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Research Application Summary

Modelling the potential impact of climate change on sorghum and cowpea production in semi-arid areas of Kenya using the agricultural production systems simulator (APSIM)

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Abstract

Managing crop production risks associated with inter-annual climate variability and climate change has received insignificant attention in the semi-arid areas of Kenya. Against this backdrop, the potential impact of climate change on sorghum *(Sorghum bicolor*) and cowpea (*Vigna unguiculata*) production in the semi-arid areas of Kenya will be assessed using the Agricultural Production System Simulator (APSIM). The study will employ participatory tools in the use of APSIM model to identify risks and cropping system improvement options and designing cropping strategies for field experimentation. The field experiments will be conducted in Makueni district of Eastern Province, Kenya. Initially, a farmers' workshop will be held to gather information on farmers' experience with recent climatic changes and possible causes, effect on current farming systems, coping and adaption strategies to current management practices. Farm households' perceptions of risks, options to reduce climatic risks, specific vulnerabilities of the current cropping systems and coping strategies will be documented using semi-structured interviews during farm surveys. This is in addition to establishing the socio-economic and agricultural systems setting of the smallholder farmers. Potential technologies to address the anticipated negative impacts of climate change in respect of cowpea (legume) and sorghum (cereal) cropping system will jointly be identified with the farmers and a subset of tactical adaptation options identified. The options will initially be tested on-station in the first year and on farm in the second year. The on station experiments will be conducted for two (four seasons) years to model sorghum and cowpea growth and soil-water, soil organic carbon and nitrogen dynamics in a legume-cereal cropping system. The APSIM model will be validated to simulate both the legume and cereal components of the cropping system. The integrity of the simulated system will be evaluated by comparing the simulated performance of the crops with actual experimental crop data and by exploring other facets such as water use, denitrification and leaching. It is envisioned that the APSIM model will allow for quick exploration of production outcomes of a range of management alternatives under a range of climatic scenarios (realized or predicted), and for a range of soil conditions. This is in addition to provision of valuable information for evaluating a wide range of cropping system options.

Key words: Agricultural system simulator, climate change, Kenya, modelling, semi-arid lands

Résumé

La gestion des risques de production agricole associés à la variabilité interannuelle du climat et au changement climatique a reçu moins d' attention dans les zones semi-arides du Kenya. Dans ce contexte, l'impact potentiel du changement climatique sur le sorgho *(Sorghum bicolor*) et sur la production du niébé (*Vigna unguiculata*) dans les zones semi-arides du Kenya sera évalué en utilisant le simulateur de système de production agricole (APSIM). L'étude fera appel à des outils participatifs dans l'utilisation du modèle APSIM pour identifier les risques et les possibilités d'amélioration du système cultural et la conception des stratégies de culture pour une expérimentation sur terrain. Les expériences sur terrain seront menées dans le district de Makueni de la Province Orientale, au Kenya. Au départ, un atelier d'agriculteurs sera organisé afin de recueillir des informations sur l'expérience des agriculteurs avec les récents changements climatiques et les causes possibles, l'effet sur les systèmes agricoles actuels, les stratégies de débrouillage et d'adaptation aux pratiques de gestion actuelles. Les perceptions des risques dans les ménages des agriculteurs, des options pour réduire les risques climatiques, les vulnérabilités spécifiques des systèmes agricoles actuels et les stratégies d'adaptation seront documentées au moyen de questionnaires semi-structurés au cours des enquêtes agricoles. Il s'agit en plus d'établir la création des systèmes socio-économiques et agricoles des petits agriculteurs. Les technologies possibles pour remédier aux effets négatifs attendus du changement climatique à l'égard du système de culture du niébé (légumineuse) et du sorgho (céréale) seront conjointement identifiées avec les agriculteurs et un sous-ensemble des options d'adaptation tactiques identifiées. Les options seront d'abord testées en station pendant la première année et à la ferme pendant la deuxième année. Les expériences sur station seront réalisées pour deux ans (quatre saisons) pour modeler la croissance du sorgho et du niébé, et l'eau du sol, le carbone organique du sol et la dynamique de l'azote dans le système de culture légumineuse-céréale. Le modèle APSIM sera validé pour simuler les composants des légumineuses et des céréales du système agricole. L'intégrité du système de simulation sera évaluée en comparant la performance simulée des cultures avec des données actuelles des cultures expérimentales et en explorant d'autres facettes, comme l'utilisation de l'eau, la dénitrification et le lessivage. Il est prévu que le modèle APSIM permettra l'exploration rapide des résultats de production d'une gamme de solutions de gestion en vertu d'un éventail de scénarios climatiques (réalisés ou prévus), et pour une gamme de conditions de sol. Cela s'ajoute à la fourniture de renseignements précieux pour l'évaluation d'un large éventail d'options du système de culture.

