

Cross-scale crop modeling and input uncertainties

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Background

The quality of data on climate, soils and agricultural management in the tropics is generally low or data is scarce. This data is needed as input for process-based crop models which are important tools in climate change impact studies, studies on mitigation and adaptation options and food security studies.

Process-based crop models simulate crop development and growth and operate at different time and spatial scales. By default, global models work with monthly climate data and coarse soil data from global soil maps on a regular grid. These grid cells can be aggregated to larger units e.g. sub-national units, countries or world regions but will not always reflect local agronomy, soils and climate. In contrast point-scale models work on daily or sub-daily time steps, with local soil and climate data on a much smaller resolution. Aggregating these to larger areas requires very detailed parameterization and local data for a lot of locations which are difficult to obtain, especially in tropical agricultural areas. Both types of model differ in their input data, their model components and model parameters. However, both aim at reflecting the farming system, agricultural management techniques, crop yields and food production properly for a certain location. Depending on the model and input data chosen the results for a given output variable (e.g. crop yield) might differ due to different model sensitivity and modeled processes. While one could argue that the more detailed the model input the better, this might not be true considering the scale the model operates on and the scale of the output variable.

The central questions of this study are:

- 1) Does more detailed information on soil, climate and management help estimating historical crop yields? Which input data is necessary to estimate national historical crop yield with crop models at different scales?
- 2) What drives the yield simulations in both models and how do the two models perform differently under different input data?

Material & Methods

We analyse the effect of two different climate, soil and management data sets on national crop yield simulations with two crop models for a case study of maize yields in Burkina Faso. Grid-cell maize yields are simulated using the point crop model APSIM (Keating *et al.*, 2003; McCown *et al.*, 1996) and the global agricultural model LPJmL (Bondeau *et al.*, 2007; Gerten *et al.*, 2004). They are aggregated to sub-national units and to national mean maize yields for the period 1971-2000. Maize is one of the most important crops in Burkina Faso in terms of production together with sorghum and millet.

Soil data is taken from the Harmonized World Soil Database v 1.2 from FAO-IIASA (Nachtergaele *et al.*, 2012) and the Africa soil profiles database including 12.000 profiles in sub-Saharan Africa (Leenaars, 2012). From these data sets we derive four soil parameters: the lower limit water content or permanent wilting point, the drained upper limit water content or field capacity, the saturated water content and the bulk density depending on the soil type. Daily temperature, precipitation and radiation is derived from two climate data sets: using a weather generator to generate daily data from monthly

time series 1901-2006 from the Climatic Research Unit (Mitchell & Jones, 2005) and daily climate data from the time series 1958-2001 from the WATCH Forcing data (Weedon *et al.*, 2010). Sowing/planting dates are taken from a global crop calendar reporting a national average sowing date for maize (MIRCA2000) (Portmann *et al.*, 2010) and calculated from a sowing date rule based on daily rainfall as in Dodd & Jolliffe (2001).

Prior to the simulation period we calibrate a management intensity factor for LPJmL and the nitrogen fertilizer application rate for APSIM for each of the input settings to reflect the average maize yields for the 10-years period 1961-1970. The models are initialized with these parameters which are kept constant over the simulation period 1971-2000. Initial soil characteristics and characteristics of the maize variety are chosen to represent local conditions (Buerkert *et al.*, 2001; Buerkert *et al.*, 2002; Kambire *et al.*, 2010; Wey *et al.*, 1998).

We statistically test the maize yields simulated with different soil and climate data:

- against national de-trended observed maize yields in 1971-2000 (FAO, 2011) to detect agreement in inter-annual variability of yields
- against sub-national maize yields (Monfreda *et al.*, 2008; You *et al.*, 2010) to detect agreement in the spatial variability across the country
- between the two crop models for a basic understanding of differences in modeled processes and model settings.

Results & Discussion

Both models are able to simulate the spatial variability in maize yields observed in Burkina Faso, which follows a NE-SW yield gradient from dry zones to wet zones.

The models differ in their response to climate and soil and therefore simulate different maize yields in certain environments, however the maize yields up-scaled to a long-term national average level in the low-input agricultural systems of Burkina Faso are similar.

The models are only sensitive to parameter settings and input data if they are related to a factor limiting crop growth and development; in the case of Burkina Faso that seems to be soil fertility and nutrient availability in the first place, another limiting factor in the absence of nutrient-stress is rainfall and radiation

Available global climate, soil and management data sets differ for Burkina Faso and therefore the choice of input data and underlying uncertainties need to be considered in crop modeling

Key References

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