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Agricultural intensification and policy interventions: Exploring plausible futures for smallholder farmers in Southern Mali

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A B S T R A C T

Assessing how livelihoods in rural sub-Saharan Africa might change given future trends in socio-economic and biophysical conditions helps to identify and direct effective efforts towards poverty reduction. Based on existing literature, hypothetical changes in farmer practices and policy interventions were described and used to build five contrasting scenarios towards the year 2027. A simulation framework was developed to assess food self-sufficiency and income per capita now and in the future for a representative village of 99 households in Southern Mali. In the current situation, 26% of the farms were food self-sufficient and above the 1.9 US$ day^{-1} poverty line. This percentage would fall to 13% in the "Business as usual" scenario. In the "Dairy development" scenario, with intensification of livestock production and support to the milk sector, 27% of farms would be food self-sufficient and non-poor. Additional policy interventions targeting family planning and job creation outside agriculture would be needed to improve both household food self-sufficiency and income per capita. In this optimistic scenario, 77% of the farms would be non-poor and food self-sufficient in 2027. Additional programs to promote Integrated Pest Management, small-scale mechanization and mineral fertilizer on traditional cereals could allow a drastic increase in productivity and would lift 94% of the farm population out of poverty. Considering the entire heterogeneous farm population was crucial to accurately assess pathways out of poverty. Our study stresses the need for a strategic and multi-sectoral combination of interventions to improve livelihoods.

1. Introduction

The human population in Africa is growing faster than in other continents and will account for more than half of the growth in the world's population between now and 2050 (United Nations, 2015). In many regions across sub-Saharan Africa there is no land suitable for further agricultural expansion, therefore farm size is decreasing (Harris and Orr, 2014). Faced with land shortage and the challenge to produce sufficient food, farmers can respond in three ways: intensifying agricultural production, migrating out of agriculture and/or reducing human fertility rates (Headey and Jayne, 2014). Policy interventions can favour these strategies, as examples from around Africa illustrate: large scale agricultural input subsidy programs improved land productivity in Malawi (Dorward and Chirwa, 2011). Educational investment targeting rural areas and creation of non-agricultural wage jobs in the cities favoured rural-urban migration in Uganda (de Brauw et al., 2014; Fox and Sohnesen, 2012). In Rwanda and Kenya, subsidized contraceptive services and education campaigns triggered the transition from high to low birth rates (Bongaarts, 2011). Yet the pace and the magnitude of the effects of such policy interventions are difficult to foresee (Thompson and Scoones, 2009). In Mali, achieving food self-sufficiency and poverty reduction are the key objectives of the latest "Loi d'Orientation Agricole" (LOA) (http://www.pcda-mali.org/site/index.php/29-mediatheque/31-la-loi-d-orientation-agricole-du-mali-loa, last accessed 19/02/2016). Hence assessing how income and food production might change under uncertain future socio-economic and biophysical conditions may generate useful information for directing policy interventions towards poverty reduction.

Scenarios help to capture uncertainty by defining plausible futures covering a range of socioeconomic and biophysical conditions (O'Neill et al., 2017). Many studies built scenarios based on hypothetical changes in population, policy interventions and efficiency of institutions and assessed their effect on land use change, intensification and diversification of agriculture (Enfors et al., 2008; Stephenne and

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Lambin, 2004). These studies illustrated how scenarios inform decision-making and help to target agricultural development investments. Some of these studies stressed the importance of considering farm heterogeneity to increase the assessment accuracy (García-Martínez et al., 2011; Gibreel et al., 2014; Herrero et al., 2014). However, they focused on land use change and did not quantify changes in food production and income for the different farm types. Scenario work is widespread for developed countries (Bizikova et al., 2015) but remains rare in sub-Saharan Africa, with scarce quantitative information on likely changes in income and food self-sufficiency. Furthermore, beyond future changes in representative farms or farm types, only few studies assess changes in entire diverse farm populations (Descheemaeker et al., 2016; Paul et al., 2017; Ritzema et al., 2017).

The "old cotton basin" in Southern Mali experiences fast population growth and increasing land shortage (Soumaré et al., 2008), common challenges in land constrained regions across sub-Saharan Africa. The region has shown a promising agricultural intensification pathway (1960–2000) linked to cotton production (Benjaminsen et al., 2010), but since the cotton crisis (2004), agricultural productivity has stagnated (Falconnier et al., 2015). Hence the Malian government is committed to increasing agricultural productivity (de la Croix et al., 2011; Kelly et al., 2011) and increasing off-farm opportunities for the youth (African Development Bank, 2012). Yet policy makers need locally grounded information to take effective decisions. Adding to the uncertainty of future trajectories of change, the heterogeneous farms of the region (Falconnier et al., 2015) are expected to respond differently to changes in socio-economic conditions.

