Stress analysis of Louisiana's water supply: Implications for water management

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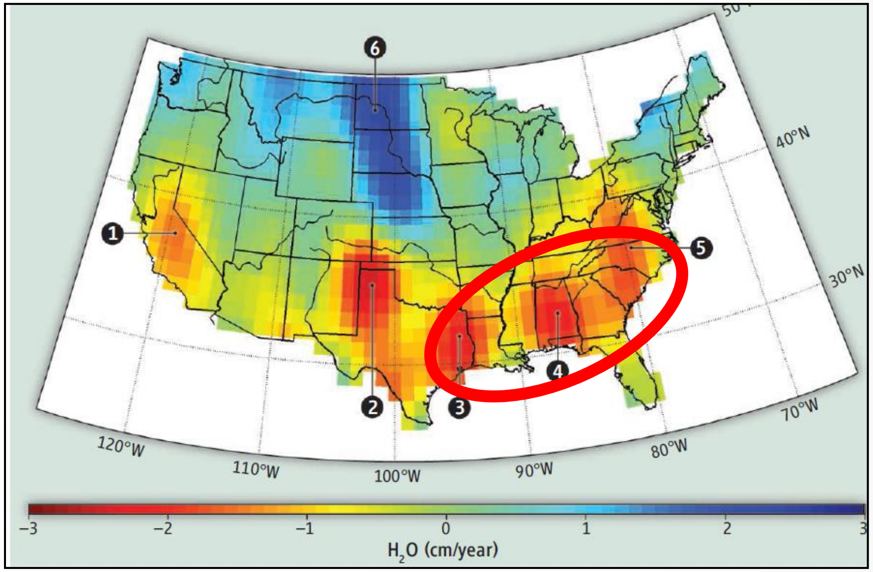
Motivation

Despite relatively abundant rainfall and surface water, groundwater is being overused across the Southeastern United States.

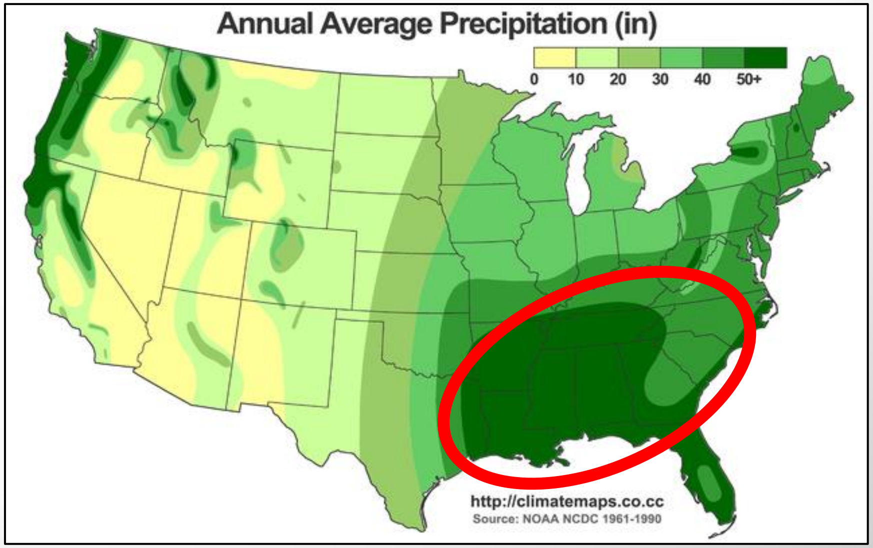
Opportunity

Unlike many areas of the country, higher rainfall rates provide relatively abundant surface water.

We can re-visit the way we manage and use surface water resources to potentially offset groundwater withdrawals and create a more sustainable water system.

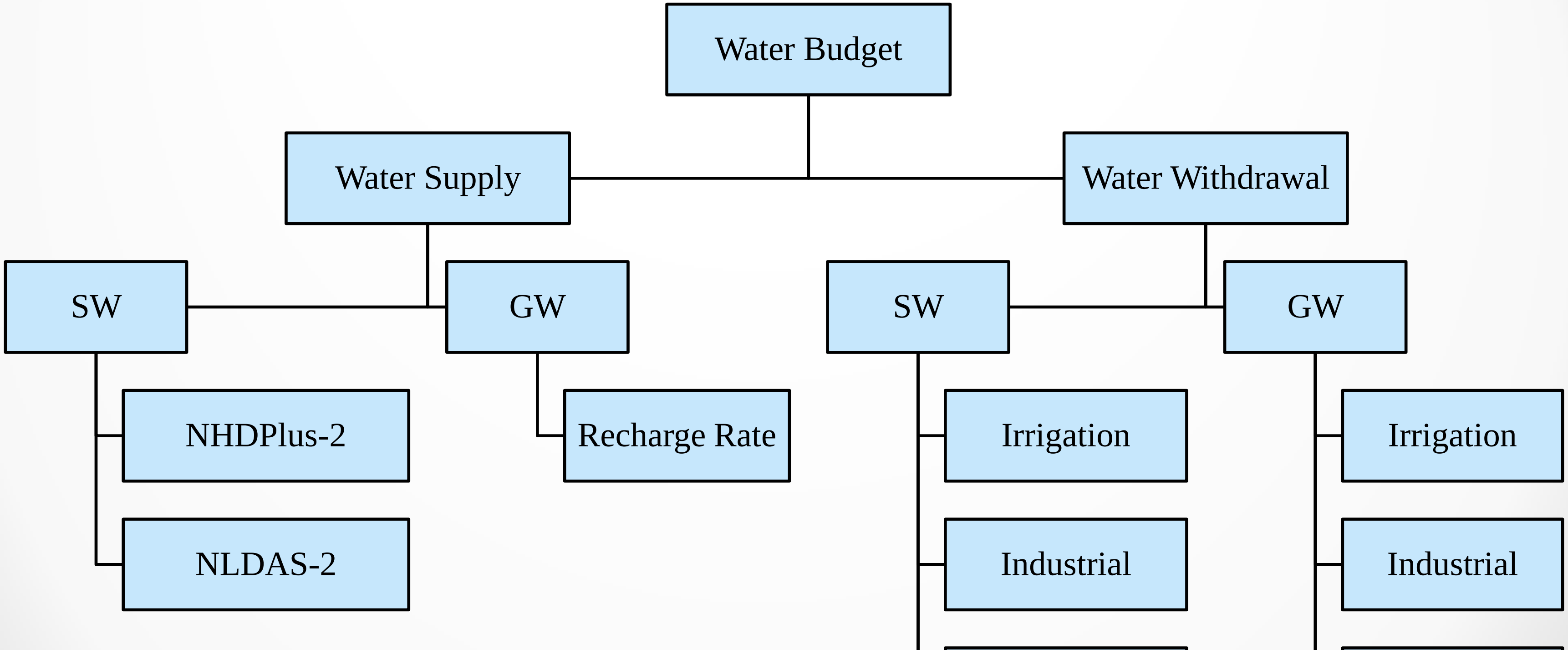


GRACE satellite investigation showing the change in groundwater and soil moisture across the US over the last decade. (Famiglietti and Rodell, 2013, Science).



Annual precipitation averaged over 30 years (NOAA)

Approach involves balancing water supply and water demand



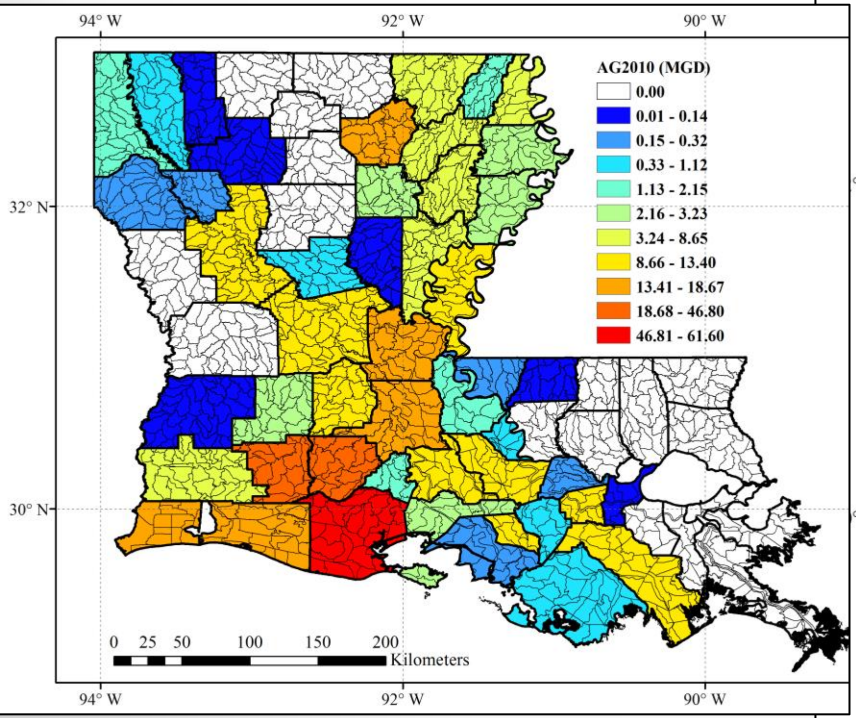
Water supply stress index

$$WaSSI = \frac{\text{Water Withdrawal (SW+GW)}}{\text{Water Availability (SW+GW)}}$$

