Impact of Climate Variability on Water Stress in Louisiana: Implications for Sustainable Water Management

Emad Habib[1] & Hisham Eldardiry[2], David Borrok[3]

(1,2) Department of Civil Engineering, University of Louisiana at Lafayette
(3) Department of Geosciences and Geological and Petroleum Engineering, Missouri University of Science and Technology

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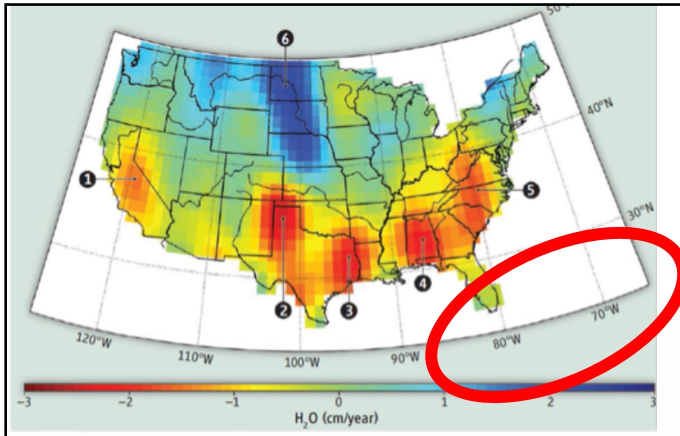
Motivation

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

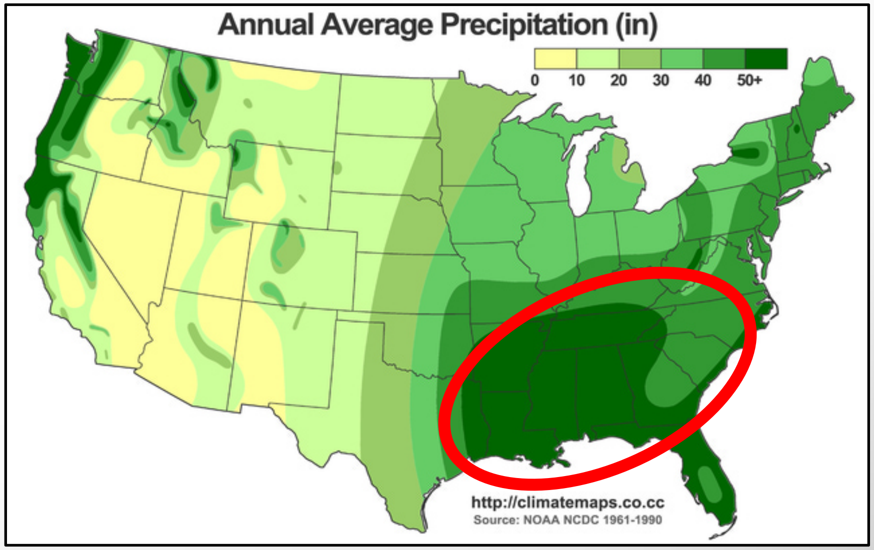
Opportunity

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.



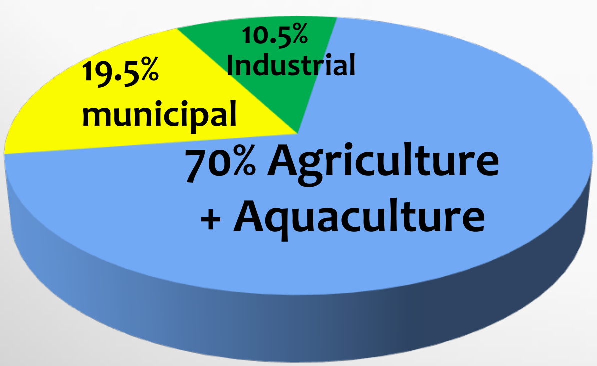
GRACE satellite investigation showing the change in groundwater and soil moisture across the US over the last decade. (Famiglietti and Rodell, 2013, Science).

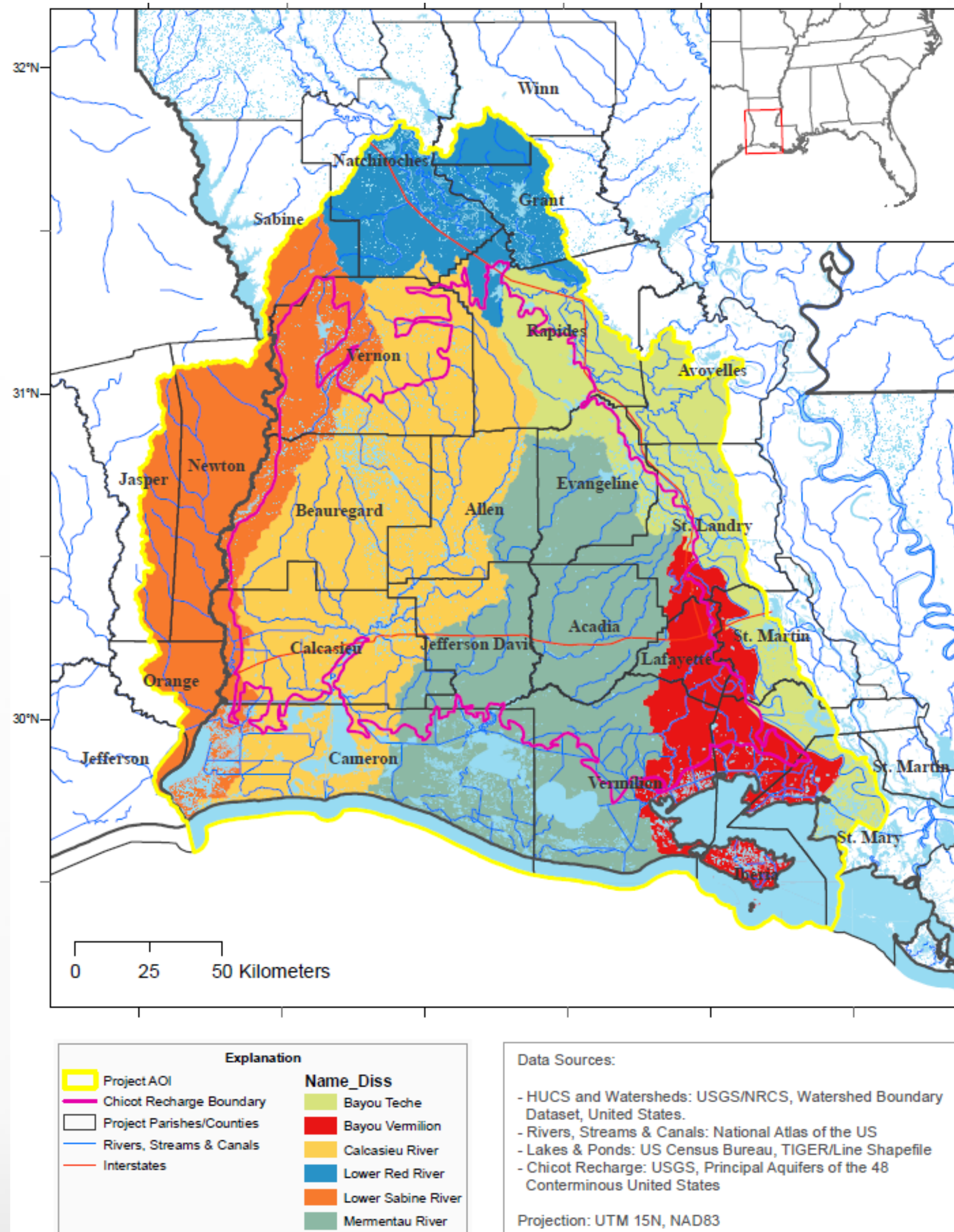


Annual precipitation averaged over 30 years (NOAA)

