FARMING SYSTEM DESIGN FOR SUSTAINABLE AGRIFOOD SYSTEMS: THEORIES AND PRACTICES

Proceedings of the 8th International Farming System Design Conference

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25 - 29 August 2025
Palaiseau (France)
Campus Agro Paris-Saclay

AgroParisTech INRAE ideas

Legume-based crop diversification in smallholder farming systems: insights from a farm-level analysis of crop allocation practices

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Keywords: crop rotation, cropping practices, legumes, maize-based systems

Introduction

Legume-based crop diversification is widely regarded as an agricultural development strategy for smallholder farmers in Africa, as it has the potential to diversify diets, improve soil fertility, and increase small-farm productivity. Farmers are generally aware of the benefits of legume integration and commonly cultivate them on small areas. Agriculture research has mostly focused on the development of innovations to intensify legume production at field-level, introducing higher yielding varieties, inoculants, fertiliser blends, as well as improved agronomic practices. The underpinning assumptions have often been that higher productivity makes legumes production more profitable, and that higher returns on investment increases farmer uptake.

The targeting of interventions has often been based on experimentally derived agronomic benefits and ex-ante modelling analyses rather than actual farmer practices, often limiting the local relevance and adoption of these technologies (Nord et al., 2021). Evaluating crop diversification strategies is crucial given rising fertiliser prices, on which maize cultivation heavily depends. This context reinforces the need to expand the area of crops like legumes, which can still yield with few inputs.

Constraints to legume expansion are often attributed to a combination of limited marketing opportunities, dysfunctional input and seed market, and resources endowment (Mhango et al., 2012). However, farm-scale studies on farmers' legume crop allocation practices remain scarce and our understand of locally relevant maize-legumes cropping systems remains limited. This study investigates, from a farm-scale perspective, how current maize-legume cropping systems are shaped through farmers' decisions on crop and resource allocation, with the aim of identifying key drivers of crop diversification practices.

Methods

The study was conducted in the Songwe Region, a major rainfed maize-producing area in Tanzania's Southern Highlands. The heterogeneity of agroclimatic conditions across the highlands results in highly localised cropping systems, where maize is consistently grown alongside one or more legumes, such as common beans, groundnuts, and soybeans.

The study draws on a farm characterization survey of 140 farms, which involved reconstructing field-level crop sequences for each field of the farms over the four preceding growing seasons (Figure 1), along with collecting detailed information on input use, labour, cropping calendar, and productions. Farmers' orientations and decision-making processes related to the observed cropping practices were further explored through follow-up semi-structured interviews.

