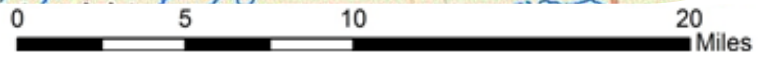
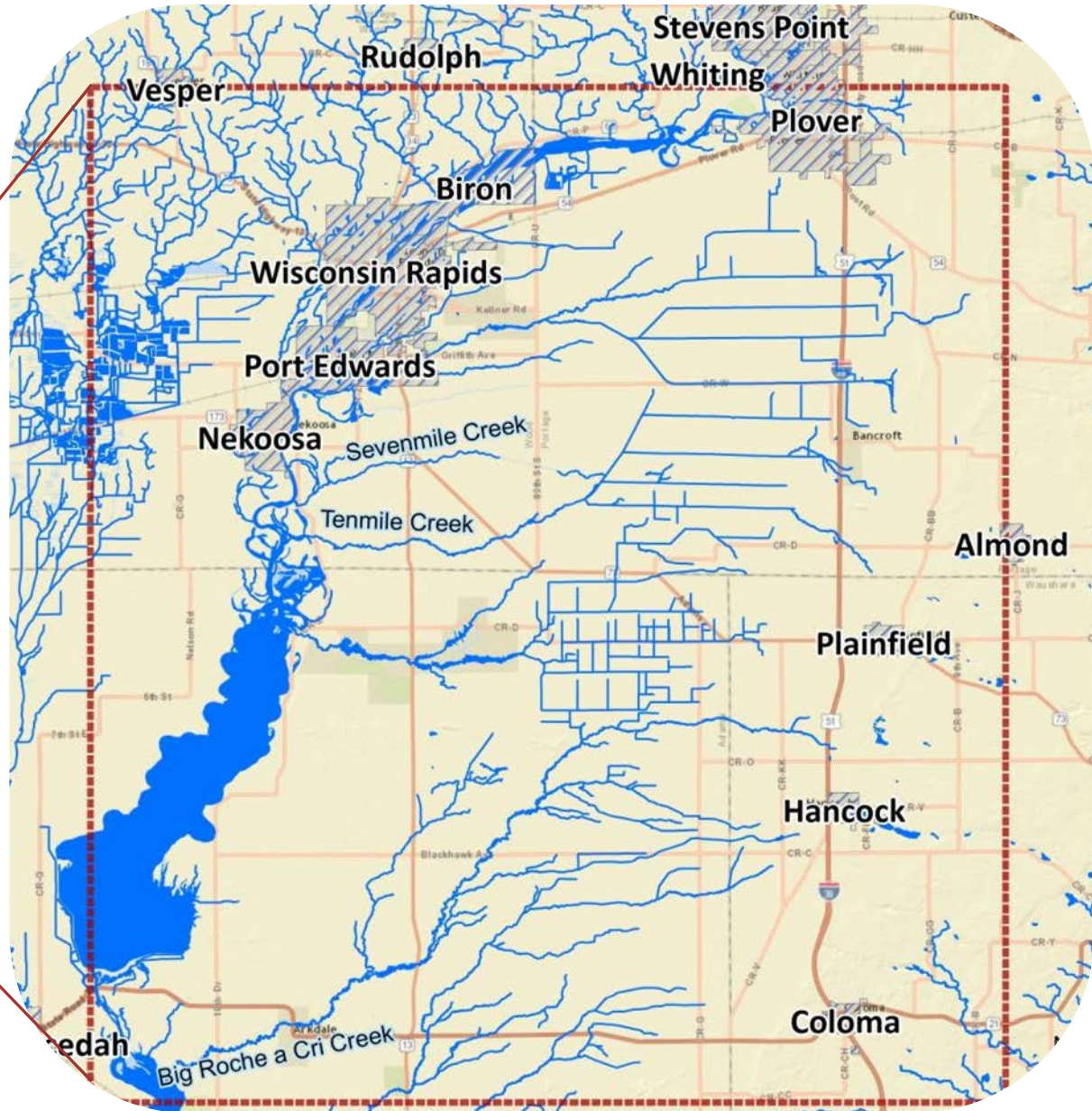
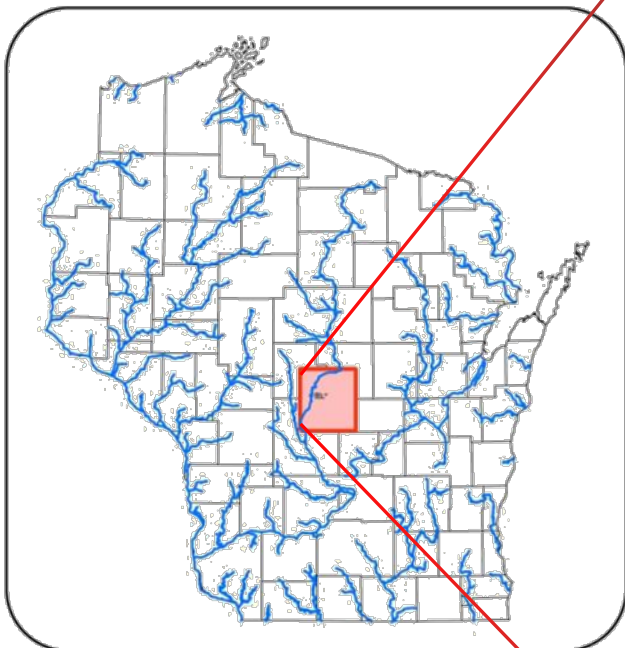


Estimating Groundwater Recharge within Wisconsin's Central Sands

Adam Freihoefer and Robert Smal
Wisconsin Department of Natural Resources
August 30, 2016



Identify a defensible approach to quantify monthly groundwater recharge in support of groundwater flow models used to evaluate existing and proposed high capacity wells





Timing: *month and annual averages*



Scale: *Landscape*

Deposits



Withdrawals

- Precipitation
- Applied Irrigation Water
- Groundwater & Surface Water Inflow

- Evapotranspiration
- Runoff
- Pumping
- Groundwater & Surface Water Outflow

Indices

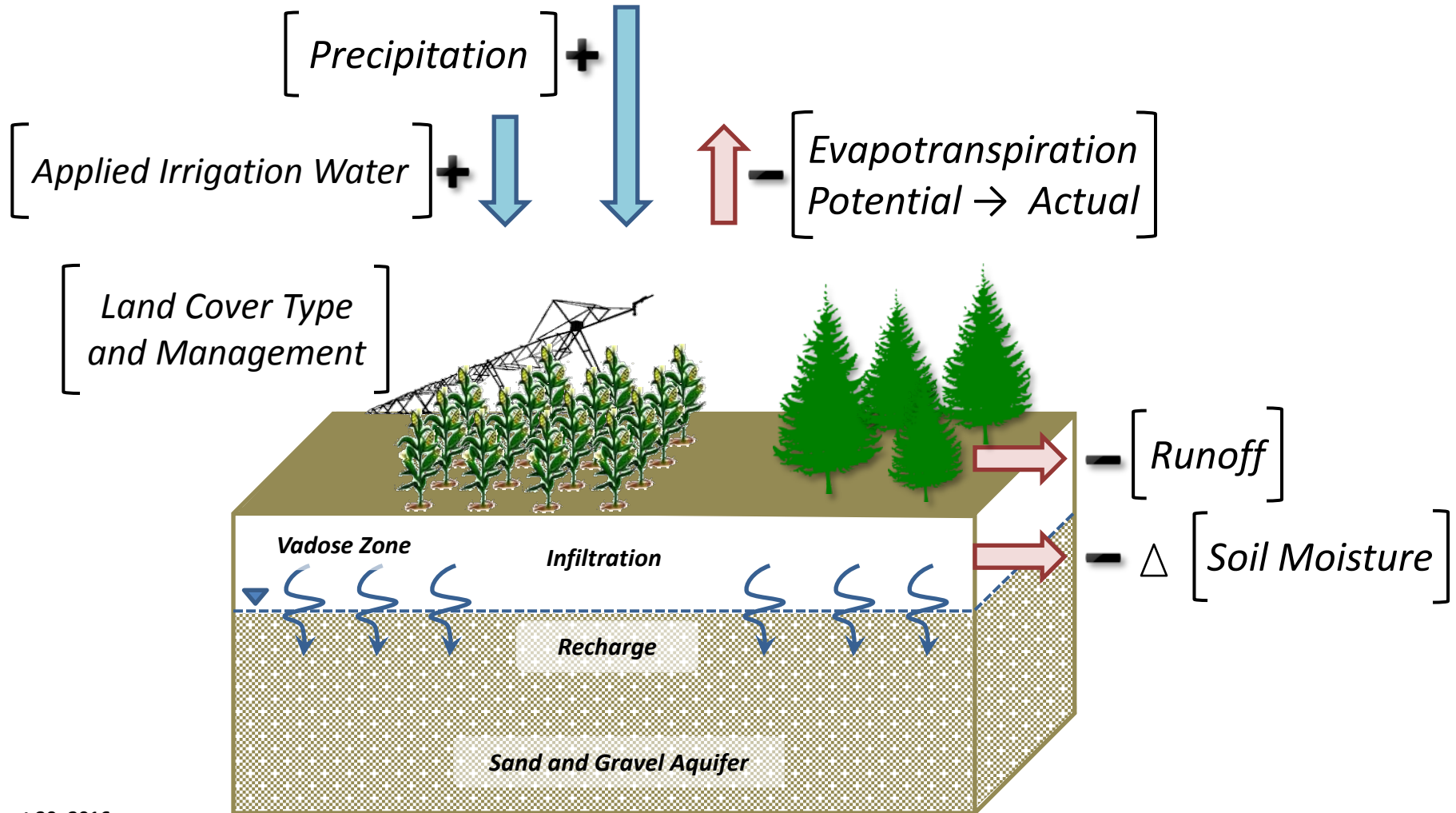


- Streamflow
- Lake Levels
- Groundwater Levels



[recharge defined]