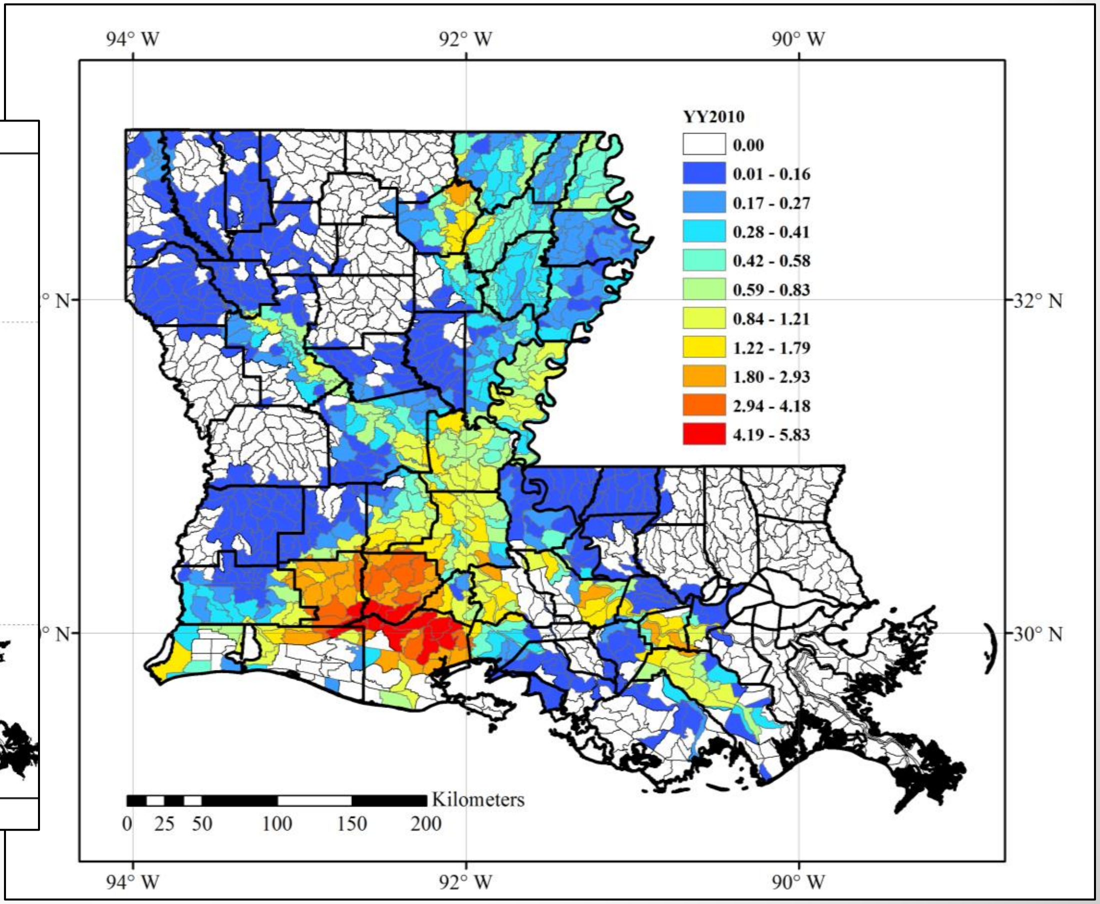
$$WaSSI = \frac{WW_{SW} + WW_{GW}}{(1 - ENV) * WS_{SW} + WS_{GW}}$$

Water Stress Analysis on the "management scale" requires careful disaggregation of larger-scale data

Water demand examples



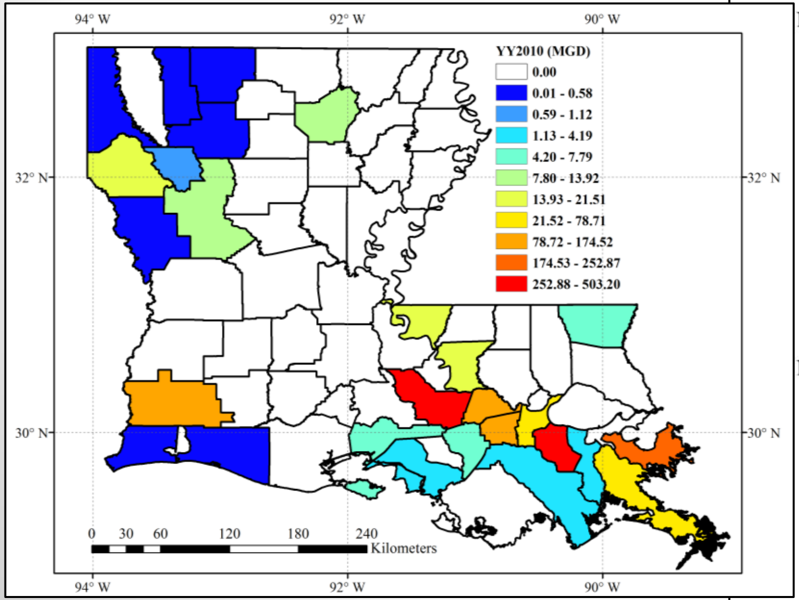
Surface water for irrigation on a Parish Scale

