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Climate variability, food security and poverty: Agent-based assessment of policy options for farm households in Northern Ghana

Tesfamicheal Wossen [a,b,*], *Thomas Berger* [a]

[a] *Institute of Agricultural Economics and Social Sciences in the Tropics and Subtropics (490d), Hohenheim University, Germany*
[b] *International Center for Tropical Agriculture (CIAT), Viet Nam*

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ABSTRACT

According to the majority of regional climate projections, Sub-Saharan Africa (SSA) will likely become warmer in the next decades and rainfall patterns will substantially shift. Understanding the effect of climate variability on food security and poverty and identifying effective adaptation measures in the context of subsistence agriculture is imperative to ensure food security now and in the future. This article presents a micro-level simulation study that was undertaken for Northern Ghana, building on the approach and data developed within a research project of the CGIAR Challenge Programme on Water and Food. The study applied agent-based modelling to analyse how adaptation affects the distribution of household food security and poverty under current climate and price variability. Specifically, we examined the effectiveness of policy interventions related to the promotion of agricultural credit and off-farm employment opportunities. Our simulation experiments suggest that both climate and price variability have a pronounced negative effect on household welfare. Moreover, we found substantial difference in the poverty and food security status of households due to climate and price variability. Provision of agricultural credit and access to off-farm employment are found to be highly effective policy entry points that deserve more empirical research.

1. Introduction

Although current data and models used for climate impact research still contain large uncertainties, most studies undertaken so far suggest that climate variability will aggravate the existing vulnerability of smallholder farmers in SSA (Nelson et al., 2009; Parry et al., 2004; Knox et al., 2012; Cooper et al., 2008). For the Volta basin in West Africa, for example, Jung and Kunstmann (2007) expect on average a 1.2–1.3 °C increase in temperature and a 5% increase in annual rainfall, with high spatial variation ranging from −20% to 50%. For agricultural production, it is usually more important when exactly it rains rather than yearly averages. In this respect, Jung and Kunstmann's simulations of future climate suggest a reduction of rainfall of up to 70% at the onset of the rainy season, when farmers are most dependent on adequate soil moisture to begin sowing their crops. These changes in future rainfall patterns might therefore have highly negative impacts on food security and poverty levels in a region that is already struggling with low

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[*] *Corresponding author at*: International Center for Tropical Agriculture (CIAT), Viet Nam. Tel.: +84 947612431.
E-mail address: mikte22@yahoo.com (T. Wossen).

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agricultural productivity, little investment, and limited ability to cope with shocks. In a systematic mapping exercise for the entire African continent, Thornton et al. (2008) overlaid hotspots of climate hazards and hotspots of current vulnerability to identify geographical areas that appear most threatened by the emerging reality of climate change. Accordingly, the arid to semi-arid parts of Northern Ghana, with their mixed rain-fed crop-livestock systems, are marked as high-risk areas demanding immediate and sustained research and development efforts.

As Arribas et al. (2011) stated: "*There is no better way of adapting to climate change tomorrow than adapting to climate variability today*". A useful way to prepare for uncertain future climate conditions is therefore to learn from current climate variability by simulating its impacts on crop yields and food security and by testing suitable policy interventions to improve resilience of smallholder farmers (Cooper et al., 2008). In this regard, process-based models with biophysical and socio-economic components will be crucial to assess the impacts of climate variability on crop productivity, a key determinant of food availability. Previous studies by Di Falco et al. (2011a), Swallow (2005), Hatch and Smith (1997), Hansen et al. (1988), Wheeler and von Braun (2013), Thornton et al. (2009), Briner et al. (2012), Bobojonov and Hassan (2014) have documented that climate variability poses threats to food security through its adverse effect on crop productivity. However, as indicated by Hertel et al. (2010), productivity changes alone are a flawed indicator for the full adversity of climate variability, as the overall effect of climate variability on food security depends on the magnitude of productivity shocks, the rate and speed of productivity induced market price changes, the market position of households (net buyer vs. net seller) and the extent of market integration of farm households. If appropriately targeted policy interventions that can offset the potential adverse effects of climate variability are to be designed, it is crucial to analyse these effects by considering heterogeneity in policy responsiveness among farm households.

