Towards Continuous, Remote Estimates of Flooded Area in the Sudd Wetland, South Sudan

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Motivation

- The Sudd Wetland in South Sudan is an important but poorly characterized water resource in the heart of the Nile River Basin. More regular monitoring of Sudd flooded extent could improve resource management [1].
- Rebelo et. al. demonstrated the use of L-band synthetic aperture radar (SAR) to measure Sudd flooded area from 2007-2008, and found a strong correlation between area and satellite-derived estimates of ETa (R^2=0.99) [2].
- These results suggest that Sudd wetland area could be monitored with near-continuous ETa estimates, generated using data available from existing satellite platforms.

Research Goal:
To reproduce and extend previous work showing that remotely-sensed estimates of Sudd flooded area and ETa are highly correlated [2] by (a) using more accessible data sources and (b) analyzing a longer time series.

Methods

A. Preprocess SAR Imagery | **B. Estimate Flooded Area** | **C. Compare with ETa estimates.**

1. Acquired 60 ENVISAT ASAR images (HH, C-band, 1km res) of the Sudd watershed, from 2007-2011, at roughly monthly intervals.
2. Performed radiometric correction (NEST v5.0.16) to obtain the spatially varying backscattering coefficient σ^o.

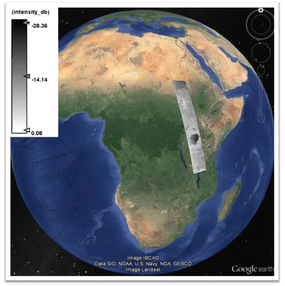


Figure 2 –SAR imagery. Shows 1 of 60 ENVISAT ASAR images covering the Sudd area, captured 12/05/2011 and overlayed in Google Earth (v7.1.2.2041).

3. Used training sites and literature to identify σ^o thresholds for the classification of open water (OW), dry land (DL), and flooded vegetation (FV).
4. Classified watershed land types using thresholding analysis to obtain five year record of total flooded area (OW+FV).

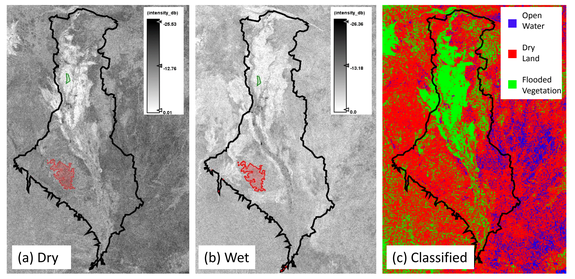


Figure 3 – Area estimation. Fig. 3a and 3b compare the processed SAR images during the dry and wet season. The location of training sites is shown in red (DL) and green (FV). Darkest pixels are OW, which reflects C-band radar away. Brightest pixels are FV, which backscatters radiation. DL pixels have intermediate brightness. Pixel classification (shown in Fig. 3c) yields estimates of the watershed area covered by the three generalized land-types. Images dated 3-10-11 (a,c) and 10-6-11 (b).

5. Estimated watershed ETa for 30-day window centered at each SAR capture date using USDA's ALEXI (Atmosphere-Land Exchange Inverse) algorithm [3].
6. Analyzed the trends in flooded area and ETa and the correlation between them. Compared with values from the literature.

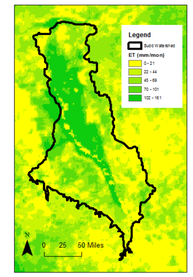


Figure 4 - ETa estimates. ALEXI estimated ETa for 3-10-11. ALEXI calculates ETa using satellite-derived land-surface temperature [3].

Study Site

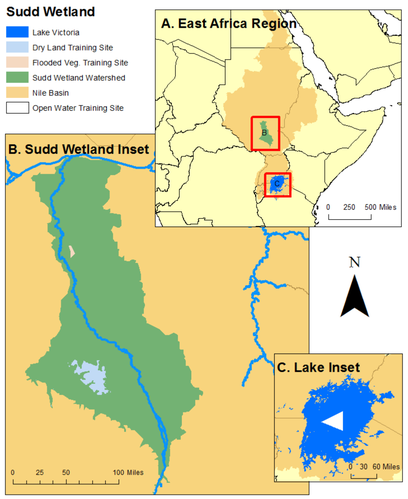


Figure 1 - Site Map. Includes training sites for classifying the three land types considered in this study. The DL site contains pixels at elevations over 455m, the FV site was determined to be perennial swamp, and the OW is over Lake Victoria.