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





Research Objectives

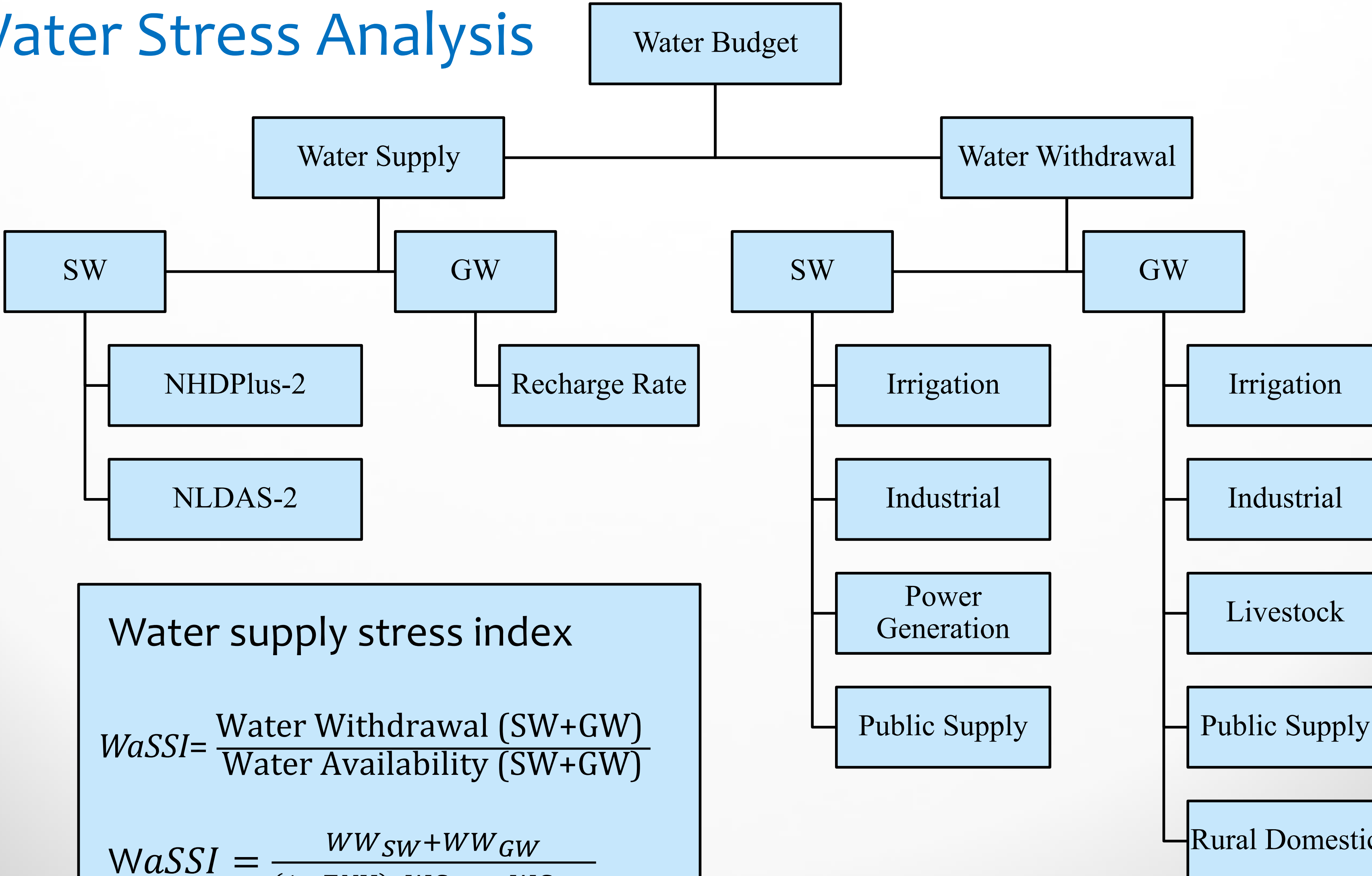
Is there enough "excess" surface water available in these regions to address groundwater supply gaps without harming coastal ecosystems?

Objectives

- Develop a geospatial analysis framework to understand water stress on fine spatial and temporal scales.
- Assess impact of climate variability on sustainability of water resources
- Identify opportunities for implementing new water management strategies in this region.
- Understand the social dynamics that underpin water usage decisions in the Southeast.
- Educate students and provide community outreach.

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

Approach for Water Stress Analysis



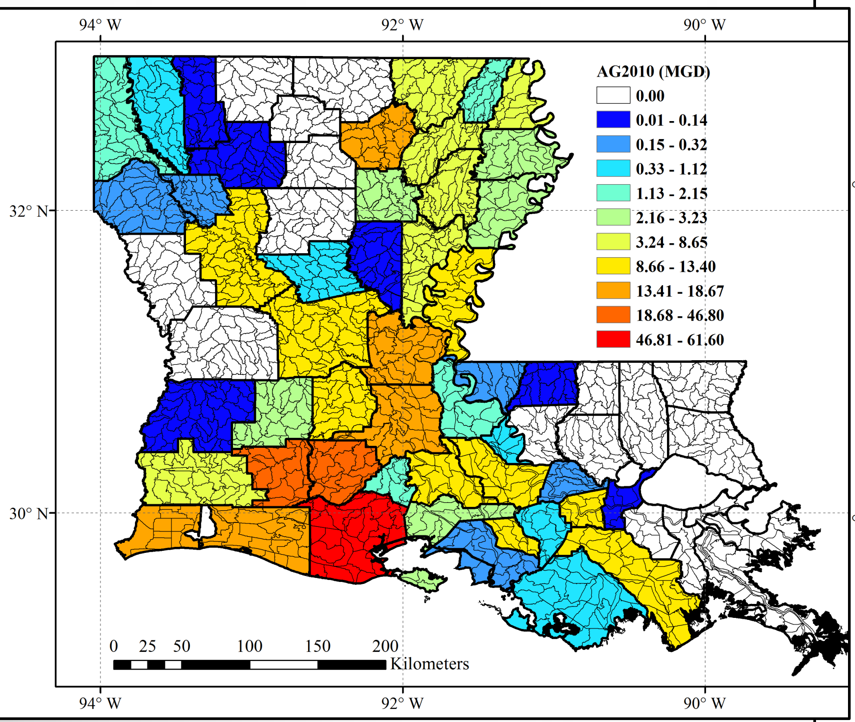
Water supply stress index

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

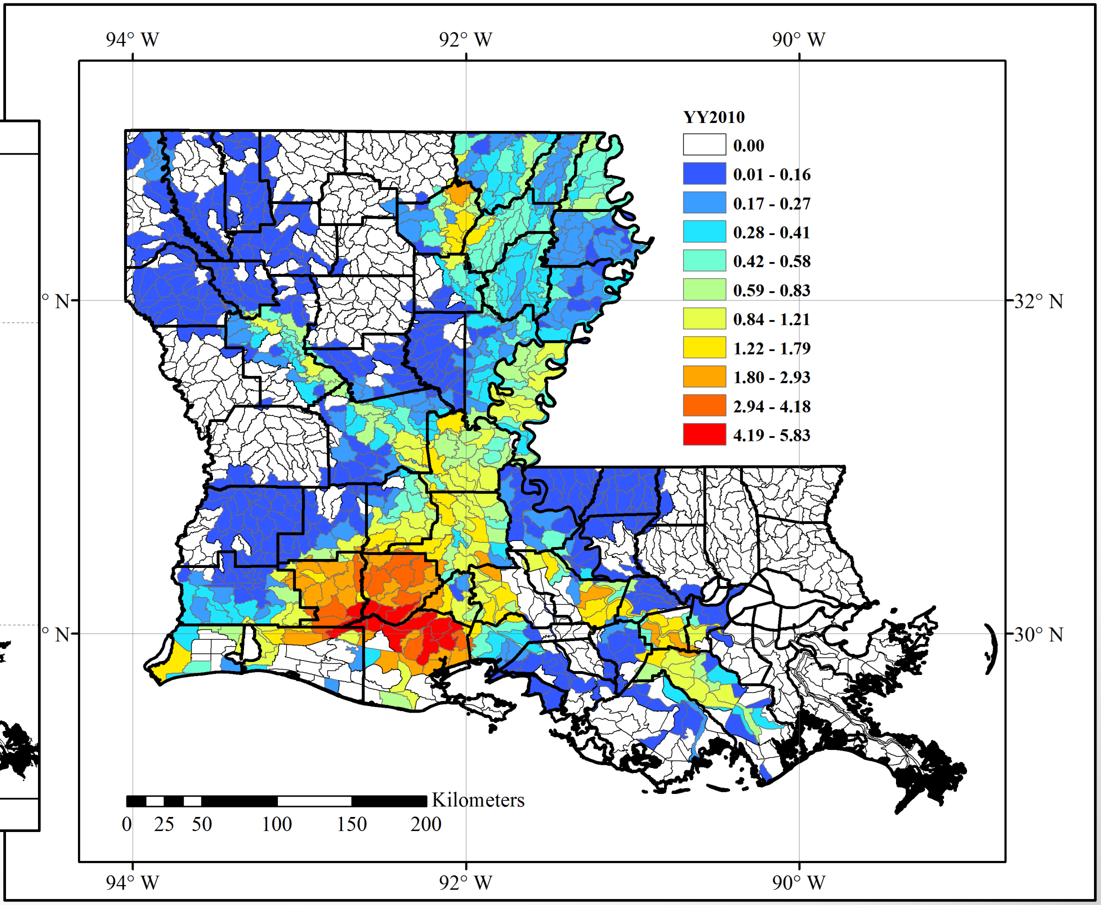
$$WaSSI = \frac{WW_{SW} + WW_{GW}}{(1 - ENV) * WS_{SW} + WS_{GW}}$$