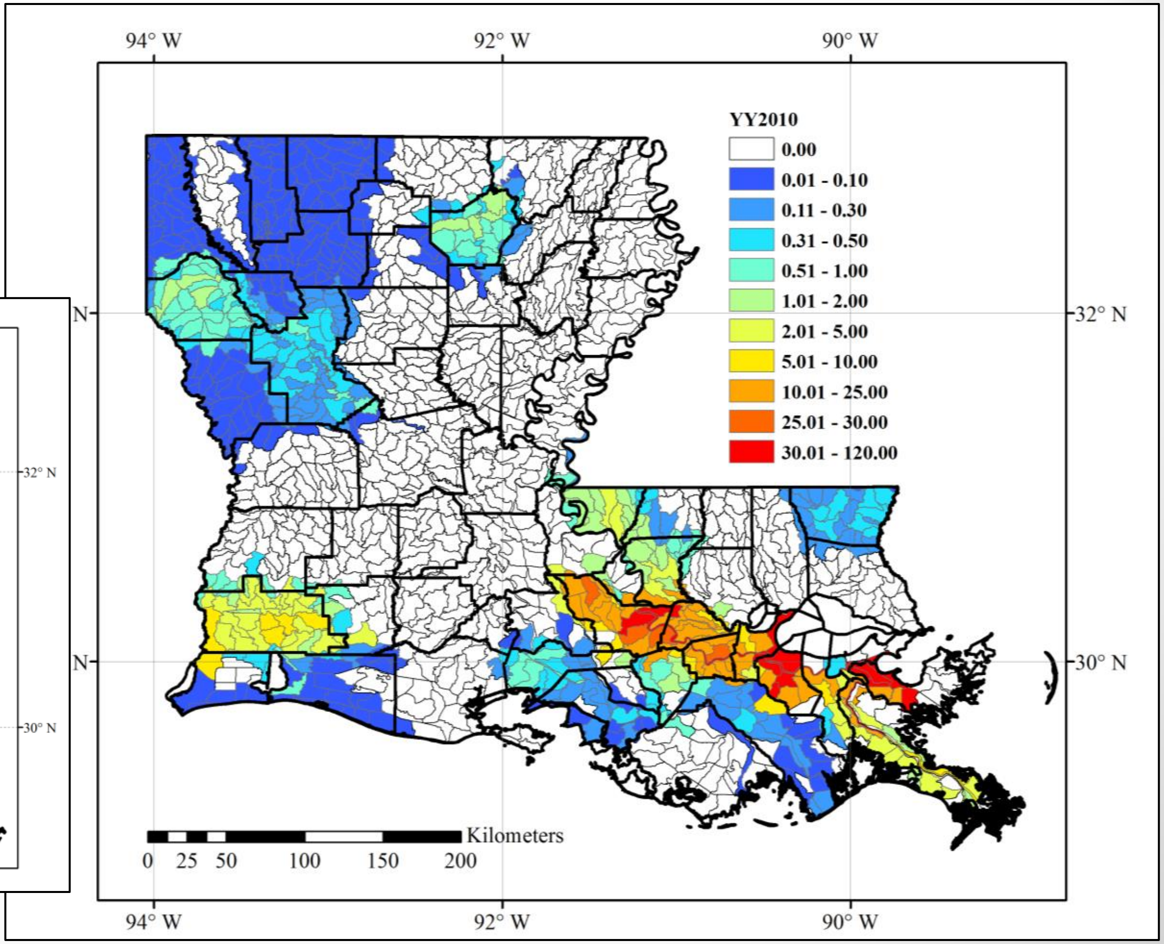


Surface water for irrigation on a HUC12 watershed scale

Water demand examples

Surface water use for Industry on a Parish Scale

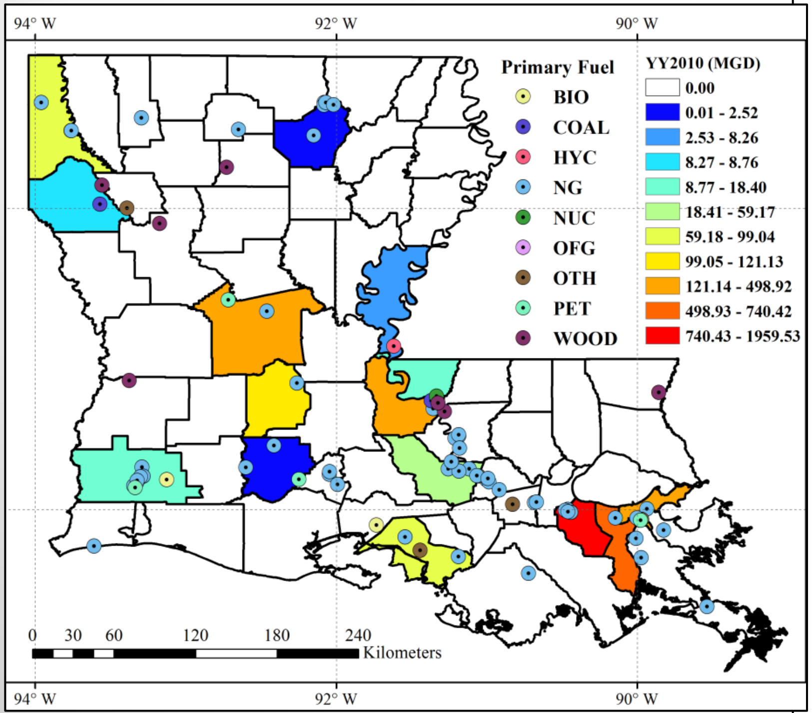




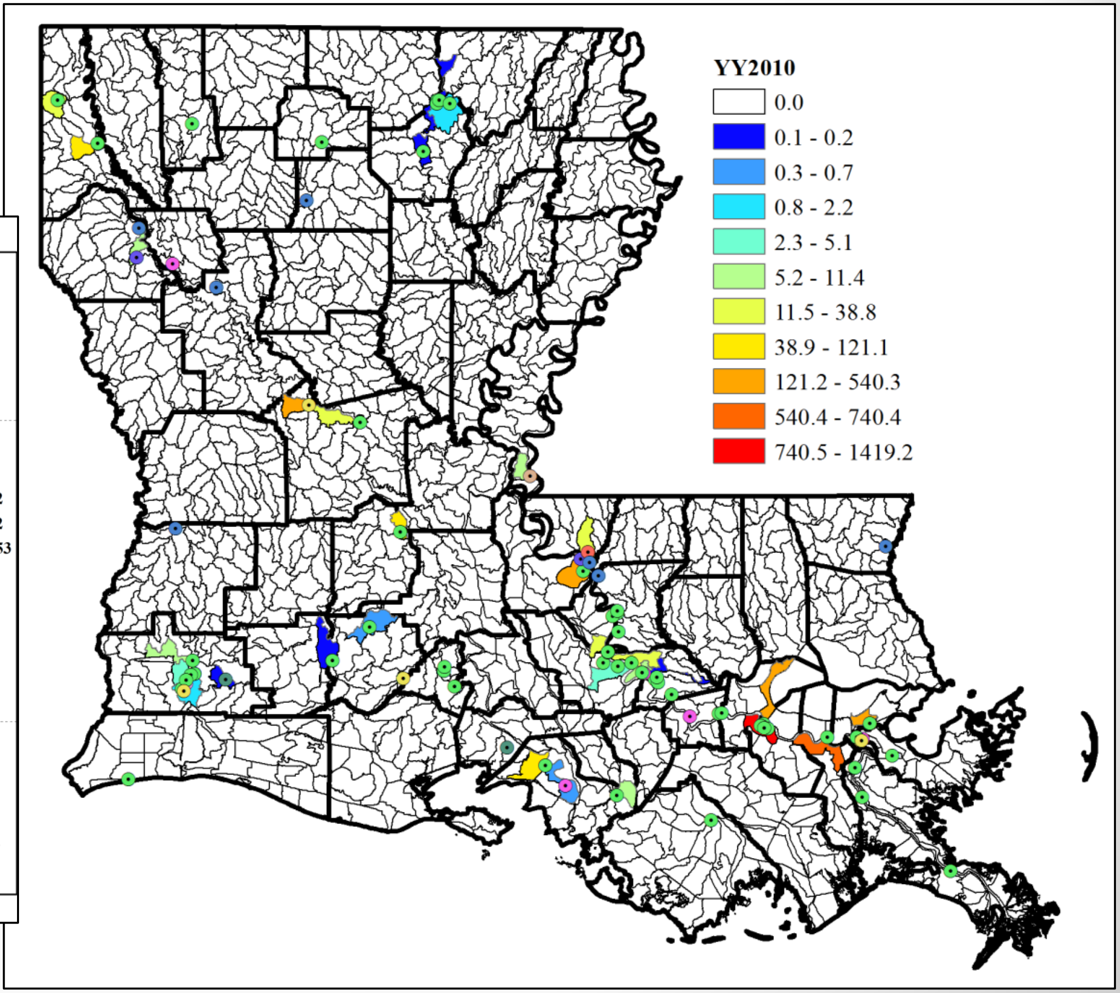
Surface water use for Industry on a HUC12 watershed scale

Water demand examples

Surface water use for Power Generation on a Parish Scale



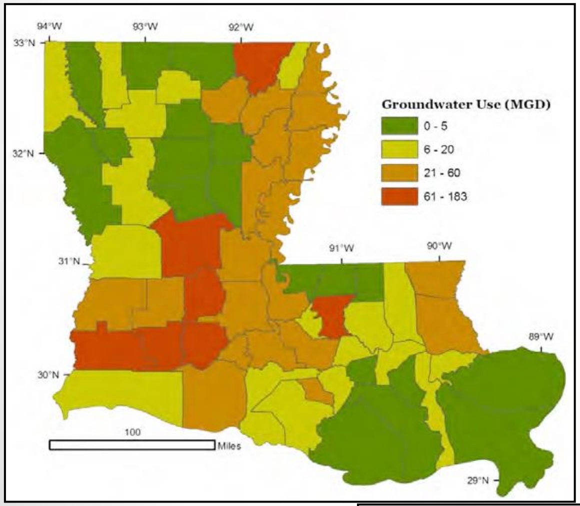
BIO: Biomass, **HYC**: Hydroelectric, **NG**: Natural Gas, **NUC**: Nuclear, **OFG**: Other Fossil Gases, **OTH:** Other, **PET**: Petroleum.

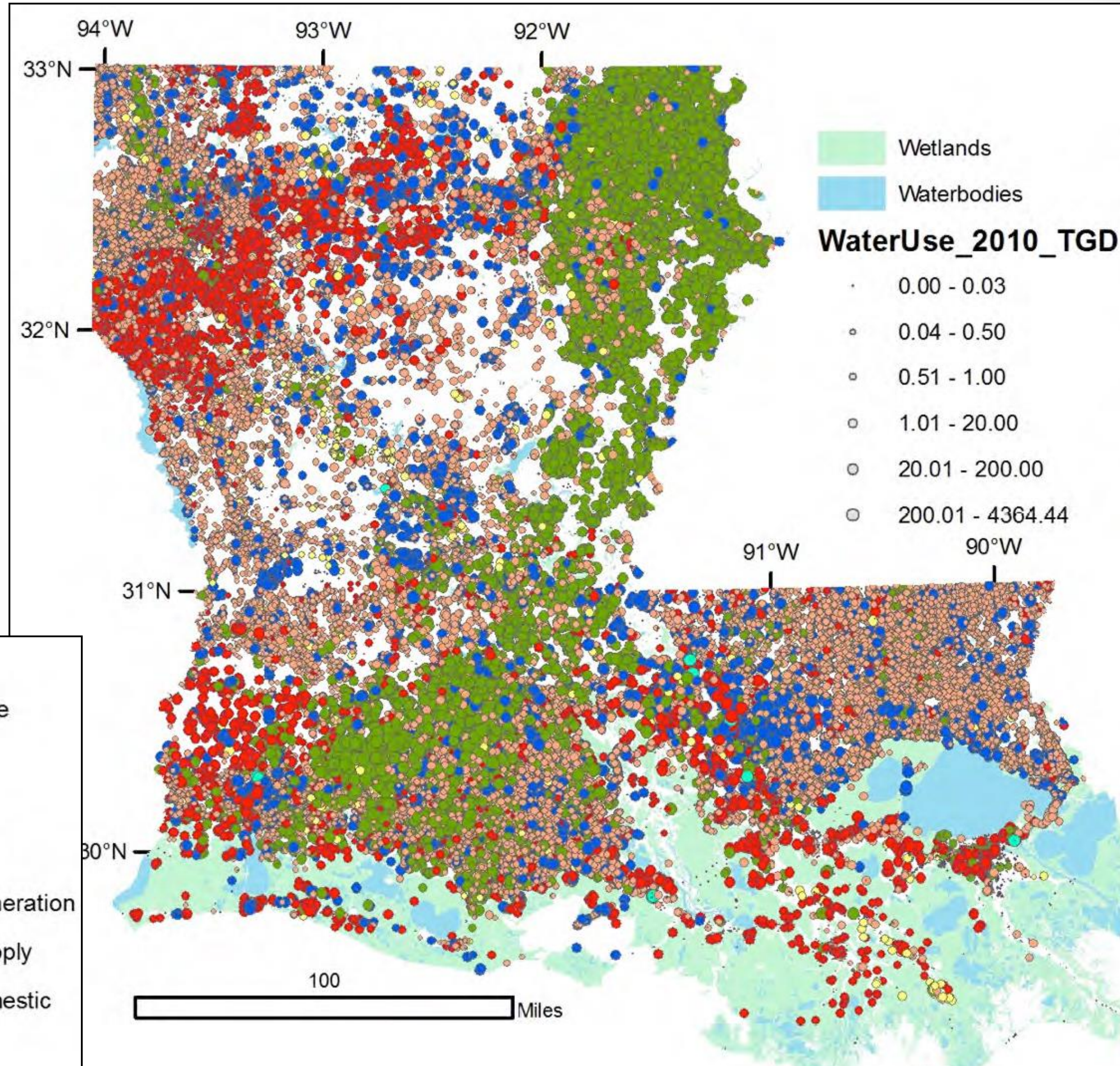


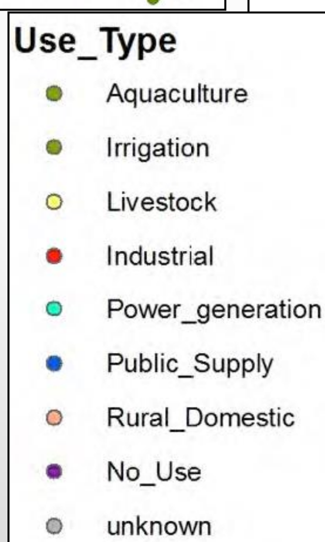
Surface water use for Power Generation on a HUC12 watershed scale

