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Soil Moisture as an Estimator for Crop Yield in Germany

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Annual crop yield depends on various factors such as soil properties, management decisions, and meteorological conditions. Unfavorable weather conditions, e.g. droughts, have the potential to drastically diminish crop yield in rain-fed agriculture. For example, the drought in 2003 caused direct losses of 1.5 billion EUR only in Germany. Predicting crop yields allows to mitigate negative effects of weather extremes which are assumed to occur more often in the future due to climate change.

A standard approach in economics is to predict the impact of climate change on agriculture as a function of temperature and precipitation. This approach has been developed further using concepts like growing degree days. Other econometric models use nonlinear functions of heat or vapor pressure deficit. However, none of these approaches uses soil moisture to predict crop yield. We hypothesize that soil moisture is a better indicator to explain stress on plant growth than estimations based on precipitation and temperature. This is the case because the latter variables do not explicitly account for the available water content in the root zone, which is the primary source of water supply for plant growth.

In this study, a reduced form panel approach is applied to estimate a multivariate econometric production function for the years 1999 to 2010. Annual crop yield data of various crops on the administrative district level serve as depending variables. The explanatory variable of major interest is the Soil Moisture Index (SMI), which quantifies anomalies in root zone soil moisture. The SMI is computed by the mesoscale Hydrological Model (mHM, www.ufz.de/mhm). The index represents the monthly soil water quantile at a 4 km^2 grid resolution covering entire Germany. A reduced model approach is suitable because the SMI is the result of a stochastic weather process and therefore can be considered exogenous. For the ease of interpretation a linear functionality is preferred. Meteorological, phenological, geological, agronomic, and socio-economic variables are also considered to extend the model in order to reveal the proper causal relation.

First results show that dry as well as wet extremes of SMI have a negative impact on crop yield for winter wheat. This indicates that soil moisture has at least a limiting affect on crop production.