BIG DATA AND MULTIPLE METHODS FOR MAPPING SMALL RESERVOIRS

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ABSTRACT

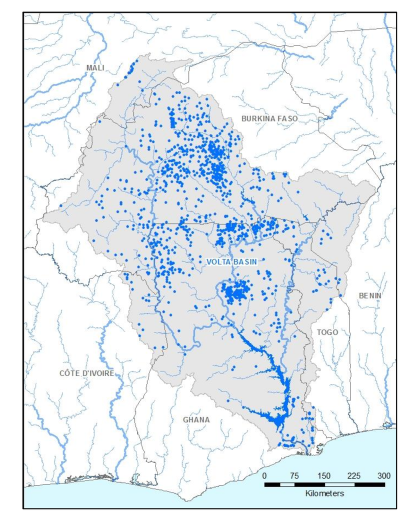
Whether or not reservoirs contain water throughout the dry season is critical to avoiding late season crop failure in seasonally-arid agricultural landscapes. But, locations, volumes and temporal dynamics particularly of small reservoirs are poorly documented globally making it difficult to identify geographic and intra-annual gaps in surface water availability or monitor their impact on people and the environment. First, we use novel data analysis tools available in Google Earth Engine to compare the accuracy of estimating surface water area from Landsat data across four existing water classification approaches, including the approach used to create the new Global Surface Water (GSW) dataset. Second, we assess the conditions under which the GSW and other Landsat-approaches may be suitable for monitoring reservoir water dynamics at regional scales by assessing how the accuracy of their reservoir extent estimates varies with reservoir size, vegetation cover, precipitation and season. Finally, we demonstrate an application of the GSW for monitoring dynamics of 1200 Volta basin reservoirs identified by visual inspection and discuss the utility of this information for agricultural water investment planning and monitoring.

INTRODUCTION

- Information on small reservoirs is challenging to compile and keep updated at the national, regional or global level
- Use of free, high (<5m) or moderate (<100m) resolution satellite imagery provides a practical approach to small reservoir mapping
- The highest resolution, free imagery that is collected on intra-annual timestep over long time scales comes from the Landsat series

OBJECTIVE

- To compare a range of methods for rapid and low-cost monitoring of reservoirs and establish levels of accuracy in reservoir characterization using these methods, as reservoir properties and environmental conditions vary.
- We use the transboundary Volta River Basin (~413,000 sq km) in West Africa as a case study.



Volta basin with reservoirs mapped from Google Earth imagery

METHODS

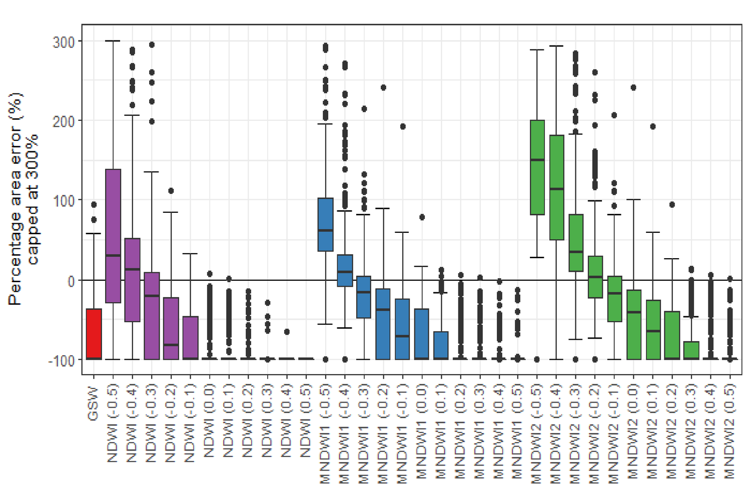
- Map visible dams and create a validation set of 300 reservoir extents from Google Earth imagery
- Source / create surface water maps from Landsat imagery using: Global Surface Water (GSW) dataset, Normalised Difference Water Index (NDWI) and two versions of the Modified NDWI (MNDWI) on L8
- Automating extraction of reservoir extents from surface water maps in Google Earth Engine
- Compare accuracy of reservoir extents against validation data
- Examine variation in accuracy with reservoir extent, perimeter-area ratio, mean normalised vegetation index signal, visible surface vegetation, month and mean precipitation

