Impact of Climate Variability on Water Stress in Louisiana: Opportunities and Implications for Sustainable 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.
SW vs. GW use in the Chicot aquifer region in SW LA

- 23,000 km²
- 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

70% Agriculture + Aquaculture

19.5% Municipal
10.5% Industrial
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.
Approach for Water Stress Analysis

Water Budget

Water Supply
- SW
  - NHDPlus-2
  - NLDAS-2
- GW
  - Recharge Rate

Water Withdrawal
- SW
  - Irrigation
  - Industrial
  - Power Generation
  - Public Supply
- GW
  - Irrigation
  - Industrial
  - Livestock
  - Public Supply
  - Rural Domestic

Water supply stress index

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

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

Spatial Data Sources

- *Groundwater Wells*: LA Dept. of Natural Resources: Well Registration Database
- *County Boundaries*: US Census Bureau: Tiger/Line Shapefile
- *HUC Boundaries*: US EPA/USGS: Watershed Boundary Dataset
- *Agricultural Land Use*: USDA: Cropland Data Layer
- *Land Cover*: USGS: National Land Cover Dataset

Tabular Data Sources

- USGS: Water use in Louisiana Reports; Parish scale
- US Census Bureau: Population estimates by census block
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
Surface water use for Industry on a Parish Scale

Surface water use for Industry on a HUC12 watershed scale

Water demand examples
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

<table>
<thead>
<tr>
<th>Use_Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aquaculture</td>
</tr>
<tr>
<td>Irrigation</td>
</tr>
<tr>
<td>Livestock</td>
</tr>
<tr>
<td>Industrial</td>
</tr>
<tr>
<td>Power_generation</td>
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<tr>
<td>Public_Supply</td>
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<tr>
<td>Rural_Domestic</td>
</tr>
<tr>
<td>No_Use</td>
</tr>
<tr>
<td>unknown</td>
</tr>
</tbody>
</table>
GW Disaggregation

Disaggregation of GW Withdrawals based on casing diameter of wells.
Water Availability Data

**Surface Water**

The 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 supply stress index (WaSSI) on the HUC12 scale using annual average estimates of water supply and demand and a 50% environmental flow requirement.

\[
WaSSI = \frac{WW_{SW} + WW_{GW}}{(1-ENV) \times WS_{SW} + WS_{GW}}
\]

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

Water stress in Louisiana
Water stress in Louisiana

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.
Water & Climate Sustainability

Accounting for Inter-Annual and Seasonal Variability on Water Stress

- Inter-annual variability in water availability
- Intra-annual variability in water availability
- Seasonal variability in water demands
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
Inter-annual variability in Water Stress

Median annual WaSSI

(97.5%-2.5%) WaSSI percentile
Annual WaSSI for all the HUC12 units in Louisiana.
Seasonal variability in WaSSI

Median Monthly WaSSI estimated over the period 1979-2013
Seasonal variability in WaSSI

[97.5% - 2.5%] Monthly WaSSI percentile during the period 1979-2013.
Seasonal variability in WaSSI

Monthly WaSSI for all the HUC12 units in Louisiana.
Results from Example HUCs

<table>
<thead>
<tr>
<th>HUC12</th>
<th>SW Supply</th>
<th>GW Supply</th>
<th>Agriculture</th>
<th>Industrial</th>
<th>Power Generation</th>
<th>Public Supply</th>
<th>Dominated Crop</th>
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<tbody>
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<td>16681</td>
<td>101</td>
<td>0</td>
<td>261</td>
<td>Rice</td>
</tr>
</tbody>
</table>
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
• Probability analysis to determine likelihood of significant water stress in any given year.
• 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 uncertainty in water stress that is hidden by annual averages.
Future Work
One of our next steps is exploring ideas for integrated water management solutions

Managed aquifer recharge (MAR)
Can we identify locations where we 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.
Our next project: Integrated 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?

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.
More information available in these publications

Environmental Research Letters

LETTER

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

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A Framework for Incorporating the Impact of Water Quality on Water Supply Stress: An Example from Louisiana, USA\textsuperscript{†}

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