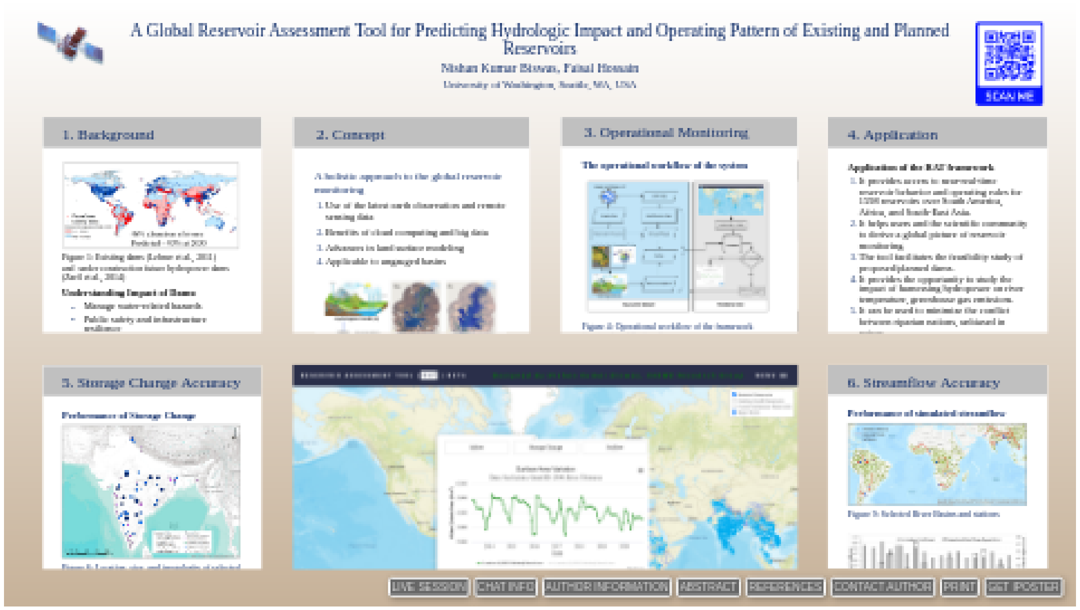
A Global Reservoir Assessment Tool for Predicting Hydrologic Impact and Operating Pattern of Existing and Planned Reservoirs



Nishan Kumar Biswas, Faisal Hossain

University of Washington, Seattle, WA, USA

SCAN ME

PRESENTED AT:

1. BACKGROUND

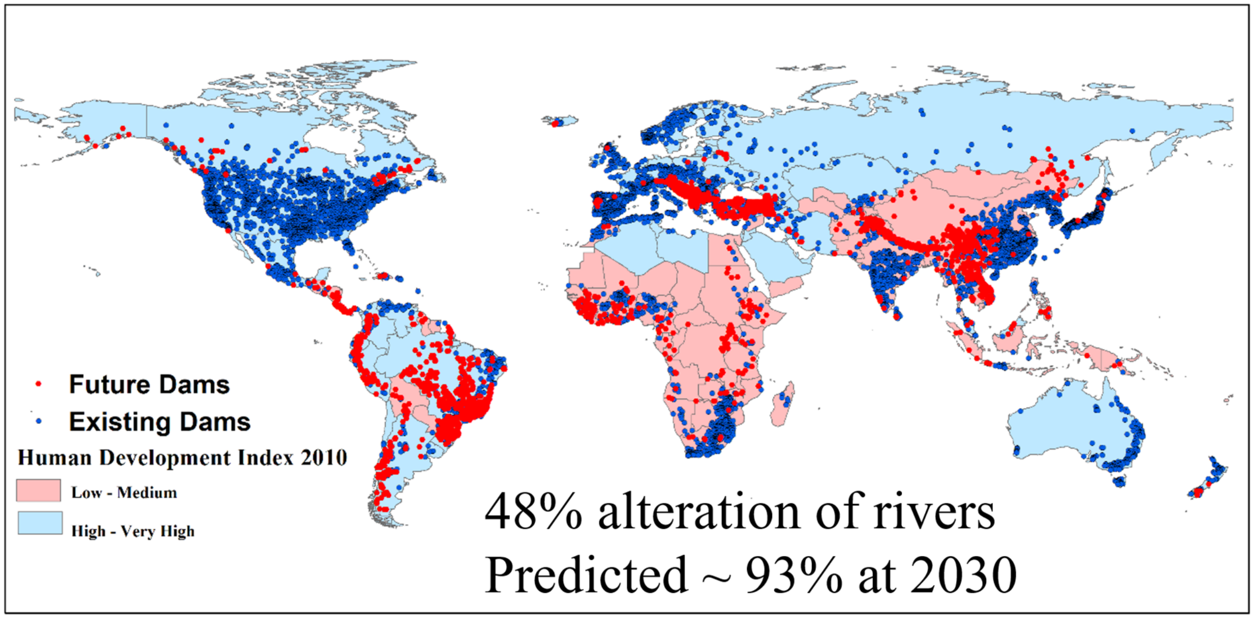


Figure 1: Existing dams (Lehner et al., 2011) and under construction future hydropower dams (Zarfl et al., 2014)

Understanding Impact of Dams:

- Manage water-related hazards
- Public safety and infrastructure resilience
- Effects of human alterations on land and hydrology
- Effect on downstream river discharge
- Revising operating pattern

Limitations of Current Reservoir Monitoring:

- Absence of direct measurements
- Simplistic representation of reservoirs
- Untested for operational monitoring and policy analysis

Mass balance approach of reservoirs

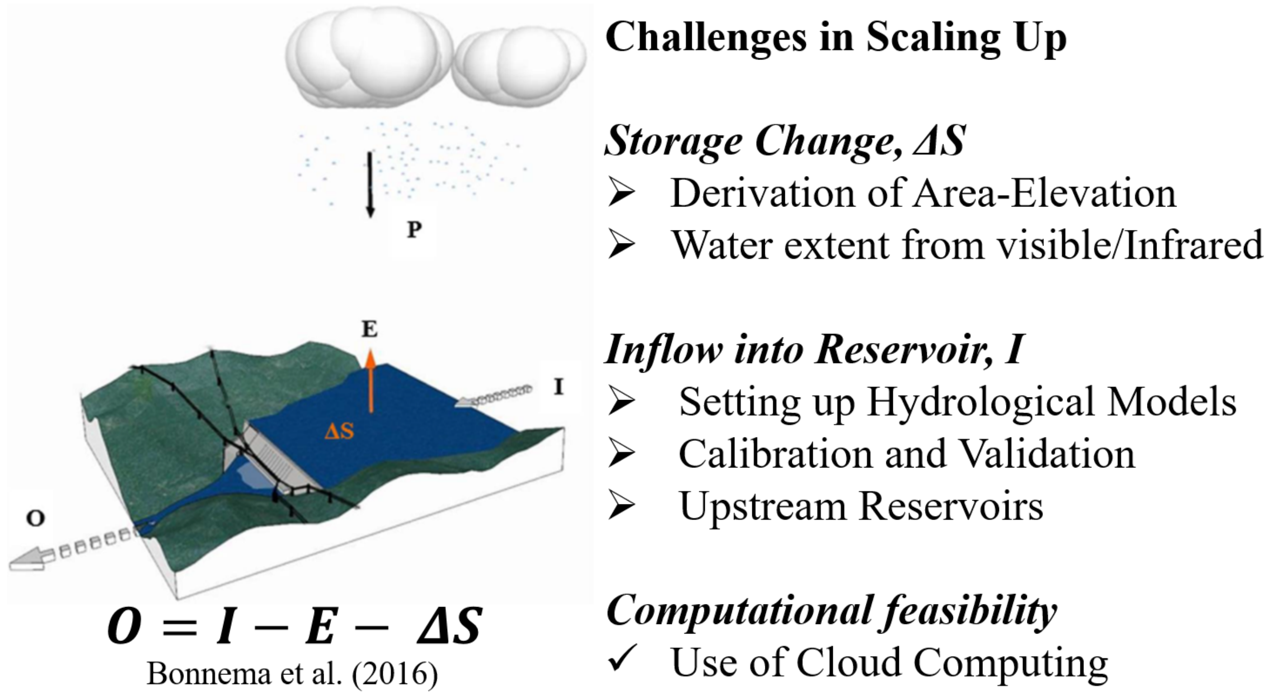


Figure 2: The latest available study (Bonnema et al., 2016) on reservoir mass balance