$$NDWI = \frac{Green - NIR}{Green + NIR}$$

$$MNDWI1 = \frac{Green - SWIR\ (band\ 6)}{Green + SWIR\ (band\ 6)}$$

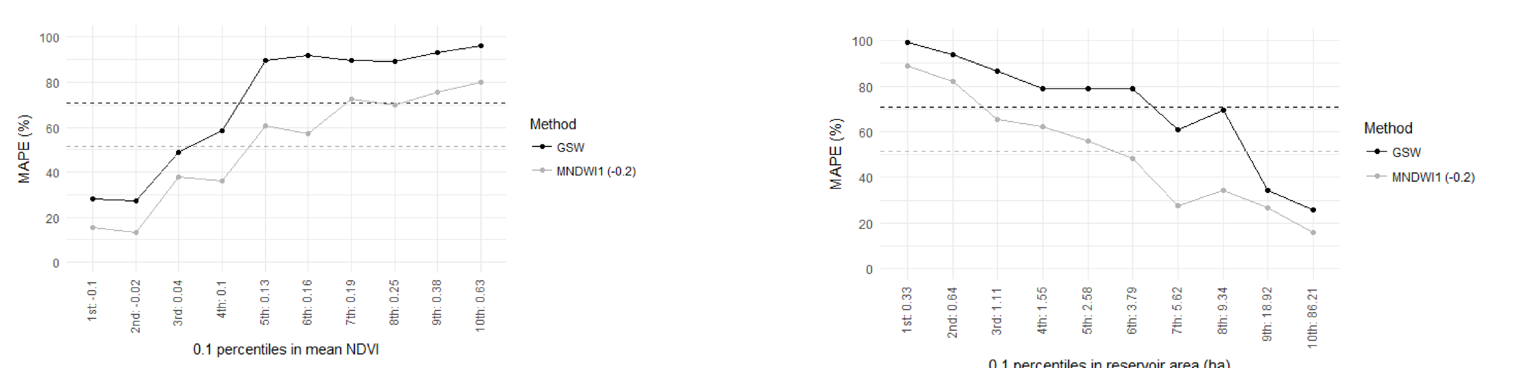
$$MNDWI2 = \frac{Green - SWIR\ (band\ 7)}{Green + SWIR\ (band\ 7)}$$

RESULTS



Boxplots of percentage errors in reservoir area estimates across water classification methods, based on valid estimations obtained across 300 validation points

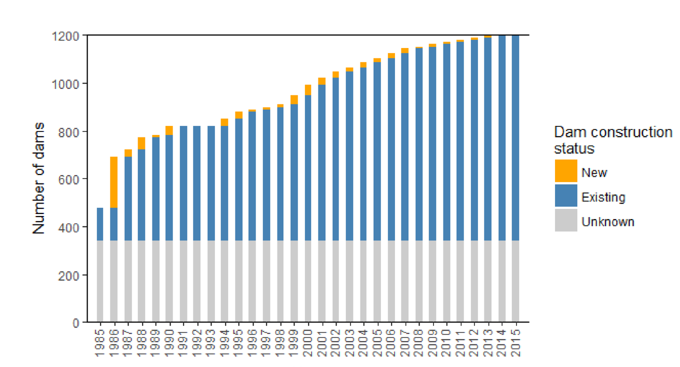
Mean absolute percentage error in area estimates from GSW and MNDWI1, stratified by NDVI and reservoir size. Dashed lines indicate overall MAPE.