The total amount of water that reaches the water table, becoming part of the groundwater system



MODIS-based Water Budget



INPUTS

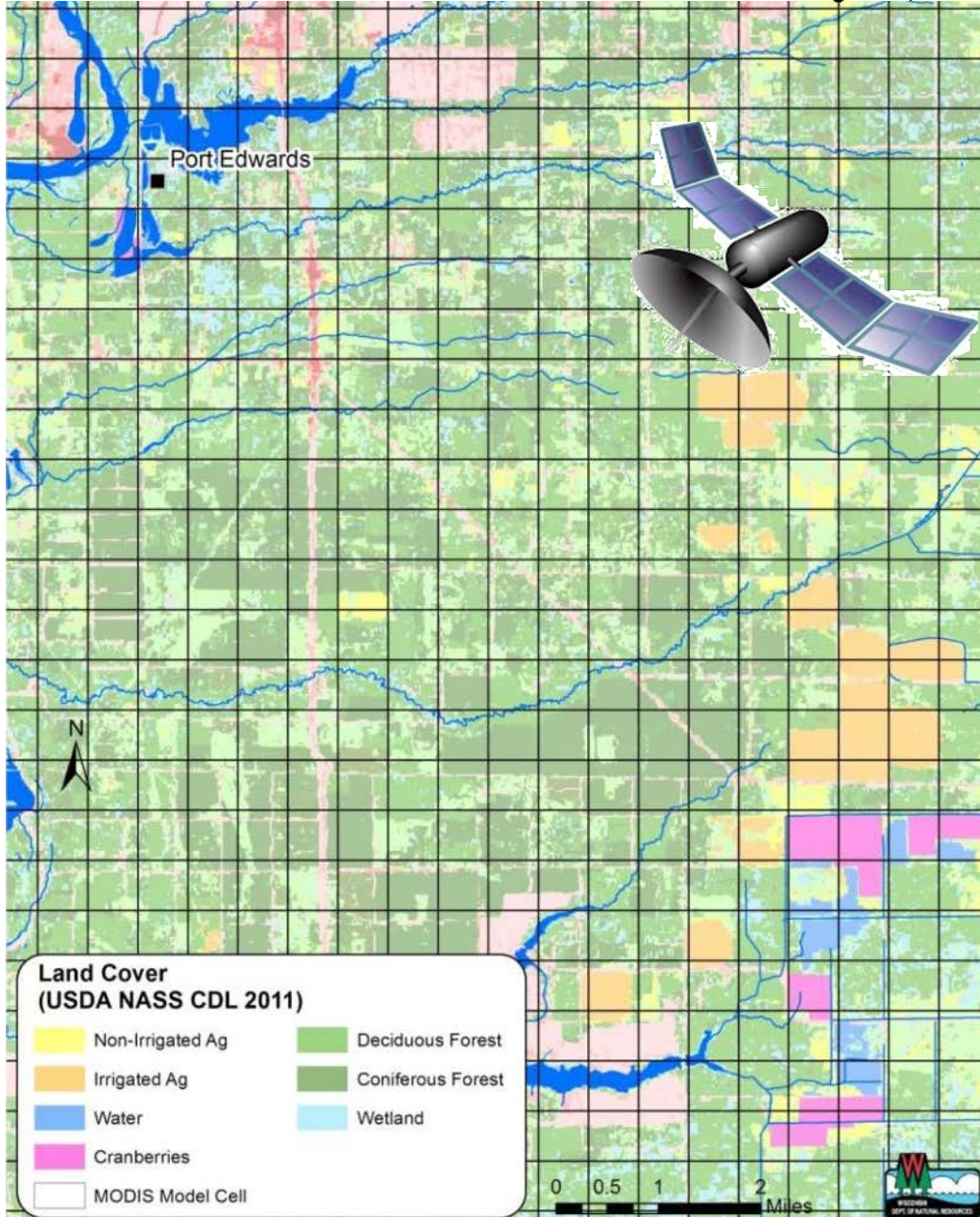
- [precipitation]
- [applied irrigation water]
- [MODIS Actual ET]
- [runoff]

OUTPUTS

- [recharge]

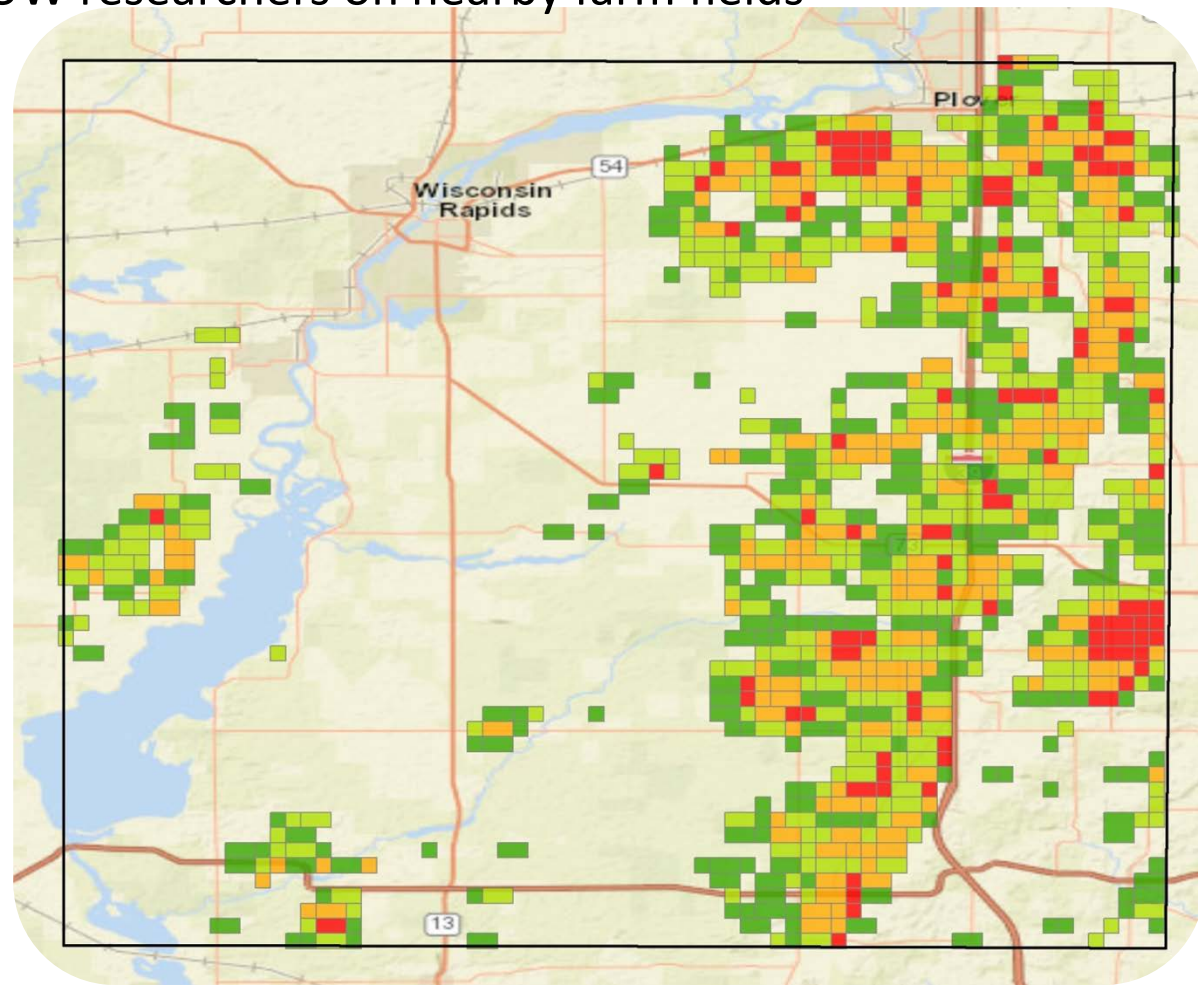
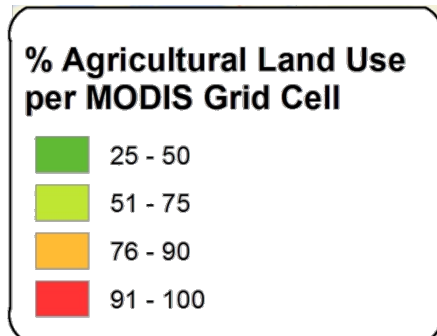
[recharge estimation technique - MODIS]

- Moderate Resolution Imaging Spectroradiometer flown by NASA satellites (ET referred to as MODIS 16)
- MODIS ET includes
 - evaporation from wet and moist soil,
 - evaporation from rain water intercepted by the canopy
 - transpiration through stomata on plant leaves and stems.
- 8-day, monthly, and annual time steps between 2000 and 2014
- Grid cells are slightly less than 1 km²
- Values derived using the P-M ET equation with climate data and other satellite acquired information as inputs, and calibrated based on measurements from eddy covariance flux towers



