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Co-learning cycles to support the design of innovative farm systems in southern Mali

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A B S T R A C T

Farm systems were re-designed together with farmers during three years (2013–2015) in Southern Mali with the aim to improve income without compromising food self-sufficiency. A cyclical learning model with three steps was used: Step 1 was the co-design of a set of crop/livestock technical options, Step 2 the on-farm testing and appraisal of these options and Step 3 a participatory *ex-ante* analysis of re-designed farm systems incorporating the tested options. Two iterations of the cycle were performed, in order to incorporate farmers' point of view and researchers' learning. We worked together with 132 farmers representing four farm types: High Resource Endowed with Large Herd (HRE-LH); High Resource Endowed (HRE); Medium Resource Endowed (MRE) and Low Resource Endowed (LRE) farms. In the first cycle of 2012–2014 farmers re-designed their farms and the reconfigurations were assessed *ex ante* using the average yields and gross margins obtained in the 2013 on-farm trials. HRE-LH farmers experienced a disappointing decrease in food self-sufficiency and MRE farmers were disappointed by the marginal improvement in gross margin. In a second cycle in 2014–2015, farmer insights gathered during field days and statistical analysis of trial results allowed a better understanding of the variability of option performance and the link with farm context: niches were identified within the farms (soil type/previous crop combinations) where options performed better. The farm systems were re-designed using this niche-specific information on yield and gross margin, which solved the concerns voiced by farmers during the first cycle. Without compromising food self-sufficiency, maize/cowpea intercropping in the right niche combined with stall feeding increased HRE-LH and HRE farm gross margin by 20–26% respectively (i.e. 690 and 545 US$ year^{-1}) with respect to the current farm system. Replacement of sorghum by soyabean (or cowpea) increased MRE and LRE farm gross margin by 29 and 9% respectively (i.e. 545 and 32 US$ year^{-1}). Farmers highlighted the saliency of the niches and the re-designed farm system, and indicated that the extra income could be re-invested in the farm. Our study demonstrates the feasibility and the usefulness of a cyclical and adaptive combination of participatory approaches, on-farm trials and *ex-ante* analysis to foster learning by farmers and researchers, allowing an agile reorientation of project actions and the generation of innovative farm systems that improve farm income without compromising food self-sufficiency. The re-designed farm systems based on simple, reproducible guidelines such as farm type, previous crop and soil type can be scaled-out by extension workers and guide priority setting in (agricultural) policies and institutional development.

1. Introduction

Farming system design can help to generate innovative farm systems to overcome the constraints faced by farmers, increase farm productivity and profitability, and improve households' livelihoods. Farming system design employs qualitative and quantitative approaches to support the analysis of current farm systems and the design and evaluation of alternatives (Le Gal et al., 2011; Martin et al., 2012). Farm systems are highly heterogeneous in terms of resource endowment, soil types, cropping and livestock systems, and livelihood

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strategies (Giller et al., 2011). This implies the need to tailor innovations to the context of the farm (Descheemaeker et al., 2016b). Tailoring innovations can be facilitated firstly by farm typologies, which are a useful tool to consider heterogeneity of resource endowment and/or production objectives (Chopin et al., 2014; Senthilkumar et al., 2012; Tittonell et al., 2010). Secondly, strong farmers' participation in the design process may enhance the relevance of the innovations for specific farmer contexts (Schaap et al., 2013). While participatory research mainly generates qualitative insights (Dorward et al., 2003; Van Asten et al., 2009), Participatory Learning and Action Research (PLAR) was proposed to combine qualitative and quantitative insights (Defoer, 2002). In PLAR, qualitative participatory research provides information that strengthens quantitative assessments, e.g. resource flow maps drawn by farmers to derive and calculate nutrient balances. Similarly, Martin et al. (2012) employed a game board to redesign livestock systems in France. In this approach, inputs from farmers playing the game were used to calculate indicators (e.g. satisfaction of animal needs) with the help of a computerized support system. Conversely, Paassen et al. (2011) showed that quantitative outputs of multiple goal linear programming models, if presented using concepts and symbols familiar to farmers, enhanced communication between farmers, farm advisors and researchers leading to relevant farm-specific solutions. In other studies, outputs from simple models (static simulation of annual farm stocks and flows), representing farmers' reality and concerns were an appropriate discussion support to jointly generate alternative farm systems (Sempore et al., 2015; Andrieu et al., 2015).

The approach of combining *ex-ante* trade-off analysis and on-farm trials in iterative learning cycles with farmers has been conceptualised in the Describe Explain Explore Design (DEED) cycle (Descheemaeker et al., 2016b; Giller et al., 2011). Where DEED was applied previously, it produced useful insights to re-design farm systems: e.g. strategies to restore soil fertility led to improved crop and cattle productivity at village scale (Rufino et al., 2011), land allocation to fodder and use of an improved cattle breed resulted in improved farm recycling efficiency (Tittonell et al., 2009). However, most existing studies applied only one DEED cycle. Having a second cycle allows to incorporate the learning from the first cycle, but there is little insight into how methods and solutions can be adapted dynamically using scientific results and farmers' appraisals (a useful exception is Dogliotti et al. (2014)). Furthermore, modelling outputs have seldom been coupled to real on-farm testing, although farmers were usually willing to test the different technical alternatives (urea treatment of straw, compost pits) in their farms (Andrieu et al., 2012). Finally, though the empowerment of stakeholders during the participatory process is widely acknowledged (de Jager et al., 2009; Defoer, 2002; Hellin et al., 2008; Sterk et al., 2007), there is little empirical evidence that a participatory approach can increase the scaling-out potential of the research outputs (Sumberg et al., 2003).