2. CONCEPT

A holistic approach to the global reservoir monitoring

1. Use of the latest earth observation and remote sensing data
2. Benefits of cloud computing and big data
3. Advances in land surface modeling
4. Applicable to ungauged basins

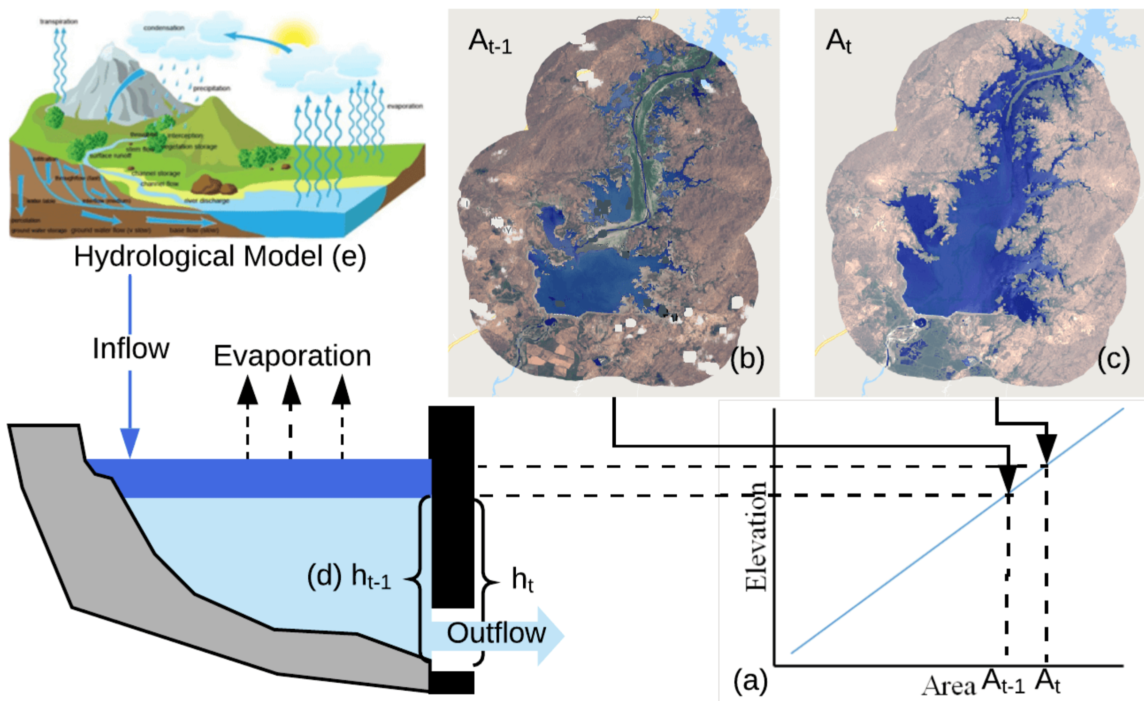


Figure 3: The basic concept of satellite data based reservoir mass balance

3. OPERATIONAL MONITORING

The operational workflow of the system

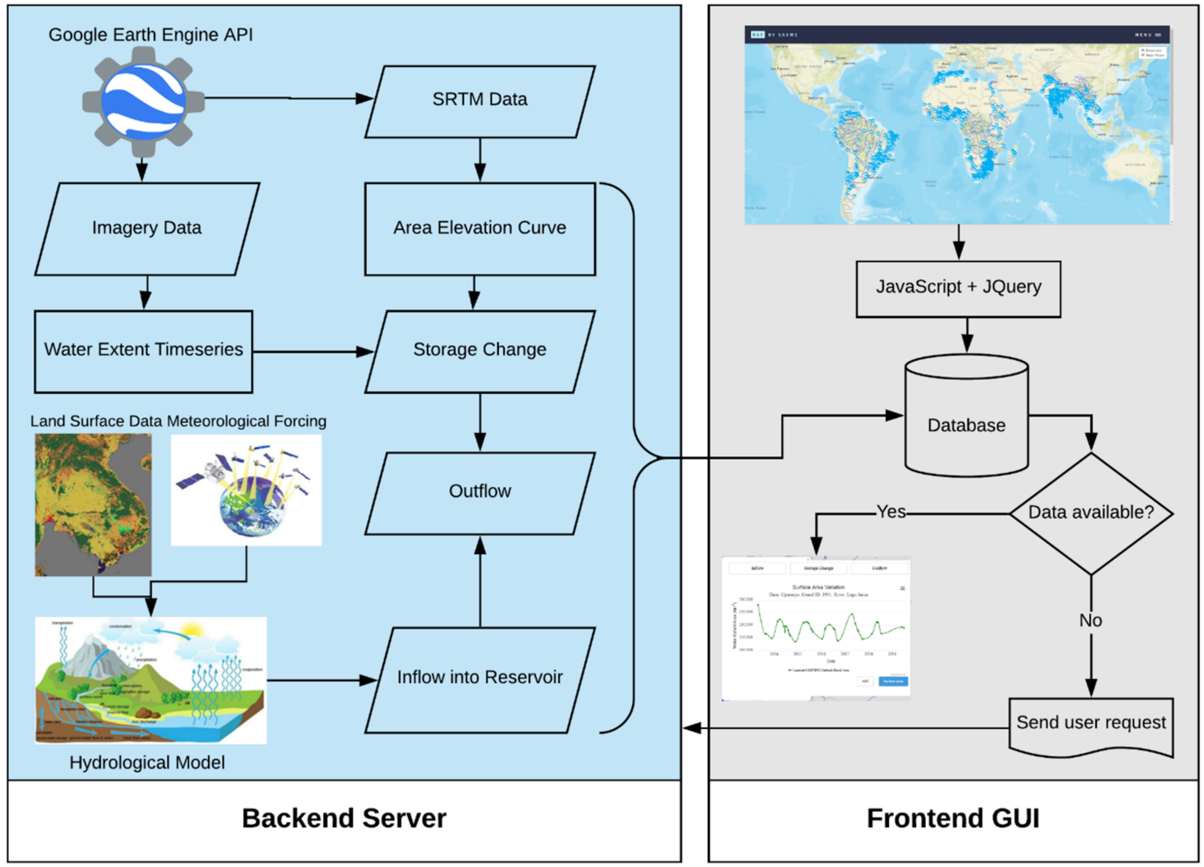


Figure 4: Operational workflow of the framework (frontend and Backend)

