Research Application Summary

Applying large area modelling approach to assess the impacts of climate variability and change: Informing policy and adaptation - A review

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Abstract

This review highlights some pertinent methodologies in dealing with uncertainty in climate projections and how crop models are increasingly used to support decisions at various levels to guide food security policy formulation, management and regulations. Crop models are increasingly being used on a large spatial scale, often coupled with general circulation models (GCMs) to assess the impact of climate variability and the effect of El Niño/Southern Oscillation (ENSO) on agricultural production and food security. Therefore, using climate change projections and crop models in order to understand the impacts of climate change on rainfed agriculture, especially on cereals (maize and sorghum), is very helpful to policy makers. Policy makers need information on the potential impact of climate change for the next few decades, as they are developing plans that will affect different sectors. In conclusion, this review demonstrates the need for calibrating and validating different crop models to attain the standard climate change impact assessment methodology for the East Africa region.

Key words: Climate change, climate variability, crop yield, large area modelling, policy

Résumé

Cette étude met en évidence certaines méthodologies pertinentes pour faire face à l'incertitude dans les projections climatiques et comment les modèles de culture sont de plus en plus utilisés pour appuyer les décisions à différents niveaux pour guider la formulation de la politique de sécurité alimentaire, la gestion et la réglementation. Les modèles de culture sont de plus en plus utilisés sur une grande échelle spatiale, souvent couplés aux modèles généraux de circulation (MGC) pour évaluer l'impact de la variabilité du climat et l'effet d'Oscillation australe /El Niño (ENSO) sur la production agricole et la

sécurité alimentaire. Par conséquent, l'utilisation des projections de changements climatiques et des modèles de cultures afin de comprendre les impacts du changement climatique sur l'agriculture pluviale, en particulier les céréales (maïs et sorgho), est très utile pour les décideurs. Les décideurs ont besoin d'informations sur l'impact potentiel du changement climatique pour les prochaines décennies, car ils élaborent des plans qui auront une incidence sur différents secteurs. En conclusion, cette étude démontre la nécessité pour la calibration et la validation des différents modèles de cultures pour atteindre la méthodologie standard d'évaluation de l'impact du changement climatique pour la région de l'Afrique de l'Est.

Mots clés: Changement climatique, variabilité du climat, rendement des cultures, modélisation de vastes régions, politique

Background

Crop model application for predicting yields over large areas is limited by the difficulty in obtaining data on local conditions or crop characteristics at any given point. Climate variability has been, and continues to be, the principal source of fluctuations in food production and is of serious concern in Tanzania. The high dependence of agriculture on rainfall in Tanzania makes it highly vulnerable to changes in climate, climate variability, seasonal shifts, and rainfall patterns. Crop simulation models can provide good simulations of crop productivity under the impact of variable weather in a range of soil, water and crop management choices (Cooper *et al*., 2008). Studies (e.g. IFPRI, 2009; Thornton *et al*., 2009) that have assessed the impacts of climate change in Africa have used large-scale GCMs in combination with crop models which provide very little information that is of practical use at country level to decision- makers on the precise extent of the impacts of climate change. Despite large uncertainty in these studies, there are several robust conclusions for policy makers that agriculture everywhere in Eastern Africa runs some risk of being negatively affected by climate change. Moreover, the preceding authors agree that using a crop model to predict yields over a region, as opposed to the plot scale, necessarily requires some assumptions about the aggregation of input parameters due to the heterogeneity of the larger region.

Literature Summary

Gregory and Ingram (2008) review the information available from a range of studies examining climate and yield records at different scales and over different time periods using a wide range of statistical and process-based modeling approaches. Moreover, Ingram *et al*. (2008) identifies the need of moving

the agronomic research from the traditional plot scale to larger spatial and temporal scales as the latter are appropriate for food security policy and climate change issues. They contend that while agronomic research is still important, alone it cannot address all issues and therefore it is recommended that integrated approaches to adaptation research are imperative as they are much more likely to address the information need of policy makers. Adaptation and coping with climate variability and change are key themes in current global climate discussions and policy initiatives, though, literature on adaptation in East Africa and Tanzania in particular appears to be still limited.

Recent studies (Challinor *et al*., 2009 and Ruane *et al.,* 2012) use GLAM and DSSAT respectively. While on the one hand, Challinor *(ibid)* observe that large-area crop modelling should simulate the impacts of climate variability and change on crops in a process-based fashion using the output from climate models directly (i.e. without any downscaling), on the other hand, Ruane *et al*. (2012) not only underscore the importance of identifying farm-level information to reduce the uncertainties, but also show the extent to which a single calibrated model configuration may shed light on many other related farming systems. Ruane (*ibid*) contend that even in regions with strong field trial sites, the application of point models to a broader region for aggregation must consider the prime sources of farm-level uncertainty, either through the end-to-end simulation of multiple farm configurations or through a combination of sensitivity studies at a sentinel location and regional surveys of farm practices and environmental conditions.

From the foregoing it is evident that there has been no agreement among the modelers community on which methodology/ approach to adopt when dealing with the spatial or large area modeling. Alternatives have ranged from obtaining and adopting appropriate downscaling methods for generating finely gridded data to spatial interpolation procedures in developing high-resolution baseline climate scenarios. Meanwhile, Rosenzweig *et al.* (2012) acknowledge lack of quality data in data-sparse regions such as eastern Africa, and thus suggest an investigation in the potential of satellite and remote sensing to fill gaps in data. They, furthermore, propose intercomparison procedures that would scale field-level outputs up to country and regional scales. For example, comparison of the techniques used in GLAM (Challinor *et al*., 2009), DSSAT (IFPRI, 2009) and CLICROP (Arndt *et al.,* 2011) may give a direction on how

best to undertake simulations at the country level such as Tanzania. Therefore, for reliable model outcomes there is need to develop a simulation framework which takes into account the spatial and temporal variability in information on soils, cultivars, sowing dates and crop management. This paper has reviewed methodologies for impacts assessments of climate variability and change, with reference to crop simulation models and the improvement required to the methods for the application to large areas.

Research Application

This review illustrates how the combination of crop simulation models and GCMs may assist with policy decisions in relation to climate change. The approach offers great potential to expand our ability to make good agricultural management decisions, not only for the current climate variability, but for the anticipated climate changes of the future. Crop simulation models can provide valuable information on the potential value of specific adaptation mechanisms either in terms of phenology or crop management. Options also exist to undertake analysis under a range of future climate scenarios that incorporate data from a range of GCMs. This is important because outputs can be used to guide decisions regarding investment priorities in order to minimise the negative impacts of climate variability and prevent the destructive impacts on food production due to future changes in climate. Despite the uncertainty in the GCMs, the review indicate an urgent need of developing a basis for selecting the most suitable climate scenario and/or aggregation method for climate change impact studies in the region. Limitations of the proposed approach relate somehow to our incomplete knowledge of physiological processes, the availability and accuracy of data. Moreover, large-area crop models do not currently simulate the non-climatic determinants of crop yield, factors which also need considerations if they are to provide useful insights for future decision making in a rapidly changing climate.

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