A geospatial framework for analysis of water quantity and quality stresses in wetter regions of the US: An application from coastal Louisiana

Emad Habib (UL Lafayette); habib@louisiana.edu)

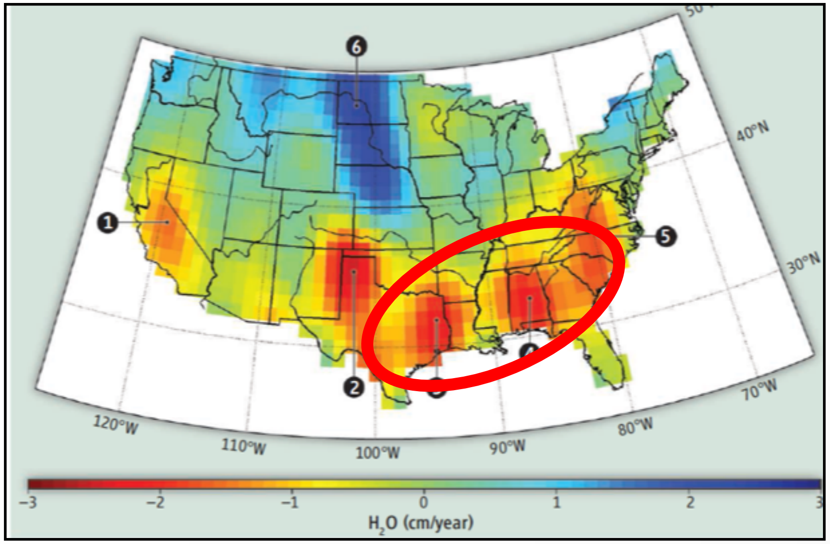
David Borrok (Missouri University of Science and Technology)
Hisham Eldardiry, Jian Chen, JoAnned DeRouen & Kari Smith
(UL Lafayette)

NSF CBET-1360398

Problem

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

This can lead to **subsidence, salt water intrusion**, coastal **land loss**, and **loss of available freshwater** for coastal communities.

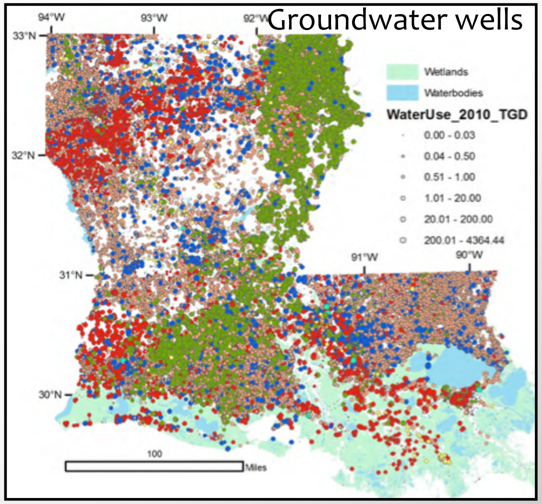


GRACE satellite estimates of changes in terrestrial water storage over the last decade. (Famiglietti and Rodell, 2013, Science).

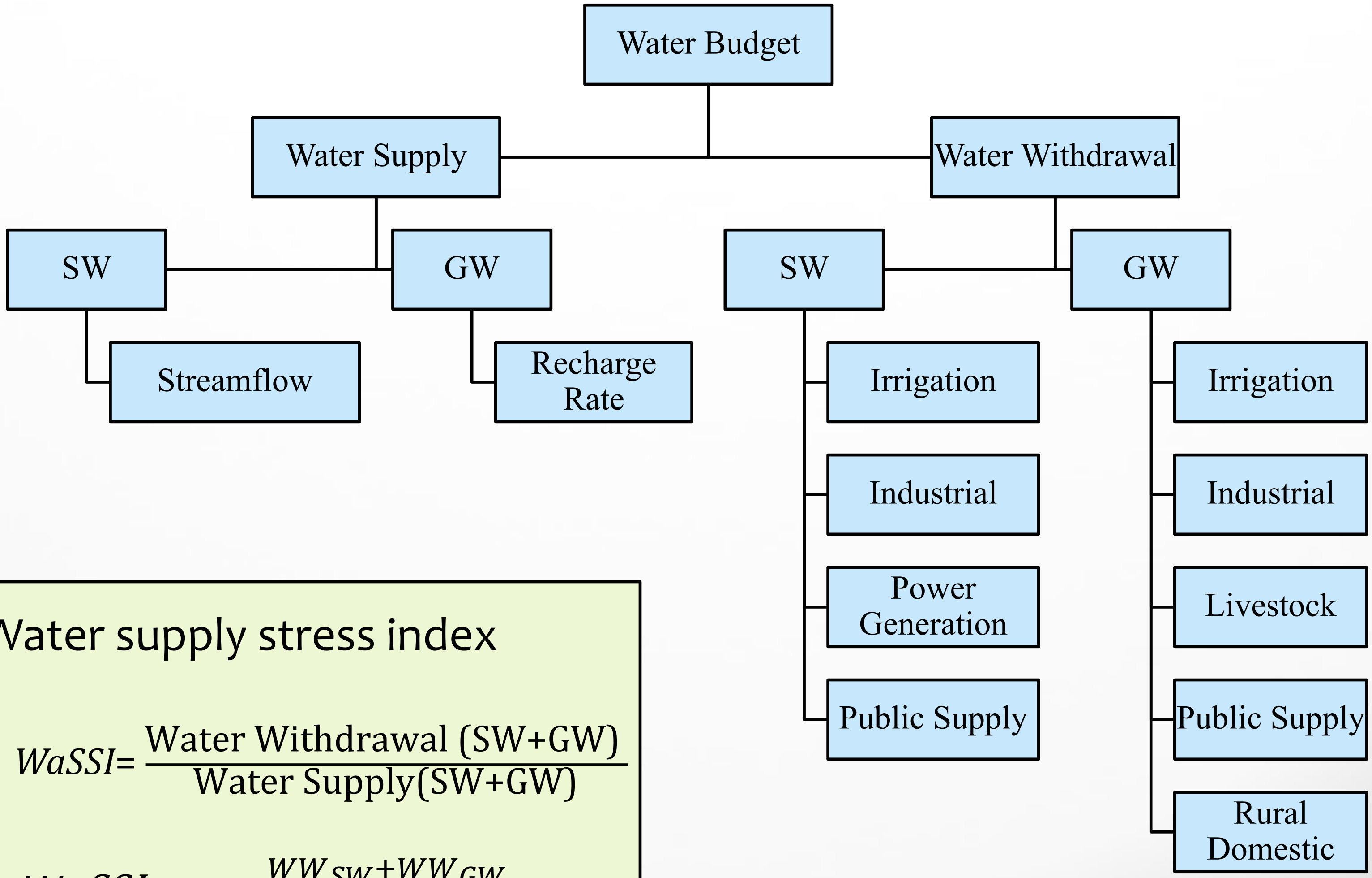
Research Questions

What are the **natural drivers and social dynamics** that control water usage decisions that lead to overuse of groundwater in coastal regions such as south LA?

