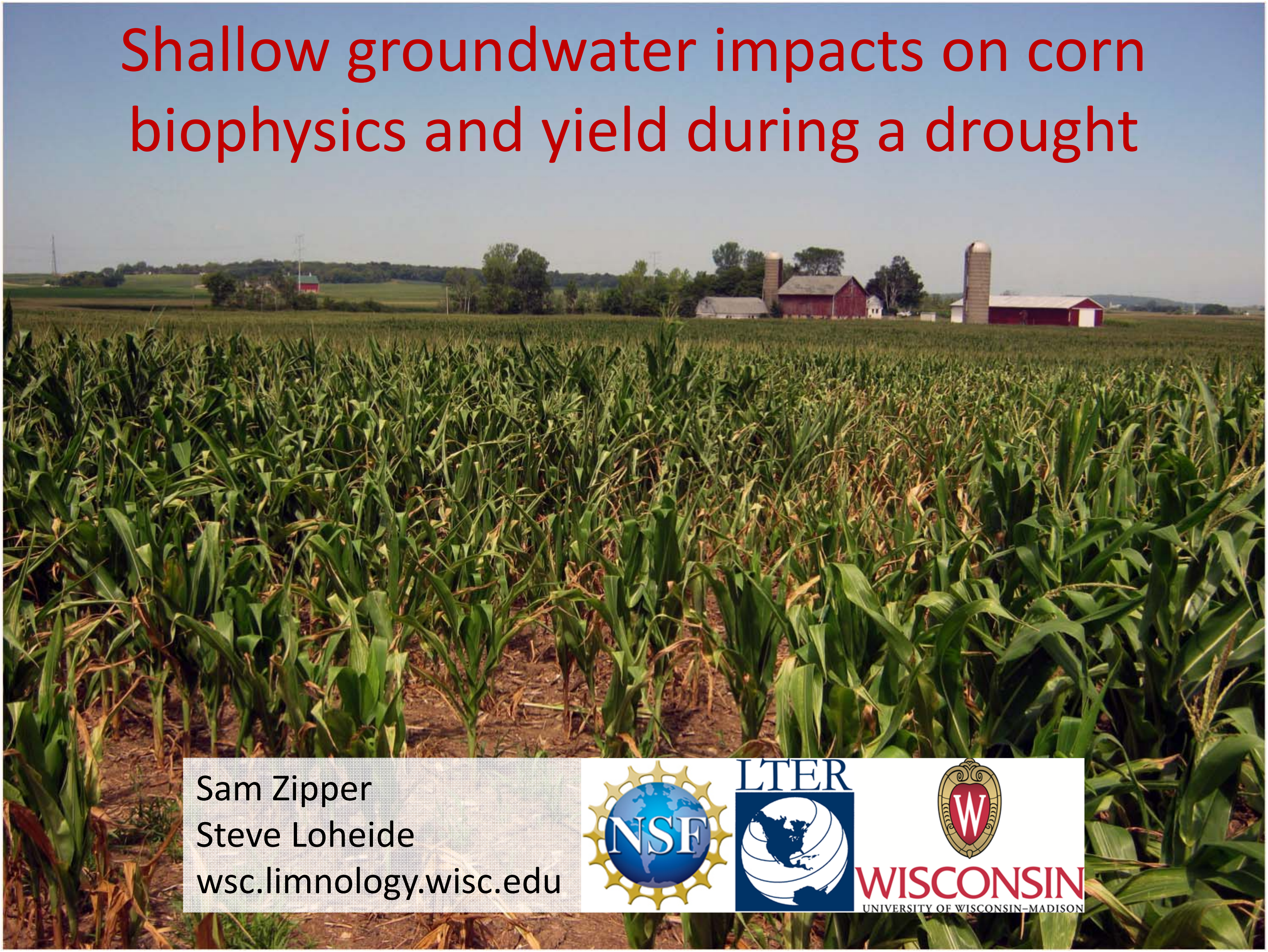
Shallow groundwater impacts on corn biophysics and yield during a drought



Sam Zipper
Steve Loheide
wsc.limnology.wisc.edu

NSF LTER WISCONSIN UNIVERSITY OF WISCONSIN–MADISON

Research Objectives

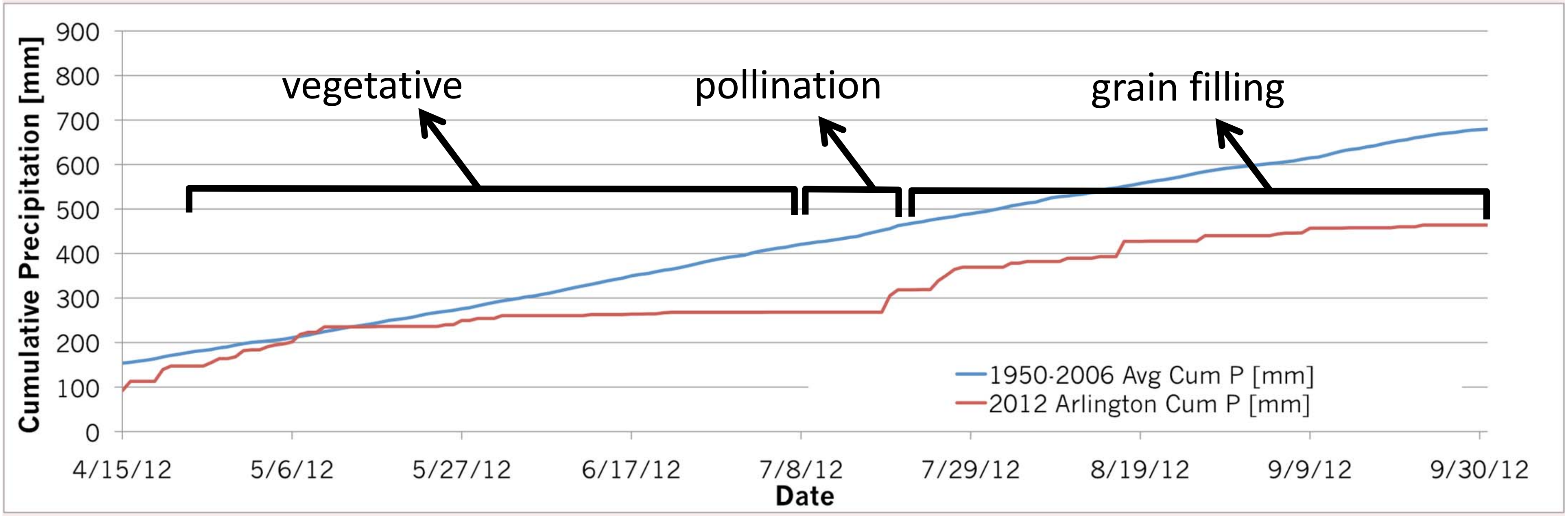
1. **Identify** major corn physiological responses to water stress during 2012 drought

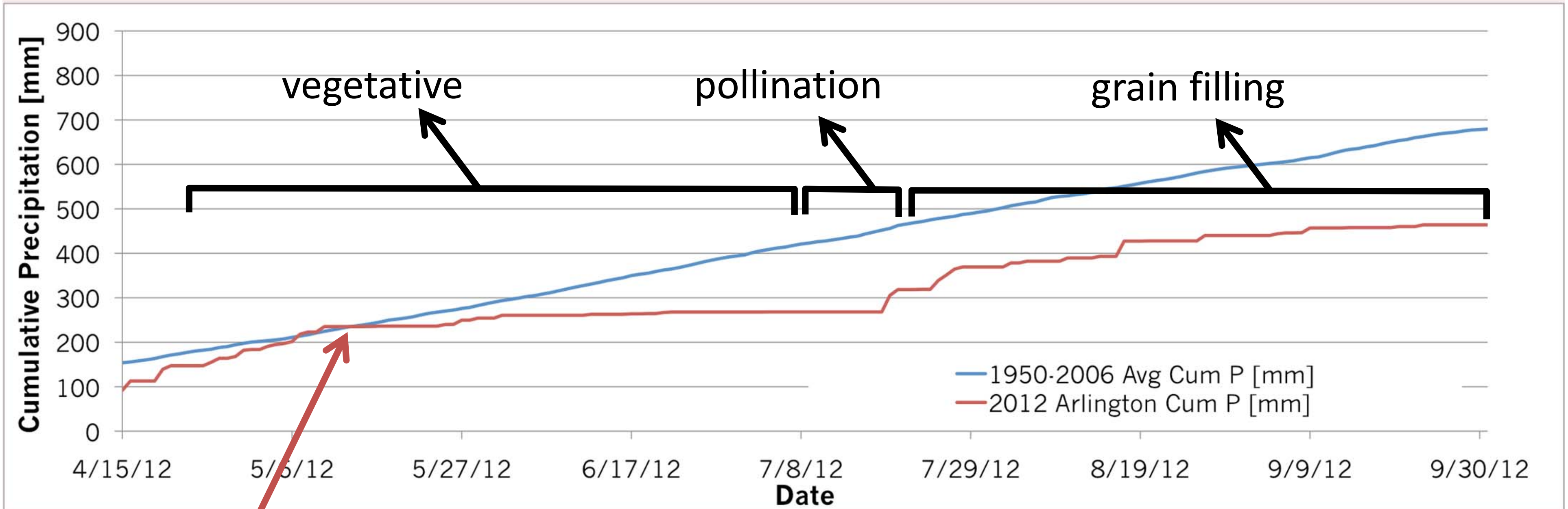
2. **Contextualize** physiological responses in terms of groundwater availability

3. **Quantify** yield losses as a result of water stress

4. **Calculate** groundwater subsidy provided to corn from shallow water table

- Water stress impacts on corn
- Study site – GW & Soil Conditions
- Physiological response
  - Micro level – stomatal conductance
  - Macro level – leaf area index
- Yield response
  - Pollination success
  - Grain yield
  - Groundwater subsidy


vegetative
pollination
grain filling
Cumulative Precipitation [mm]
900
800
700
600
500
400
300
200
100
0
4/15/12
5/6/12
5/27/12
6/17/12
7/8/12
7/29/12
8/19/12
9/9/12
9/30/12
Date
1950-2006 Avg Cum P [mm]
2012 Arlington Cum P [mm]



