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Model results versus farmer realities. Operationalizing diversity within and among smallholder farm systems for a nuanced impact assessment of technology packages

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ABSTRACT

Agricultural production in Northern Ghana is dominated by smallholder farm systems, which are characterized by low inputs and low outputs, declining soil fertility, large yield gaps and limited adoption of agricultural technologies. There is an urgent need for alternative farm designs that are more productive, yet more sustainable. Technology packages for sustainable intensification are promoted by an R4D project in the Upper East, Upper West and Northern Regions of Ghana. In this paper, we analyse differences in perceived suitability, and modelled technical impact per technology package.

We used a locally validated framework to categorise farm systems diversity that considers both, the horizontal (between households) and vertical (within households) dimension of diversity. Farm households were classified along a gradient of resource endowment. We selected one representative farm per type and per region to assess and compare their socio-economic and environmental performance (farm profitability, labour and soil organic matter inputs) using the whole-farm model Farm DESIGN. We then used Farm DESIGN to assess the potential impact of five proposed technology packages and to explore promising alternative farm configurations. We discussed model assumptions and results with farmers, including alternative cropping patterns and trade-offs. We evaluated the packages with different household members using a weighted scoring technique, subsequently juxtaposing model results with farmer perceptions.

Large differences prevailed among and within farms per type and per region, with low resource endowed farms being projected to benefit most in relative and least in absolute terms from an adoption of the packages. Farmer feedback confirmed the accuracy of alternative farm configurations, as determined by the model. However, the feedback also revealed that the most profitable farm designs would be hard to attain in reality, particularly for members of low and medium resource endowed households, due to high initial investment costs. Within households, women were more positive about the packages than men, since men heavily penalized extra costs and labour, translating into a greater congruence of model results with the male evaluation. We discuss the importance of distinguishing between technical (technology i.e. purchased tools and inputs) and managerial (techniques e.g. row planting) package components. We conclude that operationalizing inter- and intra-household diversity is a fundamental step in identifying sensible solutions for the challenges smallholder farm systems face in Northern Ghana.

1. Introduction

Smallholder farm systems produce about 80% of the food consumed in Africa and Asia (UNEP, 2013), they supply the bulk of rural labour (Collier and Dercon, 2009; FAO, 2004) and they typically maintain a high regional agro-biological diversity (Kull et al., 2013; Zimmerer,

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2014). However, their agricultural productivity is usually low and under threat of further deterioration due to their remoteness, lack of capital, inputs and information (Becx et al., 2012; FAO, 2011).

In Northern Ghana, smallholder farm systems face a variety of challenges related to low inputs and low outputs, declining soil fertility, post-harvest losses of about 20–50% as well as strong fluctuations in market prices (Affognon et al., 2015; Ellis-Jones et al., 2012; Osei-Owusu et al., 2013). Local productivity gaps in the main staple crops maize, sorghum and millet range from 80 to 90% (GYGA, 2016), suggesting a large potential for sustainable intensification (Pretty et al., 2011; Vanlauwe et al., 2014). Since agro-ecosystems are cybernetic systems that are strongly shaped to fulfil human objectives (Altieri et al., 2015; Tittonell, 2013), researchers need to team up with farmers in order to identify, discuss and implement alternative farm designs (Rodriguez and Sadras, 2011) that are more productive, yet more sustainable. Promoting sustainable intensification among smallholder farmers is the objective of the R4D (Research for Development) project Africa RISING (USAID, 2017). In Northern Ghana, Africa RISING conducted participatory on-farm trials i.a. for five technology packages that aim at an improved cultivation and a better integration of maize, cowpea and soybean within local farm systems (Kotu et al., 2016; Larbi et al., 2016a,b). In this paper we investigate how different farms and farmers respond to the five project-proposed packages.

While a differentiation of farms (household types) is common in adoption studies (Cortez-Arriola et al., 2015; Singh et al., 2016; Tittonell et al., 2010), a differentiation between farmers within a household (individual household members) is not. Adoption studies typically treat farm households as unitary (Bensch et al., 2015; Tsiboe et al., 2016), referring to 'farmers and their farms' without specifying who, within a farm household, chose or was chosen to represent the farm (Dolinska and d'Aquino, 2016; Tittonell et al., 2010; Waithaka et al., 2006). At most, existing studies consider gender differences between (unrelated) male and female farmers (Bugri, 2008; Duncan, 2004; Emmanuel et al., 2016; Jarawura, 2014; Khatri-Chhetri et al., 2017; Tetteh Anang, 2015): where survey samples include men and women it is unclear whether or not they are part of the same household. In Northern Ghana, agricultural fields and tasks are highly gender differentiated (Doss, 2002). While individual household members pursue individual production objectives and are the actual units of decision making, they are tightly bound by joint resources and responsibilities at household level (Britwum and Akorsu, 2016; Pieper and Klein, 2007; Von Schlippe and Vienna, 2013). Our technology evaluation considers both diversity among and within farms. We chose one household per farm type and per community, consulting different members of the same household for their 'reality' i.e. their evaluation of each of the five technology packages.

