An assessment of reservoir filling policies and downstream impacts under a changing climate:

Ethiopia’s Grand Renaissance Dam

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Outline

• The Nile Basin and The Grand Ethiopian Renaissance Dam
• Model Framework for Streamflow Simulation
  – Time-series Development
  – Filling Policy
  – Climate Change Scenarios
• Modeling Results and Analysis on Potential Downstream Impacts
• Future Work
The Grand Ethiopian Renaissance Dam (GERD)

- Reservoir capacity of 74 bcm, 6000 MW of power generation
- Construction period: 2011-2017 (expected)
- Benefits
  - A developing country with rapidly growing population
  - Provide electricity
  - Climate and hydrology variability
  - Flood/drought control
The Grand Ethiopian Renaissance Dam (GERD)

- Concerns from downstream countries, primarily Egypt
- Potential impacts of GERD, particularly during filling stage
- Climate variability and change add additional uncertainty
Model Framework

- Simulate streamflow at Lake Nasser from 2011 to 2060
- The GERD hydropower and reservoir model
- Climate change and variability
5 Filling Policies

- 3 policies consider fractions of total monthly streamflow entering the reservoir, impounding 5%, 10%, or 25%.
- 2 additional policies have retention rates contingent on the historical average streamflow (HASF) under a no climate change scenario
  - retain any quantity greater than the historical average streamflow or 90% of it (> 0.90*HASF)
Climate Change

GCM precipitation projections and PDF of percent change in 2060.

8 Scenarios:
- Temp.: GCMs consistently indicate an increase (+2.5 Celsius)
- Precip.: trends varying linearly from no precipitation change in 2011 to -20% ~ + 20% by year 2060;
Data & Time-series Development

Model input and output

- 50 years of **1951-2000 CRU data** to simulate streamflow from 2011 to 2060
- Bootstrapping 50-year time-series from historical data
- Streamflow outputs for each filling policy imposed with climate change scenarios
Modeling results under different filling policies

Time to Reach FSL

- FSL are never reached under 5% FP
- Large variation under >HASF FP
Modeling results under different filling policies

Percent reduction in SF at Lake Nasser

- One selected simulation
- Large Reduction under >HASF FP, but actual leaving flow close to HASF
- Defining the filling stage as 15 years (2017-2032)
Modeling results for percent change in streamflow

Median of Percent Change in SF at Lake Nasser

<table>
<thead>
<tr>
<th>filling policy</th>
<th>2017—2032</th>
<th>2017—2022</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Precipitation Trend, temp all +2.5 C</td>
<td></td>
</tr>
<tr>
<td>-20%</td>
<td>0</td>
<td>+20%</td>
</tr>
<tr>
<td>-20%</td>
<td>0</td>
<td>+20%</td>
</tr>
<tr>
<td>5%</td>
<td>-10.5%</td>
<td>-2.7%</td>
</tr>
<tr>
<td>25%</td>
<td>-15.2%</td>
<td>-7.0%</td>
</tr>
<tr>
<td>&gt;HASF</td>
<td>-12.2%</td>
<td>-6.2%</td>
</tr>
<tr>
<td>No Dam</td>
<td>-8.1%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

- Compare 25% and >HASF FP, similar over wet year for longer period
- Time required to fill the reservoir is different for each FP
- Percent reduction over a shorter period shows more variability across different filling policies.
Modeling results for percent change in streamflow

Percent Change in Annual Average Streamflow at Lake Nasser (2017-2032)

-20% Precip Trend

-10% Precip Trend

-5% Precip Trend

No Precip Trend

+5% Precip Trend

+10% Precip Trend

+15% Precip Trend

+20% Precip Trend

Filling Policy

- Median Streamflow at Lake Nasser by Filling Policy under No Precipitation Trend
GCM precipitation projections and PDF of percent change in 2060.
Modeling results for percent change in streamflow

Percent change of SF for weighted precipitation changes
Future Work

• Extending the model to demonstrate more specific downstream impacts
  
  – the effect of the filling policies on Lake Nasser operations
  – economic analysis from the perspectives of both Ethiopia and Egypt

• Additional basin development
  
  – Irrigation, dam construction
References


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