Spring:
Warm weather, normal Y.T.D. precipitation, optimistic farmers

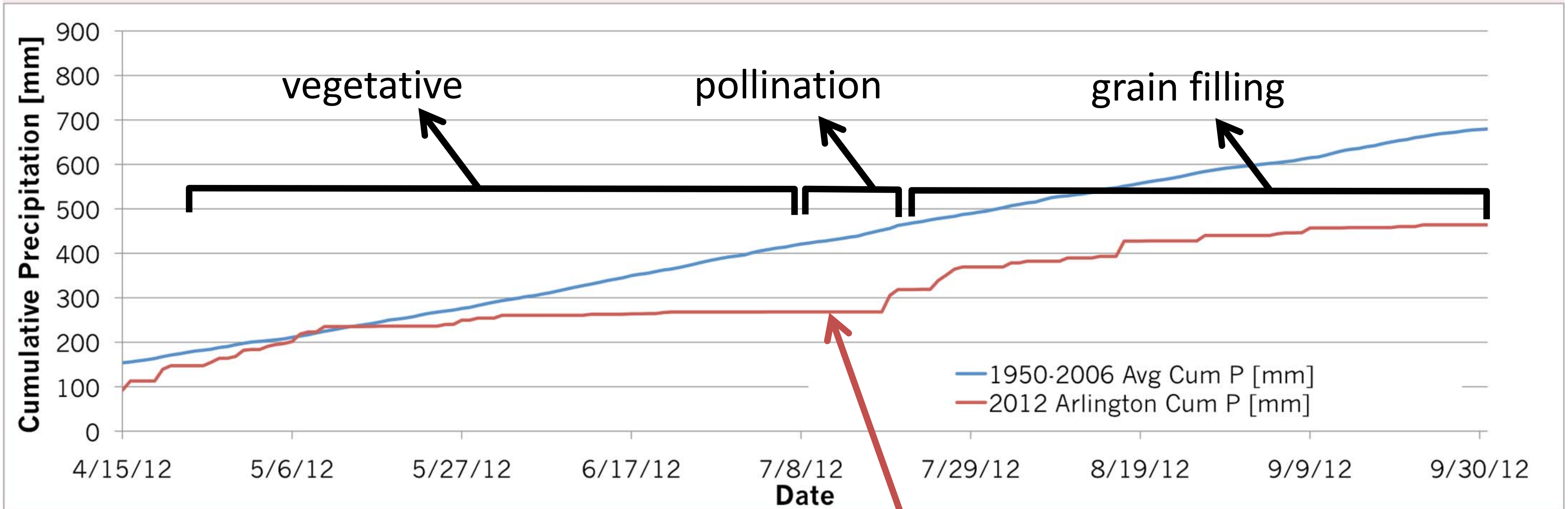
Corn crop expected to be biggest ever

AGRICULTURE | 2012 FORECAST

Recommend 0 Tweet 0 +1 0 Pin it Share Print Email

May 11, 2012 1:00 am • Associated Press

(0) Comments



July 9:
<8 mm precipitation since June 1

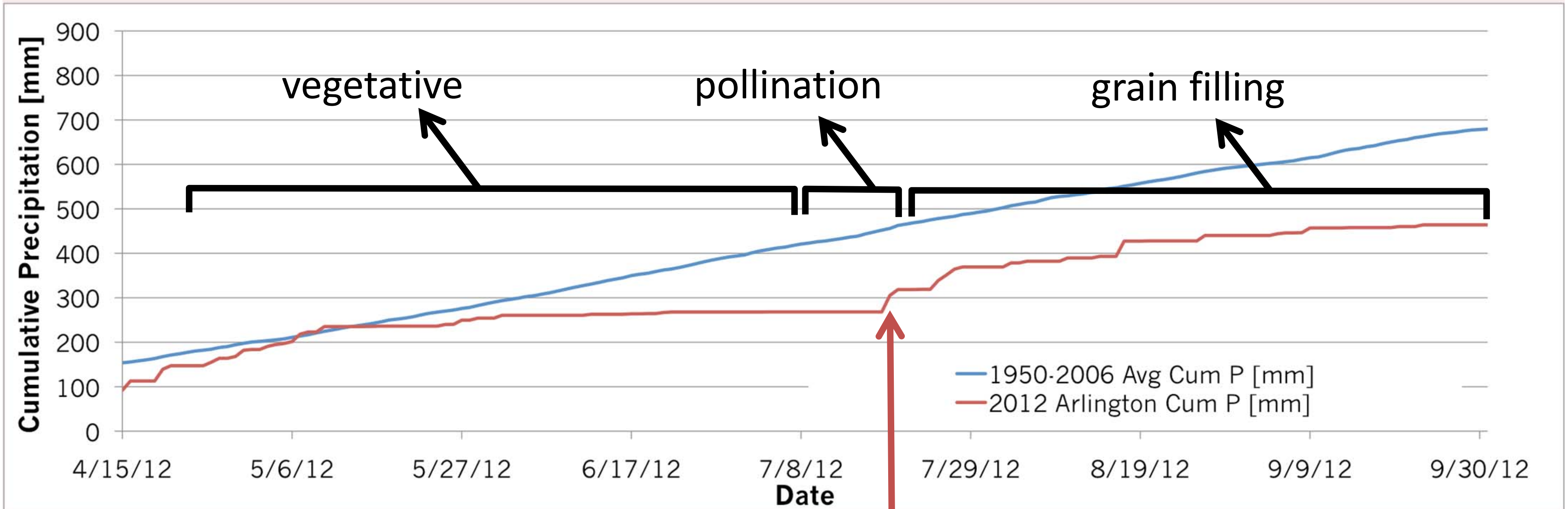
Walker declares state of emergency due to drought

Recommend 0 | Tweet 0 | +1 0 | Share | Print | Email

July 09, 2012 8:45 pm • CLAY BARBOUR | Wisconsin S
252-6129

WISCONSIN STATE JOURNAL

Irrigation permits are lifelines for drought-ravaged farmers



July 18-20:
50 mm rain… but it came too late

Drought is far from over

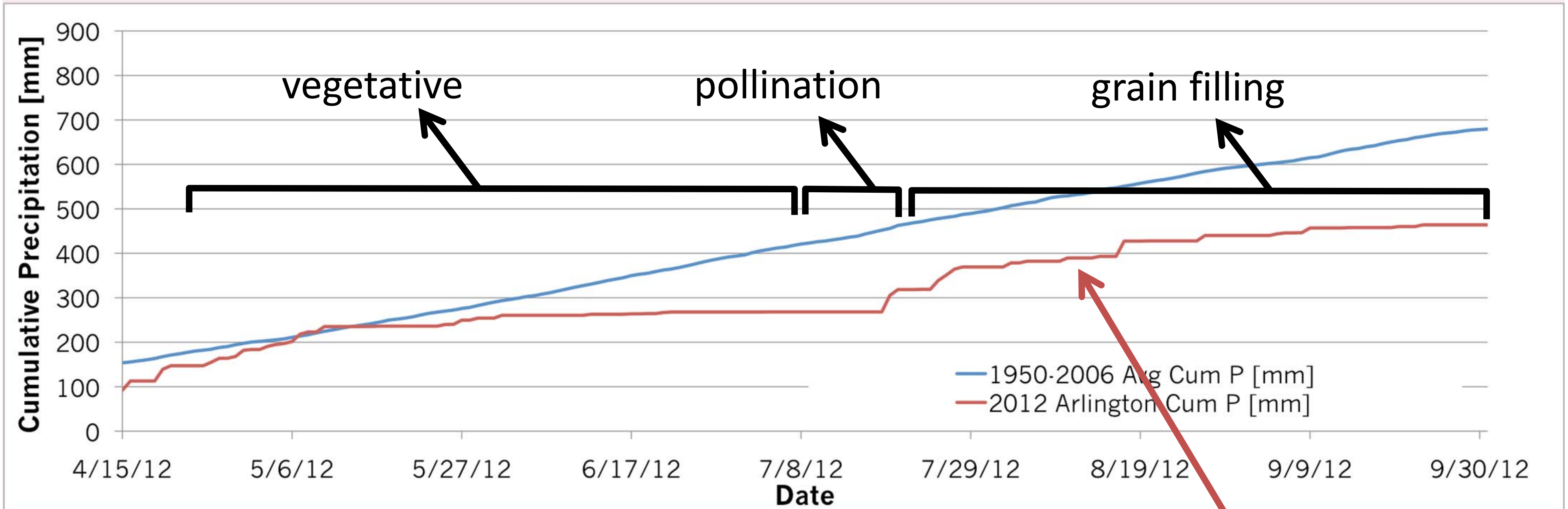
Recommend 0 Tweet 0 +1 0 Share Print Email

July 22, 2012 7:00 am • Wisconsin State Journal e

Rain won't help corn much

July 26, 2012 By Bob Hague

For corn crops, it's a case of too little, too late. That's the story in Dane County

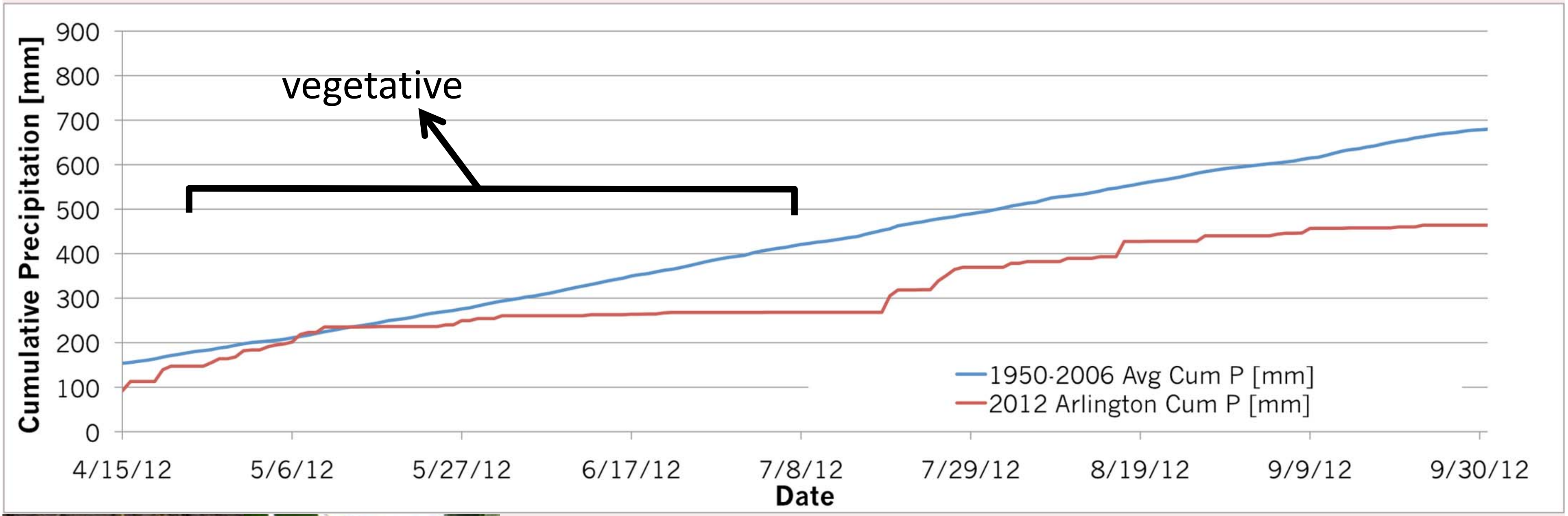


Late July, August, September:
~Normal rains, but didn't help

WISCONSIN STATE JOURNAL

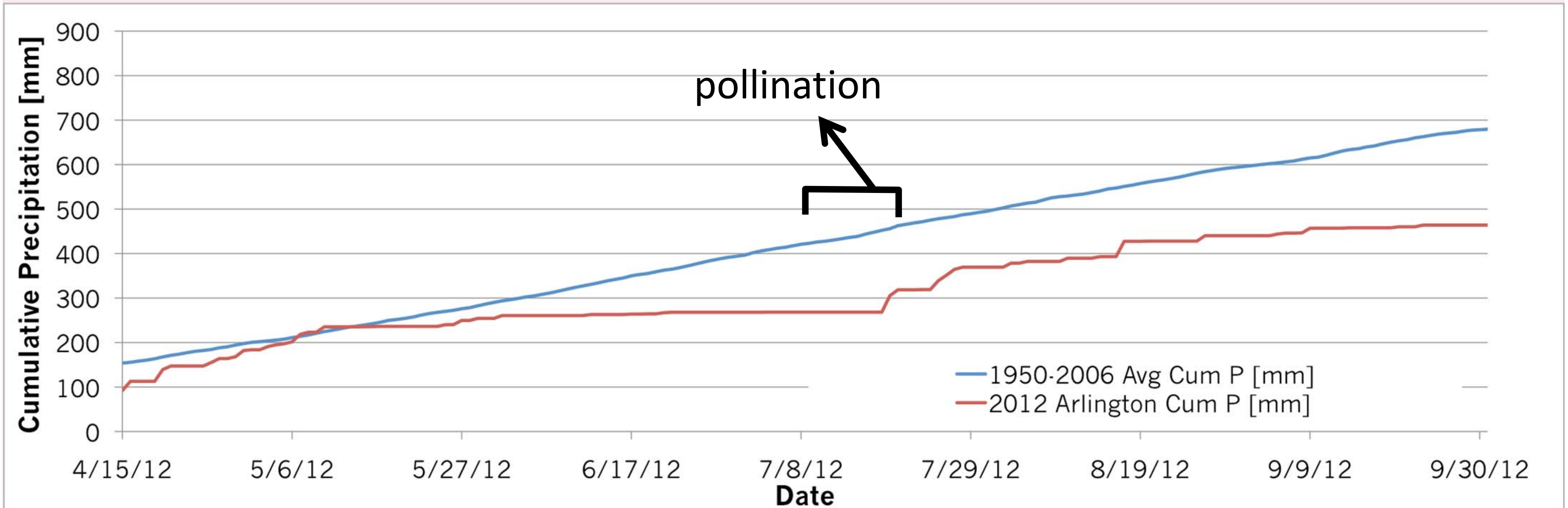
Corn yield forecast for Wisconsin low despite recent rain