Despite the progress in integrated assessment of climate variability effects, most climate-related crop simulation studies to date have focused on crop yields only, giving little attention to the linkages between crop and livestock sub-systems and the key role that livestock plays in coping-strategies of many smallholder households in SSA (Thornton et al., 2009; Claessens et al., 2012). Other studies have used macro level models (e.g., Mideksa, 2010) or Ricardian analysis, which assumes constant product and factor prices (Mendelsohn and Reinsborough, 2007). The aforementioned studies on the impact of climate variability hide a lot of heterogeneity, as smallholder farmers differ in access to resources, poverty levels, and their adaptive capacity to climate variability. The inherent aggregate nature of these studies therefore makes it very difficult to provide insights in terms of effective adaptation strategies at the household level (Di Falco et al., 2011b). As such, addressing the effectiveness of adaptation policies by capturing heterogeneity in terms of adaptive capacity will be crucial.

In addressing the challenges of climate variability, new assessments and fresh ideas are therefore needed to identify appropriate development and policy interventions that could better support current responses to climate variability that strengthen the adaptive capacity of smallholder farmers in the future. In this regard, micro-level assessments that take into account heterogeneity and interactions among smallholder farmers will be crucial to capturing the full distribution of constraints, opportunities, and responses of smallholder agriculture (Berger and Troost, 2013). One such methodology is the use of an Agent-based Model (ABM),[1] as it offers the ability to explicitly simulate decision-making processes while considering high degrees of heterogeneity, nonlinearity, interaction and feedbacks, and emergence (Berger, 2001). In this paper, we present a stochastic ABM that is capable of simulating the effects of different adaptation options by capturing the dynamic changes in climate and prices, as well as the dynamic adaptive process of different farm households to the impacts of these changes.

The applied ABM of this study is able to represent uncertainty in production and consumption decision-making processes, is flexible enough for climate impact assessment, captures causes and outcomes of adaptation processes due to its recursive nature, and assesses trade-offs and synergies between food production, consumption (and hence food security) and environmental impacts resulting from the use of adaptation options. Furthermore, the model is very strong in the quantification of consequences from variations across different households in terms of resource and wealth dynamics, adaptive capacity, production and consumption preference, knowledge and learning ability. Since the model captures farm level costs explicitly, adaptation to climate variability occurs endogenously. Furthermore, by incorporating interactions and feedbacks between the socio-economic and biophysical processes, the model is able to capture the biophysical (climate variability) impacts on socio-economic process (food security, poverty, etc.).

The ABM was applied and validated for Northern Ghana, building on the approach and data developed within a research project of the Consultative Group on International Agricultural Research (CGIAR) Challenge Programme on Water & Food (CPWF). The approach employed in this ABM captures non-separable[2] household decisions, livestock management, crop growth, policy responses, and innovation diffusion. As food security is a critical issue, the ABM employed in this study gives special consideration to the quantification and analysis of food security outcomes, a critical policy issue in Ghana.

Specially, this study aims at addressing three broad relevant questions regarding the impact of climate and price variability. First, by quantifying climate and price variability effects at agent level, it examines to what extent and for whom

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[1] In this study, we used agent-based and multi-agent-based interchangeably.

[2] Assumption of separability in production and consumption implies that a household's decision regarding production is not affected by consumption preference (Schreinemachers and Berger, 2011). However, the assumption of separability in consumption and production is misleading, since climate-induced changes in production require farm households to adapt their consumption behaviour by shifting towards goods that are less sensitive to climate variability, which clearly affects welfare level. Moreover, a non-separable modelling setup is required since rural households in many developing countries are both producers and consumers with prevalent market imperfections (Sadoulet and de Janvry, 1995; Mideksa, 2010).