User request to add new reservoirs

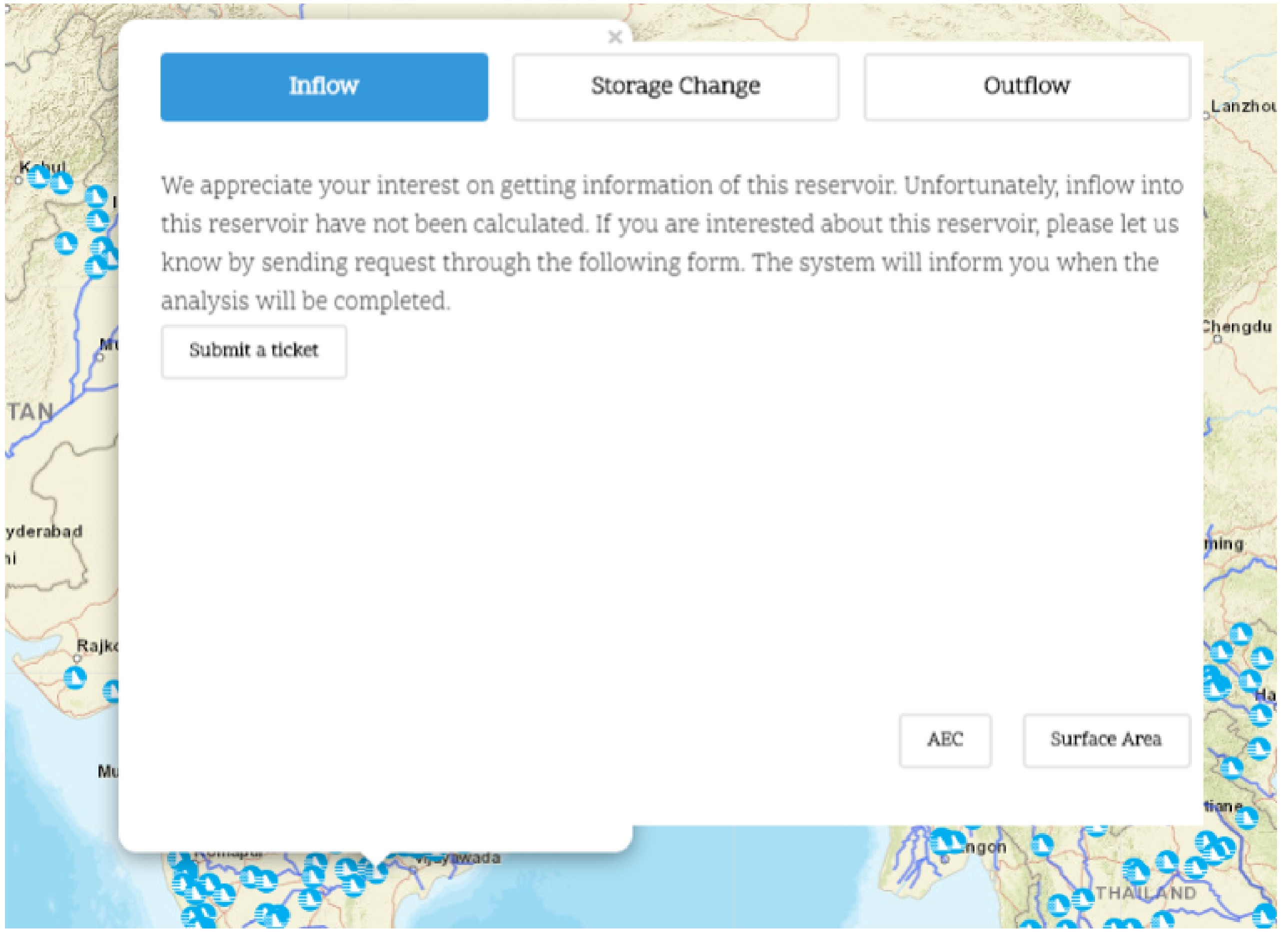


Figure 5: User request service to include new reservoirs in the domain

4. APPLICATION

Application of the RAT framework

1. It provides access to near-real-time reservoir behavior and operating rules for 1598 reservoirs over South America, Africa, and South-East Asia.
2. It helps users and the scientific community to derive a global picture of reservoir monitoring.
3. The tool facilitates the feasibility study of proposed/planned dams.
4. It provides the opportunity to study the impact of harnessing hydropower on river temperature, greenhouse gas emissions.
5. It can be used to minimize the conflict between riparian nations, unbiased in nature.

Link to the Tool (http://depts.washington.edu/saswe/rat_beta/)

5. STORAGE CHANGE ACCURACY

Performance of Storage Change

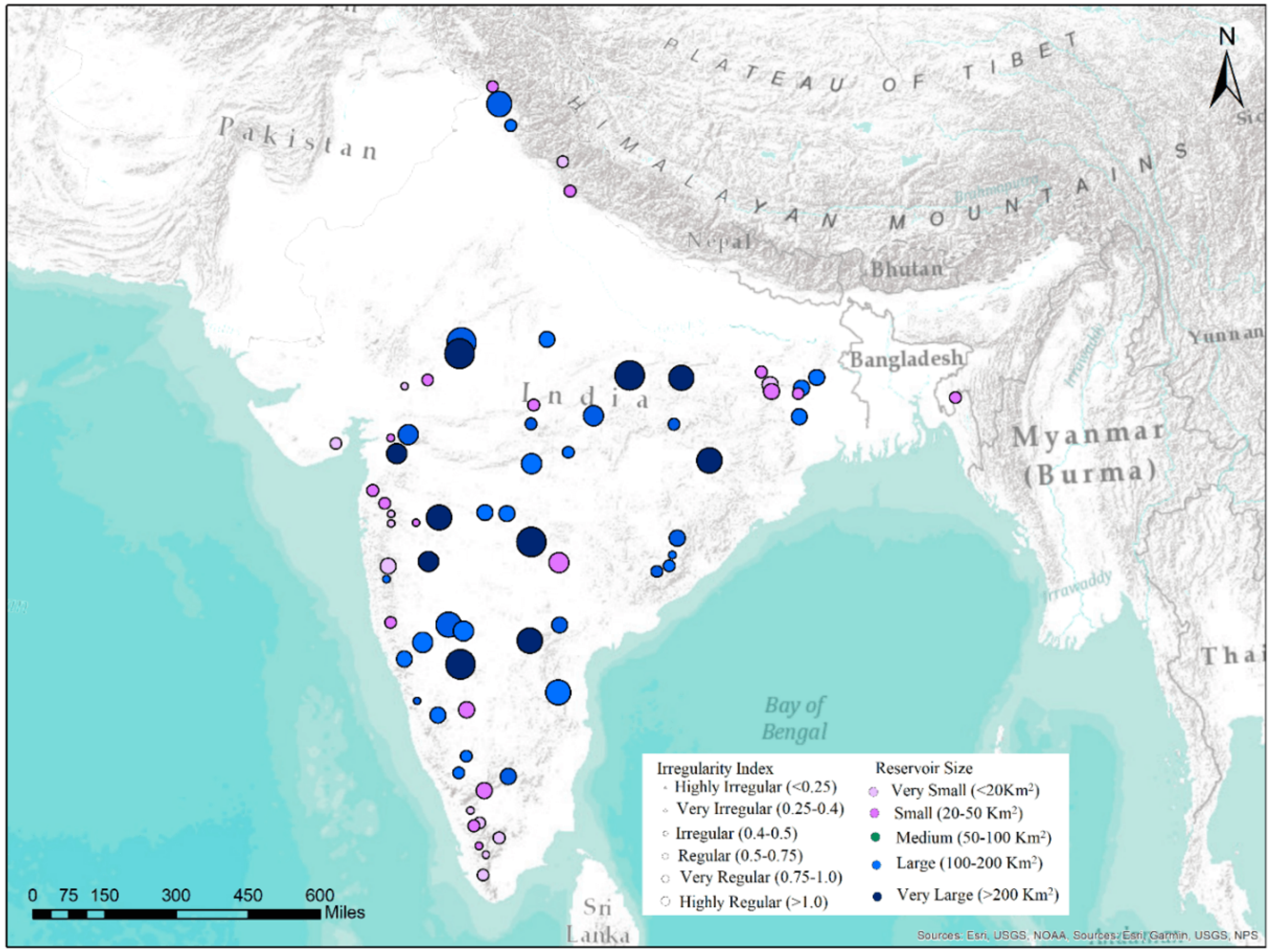


Figure 6: Location, size, and irregularity of selected reservoirs over South-East Asia