SEPTEMBER 12, 2012 1:00 PM • ROB SCHULTZ | WISCONSIN STATE JOURNAL | RSCHULTZ@MADISON.COM | 608-252-6487



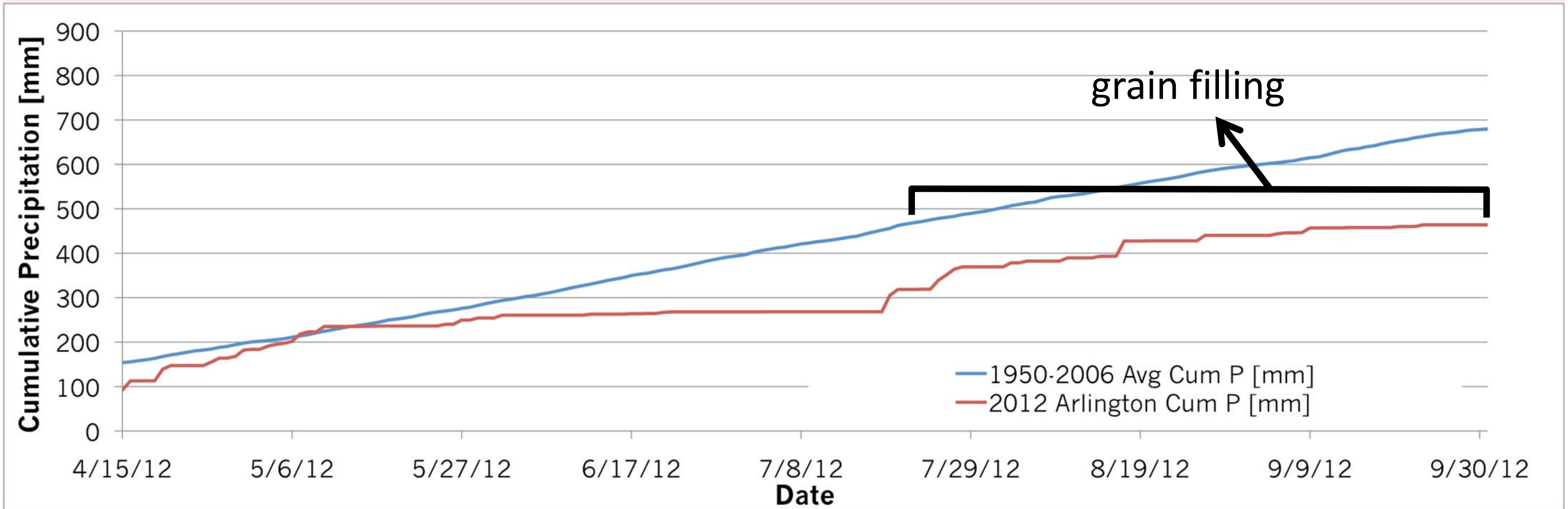
Water Stress → Reduced Biomass

- decreased root & shoot growth
- decreased nutrient uptake
- smaller cob size



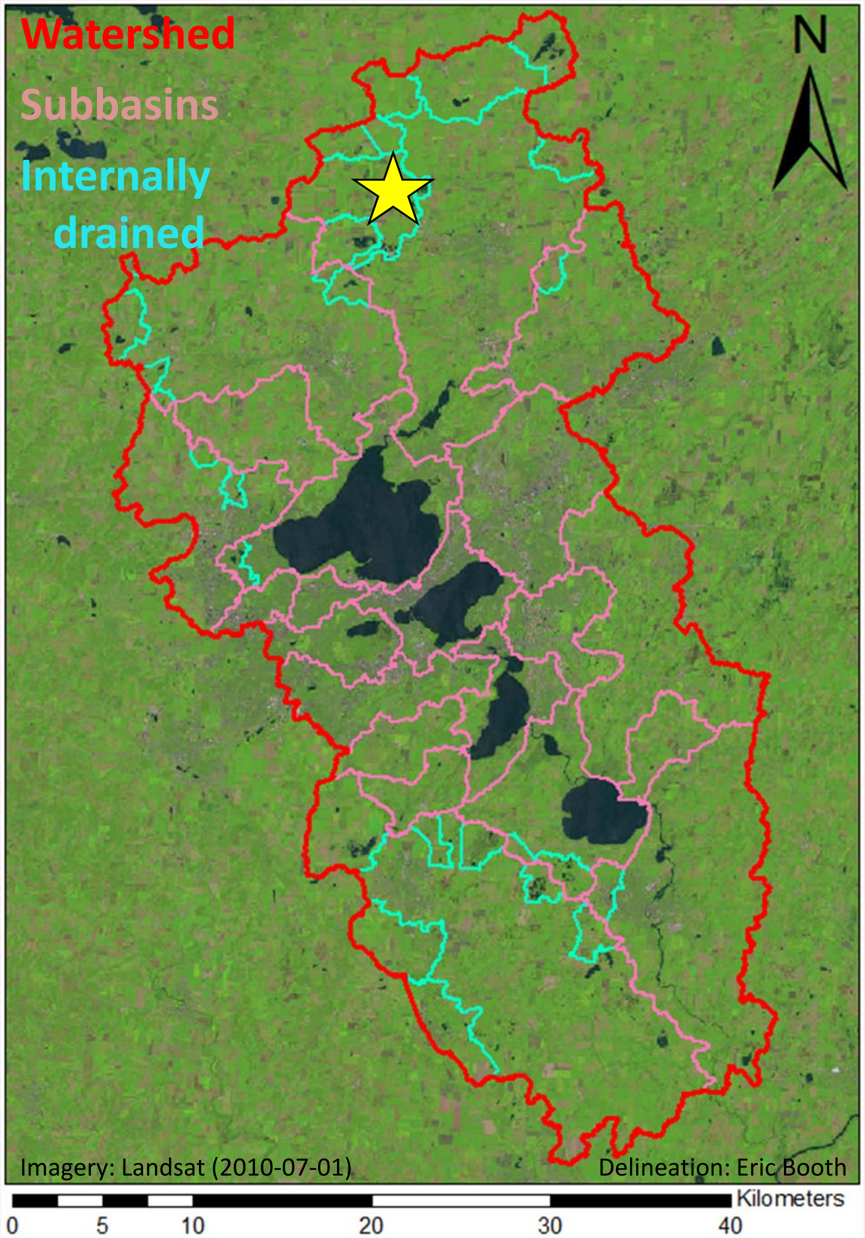
Water Stress → Reduced Grain Yield

- decreased pollination success
- lower kernel counts
- shorter cobs



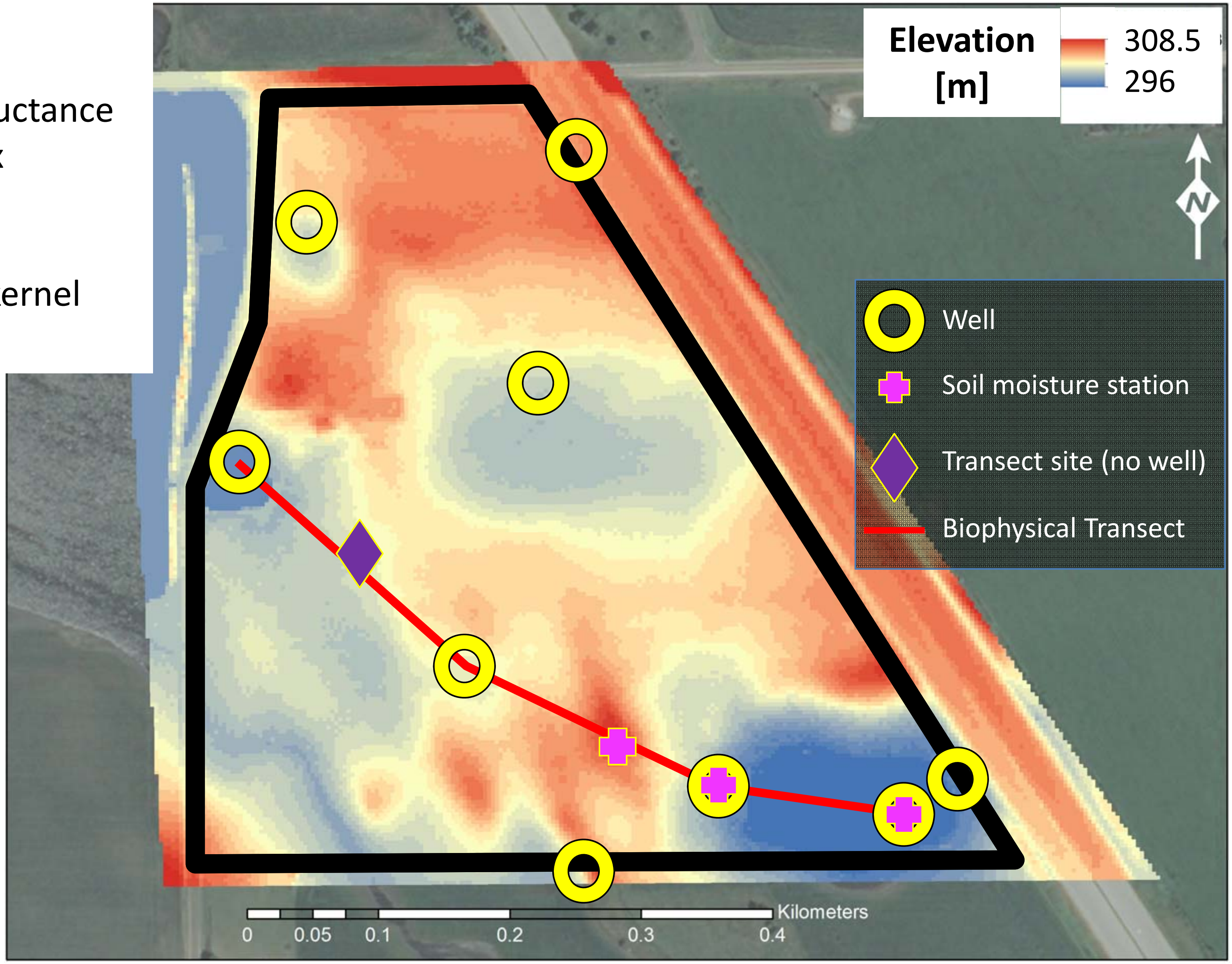
Water Stress → Reduced Grain Yield & Biomass

- reduced kernel mass
- more frequent kernel abortion
- higher risk for pests


Watershed
Subbasins
Internally drained
N
Imagery: Landsat (2010-07-01)
Delineation: Eric Booth
Kilometers
0
5
10
20
30
40

Measurements

-GW elevation
-Stomatal conductance
-Leaf area index
-Total biomass
-Grain mass
-Kernel count, kernel mass, etc.



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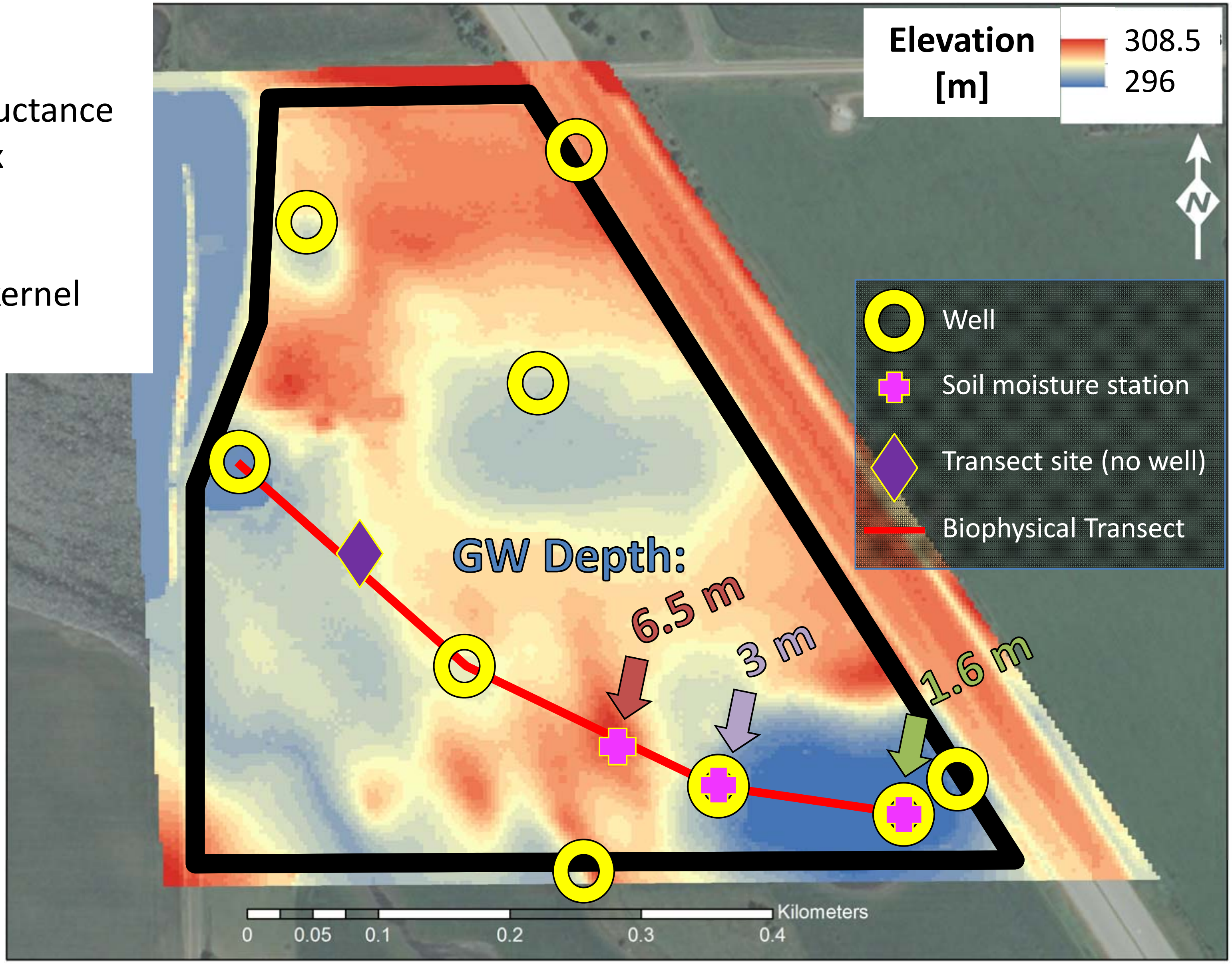