Can we identify opportunities for implementing **new sustainable water management strategies**



Approach: Water Stress Framework



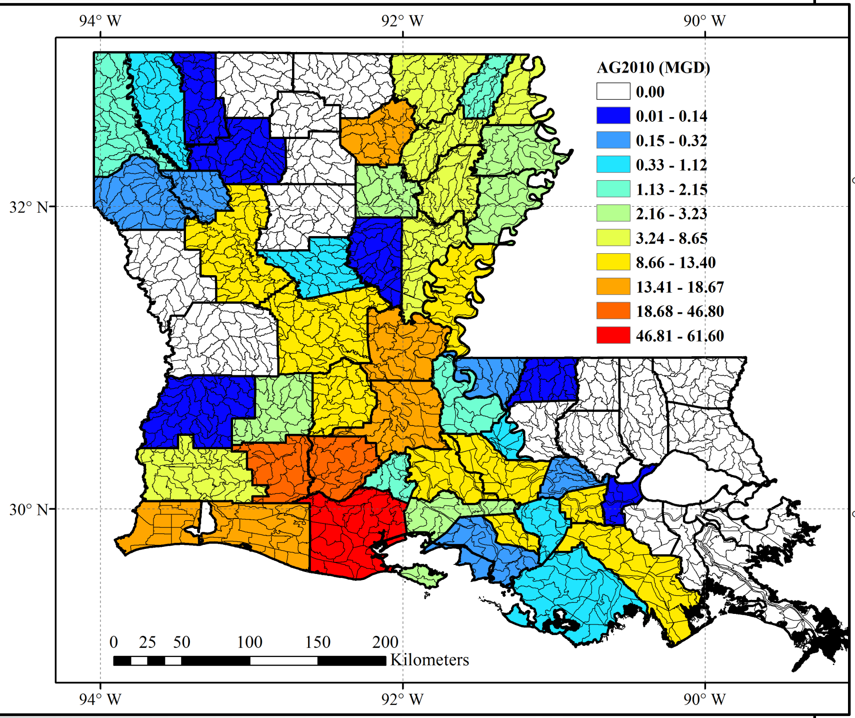
Water supply stress index

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

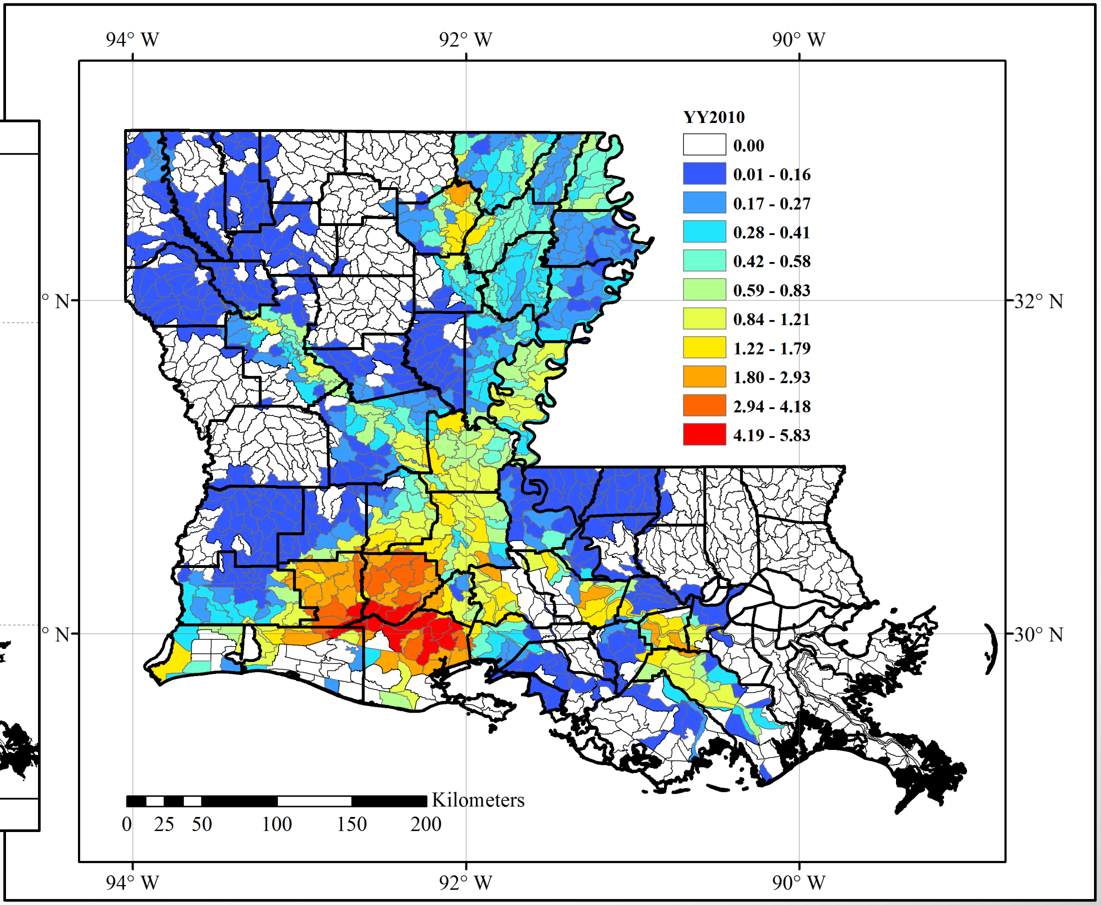
$$WaSSI = \frac{WW_{SW} + WW_{GW}}{(1 - ENV) * WS_{SW} + WS_{GW}}$$