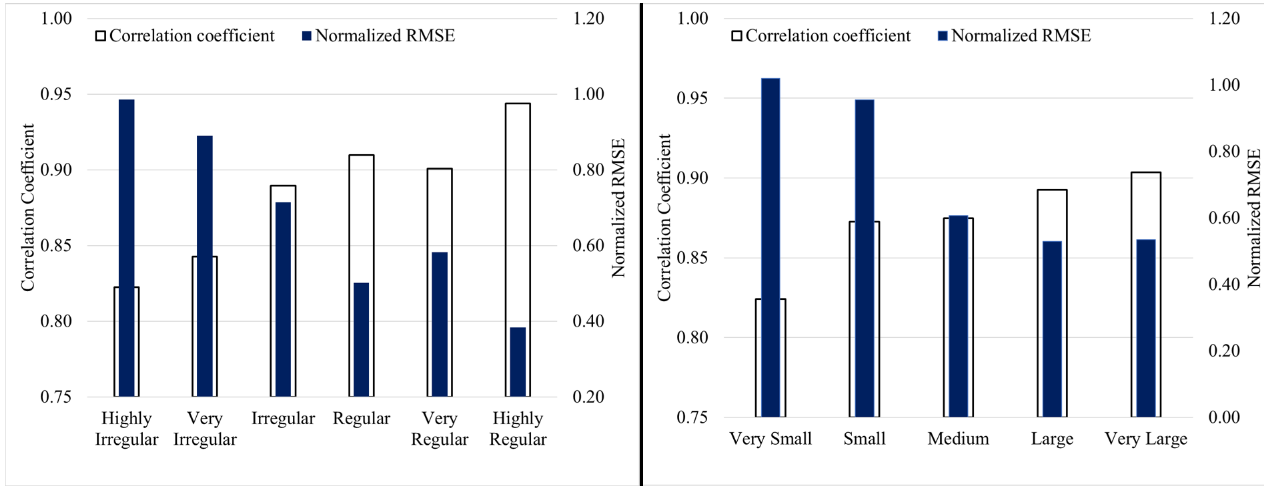


Figure 7: Correlation Coefficient and Normalized Root Mean Square (NRMSE) comparison of reservoirs based on different sizes and irregularity indexes (dams are shown in figure 6)

Performance of Surface Water Extent

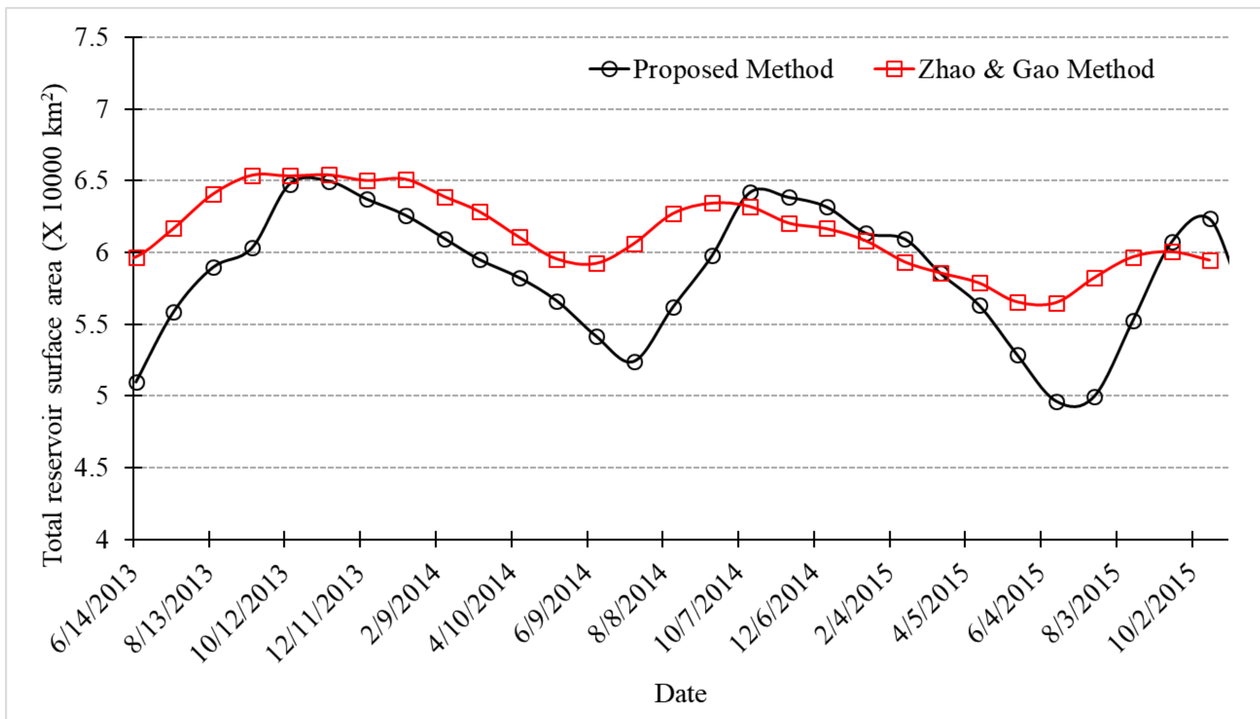
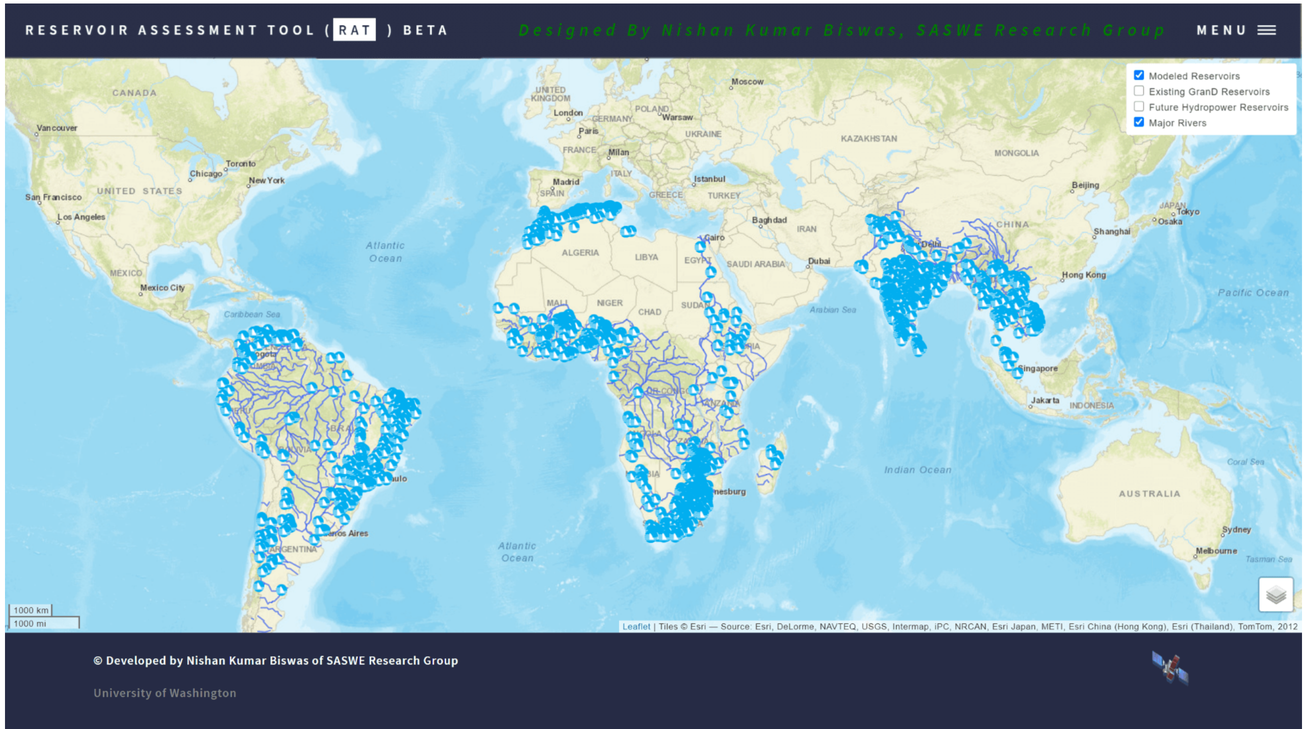