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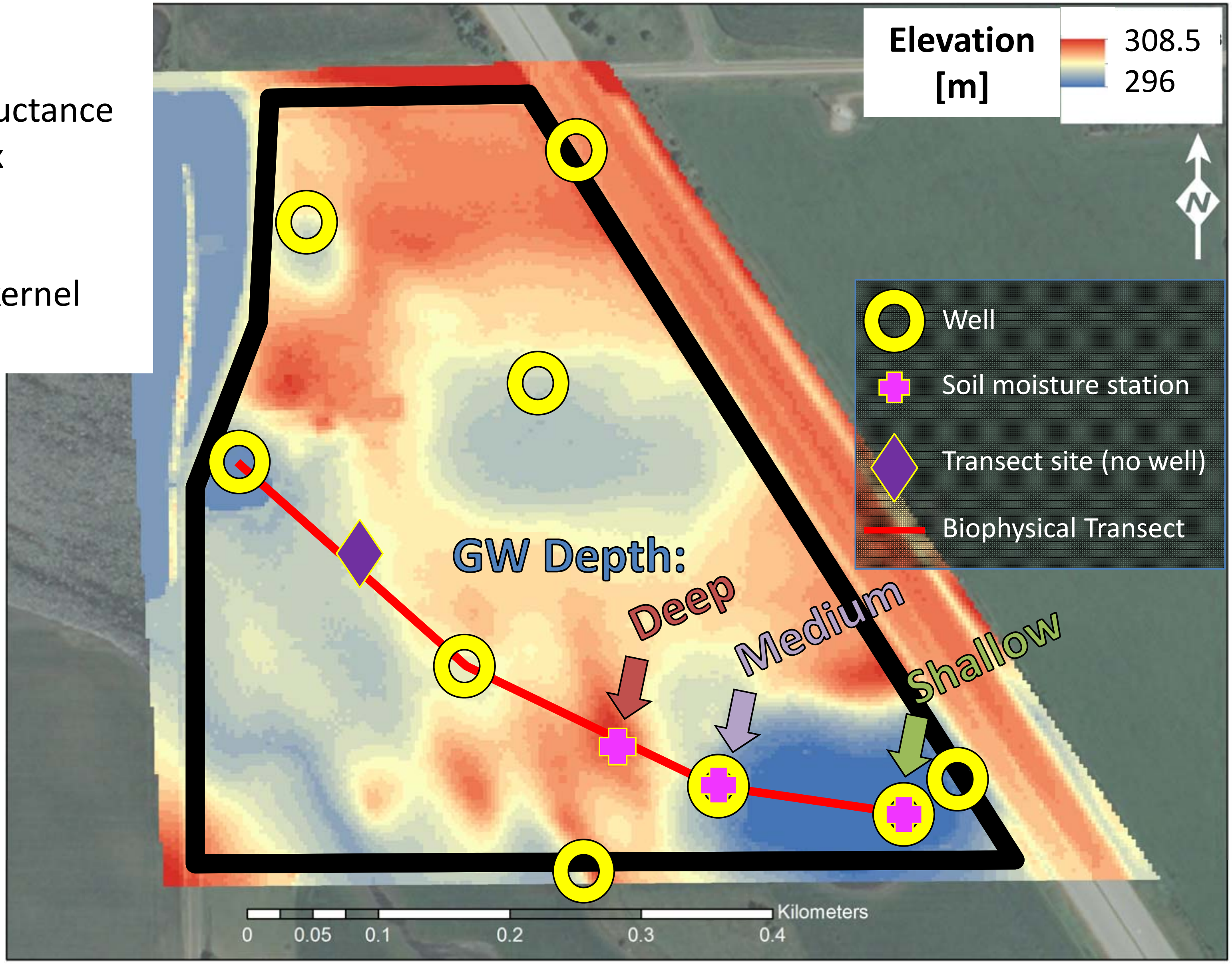
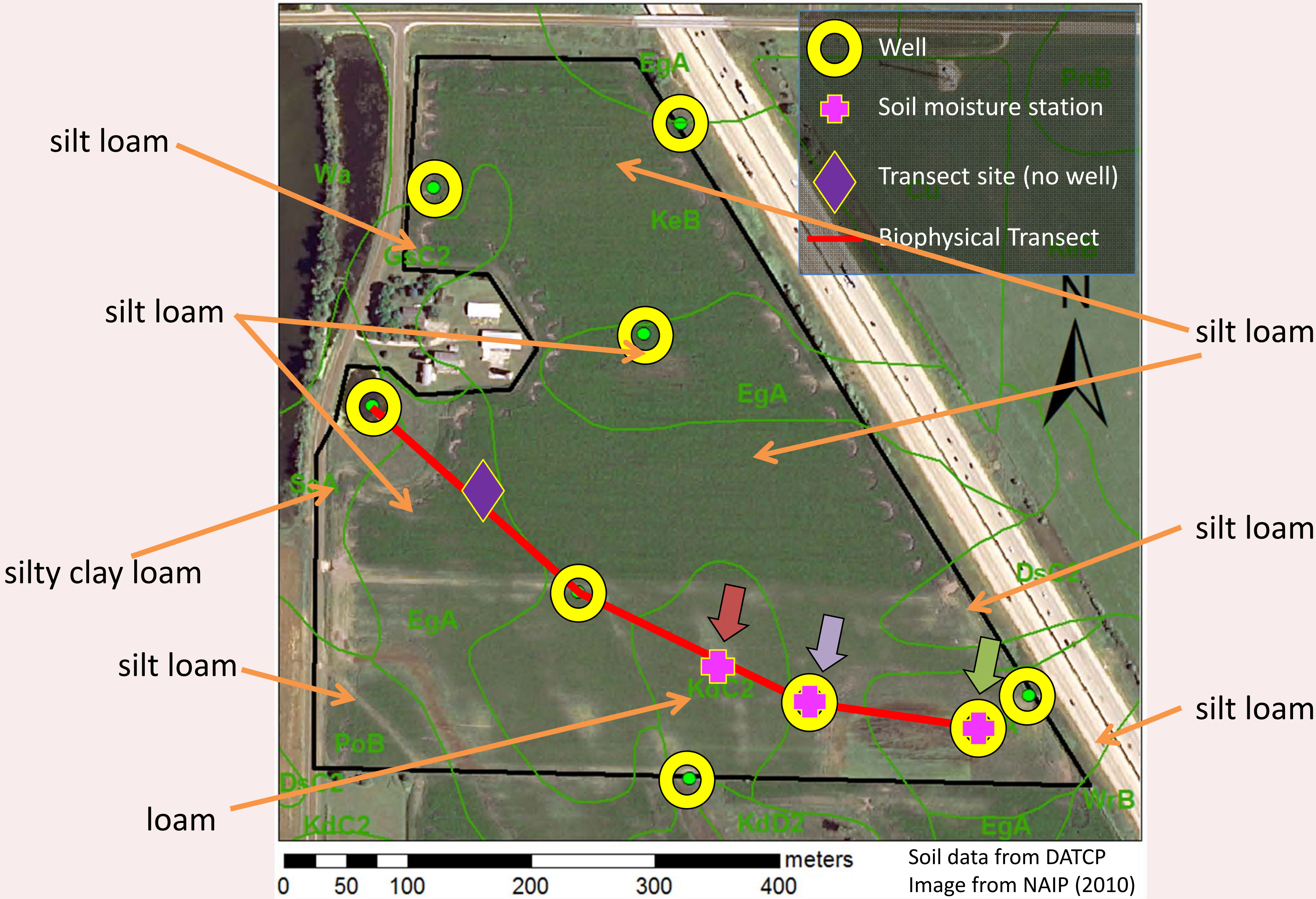



Well
Soil moisture station
Transect site (no well)
Biophysical Transect
N
silt loam
silt loam
silty clay loam
silt loam
loam
silt loam
silt loam
silt loam
EgA
KeB
EgA
EgA
Wa
GsC2
PoB
KdC2
KdD2
EgA
WrB
0
50
100
200
300
400
meters
Soil data from DATCP
Image from NAIP (2010)