Spatial Disaggregation of larger-scale data to management scales

Surface Water demand -- Irrigation

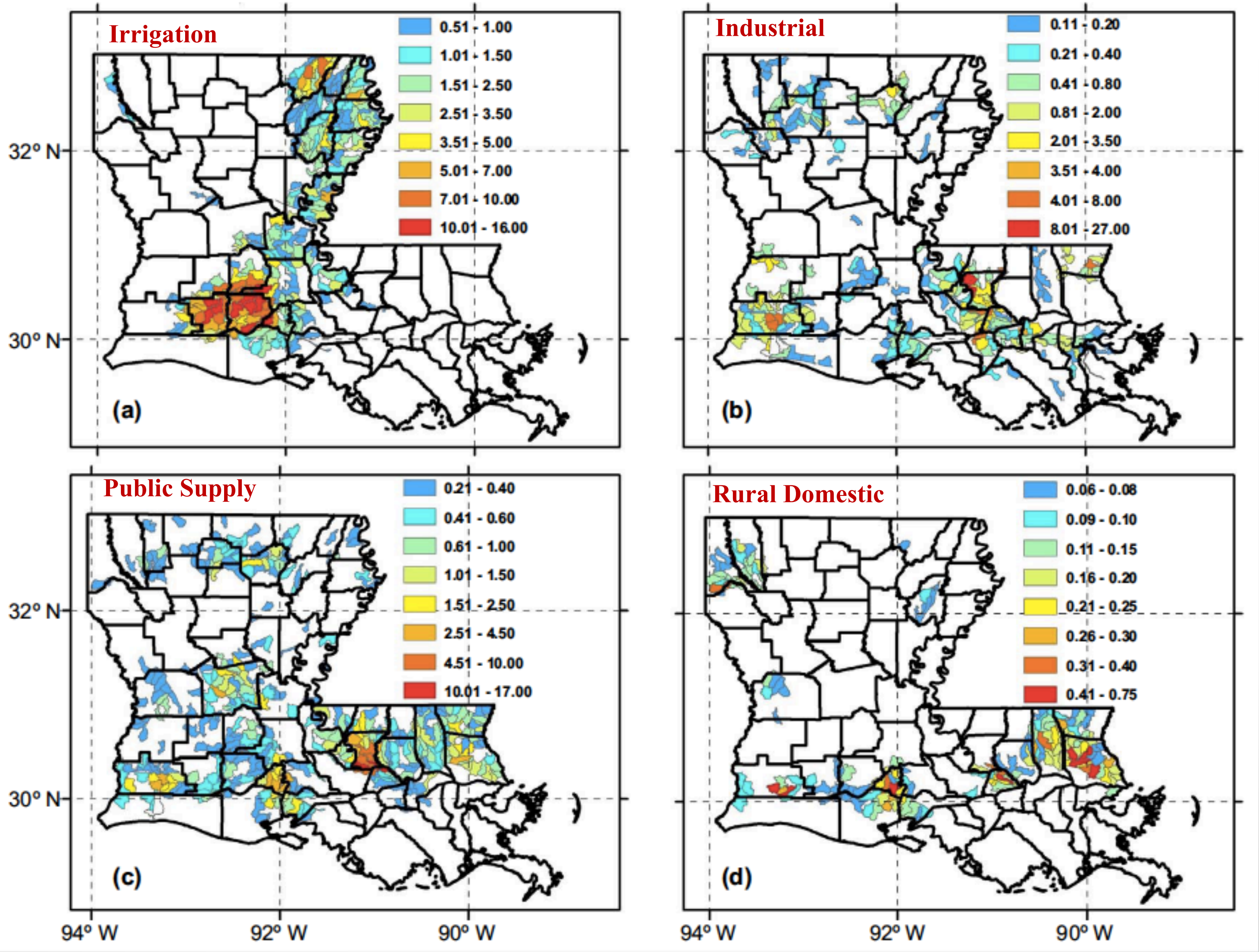


Parish Scale



HUC12 scale

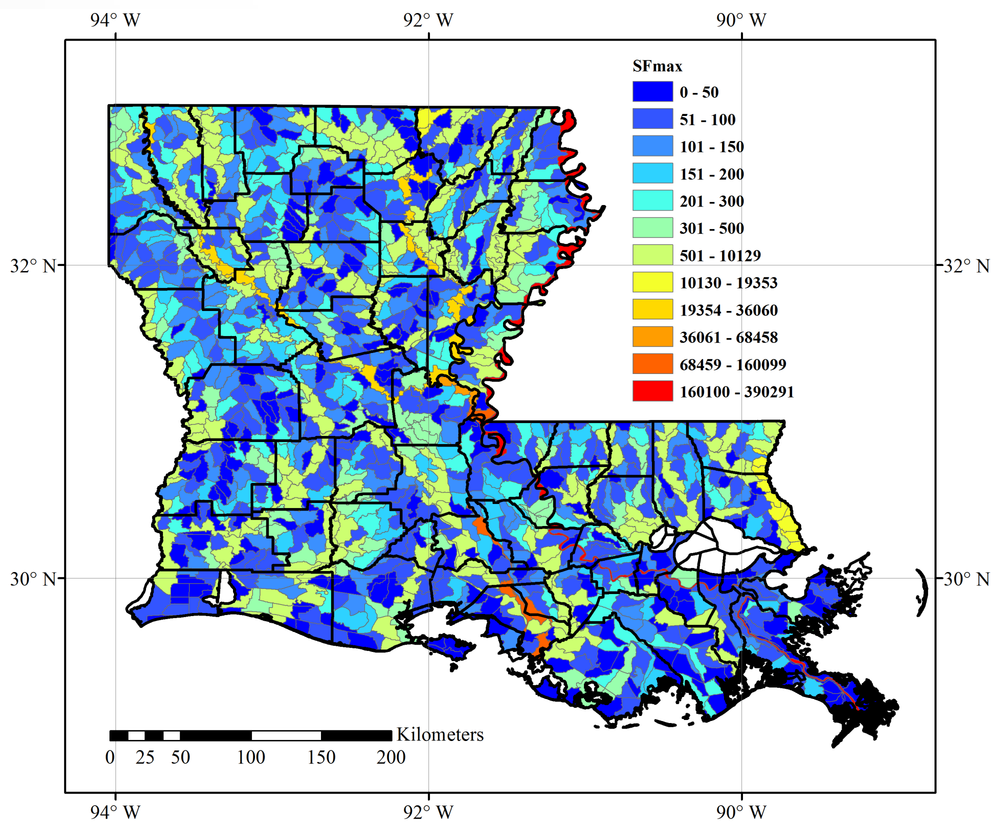
Groundwater Demand



Disaggregation of GW Withdrawals based on casing diameter of wells.

