Quantifying The Impact Of Climate-change Induced Desertification In Agrifood Production In Senegal Using BIOMASS

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Importance of Soil Moisture In The Sahel

The Senegal River Valley is a major producer of rice[1]. As a high Intervention area[2], it is heavily irrigated and as such it is sensitive to climate change, and shocks such as floods and droughts[3]. The ability to monitor soil moisture (SM) across the Sahel region would be a major influence on water management and policy in this area. SM is also related to soil salinity, which is of particular interest in the Senegal Delta region for crop resilience, security, and future stability. Here we show results from SM retrievals derived from Sentinel-1 in the river delta region, and compare to upsampled SMAP measurements obtained using machine learning models.

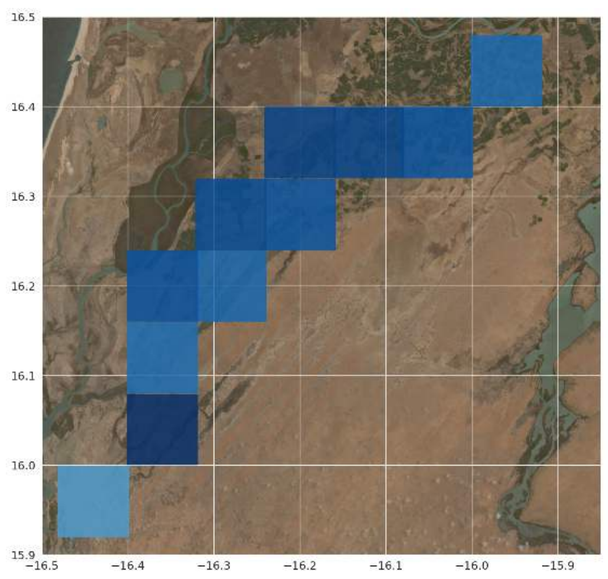

Figure 1: *The Soil Moisture Active Passive (SMAP) is a commonly used and widely available soil moisture product. However it lacks spatial and temporal resolution for precision agriculture.*

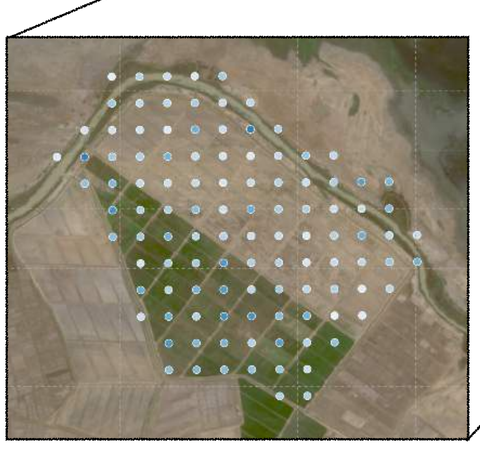

Figure 4: *Soil moisture at 250m resolution from Sentinel-1 C-band and local meteorological data.*

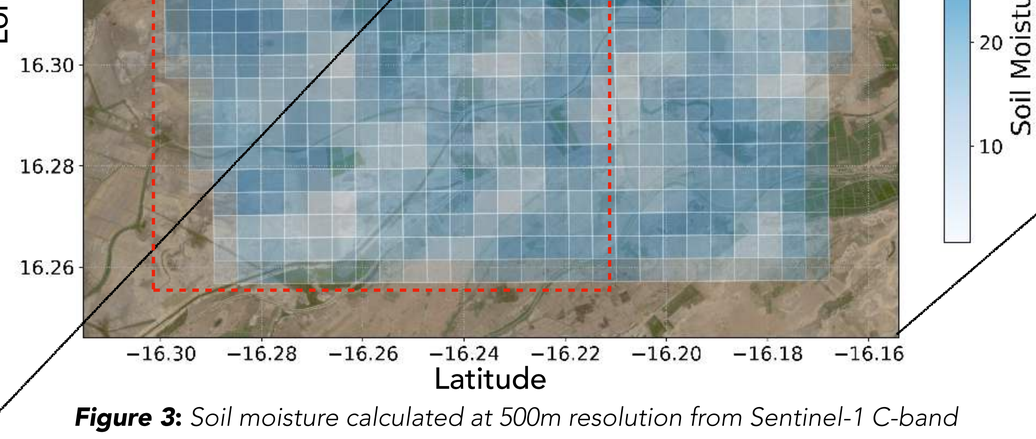

Figure 3: *Soil moisture calculated at 500m resolution from Sentinel-1 C-band closure phase and inversion techniques[5] [ISCE TopsStack combined with InSAR4SM[5] (credit: kleok@github)]. Rice crop classification for the box in red is shown in Fig. 5. The colorbar for this plot is universal for all colormaps displayed on this poster.*