The objective of this study was to assess the effects of agricultural intensification, rural to urban migration and net fertility reduction on rural poverty and food self-sufficiency for contrasting plausible mid-term futures (fifteen years ahead) for the entire population of a case study village in the "old cotton basin" of Southern Mali. Specific objectives were to (i) build scenarios that span a wide range of uncertainty in socio-economic futures, (ii) develop a simulation framework that accounts for household demographic dynamics, sensitivity of crops to rainfall variability and change in farmer practices and (iii) assess trends in food self-sufficiency and income per capita for all farms in the village population in the different scenarios.

2. Methods

2.1. Study area

The "old cotton basin" is an area situated in the Sudanian agro-ecological zone of Southern Mali (Coulibaly, 2003). The rainy season starts in May and ends in October and total rainfall fluctuates from 500 to 1200 mm. The area groups three districts (Koutiala, Dioila and the northern part of Sikasso) and accommodates more than a million of rural people (Traore et al., 2011). Households are extended families comprising the head of the household, his sons and wives and their children (Jonckers and Colleyn, 1974). Farmers grow cotton, cereals and groundnut in rotation and use manure, mineral fertilizer and oxen for draught power. The Compagnie Malienne pour le Developpement des Textiles (CMDT) buys the cotton and provides credit for mineral fertilizer for cotton and maize (Falconnier et al., 2015).

2.2. Datasets

The "Suivi Evaluation Permanent" (SEP) dataset collected by the "Equipe Système de Production et Gestion des Resources Naturelles (ESPGRN)" of the Malian Institut d'Economie Rural (IER) contains information on household resource endowment, input use and cotton yields measured by CMDT for 30 farms from three villages of the "old cotton basin" from 1994 to 2010. Farms were classified in four farm types, namely High Resource Endowed with Large Herds (HRE-LH), High Resource Endowed (HRE), Medium Resource Endowed (MRE) and Low Resource Endowed (LRE) farms according to (1) total cropped land (ha), (2) number of workers, (3) herd size and (4) number of draught tools (Falconnier et al., 2015). LRE farmers usually don't have a full span of oxen and/or a plough.

Data on resource endowment and crop area in 2013 for the 99 households of the Nampossela village (12°15′ N and 15° 20′ W) was obtained from the CMDT. All households in Nampossela were classified in one of the four HRE-LH, HRE, MRE and LRE farm types. Nampossela is a typical village of the 'old cotton basin'. It is close (10 km) to the three SEP villages where the farm typology was generated, with very similar agro-ecology, farm practices and marketing opportunities. The share of the four farm types in this village was 12%, 19%, 55% and 14% for HRE-LH, HRE, MRE, LRE farms respectively, which is close to the average share in the Koutiala region (Falconnier et al., 2015).

2.3. Scenario building

Starting from the baseline year 2013, we explored the effects of wide-ranging future agricultural and socio-economic changes within a 15-year time span (2013–2027). Hypothetical trends in agricultural intensification were conceived based on promising agricultural technologies identified for the region. On the policy side, we took into account expected changes in the cotton and milk context described in the literature and policies that would affect birth and migration rates. Key variables were selected to describe these trends and quantified by extrapolating past trends described in the literature. Eventually, combinations of hypothetical trends were bundled into five coherent and contrasting scenarios. We did not consider technological change that would result in increased potential yield due to breeding. Although the 15-year time span corresponds to the 'near term' where additional uncertainty due to climate change is assumed to be negligible (Pachauri and Mayer, 2015), climate change is considered an important threat to agriculture in the region (Traore et al., 2017). Hence, to inform decision making towards timely adaptation, we included climate change effects in the sensitivity analysis (Section 2.6).

2.4. Simulation framework

A model framework was built to simulate three major farm components (household, cropland and cattle herd) and their interactions (Fig. 1) for each of the 99 farms of the Nampossela village. The model was run for both a baseline situation (2013) and a near-term future situation 15 years later (2027). The baseline and the future situation were each simulated with the same series of 29 historical seasons (1965–1993), which is the only complete weather dataset for which corresponding water-limited potential cotton yields were observed (see Section 2.4.2). For the baseline and the future situation, food self-sufficiency and income per capita were computed for each farm, averaged across the seasons and for each farm type. Also the year-to-year variability was assessed. Furthermore, the percentage of farms above the poverty line and food self-sufficient was computed for both the baseline and the future situation. Hence, the scenario analysis was not based on a continuous temporal change, but on a comparison of separately modelled baseline and future situations, which is common practice (Miguel Ayala et al., 2016; Rajib et al., 2016). The model was built with the R programming language. Main model input comprised farm characteristics (farm type, area of the different crops, household size, number of tools and animals) and crop/livestock performances (grain, fodder and milk yield) (Fig. 1). Further input to the model comprised net fertility and migration rates and farm and socio-economic conditions derived from the scenarios. More details on parameters, input, output variables and calculations are available in supplementary material as background and resource for readers who are interested to repeat this exercise. In what follows we explain each model component and indicator separately.