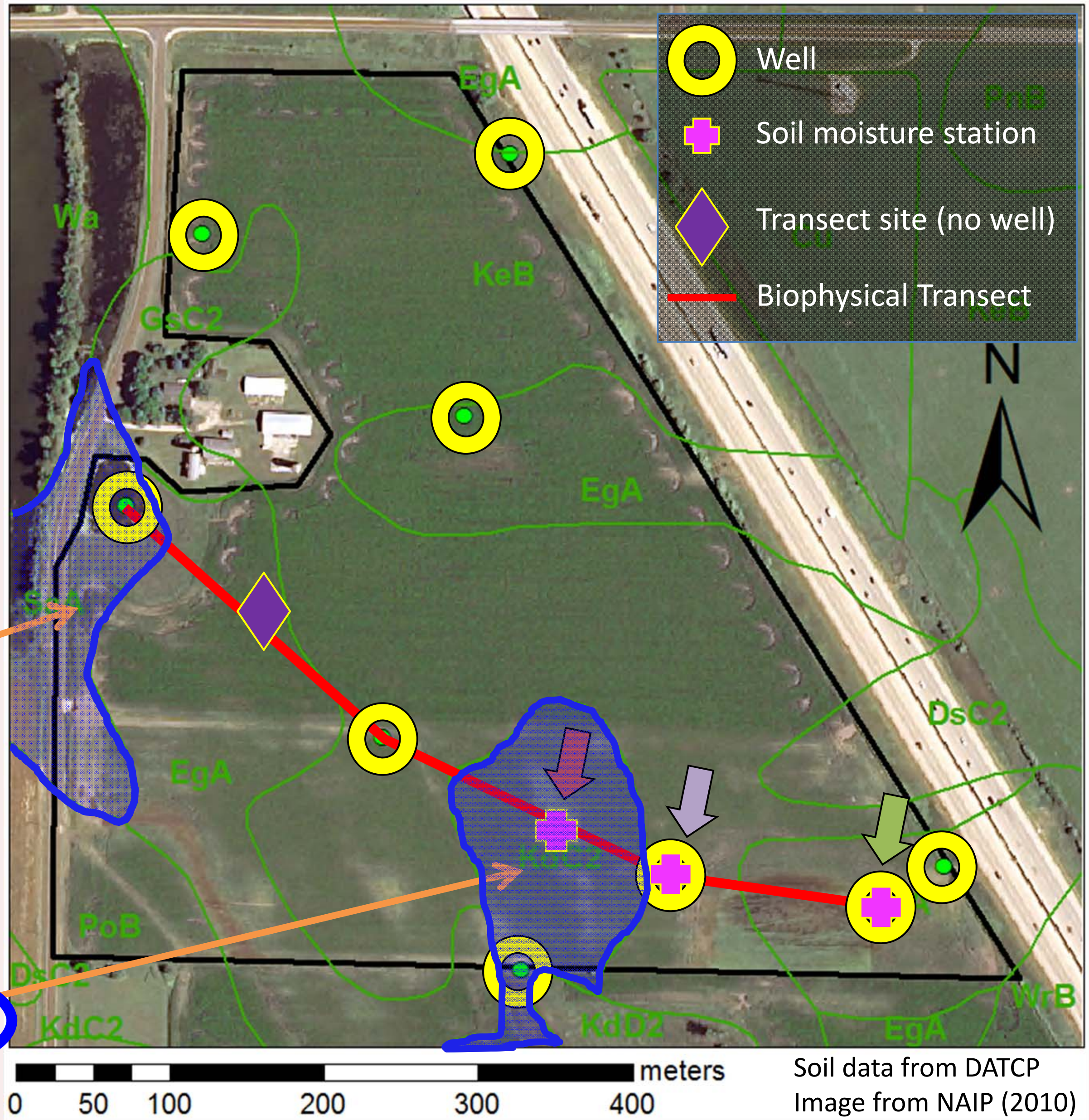
silt loam

silt loam

silty clay loam

silt loam

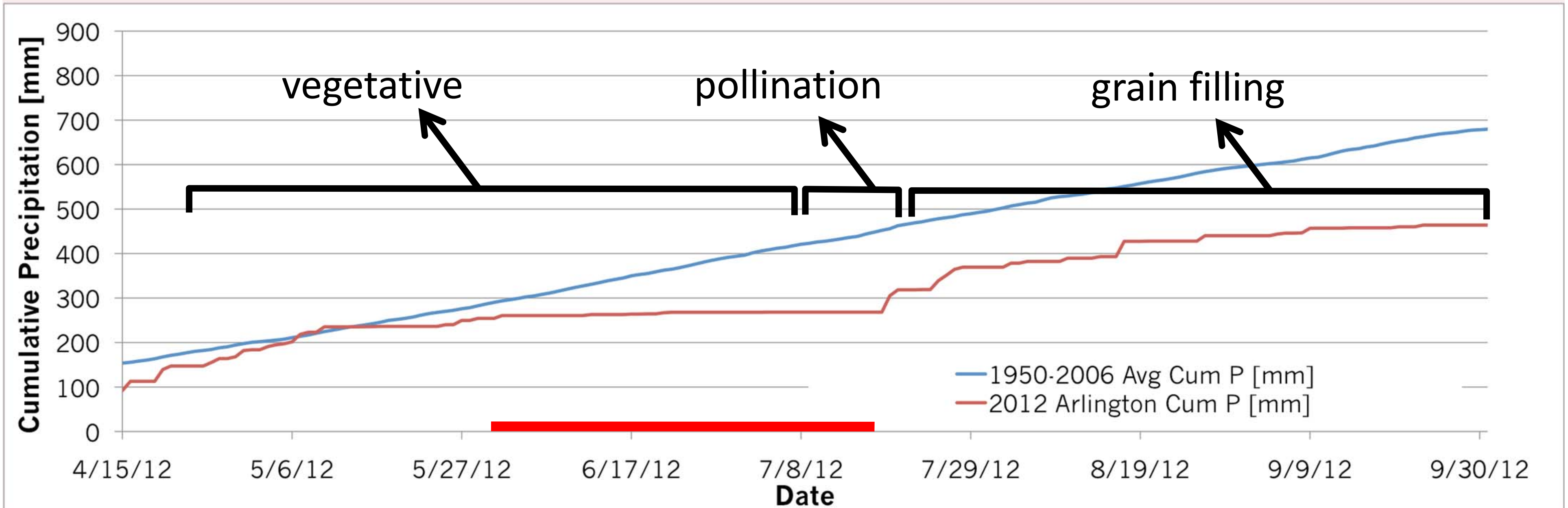
loam

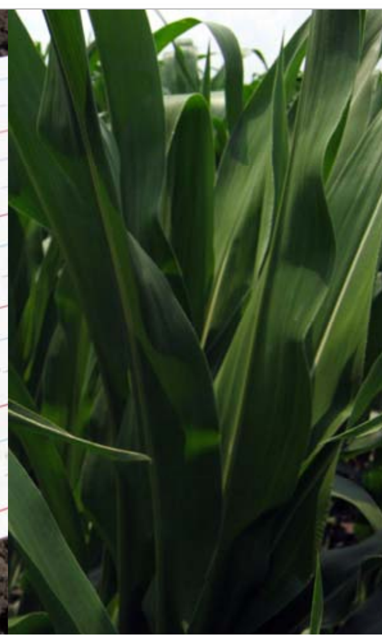


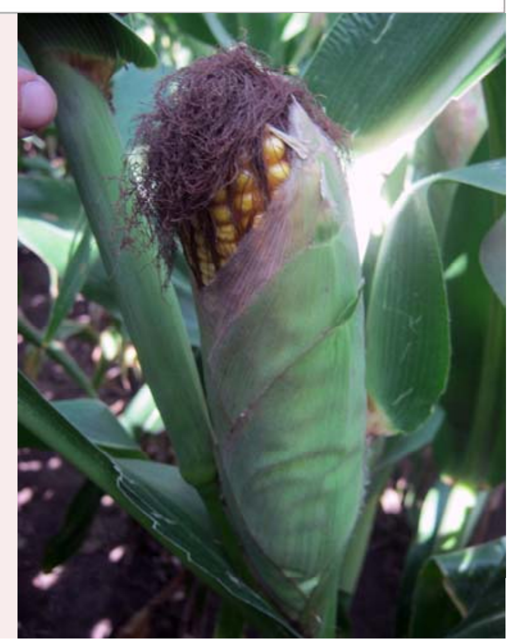
silt loam

silt loam

silt loam

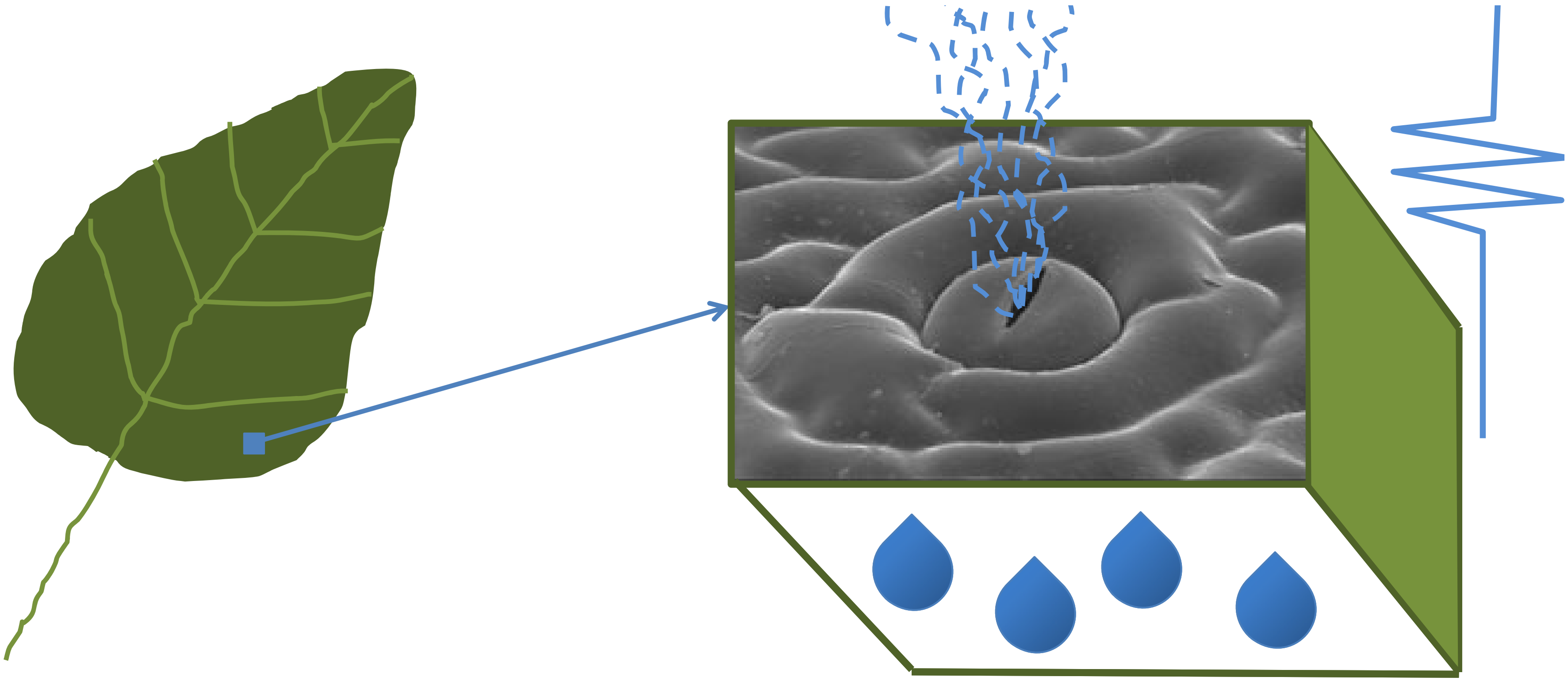

Cumulative Precipitation [mm]
900
800
700
600
500
400
300
200
100
0
vegetative
pollination
grain filling
1950-2006 Avg Cum P [mm]
2012 Arlington Cum P [mm]
4/15/12
5/6/12
5/27/12
6/17/12
7/8/12
7/29/12
8/19/12
9/9/12
9/30/12
Date



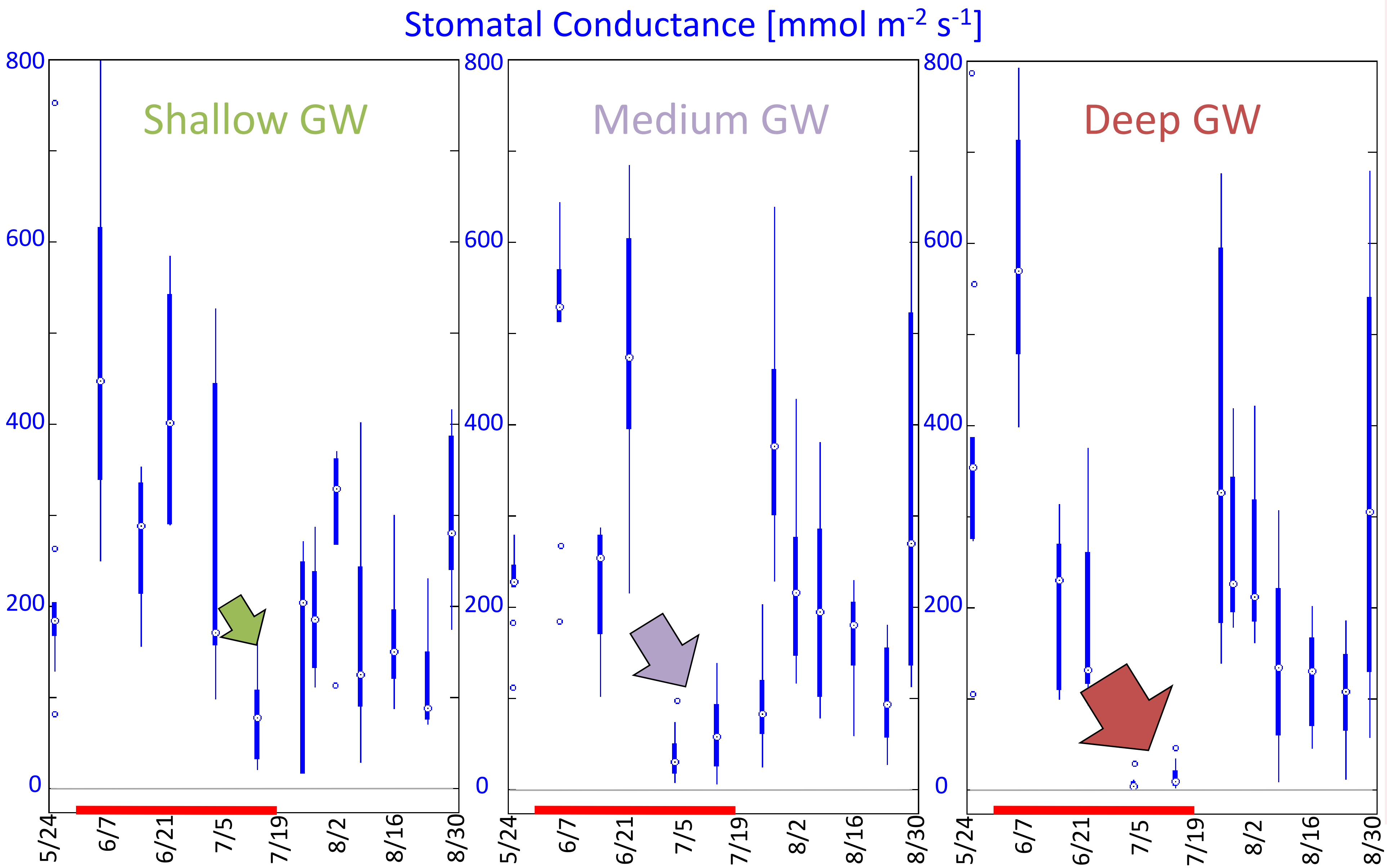


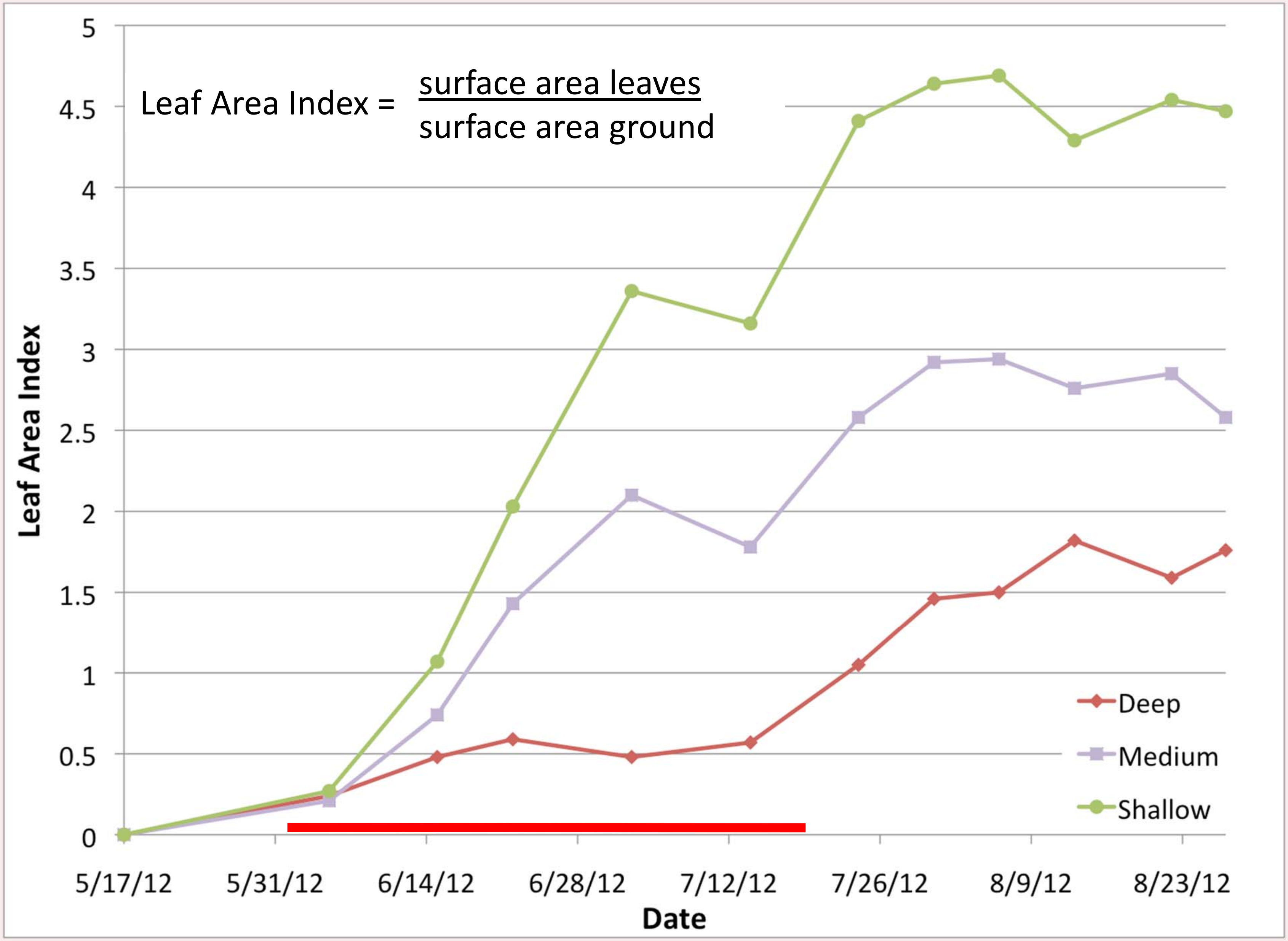
Stomatal Conductance [mmol m^{-2} s^{-1}]

