Reservoir Operations Impacts on Socioeconomic Drought in Regulated Basins

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Meteorological Drought: Deficit in precipitation

Agricultural Drought: Deficit in soil moisture

Hydrologic Drought: Deficit in runoff/groundwater/storage

Snow Drought: Abnormally low snow for the time of the year

Socio-Economic Drought: Imbalance between supplies and human water demand leading to socioeconomic impacts.

Anthropogenic Drought: Water stress caused or intensified by human activities, (e.g., increased demand, mismanagement, climate change from anthropogenic greenhouse gas emissions, growing energy and food production, environmental policy, and land use change)

A hybrid framework for water stress assessment: linking climate variability and local resilience and human influence
(Mehran et al., 2015, JGR)
A hybrid framework for water stress assessment: linking climate variability and local resilience and human influence

- Total inflow in the last $m$ months
- Total projected water demand during $m$ months
- Monthly water storage

- Inflow-Demand Reliability Indicator
- Water Storage Resilience Indicator

- Inflow-Demand Reliability Index
- Water Storage Resilience Index

- Multivariate Standardized Reliability and Resilience Index (MSRRI)

Mehran et al., JGR, 2015
Inflow-Demand Reliability Indicator

$$\alpha_t = \frac{\sum_{i=t-m+1}^{t} Q_{in} - Q_{\exp, t}}{Q_{\exp, t}}$$

where:

- \( Q_{in} \); monthly inflow in month \( i \)
- \( Q_{\exp, t} \); total expected water demand during the projected time frame
- \( St_i \); reservoir storage at month \( i \)

\( m = 6 \) for \( i = t-13+1 \)

\( m = 12 \) for \( i = t-12 \)

Water Storage Resilience Indicator

$$\beta_t = \frac{St_t + Q_{in, t} - Q_{out, t} - O_{\min} - Q_{\exp, t}}{Q_{\exp, t}}$$

Anthropogenic Drought Assessment:

A hybrid framework for water stress assessment: linking climate variability and local resilience and human influence

Mehran et al., JGR, 2015
• Within-year and over-year reservoir-demand analysis:

**IDR**

\[ a_t = \frac{\sum_{i=t-m+1}^{t} Q_{in_i} - Q_{est_t}}{Q_{est_t}}, \quad Q_{est_t} = \begin{cases} \sum_{i=t-12}^{t-13+m} (Q_{out_i}), & \text{if } m = 6 \\ \sum_{i=t-m+1}^{t} (Q_{out_i}), & \text{if } m = 12 \end{cases} \]

**WSR**

\[ \beta_t = \frac{S_t + Q_{in_t} - Q_{out_t} - O_{min} - Q_{est_t}}{Q_{est_t}} \]

• Empirical probability

\[ P(x_t) = \frac{1 - 0.44}{N + 0.12} \]

• Standardized index

\[ SI(P(x)) = \begin{cases} \text{if } 0 < P(x) \leq 0.5, & + \left( k - \frac{C_0 + C_1 k + C_2 k^2}{1 + d_1 k + d_2 k^2 + d_3 k^3} \right) \text{ and } k = \sqrt{\frac{\ln(1/P(x)^2)}{\ln[1/(1-P(x))^2]}} \\ \text{if } 0.5 < P(x) \leq 1, & - \left( k - \frac{C_0 + C_1 k + C_2 k^2}{1 + d_1 k + d_2 k^2 + d_3 k^3} \right) \text{ and } k = \sqrt{\frac{\ln(1/P(x)^2)}{\ln[1/(1-P(x))^2]}} \end{cases} \]

• Combine univariate indicators

\[ P_f = \Pr (SI(\alpha_t) \leq SI(\alpha_t), SI(\beta_t) \leq SI(\beta_t)) \quad \Rightarrow \quad P_f (SI(\alpha_t), SI(\beta_t)) = \frac{1 - 0.44}{N + 0.12} \]
Anthropogenic Drought Assessment:
A hybrid framework for water stress assessment: linking climate variability and local resilience and human influence

Mehran et al., JGR, 2015
• The ACF is a huge basin draining an area of 19,573 square miles across the states of Alabama, Georgia, and Florida.

• The ACF Basin is also home to nearly 6.8 million people. Water stress becomes much more prevalent in the ACF during times of drought; therefore, water management in this basin is important.
<table>
<thead>
<tr>
<th>Reservoirs</th>
<th>Storage Capacity (ac-ft)</th>
<th>Max Depth (m)</th>
<th>Surface Area (acres)</th>
<th>Drainage Area (mi^2)</th>
<th>FRM</th>
<th>WS</th>
<th>HPG</th>
<th>NAV</th>
<th>FW</th>
<th>REC</th>
<th>WQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lake Lanier</td>
<td>1,087,600</td>
<td>48</td>
<td>37,000</td>
<td>1034</td>
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<td>West Point</td>
<td>306,127</td>
<td>26</td>
<td>25,864</td>
<td>2406</td>
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<td>Walter F. George</td>
<td>244,400</td>
<td>30</td>
<td>45,181</td>
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<td>George Andrews</td>
<td>8,200</td>
<td>8</td>
<td>1,540</td>
<td>750</td>
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<td>Lake Seminole</td>
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<td>37,500</td>
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</tbody>
</table>

FRM = Flood Risk Management; WS = Water Supply; HPG = Hydroelectric Power Generation; NAV = Navigation; FW = Fish And Wildlife Conservation; REC = Recreation; WQ = Water Quality
Cumulative Annual Precipitation (CHIRPS) vs. SPI
SPI vs. PDSI
Multivariate Standardized Reliability and Resilience Index (MSRRI)
Federal, State Regulations vs. MSRI

USACE Reservoir Management Planning

“Revised” IOP “RIOP” replaced IOP/EDO 2008
Exceptional Drought Operations (“EDO”) 2007
Interim Operating Plan (“IOP”) 2006
IOP “Concept 5”

New Revisions to the RIOP 2012
2015 Draft Environmental Impact Statement (DEIS)

Georgia Water Management Planning Timeline

Flint River Drought Protection Act 2001
Metropolitan North Georgia Water Planning Act 2004
House Bill 579 - Agricultural Water Use (Metering) Program 2004
Georgia’s Comprehensive State-wide Water Planning Act 2006
Flint Basin Plan 2006
State Water Plan 2008
Regional Water Management Plans Adopted 2010
All permitted irrigation withdrawals require metering 2010
10 Regional Water Planning councils formed 2011
Regional Water Stewardship Act Passed 2011
Water Stewardship Act 2014
Water Management Plans Revised for Georgia’s State Water and Metro Water District 2017
MSRRI Vs. NDVI

**NDVI (MODIS) for non-regulated land**
MSRRI on Major Reservoirs
Questions?