Quantifying the Impacts of the 2022 Grand Ethiopian Renaissance Dam (GERD) Reservoir Fill on Reservoir Extent at the GERD and Downstream with Radar

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View my work on GitHub!

SCAN ME

Abstract

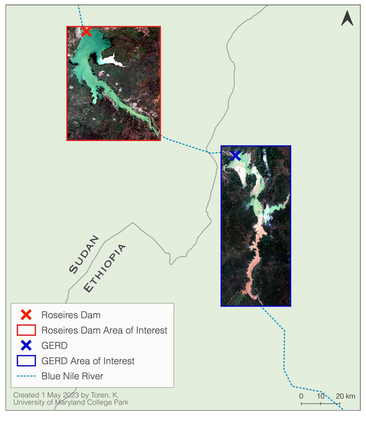
The construction of the Grand Ethiopian Renaissance Dam (GERD) on the Blue Nile River, one of two tributaries of the Nile River, has driven conflict over water rights between Ethiopia, Sudan, and Egypt since 2011. Because in-situ data on the progress of the GERD construction, GERD reservoir fills, and impacts to downstream resources is limited, those facilitating diplomatic negotiations and the international community tracking regional tensions are impeded. This research quantified the impact of the not yet assessed August 2022 fill of the GERD reservoir on reservoir size at both the GERD and downstream at Roseires Dam in Sudan. Results from running a random forest supervised classification algorithm on 2021 and 2022 European Space Agency Sentinel-1 Synthetic Aperture Radar imagery quantified the change in surface water area after the 2022 GERD fill. Results indicate impacts at both study sites. Between July 2021 and August 2022, water surface area increased at the GERD by 75.3% (282.8 km^2) and decreased downstream at Roseires Dam by 5.73% (33.37 km^2). These results, obtained via remote monitoring, confirm the possibility of water supply impacts downstream of the GERD and demonstrate a need for continued monitoring and future analysis in this area of sparse data availability and escalating geopolitical tension.

Research Objectives

To quantify the impacts of the August 2022, third fill of the GERD reservoir both at the GERD and downstream at Roseires Dam, Sudan, this project aimed to:

1. Input SAR data from European Space Agency's (ESA) Sentinel-1 satellite into a random forest supervised classification to quantify the change in water surface area at the GERD reservoir due to the third reservoir fill completed in August 2022.
2. Input Sentinel-1 SAR data into a random forest supervised classification to quantify the change in water surface area at the Roseires Dam reservoir, the first dam directly downstream of the GERD, due to the third GERD reservoir fill completed in August 2022.
3. Create supervised classification algorithm training data points using both Sentinel-1 SAR imagery and Sentinel-2 MSI as base imagery.
4. Programmatically perform analysis using openly-available and cloud-based data, methods, coding languages, and processing to ensure project methodologies and results are accessible to researchers, replicable, and extensible.

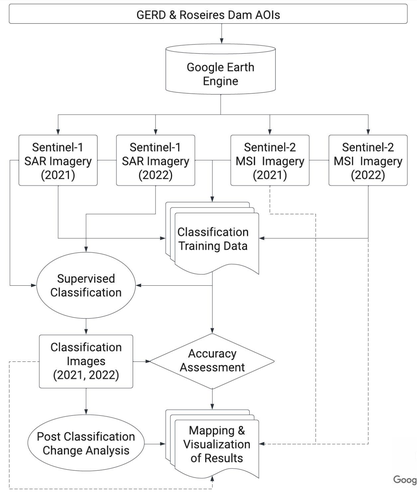
Study Area



The study area for this project covers a portion of the southern border between Sudan and Ethiopia in northeast Africa. The first area of interest (AOI), located in the Benishangul-Gumuz region of northwestern Ethiopia, covers the GERD and the GERD Reservoir on the Blue Nile River. The second AOI, located in the Blue Nile region of southeastern Sudan, covers the Roseires Dam and its reservoir approximately 100 km northwest, downstream, of the GERD.

https://www.africaintelligence.com/serial/the-renaissance-dam-a-national-symbol-but-a-regional-quandary

Methods



Training Dataset Creation

Create GEE feature collections for water & non-water → Load true-color Sentinel MSI & SAR base images → Manually create training points for water, non-water in GEE interface

Merge classes into one landcover feature collection per AOI per year → Call landcover feature collections for classification → Split training & validation data, populate with SAR pixel values

Supervised Classification

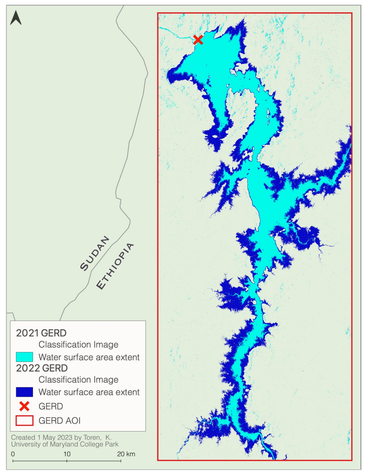
Define training datasets (water & non-water) → Define random forest classifier & inputs → Split dataset into training & validation data

