WATER CHEMISTRY OF THE GULF COAST AQUIFER

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Penn State University, MGIS Graduate Studies Peer-Review Report Presentation
Texas Water Development Board

GROUNDWATER DATA VIEWER

- Database of **private and public groundwater wells** across the entire state

- Water quality and water level monitoring data dating back to early 1900s

- **3,000 groundwater wells** in the Gulf Coast Aquifer
STUDY OBJECTIVES

- Evaluate the full suite of chemical compounds (all 33) against land use and climate data for the Gulf Coast Aquifer.

- Total Dissolved Solids (TDS) used a dependent variable (the variable that’s being predicted).

- TDS has been used as an indicator of groundwater contamination in previous studies.

- Fluoride
  - Natural and anthropogenic sources (coal burning, oil refining, fertilizer plants)
  - Beneficial and harmful impacts above MCL
  - Texas known as a state to have high fluoride concentrations
LAND USE IMPACTS ON GROUNDWATER

• ↑ land development ↓ supply of groundwater

• Impervious surfaces (roads, driveways, roofs) replace forests and wetlands, rainfall/precipitation no longer replenishes aquifers

• Texas has been in a drought for awhile and already has depleted groundwater resources
CLIMATE INFLUENCE ON GROUNDWATER

- Less precipitation and less recharge back into the groundwater

- Increased pumping due to less surface water resources

- Decreased soil moisture, increased runoff, and decreased soil infiltration
Question: What primary or secondary drivers are affecting groundwater quality and thus groundwater contamination?

- Independent variable – **Total Dissolved Solids (TDS)**
- Dependent variables:
  - **Land use** (primary)
  - **Climate** (secondary)
  - **Other chemical compounds**
LAND USE MODEL VARIABLES

- Land Cover
- Soil Moisture
- Drought Severity
- Streamflow
- Groundwater Recharge
- Precipitation
- Groundwater Quality

**Land Cover**
- Forest
- Agriculture
- Urban

**Soil Moisture**
- Moisture
- Drought Severity
- Streamflow
- Groundwater Recharge
- Precipitation
- Groundwater Quality

**Drought Severity**
- Forest
- Agriculture
- Urban

**Streamflow**
- Forest
- Agriculture
- Urban

**Groundwater Recharge**
- Forest
- Agriculture
- Urban

**Precipitation**
- Forest
- Agriculture
- Urban

**Groundwater Quality**
- Forest
- Agriculture
- Urban

**LAND USE MODEL VARIABLES**
- Forest: Land Cover
- Agriculture: Land Cover
- Urban: Land Cover

**GIS-Pro Columbus**
#GISPro2023
Over 33 chemical compounds analyzed, including:

- Antimony
- Arsenic
- Barium
- Beryllium
- Boron
- Bromide
- Cadmium
- Chromium
- Fluoride
- Lithium
- Mercury
- Nitrate
- Nitrite
- Selenium
- Thallium
GLOBAL & LOCAL REGRESSION MODELS

Global Models
- Exploratory Regression
- Ordinary Least Squares (OLS)
- Spatial Autocorrelation (Global Moran’s I)

Local Model
- Multiscale Geographically Weighted Regression (MGWR)

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Local models allow you to visualize your data in a geographic framework.
## CLIMATE MODEL
### EXPLORATORY REGRESSION

<table>
<thead>
<tr>
<th>Adjusted R-Squared</th>
<th>K(BP) ¹</th>
<th>Passing Models ²</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.81</td>
<td>0.04</td>
<td>+fluoride*** -streamflow***</td>
</tr>
<tr>
<td>0.82</td>
<td>0.04</td>
<td>+fluoride*** -recharge*** -streamflow***</td>
</tr>
<tr>
<td>0.91</td>
<td>0.01</td>
<td>+barium*** +boron*** +thallium** +streamflow**</td>
</tr>
<tr>
<td>0.92</td>
<td>0.02</td>
<td>+barium*** +boron*** +cadmium*** -soil moisture** +streamflow*** +PDSI**</td>
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<tr>
<td>0.91</td>
<td>0.02</td>
<td>+barium*** +boron*** +phosphorus** +thallium** +streamflow**</td>
</tr>
</tbody>
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¹Koenker (BP) Statistic p-value; ²Model Variable significance (* = 0.10; ** = 0.05; *** = 0.01).
# LAND USE MODEL
## EXPLORATORY REGRESSION

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<tr>
<td>0.80</td>
<td>0.03</td>
<td>+fluoride*** -forest**</td>
</tr>
<tr>
<td>0.95</td>
<td>0.02</td>
<td>+boron*** +bromide*** -nitrate*** +agriculture***</td>
</tr>
<tr>
<td>0.86</td>
<td>0.01</td>
<td>-barium** +cadmium*** +fluoride*** -forest***</td>
</tr>
<tr>
<td>0.93</td>
<td>0.04</td>
<td>+barium** + boron *** +cadmium** -nitrite*** -fluoride***</td>
</tr>
<tr>
<td>0.93</td>
<td>0.04</td>
<td>+ boron *** +cadmium** -chromium** +fluoride*** -forest***</td>
</tr>
<tr>
<td>0.87</td>
<td>0.01</td>
<td>-barium** +fluoride*** +thallium** +agriculture** -forest** -urban**</td>
</tr>
</tbody>
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VARIABLES

- Land Cover
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- Streamflow
- Groundwater Recharge
- Precipitation
- Groundwater Quality

Exploratory Regression Model

Passing models then run through OLS to check for:
- redundancy
- completeness
- significance
- bias
- performance

Passing Climate Model:
+fluoride, -streamflow

mGWR

Passing Land Use Model:
+fluoride, -forest
LAND USE MODEL – MGWR RESULTS
TDS, +FLUORIDE, -FOREST

**Question:** What primary drivers are impacting groundwater quality?

**mGWR:**
- TDS and fluoride are highly correlated (high $r^2$) in the south-west counties
- There is a lack of forest in these counties, both due to the natural landscape of TX and due to increased development and agricultural practices
- Forest and other herbaceous land covers (i.e., wetlands) filter contaminants before they reach the aquifers
**CLIMATE MODEL – MGWR RESULTS**

**TDS, +FLUORIDE, -STREAMFLOW**

**Question**: What secondary drivers are impacting groundwater quality?

- Indicative of **overall climate change** that is occurring

- Less precipitation, less streamflow, **less dilution** of contaminants in groundwater

- Intensification of the water cycle which is propagating a drought = **less infiltration** of surface water into the aquifers
THANK YOU!

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