Modifications to MODIS Budget Approach

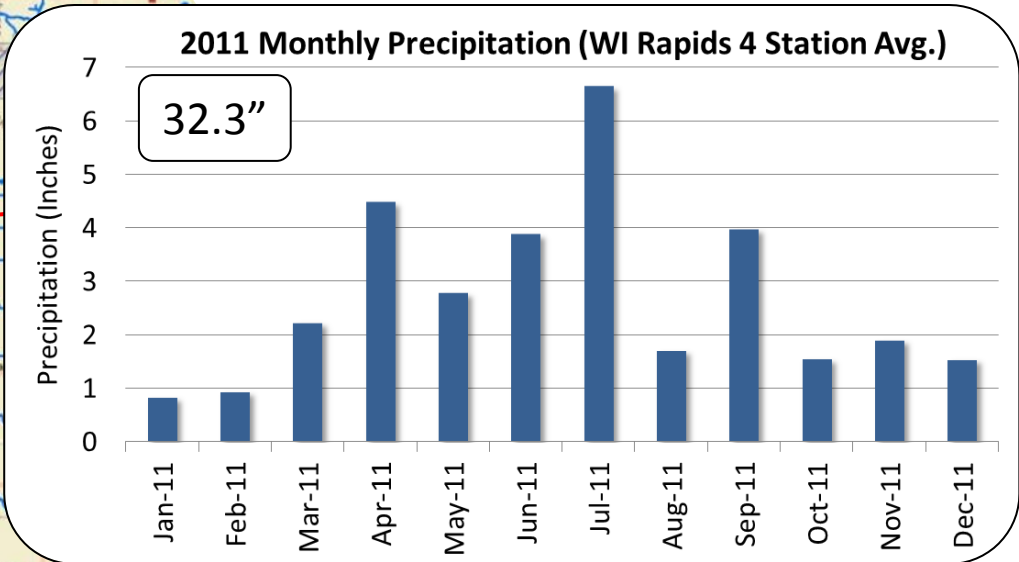
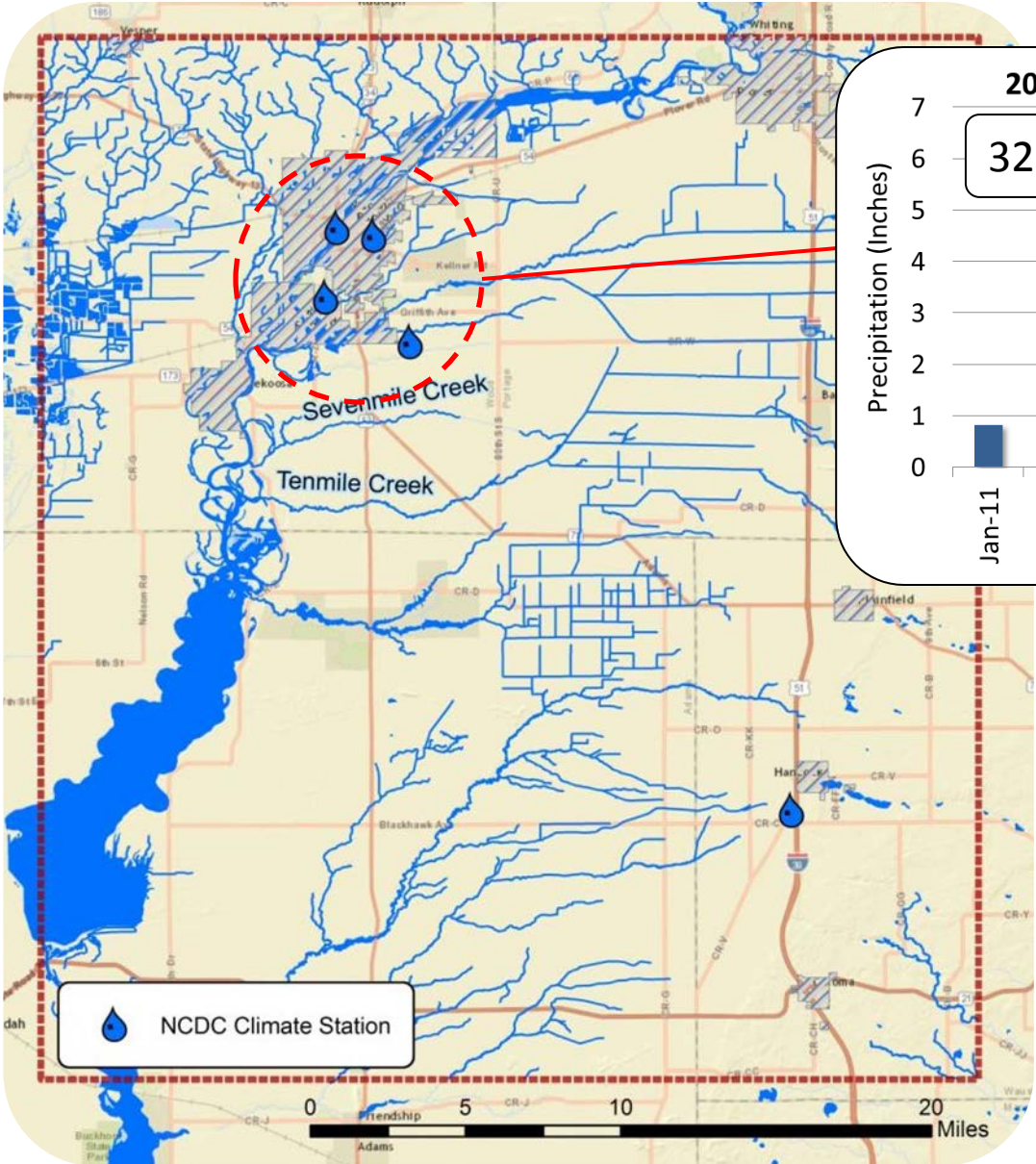
1. Increased MODIS Actual ET by 2" across growing season (0.5" per month)
Why? Acknowledge difference between MODIS 8-day LAI to individual daily measured LAI collected by UW researchers on nearby farm fields
2. For irrigated agriculture, only examined MODIS cells that were > 90% agricultural land cover



[recharge components]



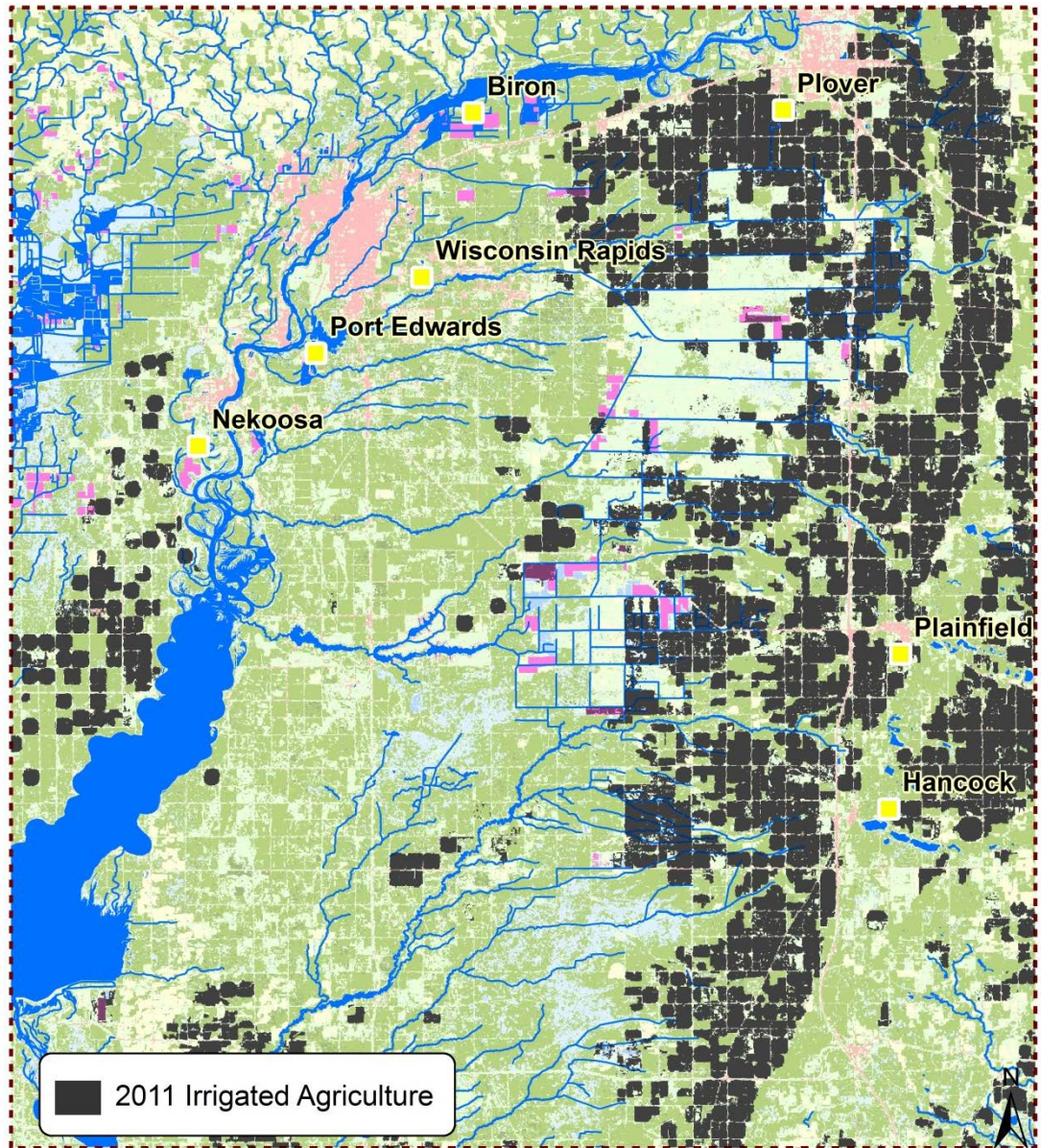
August 30, 2016



[recharge components]