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

Water demand examples



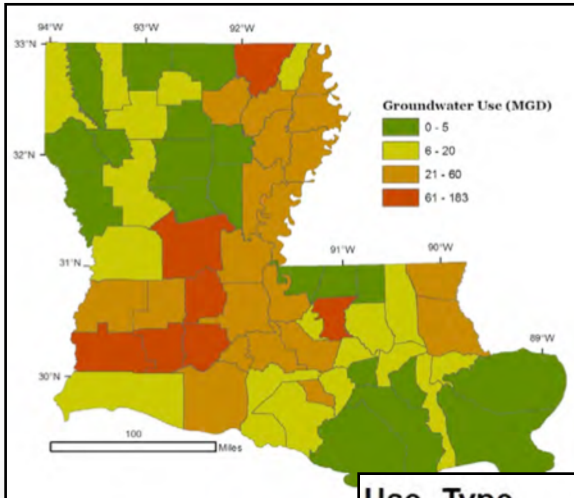
Surface water for irrigation on a Parish Scale

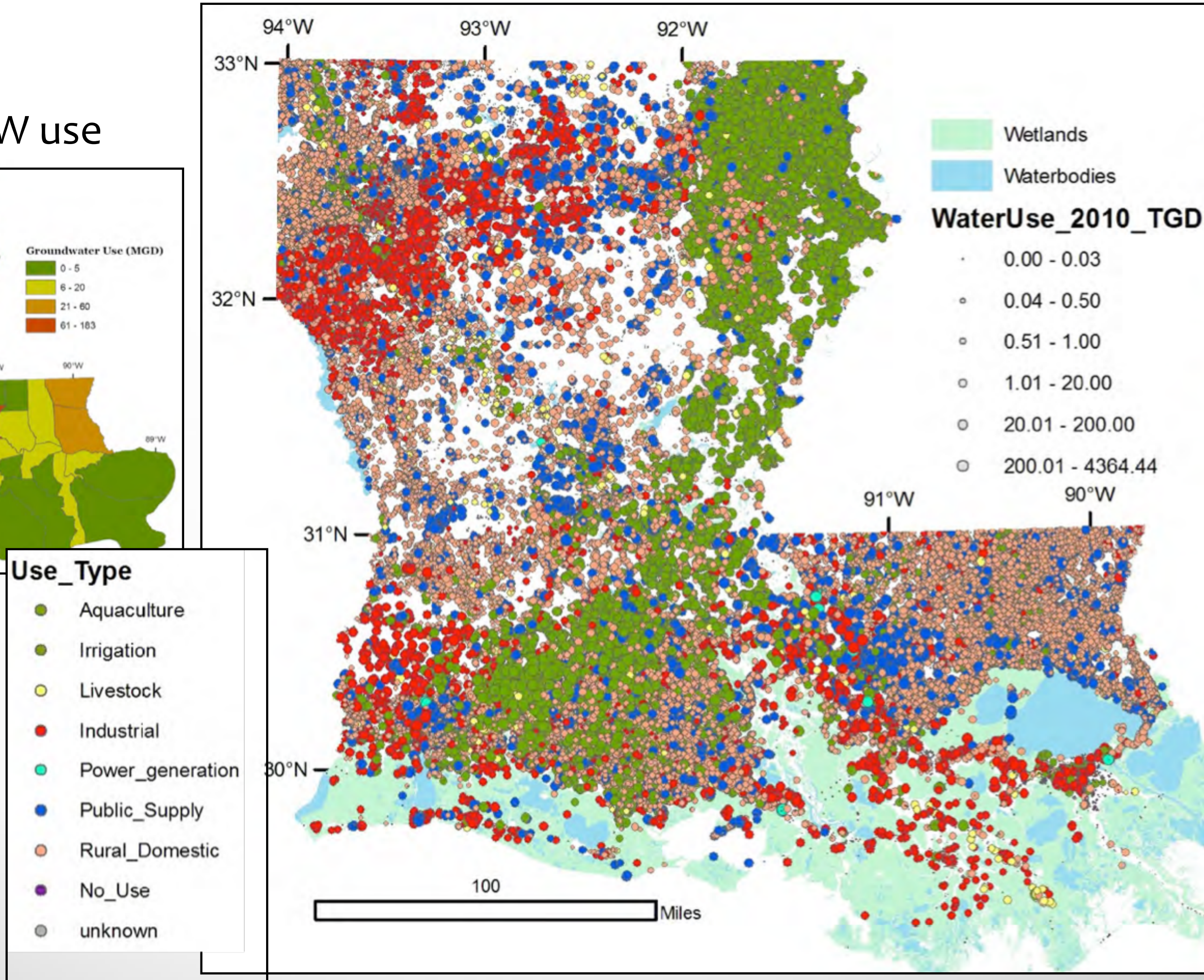


Surface water for irrigation on a HUC12 watershed scale

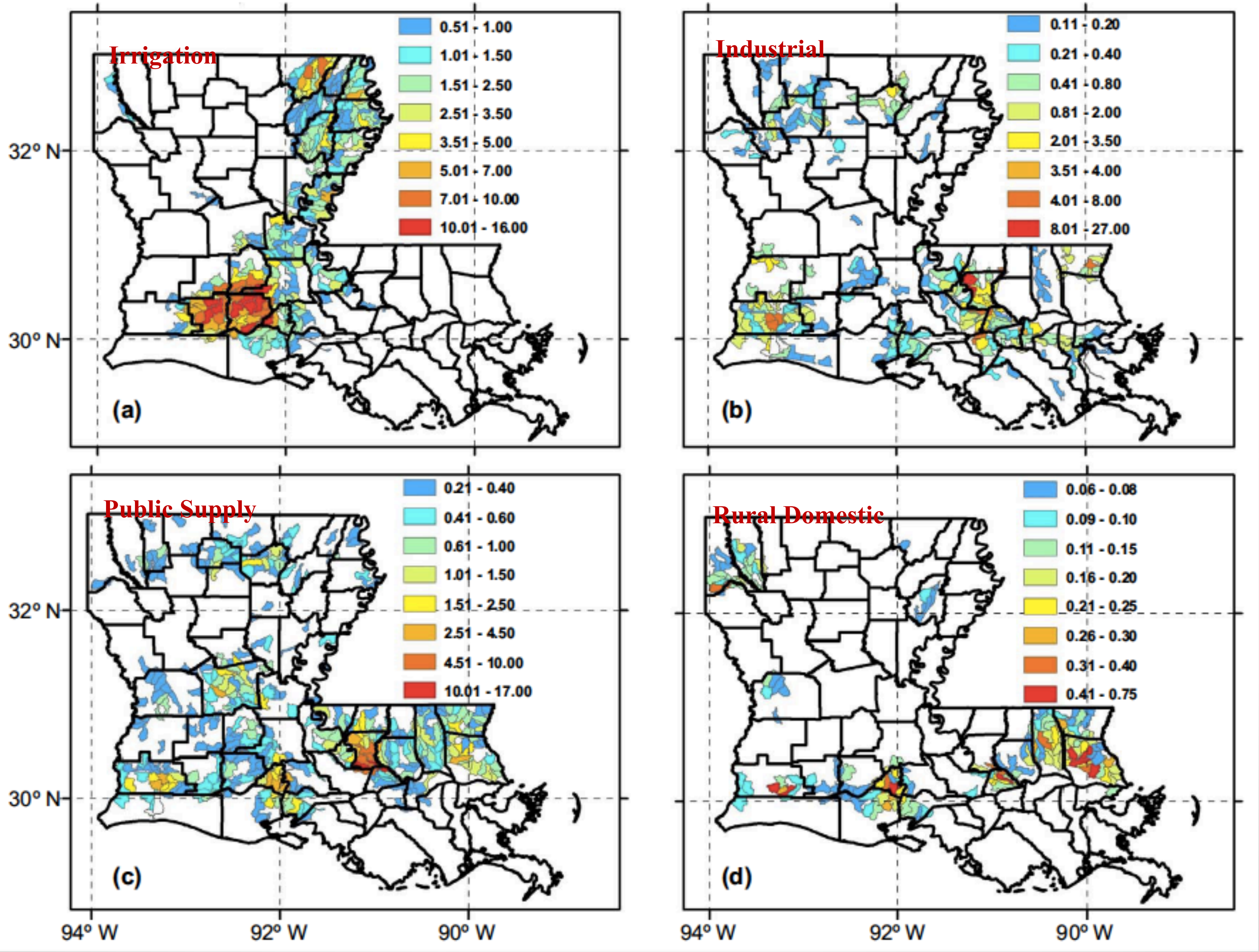
Groundwater use distributed by registered wells

