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Satellite soil moisture for drought assessment and early-warning in water limited regions

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Many parametric or index-based drought risk financing instruments are based on in situ or satellite-derived rainfall, temperature and/or vegetation health data. However, an underlying issue is that indices often do not perfectly correlate to the actual losses experienced by the policy holders. Remotely sensed soil moisture (SM) can help decrease basis risk in parametric drought insurance through complementary and/or improved parameters and variables in existing models, or as a stand-alone model. Here, we demonstrate the added value of satellite-based soil moisture for drought assessment and early-warning yield prediction for Senegal and Morocco.

SM from both ESA CCI and EUMETSAT HSAF were used in combination with rainfall from CHIRPS and SM2Rain, and Copernicus Global Land Service NDVI to assess droughts through a convergence of evidence approach. Satellite-based soil moisture, and the retrieved rainfall through SM2Rain, provided early indicators of drought onset compared to NDVI. They also corresponded to major droughts and impacts as obtained from public reports of the African Risk Capacity (ARC) and existing models used for parametric drought insurance, such as the Water Requirement Satisfactory index (WRSI).

Furthermore, rainfall, SM and NDVI were used to predict yield obtained from the Food and Agriculture Organization of the United Nations (FAO). SM showed a high predictive skill early in the growing season, where negative early season soil moisture anomalies often lead to lower yields. NDVI showed more predictive power later in the growing season. Combining satellite-based SM with precipitation and NDVI in multiple linear regression improved yield prediction. Especially at the start of the season SM improved predictions, with the ability to explain 60% (groundnut), 63% (millet), 76% (sorghum) and 67% (maize) of yield variability. These findings are particularly relevant for parametric drought insurance, because an earlier detection of drought conditions enables earlier payouts, which then help to mitigate the development of shocks into serious crises with often long-lasting socioeconomic effects.

Based on the analysis a yield deficiency indicator was developed. Strong spatial correspondence was found between the yield deficiency indicator and the WRSI as reported by the African Risk Capacity reports. For example, for millet in Senegal for the drought 2019 strong yield deficiencies in the provinces of Ziguinchor, Fattick, Kaolack and Kaffrine and moderate deficiencies in Thies, Louga and Tambacounda were found. Which corresponded to low WRSI as reported by the African Risk Capacity in its end of season report of 2019. This analysis demonstrates the high added-value of satellite-based soil moisture for anticipatory drought risk financing and early warning systems.