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Agricultural productivity through the lens of hydrologic function

Anna Scaini (1,2), David Zamora (3), Fernando Jaramillo (1,2), John Livsey (1,2), Stefano Manzoni (1,2)

(1) Department of Physical Geography, Stockholm University, Stockholm, Sweden, (2) Bolin Centre for Climate Research, Stockholm, Sweden, (3) Civil and Agricultural Department, Universidad Nacional de Colombia, Bogotá, Colombia

Human activities are altering the global water cycle in multiple ways. Both landscape-driven hydrologic changes (land cover and land use intensification, irrigation, hydropower development), and climate-driven hydrologic changes (temperature and precipitation changes) can be identified. While catchment-scale runoff is expected to decrease due to irrigation, and increase due to certain types of land use intensification, many studies have shown complex and contrasting anthropogenic effects. For example, studies integrating land use-land cover changes to watershed-scale responses in paired catchments show that climate drivers cannot alone explain hydrological changes and thus the land use changes are likely to be important.

In this analysis, we focus on how the hydrologic state of agricultural catchments is related to agricultural productivity and water use efficiency. We follow a data-based approach, and test a conceptual framework using data from 150 catchments in the US. The framework consists in comparing broad metrics of agricultural efficiency and productivity to hydrologic state variables (like rainfall-runoff ratios) across a range of agricultural settings and climates. We hypothesize that agricultural efficiency is related to hydrologic function, a measure of the capacity of the system to transfer inputs into outputs, and that this relation may constrain agricultural output under climatic changes. We use the yield-to-fertilizer use ratio, a proxy for nutrient use efficiency, as an assessment for agricultural performance. In the same way, we employ the runoff ratio as a broad metric of hydrological performance. We calculate these ratios for the major US catchments at annual temporal scales. Agricultural metrics are calculated using yield data available through the National Agricultural Statistics Services (NASS) database from USDA, and county-level fertilizer input data. County data are then masked to the watershed database and compared to the long-term discharge data, both data types available through the Global Runoff Data Centre (World Meteorological Organization). Rainfall and temperature data are available through the Climatic Research Unit (CRU) database (University of East Anglia, UK). The proposed conceptual framework is assessed by testing correlations between nutrient use efficiency and runoff ratio.