August 30, 2016



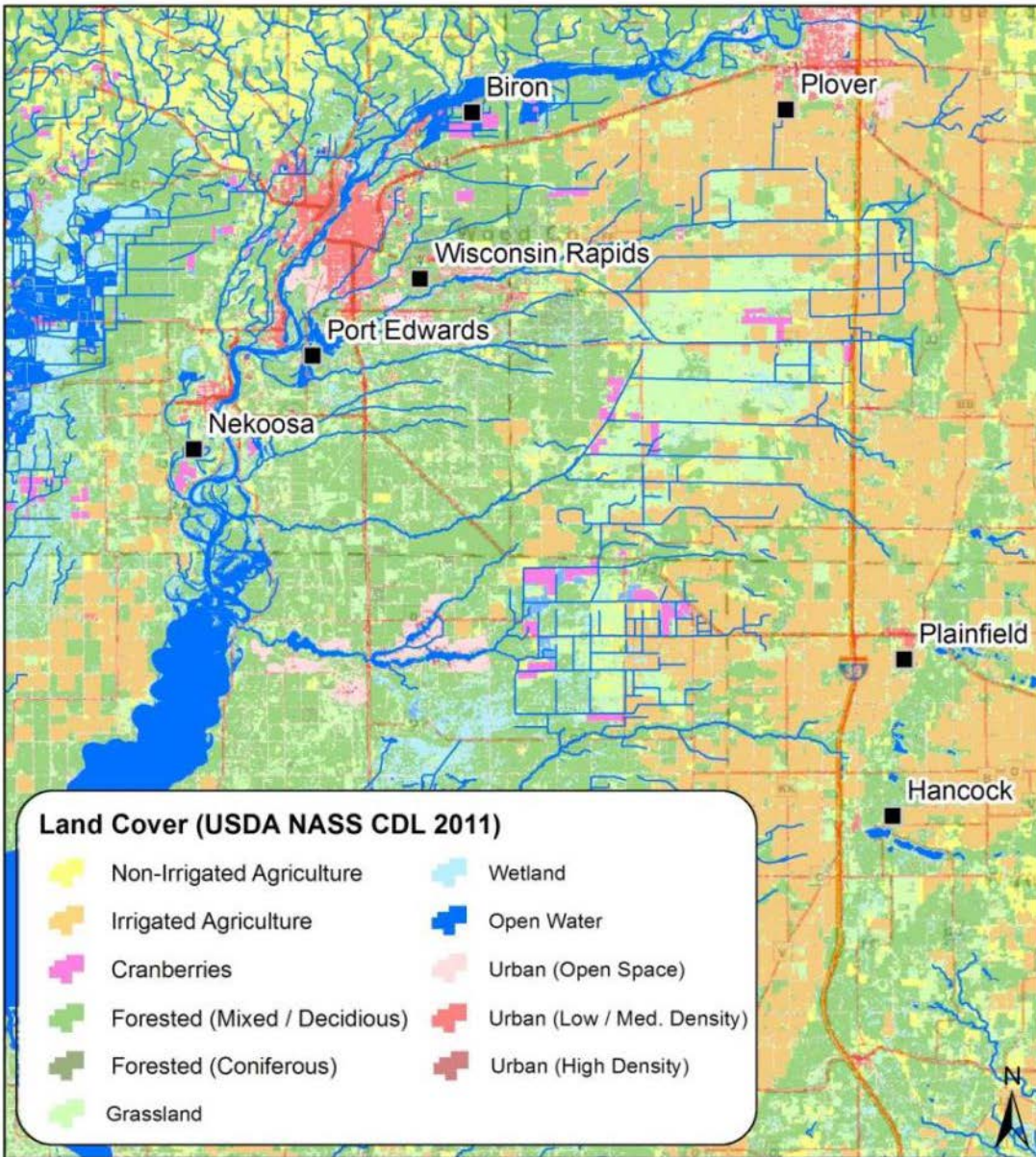
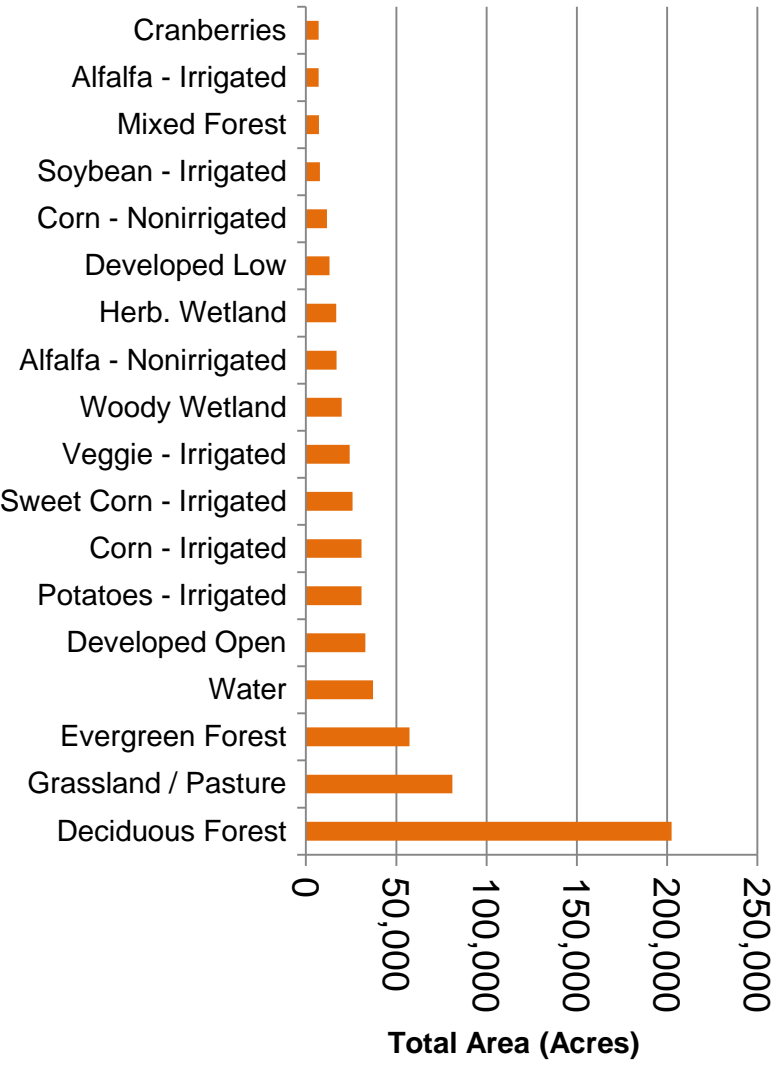
[recharge components]



August 30, 2016



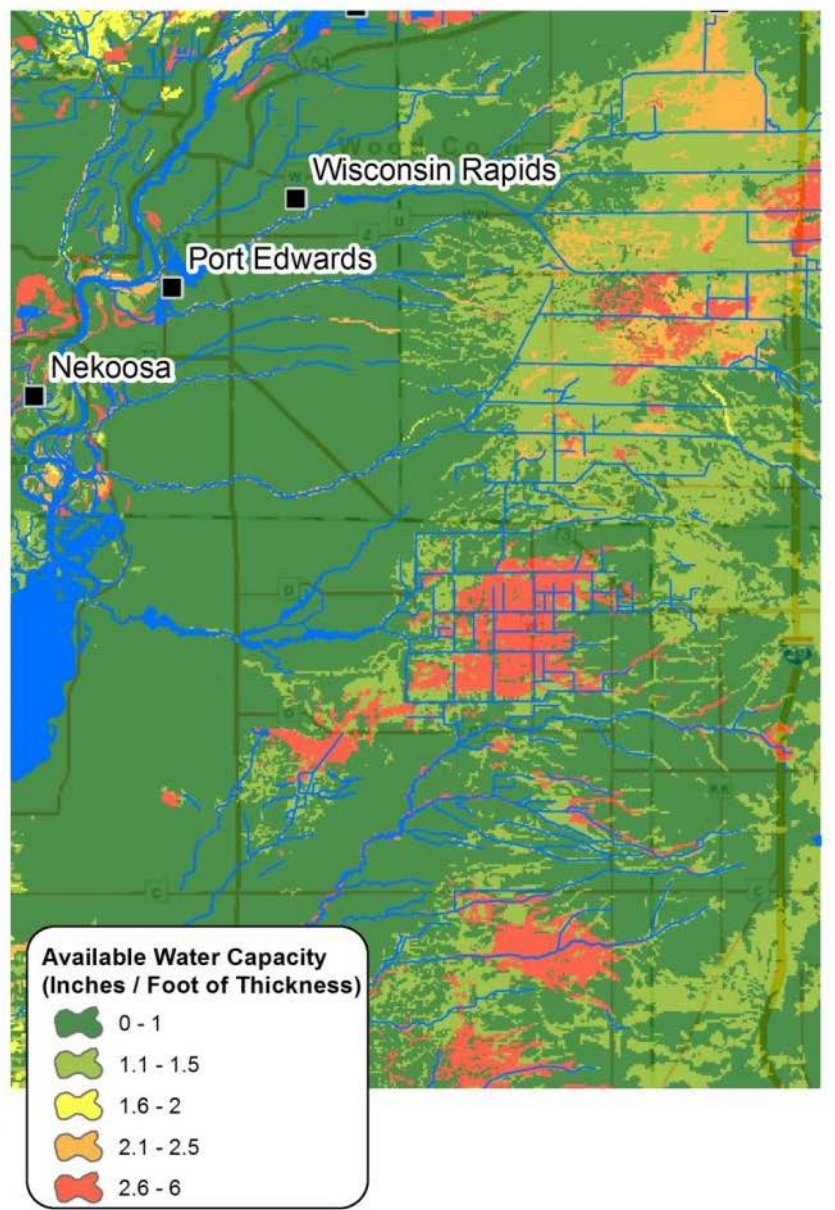
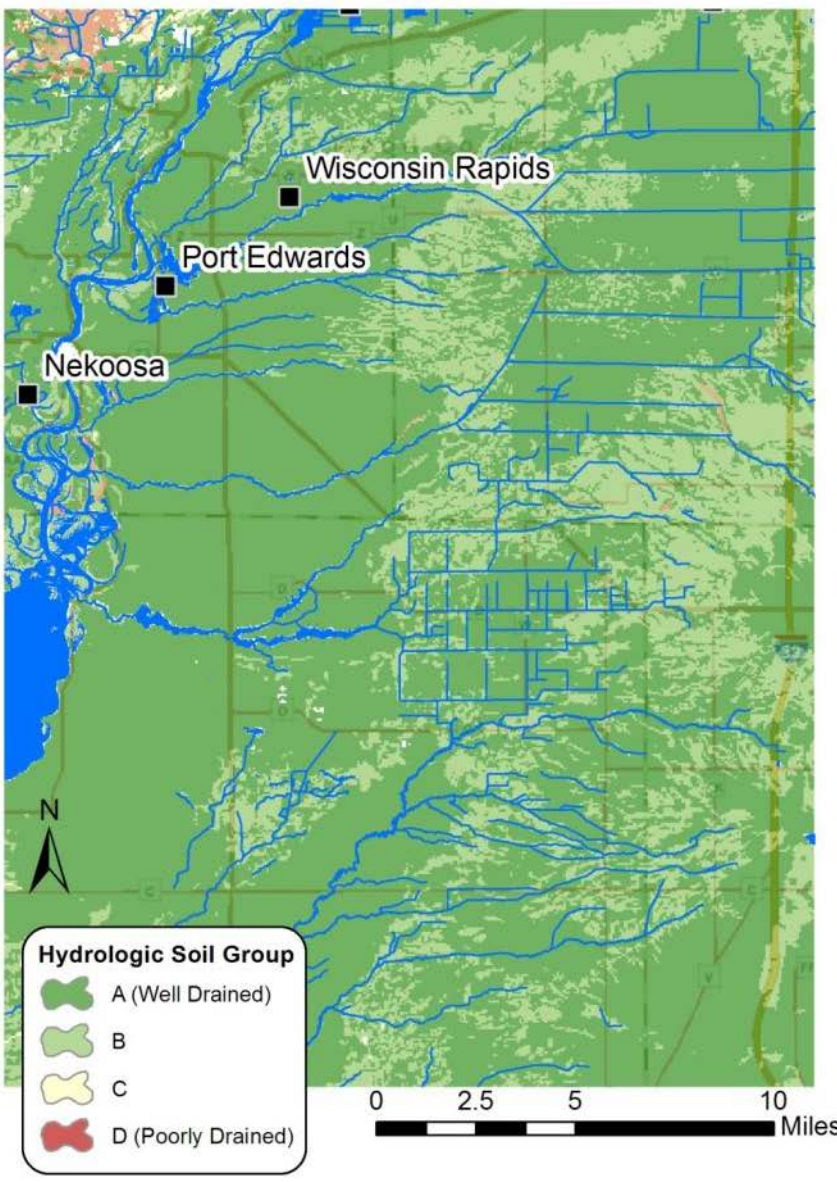
2011 NASS CDL Landcover
 Landcover Classification (Land Classes > 1% of Study Area)