Parish Scale GW use





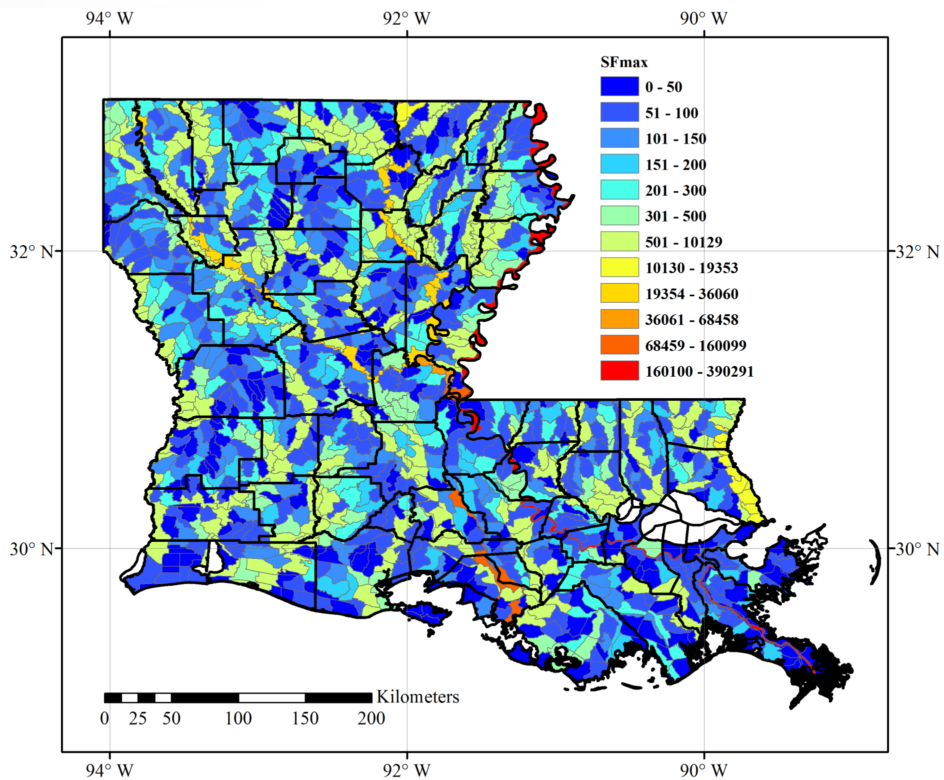
GW Disaggregation



Disaggregation of GW Withdrawals based on casing diameter of wells.

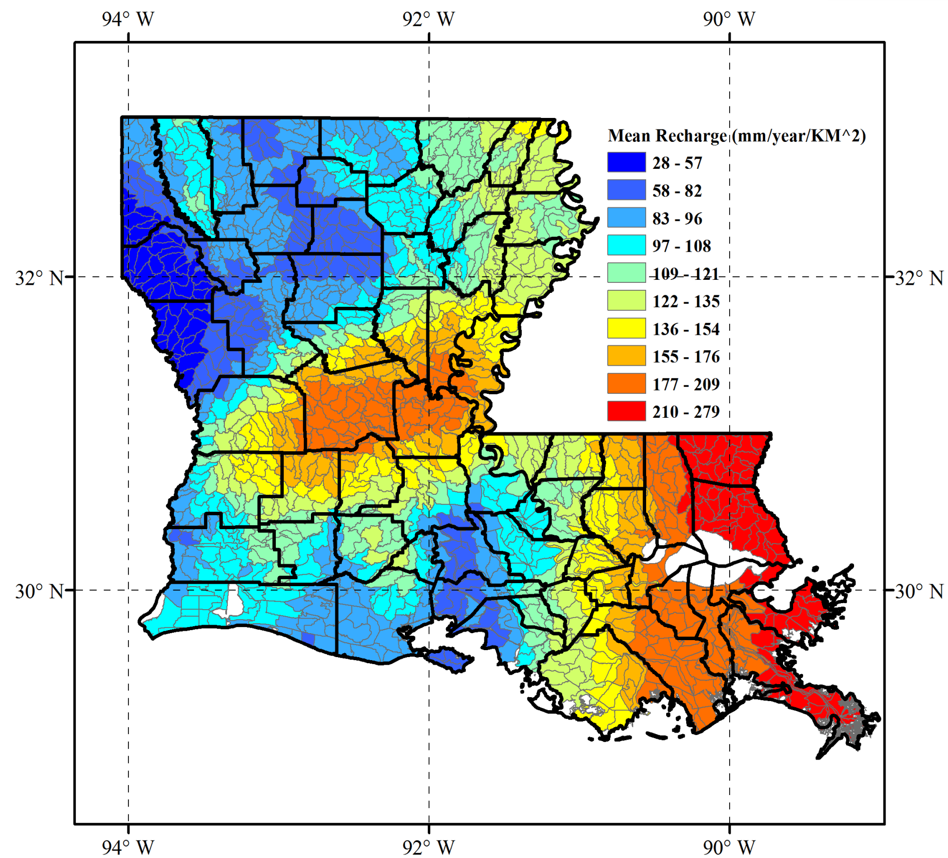
Water Availability Data

Surface Water



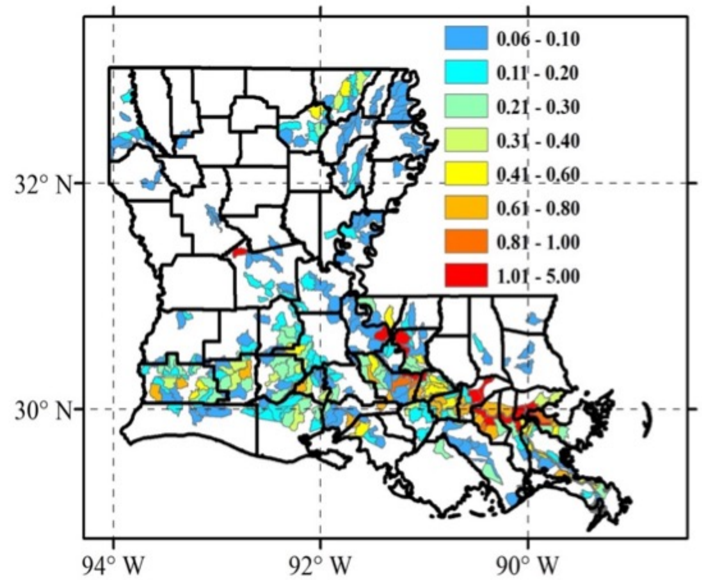
National Hydrography Dataset (NHDPlus), represents 25 year average (annual and monthly) climatological conditions of water availability.

Groundwater



USGS Groundwater recharge estimates mean annual recharge (mm/yr/km²)

Water stress in Louisiana



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

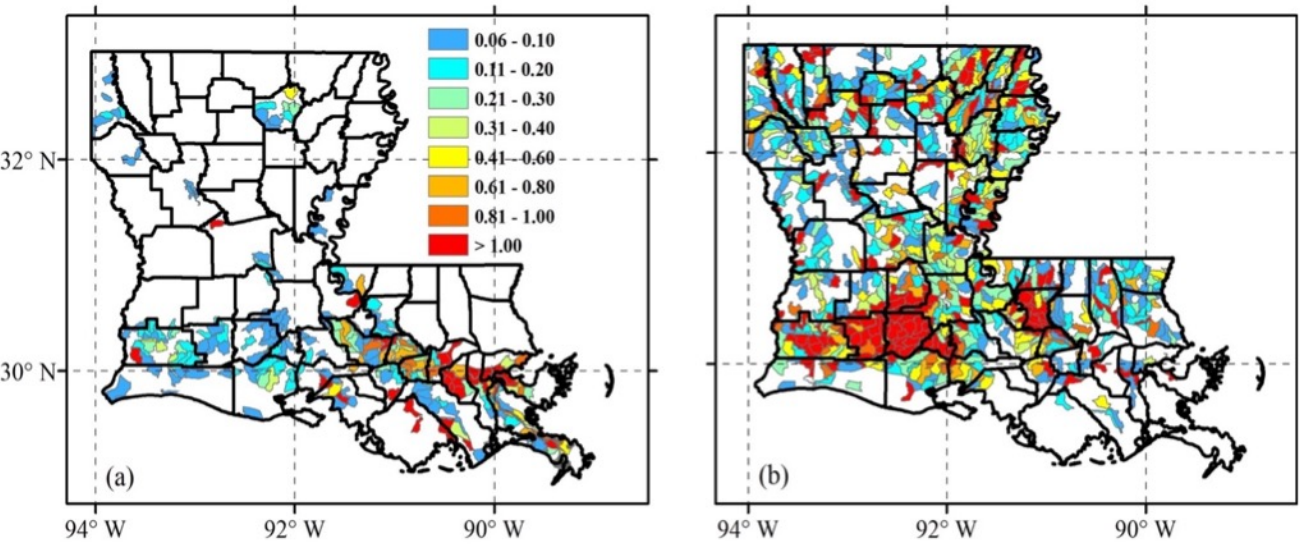
Water Supply Stress Index on the HUC12 scale using annual average estimates of water supply and demand and a 50% environmental flow requirement.