Results

The σ^o thresholds obtained from our classification differ from those reported in literature for L-Band SAR. Fig. 5 shows the location of the thresholds 'TH-A' at (-15,-9) given by [2], and 'TH-B' at (-14,-6) where the histograms intersect. We tested both.

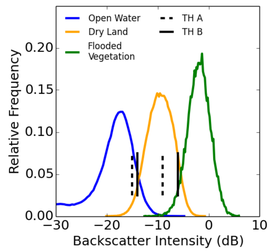


Figure 5 – Determination of classification thresholds. Shows the relative frequency of σ^o over each test site from 2007-2011.

TH-A shows a strong seasonal pattern with high correlation to ETa (R^2=.71). Fig. 6 (upper left) shows flooded area varying from 17 Gm^2 in the dry season (Feb-Apr) to 52 Gm^2 in the wet season (Aug-Oct). ETa is a predictor of flooded area even when controlling for month of year (p<.05).

TH-B shows a weaker seasonal pattern, lower total area, and lower correlation to ETa (R^2 =.41). Fig. 6 (lower left) shows that area ranges from 10 to 33 Gm^2. ETa no longer predicts flooded area when controlling for month of year (p>0.05).

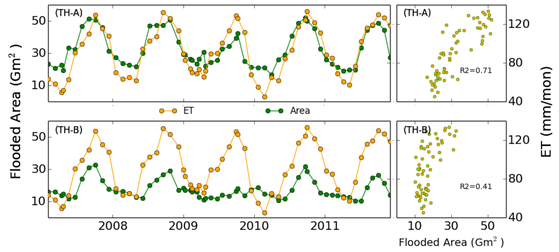
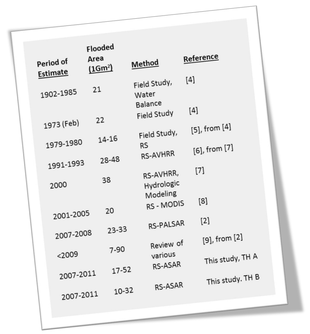


Figure 6 – Area and ETa Comparison. The left panels show estimated total flooded area (open water + flooded vegetation) using TH A (upper) and TH B (lower) along with ETa. Scatter plots between ETa and flooded area (right panels) demonstrate correlation strength.

Flooded area estimates from TH-A and TH-B are both consistent with the literature. Fig. 7 shows that estimates of Sudd wetland area have varied from 9 to 90 Gm^2, depending on the method and site definition.



Period of Estimate	Flooded Area ($1Gm^2$)	Method	Reference
1902-1985	21	Field Study, Water Balance	[4]
1973 (Feb)	22	Field Study	[4]
1979-1980	14-16	Field Study, RS	[5], from [4]
1991-1993	28-48	RS-AVHRR	[6], from [7]
2000	38	RS-AVHRR, Hydrologic Modeling	[7]
2001-2005	20	RS - MODIS	[8]
2007-2008	23-33	RS-PALSAR	[2]
<2009	7-90	Review of various	[9], from [2]
2007-2011	17-52	RS-ASAR	This study, TH A
2007-2011	10-32	RS-ASAR	This study, TH B

Figure 7 – Historic Estimates. Shows estimates of Sudd area found in the literature since 1964.

Conclusions

- We estimated 2007-2011 Sudd flooded area from 60 SAR images, using two different thresholding schemes derived from the literature and image analysis.
- The flooded area estimates exhibit large, consistent interannual variability with no significant year-to-year trend. Their magnitude and correlation with ETa depend on the choice of thresholding scheme. Efforts are ongoing to determine which scheme is most accurate by comparing with cloud-free MODIS classifications.
- Through this work we hope to demonstrate how frequently-updated ETa estimates could complement sporadic SAR measurements to remotely monitor flood extent in the Sudd and other wetlands.

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