Water Supply Data

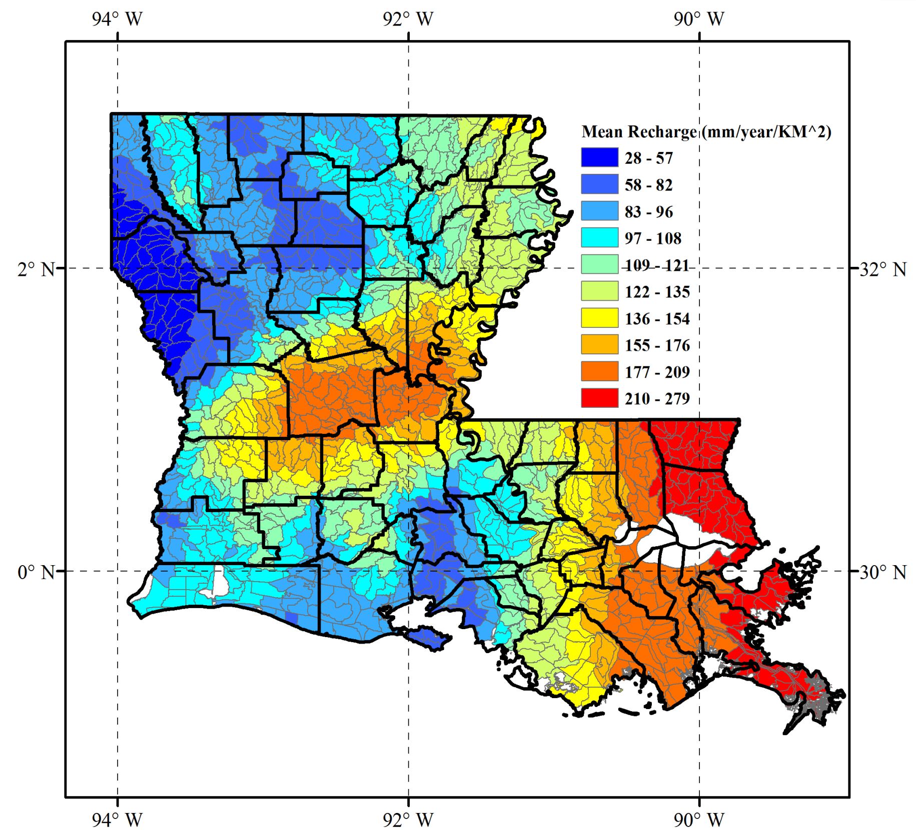
Surface Water



National Hydrography Dataset (NHDPlus)

25-year average (annual and monthly) climatological conditions.

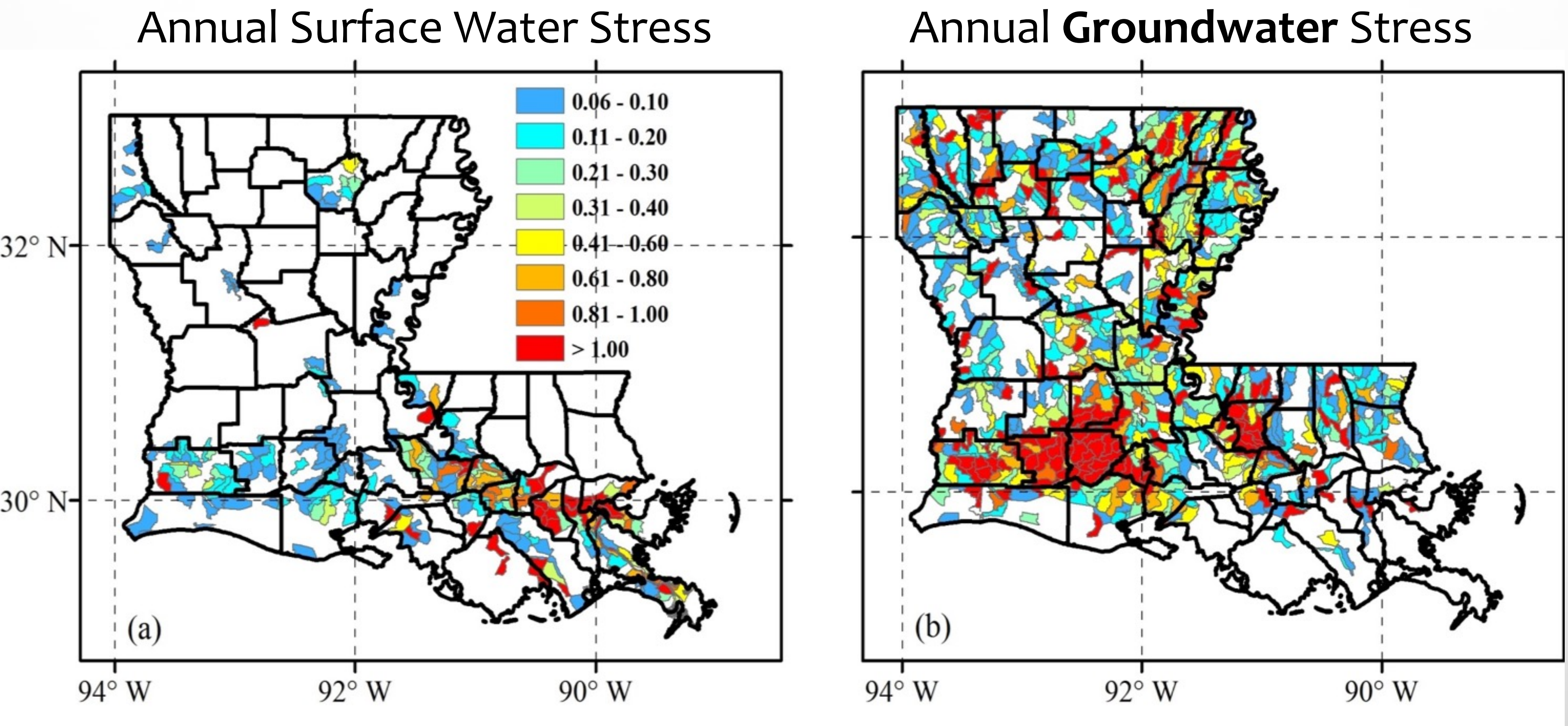
Groundwater



USGS Groundwater recharge estimates

mean annual recharge (mm/yr/km²)

