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Satellite soil moisture for yield prediction in water limited regions

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Accurate and reliable early warning systems can support anticipatory disaster risk financing which can be more cost effective than post-disaster emergency response. One of the challenges in anticipatory disaster risk financing is basis risk, as a result of data and model uncertainty. The increasing availability of Earth Observation (EO) data provides the opportunity to develop shadow models or include different variables in early warning systems and weather index insurance. Especially of interest is the early indication of climate impacts on agricultural production. Traditionally, crop and yield prediction models use meteorological data such as precipitation and temperature, or optical based indicators such as Normalized Difference Vegetation Index (NDVI), for yield prediction. In recent years, soil moisture has gained popularity for yield prediction as it controls the water availability for plants.

Here, we will present the use of different satellite-based rainfall and soil moisture products, in combination with NDVI, to develop a yield deficiency indicator over two water limited regions. An analysis for Senegal and Morocco is performed at the national level using yield data of four major crops from the Food and Agriculture Organization of the United Nations. Freely available EO datasets for rainfall, soil moisture, root zone soil moisture and NDVI were used. All datasets were spatially resampled to a 0.1° grid, temporally aggregated to monthly anomalies and finally detrended and standardized. First, regression analysis with yearly yield was performed per EO dataset for single months. For this, EO datasets where aggregated over areas where the specific crop was grown. Secondly, based on these results multiple linear regression was performed using the months and variables with the highest explanatory power. The multiple linear regression was used to provide spatially varying yield predictions by trading time for space. The spatial predictions were validated using sub-national yield data from Senegal.

The analysis demonstrates the added-value of satellite soil moisture for early yield prediction. Both in Senegal and Morocco rainfall and soil moisture showed a high predictive skill early in the growing season: negative early season soil moisture anomalies often

lead to low yield. NDVI showed more predictive power later in the growing season. For example, in Morocco soil moisture at the start of the season can already explain 56% of the variability in yield. NDVI can explain 80% of the yield, however this is at the end of the growing season. Combining anomalies of the optimal months based on the different variables in multiple linear regression improved yield prediction. Again, including NDVI led to higher predictive power, at the cost of early warning. This analysis shows very clearly that soil moisture can be a valuable tool for anticipatory drought risk financing and early warning systems.