Groundwater use distributed by registered wells

Parish Scale GW use

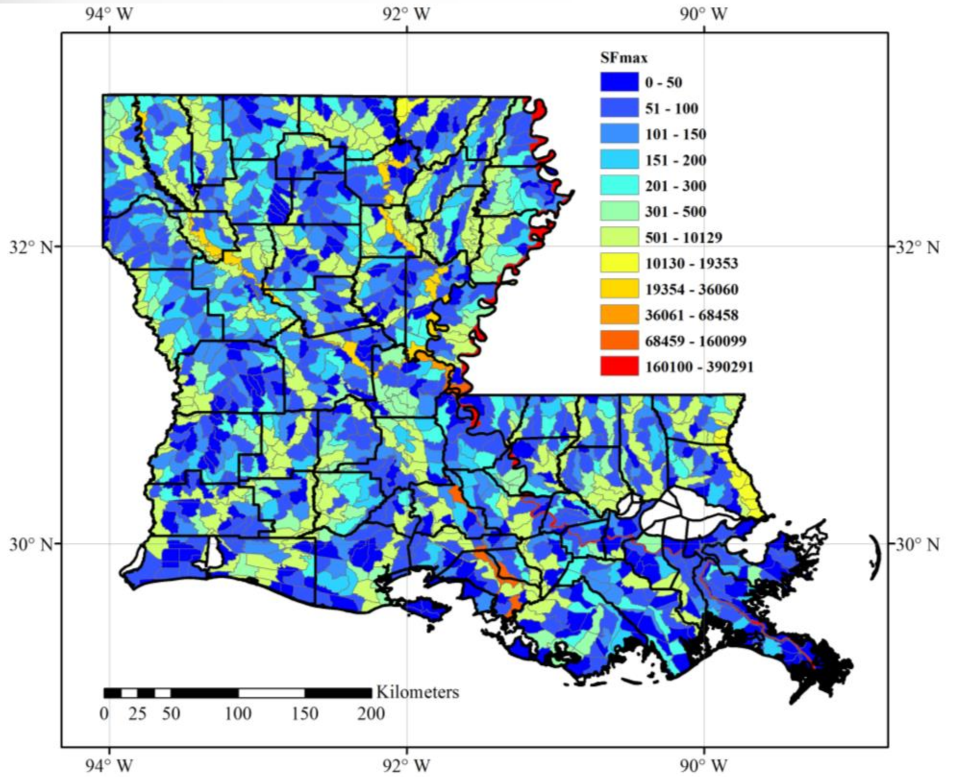






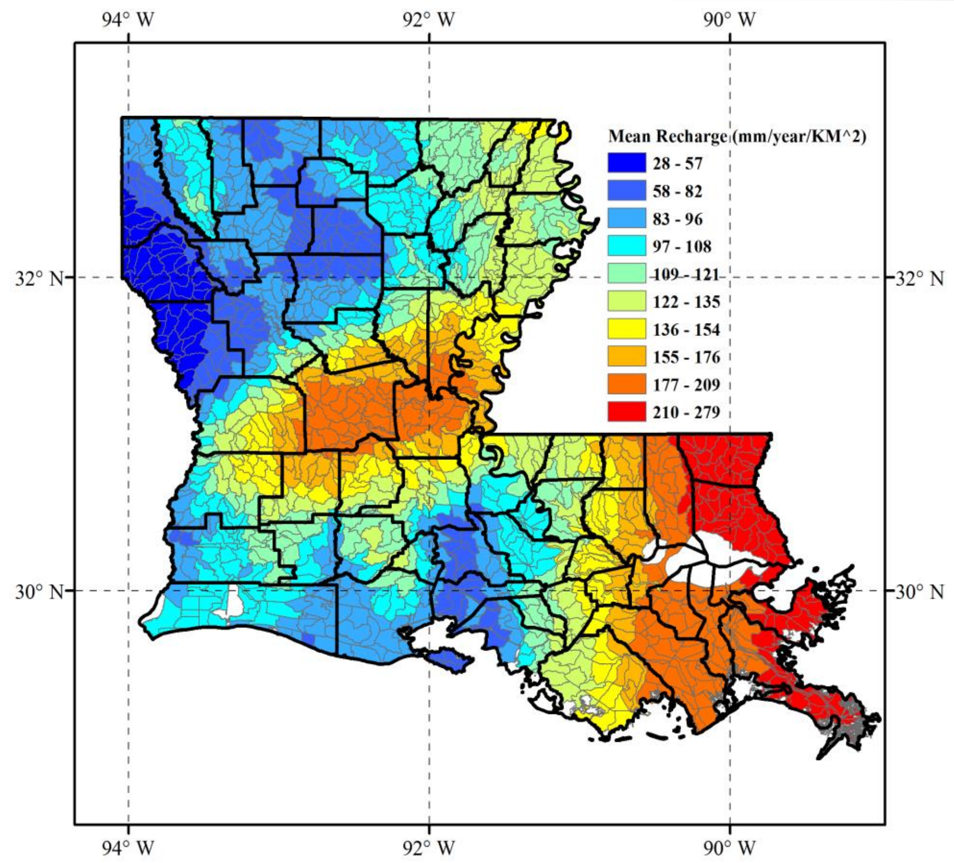
Water Availability Data

Surface Water



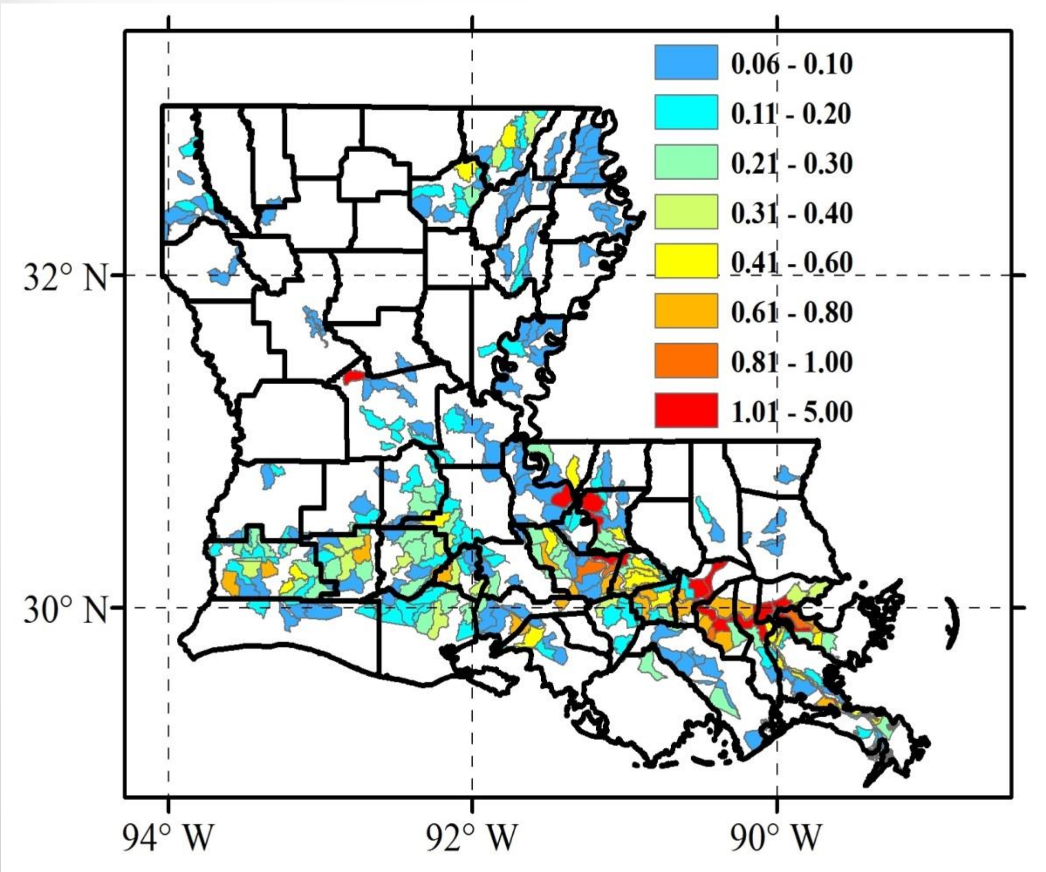
National Hydrography Dataset (NHDPlus), represents 25 year average (annual and monthly) climatological conditions of water availability.

Groundwater



USGS Groundwater recharge estimates mean annual recharge (mm/yr/km^2). Gebert, W. A., Graczyk, D. J., & Krug, W. R. (1987).

Water stress in Louisiana



(HUC12 watersheds with WaSSI less than 0.06 are displayed in white).

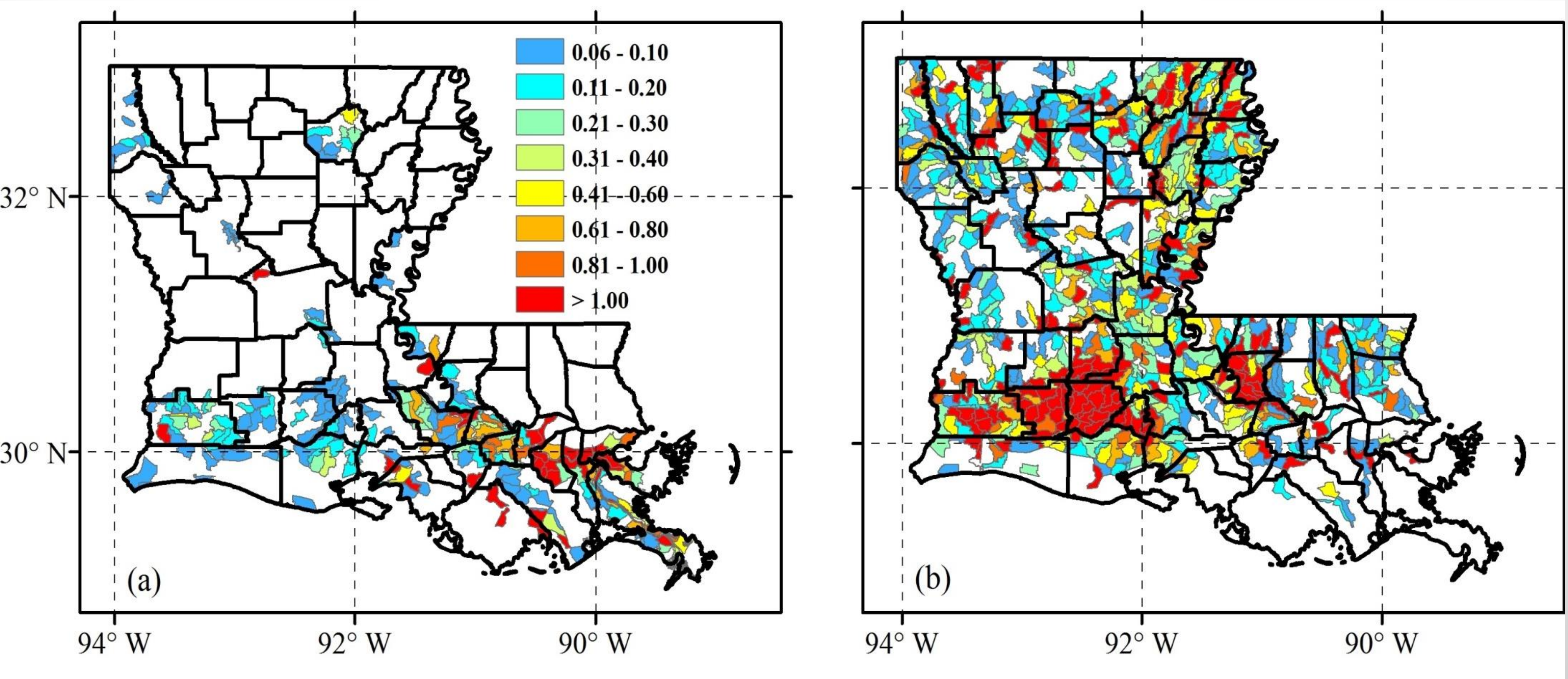
$$WaSSI = \frac{WW_{SW} + WW_{GW}}{(1 - ENV) * WS_{SW} + WS_{GW}}$$