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

Water stress in Louisiana

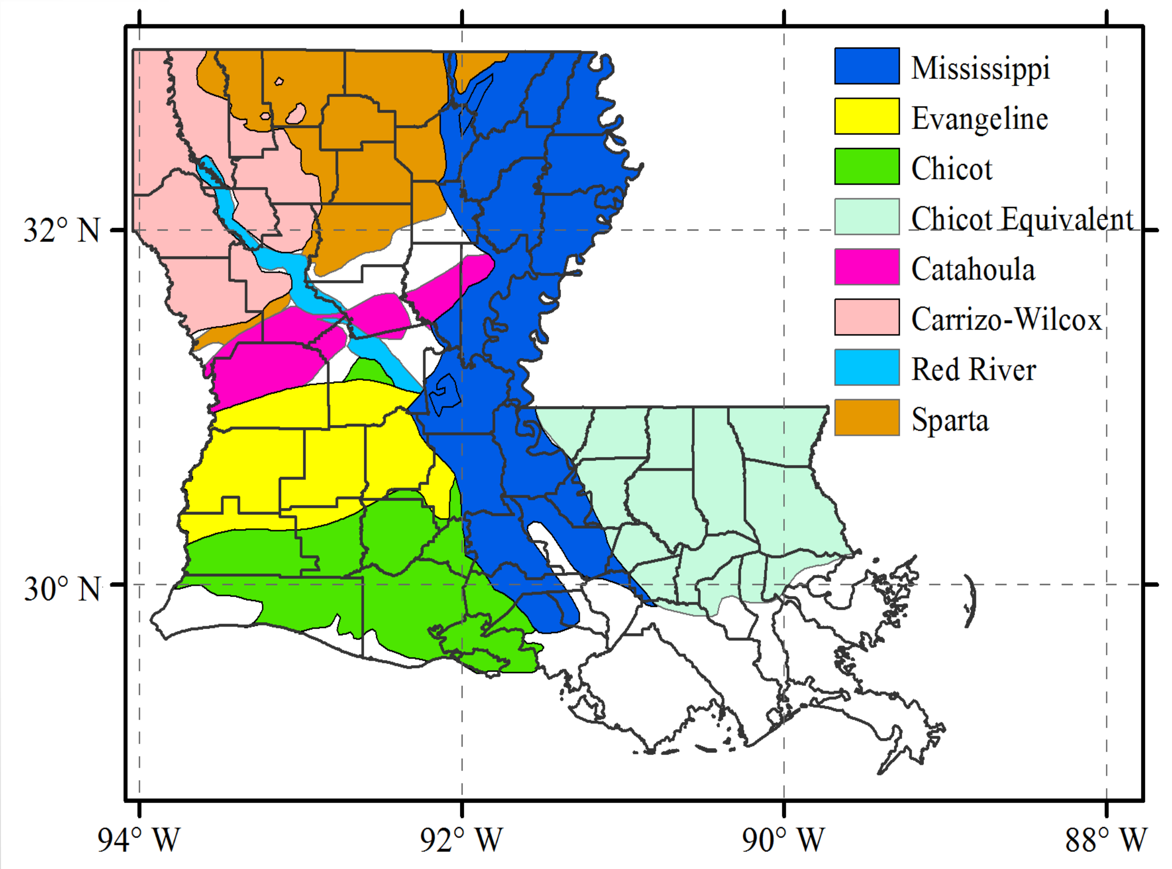
Annual Surface Water Stress

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



Aquifer	$WaSSI_{(GW)}$
Chicot	0.22
Mississippi R. Alluvial	0.21
Sparta	0.06
Carrizo-Wilcox	0.06
Catahoula	0.04
Red River	0.08
Chicot Equivalent	0.08

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

Seasonal variability in Water Demand by Irrigation

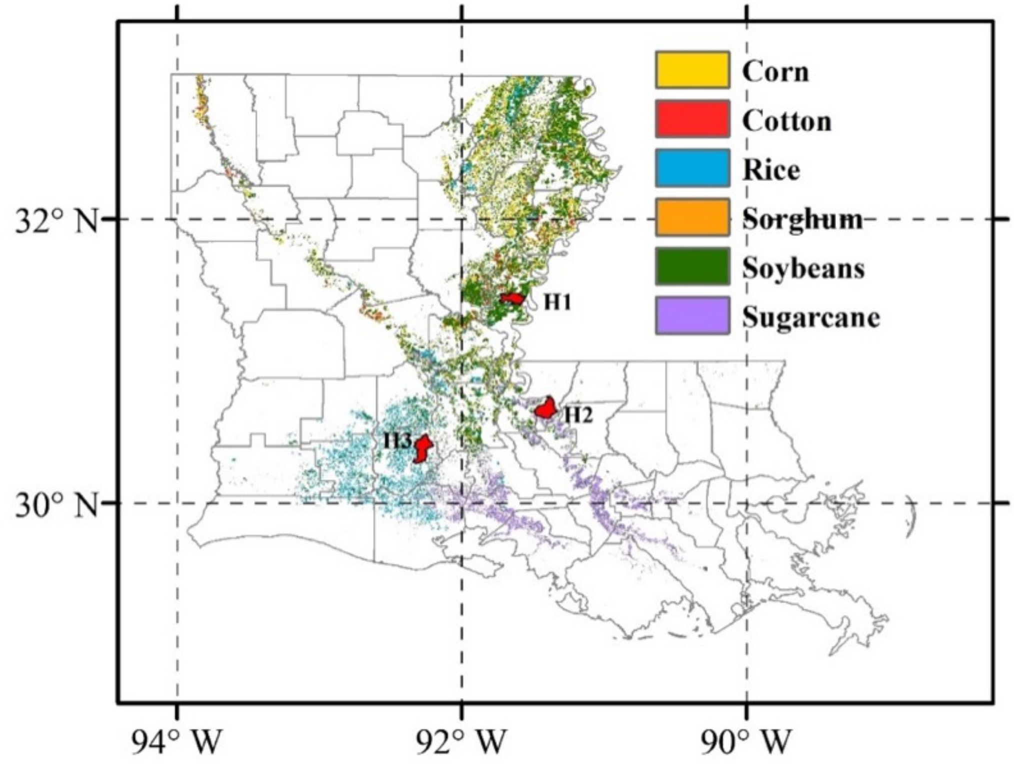


Figure 1: spatial distribution of six different types of crops in Louisiana at a spatial scale of 30x30 meters (Source: USDA/NASS).

Seasonal variability in Water Demand by Irrigation

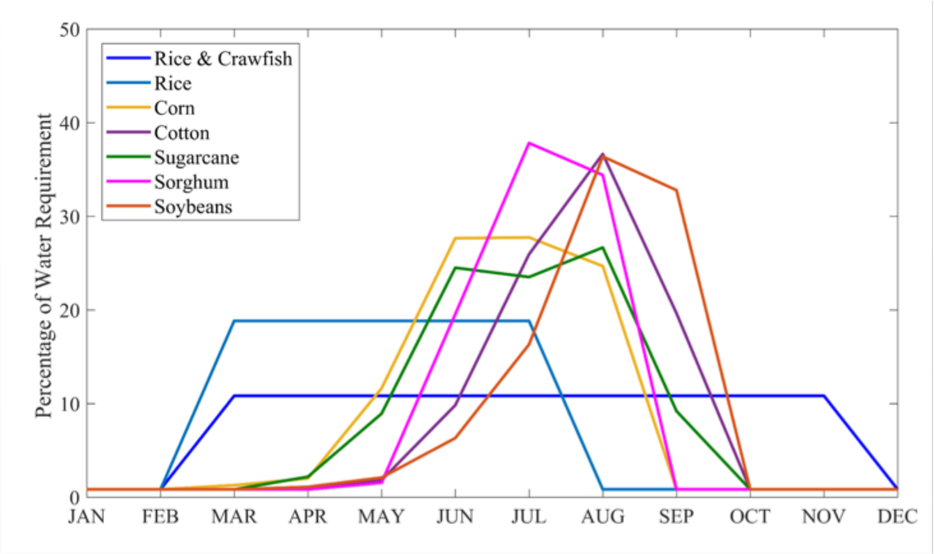
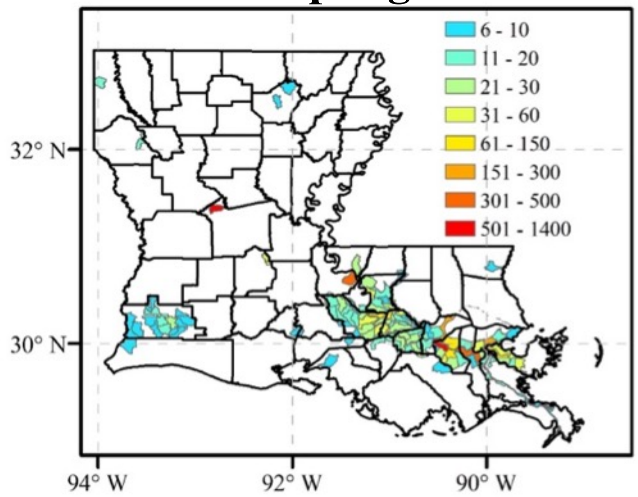


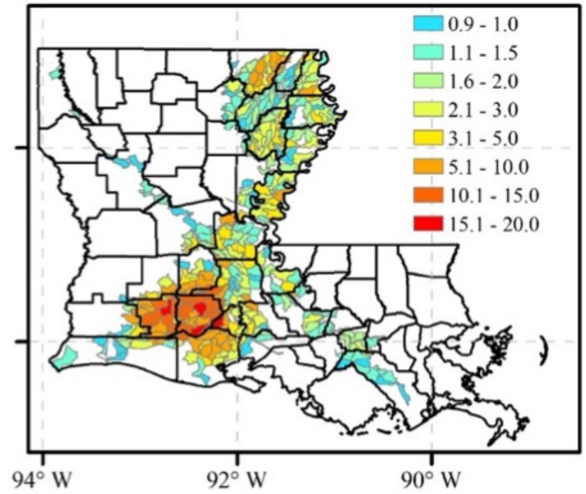
Figure 2: Monthly distribution (in percentage) of water requirements for irrigation of different crop types in Louisiana.