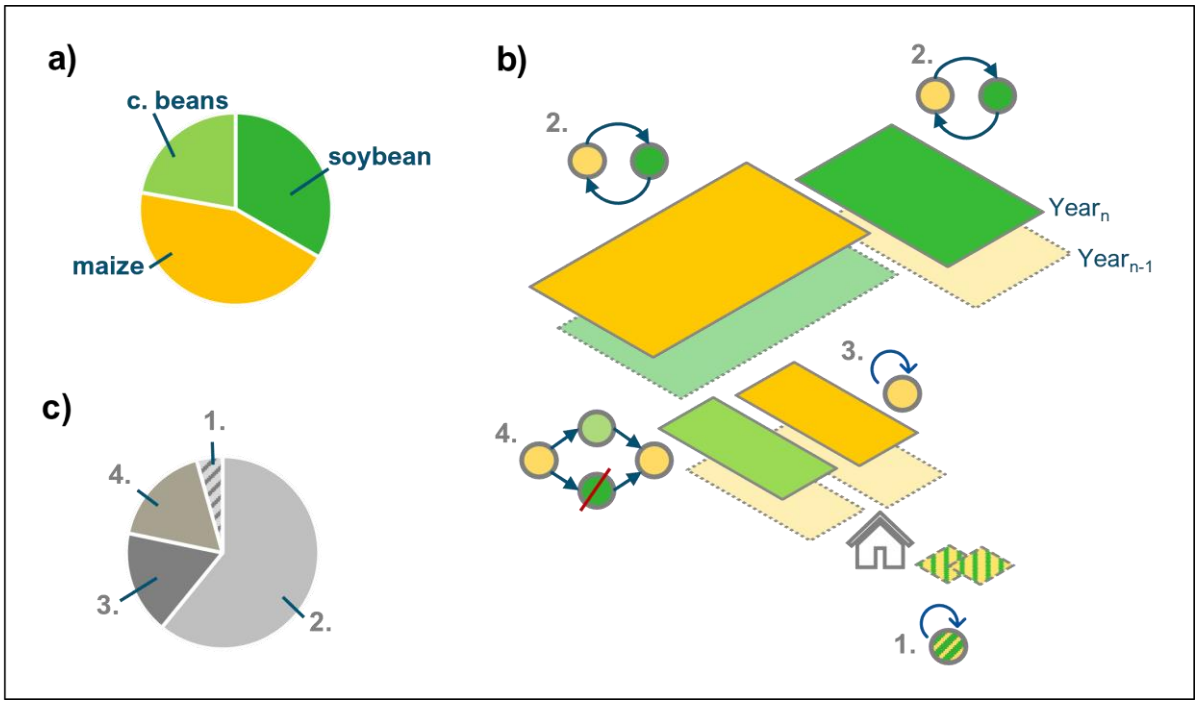

Figure 1. Farm-scale crop area distribution on an example farm for a given (n) season between maize, common beans, and soybean (a); field-based crop allocation (b) types of maize-legumes cropping systems: maize and common bean relay cropping (within season) repeated over multiple seasons (1), simple rotation between maize and a single legume species (2), flexible rotation between maize and multiple legumes species (4), and maize monocropping or maize-dominant rotation -maize cultivated 3 out of 4 years- (3). (c) Share of each cropping system over the total farm area.

Results and Discussion

Crop allocation practices result from farmers' decisions aimed at fulfilling production objectives while adapting to local constraints. Two interacting levels of decision-making can be distinguished. At the farm level, production orientation translates into a desired crop share (Fig. 1a), shaped by agroecological suitability of crops, marketing opportunities, and household's resource endowment. Maize area is typically determined first, based on food security needs and fertiliser expenditure capacity. Legume area is adjusted according to the land that remains, usually cultivated with no or minimal inputs. On average, farmers dedicated 53% of their farm area to maize and 33% to legumes (common beans, groundnuts, and soybean), with one to two legume species commonly grown on the same farm, typically one cultivated as a cash crop (soybean, groundnuts), and the other for both food and market purposes (common beans, groundnuts).

At the field level, adjustments in crop allocation were based on rotation considerations, field characteristics, and the availability of inputs and labour at the start of the season. Farmers relied heavily on maize–legume rotations (Fig. 2), with a range of cropping systems co-existing within farms (Figs. 1, 2). These systems were mostly characterised by the practices of rotating maize and legume(s) every season. These cropping systems were associated with specific functions (Dury et al., 2013). (i) Optimising input use efficiency: farmers prioritised fertiliser use on the most demanding crop and valued the reduced input requirements for maize when rotated annually with legumes. (ii) Leveraging heterogeneity of land and labour resources: legumes were often allocated to fields with declining productivity, or to plots managed by specific household members, reflecting intra-household division of labour. (iii) Providing stability within and between season: maize–common bean relay cropping enabled staggered harvests and income within a season, while flexible rotations with multiple legumes allowed

adjustments based on seasonal legume market prices and household needs. While not exhaustive, these crop allocation practices reflect diverse and increasingly complex strategies. Rotation patterns capture one important dimension, but others exist, such as dynamic land tenure arrangements, which offer additional options for crop allocation.