[recharge components]



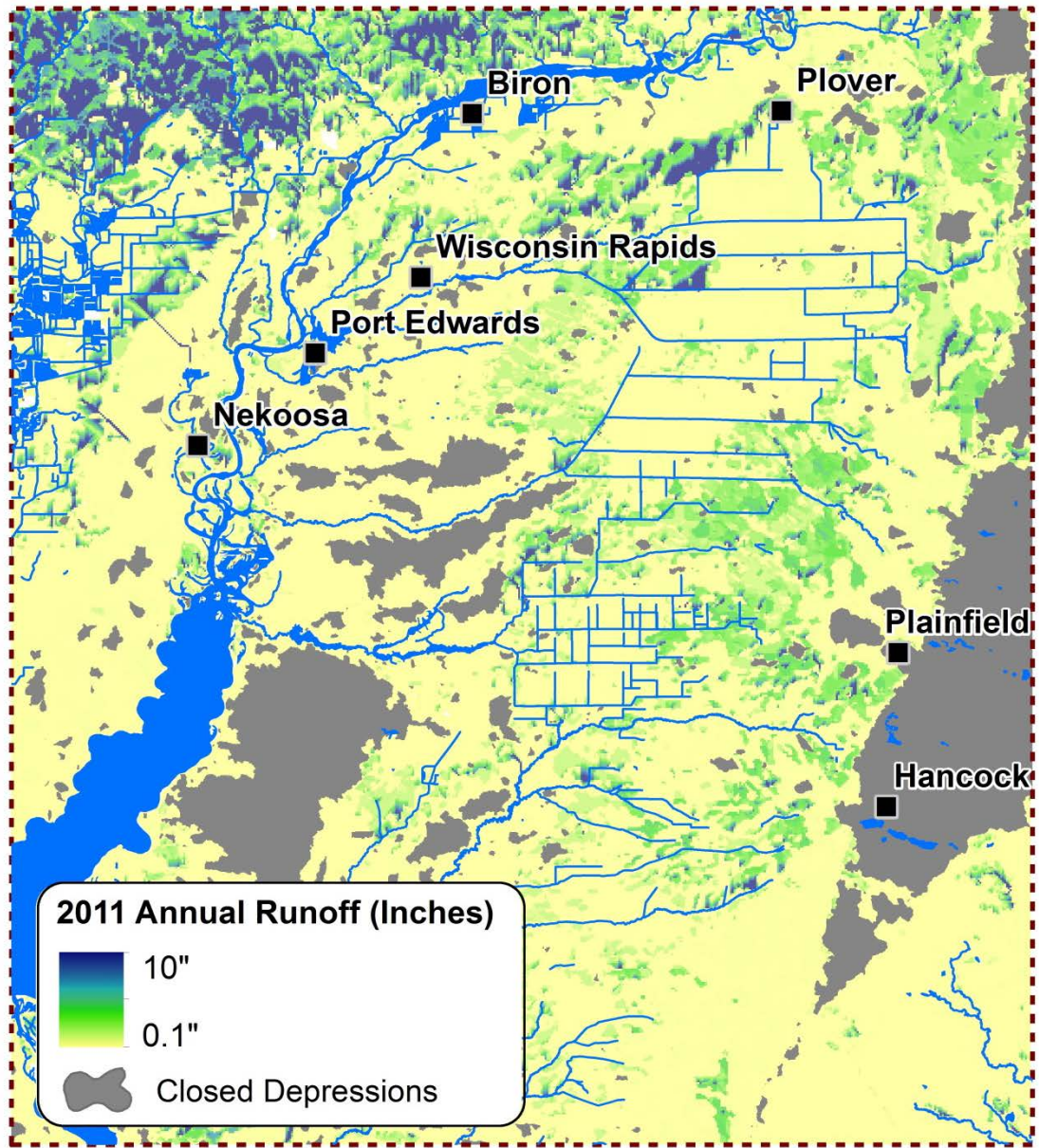
August 30, 2016



[recharge components]


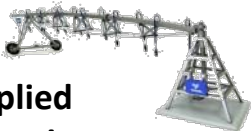




August 30, 2016



[recharge estimation – putting the pieces together]

Average Annual Water Budget (2011) Across Study Area

Irrigated Agriculture		(Inches)
 Precipitation	+	32.5"
 Applied Irrigation	+	7.5"
 Actual Evapotranspiration	-	22.9"
 Runoff	-	1.7"

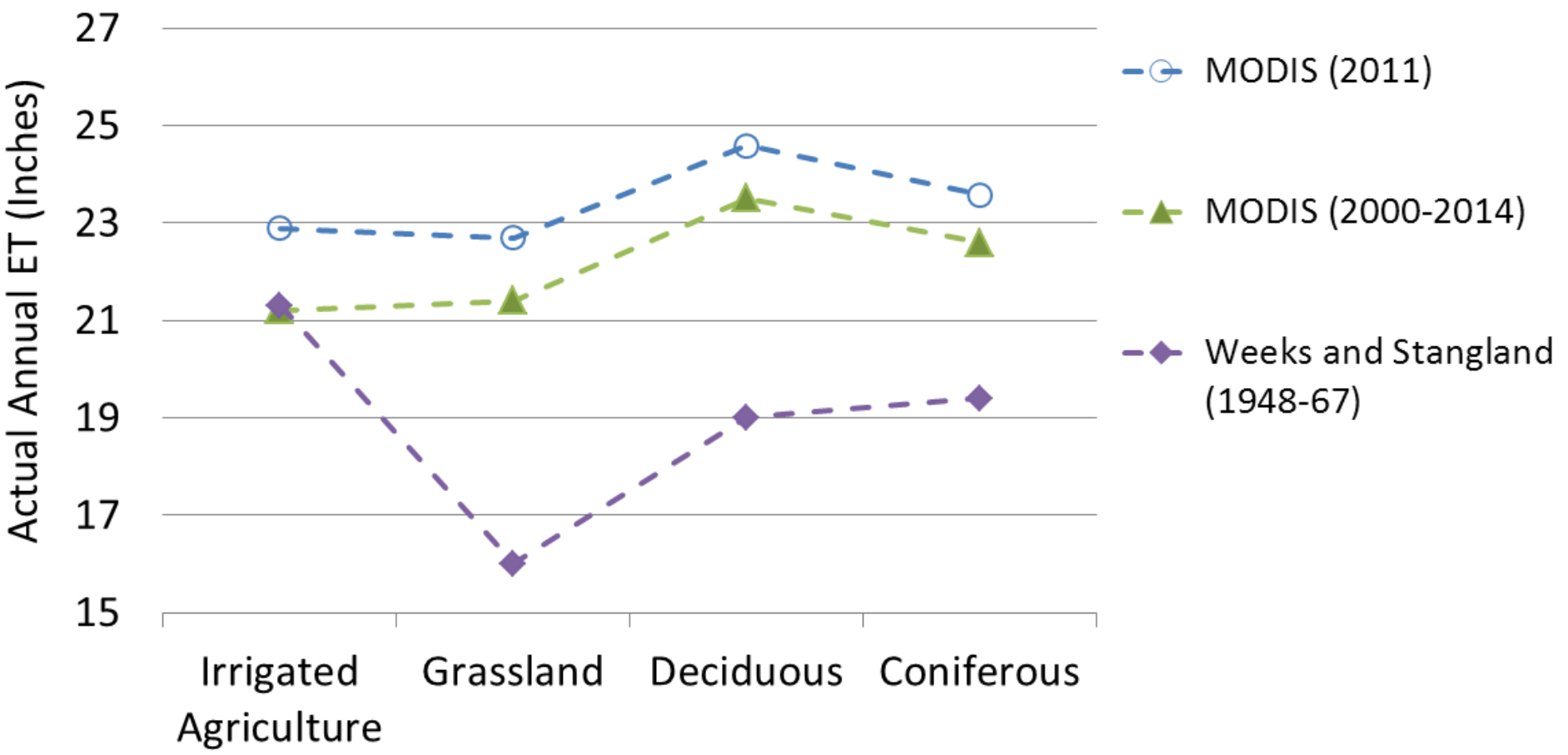
Recharge = 15.4"

