Ex ante assessment of climate change adaptation strategies in resource-poor countries: study cases from East Africa

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Abstract

Sub-Saharan Africa (SSA) is predicted to experience considerable negative impacts of climate change. The IPCC Fourth Assessment emphasizes that adaptation strategies are essential. Addressing adaptation in the context of small-scale, semi-subsistence agriculture raises special challenges. An important constraint is that data demands are high, because site-specific bio-physical and economic data are required. The development of relatively simple methods for ex ante evaluation of adaptation at the household and system levels is therefore needed. We test a new approach to ex ante impact assessment that produces site-specific results that can also be aggregated for regional analysis. The methodology uses the kinds of data that are more often available in resource-poor countries. The stochastic approach integrates socio-economic and bio-physical data on farmers' land allocation, production, input and output use. Spatially heterogeneous characteristics of the agricultural system regarding resources and productivity are analyzed and compared for both current and predicted future climate. Possible adaptation strategies are then assessed for their capability to reduce the adverse effects of climate change. We apply the methodology to some contrasting study areas in East Africa. After characterizing the current system with actual climate data, the effects of a perturbed climate are analyzed and a variety of adaptation strategies tested. Despite the limitations, the new approach offers a flexible framework for evaluating adaptation strategies using scarce data of resource-poor countries in SSA and other parts of the world. It allows a rapid integrative analysis for timely advice to policymakers and for exploration of technology and policy options.

Keywords: adaptation, climate change, **s**weetpotato, potato, East Africa, impact assessment.

Introduction

The changing climate is exacerbating existing vulnerabilities of the poorest people who depend on semi-subsistence agriculture for their survival (Slingo *et al.*, 2005; IPCC, 2007). Sub-Saharan Africa (SSA) in particular is predicted to experience considerable negative impacts of climate change (e.g., Thornton *et al.*, 2006). The IPCC Fourth Assessment emphasizes that adaptation strategies are essential and these must be developed within the broader economic development policy context (IPCC, 2007). Addressing adaptation in the context of small-scale, semi-subsistence agriculture in SSA raises special challenges that cannot be addressed adequately by the approaches taken thus far in most studies (Adger, 2003). Most of the existing research has focused on impacts of climate change and adaptation to climate change in the agricultures of industrialized countries. In the relatively few studies conducted in Africa, agricultural research has either focused on individual crops (e.g., Hijmans, 2003; Jones and Thornton, 2003), has used aggregated data and models (e.g., Winters *et al.*, 1999; Mendelsohn *et al.*, 2000), or used statistical analysis too general to be useful for site-specific adaptation strategies (e.g., Kurukulasuriya and Mendelsohn, 2006). Some recent studies at the sub-continental scale for Africa indicate the importance of assessing the effects of climate change and possible adaptation strategies at the agricultural system and/or household level, rather than focusing on aggregated results that hide a large amount of variability (Burke *et al.*, 2009; Thornton *et al.*, 2009). One of the important constraints to carrying out this type of research at this scale level is that the data demands are generally high, because site-specific bio-physical and economic data are required, typically obtained from costly multi-year farm-level surveys. At the spatial resolution required, another drawback is that projections of climate change and simulations of the effects on crop and livestock productivity come with a high degree of variability and associated uncertainties depending on the climate models and methodologies used. The development and application of relatively simple and reliable enough methods for *ex ante* evaluation of adaptation strategies at the household and agricultural system levels are needed to provide timely assessments of the potential impacts in the context of climate change.