Water Use

Water withdrawal by all sectors, except agriculture



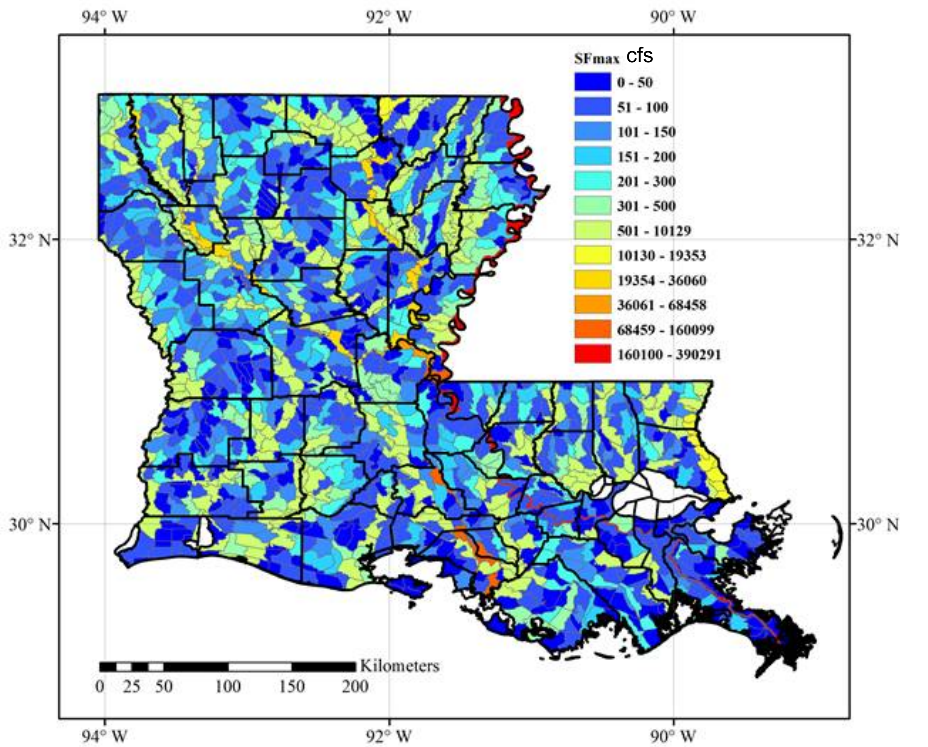
Water withdrawal by agricultural only



Mean Annual Total Water withdrawal at HUC12 scale

Variability in Surface Water Availability

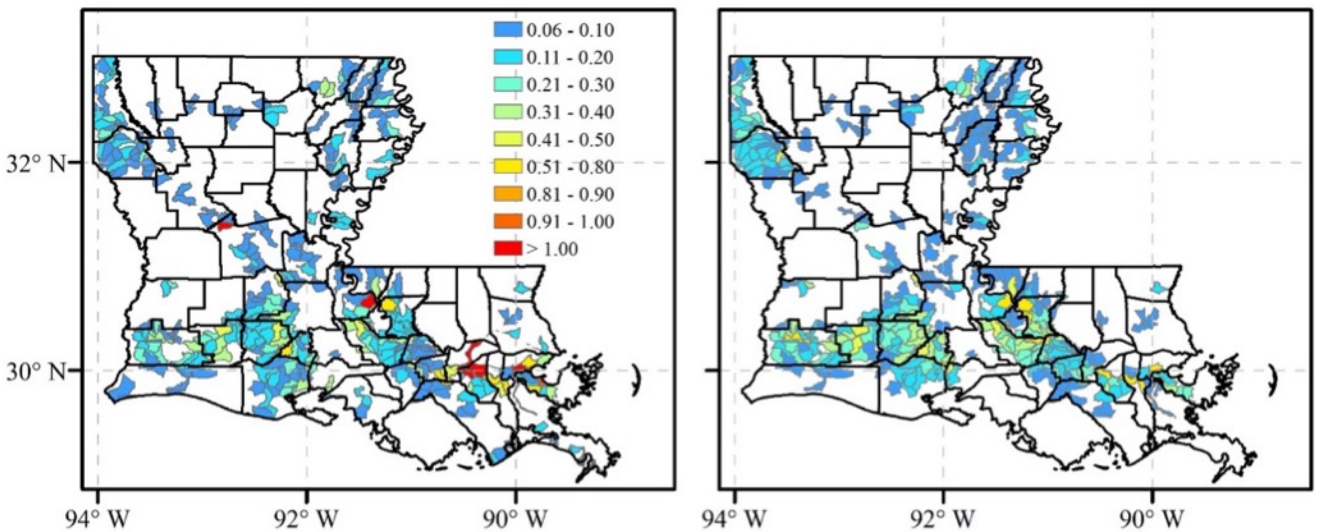
- North American Land Data Assimilation System (NLDAS)
- Temporal Scale: Hourly (1979-realtime)
- Spatial Scale: 12 X 12 km



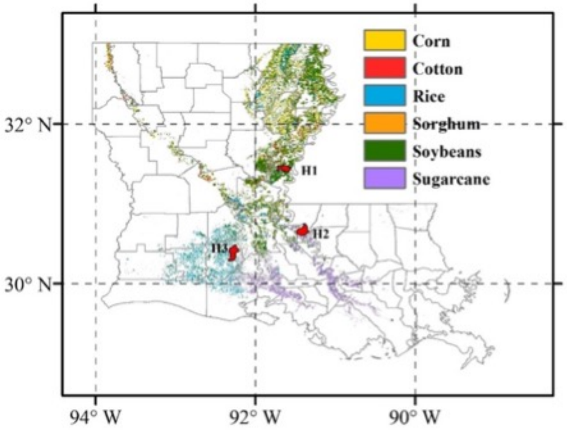
Mean annual streamflow (cfs)

Inter-annual variability in Water Stress

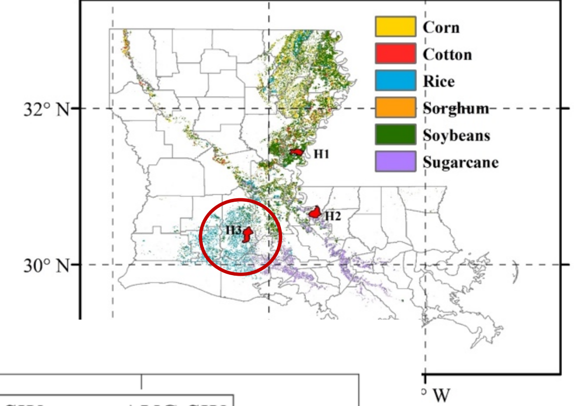
Median annual WaSSI | **(97.5%-2.5%) WaSSI percentile**