Insight in Averages

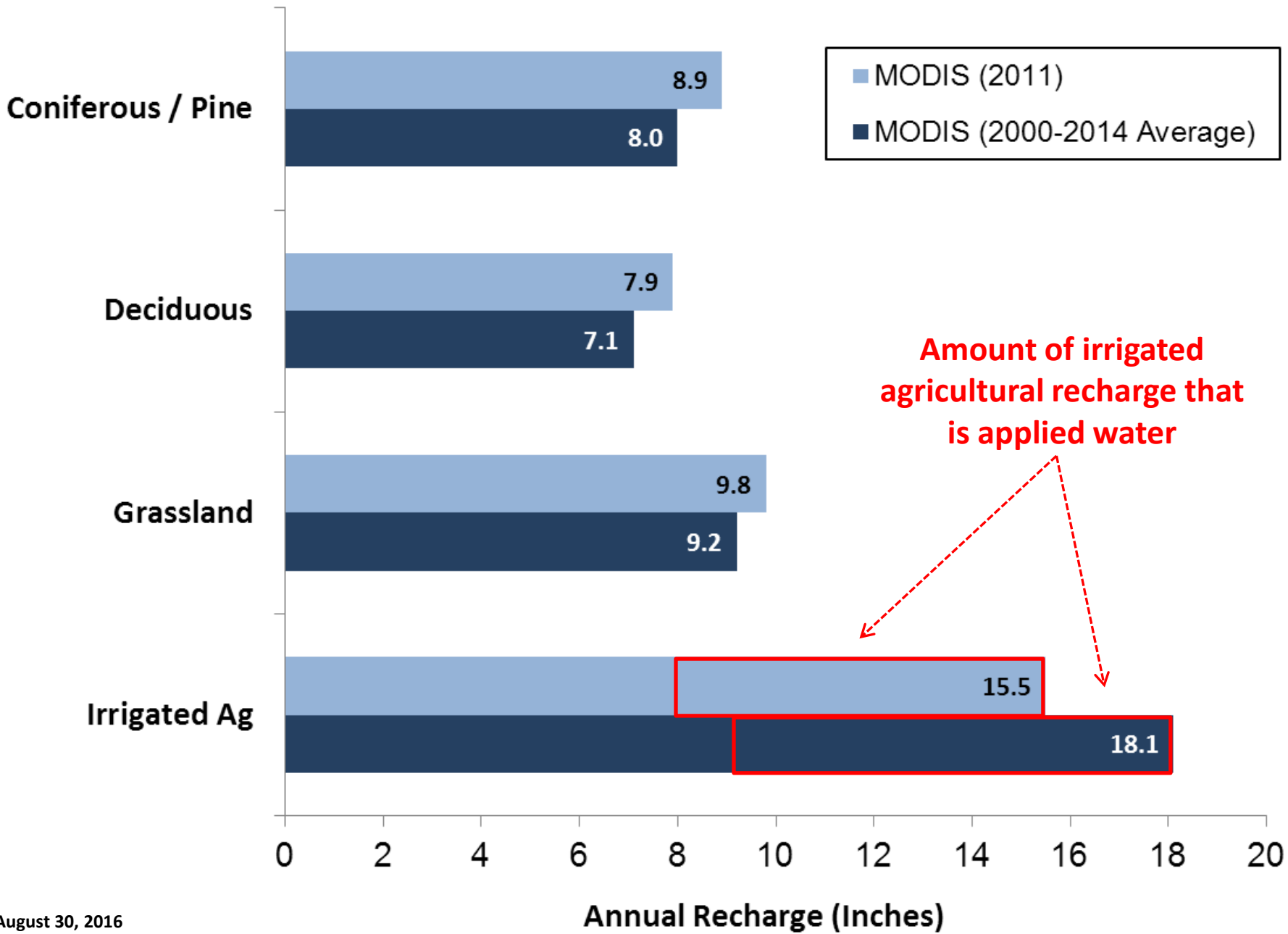
- Variability can exist across the study area (per field / farm) with respect to individual budget components.
- 15.4" represents the average for an entire year, for all irrigated agricultural in the study area.



Average Annual ET Variability Per Land Cover Type

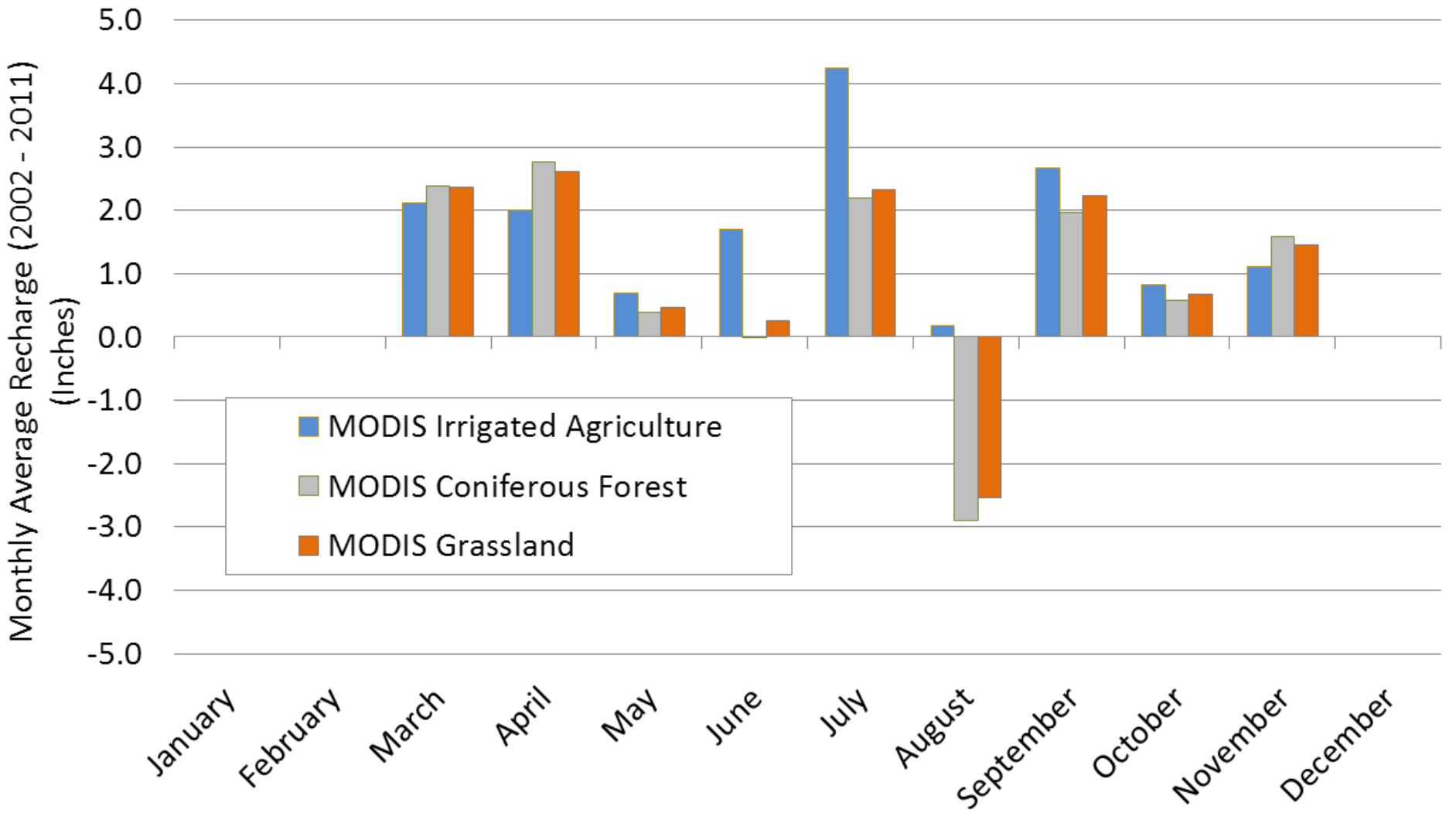


[recharge estimation – comparing annual recharge]





