approach as follows:

- The soil acts as a bank to store water
- Rain + irrigation = deposits
- Evapotranspiration + Deep percolation + Runoff = withdrawals
- There is a minimum allowable balance (minimum balance)
- There is a maximum possible deposit (Field capacity)

Checkbook Irrigation Scheduling Calculations

$$\mathbf{SWB_{today} = SWB_{yesterday} + IR_{today} + RF_{today} - ET_{today} - WL_{today}}$$

Where:

SWB = Soil water balance (inches)

IR = Irrigation application (inches)

RF = Rainfall (inches)

ET = Evapotranspiration (inches)

WL = Water losses (deep percolation, surface runoff, etc.)

Tools for Irrigation Scheduling

- Forms (irrigation scheduling worksheets for manual calculation)

- Computer spreadsheets/Online forms programed to track soil moisture – “*Anyone* **KanSched***ule irrigation!*” (https://bae.engg.ksu.edu/mobileirrigationlab/ of K-State)

- Computer models – Hybrid-Maize and Soysim (unl.edu), WISE (wise.colostate.edu), AquaCrop etc.

Gross irrigation application = Crop Water requirement x System Efficiency

Irrigation system type	*Efficiency (%)*		*Irrigation system type*	*Efficiency (%)*
Sprinkler			**Surface**	
Center pivot and lateral move	85-90		Gated pipe with reuse	70-75
Skid tow/Side roll	75-80		Gated pipe without reuse	50-55
Big gun traveler	70-75		Gated pipe with surge	75-80
Subsurface Drip			Siphon tube without reuse	45-50
SDI	90-95		Siphon tube with reuse	65-70

Strategy for Irrigation Scheduling with Under Capacity Center Pivot Systems

Some center pivot systems are planned and designed with insufficient capacity (GPM) to supply full daily crop water use. Growers with insufficient capacity systems should use high water management strategy that ensures that the soil root zone is filled with water by either rainfall or pre-watering or early season irrigation, before daily water use exceeds the irrigation capacity

Combining Soil Moisture Sensing and ET for Irrigation Scheduling

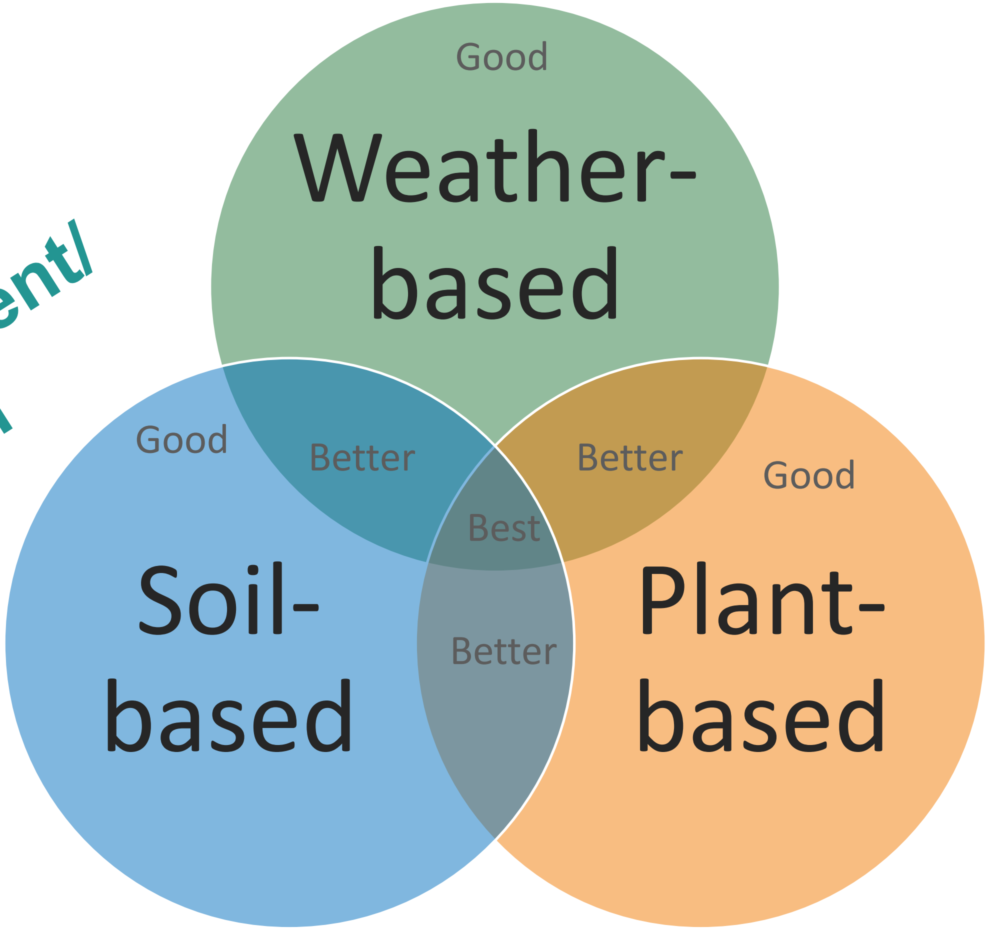
Soil moisture sensing is highly recommended to supplement ET based irrigation scheduling. Periodically (every one or two weeks), measure the soil moisture balance in the field and compare it the checkbook balance. If discrepancy occurs, use the newly measured soil water status to recalibrate the checkbook next day start water balance.