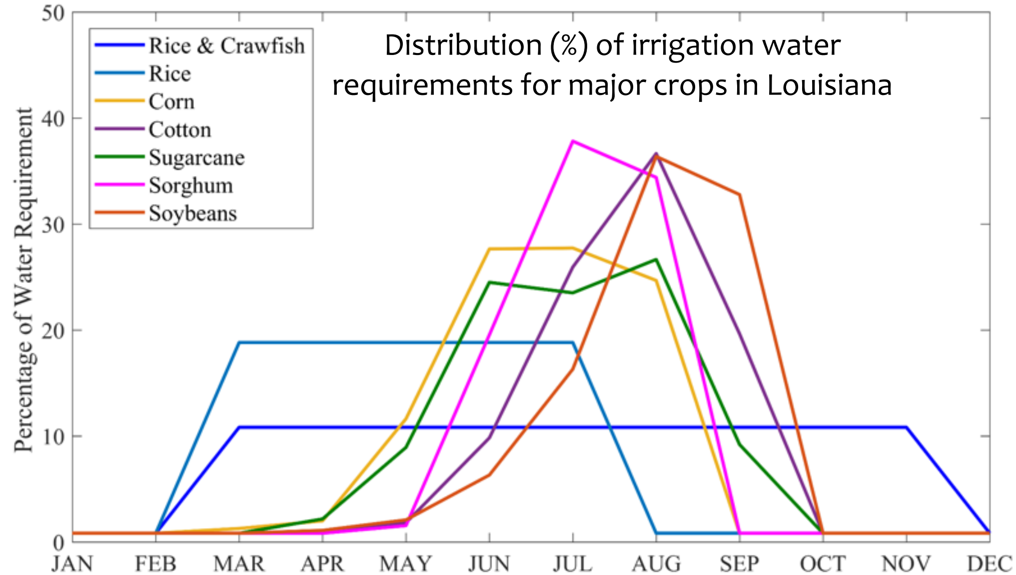
Water Stress Results



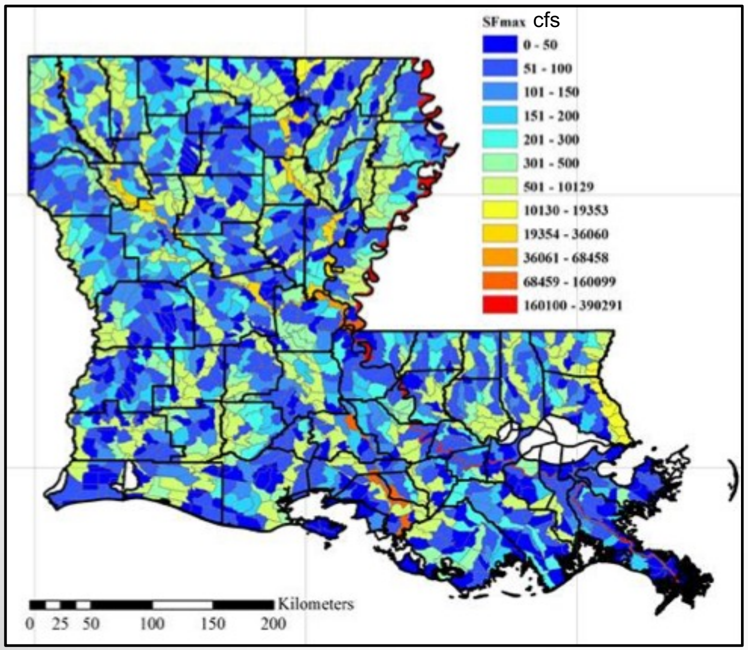
Areas in red indicate water deficits. For groundwater that implies water is being mined faster than it is replaced through natural recharge processes.

Impact of Climate Variability

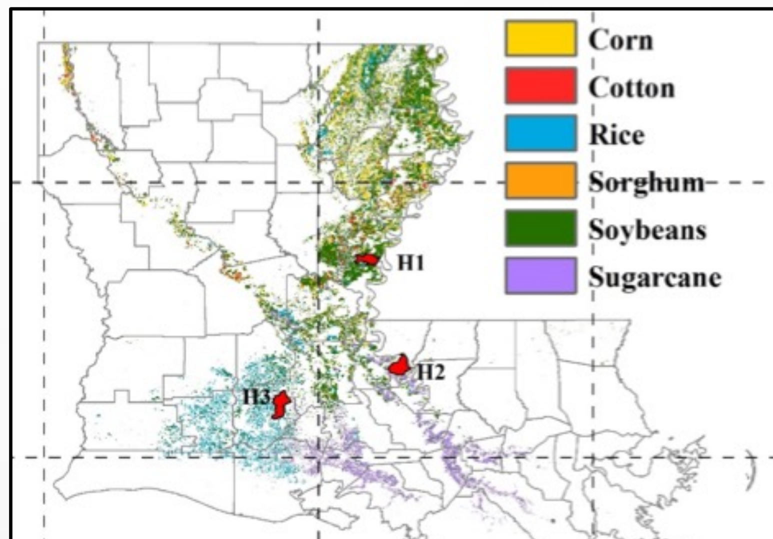
Inter-annual and intra-annual variability in water demands



Inter-annual and intra-annual variability in water supply

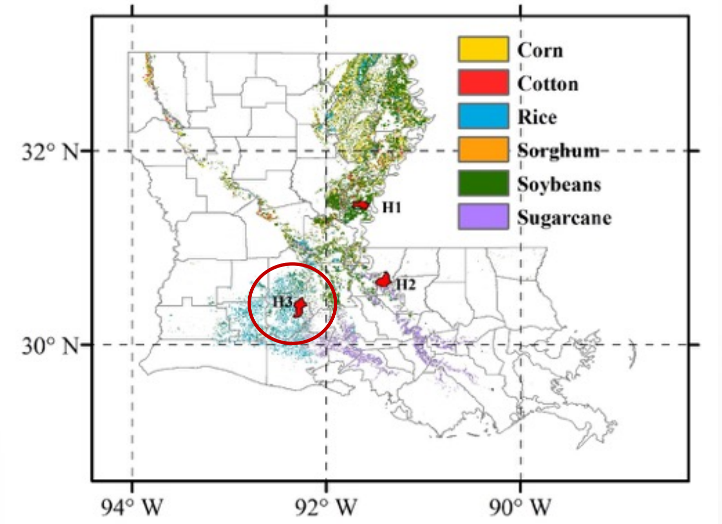


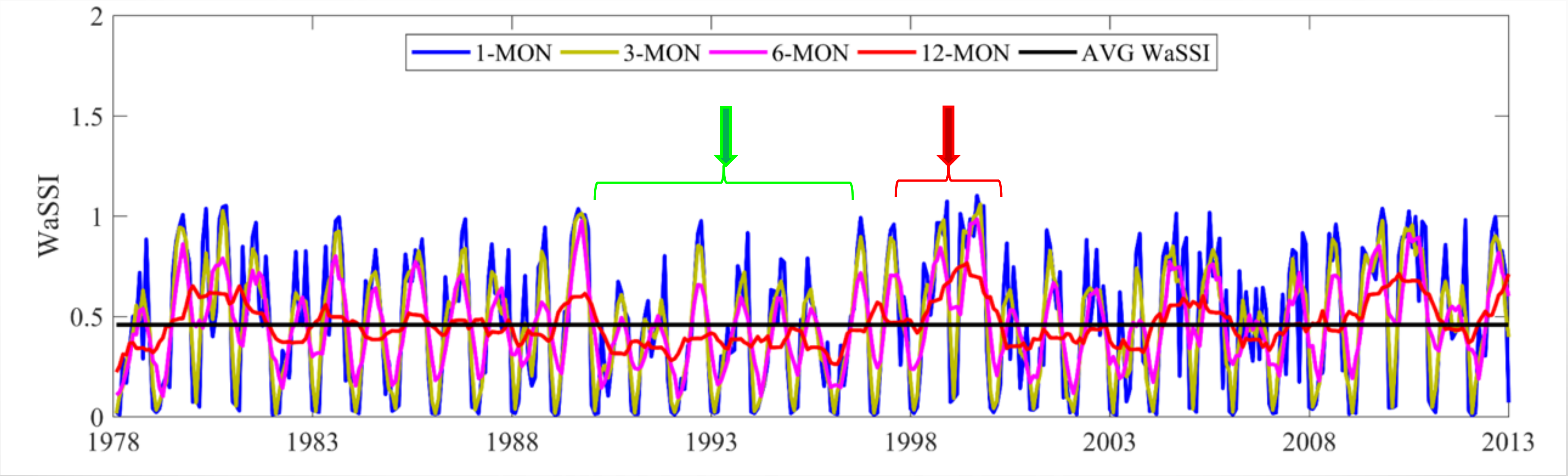
Time series of monthly (1979-present) streamflow estimates (Source: **NLDAS**)



