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The connections between rainfall regimes and crop production in semi-arid and sub-humid climates: an example from Ethiopia

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Temporal distribution of rainfall is a crucial climatic factor that controls seasonal biomass productivity and crop yield, particularly in tropical semi-arid and sub-humid climates where agriculture is primarily rainfed. This study explores the relationship between temporal rainfall attributes – seasonality, timing, and duration of the wet season -- and cereal crop productivity in the rainfed agriculture (RFA) areas of Ethiopia using the CHIRPS rainfall. In the first step, we determined the rainfall seasonality using an entropy-based dimensionless seasonality index (DSI), defined the dates of onset and cessation from the cumulative rainfall anomalies, computed the duration of the wet season, and assessed the anomalies and trends in these attributes and their associations to El Niño–Southern Oscillation (ENSO) over the period 1981-2010. In the second step, we analyzed the correlation between de-trended total cereal production (the sum of maize, teff, sorghum, wheat, barley, millet, oats, and rice productions) during the main growing season (April - September), and anomalies of the temporal rainfall attributes during 1995-2010. We also estimated the effects of variabilities in the rainfall timing attributes on cereal production using a univariate linear regression model. We show that rainfall in the northern RFA areas of Ethiopia is highly seasonal and unimodal whereas the southern and southeastern parts are characterized by low seasonality and a bimodal regime. Anomalies in the onset dates and DSI are meaningfully related with ENSO: 54% of late-onset events and 50% of negative DSI anomalies during 1981-2010 were observed in El Niño years. The response of crop production to changes in the temporal rainfall attributes depends on the rainfall regime. In regions with unimodal and highly seasonal rainfall regimes, we found that cereal production is mostly correlated with the onset (median $\rho=-0.39$) and duration ($\rho=0.24$) of the rainy season, whereas in regions with semi-arid bimodal rainfall regime, cereal production is more correlated with the rainfall seasonality ($\rho=0.21$). The median cereal production losses due to late-onset and shorter duration over the RFA areas are estimated to be □1.5% and 1.1% per 5-day period respectively, but much larger losses of up to 12% can be experienced in some regions.