TAKE HOME MESSAGE

Use One or More for Scheduling Feedback

The Low Hanging Fruit

In water management/ conservation



Upcoming event…

- Central Plains Irrigation Association Conference and Exposition
  - Tues/Wed Feb 26-27, 2019
  - Holiday Inn Convention Center: 110 South 2nd Ave. Kearney, NE
  - https://www.ksre.k-state.edu/sdi/revents/cpia.html
- Various Technical Sessions and Exhibition
  - *Irrigation Scheduling Methods and Technologies*
  - *Managing Irrigation and Nitrogen Fertilization*
  - *Performance of Irrigation Systems*
  - *Advances in Irrigation Systems*
  - *Irrigated Cropping Systems*
  - *Irrigation Management Strategies under Drought or Water Limiting Conditions*
  - *Testing Ag Performance Solutions (TAPS)*

Thank You

Irrigation Resources Audit

- **Objective:** quantify real costs of irrigation using gas vs. electric
- EPRI offering energy audit to 5 irrigators at no cost
- **Example info:**
  - Acreage, crops:
  - Number of pumps, wells, pivots:
  - Horsepower of pumps used
  - Average head pressure:
  - Irrigation schedule (daily, seasonal):
  - Electrical service available? 3-phase? What voltage?

Please reach out if you would like to participate!

Irrigation Discussion Questions

- Irrigation scheduling practices: Factors? Options? Sensors? Water balance? Etc..
- Remote telemetry?
- Terrain type and variations?

- Number of water sources per pivot?
- Length of pipe runs to pivots?

- Current challenges?
- Technology interest?

Agenda - Break Time

THURSDAY, FEBRUARY 20, 2019 (ALL TIMES MST)		
TIME	**TOPIC**	**PRESENTER**
8:30 a.m.	**Welcome & Background**	*Myles Jensen, Tri-State G&T*
8:35 a.m.	**Introductions & Learning Objectives**	*Sara Beaini & Micah Sweeney, EPRI*
8:40 a.m.	**Part A - Irrigation Scheduling Optimization**	*Dr. Lameck O. Odhiambo, Steven Melvin, Jonathan Aguilar, Irrigation Innovation Consortium*
9:30 a.m.	**Questions & Discussion**	*All*
9:45 a.m.	**Break**	
10:15 a.m.	**Part B - Pump System Optimization**	*Alex Kramer & Michael Michaud, Hydraulic Institute*
11:05 a.m.	**Adjustable Speed Drives (ASDs) for Energy Efficiency**	*Mark Stephens, EPRI*
11:20 a.m.	**Emerging Technologies**	*Sara Beaini & Micah Sweeney, EPRI*
11:25 a.m.	**Questions & Discussion**	*All*
11:40 a.m.	**Wrap-Up**	*EPRI and Tri-State G&T*

Together…Shaping the Future of Electricity