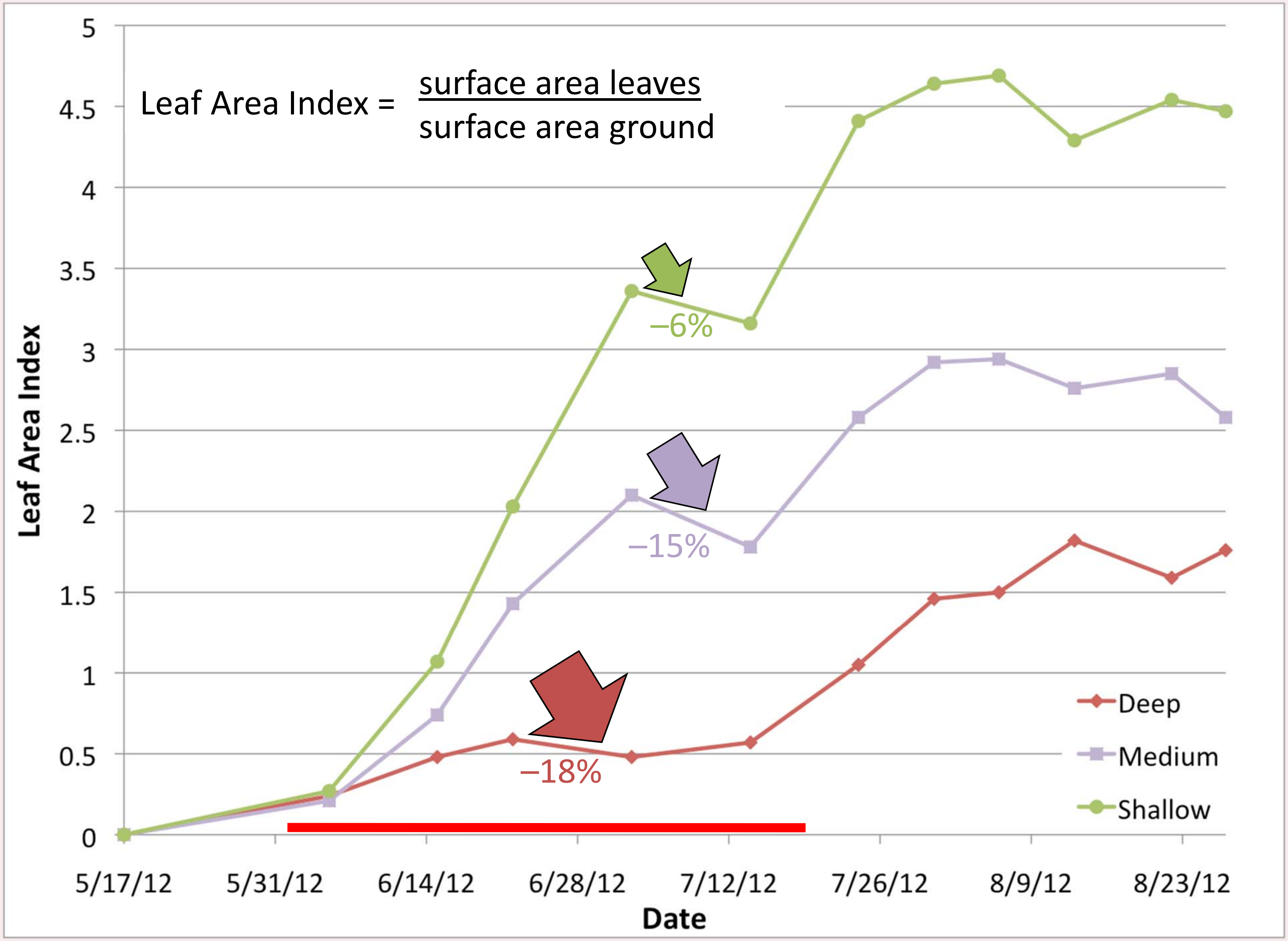
- Measure of how easily water, CO2 can enter/leave a plant
- Higher stomatal conductance → higher transpiration, photosynthesis
- Water stress → reduced stomatal conductance → reduced photosynthesis

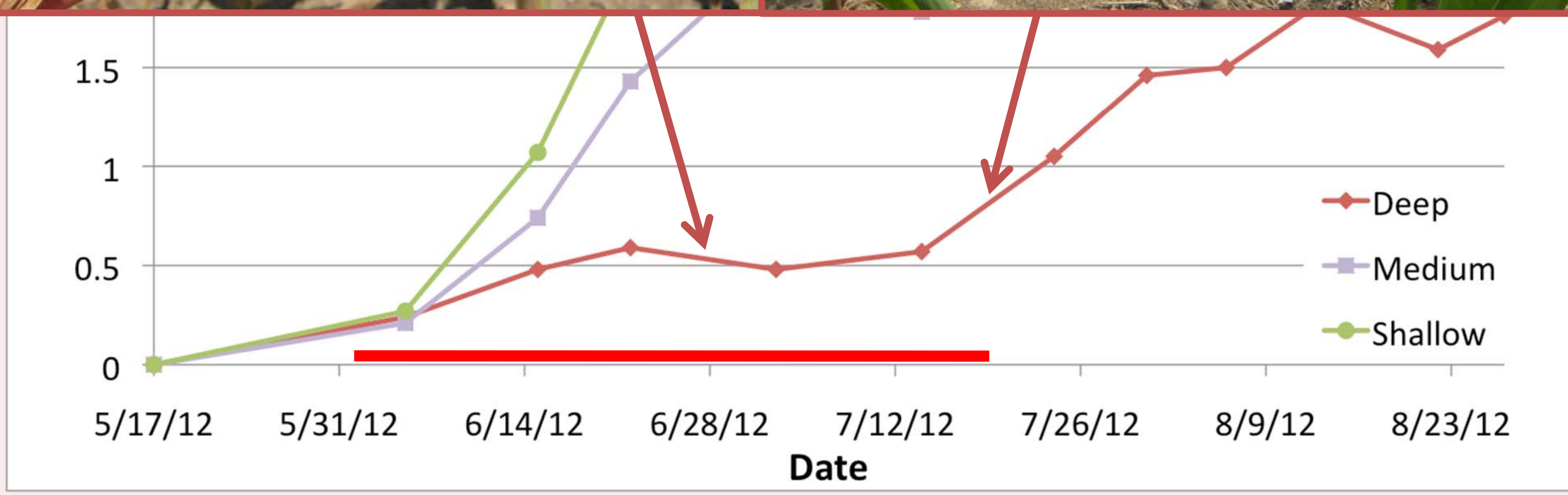


Stomata Image: http://im.glogster.com/media/4/31/83/78/31837882.jpg


Stomatal Conductance [mmol m-2 s-1]
Shallow GW
Medium GW
Deep GW
800
600
400
200
0
5/24
6/7
6/21
7/5
7/19
8/2
8/16
8/30


Leaf Area Index = surface area leaves / surface area ground
Leaf Area Index
Date
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
5/17/12
5/31/12
6/14/12
6/28/12
7/12/12
7/26/12
8/9/12
8/23/12
Deep
Medium
Shallow


Leaf Area Index = surface area leaves / surface area ground
Leaf Area Index
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
−6%
−15%
−18%
Deep
Medium
Shallow
5/17/12
5/31/12
6/14/12
6/28/12
7/12/12
7/26/12
8/9/12
8/23/12
Date


1.5
1
0.5
0
5/17/12
5/31/12
6/14/12
6/28/12
7/12/12
7/26/12
8/9/12
8/23/12
Date
Deep
Medium
Shallow

Stomatal Conductance – Micro Scale

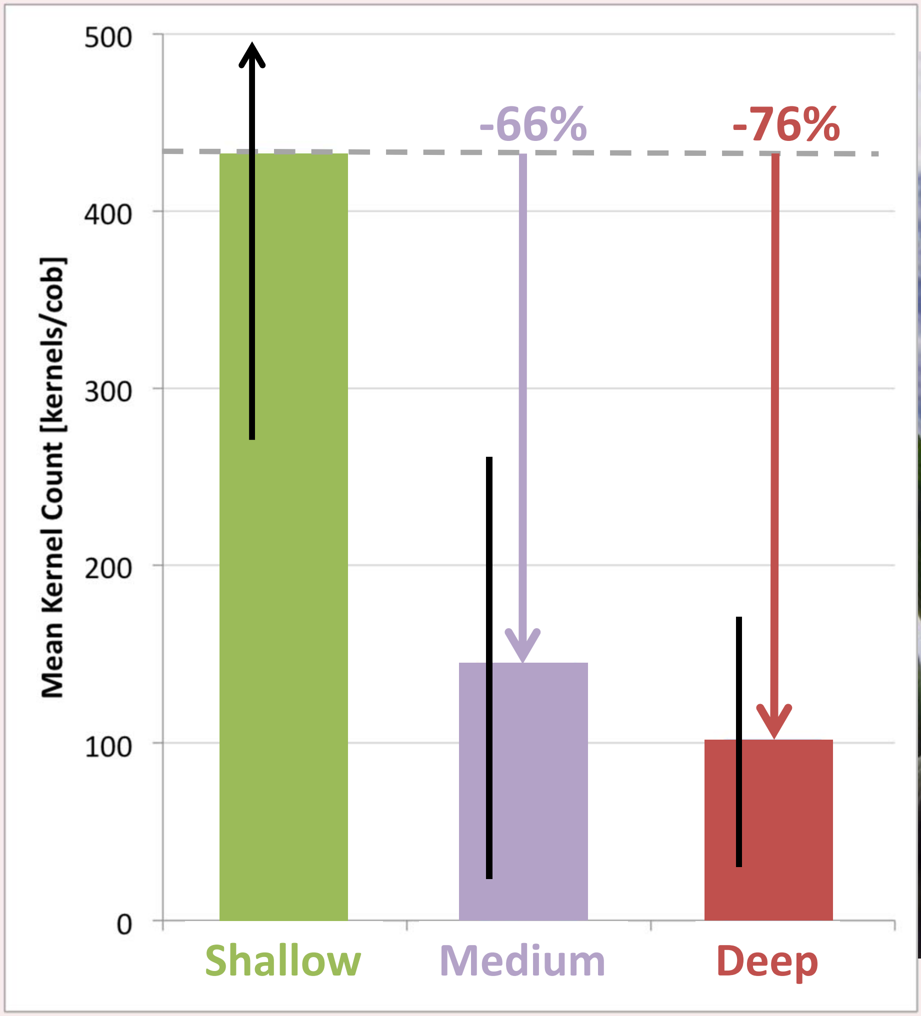
✓ Decrease in stomatal conductance during drought at all sites

✓ **Larger** and **longer** decrease at deep GW site than shallow GW site

Leaf Area Index – Macro Scale

✓ Decrease in LAI at all sites due to leaf wilting/rolling

✓ Magnitude of decrease correlated with GW depth


500
400
300
200
100
0
Mean Kernel Count [kernels/cob]
-66%
-76%
Shallow
Medium
Deep

