What level of detail in input data and crop models is required for food production studies in West Africa?

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1 Introduction

Modeling agro-ecosystems aims at describing and understanding relevant plant processes and their interactions with abiotic and biotic factors and future behavior of the system. Crop models are common tools for this task but various uncertainties exist; in the model design and model parameters, and maybe even more important in input data. While one might argue that the higher the resolution of the model input the better and the less uncertain the model output, this might not be true as models are developed for different scales and the aggregation level of the model output differs.

2 Materials and Methods

We analyze the performance of the point-scale model APSIM and the global scale model LPJmL in the maize-growing areas of Burkina Faso. We test the models´ response to different levels of input information from little to detailed information on soil, climate and agricultural management and compare the models´ ability to represent the observed spatial and temporal variability in crop yields. We simulate grid-cell and national maize yields between 1961 and 2000 with APSIM and LPJmL. We compare simulated maize yields with different input data for climate, soil and sowing dates (Table 1). Up to eight combinations of different input settings are possible for the two crop models. Even though some settings might not be very practicable for an actual model application they represent the upper and lower level of information / resolution of input data available for the study area.

Table 1. The level of information in soil, climate and management data used in APSIM and LPJmL simulations.

Level of information	Climate	Soil	Management - Sowing Date
low	CRU TS3.0; Simple, grid-cell specific monthly climate data (Mitchell & Jones, 2005)	FAO/IIASA-v1.2; Multiple, grid-cell specific soils from global soil map (Nachtergaele *et al.*, 2012)	MIRCA2000; Single national sowing date from global crop calendar (Portmann *et al.*, 2010)
high	WFD; Grid-cell specific daily climate data (Weedon *et al.*, 2011)	AfSIS; Multiple, grid-cell specific soils from African soil database (Leenaars, 2012)	Variable; Multiple, grid-cell specific sowing date from a climatic rule based on rainfall (Dodd & Jolliffe, 2001)

3 Results – Discussion

We found that the level of information of different soil, climate and management data sets influences the simulated crop yields in both models. The uncertainty in input data propagates to uncertainty in simulated maize yields and production. The country's annual maize production of about 500,000 tones is underestimated by 1-17 % in LPJmL simulations, underestimated in most APSIM simulations by 3-46 % but overestimated by 15 % in APSIM simulations with daily climate, local soil information and variable sowing dates.
However, the difference between models can be larger than between input data in particular when assessing the spatial variability of crop yields (see how the points and triangles in Figure 1 group together). Further, the agreement between simulated and observed spatial variability is higher than between simulated and observed temporal variability (not shown) due to abrupt changes in national mean yields from 1987 to 1991 in Burkina Faso which cannot be explained by rainfall variability like in the previous decades and therefore cannot be simulated from the two crop models. The most accurate estimation of spatial variability in maize yields with APSIM is possible with daily climate information and uniform sowing dates i.e. with detailed information on climate data but little information on sowing dates (R=0.65) (WFD-MIRCA, Fig. 1). In contrast the most accurate estimation of spatial variability in maize yields with LPJmL is possible with monthly climate information and uniform sowing dates i.e. with little information on both, climate and

sowing dates (R=0.80) (CRU-MIRCA, Fig. 1). APSIM and LPJmL tend to overestimate and underestimate, respectively the spatial variability of maize yields. Soil data that determines water holding capacities is less important for the skill of the two crop models to reproduce the observed spatial variability (see how simulations with different soils group together in Fig. 1) even though the spatial variation in the two soil data sets differs to a larger extent than the spatial variation in the two climate data sets and is of similar magnitude as in the two sowing date settings. However soil fertility levels and soil processes in the crop models such as NO3 leaching from the root zone are important and partly explain the deviations between both models and between simulations with monthly and climate data.

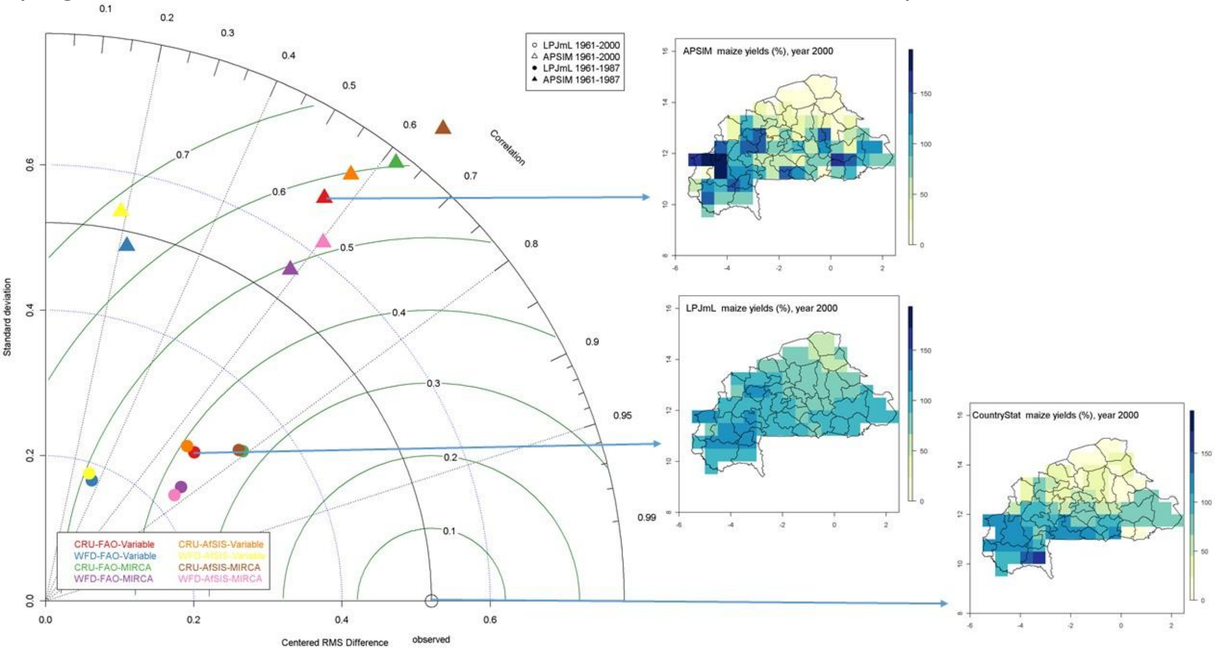

Fig. 1. Taylor diagram displaying a statistical comparison with observations of 16 model estimates (two crop models by eight input data sets) of grid-cell yields in 2000 (A). The closer the coloured symbols to the unfilled circle on the x-axes the higher the correlation and the smaller the root mean square error. The solid green and dotted blue contours indicate the centred root-mean-square (RMS) difference and the standard deviation. The three maps show the spatial pattern of observed and simulated grid-cell maize yields for one example input setting (please note that units in the maps are different from the units of the data used to plot the diagram).

Our results and conclusions are valid for the low-input agricultural systems in Burkina Faso and other parts of West Africa with low yield levels compared to other world regions and they depend on the limitations to crop growth specific to this study area. We expect changes in spatial and temporal variability with increasing yield levels which might lead to different conclusions on the ability of the two crop models to simulate observed yield levels.

4 Conclusions

The findings of our study highlight the importance of scale and model choice and show that the most detailed input data does not necessarily improve model performance. Further we inform about the magnitude of uncertainty in simulated maize yields and production arising from different input data and crop models which will assist identifying the level of detail in input data and interpretation of results in future modeling studies in West Africa.

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