Figure 8: Comparison of tool derived reservoir surface area with Zhao & Gao (2018) generated reservoir surface area


RESERVOIR ASSESSMENT TOOL (RAT) BETA
Designed By Nishan Kumar Biswas, SASWE Research Group
MENU
Modeled Reservoirs
Existing GranD Reservoirs
Future Hydropower Reservoirs
Major Rivers
Atlantic Ocean
Indian Ocean
Pacific Ocean
1000 km
1000 mi
Leaflet | Tiles © Esri — Source: Esri, DeLorme, NAVTEQ, USGS, Intermap, iPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom, 2012
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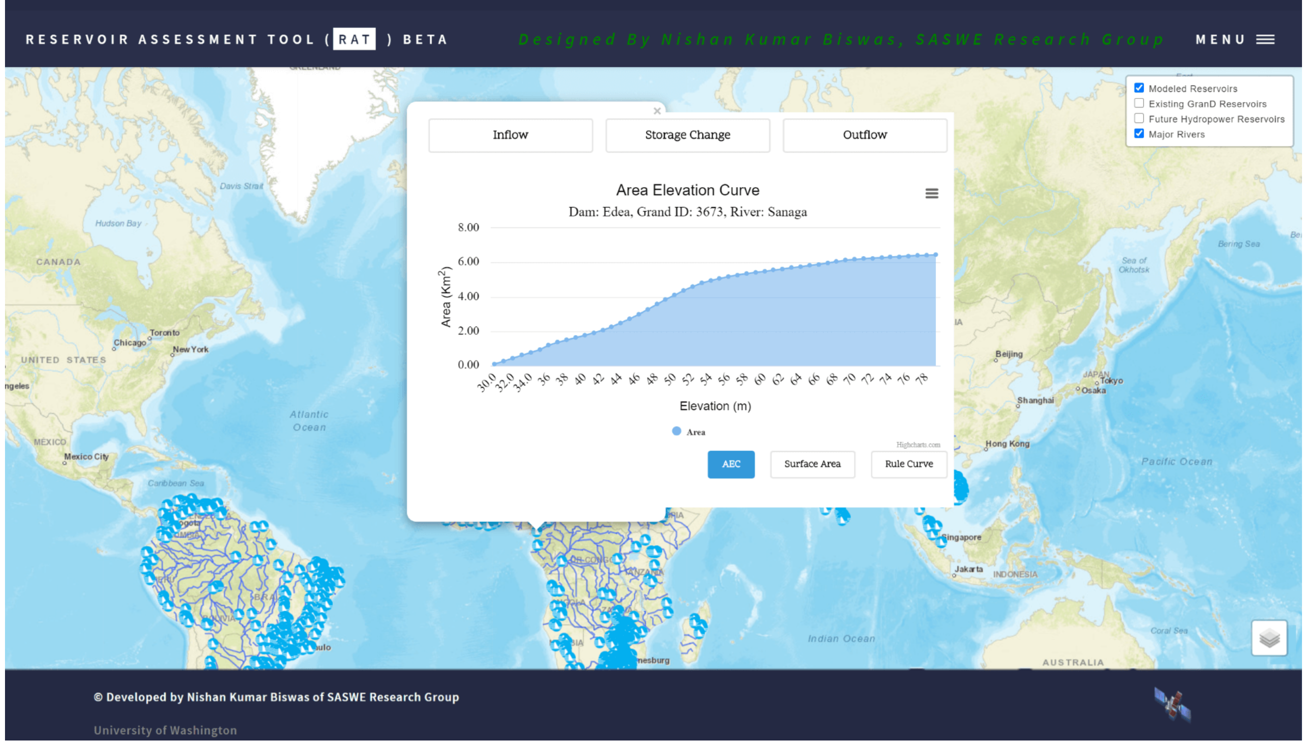
RESERVOIR ASSESSMENT TOOL (RAT) BETA
Designed By Nishan Kumar Biswas, SASWE Research Group
MENU
Modeled Reservoirs
Existing GranD Reservoirs
Future Hydropower Reservoirs
Major Rivers
Inflow
Storage Change
Outflow
Area Elevation Curve
Dam: Edea, Grand ID: 3673, River: Sanaga
Area (Km²)
Elevation (m)
Area
AEC
Surface Area
Rule Curve
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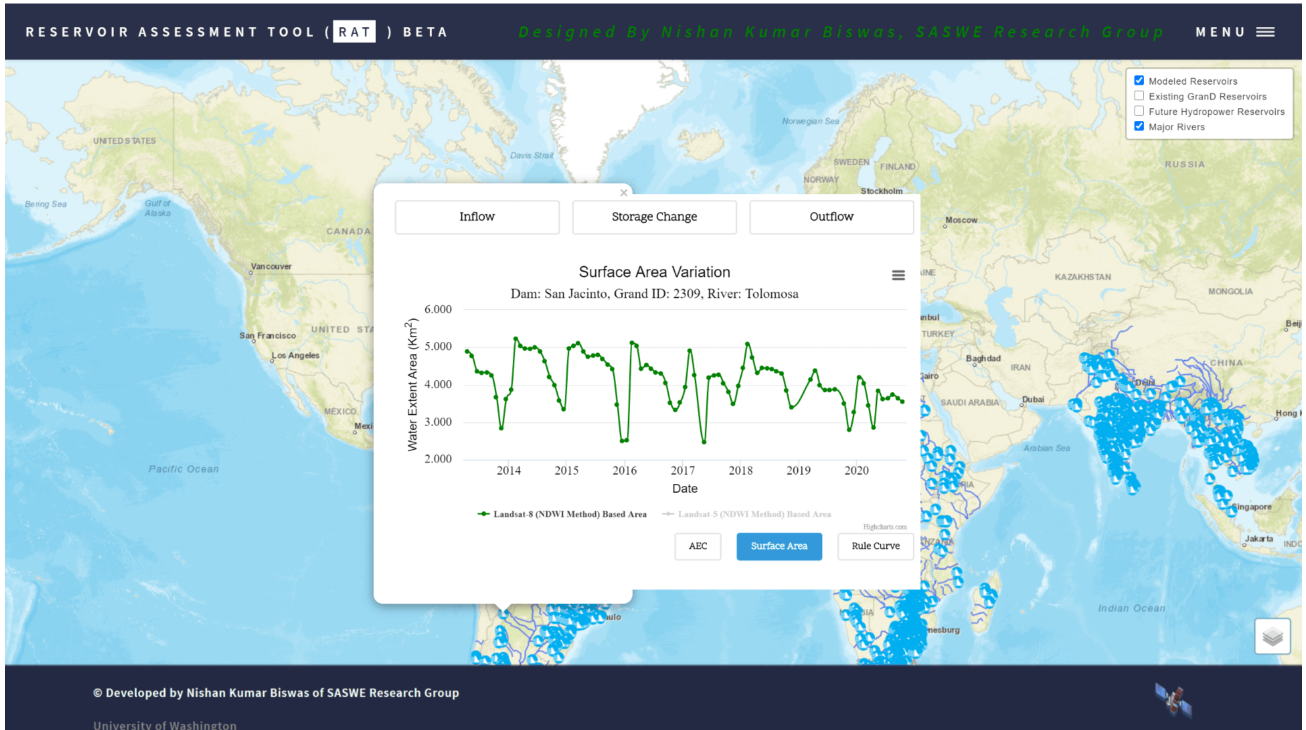
RESERVOIR ASSESSMENT TOOL (RAT) BETA
Designed By Nishan Kumar Biswas, SASWE Research Group
MENU
Modeled Reservoirs
Existing GranD Reservoirs
Future Hydropower Reservoirs
Major Rivers
Inflow