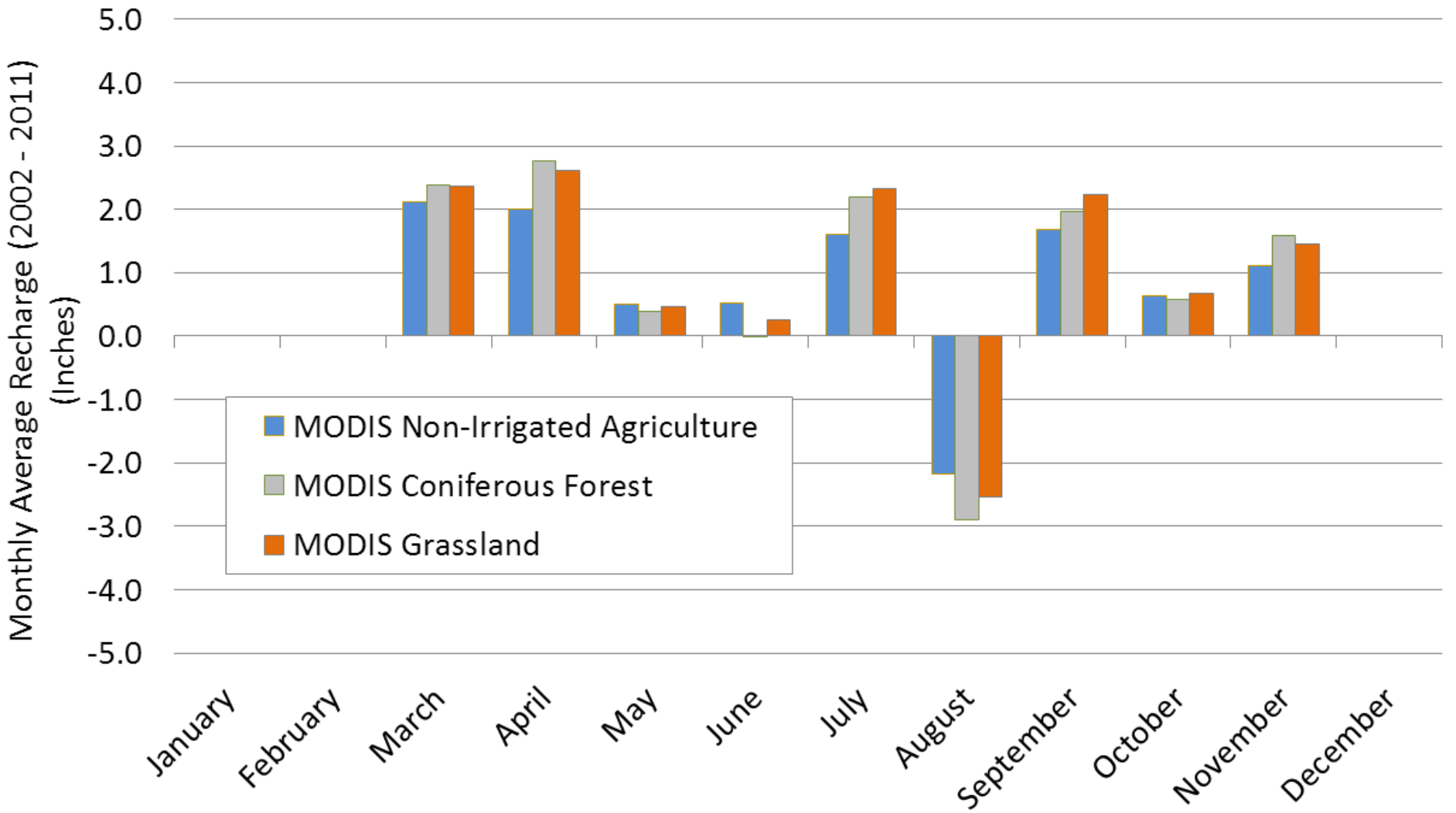
2011 MODIS Average Monthly Recharge Rates *(considers applied irrigation water)*



[recharge estimation – comparing monthly recharge]

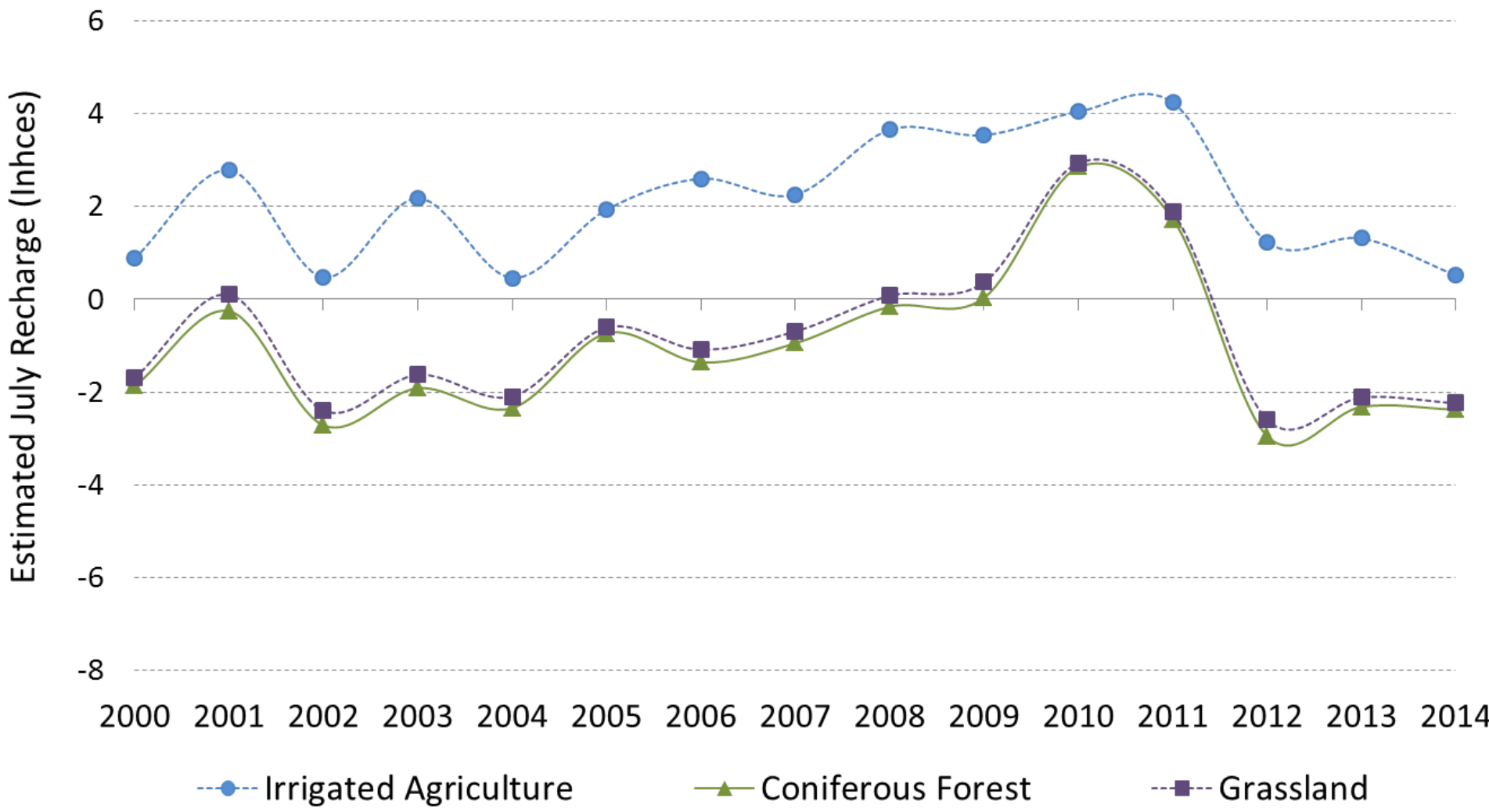


2011 MODIS Average Monthly Recharge Rates *(does not consider applied irrigation water)*

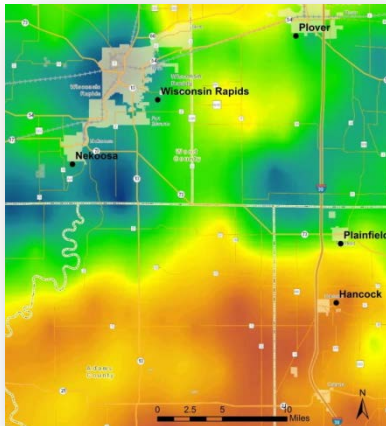




Variation in Estimated July Recharge (2000 - 2014)



