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Exploring future changes in smallholder farming systems by linking socio-economic scenarios with regional and household models

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ABSTRACT

We explore how smallholder agricultural systems in the Kenyan highlands might intensify and/or diversify in the future under a range of socio-economic scenarios. Data from approximately 3000 households were analyzed and farming systems characterized. Plausible socio-economic scenarios of how Kenya might evolve, and their potential impacts on the agricultural sector, were developed with a range of stakeholders. We study how different types of farming systems might increase or diminish in importance under different scenarios using a land-use model sensitive to prices, opportunity cost of land and labour, and other variables. We then use a household model to determine the types of enterprises in which different types of households might engage under different socio-economic conditions. Trajectories of intensification, diversification, and stagnation for different farming systems are identified. Diversification with cash crops is found to be a key intensification strategy as farm size decreases and labour costs increase. Dairy expansion, while important for some trajectories, is mostly viable when land available is not a constraint, mainly due to the need for planting fodders at the expense of cropland areas. We discuss the results in relation to induced innovation theories of intensification. We outline how the methodology employed could be used for integrating global and regional change assessments with local-level studies on farming options, adaptation to global change, and upscaling of social, environmental and economic impacts of agricultural development investments and interventions.

1. Introduction

The role that smallholder agricultural producers are likely to play in global food production and food security in the coming decades is highly uncertain. In many parts of the tropics, particularly sub-Saharan Africa, smallholder production is critical to the food security of the poor. Industrialization of agricultural production is occurring in many places, largely in response to burgeoning demand for food. Some smallholders may be able to seize the opportunities that exist and develop, and operate as sustainable and profitable smallholder agricultural production systems (Herrero et al., 2010; Thornton, 2010). Whether large numbers of smallholders will be able to do this in a carbon-constrained global economy and in an environment characterized by a changing climate and by increased climatic variability, will depend on many things such as increasing regulation, building social protection and strengthening links to urban areas, and substantial investment in agriculture (Wiggins, 2009; World Bank, 2009). Understanding how smallholder systems may evolve in the future is critical if poverty alleviation and food security goals are to be achieved.

In many parts of the tropics, particularly Africa and Asia, smallholders operate mixed crop–livestock systems, which integrate different enterprises on the farm; crops provide food for consumption and for cash sales, as well as residues to feed

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livestock, and livestock provide draft power to cultivate the land and manure to fertilize the soil. These systems are often highly diversified, and the synergies between cropping and livestock keeping offer real opportunities for raising productivity and increasing resource use efficiency (Herrero et al., 2010). Whether these systems can increase household incomes and enhance the availability of and access to food for rapidly increasing urban populations in the coming years, while at the same time maintaining environmental services, is a question of considerable importance.

Studying this question requires some consideration of theories of change. A general model of agricultural intensification originated with Boserup (1965), who described it as an endogenous process responding to increased population pressure. As the ratio of land to population decreases, farmers are induced to adopt technologies that raise returns to land at the expense of a higher input of labour. The direct causal factor is relative factor price changes, in accordance with the theory of induced innovation. At low human population densities, production systems are extensive, with high availability of land and few direct crop–livestock interactions. Population increases lead to increases in demand for crop and livestock products, which in turn increases the value of manure and feed resources and other inputs, leading to increased crop and livestock productivity. As population increases yet further, systems intensify through specialization or diversification in production as relative values of land, labour and capital continue to change: fertilizer replaces manure, tractors replace draft animals, concentrate feeds replace crop residues, and cash crops replace food crops (Baltenweck et al., 2003).

Other factors can also play a significant role in determining the nature and evolution of crop–livestock systems (McIntire et al., 1992). In humid areas with a high disease challenge for large ruminants, crop–livestock interactions are likely to be limited owing to lower livestock densities. Other factors include economic opportunities, cultural preferences, climatic variability (e.g. droughts that lead to livestock losses), lack of capital to purchase animals, and labour bottlenecks at some periods of the year that may prevent farmers from adopting technologies such as draft power (Powell and Williams, 1993). Nevertheless, common patterns of both the drivers and the outcomes of intensification of tropical crop–livestock systems can be identified. Choice of crops and livestock interventions have been shown to be at least partly dependent on relative labour and land costs and on market access, at a wide range of sites throughout the tropics (Baltenweck et al., 2003). Furthermore, in the same study education level, market access and human population densities were shown to be major drivers of crop–livestock systems intensification (Baltenweck et al., 2003).