At farm level, the adoption of a technology package typically affects multiple components, e.g. a change in crops affects fodder availability as well as the soil organic matter (SOM) balance. Despite the close-knit crop-livestock relationship in smallholder farm systems (Amankwah et al., 2012), most research on agricultural technology adoption in Ghana examines single technological innovations and impacts limited to the domain of action (Abdul Rahman, 2011; Adjei-Nsiah et al., 2007; MacCarthy et al., 2010; Zakaria et al., 2014). An exception was Yiridoe et al. (2006), who used a whole-farm model, focusing on rice production in the Northern Region. The whole-farm perspective is indispensable to analyse the integrated character of mixed crop-livestock smallholder farms. We, too, used a whole-farm model to describe, explain and explore the performance of nine local farm systems, with and without the project-proposed technology packages. We used the bio-economic whole-farm model Farm DESIGN, which is a static model complemented by a multi-objective optimization algorithm (Groot et al., 2012). The algorithm is able to generate a large array of Pareto-optimal alternative solutions. Each solution constitutes a technical possibility to re-arrange the farm, allowing an exploration of concrete alternative farm configurations for sustainable intensification. Model-based farm descriptions are, however, only meaningful if farmers can relate to them. We therefore revisited all case-study households to discuss all model assumptions as well as the model-determined farm performance and the trends such as trade-offs between farm objectives.

By independently consulting various household members and by using the whole-farm model Farm DESIGN in a participatory fashion we assess the proposed technology packages in terms of their technical as well as their social viability, advancing to bridge the divide between the generation of theoretical farm designs and farmer realities (Dorward et al., 2003; Schindler et al., 2016; Whitfield et al., 2015).

The objective of this paper is to evaluate the five technology packages by comparing and matching a model-based impact assessment with the personal perspectives of individual household members for low, medium and high resource endowed farms (LRE, MRE and HRE) in the Upper East Region (UER), Upper West Region (UWR) and the Northern Region (NR) of Ghana. Per farm type and per region, we analyse (i) the current farm performance (Section 3.1), (ii) intra-household differences in the evaluation of the different technology packages (Section 3.2), (iii) the impact of the different technologies on the socio-economic and environmental farm performance (Section 3.3) and (iv) trade-offs in resource allocation within farms (Section 3.4). Finally, we compare model results with farmer realities (Section 3.5).

2. Methods

2.1. Case-study area

The study was conducted in one community in each of the three northern regions of Ghana: Duko located in the NR, Nyangua in the UER and Zanko in the UWR. Fig. 1 displays the three regions, as well as our case-study locations. Duko and Zanko are part of the Guinea Savannah agro-ecology, spanning from Guinea-Bissau to Central-South Sudan, comprising most of northern Ghana (FAO, 2005). Nyangua is located in the Sudan Savannah agro-ecology, extending from Senegal to South Sudan, covering merely the north-eastern tip of Ghana (Germer and Sauerborn, 2005). Both agro-ecologies evince unimodal rainfall regimes with 1000–1200 mm and 900–1000 mm of rainfall per year, respectively. Temperatures range between 26 and 30 °C.

In Northern Ghana livelihoods are based on small scale, low input mixed crop-livestock agriculture. The main crops grown are cereals (maize, rice, sorghum, millet), legumes (groundnut, cowpea, soybean, Bambara bean, pigeon pea) and vegetables (roselle, okra, pepper). Depending on their level of resource endowment, farmers own cattle, donkeys, goats, sheep, pigs and poultry.

Local smallholder farm systems are family-farms, typically consisting of several partially independent units of production (Apusigah, 2009) each run by a different household member with a distinct production orientation. The partial independence is expressed in terms of 'own fields' for the different household members as assigned by the (customarily male) household head (HHH) or the community leader (the chief). Individuals live in so-called compounds, together with other nuclear or extended family members of the HHH (Al-Hassan and Poulton, 2009; Oppong, 1967).

While the male HHH cultivates cereals and tubers to ensure the family's food security, women farm different plots with vegetables and cash crops to achieve nutritional diversity (Doss, 2002) and to cover the children's basic school fees (Iddrissu Mohammed, 2015). If enough land is available also the younger household members cultivate their own plots, growing cash crops like rice to save capital for higher education or marriage. Also livestock ownership and responsibilities differ according to gender (Doss, 2002). Despite the distinct responsibilities and interests among the individual members, a household forms a strong unit of agricultural production, with tight interdependencies in decision making, exchanging and sharing resources like tools, labour, capital and food from the various crop and livestock components of their farm (Pickbourn, 2011; UNU, 1994).