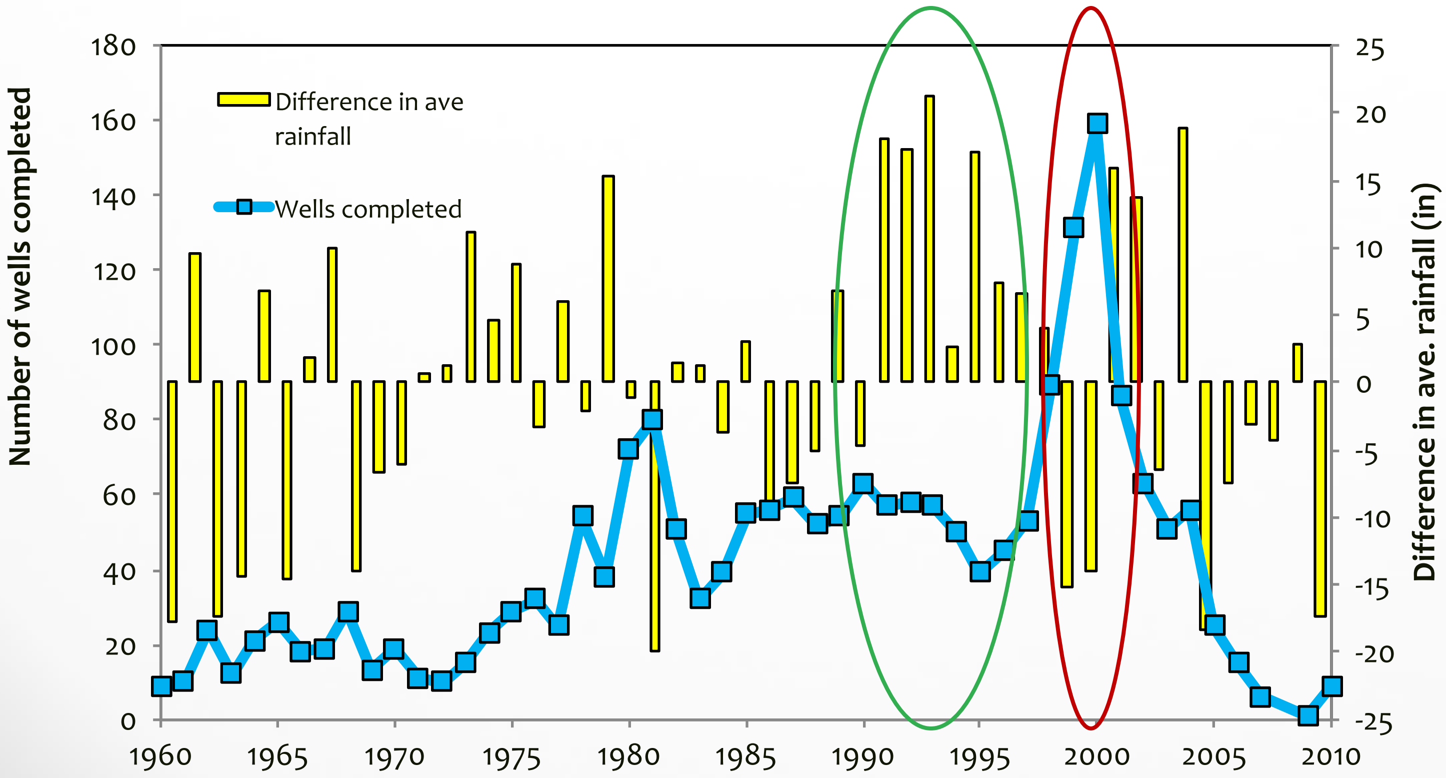
Spatial distribution of dominant crops (Source: **USDA/NASS**).

Seasonal Variability





Farmers adapt to climate variability by drilling more wells!



Farmers invested in groundwater wells instead of surface water infrastructure in response to seasonal deficits and drought.

Integrating water quality into the water stress analysis

Focus on one water use sector (agriculture):

Sector-specific Stress: $SWaSSI = \frac{WWi_{sw}+WWi_{gw}}{WSi_{sw}+WSi_{gw}}$

Use existing chemical data to quantify fraction of useable water in a given HUC12:

water quality parameter (e.g., salinity) — threshold of acceptable salinity for agriculture sector

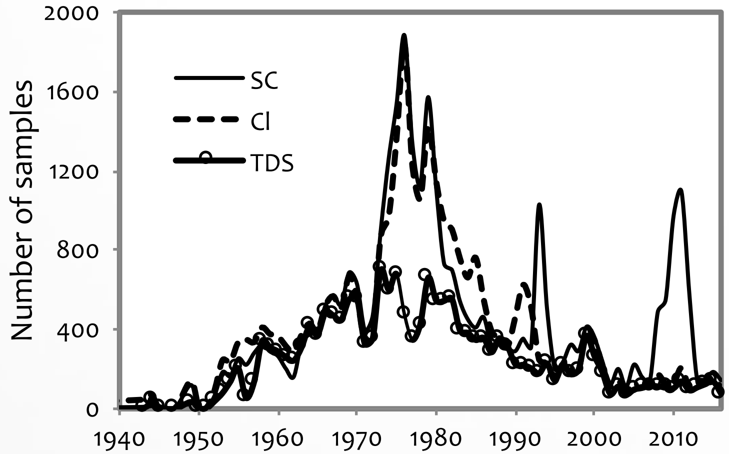
$$f_X = \frac{(\Sigma \text{ number of measurements of X > threshold value})}{(\Sigma \text{ number of all measurements of X})}$$