Water Supply Stress Index on the HUC12 scale using annual average estimates of water supply and demand and a 50% environmental flow requirement.

Water stress in Louisiana

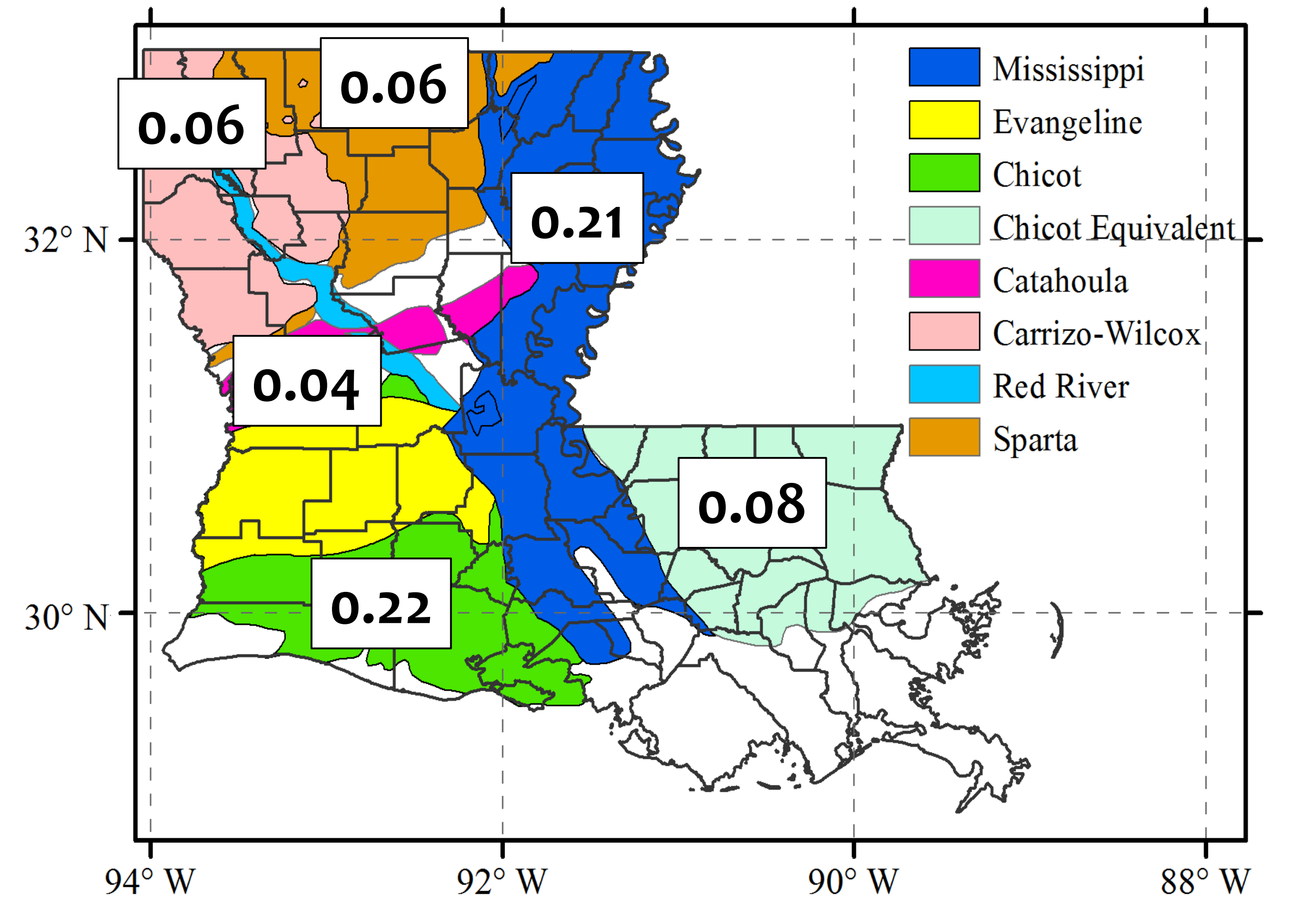
Annual Surface Water Stress

Annual Groundwater Stress



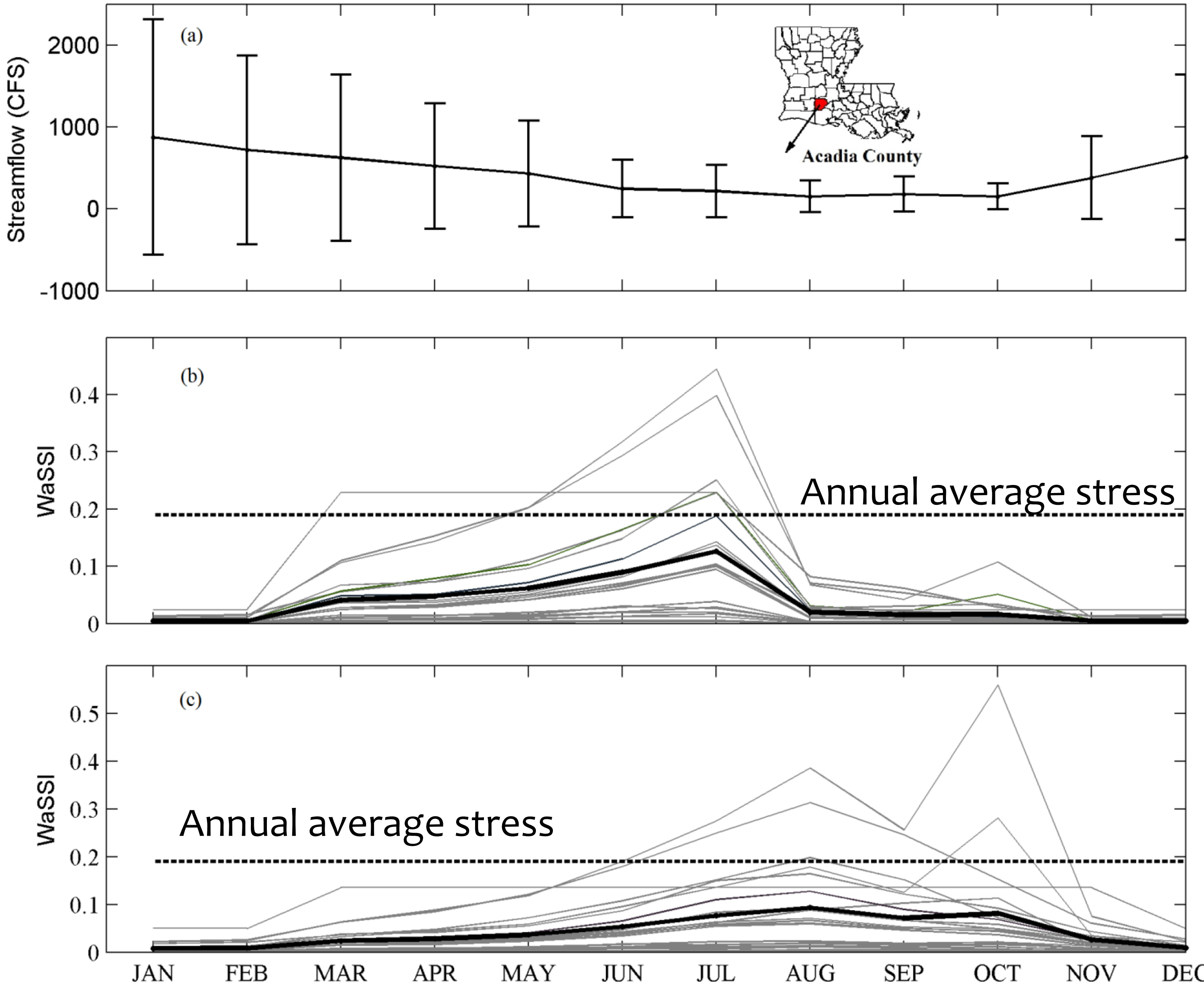
Areas in red indicate water deficits. For groundwater that implies water is being mined faster than it is replaced through natural recharge processes.

Average stress in Louisiana's major aquifer systems



The Chicot aquifer and Mississippi River Alluvial Aquifer are subject to the largest average annual water stress

Example of seasonal stress analysis



Average and std deviation of stream flow

Monthly changes in stress for all the HUC12 watersheds. Irrigation scenario 1.

Monthly changes in stress for all the HUC12 watersheds. Irrigation scenario 2.

Integrating water quality into water stress analysis

Different user sectors demand water of different quality. Example – agricultural users cannot tolerate water of high salinity. How can we account for the fraction of water in each watershed that is not usable due to its quality?