Storage Change
Outflow
Surface Area Variation
Dam: San Jacinto, Grand ID: 2309, River: Tolomosa
Water Extent Area (Km²)
Date
Landsat-8 (NDWI Method) Based Area
Landsat-5 (NDWI Method) Based Area
AEC
Surface Area
Rule Curve
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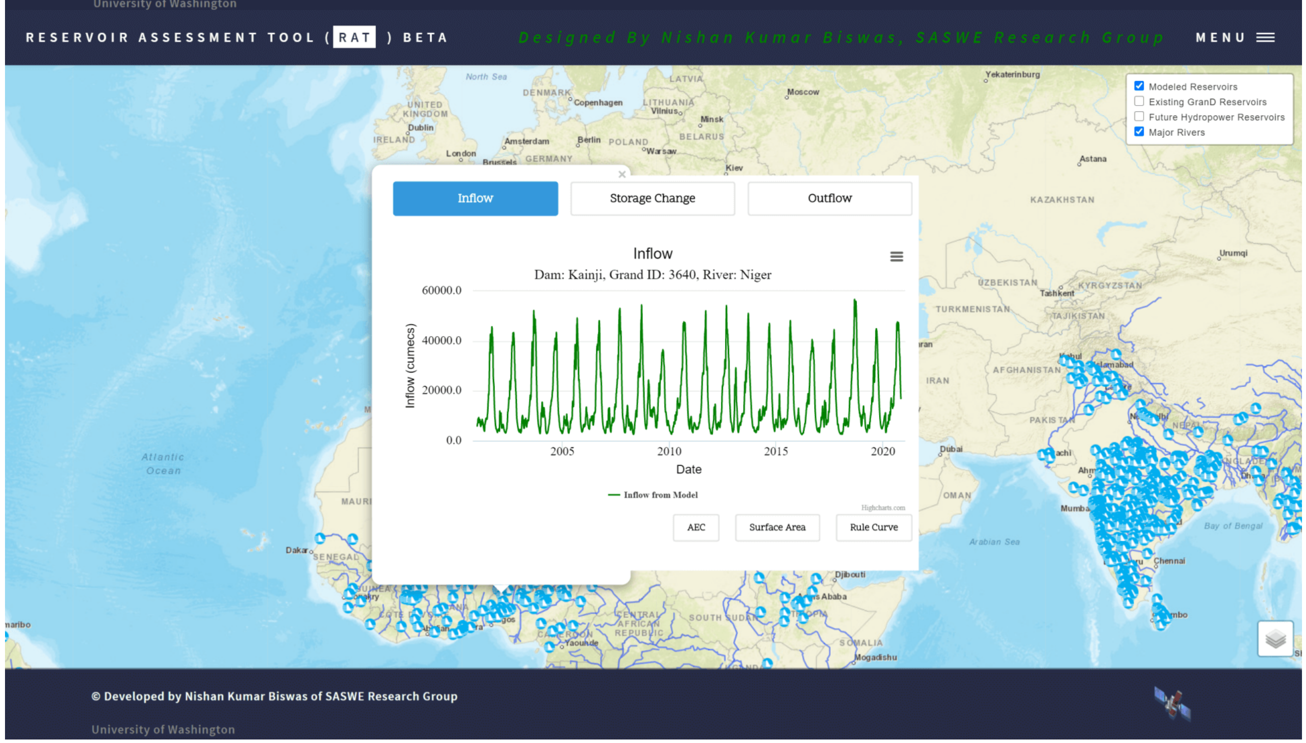
RESERVOIR ASSESSMENT TOOL (RAT) BETA
Designed By Nishan Kumar Biswas, SASWE Research Group
MENU
Modeled Reservoirs
Existing GranD Reservoirs
Future Hydropower Reservoirs
Major Rivers
Inflow
Storage Change
Outflow
Inflow
Dam: Kainji, Grand ID: 3640, River: Niger
Inflow (cumecs)
Date
Inflow from Model
AEC
Surface Area
Rule Curve
© Developed by Nishan Kumar Biswas of SASWE Research Group
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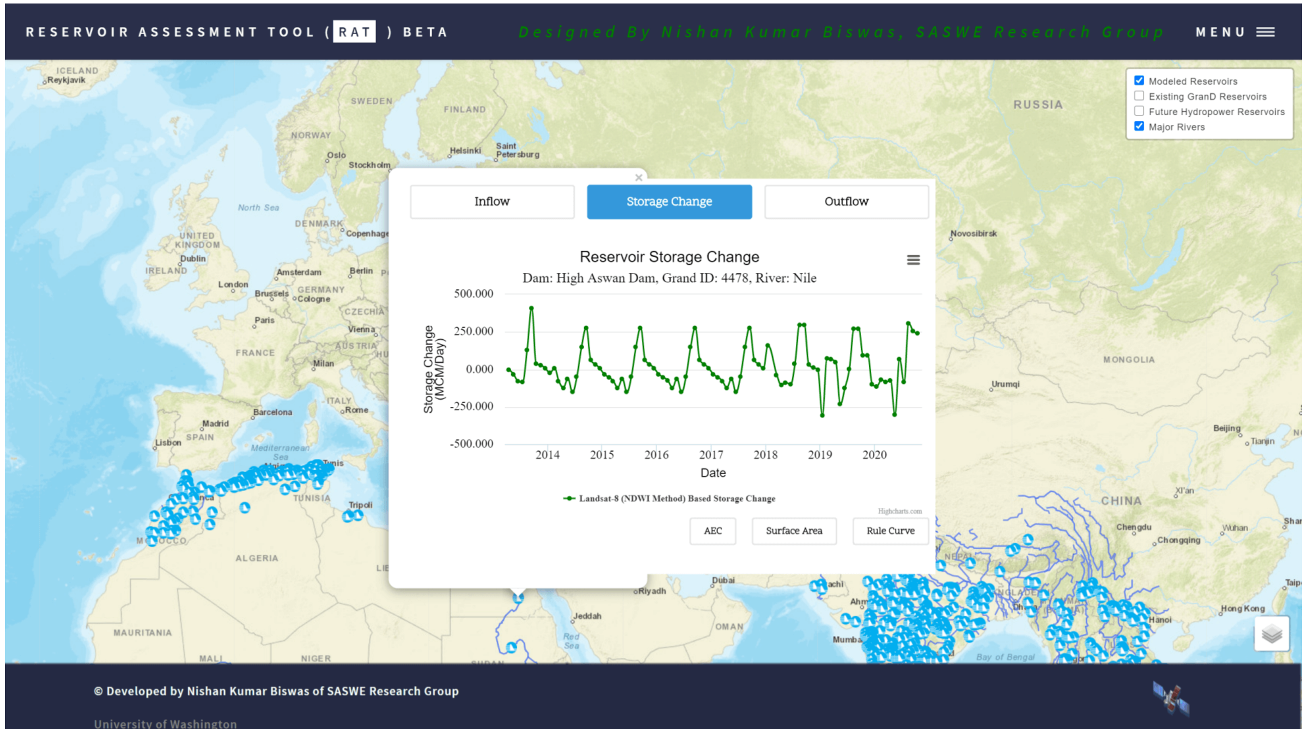
RESERVOIR ASSESSMENT TOOL (RAT) BETA
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MENU
Modeled Reservoirs
Existing GranD Reservoirs
Future Hydropower Reservoirs
Major Rivers
Inflow
Storage Change
Outflow
Reservoir Storage Change
Dam: High Aswan Dam, Grand ID: 4478, River: Nile
500.000
250.000
0.000
-250.000
-500.000
Storage Change (MCM/Day)
2014
2015
2016
2017
2018
2019
2020
Date