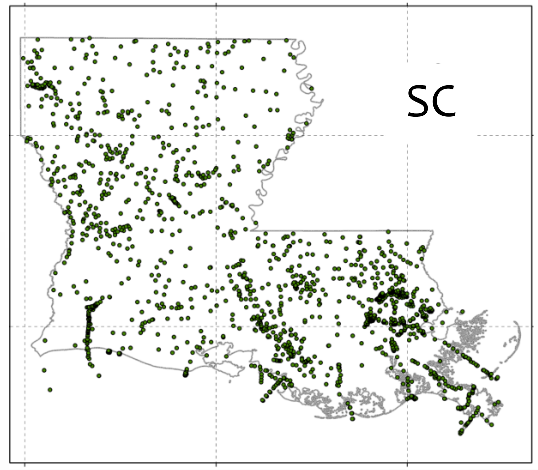
Incorporate into SWaSSI:

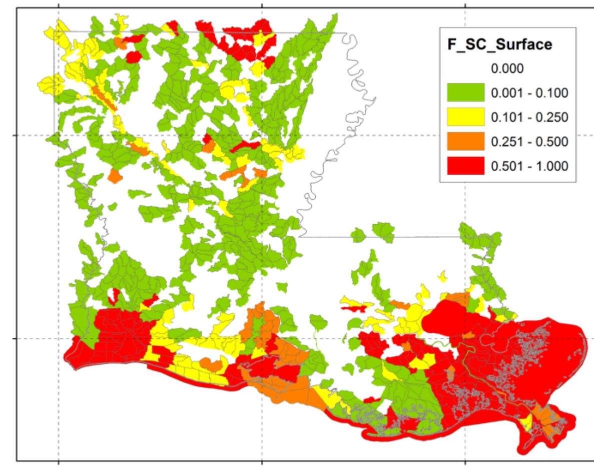
$$SWaSSI = \frac{WWi_{sw}+WWi_{gw}}{(1-f_{x\_sw})*WS_{iSW}+(1-f_{x\_gw})*WS_{iGW}}$$