1) Use existing chemical data to create a ratio that approximates the fraction of useable water for a given use sector.

$$f_X = \frac{(\Sigma \text{ number of measurements of X > threshold value})}{(\Sigma \text{ number of all measurements of X})}$$

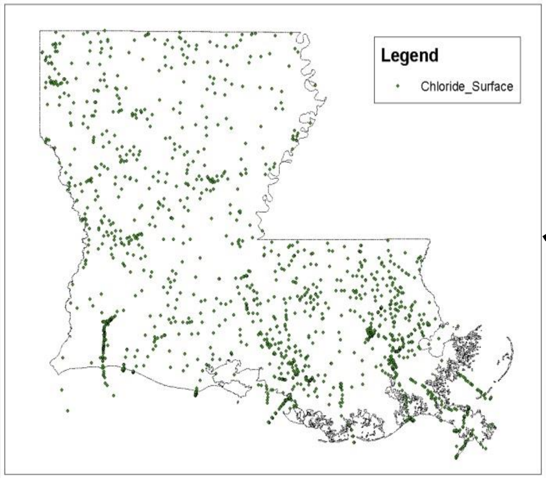
Where X is a water quality parameter like "salinity" and the threshold of acceptable salinity is set for a certain user group like "rice irrigation".

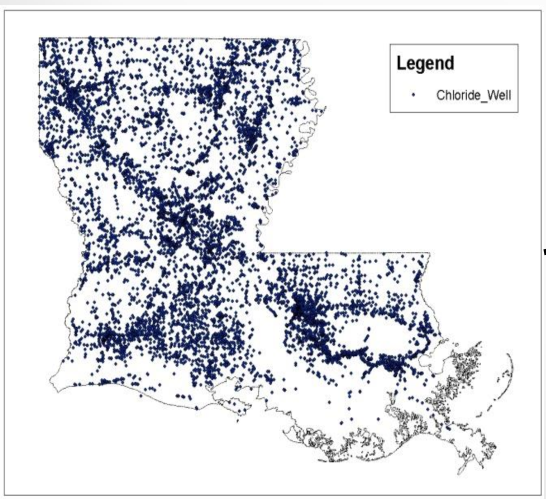
2) The WaSSI equation can be updated to exclude water of poor quality.

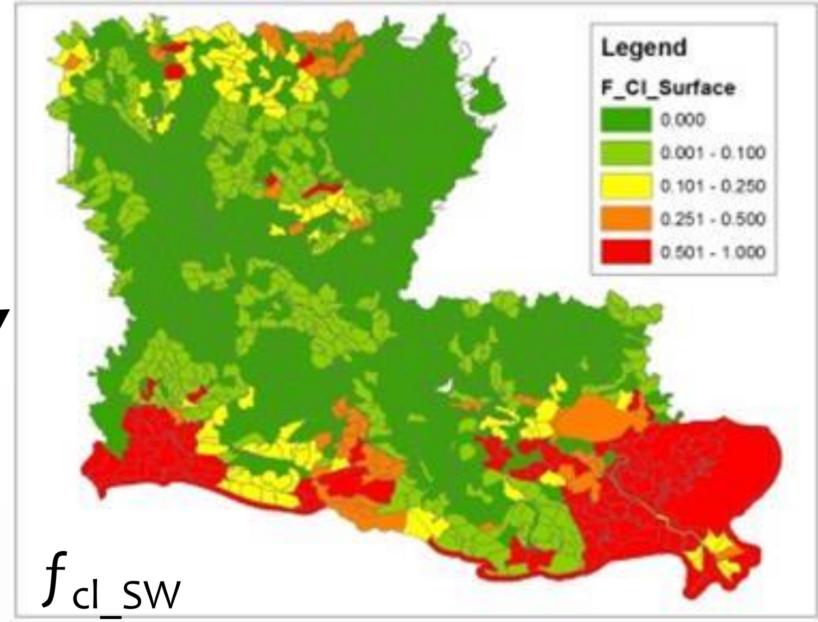
$$WaSSI_i = \frac{WW_{SW} + WW_{GW}}{(1 - ENV) * (1 - fcl\_sw) * WS_{SW} + (1 - fcl\_gw) * WS_{GW}}$$

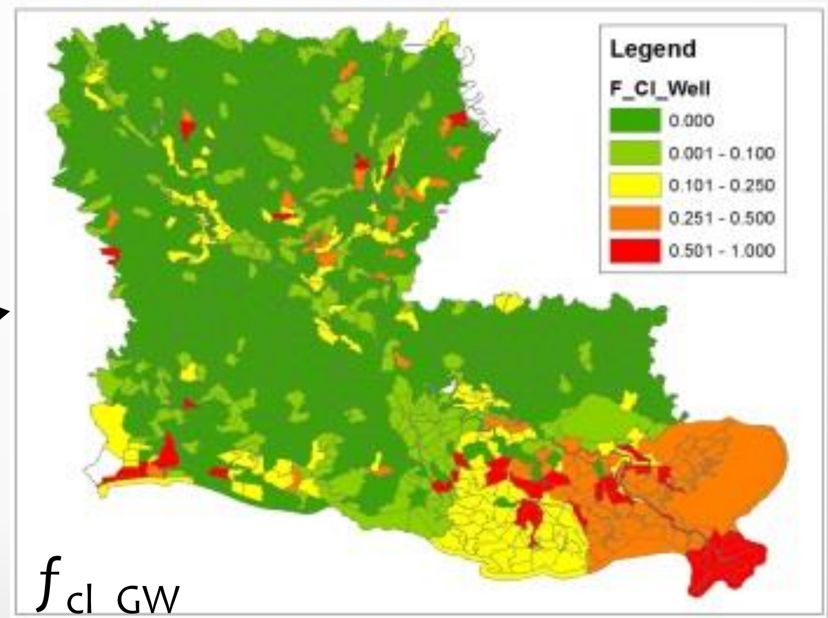
Example results for chloride

Threshold = 500 mg/L Cl (similar to about 1300 μs/cm or 800 mg/L TDS)

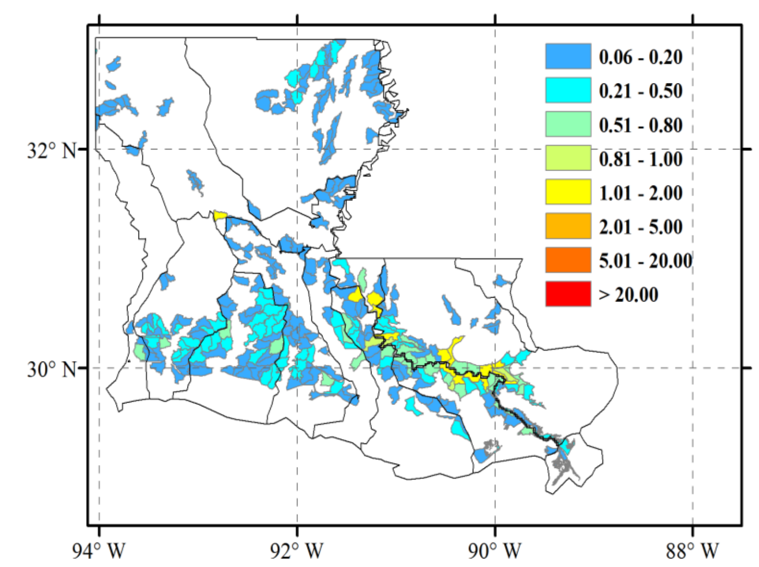




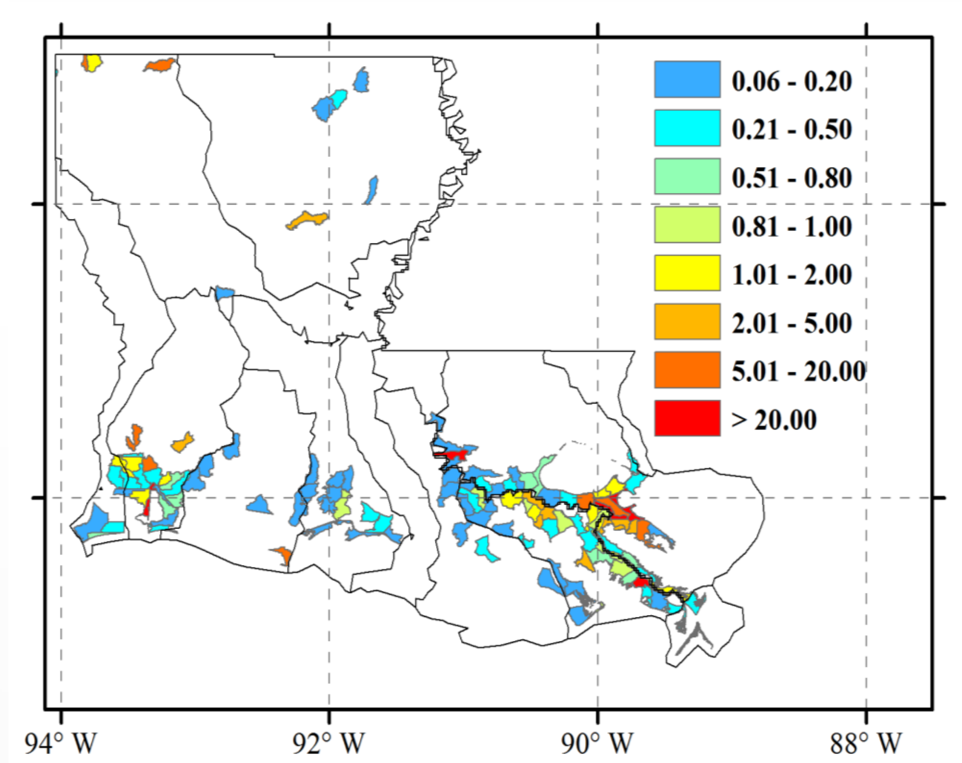




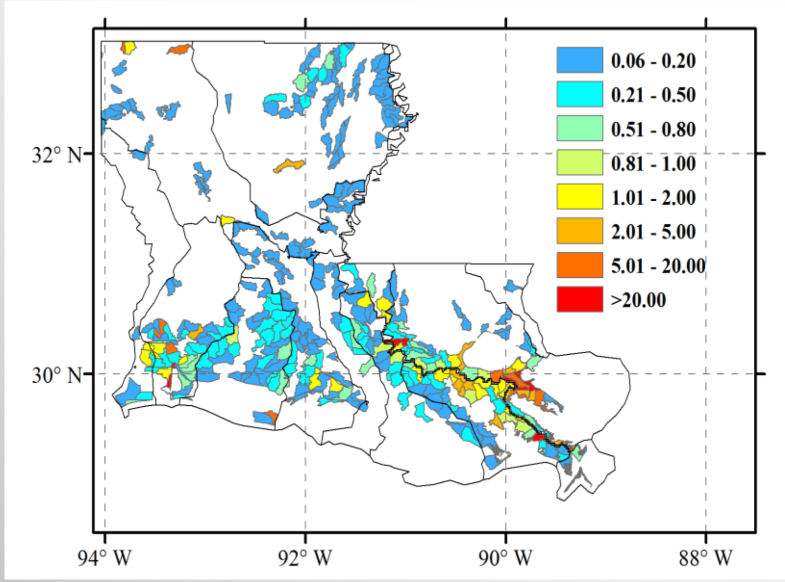
Integrating water quality into water stress analysis



Stress before addition of water quality



Difference in water stress attributable to salinity



Stress after addition of water quality

The effective spatial scale for this approach is determined by the density of available data.