Land shortage, climate variability and climate change (Descheemaeker et al., 2016a), unreliable institutional support (*e.g.* fertiliser subsidy) for crop production (Ebanyat et al., 2010), decreasing fodder availability for livestock, weak access to output markets for livestock products, and poor price setting power for cereals and livestock (Kaminski et al., 2013) are common challenges for smallholders across sub-Saharan Africa. Also the farmers in southern Mali face these constraints (Autfray et al., 2012; Coulibaly et al., 2015; Traore et al., 2013). Technical alternatives at field/cow scale (*e.g.* diversification with legumes, stall feeding of cows) can help farmers to cope with the challenging characteristics of their environment. These alternatives can be tested in on-farm trials. Strategic/tactical decisions (Le Gal et al., 2010) like changing field area per crop, producing a new type of fodder and/or changing the feeding strategy of cows need to be addressed at farm scale. Given the risk involved, this is often done with *ex-ante* analysis (Whitbread et al., 2010). Such major changes made at farm level can be referred to as "innovative farm systems" (Le Gal et al., 2011). In southern Mali, achieving food self-sufficiency and improving farm income are farmers' main objectives (Bosma et al., 1999). An assessment of the performance of the innovations is thus needed, using relevant indicators like yield, gross margin and Cost:Benefit for technical alternatives and food self-sufficiency and income for innovative farm systems.

The objectives of this study were to (i) design innovative farm systems that improve farm income without compromising food self-sufficiency in the cotton area of southern Mali, (ii) implement the DEED cycle twice with emphasis on on-farm testing of technical alternatives, *ex-ante* impact assessment through modelling, and incorporation of farmers' and researchers' learning, (iii) illustrate the feasibility and usefulness of such an approach through its ability to generate salient farm systems for farmers and practical scaling-out guidelines for extension workers. In what follows, we start by describing the different steps and their adaptation during the learning cycles. The second section presents the assessment of the agro-economic performance of the tested innovations and an analysis of farmers' and researchers' learning during the cycles. The last section discusses (i) adaptation of the research methods as a key feature of this farming system design approach, (ii) the strength of the guidelines generated, (iii) the opportunities for scaling out and (iv) the broader changes needed to trigger large-scale adoption of the innovative designs.

2. Methods

2.1. Study area and farm characteristics

The study area is located in Koutiala district in the cotton zone of southern Mali where population densities reach 70 people km^{-2} (Soumaré et al., 2008). The uni-modal rainy season starts in May and ends in October, with total annual rainfall ranging from 500 to 1200 mm. Farmers grow maize, sorghum and millet for food consumption and cotton and groundnut to generate income. Livestock provide draught power, milk, meat, manure, and a buffer against risk (Kanté, 2001). Farming is the major livelihood strategy, with achieving food self-sufficiency the farmers' main objective (Bosma et al., 1999) and cash-oriented non-farm activities providing a small (12%) but important share of the income per capita (Losch et al., 2012). A typology based on farm resource endowment (household size, number of workers, total cropped land, number of draft tools and herd size expressed in TLU, i.e. a Tropical Livestock Unit of 250 kg) distinguished four farm types in the Koutiala district: (1) High Resource Endowed Farms with Large Herds (HRE-LH) (on average 28 workers cultivating 17 ha with 4 draught tools and a herd of 46 TLU), (2) High Resource Endowed (HRE) farms (on average 18 workers cultivating 12 ha, with 4 draught tools and a herd of 8 TLU), (3) Medium Resource Endowed (MRE) farms (on average 7 workers cultivating 8 ha with 5 draught tools and a herd of 6 TLU) and (4) Low Resource Endowed (LRE) farms (on average 5 workers cultivating 3 ha with 1 draught tool and a herd of 2 TLU) (Falconnier et al., 2015).

Farmers participating in this research originated from nine neighbouring villages of the Koutiala district: M'Peresso, Nitabougouro, Nampossela, Finkoloni, Try, Koumbri, Karangasso, N'Goukan and Kani. In total, 132 farmers participated in this study (from 12 to 16 per village). The share of HRE-LH, HRE, MRE and LRE farms among the participating farmers was close to the average share in the villages of the Koutiala region (Falconnier et al., 2015), *i.e.* 22, 44, 24 and 11% respectively. Scientific activities were carried out by researchers from three research institutes, the International Crops Research Institutes for the Semi-Arid Tropics (ICRISAT), Institut d'Economie Rurale (IER) and Wageningen University, while interactions between farmers and researchers were facilitated by people belonging to a Malian NGO, the Association Malienne pour l'Eveil au Développement Durable (AMEDD). During the group discussions, the facilitators helped to create an inclusive environment, encouraged participants to share their ideas and kept discussions on track.