Irrigation and water quality sampling at a rice farm in southwest Louisiana

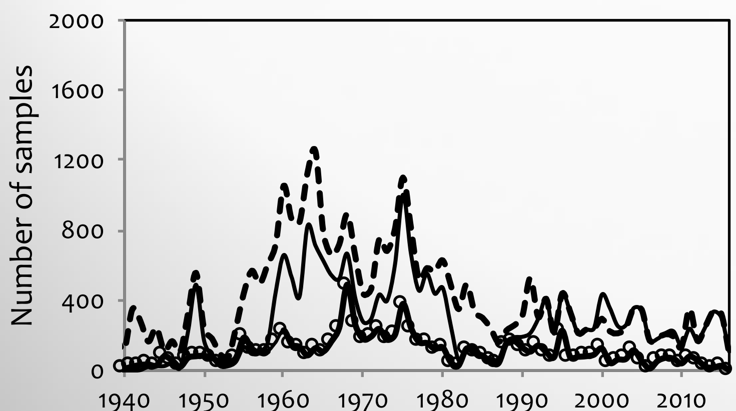
f_x : surface water

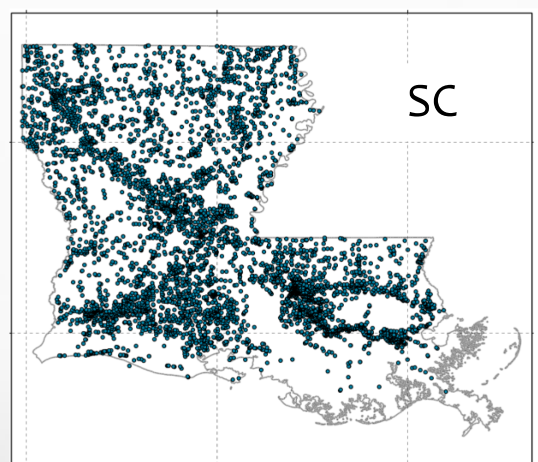


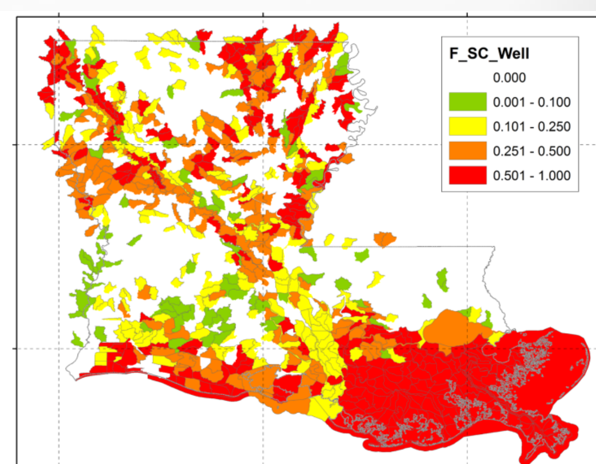




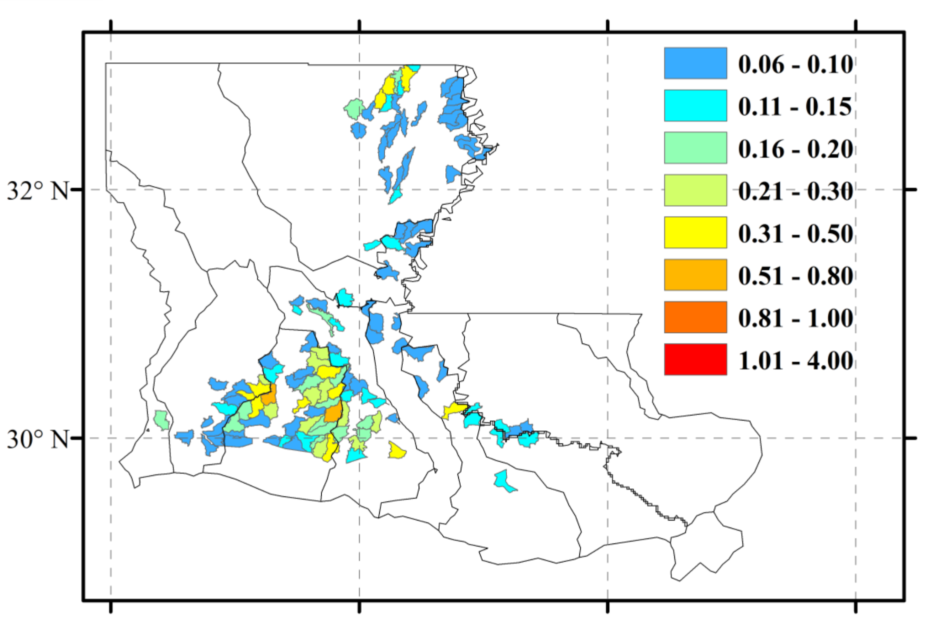
f_x : groundwater



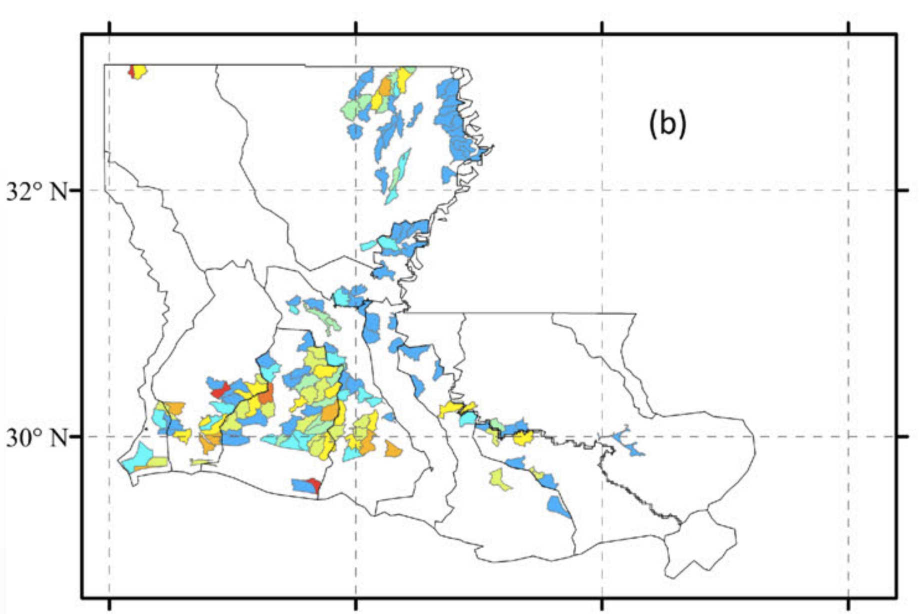




Water stress attributable to elevated salinity



SWaSSI prior to considering Water quality



SWaSSI after considering Water quality

Social Dynamics: what drives the decision making?

How our results were corroborated by field interviews?

Community stakeholder involvement

- Farmers who owned majority of acreage they farmed and who had experienced extended or repeated drought had multiple deep-water wells.
- Less than 20% of farmers stored surface water for future use. Those who did store surface water had a naturally occurring pond area, or had identified areas in their property that were not viable for farming.
- Loan qualification is easier when farmers have wells on property

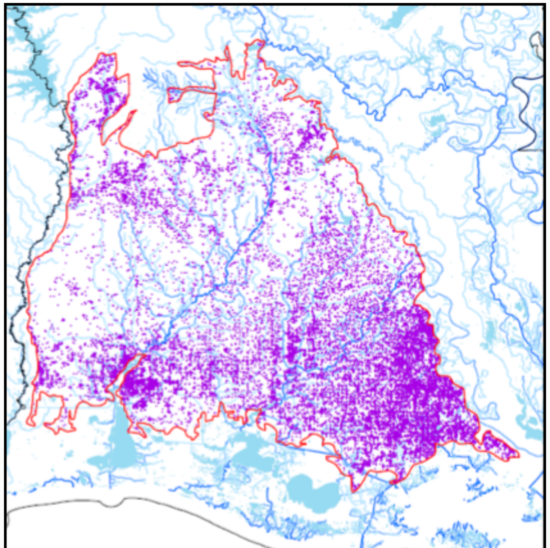
Key Insights & Implications for Water Management

- There is a **delicate balance** between freshwater and saltwater in coastal zones -- this can be disrupted by unplanned changes in water management in both systems.
- There is abundance of surface water on an average annual scale that can offset groundwater demand, but there is substantial **seasonal and inter-annual variability** that is hidden by annual averages.
- Hence, "**reliability**" appears to be a primary factor why farmers choose groundwater over surface water.
- Water quality plays an important role in affecting water management decisions
- Our water stress framework can be used to evaluate a wide variety of **scenarios**: climate, crop patterns, additions of power plant, water policy, water prioritization

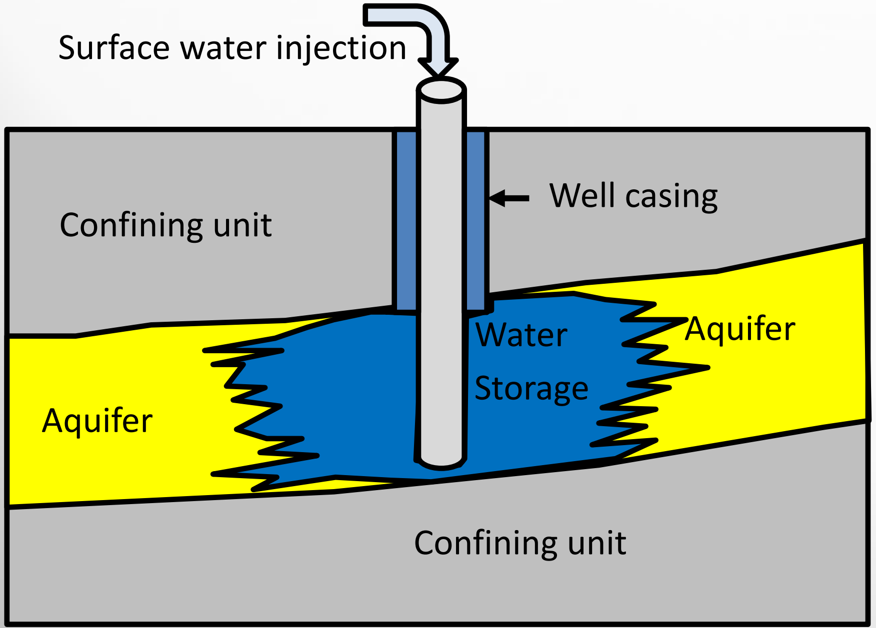
Future Work: Integrated water management solutions

<u>Developing storage capacity</u>

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



Well distribution in Chicot Aquifer



<u>Managed aquifer recharge (MAR)</u>

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

More information available in these publications

Emad Habib
(habib@louisiana.edu)
David Borrok
(borrokd@mst.edu)

Environmental Research Letters

ENVIRONMENTAL RESEARCH LETTERS

LETTER

Small-scale catchment analysis of water stress in wet regions of the U.S.: an example from Louisiana

Hisham Eldardiry[1,3], **Emad Habib**[1,3] **and David M Borrok**[2,3]

[1] Department of Civil Engineering, University of Louisiana at Lafayette
[2] School of Geosciences, University of Louisiana at Lafayette
[3] Institute for Coastal and Water Research, University of Louisiana at Lafayette

E-mail: habib@louisiana.edu

Technical Paper

A Framework for Incorporating the Impact of Water Quality on Water Supply Stress: An Example from Louisiana, USA[†]

David M. Borrok, Jian Chen, Hisham Eldardiry, Emad Habib

First published: 26 October 2017 Full publication history

DOI: 10.1111/1752-1688.12597 View/save citation

Early View

Browse Early View Articles
Online Version of Record published before inclusion in an issue