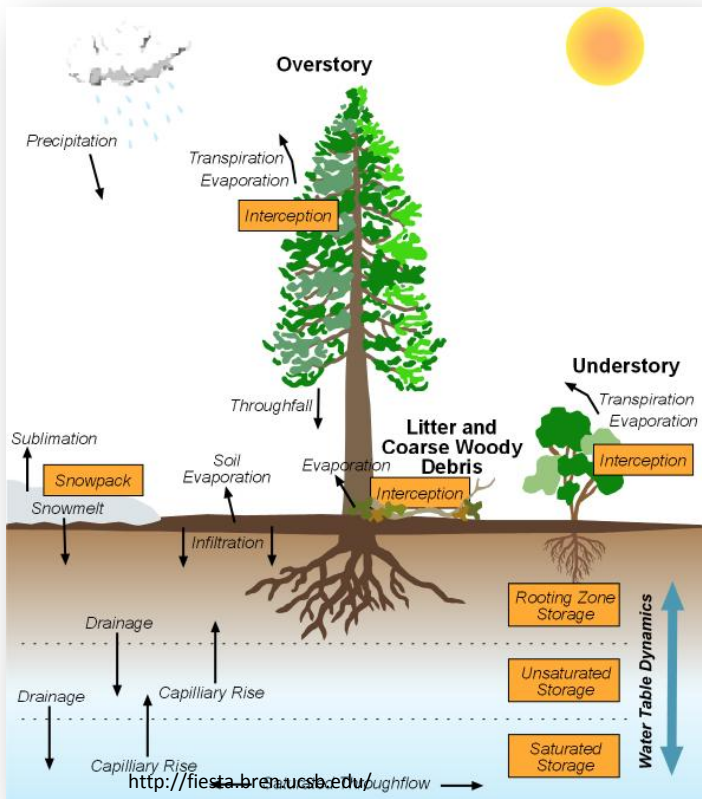
Spatiotemporal Variation



Precipitation



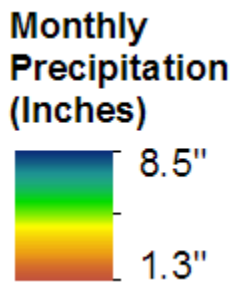
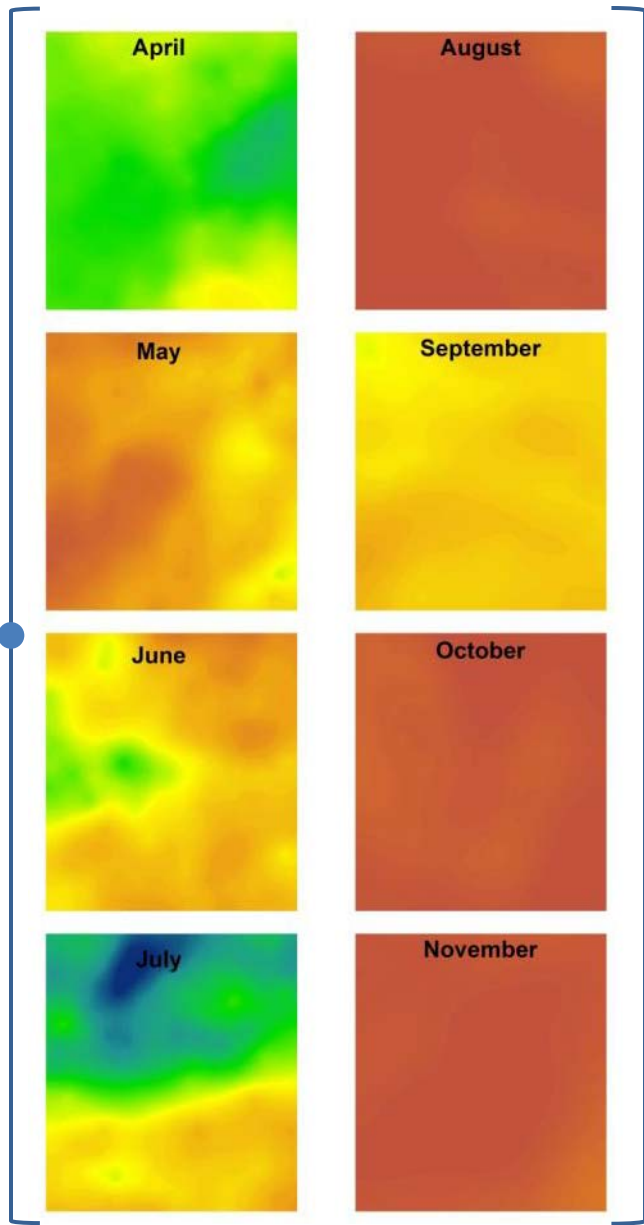
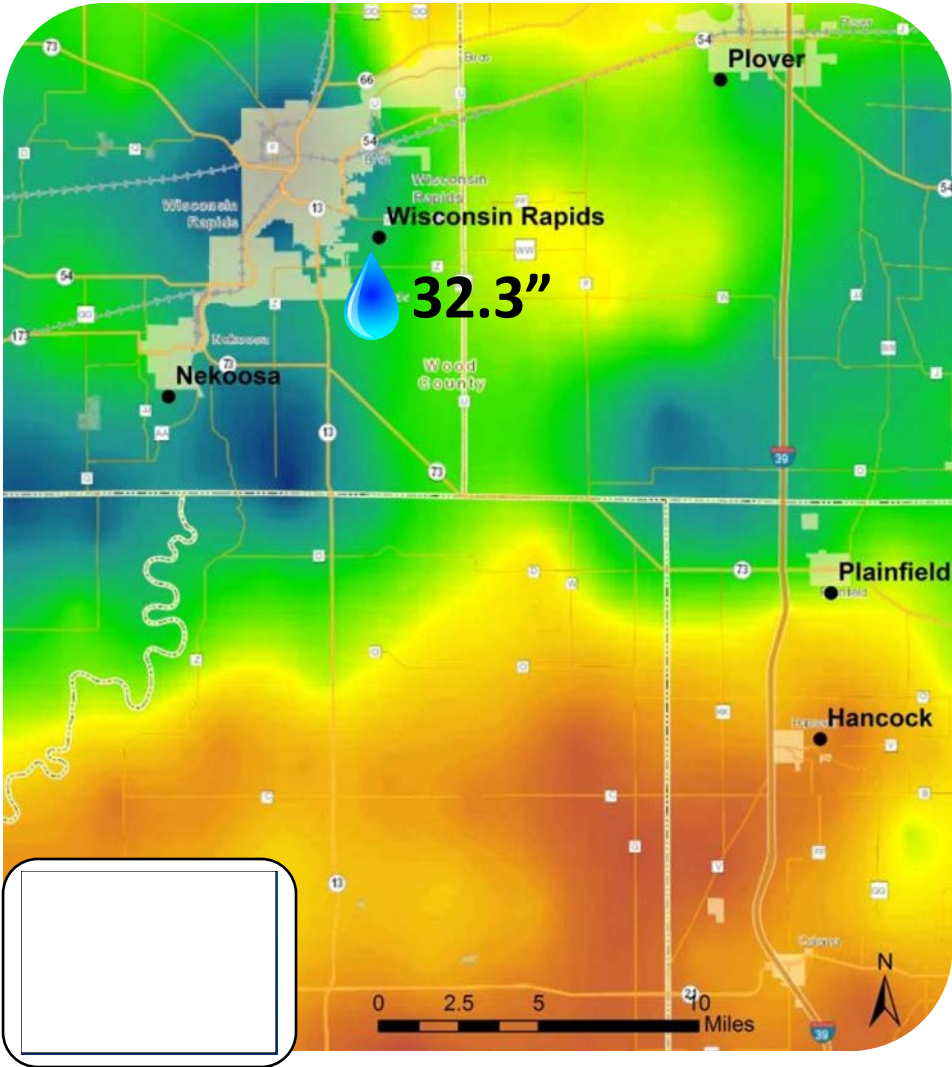
Applied water distribution



Actual ET Model



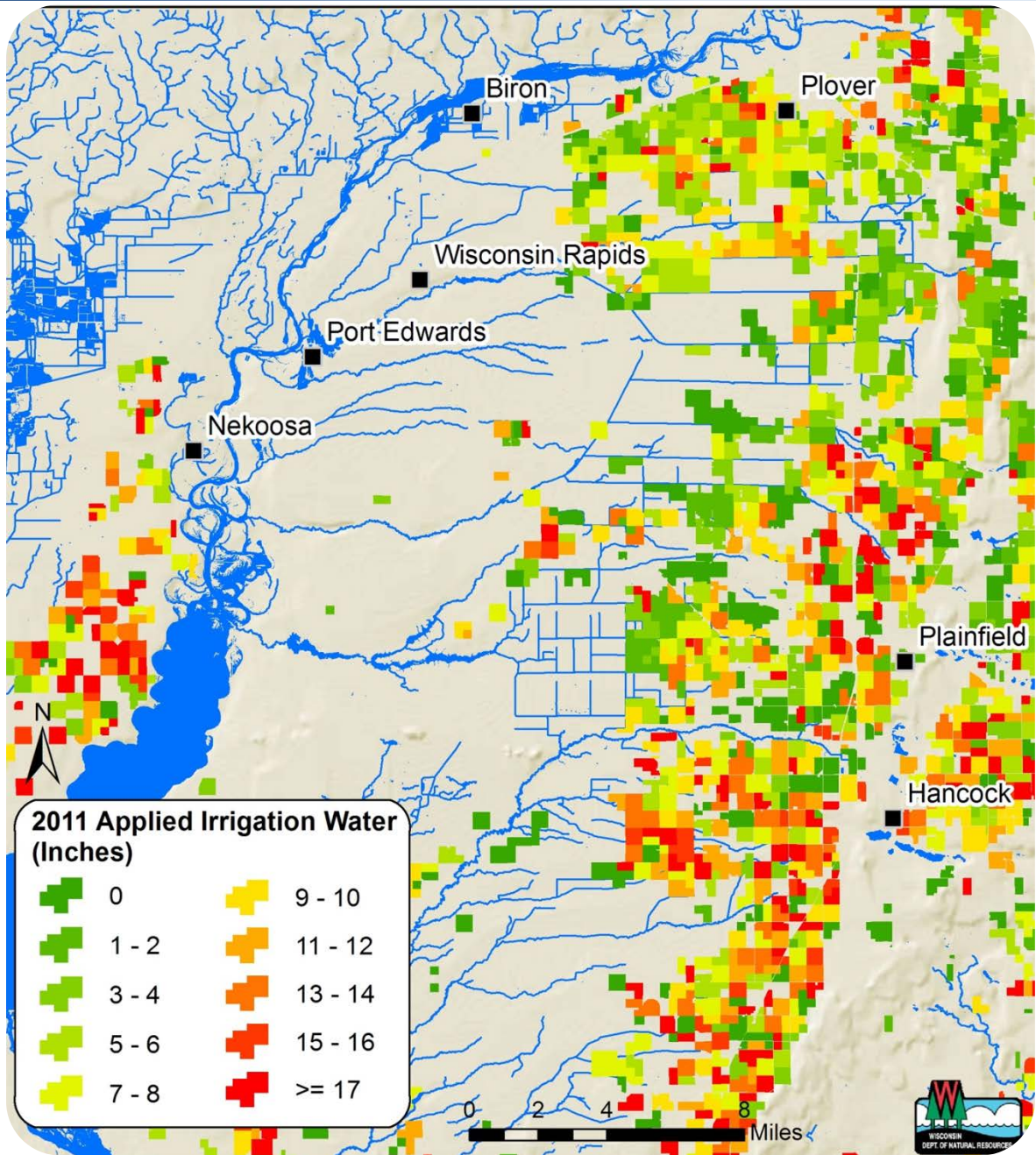
2011 Gridded Annual Precipitation NOAA Advanced Hydrologic Prediction Service





2011 Applied Irrigation Water

Derived from Reported Water Use Information, Well Location, and Acreage



- In any given year, recharge varies based on spatiotemporal variation of rainfall
- Linking recharge to resource impacts requires an examination of not just land cover type, but land management practices such as irrigation withdrawals
- Even a monthly assessment of recharge may not capture the variability of rainfall and the associated demand of the irrigated crop (e.g. June's rain falls in beginning of month, water is needed by plant at month's end)
- The MODIS approach is less time intensive if all other data products are readily available (runoff, applied water)
- Future work is needed including establishing better calibration datasets to calculate actual ET (e.g. eddy covariance towers)

Questions?



Adam Freihoefer (adam.freihoefer@wi.gov)

Robert Smal (robert.smail@wi.gov)