Methods

This paper summarizes and applies a new approach to *ex ante* impact assessment that produces locally useful, site-specific results that can also be aggregated for regional policy analysis. The methodology makes use of the kinds of data that are more often available, especially in resource-poor countries. The stochastic approach uses and integrates available socio-economic and bio-physical data on farmers' land use allocation, production and input and output use. Spatially heterogeneous characteristics of the agricultural system regarding resources and productivity are analyzed and compared for both current climate conditions and projected climate changes. A variety of possible adaptation strategies is then assessed for their capability to overcome or reduce the adverse effects of climate change (or to exploit positive projections). A static expected profit maximization model is used to characterize the opportunity cost of adaptation (Antle and Valdivia, 2006). The model can represent the impact of climate change as the "compensating variation", i.e., the loss in income that producers experience relative to the base climate scenario. Alternatively, the economic feasibility of adoption of a certain adaptation strategy or policy can be expressed (Claessens *et al.*, 2009). Details of the methodology can be found in Antle and Valdivia (2006) and Claessens *et al.* (2009). For the climate change projections we used data from the IPCC Fourth Assessment report (2007) and downscaling techniques as described in Thornton *et al.*, 2009. Crop growth simulation models as currently implemented in version 4.0 of the Decision Support System for Agrotechnology Transfer (DSSAT, ICASA, 2007) were used. For the livestock component of the Vihiga system (see next section), an empirical equation relating changes in feed quality with milk yield was used (Claessens *et al.*, 2009). The inclusion of the RUMINANT livestock model (e.g., Thornton and Herrero, 2001) in the methodology is foreseen.

Results and discussion

We apply the methodology to the mixed crop-livestock systems of Vihiga district in western Kenya and the Machakos area in eastern Kenya (Table 1). After characterizing the current agricultural system with current climate data, the effects of a perturbed climate on bio-physical and economic indicators are analyzed and a variety of adaptation strategies (agricultural technologies in this case) are tested.

Table 1. General setting of study areas

Study area	Altitude	Temperature	Precipitation	Crops
Vihiga	1300-1500 m	14°-32°C	1800-2000 mm	maize, beans, Napier grass, sweetpotato
Machakos	400-2100 m	15°-25°C	500-1300 mm	maize, beans, sorghum, vegetables, fruits, cassava

For the Machakos area, the effects of projected climate change to 2050 on farmers' income are shown in Figure 1. More than 80% of the farmers are expected to have losses as a result of climate change. Two adaptation strategies (an improved, heat tolerant maize variety and the introduction of sweetpotato in the area) are explored. Both technologies are predicted to only partly offset the adverse effects of climate change. In contrast to the Machakos area, Vihiga and the highlands of western Kenya in general are predicted to possibly benefit from climate change in terms of crop productivity. A 35% yield increase from the maize-beans sub-system was simulated and dual-purpose sweetpotato was treated as an essentially new crop with varying (but realistic, on-farm) yields. Figure 2 shows that, without climate change, between 52 and 85% of the farmers would economically benefit from adoption of dual-purpose sweetpotato, depending on average yield and assumptions made (Claessens *et al.*, 2009). The effects of climate change on the results of the analysis are negligible. Vihiga could be an example of an area where farmers can possible benefit from climate change whereby, at the regional scale level, adverse effects on crop productivity elsewhere could be offset.