Mots clés: Simulateur de système agricole, changement climatique, Kenya, modélisation, terres semi-arides

Background

Farmers experience climate change not as a shifting means but climatic variations. Climatic variability at all of its time-scales is therefore, a current challenge to development. Rainfall variability tends to be the dominant source of livelihood risk in smallholder rainfed agriculture, particularly in drier environments (Zimmeman and Carter, 2003). Erratic rainfall patterns and heterogeneous distribution of soils, in the semi arid areas of Kenya, lead to recurring site- and season- specificity of crop growth environments (Republic of Kenya, 2006). Much of the challenge in these areas relates to the inability of farmers or policy makers to anticipate and make proactive adjustments to climate variability (Okwach, 2002; Republic of Kenya, 2006). Furthermore, developing flexible, proactive strategies for managing year-to-year climate variations within farming communities and the institutions that interface with them, using advance climate information is arguably the most concrete step that the agricultural enterprise can take to build resilience to long-term changes in the global climate system. System modeling is a valuable tool under such conditions to support field research by evaluating management options for the specific conditions of site and season, and provide a means to extrapolate research results in time and space thus providing a more robust analysis of long-term productivity, climatic risk and environmental sustainability of tested management options.Regionally adapted and tested crop models allow one to quickly explore the production outcomes of a range of management alternatives under a range of climatic scenarios (realized or predicted), and for a range of soil conditions.

Simulation models, such as the Agricultural Production Systems Simulator Model (APSIM), can provide valuable information to researchers and farmers to evaluate a wide range of cropping system options. The APSIM model can also accommodate interactions among climate, soil fertility, and crop- and residue-management practices (Keating *et al.*, 2003).An emerging area of application of APSIM has been adding value to seasonal climate forecasting. The APSIM model will thus provide an opportunity to explore not only today's issues of agronomic management but also the longer-term prospects for sustaining agricultural production in the semi-arid areas of Kenya and thus improve capabilities for extrapolation and permit scenario analyses of alternative management strategies in terms of production and economics, risks and consequences for the resource and environment. It is therefore hypothesized that use of the APSIM model will be a powerful tool for predicting the impact of climate change on soil and agronomic factors of sorghum and cowpea growth and development, soil water, C, N and P dynamics in the agricultural systems of the semi-arid areas of Kenya.

Literature Summary

In many parts of the world, climate change is one of the biggest risk factors impacting on agricultural systems performance and management. The major impacts of climate change are predicted to be in the agricultural sector in sub-Saharan Africa because of the region's characteristic high heat and low precipitation (Kurukulasuriya and Mendelsohn, 2006). The overall adverse weather events that are likely due to the projected climate change will likely include; severe socio-economic impacts such as shortages of food, water, energy and other essential basic commodities, as well as long-term food insecurity. Though a few studies have been conducted to assess the impact of climate change on agriculture in developing countries (Deressa *et al.*, 2005; Gbetibouo and Hassan, 2005; Seo *et al.*, 2005), there is a dearth of literature on this impact in Kenya. The reports of the Intergovernmental Panel on Climate Change (IPCC, 2001) and the international scientific literature in general contain virtually no discussion of the potential vulnerability of this enormous arid region to climate change.

The application of crop simulation models to study the potential impact of climate change and climate variability provides a direct link between models, agrometeorology and the concerns of the society. The rationale for using system modeling for agrotechnology transfer in the face of environmental heterogeneity is relevant to the use of seasonal forecasts for climate risk management (Deressa *et al.*, 2005). Climate variability adds a time dimension to environmental heterogeneity. As climate change deals with future issues, the use of General Circulation Models (GCMs) and crop simulation models provides a more scientific approach to study the impact of climate change on agricultural production and world food security compared to surveys.This approach will presumably auger well with farmers who, in the recent past, have expressed pervasive dissatisfaction with research and development aimed at providing the "quick technological fix", and have increasingly become interested in the development of research methodologies that address the long-term economic and ecological issues (Carberry *et al.*, 2004; Dimes, 2005). The use of such models, with long runs (30 years or more) of daily climatic data thus provides a quick and much less costly opportunity of 'accelerated learning' compared with the more traditional multi-location, multi-seasonal and multi-factorial field trails (Carberry *et al.,* 2004).

