Adaptive Reservoir Operation under the Challenges of Transboundary Dams: Example from the Nile River Basin Using Satellite Remote Sensing

Hisham Eldardiry* and Faisal Hossain
Department of Civil and Environmental Engineering
University of Washington, Seattle
*Email: dardiry@uw.edu
Background & Motivation

- World’s longest river (6,650 km)
- 11 countries
- Home to more than 200 million people

Grand Ethiopian Renaissance Dam (GERD)
- currently under construction in Ethiopia
- Largest hydropower dam in Africa
- 74 km³ of reservoir storage

GRanD Database (Lehner et al., 2011) and Zarfl et al. (2015)
Background & Motivation

Food Security in NRB

Global Hunger Index, 2018

The Global Hunger Index (GHI) used to track hunger globally and nationally. The index score comprises of four key hunger indicators: prevalence of undernourishment in the total population; childhood wasting; childhood stunting; and child mortality. This calculation results in GHI scores on a 100-point scale where 0 is the best score (no hunger) and 100 the worst. A score >=50 is defined as ‘extremely alarming’, 35-50 as ‘alarming’, 20-35 as ‘serious’, 10-20 as ‘moderate’ and <10 as ‘low’.

- 34% of the population of the basin are undernourished
- Serious alarming (20-35%) in Nile Basin countries

Energy Security in NRB

Share of the population with access to electricity, 2016

Data represents electricity access at the household level, that is, people who have electricity in their homes. It comprises electricity sold commercially, both on-grid and off-grid. Countries considered as “developed” by the UN, and classified as high income are assumed to have an electrification rate of 100% from the first year the country entered the category.

- 620 million people in Africa without electricity.
Challenges in NRB

Data Availability/Sharing

Energy Demand

Food Demand

Population Growth

Transboundary Planned Dams

Climate Variability

Transboundary River

Recap the Challenges in NRB
Adaptive Reservoir Operation (ARO)

• Adapting reservoir operation to impacts from expected challenges.

Informing Decisions for ARO

• **Vision:** Building a satellite-based decision support system for advising reservoir operation in the Nile river basin

• Nile Basin Reservoir Advisory System or **NiBRAS**

NiBRAS means Light in Arabic

http://students.washington.edu/dardiry/nibras
Nile Basin Reservoir Advisory System (NiBRAS)

• NiBRAS integrates complex physical land surface and reservoir models in the back end with a front-end user interface to facilitate decision making.

Back-end
• Hydrological forcing (satellite remote sensing)
• Hydrological modeling (VIC model)
• Reservoir modeling (water balance approach)

Front-end
• Real-time monitoring of reservoir operation
• Spatial maps of basin hydrology
• Scenario assessment tool
NiBRAS Back-end

Hydrological Modeling (VIC)

- Spatially distributed grid cells
- Spatial Scale: 0.1° (~10 km)
- Temporal Scale: Daily
- Forcing: IMERG-NCDC-MODIS

NiBRAS Back-end

VIC Calibration at Khartoum Station

NiBRAS Back-end

Reservoir Modeling

• How is the HAD being operated?
• What is the water level in the HAD lake?
• How much water being released/stored every month?

Water Balance at HAD

\[ Q_{out} = Q_{in} - \Delta S - E \]

Area-Elevation Curve

Water Level in HAD Lake from radar altimetry
HAD Operation

Outflow = Inflow - Volume Change

**Inflow** = Blue Nile (VIC) + White Nile (Mon. average) + Atbara (Mon. average) - Losses (Energy Balance).

**Volume** = Altimeter water level change * Area (using Area-Elevation curve).

For five years (1998-2002) → $R^2 = 0.67$

For only 2002 → $R^2 = 0.94$

**Sources of Uncertainties:**
- **VIC Simulations**
- **Altimetry water levels**
NiBRAS Back-end

GERD Filling/Operation

- Hydropower capacity = 6,450 MW
- Impounding capacity = 74 km³
- Median Flow = 47.5 km³/year

VIC Simulations at Eldiem Station

![Diagram of NiBRAS and GERD](image)
NiBRAS Front-end

Open-source web portal development

NiBRAS Front-end

Tools

• Real-time monitoring.
• Scenario Assessment Tool (SAT) [In Progress]
• Forecast-based Adaptive Reservoir Operation (FARO) [In Progress]
• Monitoring Reservoir Initial Impoundment (MRI2) [In Progress]
NiBRAS Front-end

Tools

• Real-time monitoring for HAD Operation (Inflow)
NiBRAS Front-end

Tools

• Real-time monitoring for HAD Operation (Storage Change)
NiBRAS Front-end

Tools

• Hydrology of Blue Nile Basin (Precipitation)
NiBRAS Front-end

Tools

- Hydrology of Blue Nile Basin (Evaporation)
NiBRAS Front-end

Tools (In Progress)

• Monitoring Reservoir Initial Impoundment (MRI₂)
NiBRAS Front-end

Tools (In Progress)

• Monitoring Reservoir Initial Impoundment (MRI₂)
Scaling Up to Global Applications

- South Asian Operational Systems
- Learn more about SASWE Research group operational systems
  
  (http://depts.washington.edu/saswe/)
Scaling Up to Global Applications

• Reservoir Assessment Tool (RAT)
• Africa, South East Asia, and South America

Scaling Up to Global Applications

- Owen Falls (Lake Victoria)
Thank You!

If interested
3-day workshop on using satellite remote sensing in the Nile River Basin

http://staff.washington.edu/dardiry/SR2020/
Email: dardiry@uw.edu