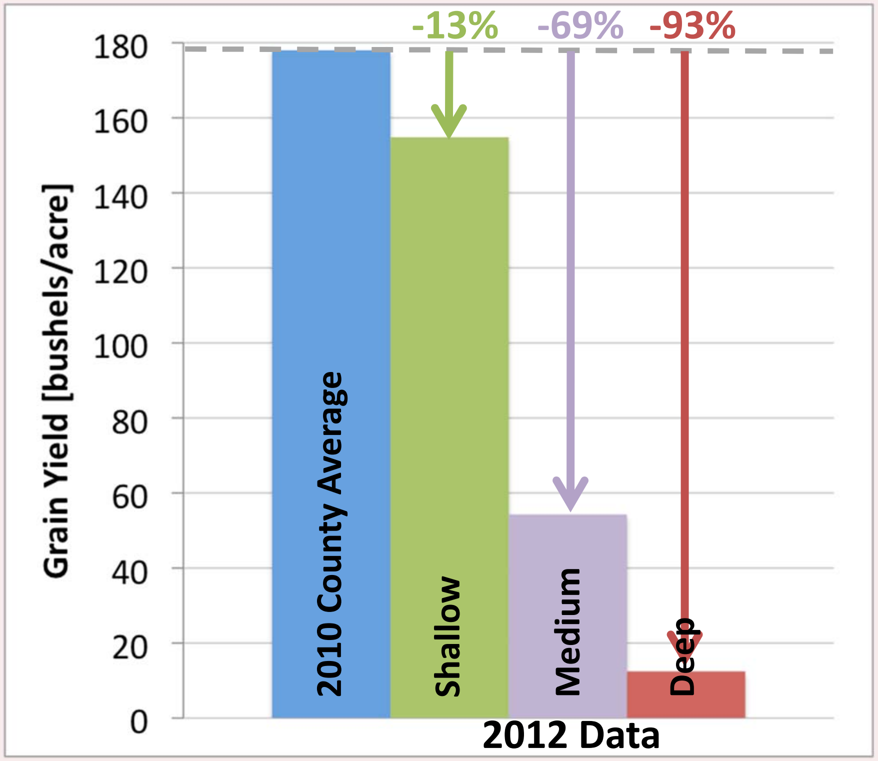


Image source: rawlingsbrokeragecompany.com

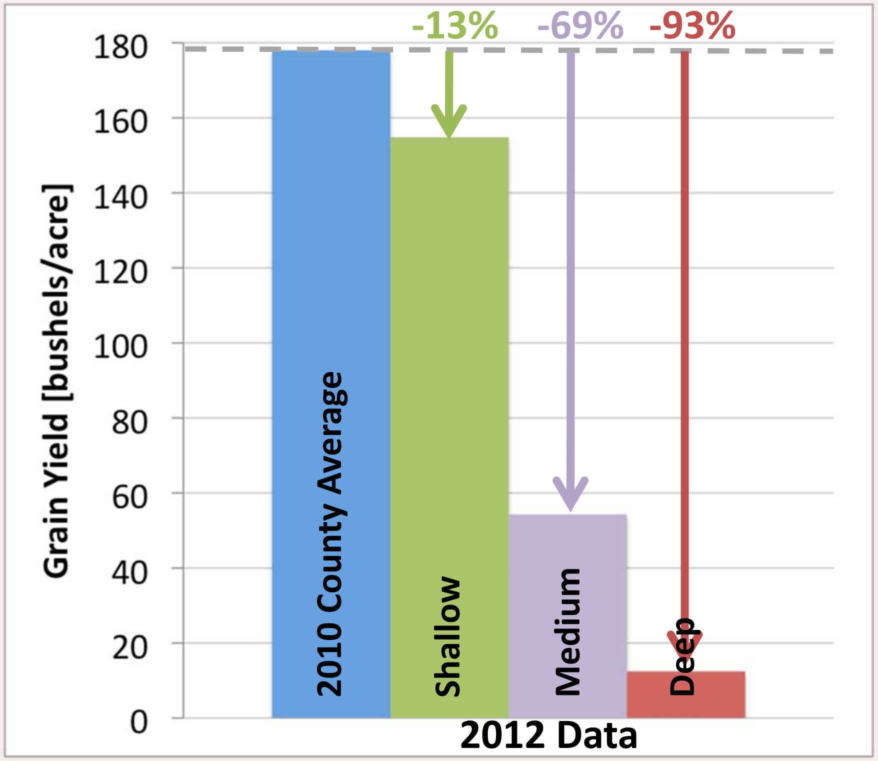
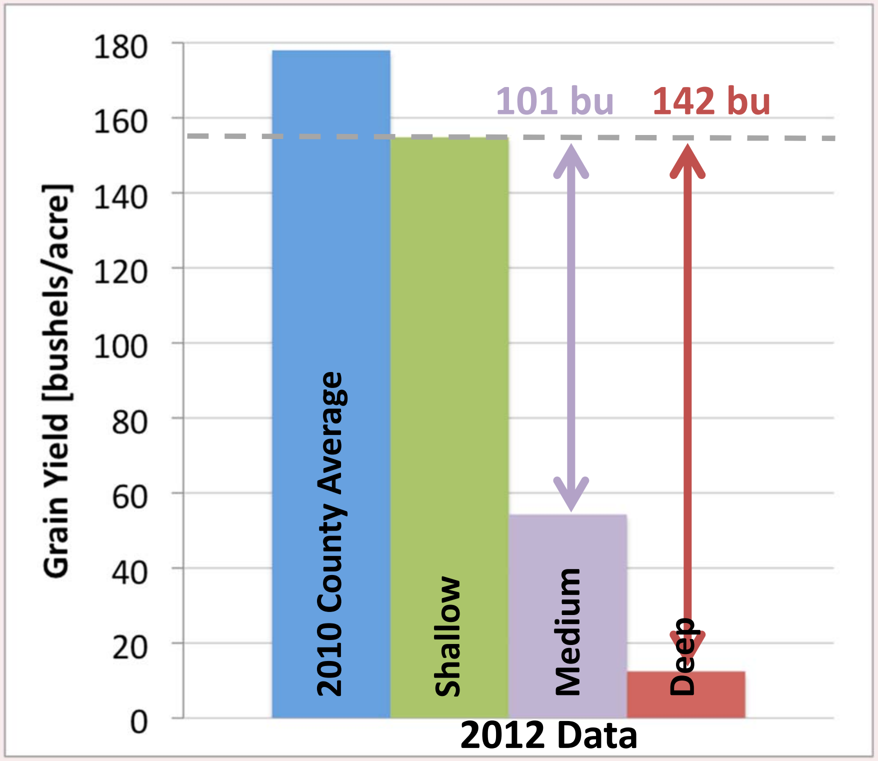


Image source: rawlingsbrokeragecompany.com

Lowry & Loheide (2010), *WRR*:

Additional plant water use in the presence of shallow groundwater, as compared to free drainage conditions

GW Subsidy = $WU_{GW} - WU_{FD}$



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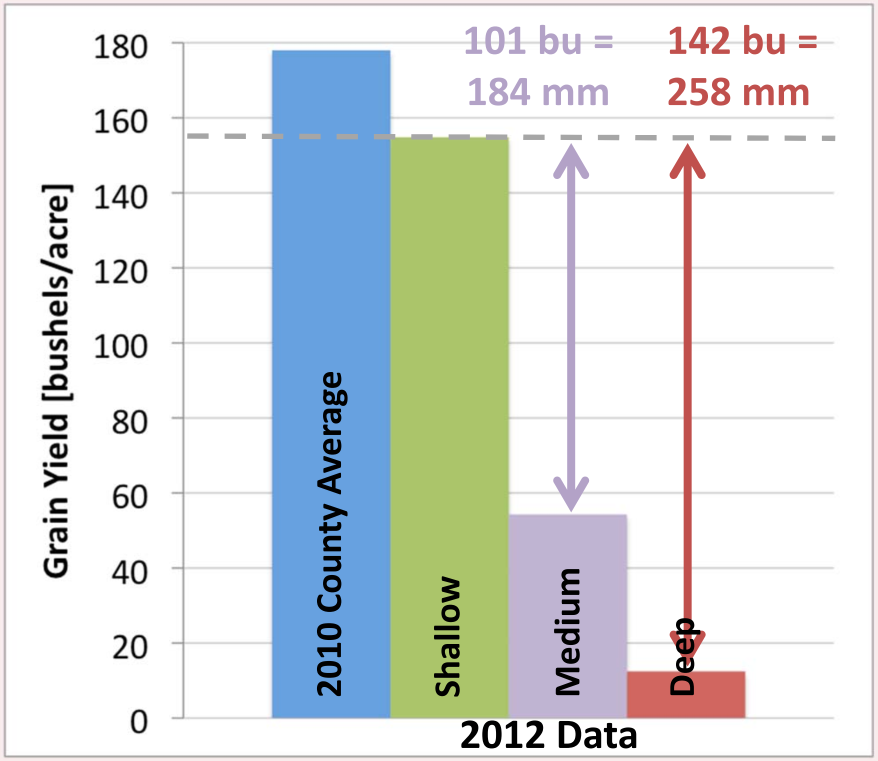
$$\text{GW Subsidy} = WU_{GW} - WU_{FD}$$

$$\text{GW Subsidy} = (\text{Yield}_{GW} - \text{Yield}_{FD})/\text{WUE}$$

Corn Grain WUE = 0.55 bu/mm (FAO TR07)



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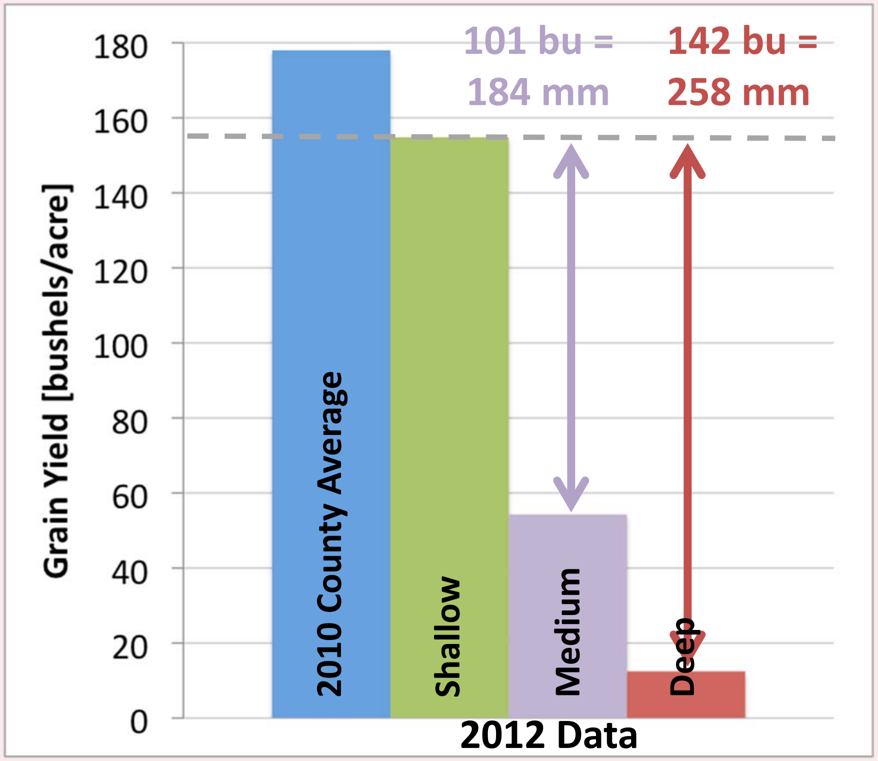

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GW Subsidy = 184-258 mm

Corn Biomass WUE = 3.3 kg/m^3 (UW-Ex)

GW Subsidy = up to 148 mm

GW Subsidy = ~150-250 mm

18-30% mean annual precipitation

28-47% mean annual ET

1. **Identify** major corn physiological responses to water stress during 2012 drought

2. **Contextualize** physiological responses in terms of groundwater availability

3. **Quantify** yield losses as a result of water stress

4. **Calculate** groundwater subsidy provided to corn from shallow water table

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   - ✓ Reduced stomatal conductance rates
   - ✓ Reduced LAI
   - ✓ Mistimed pollen release

   → Reduced transpiration, photosynthesis
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   - ✓ 28-48% mean annual ET

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GW is an important resource for crop production!!

Questions?

Funding:

NSF Grant DEB-1038759
Anna Grant Birge Award

Tons of Help:

Taylor Pomije
Erin Gross
Eric Booth

Advice:

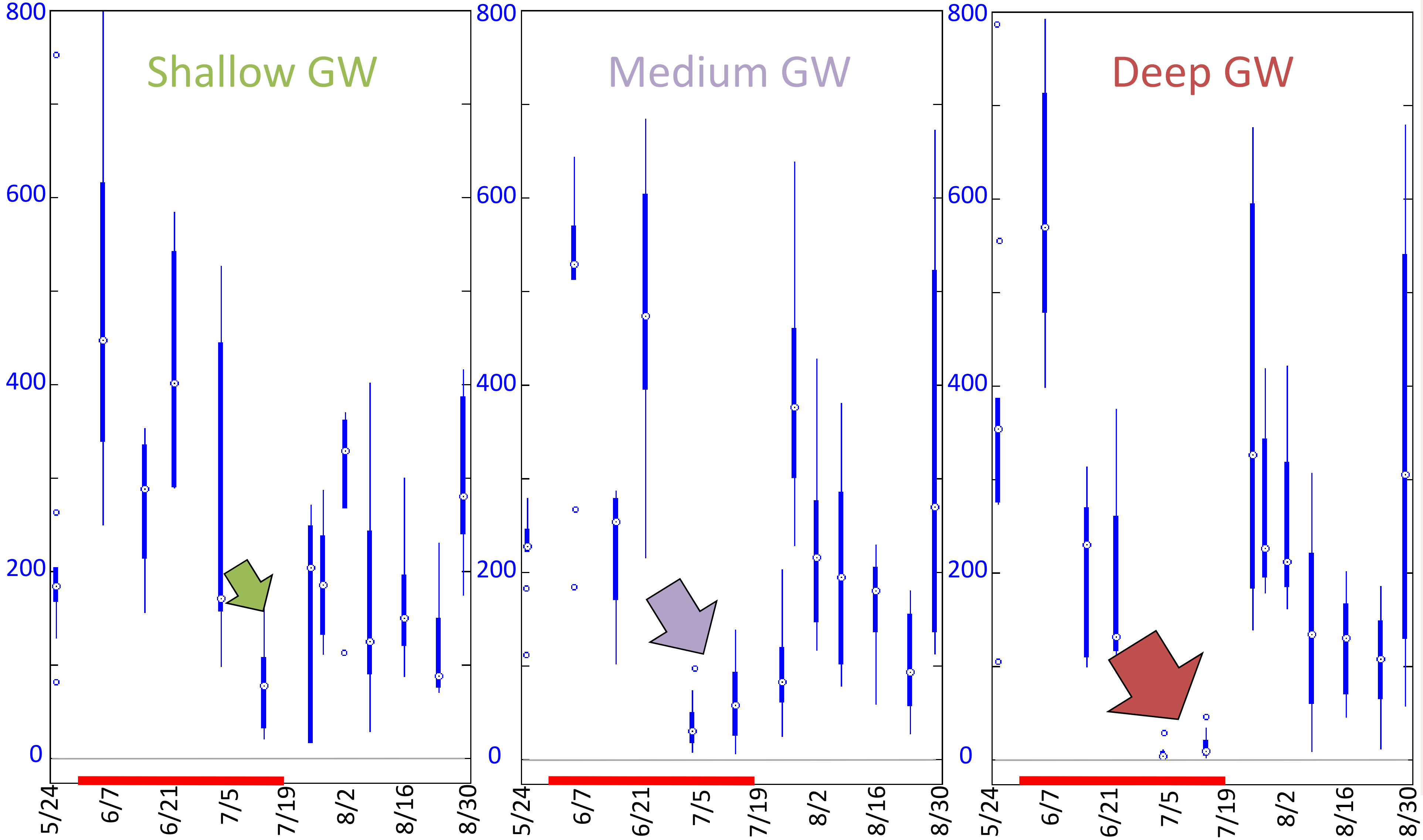
Steve Loheide
Chris Kucharik
Gregg Sanford
Other WSC/ WRE faculty, post-docs, students