At the same time, alongside these larger scale drivers of farm development, the ability of smallholders to implement new practices is further determined by intrinsic system properties that may act as modifiers to their adoption. Farmers' objectives and the rules governing labour allocation and gender differentiation in the household are examples (Thornton and Herrero, 2001; Waithaka et al., 2006). Such factors are not necessarily related to spatial or macro-economic drivers; they therefore need to be studied at the farm household level.

To understand the evolution of smallholder crop–livestock systems, we propose that these systems should be examined at multiple levels by analyzing and linking macro-level socio-economic drivers, regional-level land-use patterns, and micro-level household dynamics and strategies. Complementary methods should be used that appropriately reflect the key dynamics of each of these levels (Cash et al., 2006). The significant complexity and uncertainty associated with the interacting biophysical and socio-economic dimensions of agricultural systems should also be taken into account by using a multiple scenarios approach, informed by relevant stakeholder perspectives (Biggs et al., 2007). Additionally, the interactions of smallholder systems with changing contexts should be simulated and discussed iteratively with key stakeholders to explore longer-term evolutionary pathways (Kinzig, 2006).

In this paper we provide an example of this multi-level, multi-scenario, evolutionary framework for the analysis of smallholder systems, using complementary modelling approaches and harnessing relevant stakeholder perspectives. We build on the work of Baltenweck et al. (2003) and Herrero et al. (2007a) by studying the potential household-level impacts of crop–livestock intensification using crop–dairy systems data obtained from longitudinal monitoring of representative case studies and key informants (extension officers and policy makers) from Kenya. The objective of the study was to generate socio-economic development scenarios as to how crop–livestock systems in the highlands of Kenya might evolve in the next two decades and evaluate these plausible, alternative futures through a multi-level modelling framework that includes (a) the development of scenarios providing different socio-economic conditions at the country level and above; (b) a regional land-use change analysis projecting the spatial distribution of farming systems into the future; and (c) the use of a household model to evaluate the results of the spatial analysis at the farm level, allowing for a deeper understanding of internal farm dynamics. We conclude with a discussion of the value of multi-scale, stakeholder-generated, iterative analyses in evaluating synergies and trade-offs in farming systems, particularly related to the dynamics of global change in tropical smallholder systems.

2. Materials and methods

2.1. Area of study

The study area, which covers the highlands of Kenya is, approximately 65,000 km^2 spread over 34 districts (Fig. 1). The human population in the area has increased from approximately 21 to 26 million people in the last several years (Kenya Government, 2002; Kenya National Bureau of Statistics, 2010), representing about 68% of the Kenyan human population. Most people in the study area live in the rural areas. The region in Kenya is representative of many regions in sub-Saharan Africa with a similar climate and with similar scenarios for their socio-economic development, e.g. potentially increased economic growth in the rural areas with connections to the rapidly developing urban centres while still uncertainty remains about the supportiveness of the political and policy environment for these developments (e.g. southern Uganda). As such results of this analysis in terms of the driving factors behind changes and the constraints limiting economic growth in the smallholder farming sector can be seen as representative for large areas in the east African highlands.

The soils are predominantly deep, well-drained strongly weathered tropical soils (Nitosols and Andosols) and suited for growing tea, coffee, and wheat as cash crops. Maize and beans are the predominant staple food crops. Compared with the lowlands, the highlands of Kenya have a more favourable agro-ecology for dairy and crop production and better market opportunities because of the high population numbers with a tradition for consuming milk (Staal et al., 2001; Waithaka et al., 2000).

The area has a diversity of farming systems, varying from subsistence farmers, farmers with major dairy activities, intensified farmers with limited dairy activities, and export cash crop farmers with limited or major dairy activities. Production in the Kenyan highlands is often based on the close integration of dairy cattle into the crop production (Bebe et al., 2003). In the study area,