Sorghum and cowpea are the major crops widely grown by the resource-poor farmers in the semi arid parts of Kenya for subsistence and as a source of income (Machiara, 2004). Sorghum is ranked third among cereals grown in Kenya. It is grown principally in the often drought-prone marginal agricultural areas of Eastern, Nyanza and Coast Provinces. Consumption of sorghum is similarly localized to these growing areas (Government of Kenya, 2002). Cowpea is grown in combination with cereals such as maize and sorghum, perennial legumes such as pigeon peas and root crops such as cassava and sweet potatoes (Government of Kenya, 2002). Its grain is rich in protein and digestible carbohydrate and its energy content is nearly equal to that of cereal grains (Mukhtar and Singh, 2004).With Kenya's human population ever on the increase, pressure for farming land will continue to displace agriculture into marginal lands where sorghum is often more adapted than maize or cassava. Sorghum is tolerant to drought and nutrient-deficient soils. It also stays greener than other crops when water-stressed, and therefore continues to photosynthesize during droughts hence the crop of choice to fight nutritional and food insecurity in Africa (Jones *et al.*, 2001). Cowpea also thrives well in dry environments with as little as 300 mm of rainfall. The deep root systems of cowpea help stabilize the soil and the canopy covers the ground thus preserving moisture. These traits are particularly important in the drier regions, where moisture is at a premium and the soil is fragile and subject to wind erosion (Jones *et al.*, 2001).

Study Description

The study is being conducted at Kambi ya Mawe, Makueni Division, a semi-arid area of Kenya with a bimodal (long and short rainfall season) rainfall distribution. The research will employ a participatory approach to assess knowledge on and appropriate interventions to climate change. Farmer workshops will be held to determine the current levels of knowledge regarding climate change, cropping system vulnerability, coping strategies and local perspective of likely adaptation options. Assessment of a wide range of options, including sorghum-cowpea rotations and intercrops, planting dates, fertilizer management, and farm-level resource allocation will be explored. The researchers and farmers will identify separately potential technologies to address the anticipated negative impacts of climate change. Using various group dynamic tools such as sub-group discussion, visual tools and brainstorming sessions, a range of both tactical and strategic interventions will be identified for joint experimentation on-station and on-farm.In tandem with field experiments, farm surveys using semi-structured interviews involving households, to be obtained through stratified sampling, will be implemented for two years (four successive cropping seasons) to establish the socio-economic and agricultural systems setting of the smallholder farmers in the semi-arid areas. Focus group meetings will be conducted on site to identify the cropping system determinants. This will include identification of the major decision rules used by farmers. The current skill of predictability of relevant climate variables as a basis for understanding cropping system response to predictable components of climate will be gathered and documented. The field experiments to provide data for modelling crop growth and development, and soil-water, soil organic carbon and nitrogen dynamics in a legume-cereal cropping system will be conducted at the research stations and on farmers' fields, using the Mother/Baby trial design laid out in a randomized complete block design. Recommended agronomic practices for sorghum and cowpea growth will be applied.A subset of eight tactical coping/adaptation options identified in the workshop will be tested initially on-station in the first year. The treatments will be designed, data collection procedures agreed upon and action plans drawn for implementation of field experiments. Prior to harvest of the short rain season and long rain season crops, a field day will be organized for the participating farmers and taken through the process of experimental setup and management. The farmers will then be asked to pick specific cropping systems to practice on their farms.

Research Application

Integrating crop simulation models with dynamic seasonal climatic forecasts offers a robust means of adding value to seasonal climatic forecasts for agriculture management. The results of the study will thus enhance knowledge on management of the impacts of climate change on cropping systems at the farm scale and potential adaptations to anticipated climate change. This is in addition to better understanding of the effects of climate change for informed crop management decisions such as selection of crops, residue management and sowing dates.Additionally, system modeling will be a valuable tool in supporting field research by evaluating management options for the specific conditions of site and season, and provide a means to extrapolate research results in time and space. This will thus provide a more robust analysis of long-term productivity, climatic risk and environmental sustainability of tested management options. It also provides a quick and much less costly opportunity of 'accelerated learning' compared with the more traditional multi-location, multi-seasonal and multi-factorial field trails.

Recommendation

Preliminary results of the current study indicate that farmers were knowledgeable on the impacts of climate change on crop production and had devised coping strategies. Consequently and borrowing from their experience and indigenous technical knowledge, as exhibited during workshop deliberations and field surveys, sorghum-legume cropping systems (monocropping, rotation and intercropping) under three tillage systems (Tied ridges, ploughing and ripping) was jointly agreed upon and recommended for field experimentation and modeling with APSIM.

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