Landsat-8 (NDWI Method) Based Storage Change
Highcharts.com
AEC
Surface Area
Rule Curve
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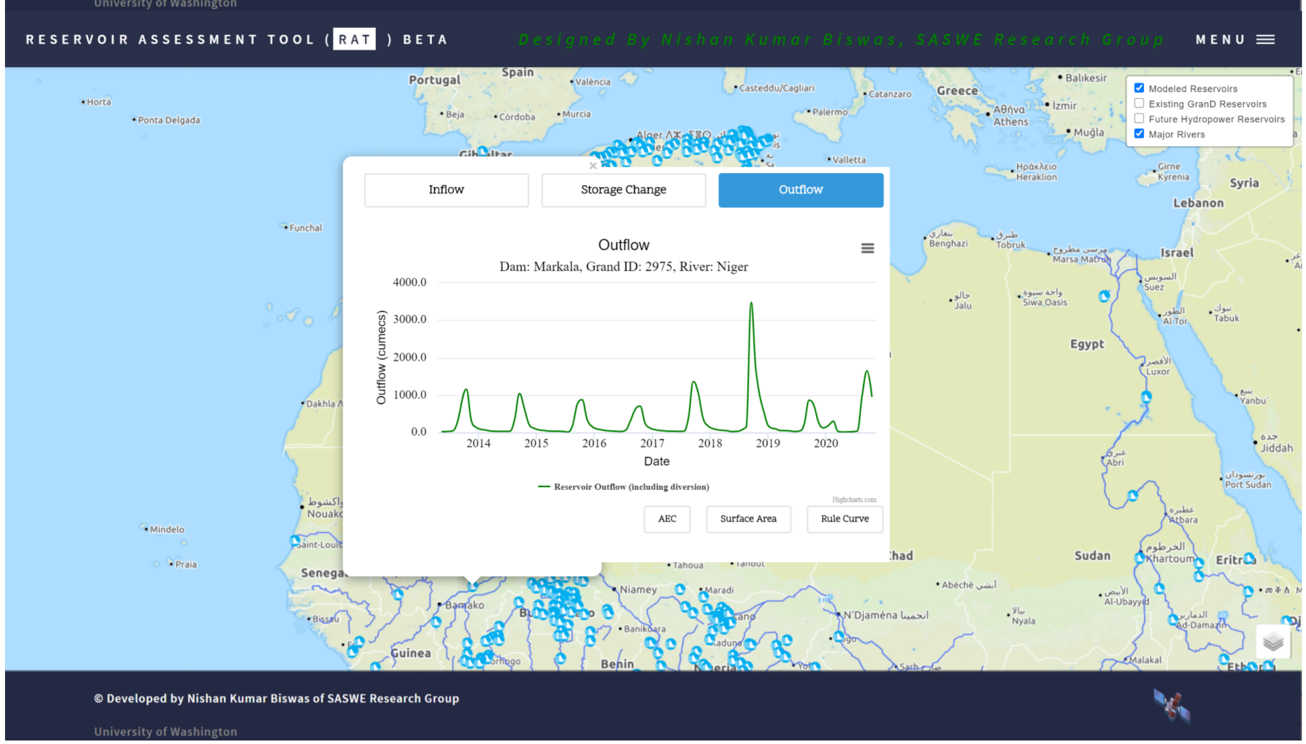
RESERVOIR ASSESSMENT TOOL (RAT) BETA
Designed By Nishan Kumar Biswas, SASWE Research Group
MENU
Modeled Reservoirs
Existing GranD Reservoirs
Future Hydropower Reservoirs
Major Rivers
Inflow
Storage Change
Outflow
Outflow
Dam: Markala, Grand ID: 2975, River: Niger
4000.0
3000.0
2000.0
1000.0
0.0
Outflow (cumecs)
2014
2015
2016
2017
2018
2019
2020
Date
Reservoir Outflow (including diversion)
Highcharts.com
AEC
Surface Area
Rule Curve
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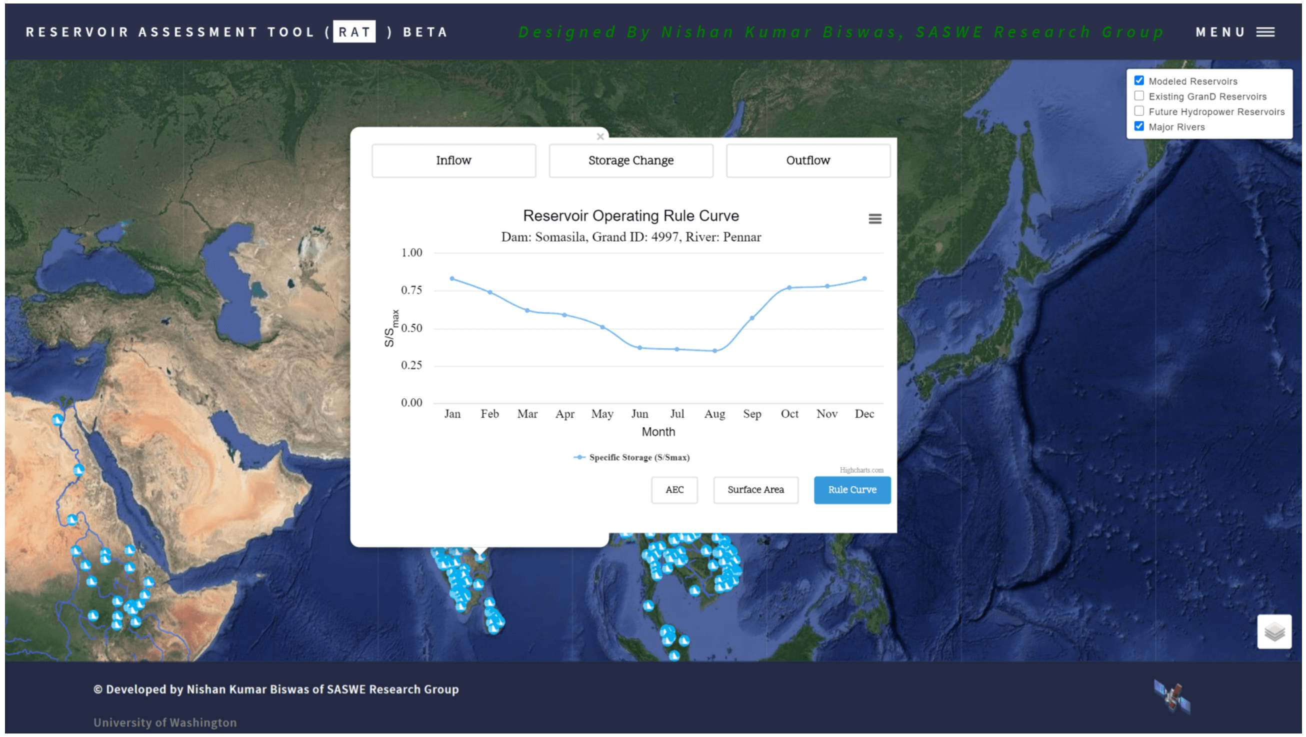
RESERVOIR ASSESSMENT TOOL (RAT) BETA
Designed By Nishan Kumar Biswas, SASWE Research Group
MENU
Modeled Reservoirs
Existing GranD Reservoirs
Future Hydropower Reservoirs
Major Rivers
Inflow
Storage Change
Outflow
Reservoir Operating Rule Curve
Dam: Somasila, Grand ID: 4997, River: Pennar
S/Smax
1.00
0.75
0.50
0.25
0.00
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month
Specific Storage (S/Smax)
AEC
Surface Area
Rule Curve
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6. STREAMFLOW ACCURACY