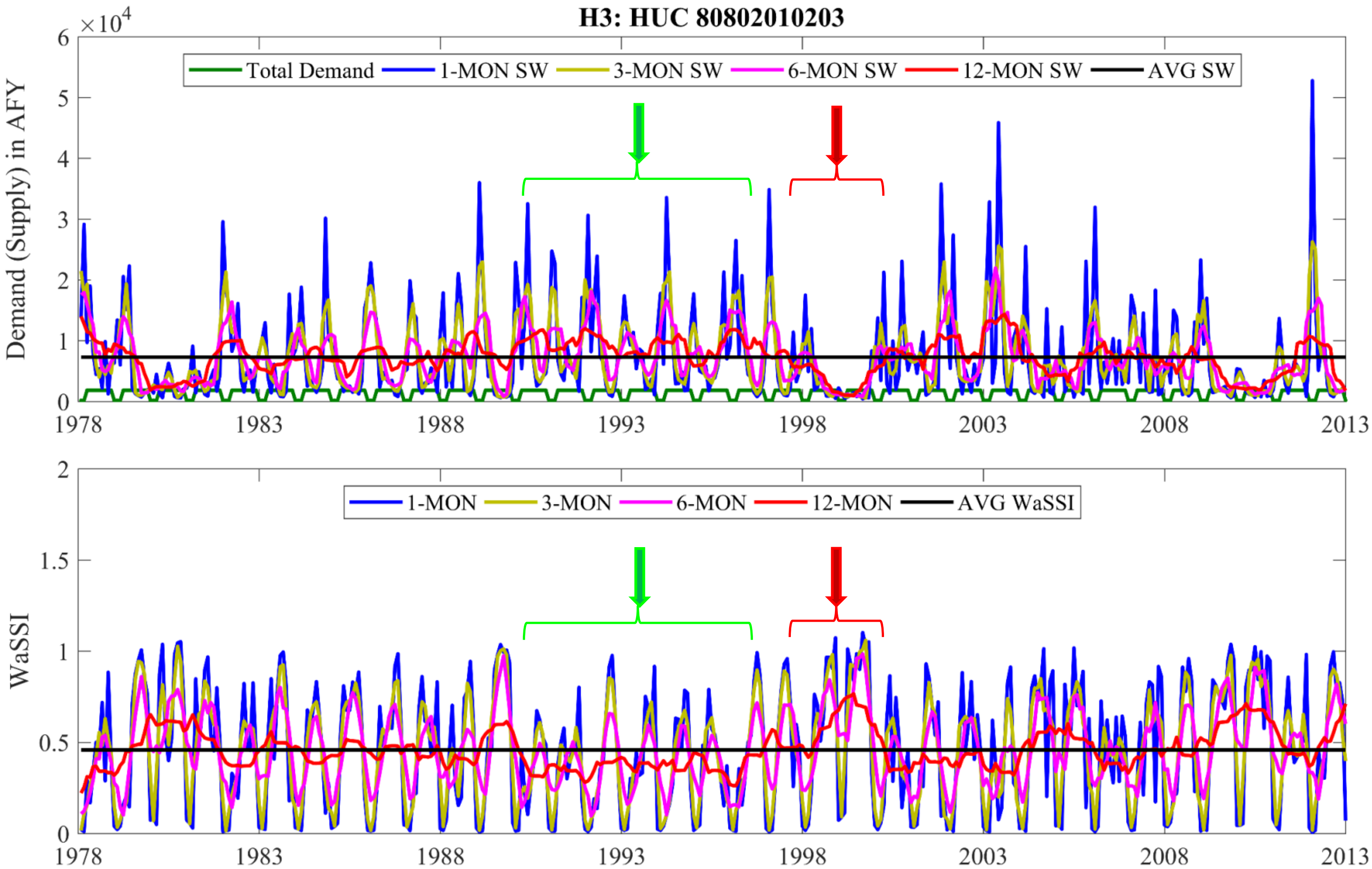


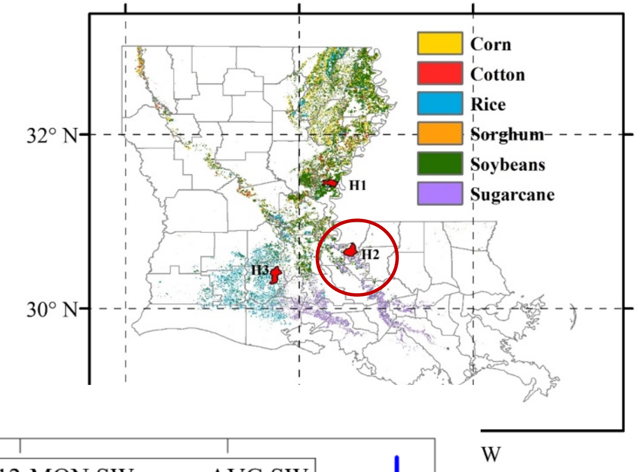
Results from Example HUCs

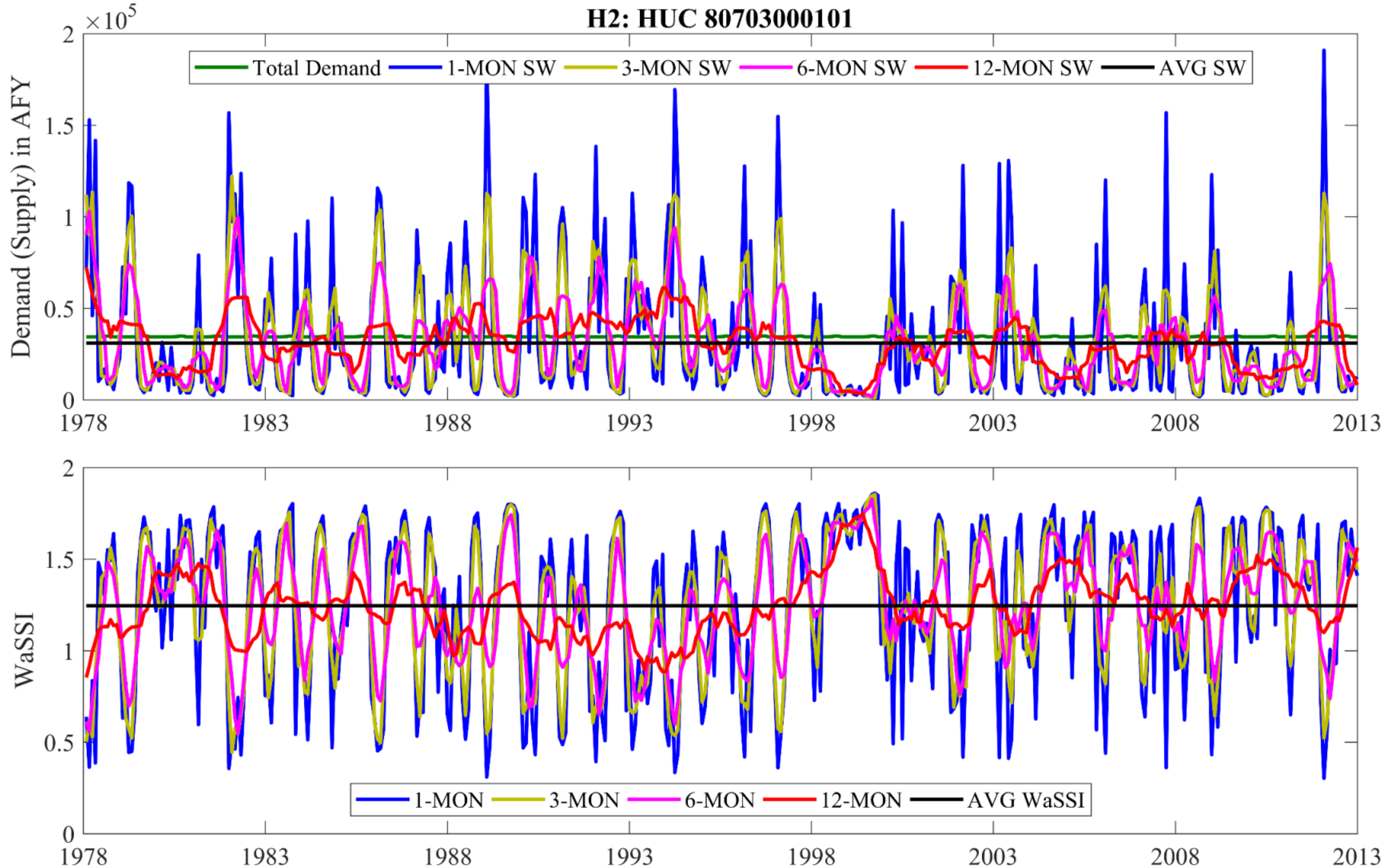


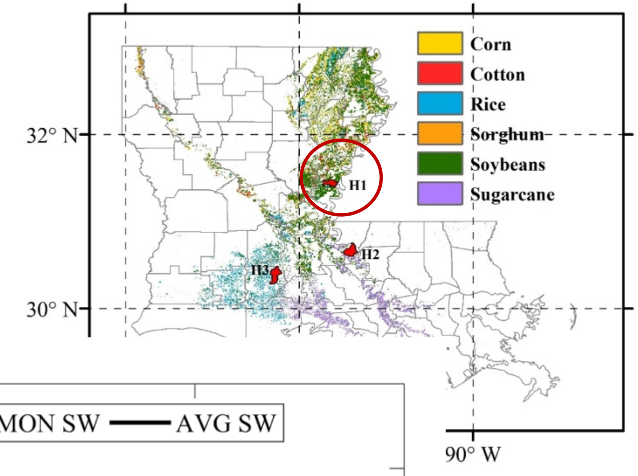
HUC12	SW Supply	GW Supply	Agriculture	Industrial	Power Generation	Public Supply	Dominated Crop
H1: 80403060201	376667	12597	3512	0	0	156	Soybeans
H2: 80703000101	42691	12433	1370	324	411116	853	Soybeans
H3: 80802010203	112303	14875	16681	101	0	261	Rice

