FARMING SYSTEM DESIGN FOR SUSTAINABLE AGRIFOOD SYSTEMS: THEORIES AND PRACTICES

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Digital advisory for African smallholder farming systems: towards design principles

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Introduction

Over the past decade, a plethora of digitally-enabled advisory applications targeting smallholder farming systems has emerged. While often seen as a game changer in Africa's agricultural transformation process, uptake of such services remains (s)low (Sida et al., 2022). Reviews of such digital agricultural advisory seem more concerned with numbers of users and the business models, than with the relevance, efficacy of these tools.

This study relates digital tool design shortcomings to a lack of understanding of diverse smallholder farming systems. For instance, a common focus on profitability in digital tool designs is problematic in a context of small farm sizes (Giller et al., 2021). Capital constraints often prevent smallholder farmers from investing in, or reap the benefits of, yield-enhancing technologies (Harris and Orr, 2014). So-called 'predictive agronomy' tools, that capitalise on geospatial soil and climatic data, as well as the power of big data analytics to predict crop yields, often ignore the unpredictability of rainfall -- the main determinant of crop yield. In addition, advisory tools often assume a high level of agronomic management, neglecting not only the large diversity in smallholder farmers' management practices, but crucially, the pivotal role of past management on crop performance.

Based on a qualitative understanding of local smallholder farming systems, diverse farmer practices and input availability, a digital, survey-based advisory tool was developed for smallholder maize-legume farmers in the Southern Highlands of Tanzania. This paper discusses experiences with this advisory tool and provides examples of how an understanding of farmers' diverse management practices may be translated into design principles for agronomic advisory tools.

Methods

Farmer Management-Based-Advisory (Farmer-MBA) was developed as an advisory-by-learning tool, and used by 40-65 extension workers annually, to provide advice for 2,865 (2021-22 season); 4,472 (2022-23); 1,296 (2023-24), and; 4,184 (2024-25) maize or legume fields. (Note! It is not a panel dataset as extensionists and operational areas changed).

Farmer-MBA incites extension workers to visit farmers and to systematically record those agronomic management practices, crop- and field-conditions that matter most for the efficient use of inputs. The recorded data is instantly used to tailor advice to a farmer's field. For instance, a GPS-measurement of the field area is used to calculate the last season's yield, but also the quantities of fertiliser and seed required for this season, depending on the crop the farmer wants to grow, his/her investment-level, the previous season's crop and level of fertilisation. The systematic recording of past agronomic management enables farmers to develop and master a field-specific 'business administration' (MBA thus has a double meaning).

As Farmer-MBA collects field-level management data at scale, it also enables data-driven learning on location-specific agronomic management practices that increase productivity and

input use efficiency. Such learnings can be translated into new advice algorithms. Here, we highlight some learnings on farming system functioning, and what they mean for tool design.

Results

As not all crops are marketed, crop prices volatile, and smallholder farmers' often cash-constrained, Farmer-MBA is investment-oriented (design principle 1), rather than profitability-focused. As fertilisers constitute smallholders' main expenditure, Farmer-MBA has three fertiliser advice options: (1) a farmer-preferred investment-level; (2) crop-requirement advice, or; (3) advice adjusted to what fertilisers the farmer has already purchased. This latter option was included as numerous farmers, particularly in the Songwe region, immediately re-invest crop sales earnings in fertiliser for the next season (Table 1).

Advice	Investment-based advice	Fertiliser(s) required for field	Additional fertiliser required	(n)
Ruvuma	**3 %**	**87 %**	**10 %**	**1,954**
maize	*5 %*	*77 %*	*20 %*	*906*
soya	*3 %*	*95 %*	*2 %*	*1,048*
Songwe	**5 %**	**66 %**	**29 %**	**2,230**
maize	*6 %*	*68 %*	*26 %*	*1,913*
soya	*1 %*	*50 %*	*50 %*	*317*

Table 1: Farmers' preference for different investment-oriented advice options by operational area (region) and crop type, Ruvuma and Songwe regions, Tanzania, 2024-25 season.

Farmer-MBA data further revealed that in any season, crop responses to fertiliser are highly variable at any fertiliser input level (Figure 1). This renders a predictive, target-yield approach based on average responses for given climatic and soil conditions problematic, when used for field-level advisory (cf. Rurinda et al. 2021); Crop responses to fertiliser inputs appear to be highly field-specific. Hence, advice provision is crop- and field-specific (design principle 2).

Rather than a 'predictive agronomy', Farmer-MBA adopts a 'response farming' approach (design principle 3), founding advice on past agronomic management of the field. For instance, as crop response to fertiliser appeared to depend on single or split application of top-dressing fertiliser (Figure 1), this is translated into new management advice. The systematic recording of farmers' diverse management practices -- like manure use frequency and crop rotation with leguminous crops -- may equally result in new advice algorithms.

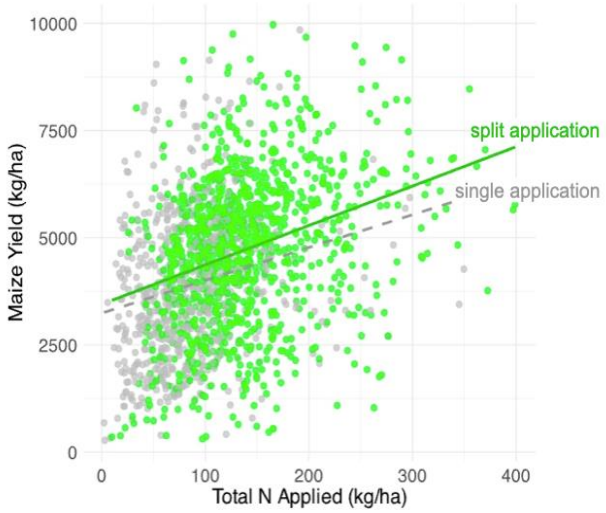

Figure 1: Maize yields (kg/ha) for single (n= 671) or split application (n=1,177) of top-dressing (kgN/ha) fertiliser, Ruvuma and Songwe regions, Tanzania, 2023-24 season. (Wilcoxon rank sum (W=255928, p < 0.000). The recommended fertiliser rate for maize in Tanzania is 120 kgN/ha. On 58% of the Farmer-MBA surveyed maize fields, farmers apply a lower N-rate (n=2,095). Farmer-MBA advice for leguminous crops is focused on P and K only, yet farmers' hardly apply any fertilisers to these crops.

Discussion

Experience with the use of the Farmer-MBA tool over four seasons reveals not only a huge diversity in the use of fertiliser inputs on maize fields (and virtually no use on legume crops), but also in crop performance among farmers using similar input-levels. Differences in agronomic management, rather than in agro-ecological (soils, climate) conditions, are at the root of this diversity. Farmer's diverse management practices are structured by the distinct organisation of their farm household system and the land, capital, labour and technological resources they can mobilize.

Our findings have important implications for the design of digital advisory tools targeting smallholders, including:

- Profitability is an ill-informed design principle for smallholder advisory tool development, as market prices are volatile, and farmers' resource constraints binding;
- Digital advisory, to have wide relevance, needs to provide diverse advice options that are rooted in an appreciation of smallholder farmers' diverse resource endowments and farm management practices;
- Rather than 'predictive agronomy', digital advisory development may more effectively be adopt an 'response farming' approach, aiming to adjust farmers' management practices in favour of practices that enhance resource use efficiency
- Agronomic advisory tools are more likely to be effective when designed as learning tools (that is, including feedback mechanisms), as this enables use(r)-informed adjustment.

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