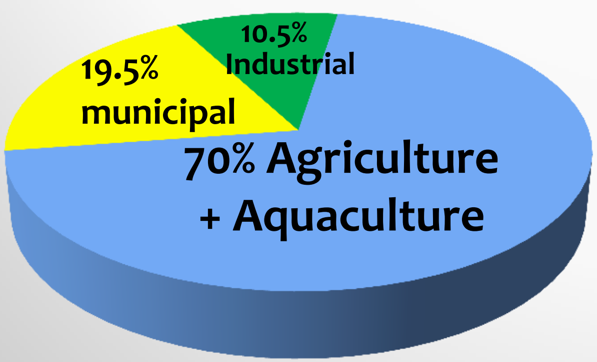
The water stress analysis framework can be used to evaluate a variety of scenarios

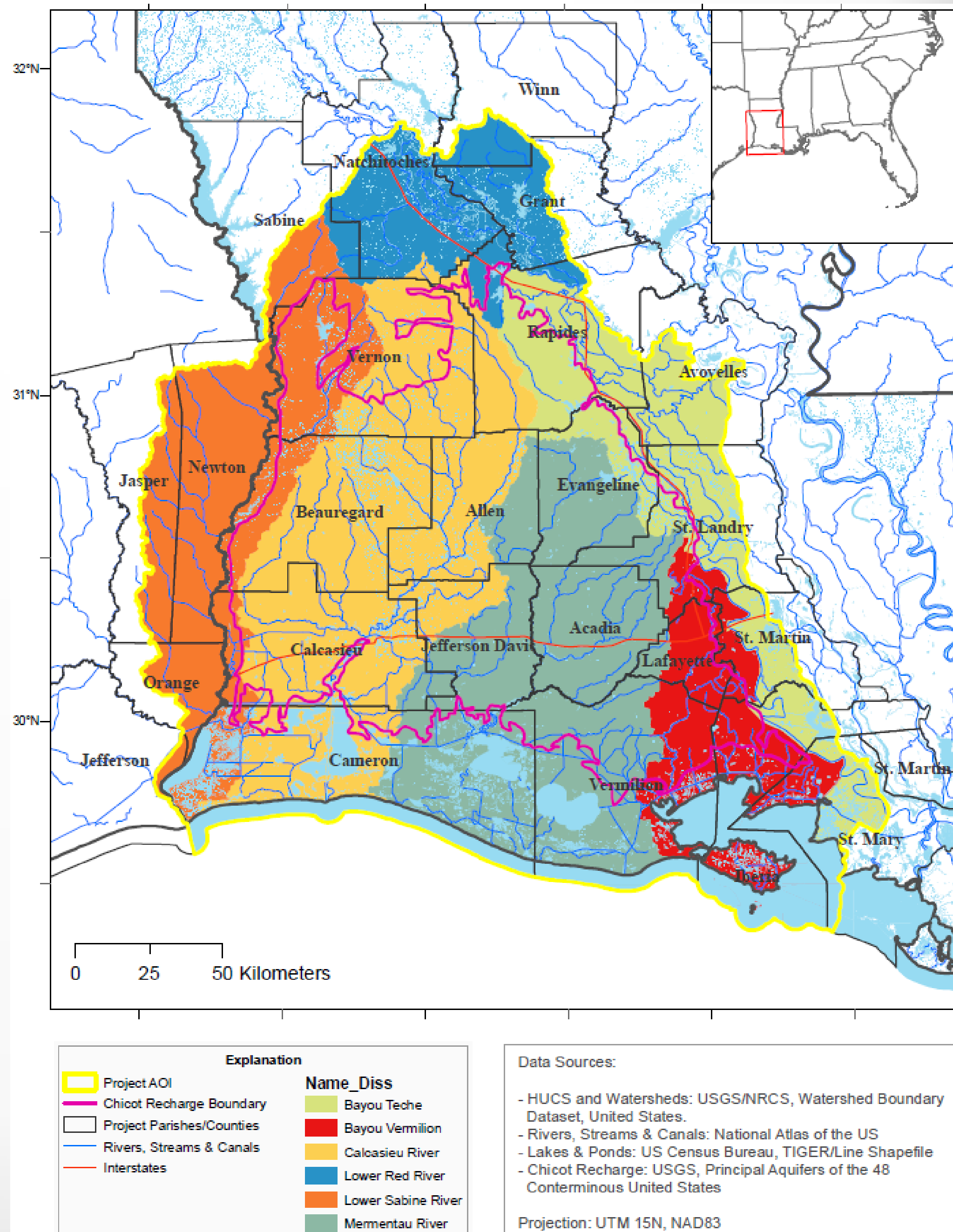
- Probability analysis to determine the likelihood of significant water stress in any given year.
- Examination of stress under different drought (climate) scenarios.
- Examination of stress under different water demand scenarios (e.g., changing agriculture/irrigation patterns, the addition of power plants/industry, etc.)

Our first manuscript detailing this approach was recently accepted for publication in *Environmental Research Letters* and should be available to the public within a few weeks.

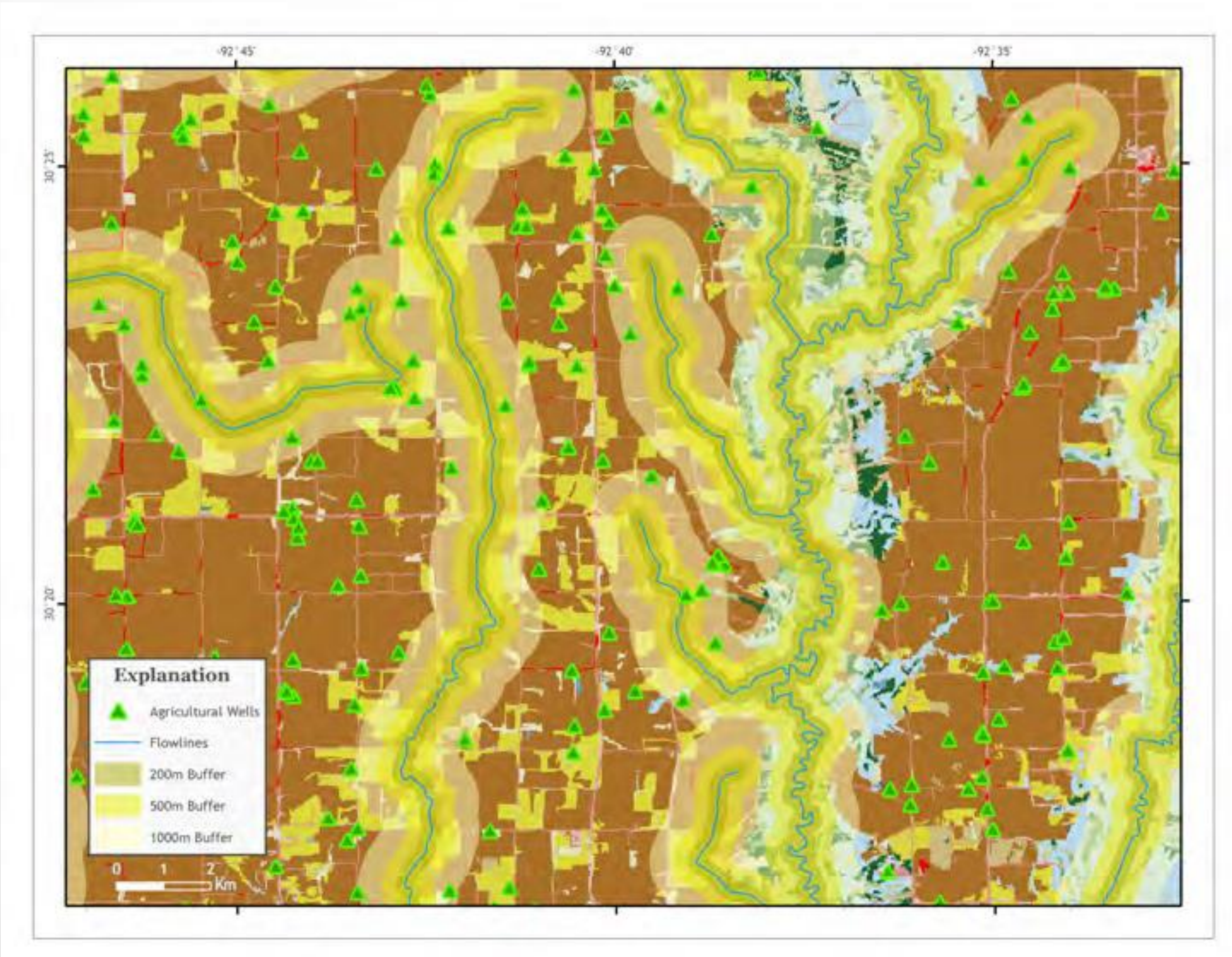
SW vs. GW use in the Chicot aquifer region in SW LA