Performance of simulated streamflow

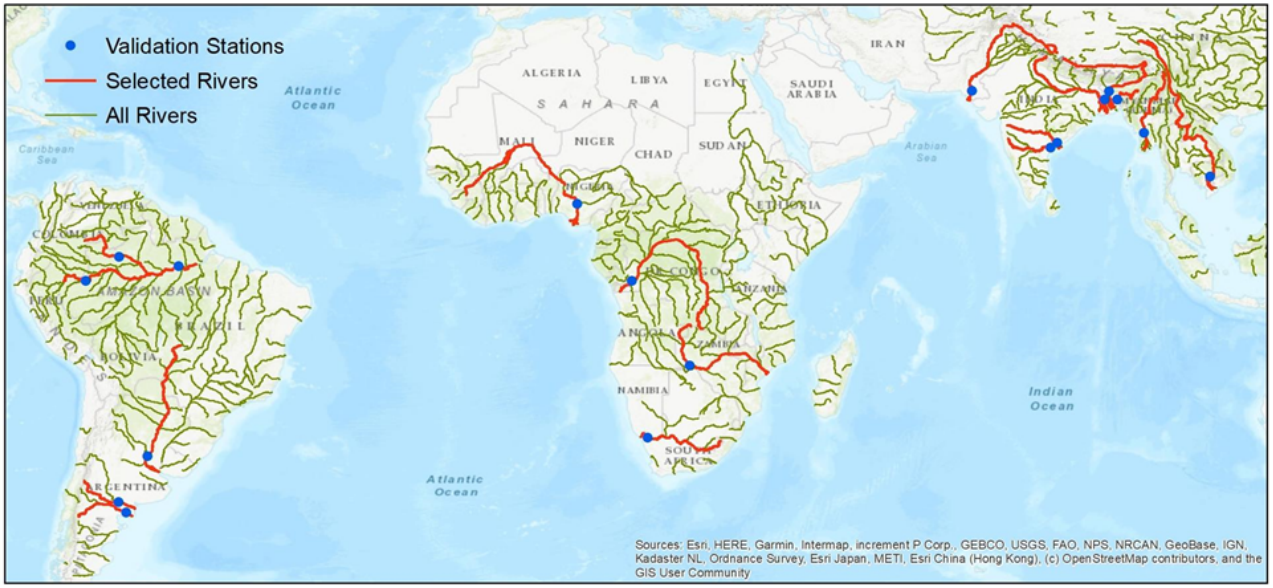

Figure 9: Selected River Basins and stations

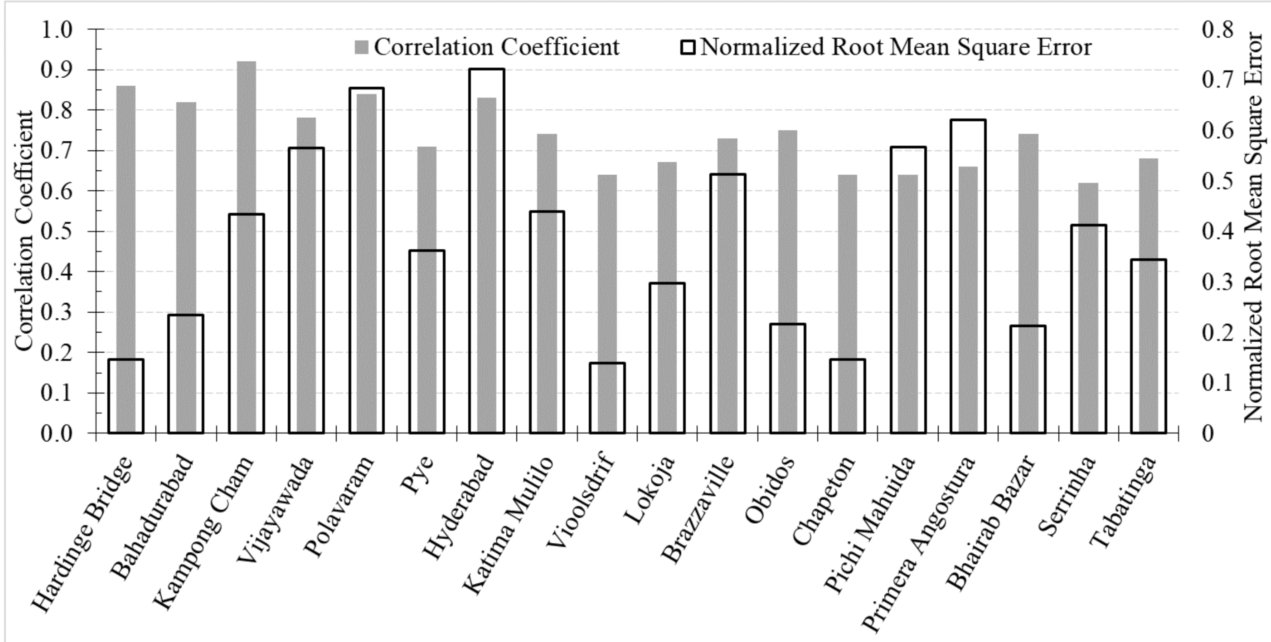

Figure 10: Correlation Coefficient and Normalized Root Mean Square Error comparison

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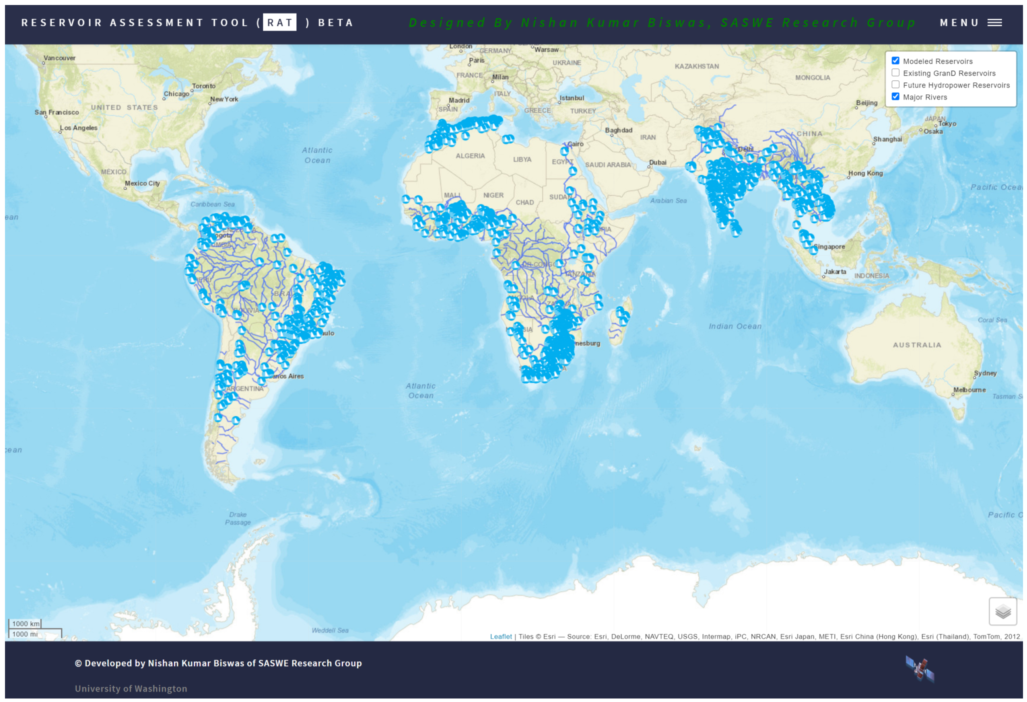
ABSTRACT

Dam construction is on the rise in developing nations. Monitoring of these dams is necessary to understand downstream hydrologic impacts and for better planning and management of water resources. Satellite observations and advancements in information technology now present a unique opportunity to overcome the traditional limitations of reservoir monitoring. In this study, a global reservoir monitoring framework is developed as an online tool for near-realtime monitoring and impact analysis of existing and planned reservoirs based on publicly available and global satellite observations. The framework uses a mass balance approach to monitor 1598 reservoirs in South America, Africa, and South-East Asia region. The framework simulated streamflow was validated in 18 river basins and the storage change was validated against in-situ data of 77 reservoirs. The framework was able to capture reservoir state realistically for more than 75% of the reservoirs. The tool can now be used to study existing and planned reservoirs for hydrologic impact and operating pattern for short and long term decision making and policy analysis.



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