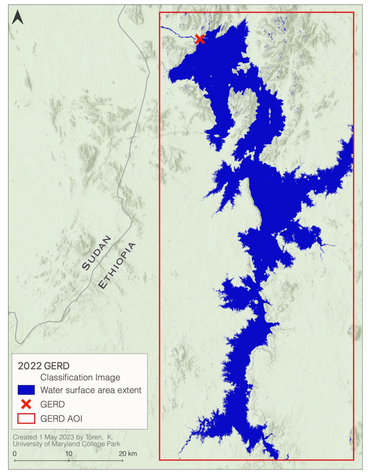
Train the random forest classifier → Classify the SAR images → Review results & assess accuracy

Google Earth Engine · QGIS

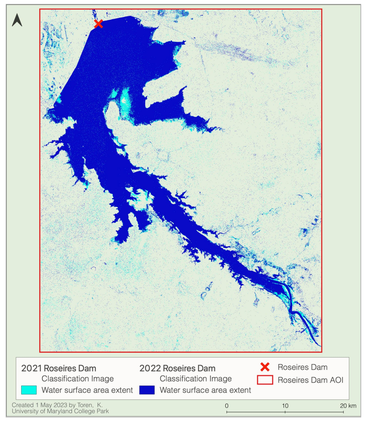
Results

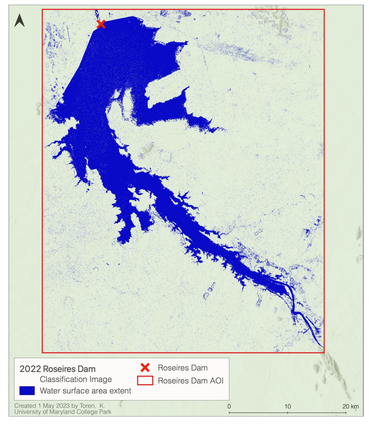
Grand Ethiopian Renaissance Dam





Roseires Dam





As hypothesized, the supervised classification of SAR imagery outputs show that the average surface area of water within the GERD AOI increased between 30 November 2021 and 20 November 2022 after the third, August 2022 GERD reservoir fill. Also as hypothesized, the average surface area of water within the Roseires Dam AOI decreased between 18 November 2021 and 25 November 2022. November dates were selected to avoid the rainy season and excess water and runoff.

	2021 Water Surface Area	2022 Water Surface Area	Change in Area (km^2)	Change in Area (%)
GERD	375.34 km^2	658.13 km^2	+ 282.79 km^2	+ 75.34%
Roseires Dam	582.33 km^2	548.96 km^2	- 33.37 km^2	- 5.73%

Likely sources of error, which were reduced by cleaning the input training class pixels and testing the numbers of trees used by the algorithm, included: human error introduced during the creation of training data, where training pixels were incorrectly identified; radar shadow pixels causing non-water misclassification as water in areas of mountainous terrain; high pixel values causing water misclassification as non-water in areas of rough water; SAR imagery noise due to preprocessing nuances and errors; and SAR imagery noise caused by small projection or slant angle differences.

Conclusions

A random forest supervised classification algorithm, run on 2021 and 2022 ESA Sentinel-1 SAR imagery, found that between July 2021 and August 2022 the water surface area of the GERD increased by approximately 75% (282.8 km^2), while the water surface area of the Roseires Dam reservoir decreased by approximately 6% (33.4 km^2). These results indicate the need for additional, future monitoring and analysis in this area of sparse data availability and escalating geopolitical tension, where the more timely and accurate the results, the better to support those on-the-ground working to improve relations between Ethiopia, Sudan, and Egypt and to bring answers to key questions regarding the impacts of the GERD on the millions of people that live downstream.

Aziz, S.A., Zeleňáková, M., Mésároš, P., Purcz, P., & Abd-Elhamid, H. (2019). Assessing the Potential Impacts of the Grand Ethiopian Renaissance Dam on Water Resources. Sustainability, 11(24), 7050. https://doi.org/10.3390/su11247050
Wheeler, K.G., Jeuland, M., Hall, J.W., et al. (2020). Understanding and managing new risks on the Nile with the Grand Ethiopian Renaissance Dam. Nature Communications, 11, 5222. https://doi.org/10.1038/s41467-020-19089-x
NASA Jet Propulsion Laboratory (2020, November 10). Grand Ethiopian Renaissance Dam. https://www.jpl.nasa.gov/images/pia24150-grand-ethiopian-renaissance-dam
Hudson Institute of Mineralogy mindat.org (n.d.). Roseires Dam, Blue Nile, Sudan. https://www.mindat.org/feature-368006.html
The European Space Agency, Sentinel Online (n.d.). Sentinel-1 SAR User Guide. https://sentinel.esa.int/web/sentinel/user-guides/sentinel-1-sar
Breiman, L. & Cutler, A. (n.d.). Random Forests. Statistics at UC Berkeley. https://www.stat.berkeley.edu/~breiman/RandomForests/cc_home.htm