- 23,000 km^2
- Most used aquifer in Louisiana
- Overdraft of ~350 million gallons per day (MGD)
- Projected overdraft of 420 MGD by 2030.
- Saltwater intrusion near the coast





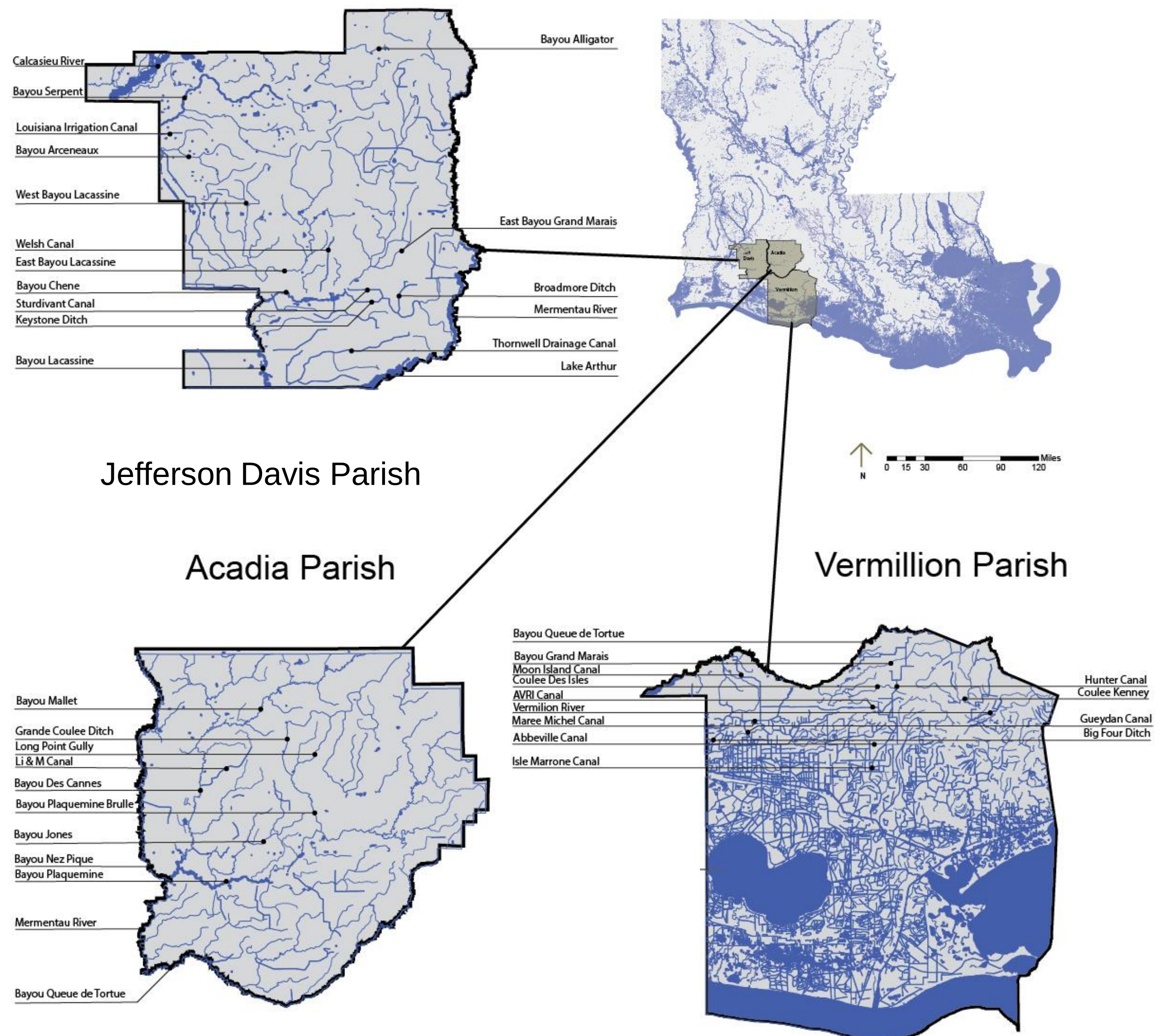
What opportunities exist for using surface water to replace groundwater?



What percentage of irrigation wells are within 500 m of a potentially useable surface water body?

What drives the decision making?

- Completed interviews of 68 farmers.
- In-person, on-site, interviews.



Combination of approaches suggests the following:

1. In many areas of coastal SW LA there is a strong probability of surface water not being available in a given year (i.e., seasonal deficits). Hence, "reliability" is a primary factor why farmers choose groundwater over surface water.
2. There is practically no investment in water storage infrastructure for dealing with the "reliability" problems for surface water on a local or larger scale.

Thinking about solutions

Developing storage capacity

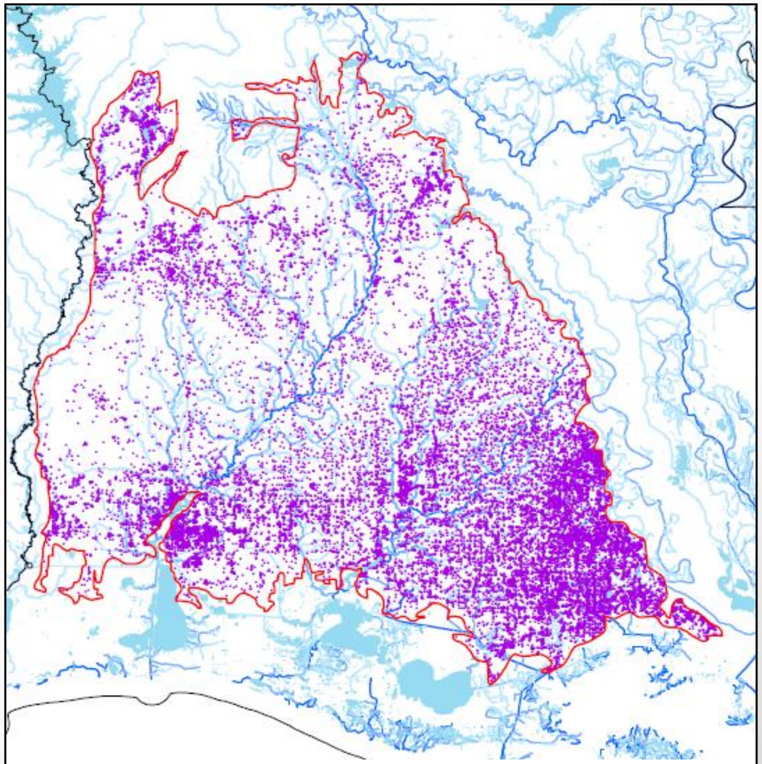
Can we identify opportunities for building surface water storage capacity that can benefit farmers during the irrigation season but also mitigate flooding during emergencies?

Thinking about solutions

Managed aquifer recharge (MAR)

Can we identify locations where we can reverse pumping and effectively recharge the groundwater system with excess (flood) water?

MAR is about storing excess surface water in the subsurface for later use



Well distribution within the Chicot Aquifer

Thinking about solutions

Example design scenarios

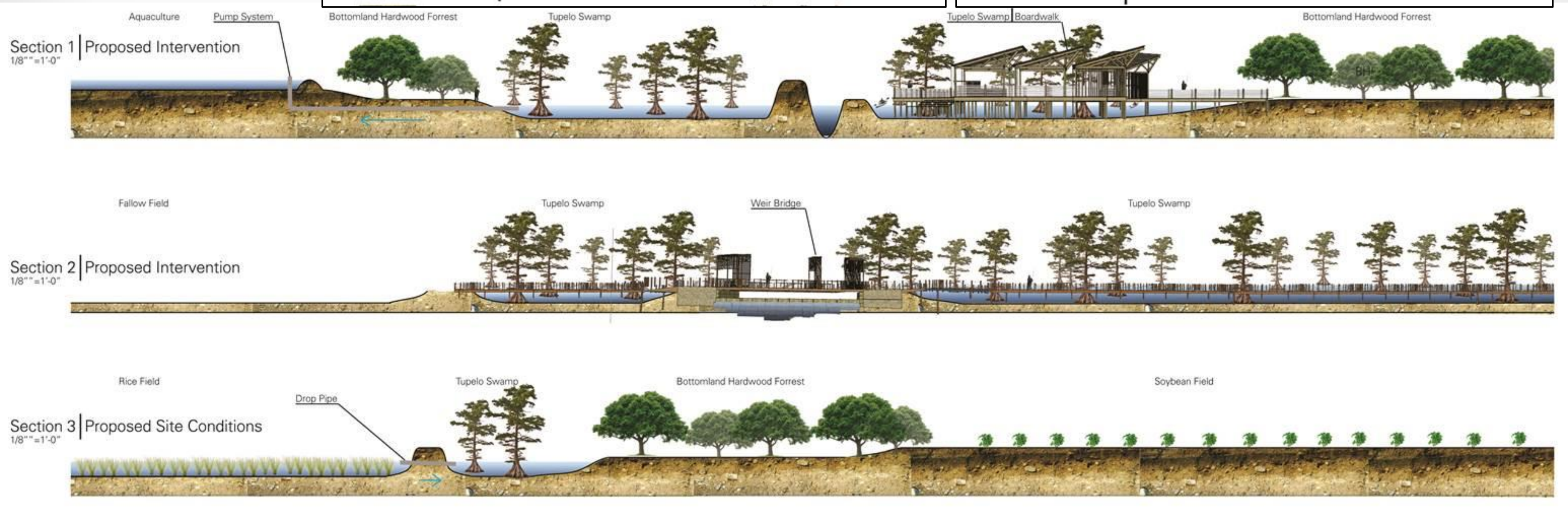


Image Credit: Matthew Landry, Kayla Rutherford;

Thanks for your time!

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