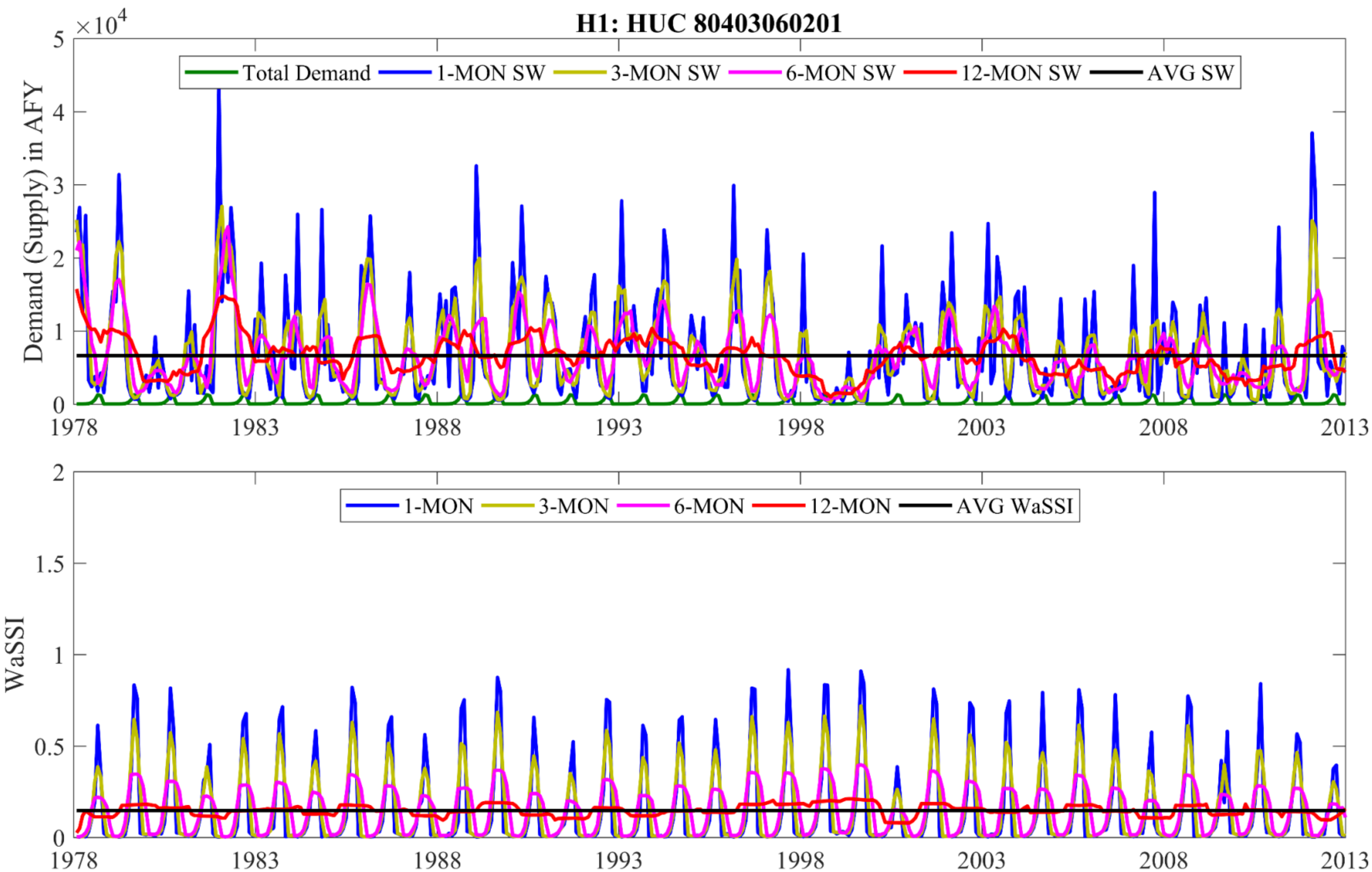

Corn
Cotton
Rice
Sorghum
Soybeans
Sugarcane
32° N
30° N
H1
H2
H3
° W


H3: HUC 80802010203
×10^4
Demand (Supply) in AFY
Total Demand
1-MON SW
3-MON SW
6-MON SW
12-MON SW
AVG SW
0
1
2
3
4
5
6
1978
1983
1988
1993
1998
2003
2008
2013
WaSSI
1-MON
3-MON
6-MON
12-MON
AVG WaSSI
0
0.5
1
1.5
2
1978
1983
1988
1993
1998
2003
2008
2013


Corn
Cotton
Rice
Sorghum
Soybeans
Sugarcane
32° N
30° N
H1
H2
H3
W


H2: HUC 80703000101
×10^5
Demand (Supply) in AFY
Total Demand
1-MON SW
3-MON SW
6-MON SW
12-MON SW
AVG SW
0
0.5
1
1.5
2
1978
1983
1988
1993
1998
2003
2008
2013
WaSSI
1-MON
3-MON
6-MON
12-MON
AVG WaSSI


Corn
Cotton
Rice
Sorghum
Soybeans
Sugarcane
32° N
30° N
90° W
H1
H2
H3


H1: HUC 80403060201
×10^4
Demand (Supply) in AFY
Total Demand
1-MON SW
3-MON SW
6-MON SW
12-MON SW
AVG SW
WaSSI
1-MON
3-MON
6-MON
12-MON
AVG WaSSI
1978
1983
1988
1993
1998
2003
2008
2013

Summary & Key Insights

Disaggregation into a HUC12 scale captures a greater level of spatial heterogeneity as compared to parish or county scale.

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

- Examination of stress under different climate scenarios.
- Examination of stress under different water demand scenarios (e.g., changing agriculture/irrigation patterns, the addition of power plants/industry, etc.)

Summary & Key Insights

- We need to identify opportunities for reallocation of surface water use to reduce groundwater over pumping and improve water sustainability.
- The abundance of surface water on an average annual basis is sufficient to offset groundwater demand.
- However, there is substantial seasonal and inter-annual variability in water stress that is hidden by annual averages.

Implications for management

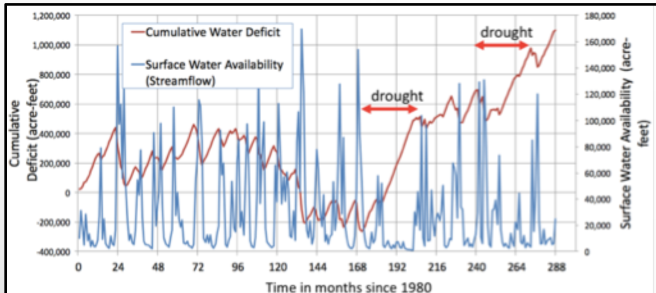
1. Results suggest that there is a strong probability of surface water not being available in a given year/season. Hence, "reliability" is a primary factor why farmers choose groundwater over surface water.

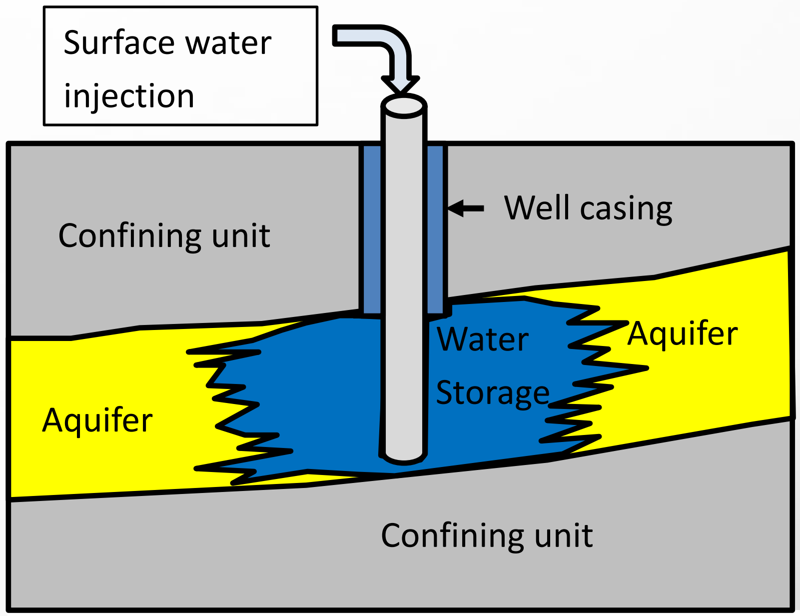
2. There is practically no investment in water storage infrastructure for dealing with the "reliability" problems for surface water on a local or larger scale.

Future Work: Integrated solutions

<u>Developing storage capacity</u>

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





Conceptual illustration of an ASR well recharging a confined aquifer. The stored water forms a "bubble" displacing the resident water. The same well or a nearby well can retrieve the stored water.

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