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Crop yield monitoring in the Sahel using root zone soil moisture anomalies derived from SMOS soil moisture data assimilation

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West Africa is greatly vulnerable, especially in terms of food sustainability. Mainly based on rainfed agriculture, the high variability of the rainy season strongly impacts the crop production driven by the soil water availability in the soil. To monitor this water availability, classical methods are based on daily precipitation measurements. However, the raingauge network suffers from the poor network density in Africa (1/10000km2). Alternatively, real-time satellite-derived precipitations can be used, but they are known to suffer from large uncertainties which produce significant error on crop yield estimations.

The present study proposes to use root soil moisture rather than precipitation to evaluate crop yield variations. First, a local analysis of the spatiotemporal impact of water deficit on millet crop production in Niger was done, from in-situ soil moisture measurements (AMMA-CATCH/OZCAR (French Critical Zone exploration network)) and in-situ millet yield survey. Crop yield measurements were obtained for 10 villages located in the Niamey region from 2005 to 2012. The mean production (over 8 years) is 690 kg/ha, and ranges from 381 to 872 kg/ha during this period. Various statistical relationships based on soil moisture estimates were tested, and the most promising one (R>0.9) linked the 30-cm soil moisture anomalies from mid-August to mid-September (grain filling period) to the crop yield anomalies.

Based on this local study, it was proposed to derive regional statistical relationships using 30-cm soil moisture maps over West Africa. The selected approach was to use a simple hydrological model, the Antecedent Precipitation Index (API), forced by real-time satellite-based precipitation (CMORPH, PERSIANN, TRMM3B42). To reduce uncertainties related to the quality of real-time rainfall satellite products, SMOS soil moisture measurements were assimilated into the API model through a Particular Filter algorithm. Then, obtained soil moisture anomalies were compared to 17 years of crop yield estimates from the FAOSTAT database (1998-2014). Results showed that the 30-cm soil moisture anomalies explained 89% of the crop yield variation in Niger, 72% in Burkina Faso, 82% in Mali and 84% in Senegal.