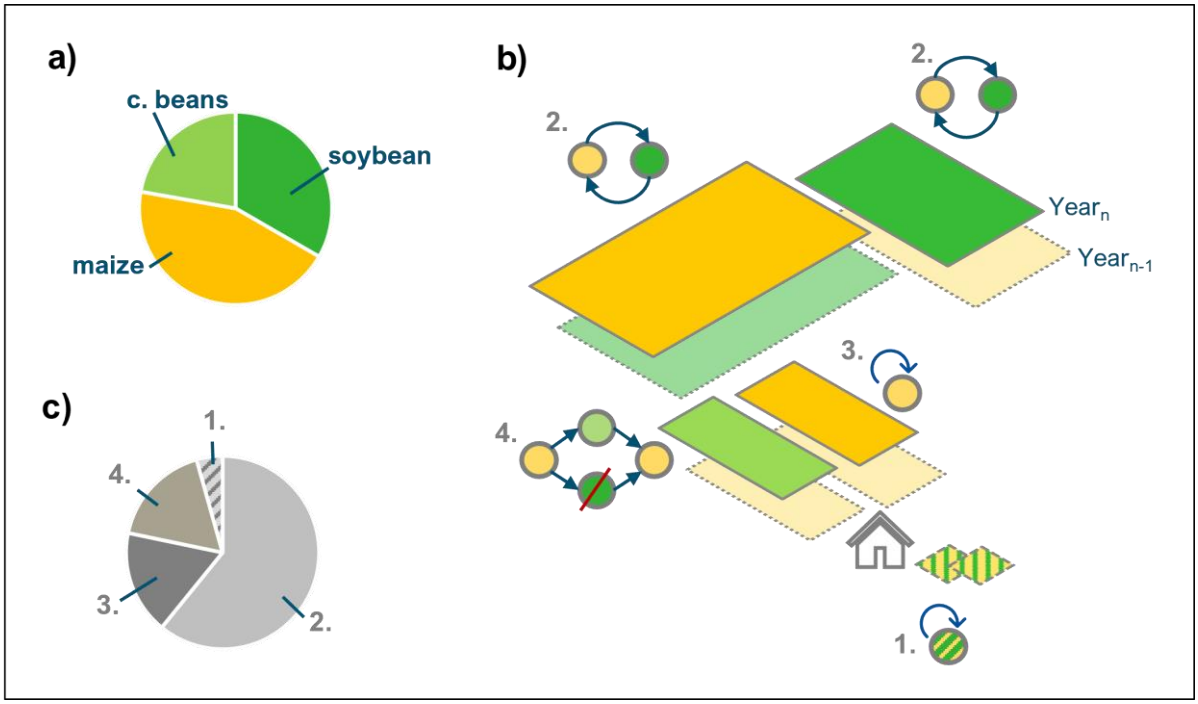

Figure 2. Cropping systems distribution over the total farm area for a sample of 63 farms. Farms are ordered in increasing order of total cultivated area during the 2023-2024 growing season and subdivided into the dedicated areas for each type of cropping systems.

Perspectives

Legume-based crop rotations are widespread in maize-dominated smallholder systems in Tanzania's Southern Highlands, primarily as a low-cost strategy to manage input use. Cost reduction remains the primary motivation for cultivating legumes. Given additional capital, most farmers would allocate resources to maize intensification, or farm expansion, rather than investing in technologies aimed at intensifying legumes production Area and rotation frequency of legumes are shaped by the arbitration of resources at the farm level, highlighting the importance to assess and design diversification strategies from a whole-farm perspective.

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The correct citation of this book of abstracts is:

Farming System design for sustainable agrifood systems: theories and practices, proceedings of the 8th International Farming System Design Conference, Marion Casagrande, Marie-Hélène Jeuffroy, Gentiane Maillet, 2025. DOI: 10.17180/j9xc-fs91

The correct citation of articles in this book of abstracts is:

Authors, year, *title*. on: Farming System design for sustainable agrifood systems: theories and practices, proceedings of the 8th International Farming System Design Conference, Marion Casagrande, Marie-Hélène Jeuffroy, Gentiane Maillet, 2025. DOI: 10.17180/j9xc-fs91