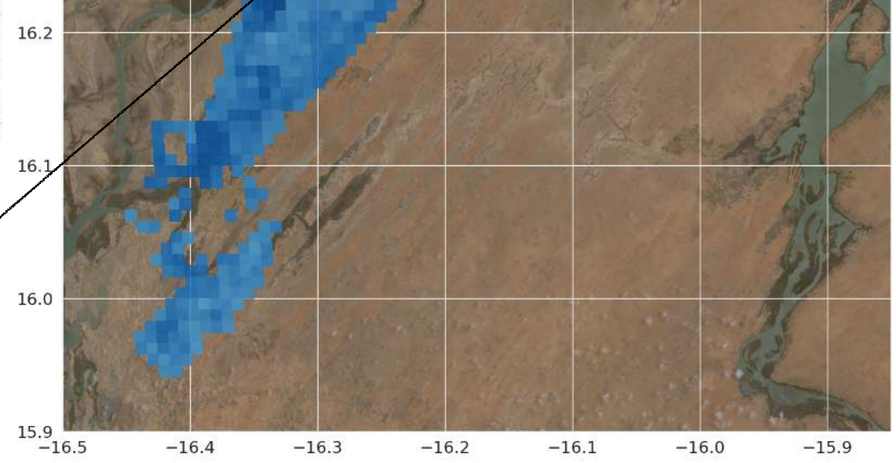

Figure 2: *Soil moisture across the Senegal River Delta calculated by upsampling SMAP data to 1km resolution using higher resolution parameters from Sentinel-1/2 and MODIS (e.g. NDVI, MNDWI, ET) in a XGBoost ML model[4].*

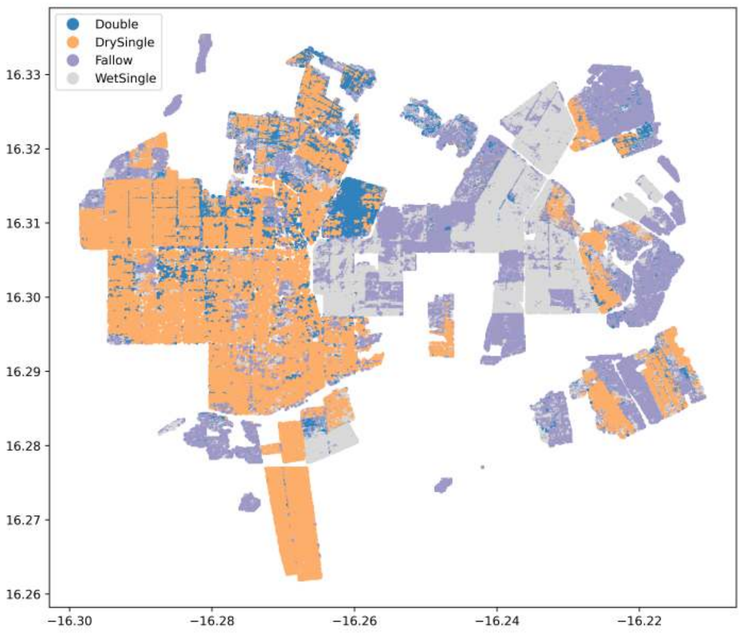

Figure 5: *Time-series-to-image CNN crop classifier[7] analysis from Sentinel-2 data shows the rice crop seasonality in 2022. Local variations in crop quality could be due to irrigation, which more accurate soil moisture measurements could improve.*

Moving towards BIOMASS

The advent of BIOMASS and global P-band data will allow monitoring that is less responsive to obstacles (e.g. foliage & surface soil texture) than shorter wavelength radar, while also probing to greater depths. This would synergise with current SM data and models (e.g. SMAP, ALOS-2, SAOCOM). Methods for consistently and efficiently retrieving SM at P-band will be required to achieve maximum impact from BIOMASS data.

In a climate vulnerable location (sub-saharan, arid), monitoring of deep soil moisture will allow better hydrological management and redirection of irrigation resources. Despite being an irrigated region of the Sahel, our analysis of the Senegal river delta shows long term soil moisture and agricultural production has subsided since 2020, despite major irrigation and infrastructure investment in the region between 2010-2016[2].

1 Grain and Feed Annual Report - Senegal SG2023-0006, USDA/GAIN, 2023
2 Harris *et al.*, "Senegal's IWRM Project at Five Years Post-Compact: Findings from a Mixed-Methods Evaluation", Mathematica, (2021)
3 Elkouk, A., *et al.* "Multi-model ensemble projections of soil moisture drought over North Africa and the Sahel region under 1.5, 2, and 3 °C global warming.", *Climatic Change* 167, 52 (2021).
4 Sashay, *et al.*, "Downscaling and validating SMAP soil moisture using a machine learning algorithm over the Awash River basin, Ethiopia", PLOS ONE, 18(1): e0279895
5 De Zan & Gomba, "Vegetation and soil moisture inversion from SAR closure phases: First experiments and results.", Remote Sensing of Environment (2018)
6 Karamvasis & Karathanassi, "Soil moisture estimation from Sentinel-1 interferometric observations over arid regions"
7 Trearty, R., et al., in prep.