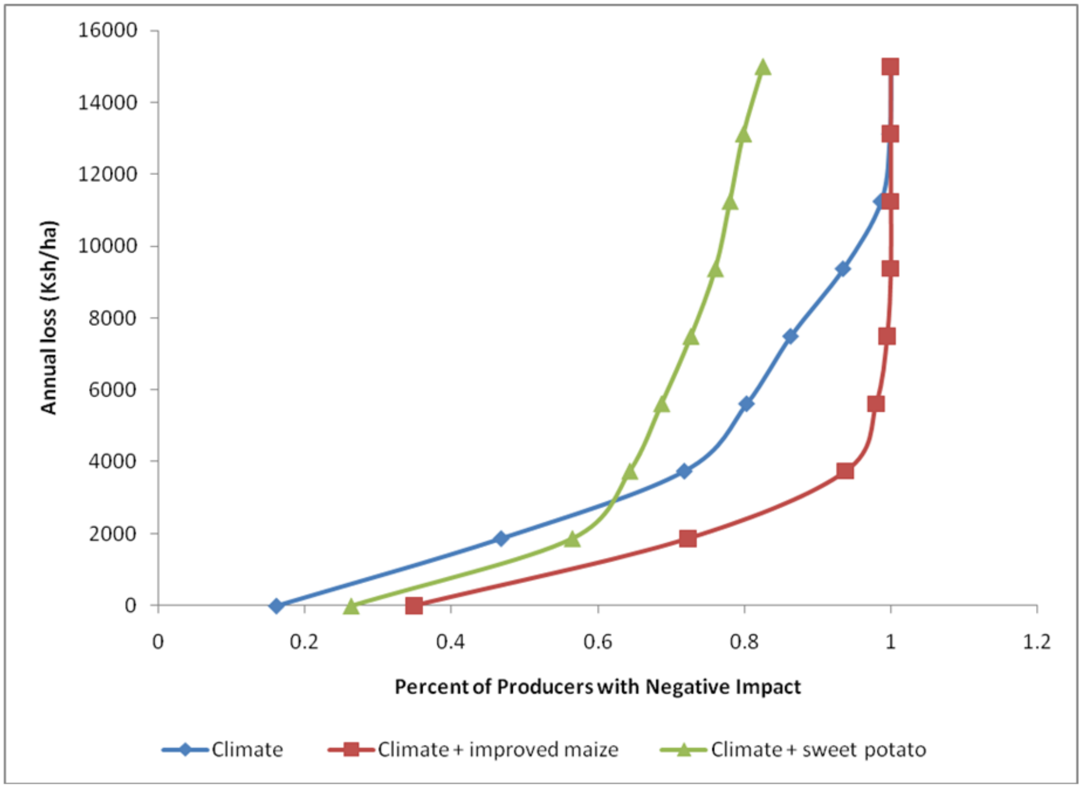

Figure 1. Impact of climate change and adaptation strategies on farmers in Machakos, Kenya

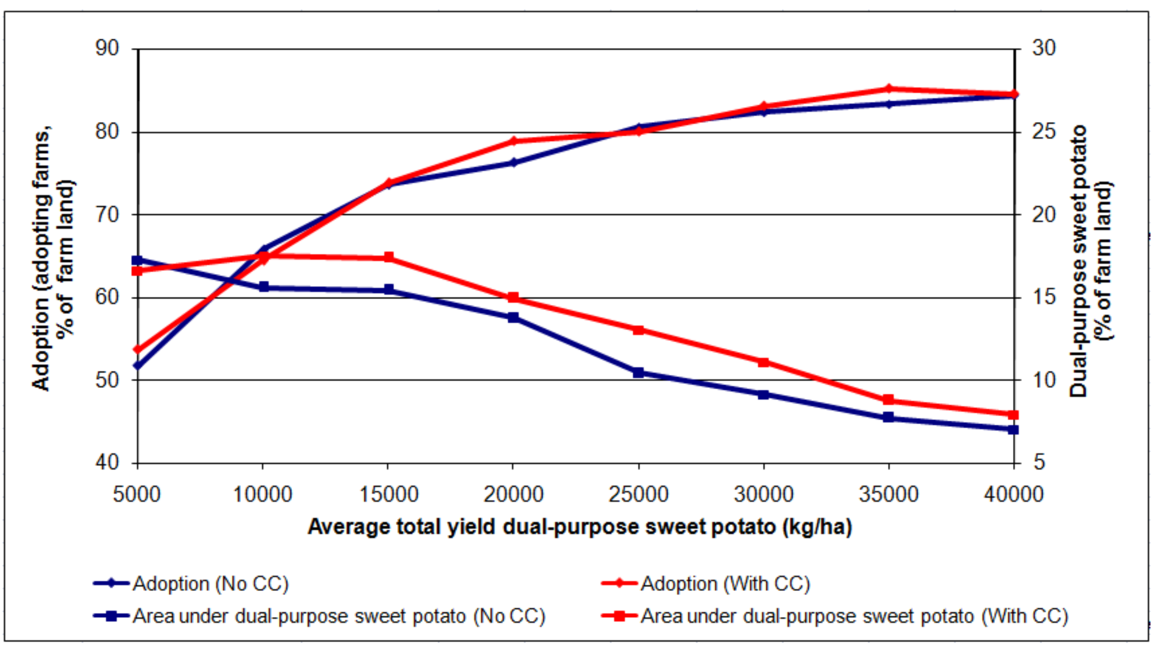

Figure 2. Adoption of dual-purpose sweetpotato in Vihiga and the effects of climate change

Conclusion

The two contrasting examples presented in this paper clearly call for the need of assessing climate change adaptation strategies at the agricultural system and household levels. Despite the limitations, the methodology presented in this paper, offers a flexible framework for evaluating adaptation strategies in the context of climate change using scarce data of resource-poor countries in SSA and other parts of the world. It allows a rapid integrative analysis for timely advice to policymakers, extension workers and for exploration of technology and policy options.

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