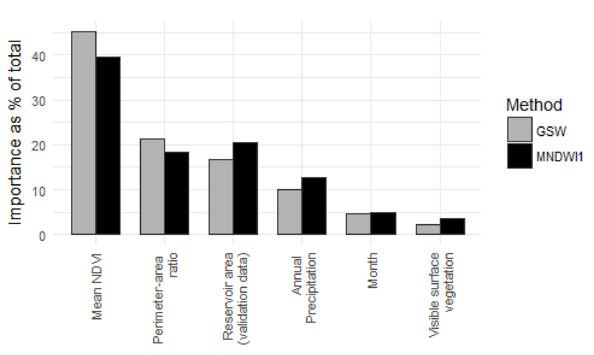


Accuracy of reservoir areal extents and volume equivalents derived from GSW and optimal thresholds applied to NDWI, MNDWI1 and MNDWI2

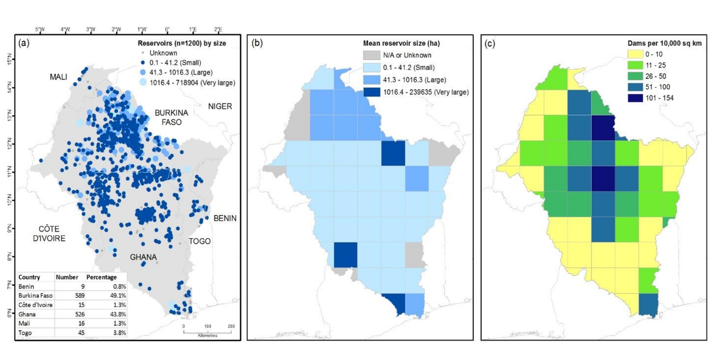
Method	Threshold	Valid reservoir area estimates (non-masked)	Mean error (ha)	SD (ha)	RMSE (ha)	RMSE (m3)	MAE (ha)	MAE (m3)	MAPE (% area)	MAPE (% vol)
GSW	-	280	-2.68	4.35	5.10	49,759.41	2.83	21,330.66	70.75	75.47
MNDWI1	-0.2	281	-1.33	2.60	2.92	22,296.68	1.68	10,039.07	51.36	58.38
MNDWI2	0	281	-1.33	2.74	3.05	23,699.19	1.74	10,623.65	52.69	60.02
NDWI	-0.2	281	-2.11	3.41	4.01	35,177.61	2.36	16,396.48	65.10	70.28

Growth in the number of Volta basin dams since 1984 based on earliest year that water is observed in GSW-MH dataset.





Importance of reservoir properties and environmental context in producing percentage errors in reservoir area estimations, for GSW and MNDWI1 reservoir area estimates, as indicated by a random forest regression analysis



GSW-based analysis of Volta basin:
(a) Reservoir locations and size
(b) Mean reservoir size
(c) Reservoir density

DISCUSSION

- Landsat approaches have high uncertainty: lowest MAPE in reservoir area estimates is 51% achieved with MNDWI1
- Accuracy of reservoir area estimates improves with reservoir size, and as NDVI signal or reservoir perimeter-area ratio decrease
- Automating mapping through Google Earth Engine substantially reduces data storage requirements and processing time
- Missing GSW monthly extent data at all reservoirs a constraint
- No approaches are consistently able to detect water in very small reservoirs: < 2 ha using MNDWI1 and <3 ha using GSW

CONCLUSIONS

- Using our approach and over our West African study site, MNDWI1 is optimal for reservoir extent analysis and out-performs GSW under all conditions tested. However GSW is equally able to detect water presence in a reservoir where the monthly rate of change is > 5.1 ha (49,759 m^3), therefore can be useful for monitoring larger reservoirs
- Adopting integrated approaches, such as manual digitising from high resolution imagery combined with Landsat imagery analysis, is essential to avoid omissions when mapping small reservoirs remotely

MAJOR REFERENCES

1. Ji, L.; Zhang, L.; Wylie, B. *Photogramm. Eng. Remote Sensing* **2009**, *75* (11), 1307–1317
2. Pekel, J.-F.; Cottam, A.; Gorelick, N.; Belward, A. S. *Nature* **2016**, *540* (7633), 418–422
3. Xu, H. *Int. J. Remote Sens.* **2006**, *27* (14), 3025–3033

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