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Review

What role can crop models play in supporting climate change adaptation decisions to enhance food security in Sub-Saharan Africa?

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ABSTRACT

In Sub-Saharan Africa (SSA) efforts to achieve food security are challenged by poverty, low soil fertility, unequal global trade relationships, population growth, weak institutions and infrastructure, and future climate changes and variability. Crop models are the primary tools available to assess the impacts of climate change and other drivers on crop productivity, a key aspect of food security. This review examines their role and suitability for informing climate change adaptation decisions in the SSA context. Perception of climate change is rarely the only factor leading to changed farming practices, with labor availability, recent extreme climatic events (floods or droughts) and access to formal credit, constituting the main factors farmers respond to. Further, farmers' socio-economic status constrains the adaptations they make in response to these drivers. Many crop modeling studies reviewed investigating climate change adaptation currently do not capture many of these drivers, adaptations nor constraints. However, a number of areas were identified where crop models could aid in adaptations decision-making. For instance, crop models can: test which changes farmers are making are most robust to future climate scenarios; be used as tools for experimentation in farmer organizations to build farmer capacity, minimize risk and empower farmers; be linked to economic, farm systems or livestock models to widen the scope of potential impacts, adaptations and farmer constraints considered, and to probe the interactions of cropping systems with other systems; and evaluate various indicators of resilience. Finally it is suggested that one of the greatest benefits of linking crop models across disciplines and in integrated assessment frameworks may be providing a platform to bring specialists and stakeholders from diverse backgrounds together to assess climate change adaptation options to enhance food security in SSA.

Contents

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1. Introduction

Hunger is prevalent in Sub-Saharan Africa (SSA) and the region faces considerable challenges to achieving food security due to a complex mix of factors that include widespread poverty, high dependence on degraded natural resources, unequal global trade relationships, population growth, and weak institutions and infrastructure (Brown, 2009; von Grebmer et al., 2008; Wheeler and von Braun, 2013). Food security encompasses food availability (crop productivity is the key determinant but it also includes food waste), food access (reflects incomes and the ability to purchase food, as well as market factors), stability of access and availability (influenced by climate variability and prevalence of extreme events) and food utilization (linked to the nutritional quality and safety of food) (FAO, 2002; FAO, IFAD and WFP, 2013). In the semi-subsistence conditions typical in many regions of SSA, crop productivity has an important influence on food security (Ringler et al., 2011). It both contributes directly to household food availability, as well as influencing incomes, local food prices and farmers' ability to invest in other cropping, farming and livelihood activities (Vermeulen et al., 2012; Jalloh et al., 2013). As climate change and variability are expected to produce negative impacts on crop growth, it can be expected to further challenge efforts to achieve household and regional food security (Easterling et al., 2007; Goklany, 2007; Meinke et al., 2009; Mertz et al., 2010; Wheeler and von Braun, 2013).

Despite the complexity and uncertainty associated with farming systems and food security, there is an urgent need for science to support adaptation decision making at all levels (Cash et al., 2003; McIntyre, 2009; FARA, 2013). Crop models are the primary tool available to assess the impacts of climate change on crop productivity, a key determinant of both food availability and access, as cropping represents an important income source in many parts of SSA. As such, they will have an important role to play in describing how cropping systems respond to key drivers. It is largely recognized that they must be improved to better account for the impacts of elevated CO_2 concentrations, high temperatures at critical crop growth stages, changing pest and weed dynamics (Soussana et al., 2010), better quantify model uncertainty (Challinor et al., 2009) and be better calibrated and validated for local conditions. Rötter et al. (2011) present a good summary of the present challenges to improve crop models. What is less clear from the literature is how these tools should be used in informing climate change adaptation decisions beyond the prediction of climate and standard management impacts on yield.

A starting place could be looking for evidence of farmer's actual adaptations, key drivers and constraints (Howden et al., 2013), as documented in social sciences literature (Mertz et al., 2009, 2011; Gbetibouo et al., 2010; Bryan et al., 2009) to investigate if crop models adequately represent reality and to identify potential synergies between the contextual nature of these studies and the predictive power of crop simulation models to better inform and support adaptation decisions. Some options that can impact crop yields may not be easily testable in current approaches to the application of crop models, and adaptations will need to be evaluated in a broader framework which integrates crop models with expertise and knowledge from outside the realm of modelers and agronomists. However, there are two key reasons for trying to bring these two ways of knowing about agricultural adaptations closer together. Pragmatically, the successful uptake by farmers of expert generated adaptations options will be more likely if they are involved and their input incorporated from the beginning. Secondly, adaptation science, in which crop models produce quantitative information, is powerful in that it generates knowledge on the set of feasible future options for landuse change (Hulme, 2011; Weichselgartner and Kasperson, 2010). Excluding farmers from the process of knowledge creation while including those who fund research has implications for whose value system shapes scientific endeavors and ultimately the direction of agricultural development (Hulme, 2011; Sarewitz, 2004).

This paper proposes to review the crop modeling and social sciences literature on adaptation studies in SSA to attempt to answer the following questions: (1) What are the main drivers of change farmers respond to and what factors enable adapted cropping systems? (2) How does the current application of crop models in adaptation studies match with the reality of farmer changes in cropping systems? and (3) How can knowledge and methodologies from crop modeling and the social sciences be combined to lead to actionable adaptation knowledge?

2. Sub-Saharan African context: climate change predictions and need for adaptation

2.1. Climate change forecasts for SSA

There is a consensus among the 21 CMIP3 GCMs that median temperatures increases across Saharan, East, West and Southern Africa will be between 3 °C and 4 °C by the end of the century relative to the period 1980–1999 for June–July–August for the A1B SRES scenario (Christensen et al., 2007). Rainfall evolution will vary between regions. Predictions for a decrease in mean precipitation for Southern Africa and an increased average in East Africa are considered robust across models (Christensen et al., 2007) and in agreement with Hulme et al. (2001), However, there is no model consensus for changes in West Africa's precipitation amounts with divergence in predicted changes between an 18% decrease to an increase of 16% for the same emissions scenario and period. The lack of agreement between GCMs is related to their coarse resolution and the complex bio-physical factors that determine precipitation in West Africa (Christensen et al., 2007). Extreme events such as droughts and prolonged periods of high temperatures are more likely and their prediction more robust than changes in mean precipitation (Christensen et al., 2007; Challinor et al., 2007; Field et al., 2012).

2.2. Climate change impacts on food security

Despite agriculture's prominent role in national economies across SSA, large parts are currently net grain importers (e.g. West Africa) (Brown, 2009). This results in lower grain prices on domestic markets and a crude assumption is that this translates into improved food security for net food buyers. Climate change is expected to contribute to higher world market prices for cereals which would make food less accessible for net importers and buyers (Wheeler and von Braun, 2013). In terms of expenditures, many smallholder farmers are net buyers as they often purchase grain during the hunger season at a higher price and are forced to sell at harvest when prices are lowest- or even before harvest to obtain credit and buy food (Brown, 2009). Further, repeated extreme events like droughts or heat waves reduce poor people's ability to cope with crop failures or maintain food security as their savings, productive assets and human capital are more frequently diminished (Devereux, 2001; Thornton et al., 2011). Globally higher food prices resulting from negative climate impacts on key crops, are predicted to result in a 1.3% decrease in food availability across SSA by the middle of the century (Ringler et al., 2011). However, there is likely to be great variability in how this decline in access will be distributed across regions and groups (Ringler et al., 2011). In a study to identify vulnerable hot spots of food insecurity in SSA in 2030, Liu et al. (2008) found that the impacts of climate