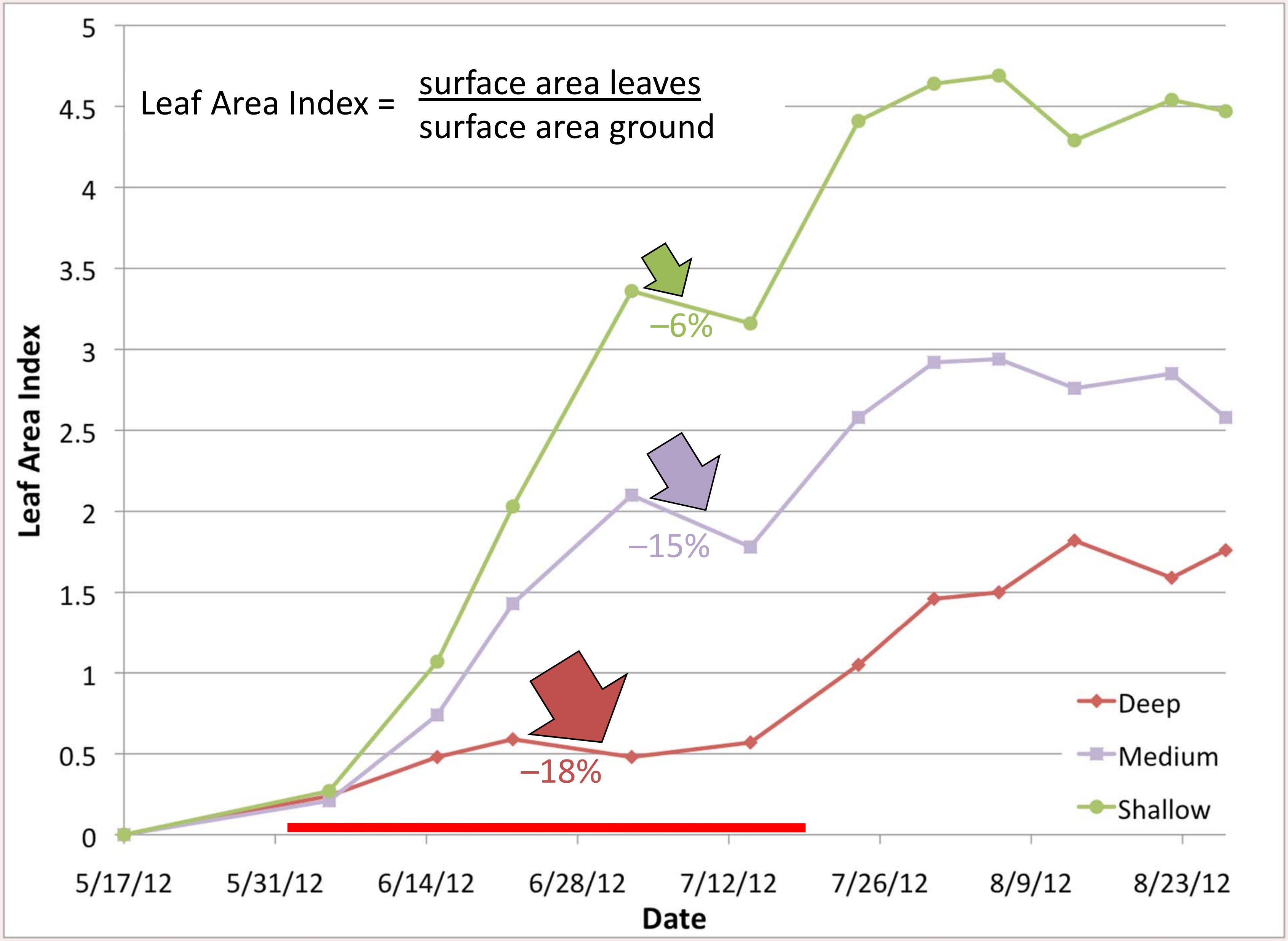
Field Help:

Doug Brugger
Erin Crabb
Sean Gillon
Emilio Medina
Missy Motew
Evren Soylu
Carolyn Voter
Nathan Wells
Jiangxiao Xiu
Joey & Tyler

http://wsc.limnology.wisc.edu

Stomatal Conductance [mmol m^{-2} s^{-1}]

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Leaf Area Index
Date
0
0.5
1
1.5
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2.5
3
3.5
4
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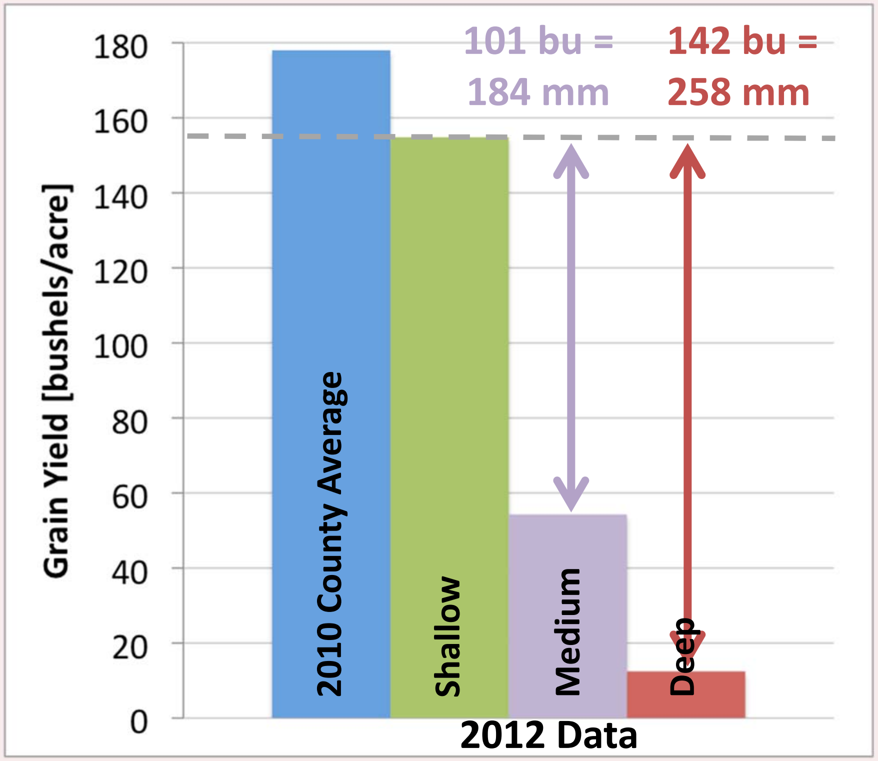
5
5/17/12
5/31/12
6/14/12
6/28/12
7/12/12
7/26/12
8/9/12
8/23/12
−6%
−15%
−18%
Deep
Medium
Shallow



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Results – Silage & Grain Yields

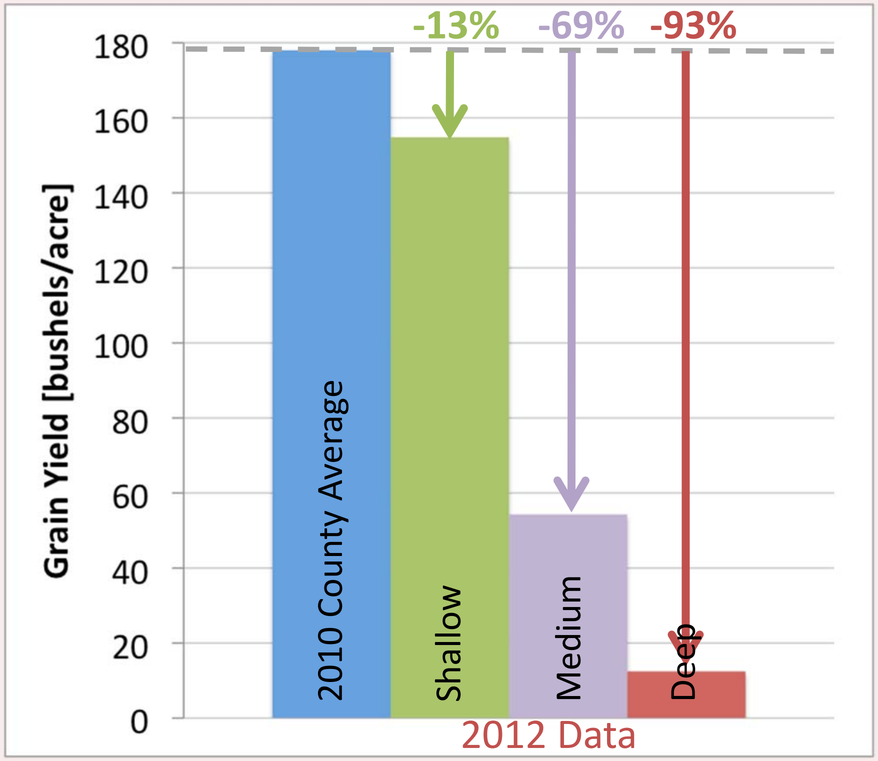


Image source: lifeonadairy.blogspot.com

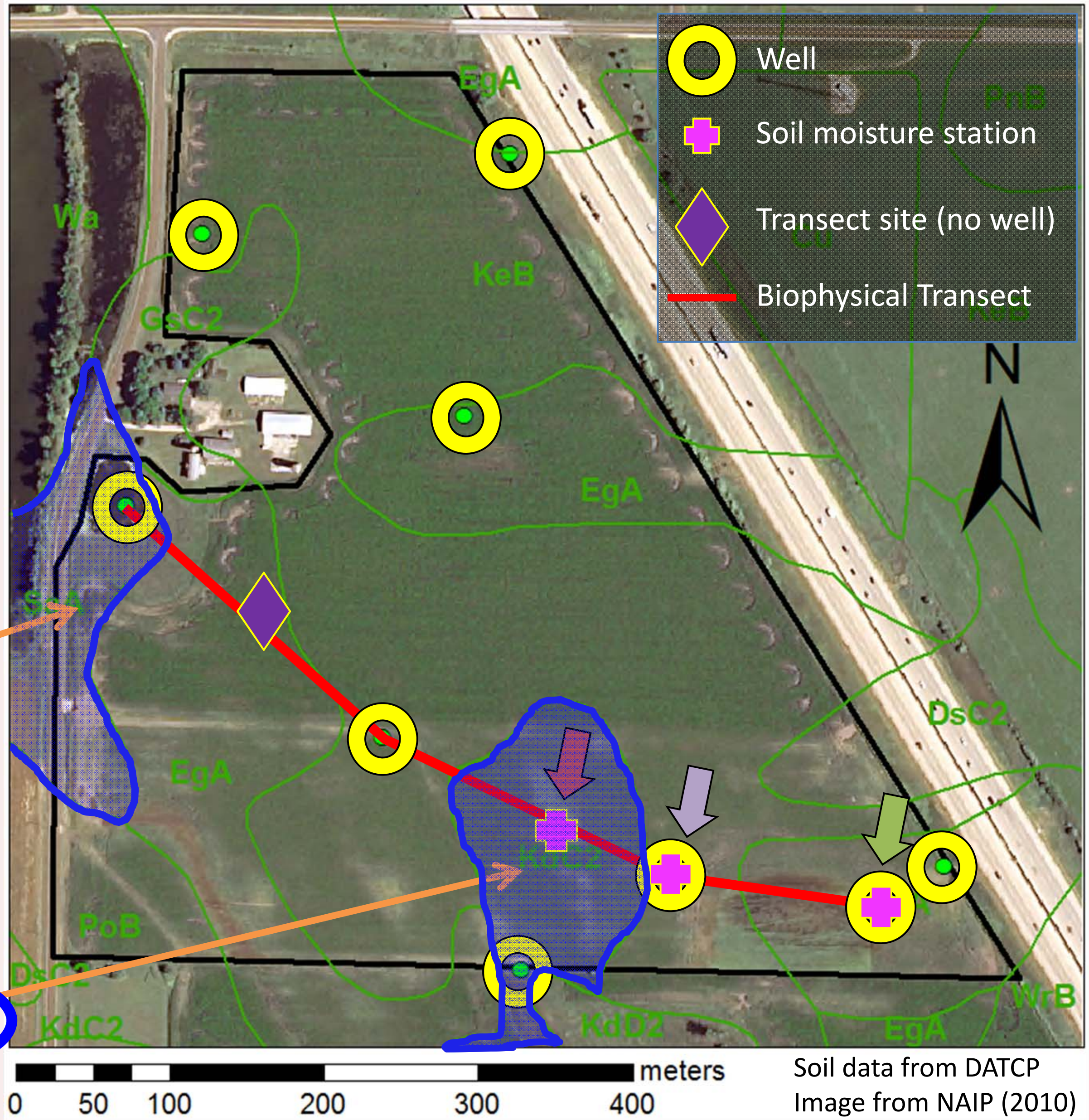
Image source: rawlingsbrokeragecompany.com silt loam

silt loam

silty clay loam

silt loam

loam



silt loam

silt loam

silt loam

Study Site

Measurements

-GW elevation
-Stomatal conductance
-Leaf area index
-Total biomass
-Grain mass
-Kernel count, kernel mass, etc.